



PHENMA 2026

2026 International Conference on "Physics and
Mechanics of New Materials and Their Applications"



**2026 International Conference on
"Physics and Mechanics
of New Materials
and Their Applications"**

PHENMA 2026

Busan, South Korea, July 15-18, 2026

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PREFACE

The success of the Russian-Taiwanese Symposium “Physics and Mechanics of New Materials and Their Applications”, PMNM-2012 (Russia, 2012), 2013 International Symposium “Physics and Mechanics of New Materials and Underwater Applications”, PHENMA 2013 (Taiwan, 2013), 2014 International Symposium “Physics and Mechanics of New Materials and Underwater Applications”, PHENMA 2014 (Thailand, 2014), 2015 International Conference “Physics and Mechanics of New Materials and Their Applications”, PHENMA 2015 (Russia, 2015), 2016 International Conference “Physics and Mechanics of New Materials and Their Applications”, PHENMA 2016 (Indonesia, 2016), 2017 International Conference “Physics and Mechanics of New Materials and Their Applications”, PHENMA 2017 (India, 2017) and 2018 International Conference “Physics and Mechanics of New Materials and Their Applications”, PHENMA 2018 (South Korea, 2018), 2019 International Conference “Physics and Mechanics of New Materials and Their Applications”, PHENMA-2019 (Vietnam, 2019), 2020 International Conference “Physics and Mechanics of New Materials and Their Applications”, PHENMA-2020 (Japan, 2021), 10th Anniversary International Conference on “Physics and Mechanics of New Materials and Their Applications”, PHENMA 2021 – 2022 (Russia, 2022), 2023 International Conference on “Physics and Mechanics of New Materials and Their Applications”, PHENMA 2023 (Indonesia, 2023), 2024 International Conference on “Physics and Mechanics of New Materials and Their Applications”, PHENMA 2024 (India, 2024), 2025 International Conference on “Physics and Mechanics of New Materials and Their Applications” PHENMA 2025 (Japan, 2025) predefined objectives and scientific directions of the 2026 International Conference on “Physics and Mechanics of New Materials and Their Applications” PHENMA 2026 (Busan, South Korea, July 15 – 18, 2026). A significant interest to the PHENMA-2025 has led to the great sponsor support from Ministry of Education and Science of the Russian Federation, Russia; Russian Science Foundation; South Scientific Center of the Russian Academy of Science; National Science and Technology Council, Taiwan; The Society of Materials Science, Kyushu Branch, Japan; Kitakyushu Convention & Visitors Association, Japan; The Korean Society for Composite Materials, South Korea; LAMSC, (South Korea); Composite Solutions Co. (South Korea); National Foundation for Science & Technology Development (Vietnam); Vietnam Association of Science Editing (VASE); Vietnam Union of Science and Technology Associations (VUSTA); New Century Education Foundation (Taiwan); Ocean & Underwater Technology Association (Taiwan); Fair Well Fishery Co. (Taiwan); Longwell Co. (Taiwan); Institute of Engineering & Technology, DAVV (India); University of 17 Agustus 1945 Surabaya (Indonesia); Don State Technical University (Russia), Kyushu Institute of Technology (Japan), Korea Maritime and Ocean University; Hanoi University of Science and Technology (Vietnam); Vietnam Maritime University; Vinh Long University of Technology Education (Vietnam); Hanoi University of Industry; Vietnamese-German University (Vietnam); Ho Chi Minh City University of Agriculture and Forestry (Vietnam); Research Institute of Agriculture Machinery (Vietnam); Fevzi Yakubov Crimean Engineering and Pedagogical University (Russia)

The PHENMA 2026 abstracts, presented by scientists from 20 countries, cover processing techniques, physics, mechanics and applications of new materials, industry and management.

Conference Chairs: Prof. Yun-Hae Kim, Prof. Shun-Hsyung Chang, Prof. Ivan A. Parinov



ABSTRACTS

Numerical Modeling of Gas Velocity Dependence in a Gas Sensor

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An important element of the main types of semiconductor gas sensors is the sensitive element, which usually requires heating to temperatures of 50 – 400 °C to ensure high sensitivity or selectivity of the sensor. The heater, located on the back side of the gas sensor chip, heats the entire sensor. This initiates natural convective gas movement, which delivers the analyzed gas to the sensor's sensitive element. The speed of the gas medium flow directly affects the response time and stability of the device readings. In some cases, artificial air flow is created, using low-power fans. However, this leads to an increase in the cost of gas sensors. At the same time, there is no information in the literature on the air medium flow speeds in sensors due to natural convective gas movement. In this work, the natural convective gas movement inside a vertically positioned conical tube was numerically modeled, through which the air medium of the gas sensor flows and in which the gas sensor is fixed. To assess the degree of influence of the sensor surface temperature and the tube's geometric parameters on the flow speed, the modeling was carried out in the COMSOL Multiphysics software package [1]. A three-dimensional problem formulation was considered. The housing shape was varied: cylindrical, conical, inverse conical, and the heater temperature T_{heat} from 50 °C to 400 °C. The temperature across the entire sensor gas chip (heater) was assumed constant (T_{heat}). The tube height (H) was taken as 65 mm, the distance from the base to the center of the sensitive element was $l = 20$ mm, the outer diameter of the housing $d_1 = 15$ mm, the taper $\frac{2k}{H}$, for k from -1.6 to 1.6 mm. The flow pattern is laminar. Figure 1 shows the dependencies of the gas flow speed at the sensor location on its temperature. Based on the numerical model calculation, it was found that the speed of the gas mixture flow near the sensor is directly proportional to the heater temperature and inversely proportional to the taper. At a low operating temperature of the sensor of 100 °C, the flow speed can reach 100 cm/min, which is sufficient for measurements. Thus, the results allow for a reasoned selection of the housing geometric parameters and heater operating modes to ensure the required device performance, while

sufficiently providing autonomy and automation by eliminating the forced convection mechanism.

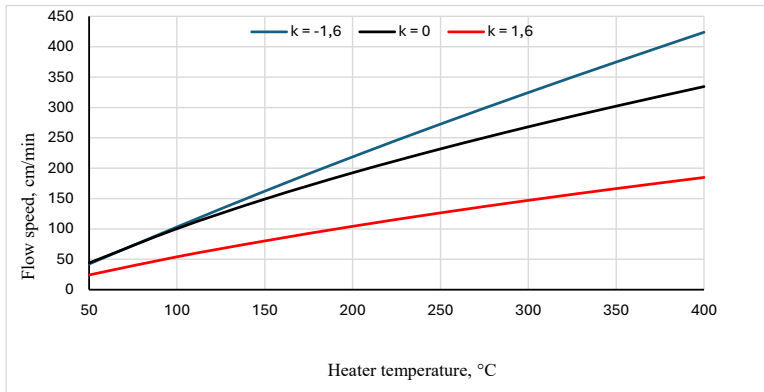


Fig. 1. Dependence of gas flow speed at the sensor location on the heater temperature

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Optimisation of Conductive Network in Porous Flexible Sensors via Controlled Dip Coating for Strain Sensing Performance

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In recent years, flexible sensors have gained significant attention due to the rise in wearable technology and the increasing demand for real-time sensing. These sensors include applications in soft robotics, human-machine interface and wearable motion monitoring. Among various sensing mechanisms, piezoresistive sensing is one of the most widely used. Its performance strongly depends on the morphology and connectivity within the conductive network of the matrix. This study focuses on the design selection criterion to identify the optimal conductive network distribution in MWCNTs dip-coated porous Polydimethylsiloxane (PDMS) foam, with a focus on strain-sensing behaviour. The sacrificial template technique was used to fabricate porous PDMS foam using sugar cubes and subsequently coated with MWCNT-OH through multiple from one to five dip-dry cycles. The main design parameter was the number of coating cycles to control the conductive network density with the PDMS foam. Samples with from one to five coating cycles were fabricated and evaluated based on baseline resistance and relative resistance change under controlled mechanical loading. However, increasing the number of coating cycles reduced baseline resistance. This is due to an increase in additional active conductive pathways. Baseline

resistance measurements showed a strong dependence on coating level, decreasing from approximately 11 kΩ for lightly coated samples to about 1.5 kΩ for heavily coated samples. However, the electromechanical response under loading conditions did not follow the same trend. Relative resistance change was evaluated using a lab-developed testing setup by applying a controlled displacement, later converted to compressive strain using the initial sample thickness of 14 mm. Each sample was subjected to 25% strain to find the optimal coating cycle. The sample with three dip-dry cycles showed the highest relative resistance of 22% in comparison to other samples. The reason for this behaviour is due to percolation-based network evolution. Lightly coated samples have fragmented conductive pathways, limiting resistance variation during deformation. In comparison, heavily coated samples form a large conductive network, leaving less scope for new conductive pathway generation under loading. The medium coating level provides a conductive network that has a higher chance of path activity under loading conditions. Based on this performance-based selection, the sample with a higher electromechanical response was further evaluated under controlled strain loading conditions to evaluate electromechanical characterisation. The selected sample was further characterised under displacement-controlled compression at different strain levels to perform the electromechanical test. The resistance measurement was used to evaluate the gauge factor. Also, dynamic loading tests were performed at multiple strain states to show the stable and repeatable signal output. To assess durability, the sensor was also subjected to 500 loading–unloading cycles, during which the resistance response remained repeatable with minimal drift. These findings show that the density of the conductive network plays an important role in determining both the strain sensitivity and the stability of the sensor response. These characteristics make the sensor promising for strain monitoring applications. By connecting fabrication parameters with electromechanical performance through a structured selection approach, this work moves the development of porous elastomer strain sensors toward a more design and optimization-oriented methodology.

Increasing Diamond Ore Beneficiation Process Efficiency with LMS-driven Production Simulation and VR/AR-approaches

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The development and advancement of simulation modeling methods provide an opportunity to study and optimize business processes of enterprises without risk to real production and with minimal costs [1]. Modern mineral processing plants, Mine Mir, Mirny, Russia, for instance, face increasing pressure to improve output, reduce downtime and minimize the cost of layout changes in highly capital-intensive environments. In this study we consider a diamond ore beneficiation and sorting line as a representative manufacturing system and propose a modular VR/AR-based system, combined with learning management system (LMS). It is quite difficult to implement every chain aspect in one package such as mining operations, diamond-bearing ore transportation, primary processing, dressing and others but unified API can be provided [2]. Technological processes at mentioned stages are described within a stochastic discrete-event simulation (DES) model of queuing type [3]. The system state reflects the utilization of mining and processing equipment, the availability of

infrastructure, state of material flows and so on. Diamond mining involves numerous risks, including health hazards, so it is important to consider safety measures and the proper use of personal protective equipment. Operation times and event probabilities are represented by probability distributions, which makes it possible to evaluate factory capacity, queue lengths and resource utilization. It is important to note key characteristics of diamond-bearing ore such as particle size distribution, bulk density, hardness, etc. to link operational performance to material specifics [4]. Operators' behavior in all modules is described, using Markov process with discrete levels [5]. Transition probabilities between levels are determined from LMS data, which records actions in VR/AR-sessions. Classic teaching techniques including points-based system, real-time tracking, adherence to set stage regulations check and others are actively used to determine and enhance trainees' skills. Immersive VR/AR-environment on the Unreal Engine 5 foundation implements modular digital twin (DT) featuring realistic 3D-graphics, multiple interactive objects and data exchange tools between different modules.

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Nano Piezo Digital-analog Actuator for Mechatronics

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The nano piezo digital-analog actuator is used for precise adjustment in mechatronics for DNA research, wave front correction and compensation deformations in scanning microscopy and XYZ micropositioning system. The nano piezo digital-analog actuator with coded control is the electromechanical instrument to conversion of the coded electric signals into mechanical displacement and force of actuator [1 – 7]. The nano manipulator with the nano piezo actuator is used for the positioning in mechatronics. Nano piezo-digital-analog actuators for mechatronics are calculated, using mathematical physics. The nano piezo digital-analog actuator solves problems of precise adjustment in nanotechnology, microelectronics, compensation of the temperature and gravitational deformations, the atmospheric turbulence by the wave front correction. The investigation of the characteristics of the piezo actuator is necessary for the calculation of the actuator control systems for nano mechatronics [1 – 14]. The structural design of the multilayered piezo actuator from PZT ceramics depends on the

manufacturing technology. For example, a multilayered piezo actuator for studying longitudinal piezo effect is made as the compound piezoelectric converter from separate elastically compressed piezoelectric plates. The stack type or the block piezoelectric converter is manufactured from the piezoelectric plates, sintered using silver paste. The compound piezoelectric converter consists of the piezoelectric stacks with elastic reinforcement. The multilayered piezoelectric converter is glued from the piezoelectric plates. The multilayered piezoelectric converter includes the layers, deposited, using the thin-film or the thick-film technologies. At present, the problems of providing precision control systems for deformation of the multilayered piezo actuator for nano- and micrometric movements in the case of the parallel and coded control are topical, and the solution of these problems requires determination of the corresponding characteristics of the piezo actuators. In the case of parallel control, all the piezo plates in the multilayered piezo actuator are connected in parallel. The application of the multilayered piezo actuator with coded control makes it possible to efficiently use electromechanical digital-analog conversion for nano- and micrometric movements. In the case of coded control, piezo plates in the piezo actuator are connected in parallel in each section. The number of piezo plates in the section is equal to a power of 2, i.e., 1, 2, 4, 8, 16, and so on and the control voltage is supplied to each section via the multiplexer. To calculate deformation of the multilayered piezo actuator for control system, it is necessary to consider the specific features of its characteristics in the case of the parallel and coded control. The main parameter of external load of the piezo actuator is the load stiffness, i.e., the ratio of the force of elastic reaction of the load to the value of the load deformation. The study of the influence of load stiffness on the characteristics of the sectional piezo actuator for transverse, longitudinal, shear piezo effects in the case of parallel and coded control are topical and represent certain interest in design of the precision equipment [10 – 30]. Elastic compliances are obtained. The characteristics of the nano piezo digital-analog actuator at the shear, transverse, longitudinal piezo effects are calculated for mechatronics.

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Dielectric Properties in the Microwave Range of Dispersed-Crystalline Powders of BaTiO₃, Modified with NiO

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In today's world, devices capable of maintaining stable operation despite interference and noise, generated by electronics, are increasingly important. Maintaining performance at temperatures, ranging from 193 to 353 K, is also essential, necessitating the selection of materials with consistent electrophysical parameters, such as permittivity, absorption and reflection coefficients, crystal structure, attenuation constant, and others. Solid solutions, based on the BaTiO₃ system, modified with various cations, are highly promising due to their inherent electrophysical properties (high Curie temperature, high losses, etc.) but have been poorly studied in the microwave range. Therefore, modifying BaTiO₃ solid solutions with Ni cations, which can alter the original properties, and investigating their properties under varying temperature and electromagnetic frequency appears relevant. The objects of the study were dispersed crystalline powders of a material with the composition Ba_{0.7}Ni_{0.3}TiO₃. The average particle size was ~100 μm. The objects were obtained by solid-phase synthesis in two stages: $T_{\text{synth.1}} = 1470$ K, $\tau_{\text{synth.1}} = 5$ hours, $T_{\text{synth.2}} = 1520$ K, $\tau_{\text{synth.2}} = 5$ hours. Radiophysical studies were conducted in a cooling mode from ~585 K to ~300 K, using a specially developed system, based on a Keysight P9375A vector network analyzer at frequencies (f) from 12.4 GHz to 18 GHz. The real (ϵ') and imaginary (ϵ'') components of the permittivity were calculated using the NRW (Nicholson-Ross-Weir) method. A sharp increase in the value of ϵ' was observed at $T \sim 500$ K with the formation of a maximum below $f = 16$ GHz. A more monotonic increase in ϵ' is observed in the temperature range $425 \text{ K} < T < 500 \text{ K}$ at $f < 15.5$ GHz. In all other values

of T and f , a constancy of ε' values is observed. For ε'' , the presence of dispersion with frequency variation was established over the entire range of studied T . The value of ε'' is $\sim 3 - 25$, decreasing as f increases. It is necessary to note the formation of a diffuse maximum of ε'' for all studied f and $T \sim 475$ K. Calculation of the reflection loss (RL) revealed a minimum value (~ -4 dB) at $T < 430$ K and $f < 12.7$ GHz. For $T > 430$ K, the extremum shifts to lower frequencies beyond the studied region. The RL maximum ($\sim -0.01 - 0.09$ dB) was established at $f \sim 14.4 - 15.4$ GHz. Based on the data obtained, a conclusion was made about the possible practical application of the materials studied.

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Low-Complexity Transversers with Square Wave Carrier for Band-Limited Acoustic Transducers

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Low-cost acoustic transducers, such as HC-SR04 and JSN-SR04T, are widely used for range-finding applications; their potential for communication is also demonstrated in lectures [1, 2].

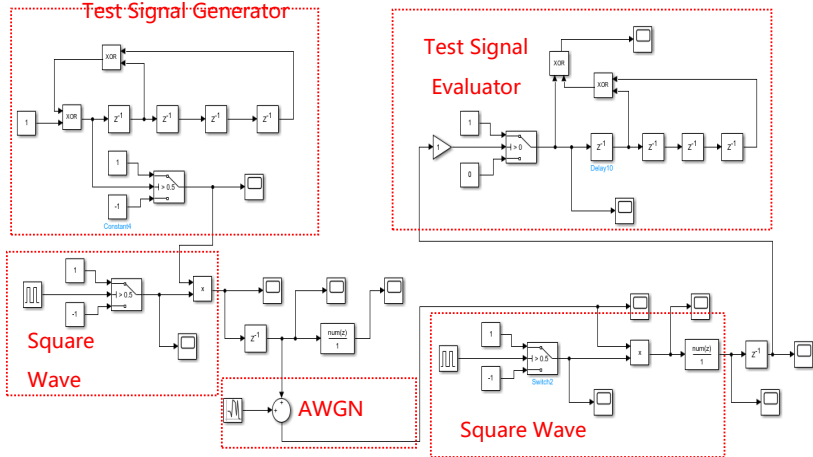


Fig. 1. Simulink model for proposed low-complexity full-digital communication system evaluation

Due to the limited bandwidth and weak driving power, only low data rate and short-range applications are possible. Most of these communication systems are integrated, using ready-made components for transmission signal generation and receiving signal detection; the detail internal signal processing are rarely investigated. In this work, a low-complexity full-digital transmitter and receiver are implemented for the low-cost acoustic transducers. The proposed communication system constructed using Simulink of Matlab is shown in Fig. 1. Thanks for the limited bandwidth, a square-wave can be used as a carrier signal, which dramatically simplifies the circuits of both the modulator and demodulator. In addition to the circuit design, the frequency responses of the low-cost acoustic transducers are evaluated for both underwater and terrestrial applications. The difference in central frequency for the individual environments has not been noted in lectures yet, but are carefully investigated in this work, and then the carrier frequencies can be optimized correspondingly.

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Study of the Dielectric Response of Dispersed-crystalline Powders of the Composition $\text{Pb}(\text{Zr}_{0.80}\text{Ti}_{0.20})\text{O}_3$ in the Microwave Range

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Traditional microwave absorbing materials based on magnetic and carbon components are limited in their use at high temperatures due to loss of properties and oxidation. This has stimulated the search for alternative dielectric materials for the microwave range. Ferroelectrics of the $\text{Pb}(\text{Zr}, \text{Ti})\text{O}_3$ (PZT) family are the most promising for solving this problem; however, their behavior in the gigahertz range has been poorly studied. The dispersed-crystalline form of PZT is of particular interest because it preserves the individuality of each crystallite, allowing the properties of the crystalline phase to be studied without the influence of intergranular layers characteristic of ceramics. Considering all the above, studying the dielectric response of dispersed crystalline $\text{Pb}(\text{Zr}_{0.80}\text{Ti}_{0.20})\text{O}_3$ powders over a wide temperature and frequency ranges seems relevant. The objects of this study were dispersed crystalline powders of a material based on the PZT system: $\text{Pb}(\text{Zr}_{0.80}\text{Ti}_{0.20})\text{O}_3$. The particle size was ~ 100 μm . The objects of study were obtained by solid-phase synthesis, which took place in two stages: $T_{\text{synth.1}} = 1143$ K, $T_{\text{synth.2}} = 1173$ K, $\tau_{\text{synth.1}} = \tau_{\text{synth.2}} = 5$ hours. Radiophysical studies were carried out in cooling mode from ~ 585 to ~ 300 K. A specially developed complex based on a Keysight P9375A vector network analyzer was used. The studies were carried out in the f range from 12.4 to 18 GHz. Calculation of the real (ϵ') and imaginary (ϵ'') components

of the permittivity was carried out using the NRW (Nicholson-Ross-Weir) method. A complex temperature behavior of permittivity's was revealed. It was found that at frequencies below 16 GHz, ε' exhibits a linear increase over the entire studied temperature range, with dispersion appearing at $T \approx 364$ K. At frequencies above 16 GHz, anomalous (nonlinear) behavior of ε' is observed. Nonlinear behavior was demonstrated for ε'' , with the formation of inflection points near phase transformations at all studied temperatures, accompanied by dispersion. A direct correlation was demonstrated between the evolution of the phase composition of the powders and the nature of the change in their dielectric parameters. A conclusion was made about the possible use of the materials studied in telecommunication devices.

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The Influence of Temperature and Microwave Power on the Dielectric Properties of the Ceramic Solid Solution $\text{PbZr}_{0.94}\text{Ti}_{0.06}\text{O}_3$

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In the development of various microwave components, the attenuation constant (α) is traditionally considered as a parameter determining the material's ability to attenuate incoming electromagnetic waves. In the context of this work, α is considered more broadly, namely, as an integral characteristic of the material's quality. When studying ferroelectric materials, understanding the dependence of their properties on electromagnetic radiation power (P) is essential for correctly calculating operating modes, specifically, impedance matching and estimating the maximum power, which the device can withstand without distorting its characteristics or causing failure. Therefore, the aim of this study was to establish patterns of attenuation, varied with variations in P and temperature (T). The subject of this study was a ceramic solid solution of $\text{PbZr}_{0.94}\text{Ti}_{0.06}\text{O}_3$ composition. Radiophysical studies were conducted in a cooling mode from ~ 585 to ~ 300 K. A specially developed system based on a Keysight P9375A vector network analyzer was used. The studies were carried out in the f range from 12.4 to 18 GHz at P from -15 dBm to 15 dBm. Constant α was calculated, according to the following formula [1]:

$$\alpha = \sqrt{2}\pi f / c \times ((\mu''\varepsilon'' - \mu'\varepsilon') + (\mu''\varepsilon'' - \mu'\varepsilon')^2 + (\mu'\varepsilon'' + \mu''\varepsilon')^2)^{1/2})^{1/2},$$

where f is the microwave frequency, c is the speed of light in free space, ε' and ε'' are the real and imaginary parts of the relative permittivity, μ' and μ'' are the real and imaginary parts of the relative magnetic permeability. It was found that the maximum of α (~ 130) is achieved at (320 – 370) K and (12.4 – 13.7) GHz. It was shown that the main contributions to α are made by T and f , while the influence of P does not exceed 2% in the ferroelectric phase. In the cubic phase at $f = 18$ GHz, the change is $\sim 7\%$. Constant α in the 12.4 – 18 GHz range is a highly sensitive parameter to the state of the PZT crystal lattice. Due to the low α values, the studied

material is not useable as a radio-absorbing material but can be considered as a material for cavity dielectric resonators in microwave systems.

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Research on Application of Lean Manufacturing in Sewing Line for Multi-layer Blazers at the Services Production Center Hanoi Industrial and Trade University

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The garment industry is one of the important industries contributing to the development of Vietnam's economy [1 – 10]. Industrial revolution 4.0 is changing a lot of the operating processes of traditional businesses. Applications of technology, digital, and artificial intelligence have been put into practice to increase the effectiveness of corporate governance around the world. Vietnamese businesses in general, and garment businesses in particular, need to enhance their management capabilities and maximize both quantity and quality of goods if they are to integrate successfully into the regional and global economy. Currently, our country is actively participating in bilateral and multilateral trade agreements, including CPTPP and EVFTA, which attract many foreign investment projects in Vietnam's textile and garment industry. It is not only an incredible opportunity but also a huge challenge faced by numerous domestic textile enterprises. Garment companies are making a strong transformation in the innovation process to promptly meet the needs of customers. Besides expanding production scale, retrofitting machinery and equipment, enhancing product designs, etc., increasing labor productivity and improving product quality is also a top priority. To solve this problem, worldwide garment manufacturing enterprises in general and Vietnamese enterprises in particular are aiming to apply lean manufacturing tools in the production process to promote production efficiency and improve product value. This study presents the method of surveying productivity, labor efficiency and product quality to identify waste and irrational points in the production of sewing lines Blazers at the Service Production Center of Hanoi Industrial and Trade University. Therefore, the authors have applied some lean manufacturing tools to develop these sewing lines. The application of these innovative tools has boosted the productivity and labor efficiency of the production teams, improved product quality, contributed to fast production conversion, and reduced waste in production, created

competitive advantages in the domestic and export markets in general and at the Service Production Center of Hanoi Industrial and Trade University, in particular.

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Computer Optimization of Shear Piezoelectric Transducers for Application as Energy Harvesting Devices

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This article focuses on the development of mathematical and computer models of shear piezoelectric transducers in the form of plates, attached to an inertial mass on one side and fixed on the other. Two types of piezoelectric plates are considered: thickness-polarized plates with electrodes on the sides; and plane-polarized plates with electrodes on the faces. The active

element of the transducers is made of a composite material (porous piezoceramics). The developed models are used to optimize the output characteristics of these devices. Within the framework of the linear theory of electroelasticity, steady-state planar flexural and shear vibrations of the plates in the low-frequency region and in the first flexural-shear mode are considered. The operation of the devices as piezoelectric energy generators (PEGs) is simulated. The ACELAN finite element package [1] is used to numerically study the dependence of the natural frequencies of resonance and antiresonance, and to determine the damping coefficients for the first flexural-shear modes of antiresonance, depending on the piezoelectric layer porosity. Based on this, the electromechanical coupling coefficients (EMCC) are calculated, and their maximum values are determined. Next, forced vibrations are considered under mechanical load on the inertial mass. Output electric potentials are calculated for the device, operating in PEG mode. For the second type of device, the dependence of mechanical stress is studied for single-layer and double-layer structures. Based on this analysis, a conclusion is drawn, regarding the superiority of the double-layer element.

Acknowledgement. The study was carried out with the financial support of the Russian Science Foundation grant (No. 22-11-00302-P), <https://rscf.ru/project/22-11-00302/> at the Southern Federal University.

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Optimization of the Finite Element Model of a Semi-passive Bimorph with an Active Layer Made of Porous Piezoceramics, Considering the Choice of Non-uniform Porosity in the Plane of the Piezoelectric Layer

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An applied theory of transverse vibrations of a two-layer electroelastic plate with non-uniform mechanical and electrical properties across the plate's thickness was developed. The applied theory was constructed using a variational principle, based on Kirchhoff-Love-type hypotheses for mechanical characteristics and a quadratic distribution of electric potential in each layer. A system of partial differential equations was obtained for the deflection of the plate's midplane and the distribution of electric potential in the midplane of each layer. Furthermore, expressions were derived for accounting for mechanical and electrical boundary conditions. An algorithm for numerical optimization of the bimorph's output characteristics

was developed, including the "operating" resonant frequency, electromechanical coupling coefficient, output potential, and maximum deflection. The optimization algorithm is based on a combination of solving a boundary-value problem, using applied theory and finite element method in the COMSOL or ACELAN package [1], and a genetic algorithm from MatLab. Numerical experiments were conducted to maximize the bimorph's output characteristics. Specifically, the dependencies of the natural resonance and antiresonance frequencies on the piezoceramic porosity distribution in the plane of a circular bimorph are investigated, and the electromechanical coupling coefficients are determined. The output electrical potential and maximum plate deflection are affected by mechanical and electrical excitation of vibrations in the low-frequency region. Numerical calculations have shown that the natural resonant frequency decreases when using porous ceramics. The highest output electric potential is achieved with a uniform porosity of 80%, but the CEMS is the lowest. The highest output potential is achieved with a linear porosity distribution from 0% at the center to 80% at the edge. When using the device as a piezoelectric generator, porosity distribution patterns in the plate plane with numbers 3, 4, and 5 are preferable, where the center of the plate contains a region of continuous piezoceramic, and the porosity increases towards the edge of the plate.

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Optimization of the Output Characteristics of Functionally Gradient Plate Transducers by Varying the Porosity and Thickness of Piezoelectric Layers for Different Boundary Conditions and Vibration Modes

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This work focuses on developing a mathematical and computational model of a piezoelectric transducer in the form of a flat semi-passive bimorph, the active layer of which is divided into two parts and made of a composite material (porous piezoceramics), and optimizing the output characteristics of this device. The steady-state flexural vibrations of the bimorph in the low-frequency region, in the first and second flexural modes, are considered. The bimorph consists

of a steel plate (substrate) and two smaller piezoelectric layers. First, the optimal dimensions of the piezoelectric layers are calculated to efficiently generate a potential difference in the second flexural mode. Two types of boundary conditions at the edge of the substrate are considered: (i) rigid support, and (ii) hinged support. Using the ACELAN finite element package [1], we numerically study the dependence of the natural frequencies of resonance and antiresonance on the thickness and porosity of the piezoelectric layers. We also determine the damping coefficients for the second flexural antiresonance mode as a function of the porosity and thickness of the piezoelectric layers. Based on this, we optimize the electromechanical coupling coefficient (EMC) by selecting the geometry and porosity of the piezoelectric layers in the second flexural mode and optimize the output potential under mechanical action on the passive bimorph layer by selecting the geometry and porosity of the piezoelectric layers in the second flexural mode.

Acknowledgments. The work was supported by the Russian Foundation for Basic Research, project No. 22-11-00265-P, <https://rscf.ru/project/22-11-00265/>, at the Southern Federal University.

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Optimization of a Semi-passive Bimorph with an Active Layer Made of Porous Piezoceramics under Different Mechanical Boundary Conditions to Increase the Output Potential in the First Bending Mode

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This work focuses on developing a mathematical and computational model of a piezoelectric transducer in the form of a semi-passive disk bimorph, the active layer of which is made of a composite material (porous piezoceramics) and optimizing the output characteristics of this device. Axisymmetric steady-state flexural vibrations of the bimorph are considered in the low-frequency region and in the first flexural mode. The bimorph consists of a steel plate (substrate) and a piezoelectric layer of smaller radius. Two types of boundary conditions at the edge of the substrate are considered: (i) rigid support, and (ii) hinged support with free movement along the radius. Numerically, using the ACELAN [1] finite element software, the dependencies of the resonance and antiresonance natural frequencies on the piezoelectric layer radius and its porosity are studied. The damping coefficients for the first antiresonance flexural

mode are determined as a function of the piezoelectric layer porosity. On this basis, the optimization of the electromechanical coupling coefficient (EMC) is carried out by selecting the geometry and porosity of the piezoelectric layer in the first bending mode and the optimization of the output potential under mechanical action on the passive layer of the bimorph, based on the selection of the geometry and porosity of the piezoelectric layer in the first bending mode.

Acknowledgments. The work was supported by the Russian Foundation for Basic Research, project No. 22-11-00265-P, <https://rscf.ru/project/22-11-00265/>, at the Southern Federal University.

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Identification of the Damaged State of Extended Elements Based on the Solution of a Non-stationary Problem of the Theory of Elasticity

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This study considers the inverse coefficient and geometric problem of determining the parameters of the damaged layer of an extended structure. This inverse problem of elasticity theory for determining the depth and extent of damage to the surface layer is solved, based on the analysis of non-stationary elastic waves. A two-layer elastic anisotropic strip is considered as a model of such a structure. The upper layer is represented by a porous composite that simulates the damage, the percentage of porosity corresponds to the degree, and the layer thickness corresponds to the depth of damage. The effective properties of the damaged layer are contained in the ACELAN-COMPOS package [1]. A piezoceramic actuator and sensor are located at the border of the strip. Waves are excited by the potential difference across the actuator and received at the sensor. As additional information for solving the inverse problem of identifying the damage parameters (porosity and depth), the time to reach and the amplitude of the maximum electrical voltage at the sensor are considered. The dependencies of these quantities on the damage parameters are plotted in the form of surfaces and their level lines. The region of their possible unambiguous identification, based on this data, is determined. This region is characterized by the fact that certain level lines of these surfaces intersect at a single point. The exception is an area with minor damage (low porosity and layer depth).

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Applied Theory for Calculating Transverse Vibrations of a Layered Structure with Polymer Matrices and Inclusions of Porous Piezoceramic Rods, Located along the Layer

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This study focuses on the development of mathematical and computational models of piezoelectric transducers in the form of multilayer plates, the material of which is a composite of 1 – 3 connectivity. The piezoceramic rods are in the plane of the layers, and adjacent layers have different pre-polarization directions. Furthermore, the piezoceramic rod material is porous, allowing for the selection of stiffness, comparable to the layer's polymer matrix. The effective properties of this composite material have been previously studied using the ACELAN-COMPOS package [1]. The plates under study perform transverse vibrations, with the "operating" frequency, being the antiresonance frequency of the first bending mode, if the piezoelectric element operates as a piezoelectric generator. The main goal of the project is to develop an applied method for calculating the output characteristics of a piezoelectric element based on hypotheses regarding the distribution of its mechanical and electric fields. These assumptions include Kirchhoff-Love-type hypotheses and a two-dimensional electric potential distribution. For steady-state oscillations, a system of two partial differential equations (two-dimensional case) was obtained for the midsurface deflection function and the electric potential. Expressions for the force and electric factors across the plate thickness were obtained, which are used to formulate the boundary conditions. For a panel (one-dimensional case), a corresponding system of ordinary differential equations was obtained. To test the adequacy of the proposed theory, a finite element model of a plate with opposite longitudinal polarization of two layers was constructed, using the ACELAN package (one-dimensional case). The calculation results from the applied theory developed were compared with those calculated in ACELAN. This comparison demonstrated the high accuracy of the applied method, with an error in determining displacements and electric potential of less than 2%.

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Mathematical Modeling of the Interaction of a Rigid Lensotome Tip with an Amorphous Lens Substance and the Selection of the Optimal Destruction Option with Maximum Efficiency

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When performing cataract phacoemulsification, not only the operating mode of the surgical instrument but also the interaction of the tip with the lens material plays a crucial role. During contact, dynamic effects can occur, causing the lens to shift and increasing the load on the supporting structures. This can reduce the effectiveness of cataract phacoemulsification and increase the risk of complications during surgery. Therefore, it is of interest to study how tip geometry, its motion parameters, and vacuum fixation conditions influence the process of lens phacoemulsification. The aim of this study was to construct a mathematical model of the interaction between a rigid lensotome tip and the amorphous lens material and to determine the impact parameters that maximize destruction while minimizing trauma to surrounding structures. Finite element modeling was used to address this problem. Various values of tip speed, amplitude, frequency, and direction of movement were considered. Vacuum retention of the lens nucleus was also assessed under different impact conditions. Special attention was paid to comparing several tip geometries, differing in the shape of the working part and the bevel angle. Modeling allowed us to determine the parameters of the tip's reciprocating motion that reduce lens repulsion and increase the efficiency of lens fracture. A comparative analysis of tips with diameters of 0.7 – 1.0 mm was conducted, demonstrating the influence of their sizes on the intensity of mechanical impact. Furthermore, it was established that the shape of the tip's working portion significantly influences the stress-strain state of the lens substance and the nature of its fracture. The resulting model can be used to further optimize the design of the lensotome tip, select the most efficient operating modes, and improve surgical safety by reducing unwanted stress on the capsular-ligamentous apparatus of the eye. The obtained results have practical implications for improving cataract microsurgery technologies.

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Fast and Accurate Quasi-atom Method Hybrid Model for Simultaneous Atomistic and Continuum Simulation of Solids

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We present a versatile, high-performance multiscale framework that effectively bridges the gap between atomistic resolution and continuum mechanics. While traditional hybrid methods like Atomic-to-Continuum (AtC) often face implementation hurdles and computational lag, our approach offers a streamlined, high-speed alternative. The foundational accuracy of this method in matching the elastic properties of composite media has been rigorously validated in our previous work in “*Computer Physics Communications*”, <https://doi.org/10.1016/j.cpc.2026.110078>. The current evolution of our framework introduces a shift from point-mass representations to morphologically flexible particles on the meso-scale. This allows the simulation to capture not only bulk elastic behavior but also the moment of inertia I and rotational degrees of freedom, providing a physically complete description of energy distribution in critical regions. Crucially, we have moved beyond legacy empirical potentials to a universal, potential-agnostic architecture. Our system now seamlessly integrates with sophisticated Machine Learning Potentials, removing previous limitations on material complexity and chemical accuracy. The multi-scale nature of this approach is visually demonstrated through simulations of high-velocity collisions between particles of varying scales, where the seamless transition between discrete atoms and meso-scale particles is highlighted (see Fig. 1).

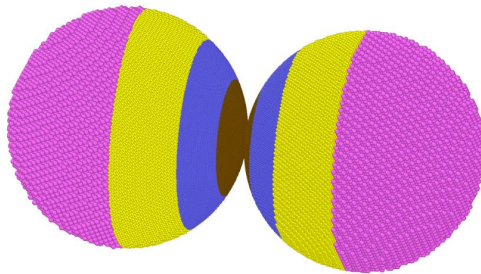


Fig. 1. Illustration of two colliding multi-scale particles comprised of real atoms (brown) in the critical region, namely the area of their contact and three different types of quasi-atoms, blue, yellow and rose, which are twice, four and eight times larger than the real atoms.

Interaction parameters are optimized via an online Machine Learning engine, ensuring coupling between the discrete and continuum domains within standard MD environments like LAMMPS. Furthermore, we discuss the ongoing implementation of an AI-driven autoreolution protocol for dynamic grid refinement, providing a significant leap in both physical realism and computational throughput for next-generation material design.

Control of Liquid-phase Synthesis Parameters to Enhance the Functional Characteristics of Iridium-containing Catalysts

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The global drive to achieve zero carbon footprint requires the development of efficient energy storage systems, in which hydrogen plays a key role as the energy carrier. Hydrogen with a purity of > 99.99% at pressures exceeding 50 bars is produced in specialized devices, namely proton exchange membrane electrolyzers. The key component of the electrolyzer is an expensive iridium-based catalyst, the content of which can be reduced by alloying with more readily available metals (Pt, Ru, Pd). This study focuses on the preparation of bimetallic IrPt catalysts of similar composition in various atmospheres (air, argon and oxygen) and the subsequent investigation of the relationship between composition and electrochemical performance. According to the results of material testing in a laboratory three-electrode cell, the catalyst, prepared in an air atmosphere, exhibited the highest activity. At a potential of 1.53 V, its activity reaches 14.0 mA/cm², which is 36% higher than that of its counterpart prepared under an argon atmosphere (8.9 mA/cm²). The lowest OER activity was demonstrated by the sample synthesized under an oxygen atmosphere of 7.2 mA/cm² (Fig. 1). The dependence of catalyst activity on the synthesis atmosphere is likely related to the oxidation state of iridium. The formation of surface oxides of Ir in air provides high activity, whereas metallic Ir, formed in an inert atmosphere, is significantly less active.

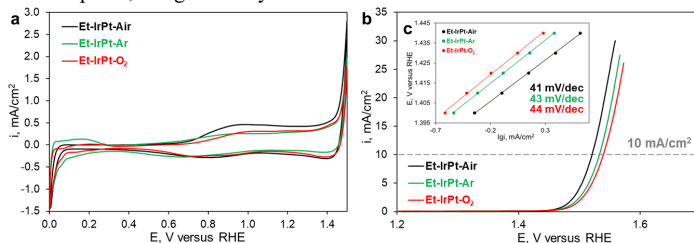


Fig. 1. (a) Cyclic voltammograms of materials, 0.1 M HClO₄, Ar atmosphere, a scan rate of 20 mV/s; (b) Linear sweep voltammograms of the oxygen evolution reaction, 0.1 M HClO₄, Ar atmosphere, a scan rate of 5 mV/s, 1600 rpm; (c) Tafel plots.

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Resistive Switching Properties of Hafnium Oxide Memristor Structures for Neuromorphic Systems

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Hafnium oxide (HfO_2) is one of the most promising materials for resistive random-access memory (ReRAM) can perform long-term memory and information processing functions due to its compatibility with CMOS technology, high dielectric constant, and excellent scalability. HfO_2 has band gap of 5.5 eV and optically transparent in the visible spectral range. Controlled fabrication of HfO_2 -based memory devices offers non-volatile memory systems [1]. This work investigates $\text{TiN}/\text{HfO}_2/\text{Ag}$ memristor structures fabricated by magnetron sputtering on Si/SiO_2 substrates at room temperature. The multilayer structures were formed in three stages: (i) deposition of a TiN bottom electrode (200 nm) by pulsed DC magnetron sputtering (p -DC) with a frequency of 100 kHz; (ii) an HfO_2 active layer (~ 30 nm) was deposited on the TiN-coated substrates by RF magnetron sputtering from a ceramic HfO_2 target; and (iii) Ag top electrodes (a thickness of 150 nm, a diameter of 760 μm) were deposited on the HfO_2 active layer surface also by pulsed DC magnetron sputtering. Electrical characterization demonstrated bipolar non-volatile resistive switching, indicating potential for application in machine vision systems and non-volatile memory devices.

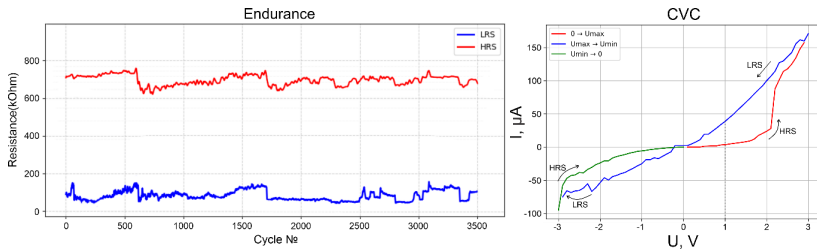


Fig. 1. $\text{TiN}/\text{HfO}_2/\text{Ag}$ memristor endurance and current-voltage characteristic

The endurance characteristics of the $\text{TiN}/\text{HfO}_2/\text{Ag}$ memristor structure demonstrate stable bipolar resistance switching over 3500 cycles. The high resistance state (HRS) remains in the range of 714 ± 48 k Ω , while the low resistance state (LRS) varies within 125 ± 32 k Ω . The HRS/LRS resistance ratio is maintained at approximately 6 – 8 throughout the cycling test, indicating reliable memory window stability. The resistance switching study was conducted with a voltage sweep from -3 to 3 V. At 1 V, the current in the high resistance state (HRS) state was 3.62 ± 0.4 μA , while the current in the low resistance state (LRS) state was 38.5 ± 0.3 μA . The obtained results can be used in the development of technological processes to produce memristor structures for neuromorphic systems of machine vision and artificial intelligence.

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Synaptic Plasticity Simulation of Titanium Oxide Memristor Nanostructures

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The development of artificial intelligence is associated with the use of a promising architecture of neuroprocessors, based on artificial synapses [1]. The most suitable for this role are memristor nanostructures, based on titanium oxide, which exhibit synaptic plasticity under the influence of external voltage [2]. However, a mathematical model has not yet been presented that allows numerical calculations of the parameters of the formation of conduction channels and the characteristics of current flow in such structures. In this work, a mathematical model was developed that calculates the processes of generation and recombination of oxygen vacancies in the volume of titanium oxide in an external electric field. The movement of oxygen vacancies under the influence of external electric field leads to a local change in the specific conductivity of titanium oxide, which in turn changes the resistance of the oxide nanostructure. Thus, by controlling the polarity of the external electric field, it is possible to switch the structure between more conductive and less conductive states.

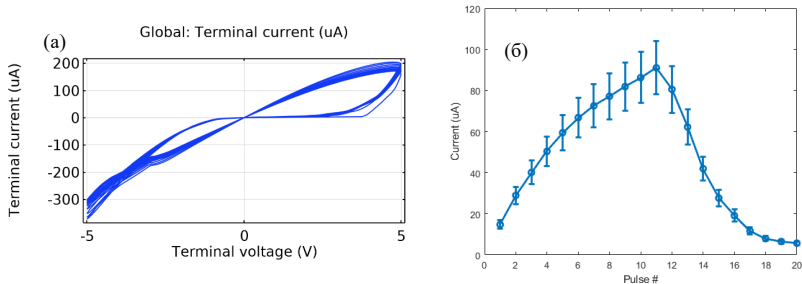


Fig. 1. Simulation results of titanium oxide memristor structures: (a) voltage characteristics; (b) STP and STD parameters

Numerical simulation was carried out in the COMSOL Multiphysics software package. The I–V-curves of the memristive titanium oxide nanostructure were calculated, and STP and STD were studied (Fig. 1). It was shown that over the 20 switching cycles, the structure reproducibly switches between a state with high and low resistance. A slight difference in the first cycle is associated with the formation of a stable configuration of oxygen vacancies in

the oxide volume, compared with the initial state. It was shown that by applying voltage pulses of +5 V, the simulated structure sequentially switches to a more conductive state, the current through the structure increases from 14.2 ± 2.1 to 91.6 ± 12.3 μA at a reading voltage of 1 V; while applying voltage pulses of –5 V switches the structure to a less conductive state, the current through the structure decreases from 91.6 ± 12.3 to 5.7 ± 0.9 μA at a reading voltage of 1 V.

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Influence of the Molecular Beam Epitaxy Conditions on the Growth of InAs Quantum Dots on the Patterned GaAs(111)B Surfaces

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Recently, there has been increased interest in epitaxial growth on GaAs(111) substrates, primarily due to the possibility of forming quantum dots (QDs) with C_{3v} symmetry, which can emit entangled photon pairs via biexciton radiative decay with vanishingly small fine structure splitting. Surface patterning via photo- or electron-beam lithography makes it possible to specify QD nucleation centers and predetermine their geometric characteristics. In this case, QD growth is typically accomplished, using metal-organic vapor-phase epitaxy, which allows formation of large InGaAs nanostructures with a limited control of their characteristics. This study investigates the molecular beam epitaxial growth of InAs on a GaAs(111)B surface patterned with tetrahedral nanorecesses via a combined technique of focused ion beams (FIB) and local droplet etching, using molecular beam epitaxy. This approach enables the formation of compact QDs with small size in each dimension (20 – 30 nm), as well as symmetrical complexes of two, three, or four QDs. Deposition of InAs at 450 °C leads to intensive nucleation at the junctions of the recess faces, leading to the formation of continuous linear chains of InAs nanostructures. Increasing the growth temperature (T) to 500 °C allows for a significant decrease in the concentration of island nucleation centers, providing an average surface density of QDs of $8 \mu\text{m}^{-2}$. Increasing the InAs deposition rate (V) from 0.05 to 0.25 monolayers (ML) per second contributes to an additional increase in the QD density to $17 \mu\text{m}^{-2}$. Increasing the arsenic pressure (P) from 5×10^{-6} to 3×10^{-5} Pa leads to a similar effect,

increasing the QD density from 8 to 23 μm^{-2} . Growth of InAs at $T = 600\text{ }^{\circ}\text{C}$, $V = 0.05\text{ ML/s}$ and $P = 5 \cdot 10^{-6}\text{ Pa}$ ensures the formation of QD complexes, located in predictable recess positions, which allows us to predict not only their positions but also their mutual distances. The number of QDs, constituting the complex in the largest number of recesses in the array varies, depending on the number of FIB passes. For example, for $N = 1$, the largest number of recesses in the array contain 1 QD (46%), for $N = 5$, 2 and 3 QDs with portions of 41% and 43%, respectively, while in the remaining cases, recesses, containing 3 QDs, predominate. The photoluminescence spectra demonstrate QD emission in the 900 – 1150 nm range, with a significant increase in the PL intensity with increasing number of FIB passes. Starting from $N = 10$, the integrated PL intensity exceeds the intensity of the reference region outside the FIB exposure area, while the emission maximum shifts to shorter wavelengths, indicating a decrease in the average QD size. The obtained results allow us to conclude that high temperature and growth rate of InAs, as well as high arsenic pressure, suppress the surface diffusion of adatoms, which contributes to an increase in the surface density of QDs. Under optimal process conditions, ordered individual QDs or complexes of QDs with controlled inter-QD spacing are formed in the arrays of recesses.

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Mechanical Properties of Polyester Resin, Modified with Carbon Fibers

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Unsaturated polyester resins (UPRs) are widely used as matrices for composite materials due to their low cost and processability [1]. However, its use as a structural material is impossible due to its poor mechanical properties. The solution to this problem is reinforcement with fibrous fillers [2]. Carbon fibers (CF) with an elastic modulus of 230 – 400 GPa and low density are a promising modifier [3]. The aim of this work is to evaluate the effect of chopped carbon fiber concentration on the elastic and plastic characteristics of the UPR/CF system under spherical indentation. The base matrix is UPR, cured under standard conditions; modification is performed with PAN-based chopped carbon fibers at concentrations of 2, 4, 6, and 8 wt.%. Mechanical properties were determined by instrumental indentation with a spherical indenter of radius $R = 6.25\text{ mm}$ using the Oliver – Pharr method for spherical contact. The load-penetration depth dependence ($P - h$ curve) was recorded, from which the contact stiffness S , reduced elastic modulus E_r , and hardness H were calculated; Poisson's ratio of neat UPR was taken as $\nu = 0.2$. For neat UPR, the elastic modulus was $E = 4.46\text{ GPa}$ and hardness $H \approx 180\text{ MPa}$, which is consistent with literature data [2]. The reduced modulus E_r was calculated from the Hertzian solution for spherical contact: $S = 2Er\sqrt{a}$, where a is the contact radius, and S is the contact stiffness (slope of the upper portion of the unloading curve). The large-radius indenter creates a contact zone encompassing several fibers, providing an average

response of the composite. The introduction of CF leads to a monotonic increase in modulus: $E \approx 4.8 - 5.1$ GPa (+8 – 14%) at 2 wt.%; $5.3 - 5.7$ GPa (+19 – 28%) at 4 wt.%; $5.8 - 6.3$ GPa (+30 – 41%) at 6 wt.%; $6.2 - 6.8$ GPa (+39 – 52%) at 8 wt.%. These values are in good agreement with theoretical calculations, using the Halpin – Tsai model, which accounts for fiber geometry and orientation [3]. Hardness increases from 180 MPa (neat UPR) to ~290 – 320 MPa at 8 wt.% of CF, since the rigid fibers bear the contact load and restrict the deformation of polymer chains, increasing the material's stiffness. Analysis of the $P - h$ curves showed a decrease in penetration depth at constant load with increasing CF content. During load holding, creep was observed due to the viscoelastic behavior of the base matrix. The creep contribution decreased with increasing fiber concentration, indicating suppression of relaxation processes by the reinforcing network [1]. Thus, the introduction of chopped carbon fibers into the UPR matrix in amounts of 2 – 8 wt.% increases the elastic modulus by 8 – 52% and hardness by a factor of 1.6 – 1.8. Indentation with a large-radius spherical indenter provides a correct determination of the integral mechanical properties of the composite and is consistent with the theoretical values, obtained using the Halpin – Tsai model.

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Game Design and Narrative Development for a Fighting Game on the Unity Platform

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The fighting game genre holds a special place in the modern video game industry due to its dynamic nature, competitive element, and high player engagement. However, the success of a project in this genre is determined not only by the combat system but also by a well-developed game design and narrative which create a unique gaming experience. Despite the traditionally secondary role of story in fighting games, modern trends show a growing interest in integrating a full-fledged narrative that enhances the player's emotional connection with the characters and the game world. The goal of this work is to develop game design and narrative for a fighting game on the Unity platform called "Battle for Brainrot." The main objective of the project is to create a coherent game system, combining dynamic combat, unique character mechanics, and an original story context. The following tasks were set for the project: developing the gameplay concept, creating a combat mechanics system, designing characters and their abilities, forming a narrative structure, and integrating all elements into the game

environment. Development was carried out using the Unity 6 engine, which allowed for the efficient implementation of game mechanics and ensured flexibility in customizing the combat system. During the conceptual design stage, the game's core style was defined, namely a dynamic arcade fighting game with elements of absurdity and satire, reflected in the project's name and visual style. Attention was paid to creating unique characters, each with their own set of skills, animations, and combat characteristics that influence their playstyle. The project's game design includes a system of basic and special attacks, combo mechanics, blocking and dodging, and unique abilities, activated by accumulating energy. To increase gameplay variety, a character status system was implemented, affecting the player's available actions and tactical options. The mechanics were balanced through repeated testing and parameter adjustments.

Analysis of Thermodynamic Processes in a Casing String during Combustion of a Thermite Mixture at the Bottom Hole Based on a Simulation Model

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The efficiency of oil extraction from oil-bearing formations, using modern, industrially developed production methods is currently considered unsatisfactory in all oil-producing countries. The average final oil recovery factor from formations in various countries and regions ranges from 25 to 40%. Residual or unrecoverable oil reserves, using industrially developed production methods reach an average of 55 – 75% of the initial geological oil reserves in the subsurface. One of the promising directions in enhanced oil recovery (EOR) methods is thermal EOR; these methods, based on artificially increasing the temperature in their wellbore and bottom-hole zone, intensify oil inflow and increase the productivity of production wells. It should be noted that one of the conditions for the widespread use of certain EOR methods is their technical and economic efficiency and availability [1]. From this viewpoint, recently, specialists in the field of thermal EOR have been attracted to the use of thermite as a source of thermal energy for treating the wellbore and bottom-hole zone. Examples of successful recent use of thermite mixtures in developing new equipment for thermal impact on the bottom-hole zone and wellbore include the experience of MEGAT LLC in creating a solid-flame heat generator, combined with a spark-arc generator, designed to enhance oil recovery by melting and removing paraffin, resin, and other contaminants from the bottom-hole zone of wells through the impact of a thermal impulse, hydraulic shock, and implosion at the bottom hole [2]. This equipment has proven its effectiveness during experimental thermal treatments of wellbores and bottom-hole zones of several wells. However, for further modernization and development of engineering design methods for such installations, the process occurring in the thermite combustion zone needs more in-depth study. The aim of this work is to create a computer simulation model for research and demonstration of thermodynamic processes and effects, arising in liquid media under high pressure in conditions of approximating the parameters of the bottom-hole zone of oil wells by using a vapor-impulse pressure generator, based on the thermal energy of thermite

combustion. At the first stage of research, a simulation model of an experimental setup was created to evaluate the predicted data of processes, occurring in a casing pipe of 3 m long. The experimental setup is a section of the steel pipe (Russian GOST 32528) of 3 m long, with an outer diameter of 194 mm and a wall thickness of 17 mm. A "cup" with a diameter of 40 mm, containing the thermite mixture is lowered on a tubing pipe with a diameter of 50 mm. The pipe is filled with water. The simulation model is shown in Fig. 1. The problem was solved in a dynamic formulation: (i) the stabilization of the water-air mixture in the setup, (ii) the combustion of the thermite mixture, (iii) the cooling of the steam-water mixture, and (iv) stabilization. The parameters of heating, vaporization, and water condensation processes were considered. At the second stage of research, modeling of thermite combustion in a casing pipe with water at a depth of 1000 m was performed. Based on the results of the first two studies, distributions of vapor propagation velocity throughout the volume in the casing pipe, pressure and temperature gradients in the near-wall zone of the pipe for depths of 3 m and 1000 m, and quantitative parameters of pressure, density, temperature, volume fraction of water and vapor at control points were obtained.

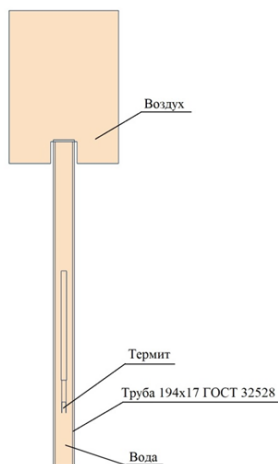


Fig. 1. Simulation model of experimental setup

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An Effective Identification Method in Problems of Low-frequency Defectoscopy

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Non-destructive testing of materials and structures is one of the most pressing areas of modern defectoscopy. Hidden inhomogeneities that arise both during production and during operation under high loads and vibrations significantly reduce the strength of structures, potentially leading to their failure. This circumstance necessitates the use of traditional non-destructive testing methods, as well as the development of new methods for diagnosing inhomogeneities in various objects. This work proposes an effective method for low-frequency non-destructive testing of structures by measuring changes in the parameters of surface waves, generated by pulsed impacts on the test object. The method involves analog monitoring of the surface wave field characteristics by measuring the acceleration of specified points on the surface of the test object, converting the analog signal to digital, and then processing it on a computer. Mathematical processing involves specially transforming the recorded signal into a two-dimensional image, using original mathematical methods. This approach enables visualization of signal change monitoring by transforming the original amplitude-time signal into a specific point in two-dimensional space. This work examines the detection capability and efficiency of recognizing the presence of a defect and its type (cylindrical cavity, cylindrical inclusion), using reflected and transmitted wavefields. The method's sensitivity to the density of the inclusion material (plexiglass, brass or steel) was also examined. The results of the experiments showed that recording both reflected and transmitted wave fields ensures good defect type recognition and determination of inclusion material density. Moreover, the reflected wave field is the most informative for detection.

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On the Identification of Parameters of Fractional-order Viscoelasticity Models

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Modeling new materials, including functionally graded materials (FGM, FGP) and complex composites, requires accounting for the significant inhomogeneity of their mechanical properties. Reliable methods for reconstructing their properties are essential for an objective assessment of their functional state, with the non-destructive nature of the approaches being a key requirement. Acoustic methods meet this requirement: they are highly accurate, easy to implement, and allow for the determination of unknown material characteristics, based on measured physical fields in individual sections of the object. When materials exhibit rheological properties, various viscoelasticity models, including fractional differential models, are used to describe them. Recent research shows that for many materials, particularly polymers, these models more accurately describe their behavior with fewer parameters compared to classical models. In this report we present an overview of fractional-order linear viscoelasticity models used in research to describe the behavior of new materials, which have complex moduli that characterize their mechanical properties when considering steady-state vibrations. A general formulation of the problem of steady-state oscillations of an inhomogeneous viscoelastic body is formulated, within the framework of which any of the viscoelasticity models presented in the review can be used. As an example, inverse problems of determining the functions-parameters of a fractional-differential generalization of the standard viscoelastic body model are considered for longitudinal and bending oscillations of inhomogeneous rods, based on an analysis of the acoustic response. The model includes four parameters: (i) instantaneous and (ii) long-term elastic moduli (in the considered inhomogeneous case, which are functions of the longitudinal coordinate), (iii) relaxation time, and (iv) fractionality parameter. For both inverse problems, an analysis of the sensitivity of the acoustic response for each parameter was performed in two ways: (i) by alternately varying each of the parameters while fixing the others; and (ii) based on an analysis of the Fréchet derivatives for each parameter. The results of the sensitivity analysis were used to develop an iterative method for solving the formulated problem statements. This method combines linearization with elements of a projection approach, supplemented by checking the conformity of the resulting corrections with the model constraints, significantly improving its convergence. We conducted computational experiments, demonstrating the algorithm's effectiveness in reconstructing various sets of functions and parameters for the considered inverse problem statements.

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Ensuring the Absence of Thermal Defects when Grinding Ball Screw Gears

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Ensuring the high quality of the surface layer of the thread in the manufacture of ball screw gears (BSGs) is associated with the preservation of metal properties, formed during thermal or chemical heat treatment in the finished product and is one of the main tasks for machining operations. When grinding ball screw threads are made of hardened steels, the main factor that can cause deterioration of the metal quality in the surface layer is the intense heat generation in the grinding area. If the surface temperature T because of heating exceeds the temperature of the structural transformations T_c , then the structure of the processed metal will change due to grinding cauterization. To ensure that there is no cauterization during grinding, it is necessary that the condition $T < T_c$ is met, i.e. the task is to determine the area of processing modes in which this condition is met. It was shown in [1, 2, etc.] that the maximum surface temperature depends on the parameters of the heat flow, entering the workpiece, which is determined by the dependence:

$$T = T_c = \frac{q\sqrt{\pi a \tau}}{2\lambda \left(1 + \frac{h}{r_0}\right)} \left(1 - \operatorname{erf} \frac{h}{2\sqrt{a \tau}}\right). \quad (1)$$

where q is the heat flux density; h is the halfwidth of the heat source; τ is the duration of the heat source; λ , a are the coefficients of thermal and thermal conductivity of the metal; r_0 is the initial radius of the threaded groove. At $h = 0$, we obtain:

$$T_c = \frac{q\sqrt{\pi a \tau}}{2\lambda}, \text{ accordingly, } q\sqrt{\tau} = \frac{2\lambda T_c}{\sqrt{\pi a}} = 1,13T_c\sqrt{\lambda_{cp}} \quad (2)$$

The right-hand side of equality (2) is an expression, consisting of the thermophysical constants of the workpiece material, and characterizes its thermal state at the beginning of structural transformations. Therefore, the value of $1,13T_c\sqrt{\lambda_{cp}}$ can be taken as a criterion for the absence of cauterization during grinding M , which for each material is determined from its thermophysical constants. When grinding screw BSG, the cutting depth and the length of the contact arc along the circle profile are uneven, which causes an uneven distribution of heat fluxes, value of $q\sqrt{\tau}$ and surface temperature along the thread profile. This dependence on the processing modes is determined by the formula [2]:

$$q_\alpha = k \frac{dN_\alpha}{dF_\alpha} = k \frac{N_{\Delta\alpha}}{L_\alpha}$$

here k is the proportion of heat, entering the workpiece; dF_α is the area of the elementary section of the contact spot; $dF_\alpha = L_\alpha r d\alpha$, where L_α is the length of the contact arc, r is the radius of the thread profile, $N_{\Delta\alpha}$ is the specific grinding power; $N_{\Delta\alpha} = \frac{dN_\alpha}{rd\alpha}$.

By determining the dependence of $N_{\Delta\alpha}$ on the processing modes, and representing it as an expression: $N_{\Delta\alpha} = C_N t^m L^p V^l$, we obtain the following dependence:

$$q\sqrt{\tau} = C_N t^m L^n V^\gamma < M$$

where $n = p - 0.5$; $\gamma = l - 0.5$.

Considering that the speed of the workpiece has little effect on the surface temperature, and the range of speed changes during thread grinding is small (0.01 – 0.04 m/s), its effect on temperature changes can be ignored and as a criterion for the absence of cauterization during thread grinding, we take the value of $\frac{M}{kC_N V^\gamma}$, i.e.:

$$t^m L^n < \frac{M}{kC_N V^\gamma} = [t^m L^n] \quad (3)$$

This criterion characterizes the maximum allowable metal removal rate. For the specific conditions of thread grinding (the characteristics of the grinding wheel, the used lubrication cooling technological means, the method of feeding it into the cutting zone, etc.), the value $[t^m L^n]$ for each material will be constant. These values obtained were $m = 0.5$; $n = 0.5$; $\gamma = 0.08$. Considering that in the speed range of $V = 0.01 - 0.04$ m/s, the right side of the inequality changes by only 11%, we assume $V = 0.04$ m/s and find that for absence of cauterization grinding, the condition $\sqrt{tL} < 0,53 \times 10^{-3}$ m must be fulfilled. Accordingly, $[tL] < 0,28 \times 10^{-6} \text{ m}^2$. As studies by various authors have shown, cauterization on the thread surface by grinding begins to appear for screws 63×10 at a cutting depth of $t < 0.11 - 0.125$ mm. In our case, the calculated value of the thread grinding depth $t = 0.11$ mm ensures the absence of cauterization for screws 63×10, i.e. the experimental values of the cutting depth to ensure burn-free grinding of the threads of screws made of 62SiMnCr4 steel practically coincide with the above-pointed ones. The proposed criterion can be used to determine the modes of defect-free grinding of screws.

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Building an Optimal Radar Sequence of Binary Phase-manipulated Signals as a Discrete Optimization Problem and Various Heuristic Approaches to its Solution

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In the radar theory, a common option for detecting echo signals, as well as compressing the received pulses, are binary phase-manipulated signals: the so-called BPM, or BPSK,

sometimes referred to in the literature as sounding signals. The corresponding mathematical models are based on the sharp peak of a matched filter is required to reliably determine the full return time of a long probing signal. Such a peak should be observed with the correct delay, and with other delays there should be responses close to zero. This requirement leads to the synthesis of long binary sequences, the aperiodic autocorrelation of which has a predominant zero shift peak and very small side lobes. We formulate the problem as a discrete optimization problem for sequences of length N , taking values from the set $\{-1, +1\}$ and propose a signal construction strategy that combines several heuristics. Among these heuristics, we specifically mention the splicing of two small signals to build longer sequences. Moreover, in the case of well-known Golay sequences, the standard method of calculating autocorrelation provides mutual compensation for positive and negative values, obtained with the same shifts of these sequences. This leads to results (and corresponding sequences) that may not be interpreted in the most successful way. Therefore, the authors propose an alternative way to calculate the autocorrelation, which is as follows. With different shifts of k in the sequence under consideration, we count the discrepancies and average the obtained values with different weights. In our proposed algorithm, the better the result (i.e., the smaller the difference between the two sequences, namely the original and the "shifted" one), the greater the weight; and *vice versa*. This averaging was called risk functions in our previous work and was used in various discrete optimization problems. The specific variant of the risk function was selected depending on the dimension. The simulation results turned out to be expected: for the classical approach, autocorrelation of Golay sequences was more successful than others, and for our variants of calculating autocorrelation, more successful results were observed when using other heuristic algorithms.

Dielectric Relaxation in SBN50-La

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Dielectric spectra have been studied in La^{3+} -modified $\text{Sr}_{0.5}\text{Ba}_{0.5}\text{Nb}_2\text{O}_6$ (SBN50-La) ceramics (modification took place at the synthesis stage beyond the stoichiometry of 1 wt. % La_2O_3). Various models differing in the type of the relaxator distribution function were considered to approximate the experimental dependences $\varepsilon''(\varepsilon')$, $\varepsilon''(f)$ and $\varepsilon'(f)$. However, the best results were achieved, using the following relation, in which the contribution from each dielectric relaxation process was described by a symmetric Cole-Cole relaxation time distribution function:

$$\varepsilon^* = \varepsilon' + i \cdot \varepsilon'' = \varepsilon_{\infty 1} + \frac{\varepsilon_{S1} - \varepsilon_{\infty 1}}{1 + (i \cdot f \cdot \tau_1)^{1-\alpha_1}} + \frac{\varepsilon_{S2} - \varepsilon_{S1}}{1 + (i \cdot f \cdot \tau_2)^{1-\alpha_2}} + \frac{\gamma_{st}}{2\pi \cdot f \cdot \varepsilon_0}, \quad (1)$$

where α_1 and α_2 are coefficients, characterizing relaxation time distributions (from 0 to 1); ε_{S1} , ε_{S2} and $\varepsilon_{\infty 1}$ are the values of static and high-frequency permittivity; τ_1 and τ_2 are the relaxation times; ε_0 is a dielectric constant; γ_{st} is the reach-through conductivity. The results of the approximation are shown on Fig. 1. Analysis of the ε' and ε'' dispersion of SBN50-La ceramics

at $T = 83\text{--}493\text{ K}$ and $f = 20\text{--}10^6\text{ Hz}$ showed that the dielectric response of the material in the frequency range $f = 20\text{--}10^6\text{ Hz}$ shows the presence of contributions from three relaxation processes, two of which are associated with the polar subsystem, and one with Maxwell-Wagner polarization. These results suggest that the incorporation of La^{3+} cations into the basic structure, even at such low concentrations, significantly affects the structure and properties of strontium-barium niobates.

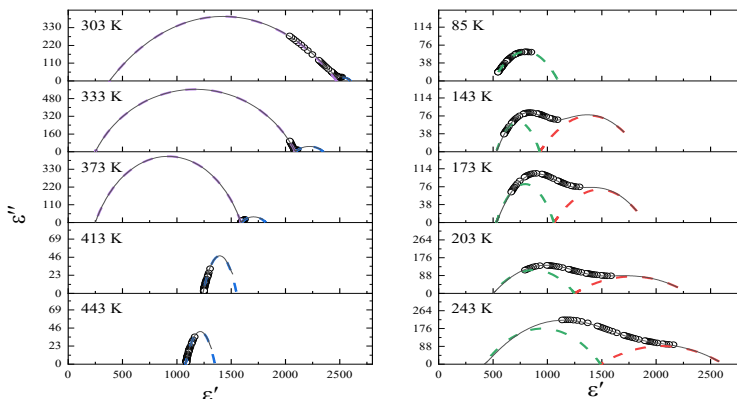


Fig. 1. Experimental (light markers) and theoretical (lines) $\varepsilon''(\varepsilon')$ dependencies of SBN50-La ceramics at temperatures of 85–473 K

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Changes in the Surface Structure and Technological Properties of Natural Spodumene, Treated with a Dielectric Barrier Discharge

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Spodumene ($\text{LiAl}[\text{Si}_2\text{O}_6]$) is a chain silicate from the pyroxene group; the crystal structure of this mineral is characterized by infinite chains of silicon-oxygen tetrahedra $[\text{Si}_2\text{O}_6]^{4-}$, which are linked by lithium and aluminum cations, occupying octahedral sites. Natural spodumene is one of the most important industrial sources of lithium. The main difficulty in spodumene beneficiation (concentration) stems from the similarity of its physical properties (density, magnetic susceptibility) to those of associated gangue minerals (feldspars and quartz). Consequently, traditional gravity, magnetic, and flotation separation methods are often insufficiently effective. In this report, we present the main results of experimental studies on the effect of low-temperature atmospheric plasma of a dielectric barrier discharge (LTP-DBD)

in air on the surface morphology, microhardness, and electrokinetic potential of natural spodumene. Spodumene crystals were extracted from the hand specimens of rare-metal pegmatites from a one of Russian deposit. The spodumene is represented by opaque, grayish-greenish crystals of a tabular-prismatic habit, containing inclusions of albite, quartz, muscovite, cassiterite, apatite, and garnet. The Li_2O content was approximately 7–8 wt.%. The morphological features, defects, and elemental composition of the spodumene surface were studied using scanning electron microscopy, coupled with electron probe X-ray microanalysis (SEM–EDX; LEO 1420VP – INCA Energy 350). The microhardness of the mineral was determined by the Vickers method (HV , kgf/mm^2 ; PMT-3M hardness tester). To measure the electrokinetic potential of mineral particles smaller than 20 μm , we used the electrophoretic light scattering method (Nanosizer Zeta Pro). The plasma of a microsecond pulse-periodic barrier discharge was generated in a plane-parallel discharge cell in air. The parameters of the initiating voltage pulses were as follows: the electrode voltage in the barrier discharge cell was $U_A = 20$ kV, the length of the leading edge of a pulse was ~ 300 ns; the pulse duration and the pulses repetition rate were $\tau_{\text{imp}} = 4$ and 8 μs , and $f_{\text{imp}} = 2$ and 16 kHz, respectively; the sample treatment time t_{treat} was ranged from 10 to 60 s. SEM–EDX results showed that the initial surface of the samples was characterized by structural defects, including cleavage plane fragments with regular triangular etch pits and microcracks along the grain boundaries of inclusions. The primary mechanism of changes in the morphology and structural state of the spodumene surface under LTP–DBD treatment is the destruction (decrepitation) of the mineral. This process involved the liberation of mineral intergrowths due to thermomechanical stresses at the boundaries of minerals with differing thermal and electrophysical properties, as well as the decrepitation of fluid inclusions, caused by a sharp increase in the internal pressure in these inclusions. The formation of new microphases also occurred, possibly representing high-temperature (molten) polymorphic modifications of spodumene. As a result of the plasma treatment, surface softening of the samples and the development of microcracks along the boundaries of micro-inclusions were observed. The maximum relative change (decrease from 1080 to 885 kgf/mm^2) in spodumene microhardness, ΔHV_{max} , was $\sim 18\%$ (achieved under treatment parameters: $\tau_{\text{imp}} = 8$ μs , $f_{\text{imp}} = 16$ kHz, $t_{\text{treat}} = 30 - 40$ s). The electrokinetic potential of spodumene particles was found to increase in the negative range (from -18 to -33 mV) at a treatment time of $t_{\text{treat}} = 30$ s, $\tau_{\text{imp}} = 4$ μs , and $f_{\text{imp}} = 2$ kHz. The obtained results demonstrate the potential of using low-temperature atmospheric pressure plasma for the targeted modification of the structural state and technological properties of lithium-bearing minerals, aiming to improve the lithium ores concentration processes.

Influence of Man-made Raw Materials on the Physical and Mechanical Properties of Lightweight Concrete

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Lightweight concrete is a versatile building material that, when used efficiently, allows for solving many of the most pressing challenges of modern construction, while simultaneously addressing environmental, resource-saving, and economic issues through the utilization of

industrial waste. Among industrial wastes, the most suitable for use as aggregates in lightweight concrete technology are rocks from mine dumps and fly ash and slag waste. The development of new building materials, based on mine rocks and fly ash – slag materials is of both scientific and practical interest and can be economically beneficial for the construction industry. The experience of using burned rocks in lightweight concrete is limited. The most well-known application is in the production of lightweight concretes, using ash and ash – slag wastes. A characteristic feature of these wastes is the presence of porosity, which is due to the specifics of their origin. The way burnt rocks and ash – slag wastes are formed contributes to the creation of material grains with macro- and microporous structures, typical of thermal insulation materials. The formation of pores is caused by the dehydration of clay minerals and the dissociation of limestone and gypsum particles during high-temperature firing when fuel is burned in furnaces and self-firing of rocks occurs in dumps. The reduced bulk density of aggregates, made from such man-made raw materials, is explained by their porosity with a developed surface. In this respect, aggregates from burnt rock of mine dumps and ash-slag waste are like artificial porous aggregates. However, unlike the latter, aggregates made from mining rocks and ash – slag waste have higher strength, measured by compression in a cylinder, and lower water absorption values. Due to the rigid structure of the crystal lattice, the micropores in the aggregate particles cannot turn into open pores, and water molecules do not penetrate the micropore spaces; therefore, the water absorption of such aggregates is low (a water absorption of 0.5 – 4.0%, a porosity of 3 – 12%). Porous aggregates, made from man-made raw materials, are highly competitive, compared to expanded clay, and concretes with such aggregates are cheaper than those with fired aggregates. The aggregates from burnt rocks are comparable in bulk density to artificial porous aggregates. Finely dispersed additives, such as fly ash and ground burnt rock, were used in the compositions of lightweight structural concrete. The specific surface area of these additives is at least 350 m²/kg. Figure 1 shows the effect of fine additives on the strength of lightweight concrete. Adding fly ash and finely ground burnt rock to the concrete mix reduces the density of the concrete while simultaneously improving the workability of the mix. According to the test results of experimental concretes, concretes made with aggregates from industrial waste not only achieve the specified strength but also show a significant strength reserve with a reduced cement consumption. Studies have shown that the use of ash – slag waste and burned rocks from mine dumps in lightweight concrete technology leads to improved strength, water resistance, resistance to deformation changes, durability against aggressive environments, and temperature fluctuations.

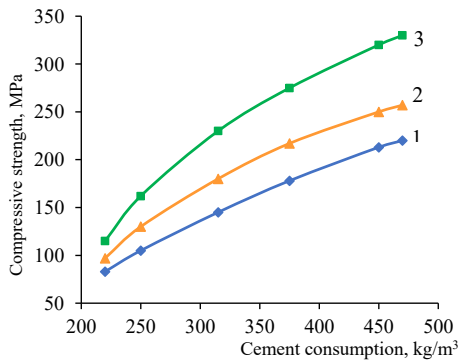


Fig. 1. Effect of finely dispersed ash and burnt rock additives on the strength of lightweight structural concrete: 1 – control; 2 – with ash; 3 – with burnt rock

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Use of Technogenic Raw Materials for the Liquidation of Mined-out Areas

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Backfilling of mined-out space is used to stabilize the ground surface during coal extraction under built-up areas, industrial facilities, natural water bodies, highways, as well as for fire prevention measures and the protection of preparatory workings. The use of man-made raw materials for backfilling mined-out spaces, including solidifying mixtures, has important ecological, economic, and technological prerequisites. The issue of environmental protection is one of the most important tasks of modern society. The mining technology that involves backfilling the worked-out space is environmentally friendly and resource-saving. The importance of the ecological and economic feasibility of using waste from the fuel and energy sector is difficult to overestimate. Work aimed at developing technologies for the recycling of man-made raw materials is highly relevant and has great scientific and practical significance. Backfilling operations, using ash-slag materials and burnt rocks were carried out at the Sadkinskaya mine. The Sadkinskaya mine is in a protected area. In this regard, coal mining with backfilling of the mined-out space is particularly relevant here. For backfilling, it was recommended to use both loose mechanical mixtures of a certain grain composition, as well as hardening compositions with cement and lime, and those based on non-clinker binders (lime, carbide sludge, etc.). A hardening backfills made from burnt rock materials and ash-slag waste allow for a backfill mass with 2 – 5% shrinkage. Using a loose backfill with combined aggregates (crushed screening, burnt rock gravel) creates a backfill mass with 10–15% shrinkage, and with an ash-slag mixture of 5 – 6%. Reducing the shrinkage of backfill mixtures can be achieved by selecting a specific particle size distribution of the mixture components. The selection of the grain composition of backfilling mixtures based on technogenic raw materials was carried out according to the principle of sequential filling of voids in crushed stone, screenings from the crushing of burnt rocks, or ash-slag materials. To optimize the particle size distribution, the Fuller method can be applied. The method is based on selecting a ratio of grains of different sizes that ensures the densest packing. This allows achieving the minimum void content in the mixture. Good transportability (flowability) of the backfill material made from the ash-slag mixture is explained by the presence of glassy spherical particles, a finely dispersed component, and a sand fraction. When using loose backfill from burnt rock, fly ash or finely ground burnt rock is additionally added to improve transportability. The principle behind obtaining a hardening backfill mass is based on the concept of contact hardening, which involves the ability of dispersed systems with an optimal ratio of components and grain composition to form a strong monolith now when the particles come into contact during compaction. Due to their origin, they can exhibit hydraulic activity. The latent physical-chemical activity of finely dispersed additives is awakened when even

small amounts of cement or lime are introduced. The strength of the mass is ensured through cementation, which depends on the activity of the additives (fly ash, ground burnt rocks). The choice of a specific backfilling scheme is made based on the results of tests on the physical-mechanical properties of solidifying backfill and considering the actual stresses and deformations, as well as the geological conditions of the mined-out space. In the coal basin of the Rostov region, among the known methods of constructing a backfill mass, the pneumatic method is the most acceptable. This method is more expensive than the hydraulic one and does not provide sufficient density of the backfill mass. However, due to the increased water content of the deposits being developed in the region, the use of the hydraulic method is ineffective. The demand for backfill materials is high. Thus, the backfilling of mined-out areas is one of the most significant directions in the utilization of waste from the fuel and energy complex.

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Analysis of the Inertial and Geometric Characteristics of a Pumping Unit, Using 3D Modeling

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Modern methods for designing equipment for oil and gas complexes involve a phased approach to synthesizing their designs and analyzing the adopted design solutions. A key characteristic of these tasks is the mandatory and thorough quantitative justification of the implemented engineering solutions, which determines their clear computational nature and a stable connection between the design procedures of synthesis and analysis. The development of process machine designs and their computational justification can be accomplished through either top-down or bottom-up design. However, both approaches are carried out under conditions of insufficient initial information necessary for obtaining an optimal solution from the first approach to the task. This fact forces the developer to repeat the procedures of synthesis and analysis of the design object, successively bringing the achieved results closer to the version required by the customer. Clearly, the technical level and speed of design are directly dependent on the effectiveness of the developer's tools for solving synthesis and analysis problems. Efficient synthesis problem solving is achieved, using solid modeling of the design object's parts and assemblies in modern CAD systems, which accelerates the design process and largely eliminates errors. The effectiveness of solving analytical problems depends on the required depth of solution, which determines the choice of mathematical apparatus, which provides a simplified or in-depth approach to solving such problems. An in-depth approach involves a comprehensive dynamic analysis of the design object, based on a multi-mass model, necessarily encompassing the widest possible range of its inertial characteristics, elastic-dissipative properties, and energy-force parameters. This becomes possible by describing the object, using Lagrange equations of the second kind or by using software packages for the dynamic analysis of objects of mixed physical nature [1]. In any case, this approach requires a developer to have the appropriate competencies and time for implementation. A simplified approach facilitates and accelerates the analysis procedures, which is acceptable and useful at the preliminary design stage of a technological machine.

This approach can be implemented on the basis of a single-mass model, which describes the dominant indicators of the state of a complex mechanical system with the movement of one mass, which is concentrated at one selected point of the kinematic chain of a technological machine and displays all of its inertial and force characteristics, reduced to this point. Reducing force characteristics does not present any significant difficulties, but reducing inertial parameters always requires answering questions about the principle of distributing the distributed masses of the structural elements of a real machine across points in the kinematic chain and the feasibility of neglecting particularly small machine masses without introducing significant errors into the calculation results. To answer these questions for the development of a single-mass pumping unit model, the masses and moments of inertia of all moving parts of this technological machine were determined by developing solid models of all its components and assemblies, followed by calculating the physical properties of the moving structural elements, using the CAD system for the following components: electric motor with belt drive, two-stage gearbox, crank, connecting rods, crosshead, crosshead support, balancer support, and balancer with head. Solid modeling of the pumping unit also allowed us to determine the geometric characteristics of its structural elements, which were necessary for further expansion and deepening the analysis procedures. These characteristics include: (i) the coordinates of the geometric centers and centers of mass of the links, (ii) the diametrical and longitudinal dimensions of the hinges, (iii) the diametrical clearances in the hinges and sliding pairs, and (iv) the areas and moments of inertia of the link cross-sections. The developed detailed solid model of the pumping unit provided an accurate assessment of the physical properties of its parts and components with the determination and analysis of the numerical values of its main inertial and geometric characteristics, and also allowed for the adoption of the necessary decisions for a reasonable representation of the installation design by a single-mass dynamic model.

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The Wave of Silicon: Past, Present, and Future of the Semiconductor Industry

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Semiconductor technology has become the foundation of modern society. From smartphones and artificial intelligence to autonomous vehicles and cloud computing, nearly every critical innovation today relies on semiconductors. To understand the significance of this industry, it is essential to explore its fundamental principles, technological evolution, and industrial structure.

What is a Semiconductor? In material science, substances are generally classified into conductors and insulators based on their ability to conduct electricity. Conductors, such as

metals, allow electric current to flow freely, while insulators block it almost entirely. A semiconductor lies between these two extremes, with a unique property: its electrical conductivity can be precisely controlled. This controllability makes semiconductors ideal for electronic devices. By applying voltage, changing temperature, or introducing impurities through a process known as doping, engineers can manipulate how electricity flows through the material. Among various semiconductor materials, silicon has become the dominant choice. This is due to several advantages: it is the second most abundant element on Earth, making it cost-effective; it can be refined into ultra-high-purity single-crystal wafers; and its oxide, silicon dioxide (SiO_2), has excellent insulating properties, which are essential for integrated circuit fabrication. Through doping, silicon can form two types of semiconductors: *p*-type and *n*-type. These materials are combined to create fundamental devices such as diodes and transistors. In particular, the transistor serves as both a switch (representing binary states 0 and 1) and an amplifier, making it the cornerstone of the digital age.

Integrated Circuits: The Core of Semiconductors. The development of the semiconductor industry began with the invention of the transistor in 1947, a breakthrough that revolutionized electronics. In 1959, the introduction of the integrated circuit (IC) marked another major milestone, allowing multiple transistors to be fabricated on a single chip. Over time, the level of integration has increased dramatically. Early chips contained only a few hundred devices, but modern chips now integrate billions of transistors within a single die. This progression, namely from Small Scale Integration (SSI) to Ultra Large-Scale Integration (ULSI) has enabled exponential growth in computing power. This trend is described by Moore's law, which states that the number of transistors on a chip doubles approximately every two years. Although physical and economic challenges have emerged in recent years, advancements in process technology, 3D integration, and new materials continue to push the boundaries. Semiconductor manufacturing involves highly complex processes, including photolithography, etching, diffusion, thin-film deposition, and chemical mechanical polishing (CMP). These steps can be compared to constructing a microscopic building, layer-by-layer, with nanometer-level precision.

Semiconductor Industry Chain and Taiwan's Role. The semiconductor industry can be broadly divided into three main segments: (i) *IC Design (Fabless)* is responsible for circuit architecture and functionality design; (ii) *Manufacturing (Foundry)* converts designs into physical silicon chips through advanced fabrication processes; (iii) *Assembly and Testing (OSAT)* packages chips and ensures their performance and reliability. Within this global division of labor, Taiwan plays a crucial role. Table 1 presents the 2024 global top 10 IC design houses, foundries, and backend companies revenue ranking. It dominates the foundry sector with over 70% global market share and has built a highly integrated ecosystem across science parks in Hsinchu, Taichung, and Tainan. This cluster effect enhances efficiency, innovation, and collaboration. In addition, Taiwan is a global leader in assembly and testing, with companies collectively holding more than half of the global market share. From IC design houses to wafer fabrication, testing equipment, and materials suppliers, Taiwan has established a comprehensive and competitive semiconductor ecosystem.

Technology Drivers and Future Outlook. The evolution of semiconductor technology is driven by market demand. Emerging applications such as artificial intelligence, high-performance computing (HPC), 6G communication, and electric vehicles are pushing the limits of performance, power efficiency, and cost. Future development trends include: (i) increasing transistor density, potentially reaching trillion-transistor chips; (ii) advanced packaging technologies such as chiplet architectures and 3D IC; (iii) adoption of new materials, including compound semiconductors and photonic integrated circuits; (iv) more efficient testing and verification technologies. At the same time, the industry faces significant

challenges, including rising manufacturing costs, massive capital investment requirements, and global supply chain restructuring. Despite these challenges, continuous innovation and cross-disciplinary integration will sustain the growth of the semiconductor industry. From a grain of sand to billions of transistors on a chip, semiconductor technology represents one of the greatest achievements in human engineering and science. It has transformed the way we process information and reshaped industries and daily life. Looking ahead, semiconductors will remain at the forefront of technological innovation. With its strong industrial foundation and strategic position in the global supply chain, Taiwan will continue to play a pivotal role in shaping the future of the semiconductor industry.

Table 1. 2024 global top 10 IC design houses, foundries, and backend companies' revenue ranking, and data from TRENFORCE, 2024

2024 Global Top Ten IC Design Houses Revenue Ranking (Unit: Million USD)									
2024 Ranking	2023 Ranking	Company	2024 Revenue	2023 Revenue	YoY	2024 Top-10 Revenue Share	2023 Top-10 Revenue Share		
1	1	NVIDIA	124,577	55,208	124%	80%	33%		
2	2	Qualcomm	34,857	30,913	13%	14%	18%		
3	3	Broadcom	30,644	28,445	8%	12%	17%		
4	4	AMD	25,785	22,680	14%	10%	14%		
5	5	MediaTek	16,519	13,888	19%	7%	8%		
6	6	Marvell	5,637	5,503	2%	2%	2%		
7	8	Realtek	3,330	3,053	9%	1%	1%		
8	7	Novatek	3,300	3,544	-10%	1%	2%		
9	9	Wii Semiconductor	3,048	2,525	21%	1%	2%		
10	10	MPS	2,307	1,821	27%	1%	1%		
Total Revenue of the Top 10 Companies			249,004	167,642	49%				

2024 Global Top 10 Foundries by Revenue (Unit: Million USD)									
Ranking	Company	2Q24 Revenue	1Q24 Revenue	QoQ	2Q24 Market Share	1Q24 Market Share			
1	台积电 TSMC	20,819	18,847	10.5%	62.3%	61.7%			
2	Samsung	3,833	3,357	14.2%	11.5%	11.0%			
3	SMIC	1,901	1,750	8.6%	5.7%	5.7%			
4	中芯国际 UMC	1,756	1,737	1.1%	5.3%	5.7%			
5	GlobalFoundries	1,632	1,549	5.4%	4.9%	5.1%			
6	华虹集团 Huihong Group	708	673	5.1%	2.1%	2.2%			
7	Tower	351	327	7.3%	1.1%	1.1%			
8	世界先进 VIS	342	306	11.6%	1.0%	1.0%			
9	力积电 PSIC	320	316	1.2%	1.0%	1.0%			
10	Nexchip	300	310	-3.2%	0.9%	1.0%			
Total of Top 10		31,962	29,172	9.6%	96.0%	96.0%			

2024 Global Top 10 Backend Company Revenue Ranking (Unit: USD Billion)									
Ranking	Company	2024 Revenue	2023 Revenue	YoY	2024 Top-10 Revenue Share	2023 Top-10 Revenue Share			
1	ASE Holdings (日月光控股)	18.68	18.54	-0.7%	46.3%	44.6%			
2	Amkor (艾司康)	6.50	6.32	-2.8%	16.1%	15.2%			
3	JCET (捷成科技)	4.19	5.00	19.3%	10.4%	12.0%			
4	TFME (通富微电)	3.14	3.32	5.6%	7.8%	8.0%			
5	PTI (力成科技)	2.26	2.28	1.0%	5.6%	5.5%			
6	TSMT (天水华天)	1.59	2.01	26.0%	4.0%	4.8%			
7	Winbond (旺达科技)	1.48	1.56	5.0%	3.7%	3.7%			
8	Hana Micro (瀚宇微)	0.74	0.92	23.7%	1.8%	2.2%			
9	KYEC (益光电子)	1.06	0.91	-14.5%	2.6%	2.2%			
10	ChipMOS (南茂科技)	0.69	0.71	3.1%	1.7%	1.7%			
前十大厂商合计		40.34	41.56	3.0%					

Contact Interaction of a Rigid Stamp and a Two-layer Poroeelastic Base

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Porous materials are a common type of material with unique physical, mechanical, acoustic, electrical and thermal properties. Due to its optimal weight-to-strength ratio, it is widely used in various industries and construction. The most important issue in the production of such materials is the control and evaluation of their mechanical characteristics. There are different approaches. One of the approaches to modeling porous materials was developed in the works of Cowin and Nunziato. This theory, called microdilatation theory, was applied to the study of porous bodies with empty (unsaturated) pores. It uses linear elasticity theory with an additional kinematic variable that describes the porosity variation properties. Thus, deformation and porosity are coupled fields that have a common response to external loads applied to the body. The work considers, based on the equations of the theory of poroelastic bodies of Cowin-Nunziato, an axisymmetric contact problem of the penetration of a rigid

stamp into a poroelastic layer, fixed on an elastic layer. The base of the stamp is flat or has the shape of a paraboloid of revolution. It is assumed that there is no friction in the contact zone, and the lower boundary of the base is rigidly fixed or lies without friction on a rigid base. Using the Hankel integral transform, the problem is reduced to solving an integral equation for an unknown contact stress. The collocation method is used to solve the integral equation. The values of contact stress were investigated, as well as the relationship between the force acting on the stamp and its displacements. The influence of the parameters of the poroelastic and elastic layers on the values studied was investigated. A comparative analysis was carried out for different parameter values. The numerical results were presented in the form of tables and plots.

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Finite Element Modeling and Homogenization of 3-1-1 Composites with Magnetolectric Coupling

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The development and analysis of multiphase functional composites with pronounced coupled fields is an important area of modern materials science, focused on creating structures with predetermined electromechanical and magnetoelastic properties. Of particular interest are systems that combine piezoelectric and piezomagnetic inclusions in a single polymer matrix, enabling controlled magnetolectric response. This work examines a 3-1-1 composite consisting of a polymer matrix, reinforced with piezoelectric and piezomagnetic rod inclusions. This architecture enables effective interaction between mechanical, electrical, and magnetic fields due to the spatial distribution of the active phases and their mutual mechanical coupling. Such systems are of interest for use in sensors, energy converters, and functional elements of intelligent structures. To describe the material's behavior, a computational model, based on a finite element approach, was developed and implemented in the COMSOL Multiphysics environment. Mathematical formulation is based on magnetoelctroelasticity equations, which allow for the interrelationship of electric, magnetic, and mechanical fields in a heterogeneous medium with a complex spatial structure of inclusions. The composite geometry is formed by a representative volume, containing oriented rod phases in a polymer matrix. The effective properties of the system are determined, using homogenization methods, based on representative volume calculations. A numerical study was conducted to examine the influence of the volume fraction and spatial distribution of piezoelectric and piezomagnetic rods on the integral characteristics of the composite, including the electromechanical and magnetolectric response coefficients. It was shown that the inclusion distribution architecture influences the level of interphase interaction and the magnitude of the resulting magnetolectric effect. The obtained results demonstrate the possibility of targeted design of

the properties of a 3-1-1 composite by controlling the geometry and concentration of active phases. The proposed approach can be used in the development of new magnetoelectric materials with specified functional characteristics.

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Modeling of Three-phase Ferroelectric – Piezomagnetic – Polymer Composites within the Framework of Magnetoelastoelectricity Theory

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The development of methods for determining and specifically optimizing the effective properties of multiphase composites, particularly three-phase 0-3 systems, based on a polymer matrix, ferroelectric and piezomagnetic inclusions, as well as two-phase ferroelectric-piezomagnetic composites, is a pressing challenge in modern materials science and engineering of functional materials. Increased interest in such systems stems from their ability to implement a complex set of interrelated physical effects, namely piezoelectric, magnetostrictive, dielectric, and elastic, which opens broad prospects for creating next-generation multifunctional devices. However, existing approaches are often limited to the consideration of simplified two-phase 2-2 structures or fail to consider the specific features of the actual microstructure, significantly limiting the possibilities for targeted design of composites with the desired characteristics. Of particular interest are magnetoelectric composites, which implement the coupled transformation of mechanical, electrical, and magnetic fields due to the interaction of the ferroelectric and piezomagnetic phases. These materials are considered a promising basis for sensor systems, energy converters, and intelligent functional elements with advanced response control capabilities. This work develops a computational methodology, based on finite element modeling of three-phase type 0-3 composites in the COMSOL Multiphysics software environment. The mathematical formulation is based on a system of magnetoelastoelectricity equations implemented, using the General Form PDE interface, which ensures a universal description and allows for the consideration of complex interrelations between fields in heterogeneous media with arbitrary microstructure. The model was verified by comparing it with known results for type 2-2 composites, confirming the validity of the proposed approach. The effective electromechanical and magnetoelectric properties are determined, using a representative volume approach and homogenization procedures. A systematic parametric study was conducted to establish the dependence of the effective characteristics and magnetoelectric coupling coefficient on the phase volume fractions and microstructural parameters. The obtained results demonstrate the high sensitivity of macroscopic properties to the composite architecture and confirm the possibility of their targeted control. The proposed methodology can be used as a tool for the

numerical design and optimization of magnetoelectric composites with specified functional characteristics.

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β -Ga₂O₃ Nanorod EGFET for Portable pH Sensing with Embedded Readout

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This work demonstrates a portable and reusable pH sensing system, based on β -Ga₂O₃ nanorod films, integrated with an extended-gate field-effect transistor (EGFET) and a compact embedded readout circuit. The β -Ga₂O₃ sensing layer was grown on ITO glass by chemical bath deposition, using gallium nitrate and hexamethylenetetramine at 85 °C for 2 h, followed by 600 °C annealing to obtain crystalline β -Ga₂O₃. The probe was coupled to a 2N7000 MOSFET EGFET configuration and interfaced with an ADS1115 ADC and Arduino microcontroller for signal acquisition, processing, display, and wireless transmission. SEM observations showed densely distributed nanorods with high aspect ratio, while XRD and EDS analyses confirmed β -Ga₂O₃ phase formation and Ga/O composition. pH sensing was evaluated in standard buffer solutions from pH 4 to 10. The $I_{DS} - V_{DS}$ characteristics varied systematically with pH, and the extracted voltage response exhibited strong linearity with an average sensitivity of ~35.2 mV/pH and $R^2 > 0.99$. These results confirm the feasibility of CBD-grown β -Ga₂O₃ nanorods for low-cost, real-time, and portable EGFET-based chemical sensing applications. The integrated architecture provides a practical pathway toward miniaturized point-of-care pH monitoring and can be extended to other solution-phase biosensing or environmental sensing platforms.

Development and Performance Evaluation of an Optical Communication System, Integrating Perovskite Quantum Dot Light-Emitting Devices and Photodetectors

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Visible Light Communications (VLCs) have experienced increasing demand for short-range data transmission. Conventional systems typically employ phosphor-converted white light-

emitting diodes (LEDs); however, their broad emission spectra and phosphor afterglow effects tend to introduce additional noise at the receiver, thereby limiting transmission accuracy [1]. To address these issues, this study develops an all-perovskite optical communication system, based on narrowband FAPbBr₃ perovskite quantum dot light-emitting diodes (PeLEDs) and FAPbI₃ perovskite quantum dot photodetectors (PePDs), and conducts a preliminary evaluation of its communication performance. Experimental results show that the transmitter exhibits a narrow full width at half maximum (FWHM) of 24.05 nm, which is significantly superior to that of conventional white LEDs. Combined with a receiver featuring low dark current under zero bias, the system effectively suppresses background noise interference. Measurement and analysis indicate that the proposed system achieves a signal-to-noise ratio (SNR) of 19.47 dB [2] and reduces the total harmonic distortion (THD) to 38.57% [3], outperforming a reference system, based on commercial white LEDs. These results demonstrate that the integration of a narrowband light source with a photodetector offers strong potential for improving signal quality in optical communication systems [4].

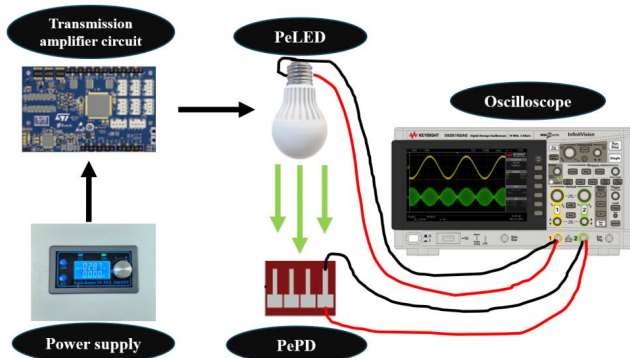


Fig. 1. Diagram of optical communication system measurement architecture

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GaN Based UV Photodetector Application as Optical Communication with Biorobot Control

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The strategic application of transient response in photodetectors is expected to open new frontiers in the fields, ranging from free-space optical communication to mechanical control systems. This study integrates these functions into a single device, developing a photo detector that combines optical communication and mechanical control, and creating a universal platform for on-demand applications. Specifically, we designed a GaN-on-Si-based photosensor and introduced a superlattice into its structure to significantly improve material quality and electrical performance. Raman spectroscopy analysis showed a more uniform distribution of compressive stress in the superlattice sample, with local stress values, ranging from -71.4 MPa to 333 MPa. X-ray diffraction rocking curve analysis revealed improved crystal quality, with the full width at half maximum (FWHM) of the (002)/(102) crystal plane changing from $\sim 498/810$ arcseconds (without superlattice) to $\sim 503/585$ arcseconds (with superlattice). The total dislocation density decreased from $1.93 \times 10^9 \text{ cm}^{-2}$ to $1.12 \times 10^9 \text{ cm}^{-2}$, and atomic force microscopy (AFM) measurements showed a decrease in dislocation density from $\sim 3.78 \times 10^8 \text{ cm}^{-2}$ to $\sim 2.20 \times 10^8 \text{ cm}^{-2}$. Hall effect measurements indicated that the carrier mobility increased from $\sim 378 \text{ cm}^2 \text{ V}^{-1} \cdot \text{s}^{-1}$ to $\sim 1034 \text{ cm}^2 \text{ V}^{-1} \cdot \text{s}^{-1}$ under superlattice conditions, confirming a significant improvement in structural uniformity and carrier transport performance. Under UV illumination, its photoelectric performance was measured using I-V curves and EQE, and the transient response time of this photodetector was voltage-dependent. We propose a photosensitive control 3D printing robotic arm, based on GaN/Si photoelectric sensors, and demonstrate its excellent operational stability and signal response capabilities. The control module uses an Arduino microcontroller, a battery, and a reference resistor to form a closed circuit for real-time optical signal detection and processing. Under ultraviolet light irradiation, the photocurrent, generated by the GaN photodetector is converted into an electrical signal and transmitted to the microcontroller for decoding. The system can receive and interpret optical Morse code signals through calibrated photo response characteristics. Changes in light intensity and irradiation time are converted into distinguishable electrical signals, thereby achieving accurate decoding of Morse code patterns. Through calibration and signal processing, the detected optical signal is converted into a corresponding digital output, demonstrating reliable and stable optical communication performance. These results highlight the great potential of integrating gallium nitride photodetectors into optical communication and photosensitive robotic arm control systems, successfully demonstrating their feasibility in Morse code optical communication and mechanical control applications, and laying a solid

foundation for future augmented reality and artificial intelligence (AI) optoelectronic integration systems.

Information-Based Framework for Assessing Building Damage in Dynamic Studies

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The use of information technology solutions and their implementation in developing an improved and automated framework for assessing building damage is quite relevant [1]. The solution to this problem lies in the use of modern automation tools that minimize the influence of the human factor and accelerate the diagnostic process. This work resulted in the development of a specialized software package that automates the stages of preparing a calculation model. A key feature is the ability to interactively construct and edit a model, followed by the generation of an APDL script for performing dynamic analysis in ANSYS. Technological implementation is based on the Python programming language, and user interaction is accomplished through an intuitive web interface that streamlines the process of collecting and structuring information about the building's geometry and characteristics. The experimental research plan includes a comparative analysis, using two types of models. The first is an idealized (simplified) scheme, while the second is a detailed model, including unconnected, discrete nodal elements. The primary objective of dynamic modeling is to determine the impact of localized damage on the spectrum of natural frequencies and the configuration of vibration modes, which will serve as the basis for developing defect identification methods. The subsequent stage involves the use of neural networks to select and analyze data and determine the extent of building damage.

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Conducting Work on Training a Neural Network to Assess Damage to a Triangular Structure Based on Dynamic Response Analysis

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One of the key tasks in ensuring the reliability of building structures is monitoring their technical condition and promptly detecting defects. Modeling dynamic processes in structural elements is an effective tool for solving this problem [1]. When working with large volumes of data, neural networks and deep learning methods are particularly relevant [2]. Their use is suitable for analyzing signals and non-stationary dynamic responses. Neural network algorithms allow for the reconstruction of structural condition parameters, based on *a priori* information and pre-trained models. The aim of this work is to develop and validate an approach to identifying damage in frame structures, based on numerical modeling and neural network technologies. As a part of the work on identifying defects in a framed structure, a simple triangular model was considered. Damage was modeled at the junction of two elements, forming the bottom chord. The solution to the problem was based on the analysis of transient vibrations of a three-dimensional body, using elasticity theory. To implement this approach, a complex of studies was performed, including the construction of a geometric model and virtual testing. All modeling stages, as well as the process of generating and collecting data for analysis, were performed, using the ANSYS software package, based on the three-dimensional model. The structure had side dimensions of $L = 3$ m and a cross-section of $a \times b = 0.2 \times 0.18$ m². For the numerical experiment, the material properties of the structure were assumed to be concrete. The effective modulus of elasticity of the material was equal to $E = 2.4 \cdot 10^{10}$ Pa, the density of concrete $\rho = 2400$ kg/m³, Poisson's ratio $\nu = 0.3$, and the damping coefficient $\zeta = 0.03$. The bottom node of the structure was fixed. The damaged zone was modeled by applying modified elastic modulus properties to the bottom beam of the frame structure. The zone had a fixed length of $0.01 - 0.1$ m and was located within a two-meter radius. An example of damage could be cracking the concrete due to exposure to aggressive environments or erosion, or poor-quality workmanship in the corresponding zone of the structure. The study was conducted in several stages. First, a static analysis of the stress-strain state (SSS) of the structure was performed. Next, a transient impulse load was simulated, during which vibration amplitudes were recorded in the defect area (100 samples with a step of 0.0001 s). A multilayer perceptron (MLP) neural network was trained to identify the damage. A truncated amplitude-frequency response (AFR) spectrum, calculated over a short time range, was used as input. Training was conducted on a sample size of 1,000 samples. The analysis of results confirmed the high accuracy and reliability of defect parameter determination, using the proposed approach.

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Application of Artificial Neural Networks to Damage Diagnosis in a Triangular-Shaped Rod Structure

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In modern diagnostic practice for technical systems, methods based on artificial intelligence are becoming increasingly important. A key advantage of using artificial neural networks (ANNs) is their ability to identify and formalize complex, often nonlinear, correlations between the dynamic parameters of a structure's operation (e.g., vibration response) and its internal structural characteristics, such as the presence of defects or the level of stress localization. This approach significantly accelerates the diagnostic process, providing the engineer with a ready-made solution without the need for time-consuming and resource-intensive computer modeling for each new loading scenario. However, it should be noted that the effectiveness of the neural network approach directly depends on the quality and volume of the initial data [1, 2]. Correct initialization and training of the network require the preliminary generation of a representative training sample, which must have a high level of correlation between the input and output parameters. The implementation of ANNs can be illustrated by the examples of computer programs [3, 4]. This study, at the current stage, addresses a specific applied problem. The study involves the development, training, and validation of neural network models, based on multilayer perceptron (MLP) architecture. The goal of these models is to reconstruct information about two key aspects of an object's condition: its degree of damage and its current stress-strain state. The object of study is triangular structure. The input data for the neural network are vibration parameters, recorded at arbitrary or predetermined points within this structure. The study considered a triangular structure, constructed using a truss-type metal structure. The triangular structure had face dimensions of 1 m, and the rod dimensions were 10 mm × 10 mm. One corner of the structure was rigidly fixed during the simulation, imposing constraints on displacements and rotation angles. In the actual model, the structure was fixed in a rigid and heavy support element. In the study, the triangular structure could have a defective node or a defect, located on one of its faces. To analyze the dynamic response, a three-dimensional finite element model of the structure was developed in ANSYS. Transient pulse loading, localized to a specific region, was simulated. Using the structural position scanning (SPS) technique, vibrations were

analyzed at two control points, located in the "search" region. The parameters of this region (e.g., stiffness) were varied to simulate the development of a corrosion defect. Due to the analysis of peak amplitudes of the transmitted wave over a short time interval, a truncated version of the full spectrum was used for further processing. It was found that the spectral dependencies can be approximated by simple polynomials. The coefficients of these polynomials formed a compact and informative dataset, which was fed to the neural network. The initial results of the trained network demonstrated a satisfactory degree of correlation and the ability to reconstruct damage information for both a straight element and a more complex case a rod joint.

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Forming a Problem for Studying the Z-Shaped Configuration of a Piezoelectric Generator Base under Stationary Oscillations

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The relevance of this research follows from the growing need for power environmental elements and portable instrumentation. As part of the development of renewable energy sources, the objective of studying the efficiency of a piezoelectric generator (PEG) was set [1]. The PEG model under consideration is a novel design. Its architecture involves the integrated use of various types of mechanical forces. The design incorporates piezoelectric elements, operating in compression mode and rigidly fixed to the generator base. Additionally, piezoelectric elements, operating in bending and torsion, are located on the base plate. This arrangement is aimed at maximizing power generation by converting several types of deformation, which distinguishes it from traditional uniaxial solutions. The generator can consist of three bars and have a mass, attached to a specific site. One bar is horizontal, the second vertical, and the third horizontal. Various angle variations are possible between the bars. Plate piezoelectric elements can be mounted at points of maximum bending with a certain

rigidity of the generator bar. Analysis of the expected operating conditions is a key design step. The piezoelectric generator (PEG) is designed for operation in environments with low and variable mechanical stress. Wind load is modeled as the primary excitation source, manifested as displacement of the upper node of the vertical base plate, causing deformation of the piezoelectric elements. Furthermore, a scenario for operation under transient vibrations of the generator's fixed base itself is studied. Integration of the device into road infrastructure elements is considered as a promising application. In this context, generator excitation is initiated by dynamic loads, arising from vehicle passage, providing a periodic and predictable energy source for powering autonomous sensors. The anticipated operating frequency range is up to 30 Hz. Based on this, the analysis consisted of two stages. The first stage involved studying the modal parameters and optimal selection of the PEG so that the first three generator frequencies do not exceed 30 Hz. Analysis of the calculations revealed that suitable configurations for this generator exist. One of the options was investigated. Its modal characteristics were obtained. A study of the transient oscillations of the selected PEG model revealed the following: when the upper end of the PEG was displaced, simulating an impact, the total output power P was equal to 6×10^{-3} W over a considered range of $t < 0.5$ s and an active load R of 1 M Ω .

Acknowledgement. The study was carried out with the financial support of the Southern Federal University, scientific project No. VnGr/26-01-MM.

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Prospects for Applying 3d Printing Technologies in Construction

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The research and implementation of 3D printing technologies in the construction industry are opening new horizons, enabling not only the optimization of traditional processes but also the implementation of architectural projects of virtually any complexity that were previously technically unachievable or economically unfeasible. The technology is based on the principle of layer-by-layer additive construction. Construction 3D printers typically utilize a gantry or robotic structure, equipped with an extruder. This unit continuously extrudes a special concrete mixture, which, layer-by-layer forms both the internal and external contours of wall structures. The key to success is mortar formulation. The mixture must have precisely defined rheological properties: high thixotropy and plasticity. This is necessary to ensure stable, smooth, and continuous flow through the nozzle without the risk of component delamination, channel clogging, or deformation of existing layers. Interchangeable nozzles of varying diameters are used to achieve varying print layer widths and textures. The solution is fed to the print head, using a screw mechanism (extruder) or a powerful pump, ensuring a continuous and precisely measured supply to the print zone. The key difference between specialized building mixtures for additive manufacturing and traditional concrete is their complete adaptation to the requirements of extrusion technology. The properties of the mixture are specifically modified

to ensure process stability and high-performance characteristics of the finished product. Specifically, the mixture must have high viscosity to maintain its shape after exiting the nozzle, a controlled setting time to prevent premature hardening in the delivery system and demonstrate high interlayer adhesion to ensure the integrity of the structure. Despite the technological advantages, the application of construction 3D printers currently faces several limitations. Technology is most effective when constructing the "shell" of building external walls and interior partitions. The narrow range of work performed is due to several factors: the technological complexity of creating continuous internal reinforcement, the critical dependence of print quality on weather conditions, and strict requirements for consistency in dosing and homogeneity of the supplied mixture supplied. 3D printing offers undeniable advantages over other building and structural construction technologies, namely: (i) reducing construction time due to layer-by-layer mortar placement and reducing labor costs; (ii) reducing construction material and labor costs; (iii) developing custom designs for the construction of particularly complex structures. Therefore, 3D printers are constantly being improved to enhance the reproducibility of printed parts and enable the creation of more complex designs.

Study of the Mechanical Properties of Modified Polyester Resins with Al_2O_3 Particles

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Creation of polymer heterogeneous antifriction composites with a controlled structure is an important task of modern materials science. The traditional approach of simply dispersing particles often leads to their agglomeration and a reduction in performance properties. The development of methods for the stepwise formation of multicomponent systems, where each phase performs a strictly defined function, makes it possible to control relaxation transitions and free volume in polymer matrices. The aim of the present work is to study the viscoelastic behavior (elastic modulus, hardness, and relaxation processes) of composites based on unsaturated polyester resin (PE) modified with micro-sized ($\sim 10 \mu\text{m}$) aluminum oxide particles using instrumental indentation [1, 2]. An unsaturated polyester resin was used as the base matrix. To prevent agglomeration, a regulated mixing sequence was applied: mechanical stirring followed by ultrasonic treatment (15–20 minutes), introduction of functional components, and degassing. Mechanical properties were studied by instrumental indentation using a NanoTest 600 device with a spherical indenter (radius $R = 3.125 \text{ mm}$) at a maximum load of 5000 mN and a loading rate of 300 mN/s. To evaluate viscoelastic characteristics, holding under load was applied for durations ranging from 10 to 900 seconds. Based on the load-penetration curves, the inverse problem of recovering viscoelastic constants was solved [1, 3]. The viscoelastic response of polymers is characterized by a decrease in effective elastic modulus (E^*) and hardness (H) over time due to stress relaxation and rearrangement of macromolecular segments. The introduction of 1% Al_2O_3 leads to an increase in the

instantaneous elastic modulus ($E_{10} = 5.135$ GPa compared to 4.916 GPa for pure PE). At the same time, a significant retardation of relaxation processes is observed: the decrease in elastic modulus over 900 s is only 20.1%, compared to 37.7% for the unfilled matrix. From the perspective of polymer physics, aluminum oxide particles at low concentration act as effective physical network nodes, binding macromolecules in a rigid interphase layer and limiting their segmental mobility [2]. However, upon increasing the Al_2O_3 concentration to 3% and 5%, a decrease in the instantaneous modulus is observed ($E_{10} = 4.413$ and 4.067 GPa, respectively). This indicates structural oversaturation: an excess of particles forms "free" interphase regions, increasing the fraction of free volume and acting as matrix defects. The maximum concentration of 7% leads to a critical drop in absolute mechanical characteristics due to agglomeration, although the relative stability over time (H decreases by only 11.8%) is due to the rigidity of the mineral filler network itself. Thus, the optimal concentration for enhancing both the instantaneous stiffness and relaxation stability of the polyester matrix is 1% Al_2O_3 .

Acknowledgement. The study was supported by the Russian Science Foundation No. 25-29-01688, <https://rscf.ru/project/25-29-01688/>.

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Green Graphene-Based Flexible Sensors for Wireless and Real-Time Pulse Monitoring

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This research demonstrates a wireless sensing platform, based on flexible green graphene for real-time and stable physiological pulse monitoring. Initially, a high-quality, low-defect monolayer of green graphene was synthesized via atmospheric pressure chemical vapor deposition (APCVD), innovatively utilizing natural camphor as a sustainable carbon source. By transferring the graphene onto a biocompatible and flexible polydimethylsiloxane (PDMS) substrate and integrating high-conductivity silver paste electrodes, the device achieves exceptional mechanical stability and sensitivity. Repetitive bending tests (over 300 cycles) verify that this electrode-sensor architecture maintains stable ohmic contact under dynamic deformation, ensuring the reliability of pulse signal acquisition. For portable monitoring, a

green graphene pulse sensor was integrated with an ESP32 microcontroller to construct a precision wireless data acquisition system. It converts small graphene deformation, induced by human pulse into digital signals for real-time wireless transmission. Experimental results confirm that the system could clearly record key physiological features such as P , T , and D waves (Percussion, Tidal, and Diastolic waves), demonstrating high diagnostic value for analyzing vascular elasticity and assessing cardiovascular health. As noted in the above results, this research highlights the effective synergy between the green graphene pulse sensor and embedded wireless systems, offering an efficient and sustainable solution for next-generation wearable remote diagnostic interfaces in smart healthcare.

Frequency-Selective Carrier Injection, Governed by Interface Physics in Monolayer WSe₂ Light-Emitting MOS Structures

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As silicon-based CMOS technology approaches its fundamental scaling limits in advanced integrated circuits, severe short-channel effects, increased leakage current, and escalating power dissipation have become major obstacles to further performance enhancement. Two-dimensional transition metal dichalcogenides (TMDCs), particularly monolayer WSe₂ with atomic-scale thickness and a direct bandgap, have emerged as promising candidates for next-generation nanoscale optoelectronic devices. Nevertheless, practical implementation remains constrained by substantial Schottky barrier heights at metal – semiconductor interfaces, Fermi-level pinning, and metal-induced gap states (MIGS), all of which hinder efficient carrier injection and limit electroluminescence (EL) performance. In this study, we investigate a monolayer WSe₂ metal – oxide – semiconductor (MOS) light-emitting device and introduce high-frequency RLC resonance engineering as an external signal modulation strategy to overcome injection bottlenecks. By reducing the oxide thickness, the effective capacitance in the equivalent RC model is increased, resulting in a 40% reduction in turn-on voltage and a 28% enhancement in carrier injection efficiency. These results confirm that electrostatic capacitance plays a critical role in modulating Schottky carrier injection. Furthermore, under high-frequency square-wave excitation, an equivalent RLC resonance condition is established. At specific resonant frequencies, the device impedance is minimized, leading to electroluminescence enhancement from three to four orders of magnitude, accompanied by a substantial reduction in driving voltage. The analysis of voltage–luminescence characteristics and time-resolved electroluminescence measurements reveal shortened carrier lifetime and increased carrier density at resonance, yielding nearly a 50-fold enhancement in emission intensity. These findings demonstrate that external RLC signal engineering enables frequency-selective carrier injection with improved recombination efficiency and reduced power

consumption. The ability to generate stable and intense optical emission at designated frequencies provides a viable pathway for integrating two-dimensional nanoscale light sources into photonic integrated circuits and high-speed optical communication systems.

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Fabrication and Application of Two-dimensional Molybdenum Disulfide Field-Effect Transistor

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This study integrates radio frequency (RF) magnetron sputtering with chemical vapor deposition (CVD) to achieve the controllable synthesis of high-quality, large-area layered two-dimensional transition metal dichalcogenide (TMDC) thin films [1, 2]. Emphasis is placed on exploring the potential of molybdenum disulfide (MoS₂) for high-performance applications in electronic and optoelectronic devices. In the first stage, MoS₂-based optoelectronic devices are systematically developed, and their material and device characteristics are thoroughly evaluated. In the subsequent stage, tungsten disulfide (WS₂) and MoS₂ are employed to fabricate optoelectronic sensing devices, with comprehensive analyses conducted of their structural, electronic, and sensing properties. The research further investigates post-annealing strategies and interface engineering approaches to enhance the performance of MoS₂ field-effect transistors (FET). By advancing integration and device optimization techniques, this work aims to promote the application and scalability of two-dimensional materials in next-generation semiconductor technologies.

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An AI-Driven Dynamic Questionnaire System to Streamline Pre-consultation for the Elderly

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In the field of public health, traditional static questionnaires face significant challenges in collecting authentic behavioral data from elderly populations. The rigid nature of standardized surveys frequently induces respondent fatigue and defensive answering, hindering the development of precision public health strategies. To overcome this data collection bottleneck, this study proposes an AI-driven dynamic questionnaire system, designed to streamline pre-consultation surveys. Built on a dual-core architecture, the system features a front-end "Care Questionnaire AI" that uses a conversational chatbot interface to simulate a natural interview. Using adaptive logic, it dynamically adapts subsequent questions based on user responses in real-time. The back-end automated data pipeline utilizes Large Language Models (LLMs) to generate structured medical prompts and cross-validate data instantly. Accessibility features, including voice-to-text, further accommodate elderly users. By omitting irrelevant sections and employing predictive autofill, the system is projected to accelerate completion times by up to 70%, significantly reducing patient fatigue while ensuring high privacy to encourage honest responses. Consequently, clinicians receive a structured, pre-visit summary that saves consultation time and shifts the focus directly to patient care. Ultimately, this AI-driven approach represents a fundamental innovation in geriatric data collection, providing the high-quality insights necessary for precise public health decision-making and the formulation of personalized treatment plans.

Architecture-Optimized Ag – CsPbI₃ Platforms for PIERS Detection

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Photo-induced enhanced Raman scattering (PIERS) has emerged as an advanced strategy to surpass conventional surface-enhanced Raman scattering (SERS) by introducing ultraviolet

(UV)-induced defect states that amplify charge-transfer processes. In this work, we report a systematic investigation of perovskite-based PIERS substrates, composed of Ag – CsPbI₃ hybrid architectures, fabricated via all-vacuum thermal deposition. Four device configurations were designed to evaluate their performance: Glass/Ag-rich perovskite, Glass/Ag/Ag-rich perovskite, Glass/Ag-rich perovskite/Ag, and Glass/Ag/Ag-rich perovskite/Ag. The Ag-rich perovskite layer was prepared by co-evaporation of CsI, PbI₂, and Ag, followed by thermal annealing to form CsPbI₃. Comprehensive morphological, optical, and structural characterizations confirmed the successful formation of hybrid interfaces and plasmonic Ag layers. Systematic performance comparisons, using rhodamine 6G demonstrated that the architecture, incorporating both top and bottom Ag layers, exhibited the strongest Raman enhancement and the highest spatial uniformity. Optimization of Ag content within the perovskite matrix and bottom Ag thickness revealed that balanced plasmonic coupling and internal reflection effects are critical for maximizing signal intensity. Under optimized conditions, UV pre-irradiation significantly enhanced Raman signals through defect engineering in CsPbI₃, primarily attributed to photo-induced iodine vacancy formation. These vacancies introduce additional charge-transfer pathways, facilitating improved interfacial electronic interactions between the substrate and analytes. The optimized substrate achieved a detection limit of 10⁻⁸ M for model analytes under PIERS conditions, representing a tenfold improvement over conventional SERS performance. To demonstrate practical applicability, the platform was employed for the detection of the pesticide thiabendazole in commercial apple juice without sample pretreatment. A detection limit of 10⁻⁷ M was achieved, well below regulatory maximum residue limits, confirming strong potential for real-sample analysis in complex matrices. Overall, this study establishes Ag – CsPbI₃ hybrid structures as a new class of PIERS-active substrates, combining plasmonic electromagnetic amplification with UV-induced defect-mediated chemical enhancement. The results provide mechanistic insight and design principles for next-generation highly sensitive, label-free Raman sensing platforms for environmental monitoring, food safety, and trace chemical detection applications.

Rice Quality Identification via Multimodal Physical Feature Analysis: An Optical Inspection System

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The inspection of rice appearance quality serves as the cornerstone for government procurement, grade classification, and market pricing. However, current practices remain heavily reliant on manual visual inspection, which is inherently susceptible to subjective bias and physical fatigue. These limitations not only compromise the consistency of judgment standards but also impede digital transformation due to low data traceability. To meet the demands for precision detection in smart agriculture, this study proposes an automated rice quality inspection framework based on cutting-edge deep learning techniques, specifically aligned with the "Official Grain Acceptance Standards" of the Agriculture and Food Agency. The technical core of this research lies in the deployment of the YOLOv11-seg instance segmentation model. In contrast to traditional object detection, which yields only coarse

bounding boxes, instance segmentation enables pixel-level feature extraction. To address the complexity of "multi-kernel-per-image" scenarios, this study innovatively implements a tiling strategy. The academic significance of this mechanism lies in resolving the contradiction between high-resolution industrial imaging and the input resolution constraints of neural networks. This approach effectively preserves the subtle morphological variations of grain edges, establishing a precise foundation for subsequent geometric metric calculations. Methodologically, the system utilizes segmentation masks to precisely extract geometric attributes of individual kernels, including length, width, aspect ratio, and projected area, thereby enabling automated classification and quantitative statistics for head rice, broken kernels, and chalky grains. Experimental results demonstrate that the system achieves a Mean Average Precision (MAP) exceeding 90% in broken kernel identification. Crucially, a high linear correlation ($R^2 > 0.95$) was observed between AI-driven measurements and manual benchmarks, validating the high fidelity and robustness of the model in large-scale agricultural data analysis and practical acceptance of field-testing. While the current research focuses on offline validation, limited by pixel-scale metrics and a narrow variety of samples (2–3 cultivars), it successfully establishes a highly scalable technical prototype. Future work will incorporate an absolute scale calibration framework and cross-device consistency protocols, alongside engineering optimizations for inference latency and operational throughput. In conclusion, this research not only overcomes the bottlenecks of traditional image processing in segmenting touching grains but also provides critical technical support for the automation of grain procurement and the digital transformation of the agrifood industry, demonstrating profound potential for enhancing inspection impartiality and operational efficiency.

F-OFDM-Based Covert Underwater Acoustic Communication, Using Chaotic Hénon Text Encryption, and Hiding Mechanisms with Bottlenose Dolphin Vocalizations

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Covert underwater acoustic communication (CUAC) is an important research area for military and marine applications. In this paper, we propose filter-orthogonal frequency-division multiplexing (F-OFDM) based CUAC integrating chaotic Hénon text encryption, SS, and bottlenose dolphin vocalizations (*BDV*)-based hiding mechanisms. The proposed CUAC method will incorporate F-OFDM, an 8×8 interleaver, (2000, 1000) low-density parity-check (LDPC) code, quadrature phase shift keying (QPSK), and a chaotic Hénon map (HM) encryption and spread spectrum (SS) (16) mechanism. The performances of the adjacent

correlation coefficient (ACC) parameter of the original BDVs and received BDVs with text encryption, SS, and hiding mechanisms (TESSHM) are evaluated. The number of changing bit rates (NCBRs) of the original and de-hiding/decryption text are analyzed (see Table 1).

Table 1. Performances of the chaotic HM-based encryption and hiding method for the decryption of text information; the BER values of the proposed CUAC transceivers with channel estimation error of 0%

Encryption Parameters x_0, y_0, δ, N	Decryption parameters x_0, y_0, δ, N	Decrypted text information
0.63, 0.19, 0.1, 10000	0.63, 0.19, 0.1, 10000	<pre>my_string = 'Welcome to Bottlenose Dolphin Vocalization Signal Processing'</pre> ACC=0.999870977172214 , NBCR=0 %; , SNR=6.14 dB, BER=9.78×10^{-4}; correct decryption.
0.631, 0.19, 0.11, 9700	0.63, 0.19, 0.1, 10000	<pre>my_string = 'á0c` jøN) BEjVàDC" * \$oâ fA% ` 'eud Þ"pP0- xfcH ßkHß,♠fε '</pre> ACC=0.986162210122698, NBCR=46.67 %, SNR=6.14 dB, BER=8.87×10^{-4}, error decryption.
0.633, 0.19, 0.13, 9900	0.63, 0.19, 0.1, 10000	<pre>my_string = ' * M %E†6` † *t*p jÄ ·Hcê†B %uÇ 2. / ' W a`ßb Ep X</pre> ACC=0.985362869467127, NBCR=47.92%, SNR=6.14 dB, BER=9.04×10^{-4}, error decryption.

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The Synthesis of Ferroelectric Solid Solutions of Antimony Sulfoiodide-Sulfobromide in Water Medium

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Antimony sulphobromide (SbSBr) and its solid solutions with antimony sulfoiodide (SbSI) are the ferroelectric materials, which also possess piezoelectric, photoconductive and

photocatalytic properties [1]. The development of simple and cost-effective methods for their synthesis opens wide possibilities for their detailed investigation and practical application. In our study, the solid solutions of $\text{SbSI}_{1-x}\text{Br}_x$ ($x = 0.1 - 0.9$) were synthesized in water-acidic solutions. The XRF analysis suggests that for high values of x the composition of solid solutions corresponds well with the formula values, but for x less than 0.3 the bromide content is higher than expected. To find the cause of this phenomenon, the composition of the solutions during synthesis was analyzed and the excess of bromide ions in each of them was calculated. This excess, as can be seen on Fig. 1, for $x = 0.1$ exceeds the target value by almost 120 times and then decreases sharply, reaching approximately 20-fold and 9-fold excess for $x = 0.5$ and 0.9, respectively. In the range of $x = 0.5 - 0.9$, as seen on Fig. 1, the bromine content in the samples practically coincides with the formula value. Although Br^- exhibits lower π -acceptor capability, compared to I^- , and considering the presence of stoichiometric amounts of iodide ions in the solution, the high bromide concentration leads to significant competition between the halide ions. This competition results in the formation of solid solutions with Br^- content, exceeding the theoretical values. These deviations arise from complex chemical equilibria, established at the sulfide sediment/solution interface during the heterogeneous transformation of Sb_2S_3 into $\text{SbSI}_{1-x}\text{Br}_x$ phases. Thus, the optimal concentration range for the bromide ion excess in the solution during the $\text{SbSI}_{1-x}\text{Br}_x$ synthesis is lying between 9-fold and 20-fold.

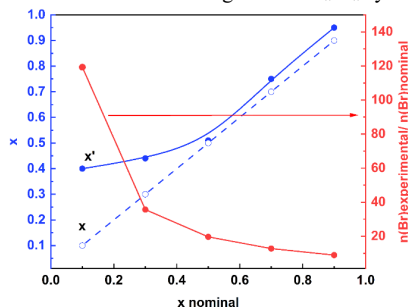


Fig. 1. Nominal (dashed line, x) and experimentally determined by XRF (solid blue line, x') bromine content in the $\text{SbSI}_{1-x}\text{Br}_x$ samples; the right vertical axis represents the molar ratio of the total bromine in the synthesis solution ($n(\text{HBr}) + n(\text{KBr})$) to its stoichiometric amount, required for obtaining 1 mole of the product

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Interdigitated Electrode PbS Gas Detector Based on Atmospheric Solution Process

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With increasing industrial development and environmental pollution, gas sensing technology plays a crucial role in environmental monitoring, industrial safety, and health protection. Developing gas sensing elements with high sensitivity, low cost, and large-area fabrication capabilities [1] has become a significant research topic in recent years. Traditional gas sensors rely heavily on high-temperature processes or vacuum deposition techniques [2], which not only result in high manufacturing costs but also limit their application in flexible electronics and large-area fabrication [3]. Therefore, developing low-cost sensing materials and fabrication technologies that can be fabricated in an atmospheric environment is of significant research value. Lead sulfide (PbS) is a narrow bandgap semiconductor material [4] with excellent electron transport characteristics and surface reactivity, making it a focus of attention in optoelectronic devices and gas sensing. This study will prepare PbS sensing materials, using a spin coating and combine it with a transparent finger-shaped [5] electrode structure to fabricate a gas sensing element. The study will explore its electrical changes and sensing characteristics in gas detection, aiming to establish a low-cost, simple, and high-performance gas sensor fabrication method, and to provide a reference and development direction for future applications of gas sensing elements (Fig. 1).

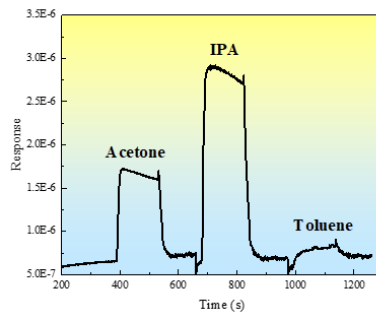


Fig. 1. Resistance changes of a gas sensor when sensing different gases

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A Multi-Mode 24GHz mmWave Radar Sensing System for Privacy-Preserving Home Security Applications

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With the prevalence of aging societies and dual-income families, the demand for home safety monitoring is increasingly growing. Existing home security devices, such as video surveillance and wearable devices, frequently encounter application limitations, including privacy infringements, frequent charging needs, and users' reluctance to wear them [1, 2]. To address these issues, this study proposes a non-contact intelligent virtual fence system based on 24 GHz millimeter-wave (mmWave) radar and Digital Signal Processing (DSP). Recent studies have recognized mmWave radar as an ideal solution for smart homes and Human Activity Recognition (HAR) due to its privacy-preserving, illumination-invariant, and non-contact characteristics [3]. The proposed system architecture integrates sensing, judgment, and response layers. In the sensing layer, a hardware-software co-design approach is adopted; in addition to programmatically defining virtual detection boundaries, mechanical modifications are applied to the radar module to narrow the effective sensing Field of View (FoV), thereby reducing echo interference from non-target directions [4]. In the judgment layer, the microprocessor dynamically tracks the target's distance, energy, and coordinates through continuous time-series analysis and feature extraction, a method proven effective in filtering instantaneous noise and determining human behavioral intent in real-time embedded systems [5]. The system features high scalability and implements event-driven modes for three high-risk scenarios in the home environment: (i) Security Monitoring Mode [6, 7], (ii) Home Care Mode (detection of sudden height changes and falls in the elderly), and (iii) Smart Perimeter Mode. The research results are expected to demonstrate that this system can provide a modernized, proactive home defense mechanism with high reliability and privacy protection, entirely without affecting spatial flow or capturing any image information [8].

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Magnet Reduction and Efficiency Limit Analysis of a Small External Rotor BLDC Motor for Precision Applications

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This research conducts an analysis of magnet reduction and efficiency limits for a 2.5 W external rotor brushless DC (BLDC) motor. The design is tailored for miniaturized equipment requiring low torque, low power consumption, and long-term operation, such as small household appliances, automation and control systems, miniature transmission units, medical and precision instruments, and agricultural micro-hydroelectric devices. Considering the cost and supply risks, associated with rare-earth permanent magnets (NdFeB), this study utilizes Finite Element Analysis (FEA) to perform electromagnetic and thermal-coupled design optimization. The resulting prototype achieved a simulated efficiency of 94.065 %. The study systematically evaluates the influence of key parameters, including magnet thickness, pole arc ratio, air gap length, and copper fill factor, on overall performance. Simulation results demonstrate that adjustments to these parameters impact motor performance to varying degrees. The design methodology proposed herein successfully achieves the dual objectives of material reduction and the development of high-efficient micro-motors.

A Portable Double-Acting Piston Pump for Biomedical Applications: Design, Modeling, and Experimental Evaluation

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In today's rapidly evolving healthcare landscape, medical devices and instrumentation have become instrumental in achieving better patient outcomes, accurate diagnostics, and effective treatment. Mechanical ventilators are a vital component of clinical equipment and are used very commonly in ICU wards and emergency rooms. As the world faced the COVID-19 outbreak, healthcare facilities have been shown to lack adequate mechanical ventilators, thus underscoring the importance of developing small-sized, inexpensive, and functional respiratory devices. Additionally, the rising incidence of respiratory disorders is another important factor driving the development of novel mechanical ventilators and their application in decentralized healthcare settings, such as domestic care and ambulance services. This study proposes a design for a compact mechanical ventilator, based on a double-action piston pump, formulated in the interdisciplinary context of biomedical engineering and medical instrumentation. The system uses a positive-pressure ventilation principle and can provide clinical parameters, including tidal volume, airflow, respiratory rate, and airway pressure. In terms of mechanics, the transmission process is designed so that a piston stroke of about 17.36 mm is provided with a lateral displacement of 0.76 mm to minimize friction and mechanical losses. A mathematical model for the air supply system is derived from experimental data, and system identification is performed using bilinear and first-order plus dead-time (FOPDT) models. The accuracy of the models is estimated by calculating the mean square error (MSE), with results showing the bilinear model, producing an MSE from 2.3×10^{-3} to 1.1×10^{-3} and 1.99×10^{-4} , whereas FOPDT produces MSE between 1.69×10^{-3} and 5.19×10^{-3} . According to simulation results, there is stable airflow, little overshoot, fast response (settling time less than 1.25 seconds), and steady-state error of less than 5 %. Through simulation, using a synthetic lung model with compliance and resistance that mimic real-life conditions, it is possible to determine that the control system can deliver the required tidal volume at 500 ml. The experimental results correlate with the simulation results despite the presence of nonlinear behavior and turbulence.

Hydrochar as a Waste Product with Added Value

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There is an actual problem of waste accumulation and disposal. Compared to existing methods, technology of hydrothermal carbonization is an environmentally and economically beneficial solution to this issue. Hydrochar, a product of hydrothermal carbonization, is rich in nutrients and carbon, possesses porosity, and contains many functional groups. The main goal of this work is to develop a hydrothermal carbonization technology and to test hydrochars as a soil improver. Hydrochar was produced from Alder wood biomass, using the Bench Top Reactor 4520. HTC conditions, including temperatures of 180, 200 and 220 °C, a residence time of 30, 60 and 90 minutes, and a water-to-biomass ratio of 1:10 (w/w). After processing, the solid material was washed three times with distilled water, filtered, and dried in an oven at 105 °C until completely dry. The soil used in the incubation experiment was collected from an arable site within the Botanical Garden of the Rostov Region, Russia. In the model experiment, 200 g of soil was placed into 350 mL containers. Dry hydrochar was added to the soil at a rate of 1% of the soil dry mass. Soil incubation with hydrochars lasted 30 days, after which a portion of the soil was sampled for analysis. Winter wheat grains (*Triticum aestivum*) were then sown into the remaining soil at a rate of 10 seeds per container and grown under laboratory conditions at a controlled room temperature. Ten days after seed emergence, germination rate, root length, shoot length, and biomass of the test culture were measured. The results showed that the application of hydrochars increases the total carbon content of soil and improves the growth of underground biomass. This study demonstrates that the method of hydrothermal carbonization allows not only the processing of waste but also the use of hydrochars as a soil improver.

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Simulation of Diffusion of Nitrogen Dioxide Molecules in TiO₂ – SnO₂ Films

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Tin dioxide (SnO₂) and titanium dioxide (TiO₂), being *n*-type semiconductors of conductivity, are the most sought-after gas-sensitive materials. Sensors based on films of a mixture of nanoscale TiO₂ and SnO₂ oxides demonstrate a higher response to nitrogen dioxide (NO₂) [1]. The sensor characteristics depend on the properties of the gas-sensitive material, film thickness and operating temperature, as well as on the diffusion of gas molecules to the adsorption sites

[2]. In thin films of gas-sensitive materials with a pore size of 10 nm or more, Knudsen diffusion is of the greatest importance. The response of the film (S) to the action of NO_2 molecules with a concentration of ($C_{A,s}$) can be expressed as follows [2]:

$$S = \frac{R_a}{R_g} = 1 + \frac{\alpha C_{A,s}}{L \sqrt{\frac{k}{D_k}}} \tanh \left(L \sqrt{\frac{k}{D_k}} \right) \quad (1)$$

where R_a and R_g is the sensor resistance before and after exposure to gas molecules, respectively; D_k is the Knudsen diffusion coefficient, T is the operating temperature, M is the molecular weight of the gas; r is the pore radius; k is the reaction rate constant; α is the sensitivity coefficient; L is the film thickness. Figure 1 shows the temperature dependence of the sensor response based on $\text{TiO}_2 - \text{SnO}_2$ thin films when exposed to NO_2 molecules. Using formula (1), theoretical calculations of the response value of the same film were carried out. The theoretical values of S are less than the experimental values. In this regard, it can be assumed that in addition to Knudsen diffusion, there may be another mechanism of diffusion of gas molecules. It was determined that the Knudsen diffusion coefficient of NO_2 molecules is $1.8 \times 10^{-7} \frac{\text{m}}{\text{s}^2}$, while the diffusion coefficient by the second mechanism is $8.43 \times 10^{-5} \frac{\text{m}}{\text{s}^2}$. The found value indicates that the second mechanism of diffusion is surface diffusion [2]. The gas sensor values obtained, using the found diffusion coefficients, are completely consistent with the values on experimental curve 1. Thus, there are two mechanisms of diffusion of NO_2 molecules in $\text{TiO}_2 - \text{SnO}_2$ films, namely surface and Knudsen diffusion.

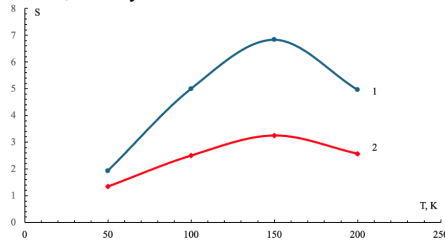


Fig. 1. Dependence of the $\text{TiO}_2 - \text{SnO}_2$ sensor response on the operating temperature: (1) experimental data, (2) calculated data

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Designing Game Mechanics in Store Management Simulators

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The current indie game market demonstrates a steady interest in the store management simulator genre. Projects such as Shop Titans, Moonlighter, and Recettear demonstrate that

audiences value not only economic depth but also customization options and additional activities beyond basic trading. This paper examines key approaches to designing game mechanics within the context of the game design of "No Time to Stop!", a robot rental and assembly store simulator. The first key task of a game designer is to create a stable core loop. In most store management simulators, the core loop is built on the "buy-sell-profit-reinvest" pattern. However, experience shows that such a cycle quickly leads to a loss of player interest due to monotony. In "No Time to Stop!" the core gameplay loop was expanded with rental and breakdown mechanics: the player doesn't simply sell a product; they rent out a robot, wait for its return, and face the risk of breakdown and the need for repairs. This creates an element of uncertainty and long-term planning, which increases engagement and retains the player. The second important aspect is the design of the customization system. An analysis of player personality types according to Bartle and BrainHex revealed that the leading personality types for the store management simulator genre are "Achiever" and "Collector." Players of this type are motivated by accumulating resources, discovering new opportunities, and creating unique objects. To this end, a system of spare parts characteristics was developed in the game, including six parameters: attack, defense, speed, maneuverability, durability, and energy. By combining spare parts, the player creates unique robots, satisfying the need for self-expression and mastery. Experience with projects like Moonlighter, where customization is limited to weapon and armor selection, shows that a deeper stat system significantly increases player retention. The third area of focus was the design of the combat system as an additional mechanic that breaks the monotony of trading. Unlike Moonlighter, where the combat system is a separate "dungeon-to-shop" phase, in "No Time to Stop!" combat is implemented as competitive duels in a Rocket League-style arena. Players control assembled robots, clash with each other, and use traps and boosters. This solution not only diversifies gameplay but also gives players the opportunity to test the results of their build. Feedback from testing confirms that the opportunity to "test the robot in combat" is a strong motivator. The design of the reputation system and client types deserves special attention. Analysis revealed that interactions with NPCs in management simulators are often perfunctory and boil down to the mechanical exchange of goods for money. The game under development featured a system of three customer types (elite collector, budget seeker, and high-speed racer), each with unique preferences and responding to the store's reputation. Reputation, in turn, influences which customers visit and how much they are willing to pay. This creates a sense of social interaction and the significance of their decisions, which, in terms of self-determination theory, corresponds to satisfying the need for relatedness. The practical significance of this work lies in the fact that the developed game design solutions can be applied to similar projects in the store management simulator genre. During the work, a game design document was created, all the main game mechanics were designed, the balance of the economy and characteristics was developed, and a working prototype was implemented, ready for alpha testing. Design experience has shown that the key factors for success in this genre are: (i) the presence of a stable cycle with an element of risk, (ii) a deep customization system, (iii) additional mechanics to break the monotony, and (iv) a social component in the form of reputation and customer types. In conclusion, developing a game design for a store management simulator requires a comprehensive approach that considers both the economic and psychological aspects of gaming experience. The most successful solutions in this area lie at the intersection of genres, adding elements of customization, competition, and social interaction to the basic trading mechanics. Further development of the project may include deepening the combat system, adding online modes, and expanding the range of customer and spare part types.

Fractional Hypersingular Diffusion Layer for Robust Signal Denoising on Metric Graphs

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Structural health monitoring of machinery and extended mechanical structures (e.g., pipelines, bridges) relies on distributed sensor networks, whose signals are inevitably corrupted by noise measurement. Classical local filtering methods such as Laplacian-based diffusion often amplify high-frequency noise or require manual tuning without theoretical stability guarantees. We propose a lightweight neural network layer, the Residual Fractional Hypersingular Diffusion (FHD) block, defined by $f_{\text{out}} = f_{\text{in}} - \gamma D^\alpha f_{\text{in}}$, $\alpha \in (0, 1)$, where D^α is the hypersingular integral of order α on a metric measure space [1]. Applied to the noise filtering problem, the operator is defined through the integration of $f(y) - f(x)$, weighted by $[d(x, y)]^{-(1+\alpha)}$ over the graph, providing non-local averaging. Rigorous theorems on the boundedness of such operators in weighted spaces of generalized variable Hölder continuity guarantee that, under specific conditions, the layer neither amplifies noise nor destroys the underlying signal regularity [2, 3]. Both α and the step γ are tuned here end-to-end via standard gradient descent. Industrial platinum resistance thermometers (Pt100) of tolerance class A according to IEC 60751 have a maximum allowable deviation of $\pm(0.15 + 0.002 |t|)$ °C from the nominal resistance – temperature characteristic [4], which at 0 °C reduces to a base tolerance of ± 0.15 °C. In practice, digitized signals from such sensors are additionally corrupted by additive measurement noise, so that a standard deviation of $\sigma = 0.15$ °C represents a realistic and conservative noise level for numerical modelling. Such noise masks small thermal anomalies, for example, localized heating, caused by incipient leaks or insulation defects, and thereby reduces the reliability of diagnostic algorithms that exploit spatial temperature gradients along a pipeline. To quantify this effect and evaluate the proposed solution, a numerical experiment was conducted in which a 10 m pipeline segment equipped with 200 equally spaced Pt100 sensors was modelled. The true temperature profile was piecewise-linear with three distinct gradients and was corrupted by additive white Gaussian noise with $\sigma = 0.15$ °C, yielding $\text{MSE} \approx 1.98 \times 10^{-2}$ and $\text{RMSE} \approx 0.14$ °C. A classical Residual Block, based on a normalized Laplacian, left these errors virtually unchanged, demonstrating that a purely local operator cannot discriminate between noise and the useful signal at this noise level. In contrast, the proposed FHD block reduced the MSE to $\approx 2.76 \times 10^{-3}$, namely a seven-fold improvement, corresponding to $\text{RMSE} \approx 0.053$ °C, a 2.7-fold reduction relative to both the noisy baseline and the classically processed result. These numerical findings were further supported by verification of the theoretical conditions underlying the FHD block, confirming the analytical guarantees established by the fundamental theorems. The FHD layer is implemented in PyTorch and can be inserted before any graph neural network (GCN, GAT) as a ready-to-use, mathematically grounded denoising module. The results demonstrate that fractional diffusion, supported by proven boundedness theorems, delivers both superior

accuracy and verifiable stability for data-driven condition monitoring of machines and structures.

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Hypersingular Integral Inversion of Mean-Field Potentials for Non-Destructive Mapping of Defect Distributions in Advanced Materials

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The reliable characterization of heterogeneities, such as dopant gradients, vacancy clusters, or charge traps, in functional materials is essential for advancing thin-film electronics, composite integrity monitoring, and quantum device fabrication. Traditional imaging techniques often require destructive cross-sectioning or suffer from limited penetration depth. This work proposes a mathematical framework for non-invasive reconstruction of defect density distributions from surface or near-field potential measurements, leveraging the analytical structure of hypersingular integral operators. In mean-field descriptions of interacting particle ensembles, the collective potential $u(x, t)$ is expressed as a convolution of the underlying particle density $\rho(y, t)$ with a long-range interaction kernel $G(x - y)$ [1]. In numerous physically relevant regimes (e.g., Coulomb interactions in dielectrics, dipolar forces in ferroelectrics), the kernel G corresponds to a Riesz potential, and the inverse mapping, recovering ρ from measured u , is governed by a hypersingular integral operator [2]. While direct inversion is ill-posed, recent advances in the generalized Hölder space theory provide rigorous stability bounds that regularize the reconstruction process. In this study, several typical problem statements are considered, which apply the achievements of spherical Riesz fractional calculus along with novel results, carried out for abstract metric spaces [3]. The aim is to provide insights from the theory of hypersingular integrals for stable numerical inversion of mean-field potentials and generating high-resolution defect maps for various applications,

which are treated as a physics-constrained computational alternative to empirical calibration delivering a quantitative link between macroscopic electrical signatures and underlying material microstructure.

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Adaptive Computational Framework for Anomalous Transport in Architected Heterogeneous Media for Biomedical Applications

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The predictive simulation of particle or molecular transport in composite biosystems (e.g., fibrotic tissues or polymer-ceramic scaffolds) requires numerical schemes that consider the non-local nature of interactions at the mesoscale. Standard finite element approaches often break down when applied to heterogeneous domains, characterized by power-law spatial correlations and memory effects, described within fractional calculus. In this work, a robust mathematical framework is introduced for simulating anomalous diffusion phenomena within complex, architected materials relevant to modern biomedical engineering and advanced manufacturing, linking rigorous estimates of hypersingular integral operators to the adaptive solution of fractional diffusion equations in generalized function spaces. Building upon recent analytical results, concerning Zygmund-type estimates for hypersingular operators in power-weighted variable generalized Hölder spaces [1, 2], we propose a microstructure-informed numerical homogenization scheme. The core innovation involves utilizing the local modulus of continuity of the solution field not merely as an error indicator, but as a direct proxy for the local material heterogeneity index. The power-law weight function, which governs the behavior of the hypersingular kernel, is physically interpreted as a spatial descriptor of interfacial energy decay near material boundaries or phase inclusions. By applying the boundedness theorems for the fractional order operators in weighted spaces, the framework provides a mathematically rigorous basis for error estimation in heterogeneous domains, aiming at *a priori* convergence guarantees that inform optimal mesh adaptation strategies in complex composite geometries. The method is assumed as particularly suited for modeling

functional gradient materials and biomedical transport phenomena where the underlying medium exhibits multi-scale porosity and power-law memory kernels.

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Vacancies: Enemies or Friends?

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In ferroelectric materials science, as in any other field, related to the development and creation of the functional materials with special electrical and magnetic properties, ion vacancies are traditionally considered as point defects that are harmful to the properties of materials. However, recently, theoretical and experimental studies have shown that vacancies, and above all, oxygen vacancies in oxide electronics, can cause new properties, converting, for example, insulating oxides into metals, forming magnetic states in substances that do not have them, generating superconductivity, etc. [1]. As noted in [1], this makes such structural imperfections a “central player” in oxide materials technologies, participating in the formation of the field now known as defect “engineering”, aimed at manipulating the nature and concentration of defects to tune the properties of materials in a desired way or to generate completely new and unexpected properties [2, 3]. For example, we have shown that the decisive factor in the formation of a complex of the physical properties of ferroelectric ceramics is the mobility of domain walls, determined by spontaneous deformation and their interaction with vacancies, while the degree of the change in the parameters depends on the concentration of vacancies and the nature of their distribution in the crystal structure. We also found that vacancies, formed in place of the *A*-cation (in perovskite-type structures), stabilize the antiferroelectric state in sodium niobate, and the observed periodicity of the phase formation processes in PZT ceramics is associated with the formation, accumulation, ordering of oxygen vacancies and their exclusion by crystallographic shift. Thus, on one hand, vacancies may be necessary to expand the functionality of materials, but on the other hand, they may seem undesirable if the goal is the perfection of objects.

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Self-Rectifying Copper Oxide Memristor for Crossbar Memristive Arrays

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When fabricating crossbar resistive random-access memory arrays, memristors, connected in series with selectors, must be used as memory cells to eliminate parasitic sneak-path currents. However, fabricating an additional selector layer is complex and requires multiple manufacturing steps. A separate class of memristor selector devices with unidirectional conductivity exists, which are analogous to the 1D1R crossbar architecture but do not require an additional selector, as the memristor itself exhibits unidirectional conductivity. A memristor based on copper oxide with silver electrodes and an indium tin oxide sublayer was fabricated. The sample was deposited on a glass substrate, using magnetron sputtering, a method, called evaporation through masks [1]. The resistive switching parameters of the fabricated memristor were measured. Current-voltage characteristics and endurance testing were investigated, using a probe station and a Keithley 6517B precision electrometer. The device exhibits 20 cycles of stable resistive switching with a self-healing effect. This effect is achieved by forming a Schottky barrier at the boundary of the Cu_2O and ITO layers. At a read voltage of -10 V, a write voltage of -20 V, and an erase voltage of 20 V, the device can switch for 4000 cycles, but the memory window gradually decreases with each subsequent switching. The resulting memristors can be used as memory cells for crossbar RRAM arrays and to simulate synapses in neuromorphic artificial intelligence systems, eliminating the problem of sneak path currents thanks to the self-rectifying effect.

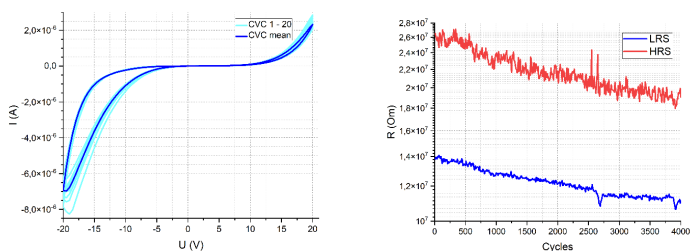


Fig. 1. I – V characteristic of 20 resistive switching cycles (left) and endurance test of 4000 resistive switching cycles (right)

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Development of a Methodology for Calculating Gears with Eccentric and Non-circular Gears

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F.L. Litvin, one of the founders of the theory of non-circular gears, wrote in his book "Non-circular gears" [1] in 1956: "We can express the hope that planetary gearboxes with non—circular wheels, both single-stage and more complex two-stage will find application not only in instrument engineering, but also in general mechanical engineering, as applied to automatic machines..." After 70 years, we can say that these words have undoubtedly been confirmed. The introduction of microprocessor-controlled metal cutting machines into production opens the possibility of cost-effective production of non-circular wheels with a rather complex geometry of tooth profiles. New gear options with non-circular wheels have led to more efficient designs for gearboxes, pumps, compressors, car transmissions, robot drives, measuring instruments, etc. Planetary gearboxes with non-circular wheels make it possible to obtain a variable speed of rotation of the output shaft in magnitude and direction. This study provides a sequence of calculations for a transmission, consisting of a round gear with an offset center and a non-circular wheel. The advantage of such a transmission is that there is only one non-circular wheel, for which the coordinates of the teeth need to be calculated.

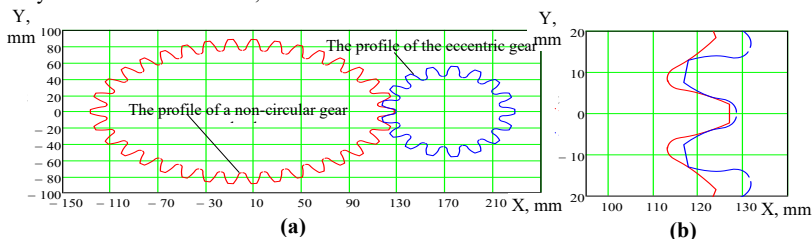


Fig. 1. Calculated wheel profiles ($m = 6$ mm; $u = 2$; $e = 19$ mm; $z_1 = 17$):

(a) General view of the profiles; (b) increased gear engagement area

To cut a particular wheel, it is necessary to calculate the coordinates of its teeth with high accuracy, which is feasible, using a computer. For elliptical and oval wheels, which are the simplest to calculate and therefore more widely used, we have already carried out such calculations [2 – 5]. Figure 1 shows the result of calculating the transmission wheel profiles for the following set of initial data: u is the maximum gear ratio; m is the wheel module; z_1 is the number of gear teeth; e is the gear eccentricity. The developed technique includes a set of analytical dependencies, algorithms and conditions for calculating gear profiles, presented in the form of large data arrays, including coordinates of points that can be loaded into a CNC system for manufacturing wheels or into a CAD system for obtaining solid-state models of

transmission parts. The methodology is implemented in the MathCad software. Several studies have been conducted aimed at defining the boundaries of the application of transmission design parameters. In particular, the conditions for ensuring the closure of the centroid of the non-circular wheel and the condition for the absence of intersection of the profiles of the teeth of the non-circular wheel are determined. The results obtained can be used in the design of planetary gearboxes with non-circular wheels to obtain a variable speed of rotation of the output shaft in magnitude and direction.

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Computational Schemes for Determining Parameters of Nonlinear Elastic Materials

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Determining the mechanical characteristics of materials and structures under large deformations remains a significant challenge in modern continuum mechanics. This challenge arises primarily from the fact that many advanced materials widely used in contemporary engineering, such as structural polymers, fiber-reinforced composites, and biocompatible soft tissues, exhibit pronounced nonlinear mechanical behavior precisely within the range of significant deformations that are relevant to practical applications. Furthermore, rapid advancements in aerospace engineering, medicine, and mechanical manufacturing require accurate characterization of material properties under conditions that closely replicate actual operational loads. In this regard, developing a reliable computational scheme for identifying material constants becomes critically important for accounting for highly nonlinear effects, arising under various loading scenarios. In this study, the identification problem is solved for the five-constant Murnaghan model, which describes the nonlinear-elastic behavior of solids. The input data consists of loading curves derived from static tensile, torsion, and bending tests on specimens. Instead of real experiments, their computational models are used: for specified values of the material parameters, loading diagrams for each type of test are constructed using

the semi-inverse method of nonlinear elasticity theory. The loading diagrams, obtained from static tests on specimens under tension, torsion, and bending are assumed to be given, namely the dependence of the rod's elongation on the tensile force, the dependence of the twist angle of the cross-section of the twisted shaft on the torque, and the dependence of the change in beam thickness on the bending moment, respectively. This approach enables the derivation of analytical solutions and reduces the dimensionality of the problem. However, the method is not universal for bodies with complex geometries and is applicable only to a limited set of external loads. To formulate problems that accurately represent actual experimental setups, the use of finite element analysis (FEA) is necessary. In this work, FEniCSx, being an open-source computational platform with a Python interface, is employed for FEA modeling. Simulations of standard mechanical tests were conducted, and specific problem classes, where the semi-inverse method is inadequate were identified. Nevertheless, the semi-inverse method demonstrated its effectiveness in providing initial approximations and benchmark solutions. The inverse problem of determining material parameters is formulated as a minimization problem for the root-mean-square deviation of the specimen's loading curve, computed for given parameters from the "experimental" curve. Given the complex landscape of the minimized function, a genetic algorithm was chosen for minimization, as it is more robust for multimodal objective functions. The integration of the finite element approach with this optimization algorithm yields satisfactory results for identifying elastic constants, even when the input data for the inverse problem is artificially noisy.

Intra- and Intermolecular Dynamics of the 4,4'-Bipyridine – an Aza-aromatic Synthron for Advanced Metal-organic Frameworks

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Metal-organic frameworks (MOFs), which have unique properties such as controlled pore size, high chemical and mechanical stability, and selective adsorption and diffusion, have been the subject of extensive research in the fields, ranging from environmental engineering to biomedicine, including sensors, water purification processes, and hydrogen and other gas storage. MOFs serve as adsorbents, catalysts for various processes, supercapacitors, and drug delivery systems. MOFs show promise under extreme conditions such as high pressure, extreme pH, and cryogenic temperatures for applications such as gas separation (deuterium), catalysis stabilization, and water treatment; however, their mechanical properties and chemical instability pose challenges. This study systematically investigates the intra- and intermolecular dynamics of 4,4'-bipyridine – an aza-aromatic synthron for MOFs with numerous potential

applications, including the production and use of functional materials for spintronics and microelectronics, as well as the development of highly effective catalytic systems. To conduct such a study, we employ a multidisciplinary approach that has previously proven to be effective [1 – 3]. An important task is to establish the relationship between the structural characteristics of the framework's building blocks and the key properties of MOFs, using a combination of complementary experimental methods (inelastic neutron scattering and X-ray diffraction) and molecular modelling methods (cluster and periodic calculations by DFT).

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Eco-Friendly and Flexible UV Photodetectors Based on PEDOT: PSS/Lead-Free Perovskite/Green Graphene Heterostructures on Paper Substrates

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We have demonstrated a low-cost, eco-friendly, and flexible photodetector based on PEDOT: PSS/lead-free perovskite (NH₄)₃Sb₂I₉/green graphene heterostructures. High-quality, cm-scale green graphene was initially synthesized through atmospheric-pressure chemical vapor deposition (APCVD), employing camphor, a natural plant product, as a carbon source, and was subsequently transferred to a flexible paper substrate. Raman spectroscopy and 50 × 50 μm² mapping revealed a weak D-peak (~1350 cm⁻¹) and a ratio of 2.2, confirming a high-quality, single-layer structure. The mapping further demonstrates over 80% monolayer coverage, highlighting the exceptional uniformity of the graphene layer. Optical characterization of organic-inorganic lead-free hybrid perovskite ((NH₄)₃Sb₂I₉) showed broad visible-light absorption in the range of 300 – 700 nm and photoluminescence (PL) emission between 540 and 570 nm. Subsequently, (NH₄)₃Sb₂I₉ and PEDOT: PSS were drop-coated onto the graphene surface to form a PEDOT: PSS/(NH₄)₃Sb₂I₉/green graphene double heterostructure. The *I* – *V* characteristics, evaluated at 1 V under UV illumination and dark conditions, yielded a photo-to-dark current ratio (PDCR) of ~12. This sensitivity is comparable to lead-based counterparts. Furthermore, the PDCR remained nearly constant after

600 bending cycles, demonstrating the device's exceptional mechanical stability. This work presents an environmentally friendly fabrication strategy that leverages the synergistic effects of perovskite's light harvesting and graphene's high carrier mobility. Such a simple and cost-effective method paves the way for the commercialization of flexible, high-performance optoelectronics in UV communication and wearable personal UV protection systems.

Improved Switching Characteristics of Bottom-Gate InWSnO Thin-Film Transistors via Dielectric Symmetry Engineering

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In this work, we investigate the influence of dielectric structural engineering on the electrical performance of bottom-gate InWSnO thin-film transistors (TFTs). Two gate dielectric configurations were compared: a conventional 100 nm Al₂O₃ layer and a stacked dielectric structure consisting of 15 nm SiO₂ / 50 nm Al₂O₃ / 15 nm SiO₂ [1, 2]. The channel layer was 20 nm-thick InWSnO (4%). Although the single-layer Al₂O₃ device exhibited a high field-effect mobility of 73.4 cm²/(V·s), it suffered from severe subthreshold degradation with a large subthreshold swing (SS) of 541 mV/dec and a high interface trap density (Dit) of 1.18×10^{13} cm⁻²eV⁻¹. By incorporating symmetric SiO₂ interfacial buffer layers, the stacked dielectric device significantly reduced Dit to 1.72×10^{12} cm⁻²eV⁻¹, corresponding to a 6.8-fold suppression of interface trap density. Consequently, the SS was dramatically reduced to 112 mV/dec and the I_{on}/I_{off} ratio increased from 3.55×10^8 to 9.18×10^{10} . Although the mobility slightly decreased due to the increased effective oxide thickness, the pronounced improvement in switching behavior indicates that interface trap suppression dominates device performance. The enhanced characteristics are attributed to reduced charge trapping and mitigation of trap-assisted conduction at the dielectric/channel interface enabled by dielectric symmetry and electric-field redistribution. These results demonstrate that dielectric structural engineering is an effective strategy for optimizing interface quality and enhancing switching performance in InWSnO-based oxide TFTs for next-generation electronic applications.

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Green Economy-based MSME Development Strategy through a Circular Management System

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This research explores the development strategy of green economy-based Micro, Small, and Medium Enterprises (MSMEs) through the implementation of a circular management system in Indonesia. MSMEs play a strategic role in the national economy, not only as drivers of economic growth and employment, but also as centers of local innovation and creativity. However, current MSME operational practices still face significant challenges related to suboptimal resource utilization and inefficient waste management. This research uses a qualitative case study approach on MSMEs in several regions in Indonesia that have implemented green economy and circular management practices. A descriptive qualitative analysis was conducted to understand the strategies implemented, the challenges encountered, and the successes achieved in integrating sustainability concepts into business processes. The theoretical framework of this research refers to the concept of the green economy. This concept emphasizes environmentally friendly economic growth, resource efficiency, and improved social welfare. Furthermore, the research also draws the circular economy. The circular economy focuses on optimizing material use through the principles of reuse, recycling, and upcycling waste into value-added products. The research results indicate that MSMEs, applying waste-based innovations, have succeeded in generating value-added products, such as organic fertilizers from sugarcane waste, plant-based eco-print batik, and paving blocks from plastic waste. Besides increasing the diversification of products and market penetration, this strategy also enhances the sustainable competitiveness of MSMEs. A circular management system, covering waste bank management and multi-stakeholder collaboration, including government, academics, communities, and businesses, has been demonstrated to enhance production efficiency, reduce operational costs, and open new economic opportunities. On the other hand, the study also pointed out certain crucial limiting factors, including capital constraints, availability and access to green technology, and human resource capacity, which may hamper the acceleration process in transforming to a green economy. This indeed verifies that MSME development strategies linked to a green economy and circular management have environmental benefits but also act as significant tools for enhancing economic resilience and social welfare. It is suggested that future studies use quantitative estimates of economic and environmental impacts from this strategy and work out effective collaborative policy models to support wider diffusion in Indonesia.

Performance Evaluation of Industrial Sectors in Indonesia Using DEA Stepwise Modeling and PCA– DEA Approaches

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The performance analysis of the industrial sector is a strategic step in enhancing the efficiency, competitiveness, and viability of the national industries. The purpose of this study is to assess the performance of the industrial sector in Indonesia. It uses a combination of the traditional Data Envelopment Analysis (DEA), Principal Component Analysis-DEA (PCA-DEA), and DEA Stepwise Modeling in a single analysis framework. These are intended to mitigate the shortcomings of the traditional DEA. Particularly regarding multicollinearity, the variables were used for analyzing. It might lead to a misinterpretation of actual efficiency results. The analysis will be carried out, using secondary data, concerning industrial sectors in Indonesia, whereby each industrial sector will be referred to as a Decision-Making Unit (DMU). The DEA model will be input-oriented with a CRS assumption and a VRS assumption. Results from the conventional DEA analyses show that the proportion of DMUs that attain full efficiency is between 20% and 40% in the CRS model. However, the proportion increases to 35 – 60% in the VRS model. This result suggests that the inefficiency in the industry is mostly driven by size mismatches. However, the inefficiency scores for the inefficient DMUs are between 0.50 and 0.90 in the CRS model, while the scores are between 0.70 and 1.00 in the VRS model. This implies that even the inefficient DMUs have the potential to decrease input slack from 10% to 35% without any change in the output. Using the PCA-DEA approach helps in effectively reducing the number of variables ranging from 2 to 3 principal components. Moreover, the approach helps in explaining from 75 to 90% data variability, using the principal components. This approach helps in overcoming the multicollinearity problem. Additionally, the results are more stable. Quantitatively, the proportion of efficient DMUs using the PCA-DEA approach was measured at 15% to 30%. Additionally, the results show that the proportionate distribution of the scores was within the range from 0.60 to 1.00. The approach of DEA Stepwise Modeling gives the most parsimonious model after eliminating about 30 – 50% of the original variables and retains only 2 – 4 significant variables. The percentage of DMUs declared efficient decreases further to around 10 – 25%, while the efficiency scores of inefficient DMUs are concentrated in the range of 0.60 – 0.85. Comparisons between methods reflect that conventional DEA is more permissive, while the methods of PCA–DEA and DEA Stepwise Modeling give a more binding, conservative, and robust efficiency estimate. This study offers methodological contributions because it integrates different DEA approaches, while empirical contributions consist of recent evidence on the performance and improvement potential of industrial sector efficiency in Indonesia. It thus follows that the use of a more demanding evaluation framework would be associated with substantial enhancement in operational practices. Future research may aim to identify concrete

strategies that inefficient DMUs could implement with a view to increasing their performance and overall productivity. It is expected that the results of this study will set a base for the formulation of more selective and evidence-based policies and strategies for improving industrial efficiency.

Plant Waste-based Batik Ecoprint: A Study of Product Development and Its Commercialization Potential

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Consumer demand for environmentally friendly products continues to rise. This change has pushed the batik industry to adapt. They are seeking cleaner production techniques that do not rely on synthetic chemicals. Plant-based ecoprinting has emerged as one solution. This technique utilizes fallen leaves, dried flowers, tree bark, and prunings as dye sources. Utilizing plant waste adds value because these materials are not typically used. Waste materials are also safer for the environment. Ecoprinting has a unique visual character. The motifs that emerge are derived from the natural forms of plants. Each piece of fabric has a distinct pattern. This distinction gives the product a strong identity. Ecoprint products are also closer to local cultural concepts. The use of natural materials strengthens the image of batik as a work based on tradition and creativity. This cultural value gives the product an advantage when marketing. This research employed a descriptive qualitative method. Data was obtained through a literature review. The literature reviewed covered the creative industry, MSMEs, the circular economy, eco-friendly innovation, and the commercialization of local culture-based products. The analysis was conducted using a thematic approach. Each theme was examined to identify the relationship between the production process, environmental benefits, the strength of MSME clusters, and market opportunities. This approach helps understand the dynamics of ecoprint development comprehensively. The results show that the ecoprint production process is relatively simple. The process begins with selecting plant waste that still contains pigment. The material is then applied to the fabric. The fabric is heated to allow the pigment to adhere. This process does not use harmful chemicals, thereby reducing the environmental impact. The dyeing results appear natural and soft. This aesthetic value increases consumer appeal. This study identified that MSMEs in East Java have strong support. These creative clusters provide shared facilities, such as training, mentoring, and production space. Business networks within these clusters also can conduct marketing. Collaboration between MSMEs accelerates the innovation process. Production capacity is designed to increase. Product quality is easier to maintain. The potential for ecoprint commercialization in East Java is significant. Raw materials are abundant. Consumers are increasingly seeking unique, natural, and culturally valuable products. Ecoprint products meet these needs. Digital marketing strategies also

expand the market. The use of social media and e-commerce increases product visibility. Ecoprint products are easily accessible to consumers from various regions. Export opportunities are opening as the global market begins to prioritize sustainability. Therefore, plant waste-based ecoprinting is worthy of development as a superior product in East Java. This product is environmentally friendly, unique, culturally valuable, and has strong market prospects. Strengthening MSME clusters and appropriate marketing strategies are key to its successful commercialization.

Sustainable Blue Economy Development Based on Coastal MSME Performance Optimization

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MSMEs in the coastal areas of East Java Province have an important position during economic development in the region. These MSMEs include the fisheries industry, aquaculture industry, seafood processing industry, ecotourism industry, and creative industry in the Blue Economy. Despite their significant economic potential, MSMEs in coastal areas still face challenges. These include a lack of productivity technology, low human skills, limited financial leverage, limited use of digitalization, and a lack of synergy among business actors. Previous research has not provided an overall model incorporating the Blue Economy approach and MSME performance optimization. This study aims to develop a performance optimization model for coastal MSMEs based on the Blue Economy. This model can improve productivity, competitiveness, and business sustainability of MSMEs. Furthermore, the model strives to maintain environmental sustainability and the well-being of coastal communities. The research approach is descriptive-analytical. The focus of this research consists of identifying the actual conditions of MSMEs, analyzing the determinants of performance and sustainability, and designing a GCBE-MSME framework. This framework integrates cluster management, product innovation, marketing digitalization, supply chain optimization, and environmentally friendly blue economy practices. The research results show that implementing the GCBE-MSME framework provides benefits to business organizations. These benefits include increased competitiveness, increased productivity, large-scale added value, and the potential to contribute to the achievement of the Sustainable Development Goals (SDGs). The research work of this study adds to SDG-8 as it promotes inclusive and sustainable economic growth and development, full and productive employment, and economic empowerment. For SDG-12, the research work promotes sustainable production and consumption patterns and effective management of marine waste to create value-added products. SDG 13 aims to reduce the burden on the environment and to adapt to and mitigate the impacts of climate change. It can be achieved through promoting environmentally friendly business practices. Furthermore, SDG 14 focuses on preserving the sustainability of marine ecosystems through sustainable management of marine resources and developing ecotourism based on coastal conservation principles. This research focuses on an integrative approach

with a Blue Economy-based strategy for developing coastal MSMEs. The development aims to achieve socio-ecological balance and economic sustainability and improve the welfare of coastal communities.

A Strategy for Developing Local Culture-based Creative Industries to Increase the Competitiveness of MSMEs in Indonesia

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MSMEs in the era of the global creative economy face growing competitive pressures that are increasingly complex, ranging from domestic to international. Factors such as low innovation capability, less product differentiation, and limited market access require the development of local cultural potential as a source of their competitiveness. On the other hand, Indonesia's rich culture, traditions, and local wisdom bring huge potential for serving as the foundation for unique and value-added creative product innovations that will consolidate MSMEs in the global market to develop an economically sustainable position. A strategy to develop creative industries based on local culture is relevant within this context, serving as an instrument of strengthening the competitiveness of MSMEs. The objective of this study is to formulate a development of strategy for creative industries that are based on local culture as an attempt to strengthen Indonesian MSMEs' competitiveness. MSMEs are considered one of the economic sectors that contribute significantly to labor absorption, regional economic development, and improvement in welfare in the community. However, it also faces challenges in terms of global competition, which requires innovation, product differentiation, and adaptability to the market. The strategy based on local culture is relevant. It is because utilizing cultural values, traditions, and local wisdom can result in the creation of unique, authentic, and difficult-to-imitate creative products. Therefore, it will increase the competitive advantage of MSMEs. This research employs a descriptive qualitative approach with a case study method on creative industry of Surabaya and Sidoarjo City. The research subjects consist of MSMEs, local governments, academics, supporting institutions, and creative communities. Data was collected through documentation studies of scientific publications and previous research reports. These data are analyzed using thematic and comparative analysis techniques to find patterns in creative industry development strategies, factors of success in clustering, multi-stakeholder collaboration, and the contribution of product innovations based on local culture, such as Eco-Print Batik, Teyeng Batik, and Ecoprint plant waste. The research results show that a creative industry development strategy based on local culture can enhance the competitiveness of MSMEs. This improvement occurs in several ways: First, MSMEs make

use of local culture as a source of creativity and product differentiation. Second, the development of creative industry clusters serves to enhance productivity, efficiency, and marketing networks. Third, multi-stakeholder collaboration among the government, academics, communities, and MSMEs strengthens the innovation ecosystem. Fourth, product innovation has the potential to offer added economic value, strengthen product identity, and open new markets both at the national and international levels. An integrated strategy that includes support for marketing digitalization, and government policies, has proven effective in widening market reach and maintaining the sustainability of the creative industry. This research also resulted in a conceptual framework and an implementation roadmap that could be used as guidelines for developing the MSME creative industry in Indonesia. These findings make a scientific contribution to strengthening the creative economy based on local culture and product innovation.

Comparative Performance Evaluation of Industrial and Service Sectors in Indonesia, Using Advanced Dea Techniques

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The industry and service sector are of prime significance in the Indonesian economy. Different structures of production characterized these sectors. The input intensity and scale also vary in these sectors. This condition requires objective and comparative analysis for measuring their performance. This analysis becomes highly significant in view of the limited resources and competition prevailing in the industry. The aim of this research is to compare the efficiency of the industrial and service sectors in the context of the Indonesian economy. The method used to compare efficiency was the result of combining the conventional DEA and advanced DEA. The advanced DEA methods are the Principal Component Analysis DEA (PCA DEA) and Stepwise DEA Modeling. The methods are applied to overcome the problem of multicollinearity, the problem of overestimation, and the problem of the DEA model's lack of power in the conventional DEA. The research employed a quantitative approach with an evaluative-comparative design. The data used was secondary and cross-sectional. The units of analysis were Decision-Making Units (DMUs). DMUs represented the industrial and service subsectors. Efficiency evaluation employed an input-oriented model. The initial stage involved applying DEA CRS to measure total technical efficiency. DEA VRS was used to

identify pure technical efficiency and scale inefficiencies. PCA–DEA was applied to reduce variables. DEA stepwise modeling was used to select key variables and establish a stable efficiency frontier. The results showed that the service sector was more efficient than the industrial sector. This pattern was consistent across all DEA approaches. In DEA CRS, the average efficiency of the industrial sector ranged from 0.58 to 0.70. The service sector was from 0.65 to 0.75. In DEA VRS, the industrial sector's efficiency increased from 0.68 to 0.80. The service sector's efficiency increased from 0.75 to 0.85. The greater increase in the industrial sector indicates scale inefficiencies. The service sector tends to operate on a more optimal scale. PCA–DEA reduces the number of efficient DMUs in both sectors. The correction effect is stronger in the industrial sector. This finding indicates a bias in conventional DEA. Stepwise DEA modeling produces a more stable frontier. The resulting benchmarks are more selective and realistic. This method is effective for sectoral policy analysis. This study confirms that sectoral performance evaluation cannot be conducted aggregately. The industrial and service sectors require different approaches. The integration of conventional and advanced DEA improves the discriminatory power and accuracy of the analysis. The results provide an empirical basis for policies to increase productivity in the industrial and service sectors in Indonesia.

Mathematical Modeling of Error Correction in Contact and Optical Profilometry

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The control of the roughness parameter is a key task in mechanical engineering. Contact and optical measurement methods have systematic errors, which are more pronounced on curved surfaces, with high purity classes, the presence of contamination, vibrations and temperature gradients. The lack of a unified correction technique leads to the non-reproducibility of the results [1]. In recent years, laser profilometry methods, including interferometric methods, have become widespread and demonstrate high resolution [2]. Based on experimental data on parts with different values of the roughness parameter (R_a from 0.1 to 25 microns), mathematical models of the influence of factors on the measurement error are proposed. The thermal expansion of the part leads to a relative change in the parameter R_a , where the temperature correction of the roughness parameter is determined by the formula:

$$R_a^{corr} = \frac{R_a^{meas}}{[1 + \alpha(T - T_0)]} \quad (1)$$

where R_a^{corr} is the adjusted value of the roughness parameter (μm); R_a^{meas} is the measured value of the roughness parameter (μm); α is a coefficient of linear expansion of the material ($1/^\circ\text{C}$); T is the part temperature ($^\circ\text{C}$); T_0 is the reference temperature (20°C). The empirical dependence of the relative temperature error (in fractions) for steel 45 in the temperature range of $20 - 45^\circ\text{C}$ is determined by the formula:

$$\Delta R_a(T) = -0.0002(T - 20)^2 + 0.0015(T - 20). \quad (2)$$

The relative error from the contamination layer during measurement is defined as

$$\delta = A(1 - e^{(-kh)}), \quad (3)$$

where δ is the relative measurement error (%); A is the maximum error (40% for emulsion, 20% for oil); k is an empirical coefficient (0.8 – 1.2) (1/ μm); h is the thickness of the contamination layer (μm). The influence of the directions of irregularities on the error at the angle θ between the movement of the probe and the risks is found as

$$\Delta R_a(\theta) = \Delta \cos \theta_{max} \quad (4)$$

where $\Delta R_a(\theta)$ is the angle error; θ is the angle between the direction of movement of the probe and the direction of the irregularities; $\Delta_{max} = -0.45$ for the turning process, and -0.35 for grinding. A correction factor is determined considering the orientation:

$$K_{or} = \frac{1}{1 + \Delta \cos \theta_{max}}. \quad (5)$$

The change in the roughness parameter R_a is influenced by vibration interference with amplitude A_v and frequency f_v :

$$K_{vibr} = \frac{1}{1 + \gamma A_v f_v}, \quad (6)$$

where γ is a sensitivity coefficient (0.01 – 0.05 $\mu\text{m}^{-1} \cdot \text{Hz}^{-1}$).

The required optimal force of the F_{opt} probe to minimize plastic deformation is found as

$$F_{opt} = k \frac{H^2}{E} R^2, \quad (7)$$

where F_{opt} is the optimal force (mN); H is the Vickers hardness (MPa); E is the modulus of elasticity (GPa); k is an empirical coefficient (0.8 – 1.2); R is the radius of the tip needle (mm). Finally, the error from deformation in fractions is defined as

$$\Delta R_a^{def} = k_{def} \frac{F}{H} R_a^{meas}. \quad (8)$$

Thus, the developed models make it possible to quantify the main technological and operational factors, reducing the systematic error of roughness measurements to 5 – 7 %, compared with traditional methods. The recommended method selection algorithm (contact or optical) is based on the roughness class, radius of curvature, and measurement conditions. The proposed dependencies on the adjustment of the roughness parameter ensure comparability of the results, obtained by different devices in laboratory and workshop conditions.

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The Effect of Modified Lubrication Cooling Technological Means on the Thermal Balance in the Cutting Area and the Quality of the Treated Surface

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This study describes a thermophysical model applied to the process of cutting materials under conditions of using oil-based lubrication cooling technological means (LCTM) with an additive in the form of nanoclay minerals. The choice of an additive with endothermic properties is based on an earlier study [1]. This additive improves the tribological characteristics of the oil-based LCTM and withstands high specific loads in the metal cutting zone [2]. At the same time, the main function of a modified LCTM based on nanoclay minerals, when studying thermal cutting processes, is reduced to convective heat exchange of the environment when cutting metals with rapid heat removal from the chip formation zone. As a result, the length of the plastic contact decreases, leading to a decrease in contact loads. All thermophysical processes, taking place in the cutting zone, negatively affect the thermal load of the chip forming zone and the formation of the cutting wedge. As the results of theoretical studies show, when justifying the calculation of the thermal balance in direct contact between the cutting edge of the tool and the material being processed (chips), considering the presence of nanoclay minerals in the composition of the LCTM, it leads to an endothermic effect. Considering the physical-mechanical features of the processed material and the oil-based LCTM with additives of nanoclay minerals, a graphical representation of the temperature dependence on the time parameters of the cutting process is obtained (Fig. 1), which makes it possible to analytically analyze its temperature regime.

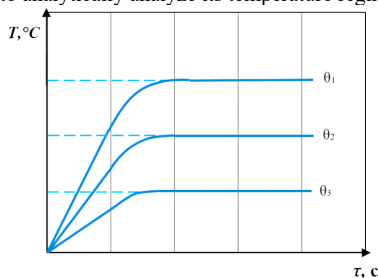


Fig. 1. Temperature of LCTM as a function of time and a parameter, characterizing the density of LCTM, θ_i .

The obtained graphical dependence reflects the influence of the thermophysical and hydrodynamic properties of the modified LCTM based on nanoclay minerals on the cutting process. As a result, a decrease in the temperature of the modified LCTM is possible by reducing the dynamic viscosity in the presence of parameter θ , which characterizes its density. Also, in the process of cutting, using a modified LCTM, the process of increasing the enthalpy

of thermal degradation allows one to reduce the temperature. The roughness parameter was also measured, using a profilometer, the arithmetic mean deviation of the Ra profile in microns. The results of measurements of the roughness of the holes, obtained by feeding four varieties of LCTM, are presented in Table 1.

Table 1. Roughness measurements during drilling, depending on the composition of supplied LCTM

Processed material	Cutting tools, cutting modes	Composition of LCTM	Roughness, μm
Steel 12X18H10T	High-speed steel drill bit R6M5, diameter 22.0 mm, $V_{\text{cut}} = 11 \text{ m/min}$, $s = 0.076 \text{ mm/tur.}$	Without LCTM	11.64
		Sunflower oil	4.36
		Industrial oil I-20A	7.8
		Industrial oil I-20A + NMA	5.08
		Sunflower oil + NMA	3.96

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Dry-Jet Wet-Spun Bamboo-Derived Continuous Cellulose Fibers for Composite Applications

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Cellulose-based thermoplastic composites are gaining increasing attention as sustainable lightweight alternatives to glass-fiber reinforced composites for automotive applications. However, natural short fiber composites are often limited by poor fiber alignment, inefficient stress transfer, and high variability in mechanical performance, limiting their use in semi-structural applications. In this context, continuous cellulose fibers offer a promising approach to overcome these limitations by enabling controlled fiber orientation and more effective load transfer. Despite these advantages, a clear “process – structure – property” relationship for

bamboo-derived continuous cellulose fibers has not yet been established. In this study, bamboo cellulose was extracted from raw bamboo culms and dissolved in N-methylmorpholine-N-oxide (NMMO) to prepare a spinning dope. Continuous cellulose fibers were fabricated via dry-jet wet spinning, and the draw ratio was systematically varied to tailor fiber orientation and crystallinity. The fibers were characterized in terms of morphology, mechanical properties, crystallinity, and molecular orientation, and then subsequently incorporated into polypropylene (PP) unidirectional composites for tensile testing. The results demonstrate that draw ratio governs fiber orientation and crystallinity, thereby enhancing load transfer and improving composite tensile performance, compared with natural short fiber composites. These findings establish a robust “process – structure – property” relationship, enabling the design of high-performance bamboo-derived continuous cellulose fiber composites for lightweight automotive semi-structural applications.

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Guided Wave Group Velocity Estimation in CFRP Composite Sublayers

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The present study is a continuation of our previous work at PHENMA-2025 [1], in which the approach, based on a semi-analytical model has been proposed to identify specific guided waves (GWs) that determine the group velocity of a signal, propagating along a carbon fiber-reinforced plastic (CFRP) laminate microcomposite plate. In this research, we focus on the propagation of GWs, excited by a high-frequency narrow acoustic beam, acting on the edge of the CFRP plate. The aim is to determine the ultrasonic propagation velocity along sublayers and analyse its dependence on the elastic properties of composite prepregs and beam focal position at the end face. The estimation of the ultrasonic velocity in CFRP sublayers allows the use of such an advanced diagnostic tool as acoustic microscopy, which provides insight into materials at the microscopic level [2]. The focused acoustic beams, generated by an acoustic microscope allow for better measurement of signals, propagating inside composite plies. The data on the microstructure and mechanical properties of each individual composite sublayers forms the basis for predicting macroscopic properties. The ultrasound propagation velocity along the sublayers is determined by the group velocity of GWs, excited at the central frequency of the probing signal. High-frequency ranges (~50 MHz) are characterized by the excitation of many modes, which makes their analysis more complex. Additionally, the set of waves, carrying the main part of the wave energy and, therefore, determining the desired velocity, also depends on the beam focal position at the plate edge. The analysis is performed within the framework of a semi-analytical model, based on integral and asymptotic representations of excited wave fields through the Green's matrix elements for arbitrarily anisotropic laminated structures [3]. The approach involves determining the wavenumbers (dispersion curves), after which the eigenmodes are calculated and normalized. Those with maximum amplitudes in the beam's impact zone are then selected. Furthermore, the main

modes are selected, based on minimizing the discrepancy of boundary conditions at the end face. The developed approach is illustrated with numerical examples and compared with experimental data and FEM modelling.

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Directivity of Surface Acoustic Waves in Monocrystals with Cubic Anisotropy

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Materials with cubic anisotropy, such as copper or monocrystalline nickel alloys, are widely used in modern high-tech industries, for example, in micro-electro-mechanical systems (MEMS) or the production of heat-resistant turbine blades. The packing density of atoms varies significantly in different crystal lattice directions, resulting in strong anisotropy of elastic properties with the anisotropic factor $A = 2C_{44}/(C_{11} - C_{12}) \sim 3.19$ (for copper) and even greater. Furthermore, in some directions, Poisson's ratio becomes negative, indicating that these materials belong to the class of auxetics. These properties significantly affect the specific features of elastic wave propagation in different directions, leading to variations in wave speed, the appearance of additional modes of bulk and traveling waves, dominant lobes in radiation patterns, caustics and resonant amplitude peaks [1 – 3]. Such wave properties complicate the design of surface acoustic wave (SAW) devices, ultrasonic nondestructive testing of products, made from such materials and similar. A. Every has shown that in cubic monocrystals additional supersonic SAWs can arise along with the classical Rayleigh wave, whose speed in an anisotropic material already depends on the direction of propagation [1]. In the present study, we focus on the analysis of the velocity and amplitude angular dependencies of the Rayleigh and Lamb SAWs, generated in such materials, based on explicit asymptotic representations for guided waves, excited by a local surface source in arbitrarily anisotropic elastic waveguides, derived in terms of Green's matrix elements [2]. Numerical analysis, performed on samples with properties gradually changing from isotropy to cubic anisotropy, revealed the emergence of sharp peaks in the amplitude of these additional supersonic waves in certain propagation directions, accompanied by attenuation of the Rayleigh wave amplitude. To verify these effects, experimental measurements of the characteristics of surface waves excited in copper plates, using circular piezoelectric broadband actuators and recorded with a

laser vibrometer, are conducted. A comparison of the measurements with numerical results is discussed, along with the semi-analytical representation, used to depict the structure of the recorded wave packets.

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Two Step Topology and Shape Optimization Process for Electroelastic Bodies

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Topology and shape optimization techniques can be combined for the full process of adaptive optimization for elastic and electroelastic devices to achieve better performance by reducing weight, stress or strain or by fitting the design for needed vibration modes. Topology optimization uses algorithms to find the best material distribution in each design area. This process is based on preset boundary conditions and a set of constraints, such as loads, the mechanical properties of materials, or allowable deformations. The result is usually intended to maximize system performance or minimize costs, while maintaining or improving functionality [1]. Preferably, the material distribution is such that the stress level in the structure is close to the limit but safe value and evenly distributed. Topology optimization works with fixed finite element meshes. Therefore, the boundary between the material and the void always runs along the edges of the elements. Step-like structures and sharp corners appear at the boundaries of materials. Such topologies are not well suited for practical purposes. Stress concentrations occur in the sharp inner corners of the stepped boundaries. The use of smaller grids partially solves these problems. However, form optimization is the most effective. During shape optimization, the position of the points places on the surface of the body changes. The points move along the normal to the surface of the body. This study considers the implementation of software modules for topology and shape optimization in the ACELAN-COMPOS [2] package. The topology optimization module uses evolutionary methods. An indicator of inefficient material use is a low level of stress or deformation. Shape optimization is based on the Covariance Matrix Adaptation Evolution Strategy (CMA-ES) [3]. The objective function is used to minimize the Mises stress. Thus, topology optimization determines the structure of the body and the location of the caveats, and shape optimization determines exactly how the boundaries of these caveats should look. The two-step process was tested on 2D and 3D models of piezoactuators to reduce weight while maintaining acceptable

levels of maximum stress. Results were compared with the topology optimization, performed in COMSOL package.

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Multiscale Simulation of Wave Propagation in Porous-Elastic Media, Saturated with Several Fluids

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Porous materials are some of the most common media in nature. The need for investigation of wave processes in porous elastic media arises from the observation of new sponge materials used in thermal and vibroinsulation of aerospace components as well as in biomechanics such as ultrasonic inspection of spongy bones and lungs. Many artificial materials, such as metal alloys and polymer composites, also have a certain degree of porosity. This should be considered when modeling certain phenomena. If the pores of a medium are filled with multiple fluids, its mechanical properties will differ when saturated with a single fluid, compared to when it is not saturated at all. Previously, it has been shown experimentally that at high vibration frequencies the elastic properties of porous materials can significantly differ from those in the static state. To estimate the static moduli of porous media, various theories have been developed, including models of the Mori-Tanaka type and the differential theory of effective media. However, to construct an adequate model for high-frequency oscillations, it is important to consider the dynamic elastic moduli. The difference between static and dynamic modules is based on complex oscillatory processes that occur at the micro- and mesoscopic levels of the porous medium's structure. A widely accepted model for elastic waves in fluid-saturated porous media is the Biot theory, which, like any other phenomenological model, only partly reflects the microstructural mechanical properties of the porous material such as elastic properties of individual components, pore distribution, etc. To understand the dependencies, this study proposes to perform mechanical modeling on the mesoscale structure of a porous medium and then obtain homogeneous macroscopic characteristics. The derivation of the equations of state and motion, like as Biot model, and the effective parameters of a porous medium with one or more immiscible (heterogeneous) fluids is presented and discussed. The finite element method is used for mesoscale simulation. The effective parameters, depended on the porosity of the medium, the fluid concentration,

It was revealed that the unshaded areas (see Fig. 1), in particular, between the PbZrO_3 and CdTiO_3 AFEs, belong to ternary AFEs of the OPS, as well as OPSs with PTs of the crumple-type, while the area between KNbO_3 and SrTiO_3 and further up to $\delta_{AO} = 2$ is occupied by ternary FEs, AFEs, and multiferroics. Similar distributions of the δ_{AO} , δ_{BO} intensities and the Curie (T_C) and Néel (T_N) temperatures depending on them are also observed for ternary OPSs. For other PTs, for example, rotational ones, similar scheme has been constructed, allowing one to determine [3] what will happen in solid solutions with their participation.

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A Fundamental Study on the Effects of Laser Power and Irradiation Time on Surface Morphology in Concrete Scabbling Using Fiber Laser

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In the process of nuclear facility decommissioning, radioactively contaminated concrete can be classified as cleared waste and disposed of economically if its radioactivity level is reduced to the clearance level through decontamination. Conventional decontamination technologies have limitations: chemical methods generate substantial secondary waste, while mechanical methods involve reaction forces and produce contaminated consumables due to direct tool contact. As an alternative, non-contact laser scabbling technology can supplement these issues. This study used a high-power CW fiber laser to investigate scabbling surface characteristics through explosive spalling reactions as fundamental study. The laser was irradiated onto the concrete surface in a stationary state, with a power varied from 5 to 15 kW, and an irradiation time, ranging from 5 to 20 seconds. Surface and morphological changes of the scabbled specimens were analyzed, using high resolution 3D microscopy and visualized as topography of the scabbling depth and width utilizing MATLAB. The results revealed that sound scabbling proceeded predominantly by explosive spalling at a laser power of 6 kW with an irradiation time of 20 seconds or less, or at 7 kW for 10 seconds or less, whereas a vitrified

zone, caused by melting and subsequent rapid, was observed under certain conditions. Notably, sustained and stable scabbling, driven by explosive spalling, was observed at 6 kW for 20 seconds, confirming this as the optimal condition.

Search for New Methods for Producing Inorganic Electrides

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Electrides are a new class of materials in which free electrons act as anions. This class of materials was discovered relatively recently; the first inorganic representative (mayenite) was obtained only in 2002. Electride materials are characterized by unusual properties. Due to their high porosity and the presence of free electrons, these materials can be expected to exhibit high catalytic activity, allowing their using as highly efficient catalysts in ammonia production processes. Importantly, electrides exhibit conductive properties like those of metals, unlike the original material, making them promising base for microelectronic devices. Currently, only a very limited number of methods are known for producing electrides. Among them, heat treatment methods such as melt-curing and glass-ceramic processes, as well as annealing in a reducing atmosphere, are prominent. Recent quantum chemical calculations have shown that electride properties can arise not only in compounds based on mayenite-type structures but have also been predicted for alkaline earth oxides such as MgO, BaO, CaO, and SrO. Therefore, this study focuses on developing a method for producing electrides, based on alkaline earth oxides and mayenite-type compounds. The method being developed involves an integrated approach, combining mechanical activation, gamma irradiation, and annealing in a reducing environment. In this work, various compositions were synthesized, including magnesium and calcium oxides, as well as compounds with a mayenite-type structure: $12\text{BaO} \bullet 7\text{In}_2\text{O}_3$, $12\text{MgO} \bullet 7\text{In}_2\text{O}_3$, $12\text{CaO} \bullet 7\text{Nb}_2\text{O}_5$, $12\text{MgO} \bullet 5\text{Nb}_2\text{O}_5$, and $7\text{In}_2\text{O}_3 \bullet 5\text{Nb}_2\text{O}_5$. To study the structural features of the synthesized materials, diffraction patterns (XRD) and micrographs (SEM) were obtained. The samples were subjected to various processing methods, including mechanical activation, irradiation with high-energy gamma radiation, annealing in reducing atmospheres (Ar/CO and Ar/H₂), as well as combinations of these methods, which made it possible to identify the influence of various types of impacts on the structure of the materials. The study demonstrated that mechanical activation and high-energy gamma radiation did not result in electride formation from magnesium and calcium oxides, but the combined effects of these methods on the sample resulted in changes in the diffraction patterns of the samples. An attempt to obtain electride materials, based on mixed oxides type of mayenite by sequential annealing at 600 °C for 8 hours, first in an Ar atmosphere and then in a CO atmosphere, revealed that the color of the $12\text{MgO} \bullet 5\text{Nb}_2\text{O}_5$ sample changed from white to dark gray, which is the first indication of electride properties. Heat treatment of the $7\text{In}_2\text{O}_3 \bullet 5\text{Nb}_2\text{O}_5$ composition at 870 °C for 6 hours in an Ar/H₂ atmosphere resulted in a change in the sample's color to black. Thus, based on an analysis of the experimental data obtained, a preliminary characterization of the structure of the samples under study was conducted. The results obtained form the basis for the further development of promising electride materials.

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The Role of BiFeO₃ in the Formation of the Storage Characteristics of Lead-free Ceramics $(1 - x - y) \text{Bi}_{0.5}\text{Na}_{0.5}\text{TiO}_3 - x\text{K}_{0.5}\text{Na}_{0.5}\text{NbO}_3 - y\text{BiFeO}_3$

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Growing environmental concerns, reflected in stricter directives like RoHS and WEEE across Europe and Asia, have significantly boosted research into lead-free ferroelectric materials over the last ten years. These regulations restrict the use of lead zirconate titanate (PZT)-based materials, prompting a focus on alternative systems. Among these, solid solutions, based on potassium sodium niobate ($\text{K}_{0.5}\text{Na}_{0.5}\text{NbO}_3$), sodium bismuth titanate ($\text{Bi}_{0.5}\text{Na}_{0.5}\text{TiO}_3$), and bismuth ferrite (BiFeO_3), hold a prominent position. Despite advances in the study of individual compounds, producing dense and homogeneous ceramics in the systems, based on these materials, is complicated by the evaporation of alkaline components and the formation of secondary phases during sintering. Of particular interest are the storage properties of these materials, which, due to their high permittivity and relaxor behavior, are promising for the creation of pulse capacitors. However, according to current reviews, the influence of structural distortions during combined substitution in the *A*- and *B*-positions of perovskite on the polarization mechanisms has not been sufficiently studied. The aim of the work is to establish the patterns of formation of the structure and properties of ceramics in systems $(1 - x - y) \text{Bi}_{0.5}\text{Na}_{0.5}\text{TiO}_3 - x\text{K}_{0.5}\text{Na}_{0.5}\text{NbO}_3 - y\text{BiFeO}_3$ to optimize their dielectric and storage characteristics. The subjects of research were solid solutions of the system $(1 - x - y) \text{Bi}_{0.5}\text{Na}_{0.5}\text{TiO}_3 - x\text{K}_{0.5}\text{Na}_{0.5}\text{NbO}_3 - y\text{BiFeO}_3$, where $x = 0.1$, $0.0 \leq y \leq 0.9$. The production was carried out by the two-step solid-phase synthesis: $T_{\text{syn}1,2} = 850^\circ\text{C}$, $\tau_{\text{syn}2} = 4 - 10 \text{ h}$; $T_{\text{sint.}} = 1100^\circ\text{C}$, $\tau_{\text{sint.}} = 2 \text{ h}$. The purity and formation of perovskite phase in products were monitored by powder X-ray diffraction, using $\text{CoK}\alpha$ radiation. Dielectric hysteresis loops were obtained, using a measuring set-up, assembled according to the Sawyer-Tower scheme at room temperature. Energy density was obtained from the curves of the dependence of polarization on the electric field ($P - E$) by integrating the area between the axis of polarization and the curve $P - E$. The presence of a morphotropic phase transitions in the $(1 - x - y) \text{Bi}_{0.5}\text{Na}_{0.5}\text{TiO}_3 - x\text{K}_{0.5}\text{Na}_{0.5}\text{NbO}_3 - y\text{BiFeO}_3$ system at $0.3 < y < 0.5$ from the cubic to the rhombohedral phase by the nucleation and growth mechanism and in the range at $y > 0.7$, phase transition type of spinodal decomposition was established. Modulation of the crystal lattice was detected, indicating the presence of planar defects and compositional inhomogeneity with alternating regions, enriched in titanium or niobium. It was shown that ceramics exhibit relaxor behavior, caused by the existence of chemically nonequivalent nanoregions (at $y < 0.4$), and Maxwell-Wagner relaxation, associated with the mobility of oxygen vacancies (at $y \geq 0.5$). It was found

that the best storage properties are achieved with a BiFeO₃ content of 20 – 30 mol.%, while a further increase in the BFO concentration leads to a deterioration in energy-intensive characteristics.

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Characterization of Elastic Moduli of Polymers Used in Additive Manufacturing Using Guided Waves

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Additive manufacturing is increasingly adopted for producing geometrically complex structures, ranging from engineering components to personalized prosthetic sockets, yet predicting the mechanical behavior of polymer-based components, remains challenging due to insufficient data on elastic moduli under dynamic loading. This study proposes an advanced non-destructive technique characterization to address this limitation. We develop a two-stage inverse algorithm to determine the elastic properties of fused deposition modeling (FDM) specimens by leveraging experimental dispersion characteristics of guided elastic waves measured via laser Doppler vibrometry. The method employs a Fourier transform-based initial approximation, refined by minimizing the discrepancy between theoretical and experimental dispersion relations, which significantly improves convergence robustness and reduces parameter estimation error. The identified material properties are subsequently utilized in the finite element method simulations to analyze the stress-strain state of patient-specific prosthetic sockets under various loadings. Validation against standard tensile tests and synthetic data confirms the method's accuracy, establishing a reliable pathway for optimizing personalized prosthetic designs through precise material modeling and enhancing ergonomic fit in clinical applications.

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Novel Finite Element for Porous Piezocomposites Modeling

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When modeling composite materials, using the finite element method, an important step is constructing a polygonal mesh of a representative volume. Since most existing mesh generators are oriented toward building tetrahedral meshes, tetrahedra are often used as finite elements. However, this approach is not universal. Microstructural images of porous ceramics [1] show that the solid framework of the material may consist of more complex geometrical primitives. This study explores the use of various types of polyhedra as finite elements for modeling porous materials. For this purpose, an approach, based on regular tessellation of space with polyhedral cells, followed by the formation of a porous structure through the removal of some cells, was chosen. In this approach, the geometric model of the microstructure and the finite element discretization are consistent, and the tessellation cells themselves of various types can be used as finite elements. To implement the proposed method, a mesh generation module was developed in Python software, using the GMSH library [2] and the formulation for linear and quadratic finite elements with 24 main nodes in the shape of two truncated octahedrons. The process of generating a representative volume in the developed module includes the following steps: (i) constructing octahedral-tetrahedral honeycombs; (ii) assigning labels to tetrahedra, belonging to the same octahedra after triangulation; (iii) constructing a graph of polyhedron adjacency within the honeycomb; (iv) iteratively removing random cells, while monitoring the connectivity of the adjacency graph. Monitoring connectivity at each iteration ensures that the solid framework in the resulting volume remains connected in all three spatial directions (3-0 type connectivity). To validate the proposed approach, the problem of identifying the properties of a piezocomposite was solved using the finite element package ACELAN-COMPOSE with the generated representative volume. A comparison was performed on the same geometric model, using tetrahedral and polyhedral finite elements.

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Optimizing Software Modules for a Horror Game on the Unity Platform Using C#

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The horror genre holds a special place in the modern computer game development industry, as key tension is created through the synchronization of visual, audio, and gameplay mechanics. Modern engines like Unity offer ample opportunities for implementing complex logic, but most developers face the challenge of designing flexible and scalable code architecture capable of supporting the interactions between various game systems. To achieve deep and atmospheric immersion, it is necessary to competently implement a software framework as a set of scripts that adapt to player actions, control enemy behavior, and ensure the correct operation of all gameplay mechanisms. The goal of this work is to develop game scripts in C# for the horror game "Dark Forest" on the Unity platform, ensuring the implementation of key gameplay mechanics and the stable operation of the project. The tasks included developing puzzles, designing player interaction systems, developing enemy behavior logic, creating scripts for interactive objects, implementing the user interface (UI), and ensuring stable performance for a comfortable gaming experience. Development was conducted on the Unity 2022 platform using the C# programming language. Over 30 scripts were created, grouped by functional categories: (i) enemy logic scripts, (ii) puzzle and interactive object scripts, (iii) environment management scripts, (iv) UI scripts, and (v) progress saving system scripts. All code was written, using an object-oriented approach with SOLID principles to ensure the project's flexibility and maintainability. Initially, a requirements analysis of the game systems was conducted, followed by an architecture design that allowed for easy expansion of functionality as the project evolved. Proven design patterns in the gaming industry were applied as key architectural decisions. The State Machine pattern is used to manage player and enemy states, allowing for a clear separation of behavioral logic and simplifying the addition of new states. The Observer pattern is implemented through a custom event system to ensure loose coupling between scripts; for example, an enemy logic script notifies the sound system of its actions without direct references. The Object Pool pattern is used to manage frequently created and destroyed objects, such as visual effects and particles.

On the Applied Theory of Deformation of Slender Elastic Prisms Based on Variational Principles

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An approach is proposed for constructing reduced-order deformation models for long elastic prisms of arbitrary cross-section within the framework of linear elasticity. Dimensionality reduction is achieved through the Kantorovich method: the sought functions are represented as polynomial expansions of the transverse coordinates, with the coefficients, serving as unknown functions of the longitudinal coordinate. A hierarchy of models of various orders is established, depending on the degree of the approximating polynomials. The simplified boundary value problems are formulated based on two fundamental approaches. (i) *Lagrange Variational Principle*: This model is based solely on the approximation of the displacement field. Integrating the total potential energy functional over the cross-section area and subsequent variation reduces the original three-dimensional problem to a system of ordinary differential equations regarding the unknown functions and defines the corresponding boundary conditions. (ii) *Hellinger–Reissner Variational Principle*: This model employs a mixed formulation with independent variation of the expansions for both displacements and stresses within the Hellinger–Reissner functional. While this approach leads to an augmented system of differential equations, it allows for the rigorous satisfaction of boundary conditions on the lateral surface of the prism by introducing hypotheses regarding the components of the stress tensor. It has been established that in the case of a clamped end, the solutions in both variants consist of a regular (beam-like) part and a boundary layer (localized near the support) part. The developed method is adapted for the analysis of both longitudinally homogeneous and inhomogeneous materials. The theory is generalized for slender prisms of arbitrary cross-section, with detailed investigations into specific cases: narrow rectangles (reduction to a plane problem), circles, and squares. The validity of the constructed models is verified by comparison with direct three-dimensional finite element modeling (FEM) with numerical results, obtained using the FlexPDE environment. The developed applied deformation models, based on variational principles, occupy an intermediate position between classical beam theory and full three-dimensional elasticity problems. This approach offers high computational efficiency and provides new opportunities for solving inverse problems, related to the property identification of novel materials.

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Development of High-Efficiency Photodetector and Solar Energy Conversion Devices Based on PbS & Ag₂S Mixed QDs Materials

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Near-infrared (NIR) light possesses excellent tissue penetration depth, making it highly valuable for applications in medical imaging, optical communications, and environmental monitoring [1]. Among various materials, silver sulfide colloidal quantum dots (Ag₂S CQDs) have garnered significant attention due to their superior optical and electrical properties [2, 3]. CQDs can be fabricated into semiconductor thin films via solution processing and have demonstrated great potential in optoelectronic devices such as photodetectors, light-emitting diodes (LEDs), and solar cells. This study focuses on the application of a PbS/Ag₂S hybrid active layer. By tuning the blending ratio, the energy levels are better aligned, thereby enhancing the carrier transport efficiency of the device (Fig. 1). The experimental architecture utilizes a Glass/ITO/ZnO/PCBM/PbS/PbS – Ag₂S/TFB/MoO₃/Ag structure. The results indicate that the appropriate addition of Ag₂S significantly improves device performance. The power conversion efficiency (PCE) of the solar cells increased substantially from 1.58% to 4.65%. Regarding photodetection, the device achieved broadband detection from 300 to 1200 nm, with a peak external quantum efficiency (EQE) of 31.62% and a detectivity (D^*) of 3.19×10^{11} Jones.

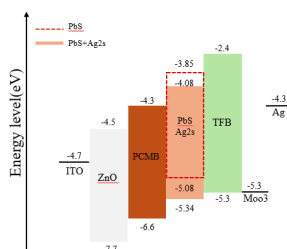


Fig. 1. Energy alignment before (dashed lines) and after (solid lines) mixing

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Study of a Highly Selective Ammonia Gas Sensor Based on a Sputtered Amorphous Aluminum-Doped Indium Zinc Oxide Thin Film, Decorated with Evaporated Platinum Nanoparticles

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Ammonia (NH₃) is a naturally occurring compound that finds extensive applications in various sectors, including agriculture, refrigeration, food processing, chemical production, and healthcare. Despite its versatility, the use of NH₃ poses significant risks. Many countries classify it as a hazardous substance due to its colorless, toxic, and pungent properties. Consequently, the development of reliable detection techniques for NH₃ is critical for both industrial efficiency and safety standards. The environmental implications of NH₃ emissions have become an increasing concern. When released from industrial or agricultural activities, NH₃ can react with acidic pollutants in the atmosphere, leading to the formation of harmful nanoparticles. These particles contribute to air quality deterioration, enhance smog formation, and intensify the effects of global warming, highlighting the necessity for rigorous monitoring and control of NH₃ emissions. In recent years, remarkable progress has been achieved in the development of NH₃ gas sensors based on diverse semiconducting metal oxide materials. Leveraging these advancements, researchers have introduced a new composite material that integrates the benefits of indium oxide and zinc oxide to form aluminum-doped indium zinc oxide (Al-doped IZO). This innovative material combines the excellent electrical conductivity of indium oxide with the outstanding durability of gallium oxide, particularly under challenging operating conditions. The result is a highly effective and robust sensing layer for NH₃ detection, offering an optimal balance between performance and reliability. In this study, we present the development of an advanced NH₃ gas sensor through the integration of Al-doped IZO thin films with platinum nanoparticles (Pt NPs). The Al-doped IZO thin film was fabricated, using radio-frequency magnetron sputtering, a method renowned for producing uniform and high-quality films. Pt NPs were subsequently deposited on the Al-doped IZO surface via vacuum thermal evaporation (VTE), ensuring precise control over nanoparticle distribution. The introduction of Pt NPs significantly enhances the sensitivity of sensor to NH₃, attributed to catalytic properties of Pt that facilitate the adsorption and reaction of ammonia molecules, thereby amplifying the sensing response. A comprehensive analysis of the sensor's structural, elemental, and material properties revealed a synergistic effect. This combination of high conductivity from Al-doped IZO and catalytic activity from Pt NPs achieves superior sensing performance. Under controlled conditions, the sensor demonstrated remarkable responsiveness: at 1000 ppm NH₃ in air at 300 °C, the sensing response (S_R) reached 112, highlighting its capability to detect ammonia across a wide concentration range. The temporal performance of sensor was equally impressive, with rapid response and recovery times of 373

seconds (τ_a) and 15 seconds (τ_b), respectively, making it suitable for real-time monitoring applications. Additionally, the device exhibited excellent selectivity towards NH_3 , ensuring reliable detection in complex environments. Long-term stability is crucial for practical applications. Encouragingly, our sensor maintained consistent performance over a 90-day period, underscoring its durability and reliability for sustained use in industrial settings.

Effect of Hydrogen on Strain Induced Martensitic Transformation of Austenitic Stainless Steel JIS SUS304

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To reveal the effect of hydrogen on strain-induced martensitic transformation in austenitic stainless steel JIS-SUS304, tensile tests were conducted using both hydrogen-charged and uncharged specimens. Figure 1 shows the shape and dimensions of tensile specimens. Thin plate specimens were used to promote hydrogen diffusion into the specimen interior. Hydrogen charging was performed by cathodic charging method. Tensile tests were carried out at a crosshead speed of 1 mm/min. The tests were interrupted at specific crosshead displacements of 4, 10, 20 and 40 mm, and the corresponding strains were measured. Subsequently, X-ray diffraction (XRD) measurements were performed to compare the changes in peak intensities of the austenite phase (γ) and the martensite phases (α' and ϵ) between the hydrogen-charged and uncharged specimens. The Reference Intensity Ratio (RIR) method was used to investigate the effect of strain and hydrogen on changes in the martensitic phase fraction.

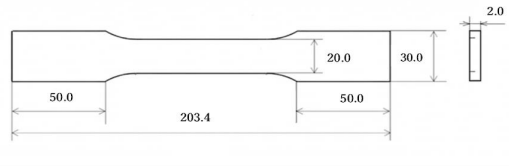


Fig. 1. Shape and dimensions of tensile specimens (mm)

Deep Learning-based Feature Extraction for 40 Hz SSVEP Recognition in Flicker-Free Neuromodulation Systems

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With the advancement of non-invasive neuromodulation, inducing gamma oscillations via 40 Hz visual stimulation has emerged as a pivotal method for enhancing cognitive functions. However, traditional low-frequency flickers often lead to visual fatigue and safety concerns. While emerging Dual-Frequency Modulation (DFM) techniques achieve a "flicker-free" experience by utilizing the Critical Fusion Frequency (CFF) effect, they suffer from a significantly lower Signal-to-Noise Ratio (SNR) in Steady-State Visually Evoked Potentials (SSVEP) due to the dispersed nature of beat-frequency energy. This poses a substantial challenge for traditional frequency-domain feature extraction algorithms. To address this bottleneck, this study proposes a specialized Deep Convolutional Neural Network (CNN) architecture, designed to precisely extract subtle 40 Hz beat-frequency neural signatures from EEG signals. The proposed "Multi-scale Spatial-Temporal Fusion Network" employs diverse convolutional kernel sizes to automatically suppress residual noise, generated by high-frequency carriers (e.g., 100 Hz and 60 Hz) while capturing the non-linear neural features, associated with the 40 Hz entrainment. Experimental results demonstrate that in a flicker-free stimulation environment, the proposed deep learning model achieves a 20% improvement in recognition accuracy, compared to the conventional Canonical Correlation Analysis (CCA) algorithm. This research not only overcomes the detection difficulties inherent in DFM-based systems but also provides a critical algorithmic foundation for future "Closed-loop Adaptive Neuromodulation Systems". Such systems will enable real-time adjustment of stimulation parameters, based on individual brainwave feedback, moving toward the goal of personalized precision medicine for neurodegenerative disorders.

Modified Fields–Backofen Constitutive Modelling of Cold Deformation Behavior for 10B38 Boron Steel

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The constitutive characterization of boron steels is essential for understanding their deformation behavior and improving process design in cold forging applications. In this study, the deformation behavior of 10B38 boron steel was investigated through compression tests using a Gleeble-3500 thermomechanical simulator. The experiments were conducted at room temperature (30 °C), 100 °C, and 200 °C under strain rates of 0.1, 1.0, and 5.0 s⁻¹. During the

compression tests, force – displacement data were recorded and subsequently processed to obtain the corresponding stress – strain curves. Considering the heat generated during plastic deformation, a stress correction procedure was applied to account for the temperature rise, induced by deformation. Based on the processed experimental data, the constitutive relationship of 10B38 steel was established, using the modified Fields – Backofen model. The predictive capability of the proposed model was evaluated using several statistical methods, including the correlation coefficient (R), average absolute relative error (AARE), and logarithmic mean squared error ($\ln$ (MSE)). The results indicate that the modified Fields – Backofen model provides good agreement between predicted and experimental flow stresses under the investigated deformation conditions. Furthermore, numerical simulations of cylindrical upsetting compression were performed, using Simufact Forming to compare the predicted force with the experimental observations.

Hybrid Siloxane Network Engineering, Using MTMS and PDMS-OH for Improved Mechanical Integrity of Aerogel Fiber Composites

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Insulation layers, used in floating LNG transfer hoses are required to simultaneously provide thermal stability under cryogenic conditions and high mechanical flexibility. However, conventional aerogel-based fiber-reinforced insulation composites exhibit inherent brittleness, leading to crack formation during bending processes, which subsequently causes aerogel particle detachment and degradation of thermal insulation performance.

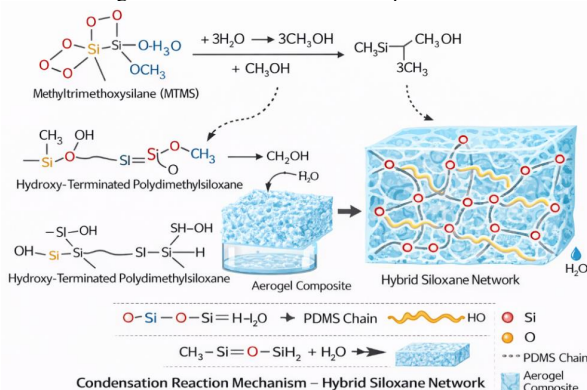


Fig. 1. Schematic illustration of hybrid siloxane network formation in an aerogel composite via condensation of MTMS and PDMS-OH, enhancing flexibility and crack resistance

This study aims to enhance the structural stability and flexibility of such composites by applying a post-impregnation process, using a silane-based precursor (MTMS) and a silicone-based polymer (PDMS-OH). A hybrid siloxane network was formed via hydrolysis and

condensation reactions of methyl-trimethoxysilane (MTMS), generating a three-dimensional Si-O-Si network within the porous structure of the aerogel composite. Simultaneously, hydroxyl-terminated polydimethylsiloxane (PDMS-OH) was incorporated to introduce flexible polymer chains into the network (see Fig. 1).

A Study on the Mechanical-Thermal Properties of Reformed Perlite Cores and BF/HDPE Sandwich-Structured Composites

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In this study, sandwich-structured composites were fabricated, using core boards, prepared from pulverized and reprocessed commercial insulation material and HDPE film-based basalt fiber-reinforced composite facings, and their properties were evaluated. The objective of this work was to explore the eco-friendly utilization of reprocessed insulation materials and to extend the application of conventional insulation materials to the core of sandwich-structured composites. For this purpose, the insulation material was pulverized, classified according to particle size, and reformed into core boards, and the effects of particle size on the formability and properties of the boards were compared. During the reforming process, noticeable differences were observed in the consolidation behavior and shape retention, depending on particle size, indicating that the degree of pulverization strongly influenced the internal structure of the core board. In particular, the board, prepared with 2 mm particles, exhibited lower density and better thermal insulation performance than that prepared with powders less than 250 μm . In addition, the flexural strength of the core board itself was confirmed to be approximately 1.6 MPa. Subsequently, the selected core board was used as the core material, and thermoplastic composite facings were prepared by stacking plain-woven basalt fiber fabric and HDPE films. During the fabrication of the sandwich-structured composite, HDPE film was used as both the matrix material of the facings and the adhesive layer, and the final sandwich-structured composite was molded through a heating and vacuum bagging process. Comparison of the heat-transfer behavior between the core-only specimen and the sandwich-structured composite revealed a distinct difference, which was considered to result from the partial penetration of molten HDPE into the core during processing, thereby affecting the internal structure and heat-transfer pathway. This suggests that the thermal behavior of the sandwich structure was influenced not only by the insulation performance of the core but also by the interfacial changes, introduced during molding. Therefore, this study demonstrated that reprocessed insulation materials can be utilized as the core of sandwich-structured composites and confirmed their potential for eco-friendly and value-added applications through the introduction of HDPE film-based basalt fiber-reinforced composite facings and the corresponding molding process. These findings can serve as basic data for the fabrication and thermal performance control of eco-friendly sandwich-structured composites.

Analysis of the Friction–Wear Correlation of Tire Tread Compound, Considering Strain-Dependent Nonlinear Viscoelastic Properties

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Rubber friction on rough surfaces is of major practical importance for understanding tire wear mechanisms. The multi-scale roughness of self-affine surfaces causes dynamic deformation of tire tread compounds over a range of frequencies during sliding friction, and the resulting viscoelastic properties significantly affect friction behavior. Asperity indentation induces large deformations and subsequent non-linear softening in tread compounds during actual rough-surface contact. However, conventional approaches, based on linear viscoelastic assumptions, do not sufficiently reflect these effects, and the strain range, corresponding to the non-linear region needs to be incorporated into friction analysis. In this study, the impact of increasing strain on the friction-wear behavior of tread compound was quantitatively examined. Non-linear viscoelastic properties under large deformations were derived by combining linear viscoelastic master curves with strain-sweep data. These properties were then incorporated into a physics-based friction model, together with fractal surface data, obtained from 3D surface measurements and experimentally measured temperature variations during wear testing. The analytical results demonstrated that accounting for non-linear viscoelasticity more clearly captured the changes in energy dissipation with increasing strain. In addition, friction was analyzed in terms of adhesive and hysteresis components, and the principal friction parameters, determined as functions of temperature, slip velocity, and strain, showed reasonable correspondence with the experimentally measured wear rate. This ultimately demonstrates the critical importance of considering the large strain of the contact interface and operating temperatures in the friction-wear analysis of tread compound on rough surfaces.

Acknowledgments. This work was supported by the National Research Foundation of Korea (NRF) grant, funded by the Korea government (MSIP) (2022R1A2C3011968).

A Stable and High-Efficiency Boost Converter LED Driver with PWM Control for High-Voltage Applications

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A boost converter-based LED driver with pulse-width modulation (PWM) control is proposed in this study. LEDs are current-driven devices, and variations in the supply voltage may lead to unstable luminance and reduced reliability. Therefore, a boost converter is employed to regulate the output voltage, while a PWM controller is utilized to achieve precise brightness control. The proposed architecture improves power efficiency and ensures stable operation

under varying input conditions. The circuit is implemented, using a TSMC 0.18 μm HV process to support high-voltage operation. Simulation results demonstrate that the proposed design achieves stable performance with a peak power efficiency of 85%.

Magnetic Nanocarriers in Oncology Therapy: Physical Aspects

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Magnetic nanocarriers (magnetic complexes, magnetic nanoparticles (MNPs), ferromagnetic fluids, etc.) are used for targeted delivery of medical ligands to tumors. They also facilitate remote heating, thereby conducting treatment that is a process known as magnetic hyperthermia therapy (MHT). In this case, the energy of an alternating magnetic field is converted into localized heat, increasing the tumor temperature by 5 – 8 °C relative to adjacent healthy tissue [1]. Boron neutron capture therapy (BNCT), a new approach to cancer treatment, has demonstrated great potential. It is based on the interaction of the stable isotope ^{10}B and an epithermal neutron, resulting in a nuclear reaction, producing the nucleus of a lithium atom, ^7Li , an alpha particle (^4He), and γ radiation. α -particle beams with high linear energy transfer and a short range, corresponding to the typical mammalian cell size ($\sim 10 - 100 \mu\text{m}$), damage and lead to almost immediate tumor cell death. From one to two BNCT sessions result in the death of virtually all cancer cells [2]. In both methods (MHT and BNCT), the properties of the magnetic nanoparticles used significantly determine their effectiveness [3]. This study briefly analyzes the scientific literature on the use of magnetic nanocarriers as magnetic nanoparticles (MNPs) in oncology applications in magnetic hyperthermia (MHT) and boron neutron capture therapy (BNCT). Several key aspects of known techniques in which Fe_3O_4 MNPs are the primary magnetic agent are highlighted. MHT results are highly dependent on many MNP parameters, including the nanoparticle size, shape, and residual magnetization. The effectiveness of BNCT is influenced by many factors, including the type of composite nanocarrier, containing the ^{10}B isotope and MNPs, the neutron flux dose, and the tumor accumulation concentration of the agent. This study focuses on physical parameters (residual magnetization, geometric shapes, dimensions, etc.), delivery methods to cancer sites, and the precision and duration of retention of MNPs complexes at the desired locations. It is noted that both MHT and BNCT methods have not yet been systematized, widely implemented in clinical practice, and require improvement. However, they have high potential for future development and are likely to be widely used alongside traditional cancer treatment methods. **Acknowledgements.** The work was performed using the equipment of the Shared Use Center "Center for Laser Technologies in Medicine". The work was carried out within the framework

of the state assignment of the Ministry of Science and Higher Education of the Russian Federation (Project FSMR-2024-0003).

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Magnetic Field Concentrator with a Size of 2 mm

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Ultra-high-sensitivity magnetic field sensors are primarily in demand in biomedical applications, as they enable the detection of ultra-weak magnetic fields in the range of $1 - 0.000001$ nT, generated by various human organs (brain, heart, stomach, etc.), as well as current pulses, occurring in the nervous system. The lowest detectable magnetic field values, $\delta B \approx 1 - 5$ fT, are achieved in a class of commercial sensors known as superconducting quantum interference devices (SQUIDS), which utilize magnetic field concentrators (MFCs). However, SQUIDS are large (concentrator ring diameter ≥ 6 mm), which limits their dense packing in the receiving matrix and reduces the spatial resolution of the object under study. In this regard, combined magnetic field sensors (CMFS) exhibit δB values of the same order of magnitude as those recorded by SQUIDS, directly sense the absolute value of the magnetic field, and allow for close-packed arrangements. In this study, an MFC, based on a superconducting annular film within a CMFS, is investigated. The following parameters are determined: (i) the concentration coefficient, (ii) the nonuniformity coefficient of the concentrated magnetic field on the magnetically sensitive element (MSE), (iii) the recorded values of the average and effective magnetic fields, and their measurement ranges. The characteristics of the MFC and CMFS significantly depend on the size of its component parts and the type of superconducting film materials, included in its composition. It was found that the studied CMFS with an MFC ring of diameter ~ 2 mm, an active strip width in the range of $0.6 - 60$ μm , and a thickness of $\sim 0.05 - 5$ μm , achieved a maximum magnetic field concentration coefficient of ≥ 200 , a concentrated magnetic field nonuniformity coefficient at MSE of $\sim 1\%$, and a threshold magnetic sensitivity of $\delta B \approx 0.1 - 1$ pT. It was noted that the combined magnetic field sensor, which we studied, is suitable for non-invasive monitoring of the functionality of various neurointerfaces, as well as for recording pain signals, passing through the spinal cord. Adjusting the dimensional ratios between the CMFS component parts will reduce the degree of non-uniform magnetic field distribution on the magnetically sensitive element and thereby improve its parameters: the threshold magnetic sensitivity will be lowered severalfold and the magnetic field concentration coefficient will be increased. Due to the small

size of the CMFS, it will be possible to significantly increase (by an order of magnitude or more) the density of their placement on the surface, for example, in a typical head-mounted helmet, used in various magnetoencephalographs

Acknowledgements. The work was performed using the equipment of the Shared Use Center "Center for Laser Technologies in Medicine". The work was carried out within the framework of the state assignment of the Ministry of Science and Higher Education of the Russian Federation (Project FSMR-2024-0003).

Modeling the Characteristics of a 3D Chessboard-Structured Metasurface for Improving Electromagnetic Compatibility of RF Systems

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At present, the application of metasurfaces in various components of RF telecommunication systems is being actively investigated. New frequency bands (30 – 300 GHz) are being explored for telecommunication, security and medical applications. The transition to shorter wavelengths entails both advantages and disadvantages. The principal advantage of millimeter-wave (mmWave) operation is the potential increase in channel capacity and reduction in transmission latency. However, significant challenges, related to wave propagation, must be considered. These include higher atmospheric attenuation and a stronger dependence on online-of-sight conditions between transmitter and receiver. Consequently, mmWave communication systems are typically designed for short-range applications (e.g., indoor signal propagation). The short wavelength reduces the impact of small obstacles (such as furniture or the human body) but simultaneously results in increased signal attenuation when propagating through volumetric obstacles (walls, ceilings). Therefore, in the design of radio-electronic devices, it is necessary to account for interference and electromagnetic coupling, associated with mmWave signals, since the simultaneous operation of multiple high-frequency components in the near-field region reduces the overall level of electromagnetic compatibility (EMC). Conventional shielding approaches may not provide the required level of protection of electronic components against parasitic electromagnetic воздействия from neighboring components. In this context, qualitatively new techniques, capable of suppressing parasitic fields and reducing the impact of particle fluxes on transmitting, receiving, and signal processing modules, are required. One possible implementation of such protective coatings is based on metasurfaces [1–3]. This report presents the results of modeling the characteristics of a miniature reflective surface, intended to reduce the backscattered field inside the enclosure of a radio-electronic device and to decrease the level of electromagnetically induced fields, generated by adjacent components. The dielectric substrate material is silicon (Si) with a relative permittivity of 11.7. The overall dimensions of the surface are $45 \times 45 \text{ mm}^2$. The unit cells of the 3D metasurface have two fixed substrate thicknesses, namely 1 and 5 mm, and are arranged in a chessboard configuration. The metallic patches are implemented in the form of low-pass and high-pass frequency selective structures, as well as split-ring resonators (SRRs). Within the framework of this study, numerical simulations and a comparative analysis of the scattering characteristics were performed for four structural configurations. The differences

between the models lie in the geometry of the metallic patches on the top layer, which affects the resonance amplitudes and resonance frequencies. The reduction of the backscattered field is significant compared to the backscattered field amplitude of a metallic plate of identical dimensions. The resonances, excited in these structures, are in the vicinity of wavelengths commensurate with the characteristic surface dimension. At wavelengths, exceeding the surface size, the backscattered field reduction does not exceed 5 dB. As a result of this study, frequency-dependent characteristics of backscattered field reduction, achieved by coating a metallic surface with a complex-shaped 3D metasurface, were obtained. These results may be applied in a wide range of RF devices, operating in centimeter and millimeter wavelength bands, including satellite communication systems and radio astronomy equipment, where such structures can serve as enclosure elements responsible for suppressing spurious radiation modes, generated by other electronic subsystems.

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Sound Design for a Fighting Game on the Unity Platform

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In the modern digital gaming industry, the quality of sound is of particular importance. Along with the visual component and game mechanics, it shapes the user's overall perception of the product. For dynamic genres such as fighting games, sound plays not only an artistic but also a functional role, providing immediate feedback and improving the player's reaction to events. The goal of this study is to design a sound design for a fighting game on the Unity platform. This study addressed the issues of analyzing the sound design features of dynamic game scenes, designing the structure of the sound subsystem, and integrating sound effects into the game logic. Sound in a fighting game includes several key components: character action sound effects, background music, and additional interface sounds. Attention is paid to the effects of strikes, blocks, movements, and special moves, as they inform the player of the results of their actions. Various signal characteristics, such as volume, duration, and timbre, are used to enhance the distinguishability of sounds. The sound subsystem was developed in Unity using built-in audio playback components. For each game object, interacting with sound, audio signal sources were used, linked to specific events, such as the start of an attack, hitting an enemy, or receiving damage. Playback was controlled through software scripts, ensuring precise synchronization of sound with animation and game logic. To organize the soundscape, a mixing system was used to manage the volume levels of various sound groups and prioritize signals in highly eventful environments. The musical accompaniment was implemented with the ability to change intensity, depending on the state of the battle, enhancing the emotional experience of the gameplay. Optimization of the sound subsystem was an important stage of

development. To reduce the system load, we reused audio resources, limited the number of simultaneously playing sources, and rationally allocated computing resources. Testing was also conducted to identify playback delays and discrepancies between audio and visual events. The practical significance of this work lies in the applicability of the developed solutions to the creation of fighting games and other dynamic gaming applications. The implemented audio subsystem increases the informativeness of the gameplay, improves the user experience, and creates deeper immersion in the gaming environment. This work involved developing and implementing key audio elements for a fighting game on the Unity platform, ensuring correct synchronization with game actions, distinct sound cues, and adaptive musical accompaniment. The results demonstrate that an integrated approach to sound design can improve the quality and expressiveness of a gaming application.

Automation of Parametric Analysis of Contact Problems Using Machine Learning Methods for Predicting Stress Concentration Zones

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Contact problems in elasticity theory for non-homogeneous and functionally graded materials represent a fundamental challenge in modern mechanics, with critical applications in foundation engineering, coating design, composite structures, and nanotechnology. Traditional analytical and numerical approaches, such as integral equation methods, asymptotic analysis, and finite element modeling provide accurate solutions but require substantial computational resources for parametric studies and optimization tasks [1, 2]. This study introduces a hybrid methodology that integrates classical contact mechanics frameworks with modern machine learning (ML) techniques to automate parametric analysis and enable rapid prediction of stress concentration zones. Building upon the theoretical foundation of Fredholm integral equations of the first and second kind for elastic layers and wedges with depth- or angle-dependent material properties, we develop surrogate ML models, trained on high-fidelity numerical solutions. The proposed approach employs: (i) a physics-informed dataset generation pipeline based on established analytical-numeric methods for contact problems; (ii) feature engineering incorporating geometric parameters, material gradation laws, boundary conditions, and loading configurations; (iii) supervised learning architectures (gradient boosting, neural networks, Gaussian processes) for predicting stress field distributions and concentration factors; and (iv) uncertainty quantification to assess prediction reliability in extrapolation regimes [3]. Validation against benchmark solutions for homogeneous and functionally graded layers demonstrates prediction accuracy within 2–5% error margins while achieving computational speedups of $10^2 - 10^4$, compared to direct numerical simulation. The framework enables rapid exploration of design spaces for coated systems, layered foundations, and graded interfaces, supporting inverse design and real-time structural health monitoring applications. To further improve accuracy and robustness under scarce, noisy or partially observed data, we incorporate advanced physics-informed neural network (PINN) formulations. We explore stepwise and gradient-alignment-aware training

strategies that mitigate optimization pathologies in standard PINNs and enable stable approximation of displacement and stress fields for nonlinear, path-dependent deformation regimes. These developments are inspired by recent progress in stepwise PINNs for large deformations and gradient-alignment methods for stiff PDE-constrained learning problems [4]. The resulting hybrid analytical – ML – PINN framework yields (i) accelerated evaluation of the coating response, compared with conventional finite element analysis, (ii) improved generalization with respect to variations in material gradients and process-induced inhomogeneities, and (iii) a natural route for integrating experimental and numerical datasets into the modeling pipeline. We demonstrate, through a set of numerical case studies, that the proposed approach can reliably predict the stress–strain state and key performance indicators (such as peak interfacial stresses and strain localization zones) across a broad design space of functionally graded coatings, thereby providing a practical tool for intelligent design and optimization of gradient thin coatings on rigid substrates.

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Application of Minimum Lubrication Technology, Using Epoxidized Ginger Oil for Stable Machining of Austenitic Steel

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There are many areas of sustainable production, and one of them is sustainable machining. Sustainable machining is a process that helps to improve environmental parameters by reducing the cost of processing, energy consumption, and consumption of lubricants and coolants in the workflow. We conducted a study to determine the effect of lubricants and coolants on surface roughness and tool wear during turning of austenitic stainless steel 12X18H10T using carbide plates made of VK8 alloy as a cutting tool. The factors and parameters considered were (i) cutting depth (1.2, 1.0, and 0.5 mm); (ii) cutting speed (95, 60, and 40 m/min); and (iii) feed rate (0.28, 0.25, and 0.20 mm/rpm). The type of lubricants and coolants is also a parameter: pure ginger oil or its mixtures, as well as epoxidized derivatives of the oil. Numerical models of cutting and coolant parameters (considering the viscosity of each coolant at 40 °C) were obtained by using regression analysis to assess tool wear and

surface roughness. A dispersion analysis was performed to determine a significant parameter, affecting tool wear and surface roughness. The equations of the models of surface roughness and tool wear, obtained during the study, are presented in the following relationships:

$$V_b = 0.00052V_c + 0.0194d + 0.336f + 0.000069\eta \quad (1)$$

$$R_a = 0.00280V_c + 0.299d + 6.87f + 0.00067\eta \quad (2)$$

where V_b is the wear of the rear surface (mm), V_c is the cutting speed (m/min), d is the cutting depth (mm), f is the feed rate (m/rpm), R_a is the surface roughness (μm), η is the viscosity of the oil or its mixture (mPa·s). In addition, the process of epoxidation of ginger oil has been carried out to use the resulting product as a coolant in metal and alloy processing the processes.

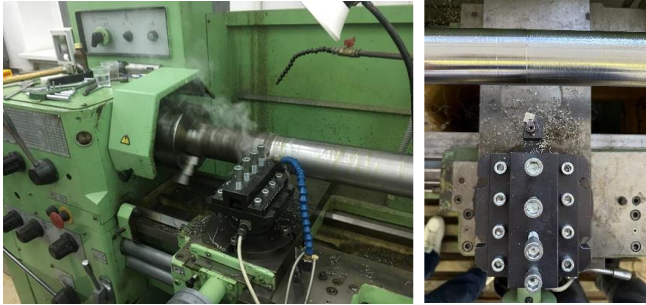


Fig. 1. Experimental installation based on the SAMAT-400M lathe

A comparison was made between pure and epoxidized oil in terms of surface roughness by using a tribometer. The experimental studies of the friction coefficient of oils and the wear rate of cutting tools during turning of stainless steel 12X18H10T have been performed. The experiments were carried out on a SAMAT – 400M lathe (Fig. 1). The lathe is equipped with a frequency converter to control the spindle speed. The stainless steel (STS) was supplied, using minimum lubrication technology (MLT). After tribometry tests of the oils, the roughness of the indenter trace on the surface of 12X18H10T stainless steel was measured. Roughness measurements were carried out, using a TR200 profilometer with a TS100 sensor (Fig. 2). The average results of determining the coefficients of friction and the wear rate of the cutting tool are shown in Table 1. The wear rate of the cutter decreased with the use of epoxidized ginger oil by up to 20%, which proportionally increases its service life.



Fig. 2. TR200 profilometer with TS100 sensor

Table 1. Coefficients of friction and wear rates (V)

Lubrication	Coefficient of friction	$V \times 10^{-6}, \text{mm}^3/\text{N} \cdot \text{m}$
Ginger oil	0.115	4.46
Epoxidized ginger oil	0.090	3.60

The lubricating effect of epoxidized ginger oil contributed to a smoother cutting process. This means that the contact between the tool and the chips was smooth, which led to a reduction in cutting force during the machining process. Therefore, the use of epoxidized ginger oil reduces the coefficient of friction between the tool and the chips. It should be noted that the increase in viscosity did not lead to a significant increase in the solidification temperature of ginger oil. Experimental studies to determine the effect of STS on the wear of cutting tools during turning of 12X18H10T steel using carbide plates made of VK8 hard alloy have shown that the wear rate of the cutter decreased with the use of epoxidized ginger oil by up to 20%. The cutting force was reduced by 15 – 28 % when processed with the application of STS using minimal lubrication technology compared to pure ginger oil. The cutting force was reduced by 5 – 28% during MLT processing compared to the dry mode. Both these effects were due to the low coefficient of friction and the smaller size of the particles, penetrating the cutting area. The cutting temperature was reduced by 10 – 30 % during MLT processing, compared to the dry mode. Reducing the temperature has increased the service life of the tool, which contributes to sustainable production. The combination of thermal stability, viscosity, and tribological characteristics confirmed the promise of the potential use of epoxidized oil as an effective modification of vegetable oils, including ginger [1 – 3]. Undoubtedly, this modification of ginger oil is a promising direction for its use as a surface operation/tooling solutions in the processes of turning stainless steels.

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Theoretical Justification for Increasing the Durability of a Soil-cultivating Working Tool, Created Using Bionic Similarity

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Issues related to increasing the service life of tillage machinery working parts are discussed in [1, 2]. The principle of operation of the digging limbs of living organisms, which act on the environment discretely in space and cyclically in time, can serve as the basis for developing designs with increased service life [1]. When studying the potential for increasing the service life of cultivators and disc harrows, using a biosystems approach, two types of modeling were employed: physical and simulation [3]. Physical modeling involved studying the functional structure features of excavating animals, in particular, the fan-shaped jaw structure of the scarab beetle (*Scarabaeus*), with the aim of reproducing its geometric parameters. Simulation

modeling, in turn, allowed for the adaptation (approximation) of this jaw shape to create new design elements for tillage implements [2 – 4]. According to analytical studies, soil abrasiveness is one of the key factors, reducing the service life and, consequently, the longevity of working tools, primarily due to intensive wear of the blade's cutting edge. Therefore, the longevity of a working tool, designed using the bionic principle can be expressed by the following relationship [3]:

$$T_{w.t.} = \left(\frac{(a-c)\varepsilon_{ref}\eta_2\chi A}{0.016m_{ref}\eta_1 p V_{t.m.} \tan i} \right) k_{a.p.}, \quad (1)$$

where a is the initial length of the blade of the working element (cm); c is the maximum length of the working tool blade (cm); ε_{ref} is the relative wear resistance of the metal of the working element under the reference pressure of abrasive soil particles; η_2 is a coefficient that considers the relative wear resistance of the metal of the working element, depending on the pressure of abrasive soil particles; χ is the ratio of the linear speed of movement of the tillage machine to the speed of movement of the soil layer along the surface of the working element; A is the productivity of the working element (ha/h); m_{ref} is the relative wear capacity of the processed soil layer under the reference pressure of its abrasive particles; η_1 is a coefficient that considers the change in the wear capacity of the processed soil layer, depending on the pressure of its abrasive particles; p is the pressure of abrasive soil particles at the point of greatest wear (MPa); $V_{t.m.}$ is the linear speed of movement of the tillage machine (km/h); $\tan i$ is the sharpening angle of the working element blade (deg); $k_{a.p.}$ is the coefficient of adaptation performance of the working organ created according to bionic similarity. Experimental data, obtained during a study of cultivator ties, indicate uneven wear limit $W_{w.l.}$ along the cutting edge [3]. Analysis of the wear pattern revealed that the maximum intensity of abrasive friction is observed at the tip of the tine. This pattern is explained by the varying density of the soil layer in different zones: in the tip area, where the main deformation occurs, the soil is most dense, whereas near the wings it is already loosened, reducing the abrasive impact. The significant influence of soil granulometric composition on wear intensity has been experimentally confirmed. Therefore, it is necessary to determine the average value of the wear limit $W_{w.l.}$, which should be adjusted by the wear unevenness coefficient $k_{u.w.}$, considering two main factors: (i) the shape of the working area and (ii) the relative wear capacity, according to the fractional composition m . The coefficient of uneven wear is determined by the formula:

$$k_{u.w.} = \frac{\Delta l}{\Delta L}. \quad (2)$$

As a result, the coefficient of uneven wear of the tillage working tools for the presented soil types $k_{u.w.} = 0.26$. The average value of the wear limit $W_{w.l.}$ is determined by the formula:

$$W_{w.l.} = \frac{\Delta L + \Delta l}{2}. \quad (3)$$

After appropriate transformations, Equation (1) takes the form:

$$T_{w.t.} = \left(\frac{(0.5(\Delta L + \Delta l))\varepsilon_{ref}\eta_2\chi A}{0.016m_{ref}\eta_1 p V_{t.m.} \tan i} \right) k_{a.p.}, \quad (4)$$

The key difference of the presented mathematical relationship is the introduction of an adaptation coefficient. This coefficient serves as an integral indicator, reflecting the level of system reliability of working elements, designed based on bionic principles and considering bio ergonomic requirements [3]. It allows for a quantitative assessment of the structure's ability to maintain functionality during long-term operation by adapting to variable soil conditions.

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Effect of Surface Treatment on Interfacial Bonding of Al–CF/LM-PAEK Dissimilar Joints

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Dissimilar joints between metals and thermoplastic composites are promising for lightweight aerospace and transportation applications. Their bonding strength depends on surface roughness and the wettability of metal, which influence resin infiltration and mechanical interlocking. Mechanical grinding is a simple and cost-effective method, but it does not provide a consistent result and can lead to uneven distribution of material on the surface. In contrast, laser surface treatment enables precise, non-contact control of surface patterns, improving interfacial bonding. In this study, sandpaper abrasion and laser surface treatment were applied to Al (6064 Ti alloy) specimens, followed by joining with Carbon Fiber Reinforced Low-Melt Poly (Aryl Ether Ketone) (CF/LM-PAEK). Laser parameters were controlled to form straight-line, grid, and dimple patterns. Joining was performed at 380 °C under constant pressure to promote resin flow and interlocking. Bonding performance was evaluated, using ILSS (ASTM D2344) and lap shear tests (ASTM D5868). Sandpaper-treated specimens showed improved ILSS due to increased roughness and contact area. Laser-treated specimens exhibited further enhancement as micro-patterns promoted resin infiltration and anchoring. Fracture analysis showed interfacial delamination in neat specimens, mixed failure in sanded specimens, and internal composite failure with resin residues in laser-treated specimens. These results indicate that laser surface treatment is more effective than mechanical abrasion in improving the strength and reliability of Al–CF/LM-PAEK joints.

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Metasurface Structure Processing for Mid-IR Range Refractive Index Sensor

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One of the promising directions in integrated photonics is the development of compact optical sensors, based on metasurfaces sensitive to refractive index changes in the surrounding environment. Such devices are applicable in environmental monitoring, including detection of greenhouse gases like methane, due to their high sensitivity, miniaturization potential, and suitability for mass fabrication. This study focuses on a waveguide-grating structure, whose optical response is modulated through coupling with surface waveguide modes in the mid-infrared range. The key challenge is ensuring correspondence between the designed characteristics and the actual geometry of the fabricated structure. First, numerical estimations were used to calculate the response of the waveguide-grating structure over the target wavelength range. Critical geometric parameters of the metasurface (width, period, and height) were determined. The structure was fabricated, using UV lithography on model Si(100) wafers. SU-8 photoresist films were spin-coated, and then patterned, using SUSS MA8/BA6 lithography system. The geometry of the fabricated structures was characterized, using scanning electron microscopy (JEOL) and stylus profiler (Veeco Dektak 6M). A major technological challenge at the initial stage, for feature sizes of 2 – 2.5 μm , was poor adhesion of the photoresist to the substrate surface. Without special preparation, complete delamination of the structures occurred at an early stage of development, regardless of wafer cleaning quality or exposure time. The introduction of an adhesion-promoting layer thinner than 30 nm (EDS) eliminated delamination and ensured pattern stability throughout the processing steps. Systematic variation of exposure and development parameters allowed identification of the optimal range, achieving maximum accuracy in pattern transfer. As a result, processing conditions were established that enable reproducible formation of metasurface structures with geometry closely matching the design. The approach, demonstrated in this study, confirms the suitability of standard UV lithography for creating 2-micron metasurfaces from SU-8 and establishes a technological foundation for developing highly sensitive integrated sensors in the mid-IR range on specialized substrates.

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Multi-Stage Process Optimization of Bottom-Gate IGTO Thin-Film Transistors

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This study investigates process routes to improve bottom-gate indium–gallium–tin oxide (IGTO, In:Ga:Sn = 2:2:1) thin-film transistors (TFTs), fabricated on 200-nm SiO₂ gate dielectrics through (i) baseline oxygen-flow screening, (ii) IGO/IGTO bilayer channel engineering, and (iii) low-temperature post-deposition annealing [1, 2]. First, IGTO TFTs with a 50-nm single-layer channel were fabricated under oxygen flow ratios of 0%, 4%, 8%, and 10%. Within the 0 – 10% window, 4% oxygen provided the best as-deposited trade-off, achieving an on/off current ratio of 6.34×10^4 , a SS of 1326.17 mV/dec, and a μ_{sat} of 1.94 cm²/(V·s). Next, an IGO (In:Ga = 4:6) overlayer was introduced (100 W sputtering) to form a 20-nm bilayer channel with IGTO as the bottom sub-layer. The best balanced bilayer device (8 nm IGTO at 4% oxygen / 12 nm IGO at 4% oxygen) improved the on/off ratio to 1.11×10^5 and μ_{sat} to 3.10 cm²/(V·s) (SS = 1210.29 mV/dec), whereas the highest μ_{sat} was obtained at 10 nm IGTO with 4% oxygen / 10 nm IGO with 8% oxygen (μ_{sat} = 7.81 cm²/(V·s)) with an on/off ratio of 1.58×10^4 and a SS of 641.74 mV/dec, indicating a mobility-switching trade-off. Finally, annealing at 200 °C yielded the best post-anneal characteristics, with the 0% oxygen device reaching an on/off ratio of 6.04×10^5 , a SS of 614.12 mV/dec, and a μ_{sat} of 13.0 cm²/(V·s), while the 10% oxygen condition remained mobility limited. Overall, oxygen-flow screening, bilayer engineering, and annealing provide complementary routes to tune transport and switching, depending on whether maximum mobility or balanced performance is prioritized.

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Effect of Electrode Size and Bending on a Flexible ITO/TiO₂/Gr Memristor

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The von Neumann architecture remains the most universal for modern computing. However, training neural networks demands significant computational power, leading to increased

energy consumption and overheating. A promising alternative is the memristor, namely a device, combining information storage and computation via resistive switching. This property enables energy-efficient memory and neuromorphic systems, including flexible and wearable electronics. A memristor consists of two electrodes with an active layer in between, where resistive switching occurs. Oxide materials are commonly used for the active layer due to their well-studied properties. In these materials, switching is governed by oxygen vacancy migration under an external electric field, leading to conductive filament formation and resistance modulation [1, 2]. Material selection is critical for device performance. Two-dimensional materials such as graphene enable the fabrication of reliable and energy-efficient devices, while their atomic thickness, combined with flexible substrates, facilitates the development of flexible electronics [3]. In this work, multiphysics modeling is applied to a flexible ITO/TiO₂/Gr memristor on a PET substrate under tensile and compressive bending. The effect of top electrode width (50 – 1500 nm) on oxygen vacancy distribution and current–voltage characteristics is investigated. The active layer thickness is 10 nm, the top electrode is 50 nm, and the structure is simulated under vacuum. Results show that reducing the top electrode width leads to vacancy formation, localized at the electrode edges in both bending modes, whereas a full-coverage ITO electrode results in uniform vacancy distribution. Increasing the electrode width from 50 to 1500 nm under tensile bending increases the current by a factor of 49.25. Under compressive bending, the current increase is approximately 42.6 times. Thus, current variations due to mechanical bending must be considered when developing flexible memristive structures. Additionally, integrating two-dimensional materials enhances the mechanical and physical properties of such devices.

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Comparative Study of TiC and TiN Reinforced CoCrFeNiAl High Entropy Alloy Composites, Fabricated by Laser Powder Bed Fusion

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High Entropy Alloys (HEAs) refer to alloys, which contain the combination of multiple principal elements in nearly equimolar concentrations [1]. Recently, HEAs have been extensively investigated by researchers due to their superior performance and vast compositional design space [2]. Their attractive combinations of strength, ductility, and stability make them promising candidates for demanding applications in aerospace, nuclear energy, and marine engineering [3, 4]. HEAs can be also reinforced by ceramic particles to achieve further high mechanical properties [5], however, further strengthening via ceramic reinforcement often introduces trade-offs in corrosion resistance and microstructural stability.

In this study, CoCrFeNiAl is reinforced with TiC and TiN, respectively, fabricated by laser powder bed fusion. Process parameters including printing speed, energy density and layer thickness were systematically optimized to achieve dense microstructures, followed by post heat treatment to further tailor phase evolution and increase the mechanical properties. Comparative analyses reveal that TiC and TiN induce distinct interfacial characteristics and phase evolution leading to different strengthening mechanisms and corrosion behaviors. This study shows the synergistic effects of ceramic particle reinforcement and additive manufacturing on the performance of HEAs, providing insights into the design of metal matrix composite materials.

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Wavefront Metrology for Precision Optical Machining via Lateral Shearing Interferometry

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To address the demands of modern precision manufacturing, this research presents a robust wavefront metrology platform based on Quadri-wave Lateral Shearing

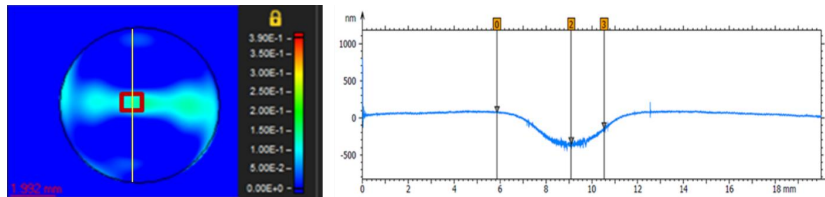


Fig. 1. Representative 2D wavefront map (left) and 1D cross-sectional profile (right) of a micro-machined optical surface characterized by the QWLSI system.

Interferometry (QWLSI) [1 – 3]. Unlike traditional interferometry, the developed system utilizes a specialized collimated module and a QWLSI sensor to achieve high-resolution, real-time analysis without the need for a complex reference arm. Our experimental findings yield a wavefront stability RMS of 4.08×10^{-3} wave, while Zernike aberrations are consistently suppressed below 2×10^{-3} wave, confirming its high-fidelity performance. The system's intrinsic vibration immunity and compact architecture make it uniquely suited for challenging environments. In conclusion, this QWLSI metrology solution provides a critical breakthrough for real-time feedback in optical machining, offering a scalable path for automated quality control in advanced lens production (see Fig. 1).

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Methodology for Testing and Monitoring Partial Discharge Activity of Equipment to Assess Insulation Condition

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One of the pressing issues in the operation of high-voltage power equipment is the occurrence of local electrical discharges in small volumes of insulation. The presence of such partial discharges (PDs) is an indicator of incipient damage to high-voltage insulation. Analysis of PDs activity is widely recognized as an effective means of early warning of deterioration in the condition of high-voltage insulation [1]. For this reason, the collection and processing of PDs data is very important when making critical decisions, regarding the shutdown or repair of equipment in power systems. Certain statistical values are required to characterize HR activity, such as intensity, frequency spectrum, amplitude, etc. However, multiple sources of electrical noise are often present in measurement environments, making the correct interpretation of HR patterns problematic when identifying sources of different natures. In addition, it should be noted that it is not possible to measure the discharge current directly, so we only record its external manifestations, and therefore, when measuring HR, we almost always talk about measuring the apparent discharge (charge) [2]. Thus, the purpose of this article is to analyze existing tools and develop an HR monitoring system capable of displaying classic HR parameters, HR signal shape, and frequency spectrum in real time, as well as calculating statistical parameters for data collection. To implement the system, it is necessary to develop a methodology, based on testing a combination of several different devices (sensors), and an instrument for displaying and interpreting the results of monitoring the insulation condition of equipment (transformers, distribution panels on busbars). The relevance of the study is determined by several issues. The operation of partial discharge

monitoring systems in power transformers, developed two decades ago and earlier, has led to low confidence in the diagnostic conclusions obtained. This is argued by the fact that high levels of electromagnetic interference prevent reliable measurements of partial discharges in transformers, which are key elements of the power system [3]. Oscillography is often used to display recorded PDs pulses; it is a simple and straightforward method of pulse recording that works well in laboratory conditions. However, when measuring on real objects, general noise and induced signals from different phases significantly complicate data analysis and make it difficult to determine the type of PDs. This study presents an analysis of the applicability of various partial discharge monitoring systems and an assessment of their effectiveness for several types of electrical equipment under various operating conditions at a power facility. Depending on the type of device, a selection of methods for monitoring the insulation condition of associated equipment is proposed. Such methods are usually developed for a specific type of equipment, and their application to other types of equipment requires significant modification or complete replacement. In the case of modification, it should be noted that the issue is not only from a technical viewpoint, but also from the viewpoint of forming a database of defect masks.

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A New Representation of the Thermodynamic Potential of Lithium Tantalate

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Lithium tantalate is one of the most promising multifunctional materials with piezoelectric, electro-optical and nonlinear optical properties. Numerous experimental studies to determine the material constants of lithium tantalate have been performed at room temperature [1, 2]. The current level of requirements for developers of various types of devices leads to the need to use the patterns of behavior of material constants under changing external conditions (temperature, pressure, electric field, deformation). Experimental research in this area is associated with significant costs, provided that specialized expensive equipment is used. Expansion of the operating frequency range and miniaturization of acoustoelectronic devices lead to the need to use thin films, the deposition of which is carried out at fairly high temperatures. Due to the difference in the thermal expansion coefficients of the heterostructure elements, this leads to a significant change in the material constants of the film. Recently, a technology has appeared for transferring ferroelectric-rigid materials onto a substrate at lower temperatures [2]. At the same time, the problem of modeling the behavior of a thin film under

the influence of various external factors remains highly relevant. To describe the influence of external factors on the behavior of the material constants of a ferroelectric film, it is convenient to use the nonlinear potential of the Landau theory of phase transitions. A particular example of such an application can be found in [3], where a fourth-degree potential was proposed to describe the behavior of lithium tantalate. It adequately describes the behavior of the material constants at room temperature but loses its effectiveness as the range of external conditions expands. In the present study, a sixth-degree Landau potential is proposed in the form of a polynomial with respect to invariants, constructed on the components of the polarization vector. The specific form of this function for a similar case can be found in [4]. A detailed analysis of the behavior of the permittivity tensor components and the spontaneous polarization and deformation vectors as functions of temperature was performed. It showed that the calculation results are in complete agreement with the experimental results, obtained by other authors. Based on the proposed potential, a complete set of material constants of the linear equations of the piezoelectric effect, as well as the electro-optic and acousto-optic constants, were calculated. As the analysis showed, some material coefficients, primarily elastic ones, demonstrate thermal stability of the elastic properties of lithium tantalate up to 600 K. Some piezoelectric, electro-optical, and acousto-optic constants of lithium tantalate are also thermally stable in this range.

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Crystal Structure, Thermodynamic and Dielectric Properties of the SmFeO₃– NaNbO₃ Composite

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This study synthesized and studied the structure, heat capacity, dielectric, and magnetodielectric properties of $(1 - x)\text{SmFeO}_3 - x\text{NaNbO}_3$ composite ceramics over a wide

temperature and frequency range. Based on X-ray diffraction and calorimetric measurements, the coexistence of two phases was demonstrated, and a temperature-concentration phase diagram was constructed. A magnetodielectric effect and its dependence on the sodium niobate concentration x were detected. The dielectric properties ε' and $\tan\delta$ were found to exhibit frequency dispersion of ε' , typical of inhomogeneous ceramics. The temperature dependences of ε' exhibit composition-dependent dielectric anomalies in NaNbO_3 -containing composites, which correlate with structural phase transitions identified by calorimetric data. In contrast, SmFeO_3 demonstrates a broad maximum near $90 - 100^\circ\text{C}$ followed by a gradual decrease in permittivity. The frequency dependence of the permittivity corresponds to the Maxwell–Wagner interfacial polarization scenario. For losses, it was found that in the low-temperature region, Na-containing composites exhibit an initial decrease in $\tan\delta$, followed by a steady increase. The local maximum of NaNbO_3 at $270 - 280^\circ\text{C}$ shifts to higher temperatures at $x = 0.8$ and $x = 0.6$ and disappears with increasing SmFeO_3 fraction ($x = 0.4$ and 0.2), while for $x = 0.4$, an additional local maximum is recorded at about $\sim 320^\circ\text{C}$. Taken together, these results indicate that varying x (composition) allows for targeted tuning of the frequency-temperature response and loss level: $x = 0.4$ is promising for low-loss applications at room temperature, while compositions with an increased NaNbO_3 fraction provide minimal losses at high frequencies. In the frequency range of $1\text{ kHz} - 1\text{ MHz}$, the AC conductivity of the composites obeys the universal Jonscher law: $\sigma_{\text{AC}} \approx \sigma_{\text{DC}} + A\omega^s$ with $s \sim 0.31 - 0.76$, which indicates correlated barrier hopping (CBH) model. Temperature “windows” on the curve $\ln \sigma_{\text{AC}}(1/T)$ are accompanied by characteristic effective E_a and their decrease with increasing frequency, which is consistent with the correlated barrier hopping model.

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Computational Biomechanics and Digital Design of Personalized Additively Manufactured Prosthetic Sockets

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Prosthetics serves as a critical stage in rehabilitation, restoring physical activity and psychological well-being. However, the efficacy of treatment largely depends on the ergonomic fit of the prosthetic socket. While traditional plaster casting remains prevalent, it is labor-intensive and lacks reproducibility, whereas digital workflows, involving optical scanning, computational modeling, and additive manufacturing offer high precision and the capability to create complex functional structures. This study presents a mechanical analysis of personalized sockets, fabricated from composite polymers, where elastic moduli are obtained via non-destructive ultrasonic characterization as input for finite element simulations. Based on real clinical geometries, numerical experiments encompass static analysis of the stump-socket interface, dynamic response modeling across gait phases, and parametric investigations into wall thickness and local architecture. The results correlate contact pressure

distribution with patient acceptance, identifying critical local stiffness ranges and formulating recommendations for material and topology selection, based on stump morphology and patient mass. Ultimately, these models facilitate a transition from empirical fitting to predictive design, enhancing the efficacy of 3D-printed medical devices through integration into specialized software solutions.

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Effect of Adherend Materials on the Adhesive Strength of Protruding Butt Joints without Singular Stress Field

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Regarding the adhesive strength of bonded joints, evaluated according to JIS standards, a singular stress field exists in all test specimens, and the measured strength varies, depending on the adhesive layer thickness h , as shown in Fig. 1(a). In this figure, the black circles indicate experimental results for carbon steel/epoxy butt joints, while the red circles represent those for aluminum alloy/epoxy joints. Even when the same epoxy adhesive is used, the measured adhesive strength differs, depending on the adherend materials. In this study, a protruding butt joint was proposed to maintain a constant interfacial stress distribution and to determine a new intrinsic adhesive strength free from singular stress effects. Unlike the conventional JIS butt joint, where the adhesive strength is strongly influenced by the adhesive layer thickness h , the proposed joint exhibits a constant adhesive strength independent of h . As shown in Fig. 1(b), the black squares denote experimental results for carbon steel/epoxy joints, and the red squares denote those for aluminum alloy/epoxy joints. The same adhesive strength was obtained regardless of the adherend combination.

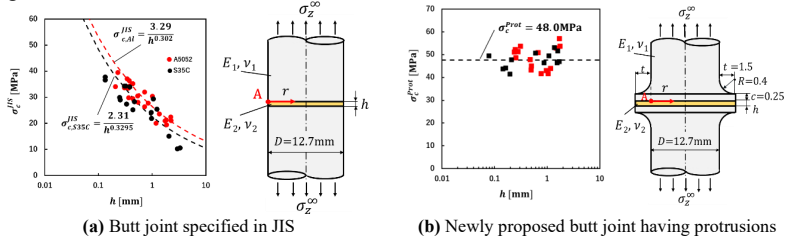


Fig. 1. Critical JIS adhesive strength, expressed as $\sigma_{c,SSC}^{JIS} = 2.31/h^{0.3295}$ MPa and $\sigma_{c,Al}^{JIS} = 3.29/h^{0.302}$ MPa for JIS butt joints, and critical adhesive strength $\sigma_c^{Prot} = 48.0$ MPa, experimentally obtained for the butt joint having protrusion.

A Novel Approach to the Synthesis of Bimetallic PtPd/C Electrocatalysts for the Cathode of a Proton Exchange Membrane Fuel Cell

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The great interest in nanostructured materials, based on platinum, palladium, and their alloys, is associated with their application as catalysts in chemical processes and automotive exhaust aftertreatment devices, electrolyzers, and proton exchange membrane fuel cells. The need to enhance the catalytic activity of catalysts in current-generating reactions requires the development of new synthesis methods that enable control over the architecture of bimetallic nanoparticles (NPs) and the morphology of the resulting materials. The most common methods for preparing noble metal NPs are liquid-phase synthesis approaches. However, the formation mechanisms of noble metal NPs, and especially their alloys, under liquid-phase synthesis conditions are poorly understood, which limits the ability to control the architecture of bimetallic NPs and the morphology of the final materials, forcing researchers to rely on trial and error when improving synthesis procedures. The aim of this study is to develop a new approach to the synthesis of bimetallic PtPd nanoparticles and catalysts based on them, relying on simultaneous or sequential introduction of platinum and palladium precursors into the reaction medium under monitoring of their reduction kinetics. The monitoring methods employed were (i) continuous tracking of changes in solution color intensity and (ii) the electrode potential of the solution during the phase-formation process. X-ray spectroscopy, electron microscopy, and voltammetry were used to evaluate the composition, particle size, morphology, and catalytic activity of the electrocatalysts. A series of Pt₃Pd/C catalysts with a metal mass fraction of approximately 40% was prepared. The differences in material preparation consisted in the time points at which the palladium precursor was introduced into the reaction medium during the platinum reduction process. These points correspond to different extents of platinum reduction, determined by using the phase-formation kinetics monitoring method developed by us. It was established that the time of palladium precursor introduction into the reaction medium influences the characteristics of the forming PtPd nanoparticles and the electrochemical behavior of the resulting materials. The best synthesized PtPd/C catalysts exhibit 1.2 – 1.6 times greater active surface area and at least 1.4 times higher catalytic activity in the oxygen reduction reaction, compared with the commercial analogue HiSPEC4000 (Johnson Matthey). Testing of the catalysts in fuel cell prototypes demonstrated that the obtained PtPd/C sample is at least 15% more resistant to degradation and delivers 19% higher maximum specific power after 30,000 stress test cycles, compared with the commercial analogue. Thus, the developed approach to the synthesis of PtPd/C catalysts with controlled bimetallic nanoparticle architecture enables the preparation of promising materials for use in proton exchange membrane fuel cells.

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Temperature Sensor Based on a Two-peak SAW Resonator with a Transverse Mode

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The temperature dependence of resonant peaks of surface acoustic wave (SAW) resonators enables their use as passive wireless sensors for remote temperature monitoring. Recently we showed that the use of two-peak SAW resonators can significantly increase the sensitivity of temperature sensors [1]. Moreover, the monitoring of the difference frequency of two SAW resonators instead enables one to overcome the known serious shortcoming of SAW sensors, caused by instability of the reader's reference oscillator. However, using two SAW resonators in sensors makes the design more complicated and bulkier. We propose a temperature sensor, based on a single SAW resonator where the temperature dependent difference between its longitudinal and transverse SAW modes is exploited instead of using additional SAW resonator. Normally, transverse mode is considered a parasitic effect, and significant efforts are made for its suppressing [2]. We have successfully fabricated a SAW resonator on YX-112°-cut lithium tantalate substrate. The frequency of transverse mode resonance is 1.5 MHz greater than major resonance at 868 MHz and its peak amplitude is comparable with major one. The use of an extended inter-digital transducer (IDT) with 450-digit pairs with no reflectors, i.e. so-called self-resonant IDT and narrow IDT aperture, introduces several important features of resonator:

- **No transverse mode suppression.** In a classic SAW resonator, the reflectors are typically designed to effectively reflect only the major SAW mode with not effecting or scattering the transverse ones. In present design with no SAW reflectors all modes remained. This facilitates obtaining a transverse resonance peak comparable in amplitude with major one.
- **An Extended IDT of $\sim 900 \lambda$ in length** allows one to obtain a better acoustic waveguide. Stable standing transverse mode forms across entire aperture width of 50 μm .
- **The narrow IDT aperture** of 50 SAW wavelengths (50 μm) results in a tight SAW energy localization increasing the frequency separation between modes.

The temperature coefficients of the major resonance frequency and transverse mode frequency are different. The temperature coefficient of the difference frequency is as large as 600 ppm/°C, which is much greater than the temperature coefficients of frequency shifts in single-peak resonators.

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Surface Acoustic Waves to Monitor Active THz Diffraction Grating Based on Vanadium Dioxide

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Metasurfaces pave a broad avenue for advanced flat optical tools and technologies due to their unique capabilities in the formation of previously inaccessible field distributions within the wavefront. Metasurfaces are extensively studied to build a basis for new methods of terahertz (THz) nondestructive testing, THz spectroscopy, THz imaging, thermal and THz monitoring, parallel optical processing and other fields. Active metasurfaces with build-in *in-situ* monitoring of all individual meta-atoms during operation are highly desired as they are expected to provide considerable contribution to all-optical diffractive processors. An electric field of a surface acoustic wave (SAW) propagating on the surface of the acoustic channel penetrates to VO₂ film and interacts with charge carriers. Recently, by using SAW, we experimentally examined an unusual metal-to-insulator transition (MIT) in VO₂/TiO₂/LiNbO₃ composite [1] that allowed us not just switch material between insulator and metallic states but also to gradually tune the conductivity to any point of MIT hysteresis loop. Such unique property discovered in VO₂/TiO₂/LiNbO₃ composite opened a new way to build active metasurfaces of “gradient” type. In this study, we report a new approach of using SAWs, which are generated in LiNbO₃ substrate to *in-situ* monitor the states of pixels in VO₂ based active THz metasurface. More specifically, we propose a novel SAW-based approach to simultaneously and independently monitor the states, i.e. the gradual tuning, of the THz reflection properties within all N lines of active metagrating. A single broadband RF response is recorded with N narrow-band frequency channels that code the feedback information about the current state of each line (“pixel”) of the grating. This all-electrically addressed “gradient” type metagrating inherits the properties of recently discovered VO₂/TiO₂/LiNbO₃ composite [1]. The resistance alteration due to metal-to-insulator transition of all VO₂ based pixels in the active THz grating is monitored in advance even without incident THz radiation. The method provides important new options for monitoring of a metasurface including material aging, incorrect pixel switching due to technological defects, heat flow induced pixel crosstalk and others. Using the SAW device to monitor functioning of all-electrically addressed VO₂ based binary grating with tunable period as well as advanced gradient type gratings are modeled. *In-situ* monitoring of active metasurfaces, using SAWs paves a broad avenue for controlling flat optical devices for all-optical data processing.

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Influence of Temperature and Pressure of the Energy Carrier on the Capacity of a Horizontal Section of a Stopped Pipeline

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The influence of temperature and pressure of the energy carrier on the capacity of a horizontal section of a stopped pipeline is a crucial factor determining the accuracy of commercial metering of the energy carrier and the safety of pipeline system operation. In a stopped state, when the pipeline section is isolated by valves and pumping is absent, a certain pressure remains inside, and the product undergoes heat exchange with the environment. The nominal capacity of a pipeline is usually specified for standard conditions (temperature +20 °C and atmospheric pressure). However, under real operating conditions, because of working pressure and temperature, both the geometry of the pipe and the physical properties of the energy carrier change, which requires the introduction of correction factors. Pressure has a dual effect on pipeline capacity: internal pressure creates circumferential stress in the pipe wall, causing elastic deformation and an increase in the internal diameter, which leads to an increase in the internal volume of the pipe. Temperature affects the capacity of an oil pipeline through thermal expansion of the pipe material and volumetric expansion of the product [1]. The horizontal position of a pipeline section in a stopped state provides an important methodological simplification: unlike inclined sections, where pressure changes along the height due to the hydrostatic component, in a horizontal pipeline, pressure and temperature can be assumed constant along the entire length. This allows one to perform calculations without dividing the pipeline into elementary segments, using uniform values of correction coefficients [2]. This work investigates the effect of changes in oil temperature and its average pressure on the capacity of a pipeline section. A mathematical model of the process under consideration was developed, and a computational experiment was carried out using the Mathcad software to determine the capacity of the pipeline section. Based on the results of the calculations, graphical dependencies of the change in the volume of the energy carrier with increasing temperature and pressure were constructed.

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Transparent VO₂/VO₂:Ru MIT Device for Neuromorphic Electronics

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As the demand for energy efficient devices for AI applications grows higher scientists look for more approaches to the neuromorphic devices. As for image recognition tasks, transparent materials with memristive properties seem to be a solution. We report studying metal-insulator transition (MIT) in transparent VO₂ films as well as VO₂ films, doped with Ru. Samples were grown, using aerosol assisted chemical vapor deposition technology (AACVD)

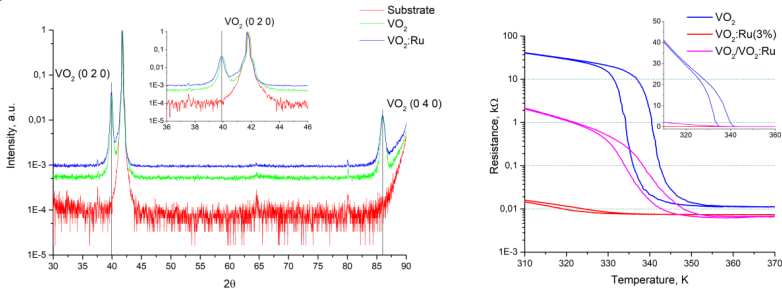


Fig. 1. Crystalline structure and electrical properties of VO₂ and VO₂:Ru films.

We have studied crystalline structure of the VO₂ and VO₂:Ru films as well as their electrical properties. Fine tuning of the technological parameters of AACVD process enables obtaining high quality films which show clear metal-insulator transition, as shown on Fig. 1. Remarkably thermally induced MIT allows us to expect that a noticeable transition could also be induced by electrical stimulus. This allows a far more convenient integration of MIT-based device into common electronic devices. Such results allow us to propose the VO₂/VO₂:Ru device as a promising candidate for transparent neuromorphic device

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Guided Waves in Elastic Metamaterials and Laminates with Voids and Piezoelectric Transducers: Semi-analytical Models and Experiments

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Advanced semi-analytical approach for the simulation of the guided wave phenomena in elastic metamaterials and laminates is presented in this study. The proposed numerical methods are capable to describe wave excitation, scattering and sensing in a multi-layered elastic waveguide with a system of internal delaminations and piezoelectric/elastic inhomogeneities, located on the surface of the waveguide. The hybrid semi-analytical method, suitable for fast parametric analysis of guided wave propagation in the considered structures, allows one to evaluate energy flow, transferred from an actuator into the waveguide and provides an opportunity to analyze resonance frequencies of a laminate with multiple delaminations and surface mounted inhomogeneities. Such resonances manifest themselves by prolonged, weakly decaying standing waves at the defect's location. Their spectra are concentrated at the resonant frequencies, strongly depending on the defect's type, shape, and location. The problem of guided wave scattering by local voids is considered, and the experimental validation of resonance scattering is demonstrated with surface mounted piezoelectric actuators and laser Doppler vibrometry. Several laminated elastic metamaterials with crack-like inhomogeneities or thin planar voids recently proposed are considered both numerically and experimentally as well. It was shown that the presence of such obstacles in elastic metamaterials can provide unidirectional propagation of guided waves or sufficiently widen bandgaps.

A Novel Approach to the Preparation of Anode PtRu/C Catalysts with High Activity toward the Methanol Oxidation Reaction

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Direct methanol fuel cells (DMFCs) are considered promising energy sources; however, their widespread application is limited by the high cost of platinum-based catalysts and their insufficient activity in the methanol oxidation reaction (MOR) at the anode and the oxygen reduction reaction (ORR) at the cathode. MOR is associated with high overpotential due to the formation of intermediate species (formaldehyde, formic acid, CO, etc.) that block the active sites of Pt [1, 2]. The most efficient anode catalysts are PtRu/C materials, in which a bifunctional oxidation mechanism is realized, namely Ru promotes the formation of OH species at lower potentials than Pt, thereby facilitating CO oxidation and reducing surface poisoning [2]. High catalytic activity is achieved when the nanoparticle size is below 4 nm,

with uniform distribution and, consequently, a high electrochemically active surface area (ECSA) [3]. Control over nanoparticle size and size distribution can be achieved during the synthesis process. The aim of this work is to optimize the synthesis of PtRu/C catalysts by controlling the phase formation process of bimetallic nanoparticles. We have developed a method for monitoring the synthesis process, based on tracking changes in the redox potential and the color of the reaction medium. This approach allows variation of the Ru precursor addition time, depending on the reduction degree of the Pt precursor, which is reflected in changes in potential and solution color. Thus, we can influence the structure and composition of the resulting nanoparticles. A series of PtRu/C catalysts (≈ 30 wt.% metal loading) was prepared, using simultaneous ($p1$) and sequential ($p2, p3$) introduction of metal precursors into the reaction medium. The crystallite size varies from 1.5 to 5.5 nm, while the composition is close to the nominal Pt₅₀Ru₅₀. Based on ECSA values, the materials follow the order: $p1 \ll p3 < p2$. Notably, the ECSA of sample $p2$ reaches 113 m²/g, which is 2.3 times more than that of a commercial analogue (PtRu/C, 60 wt.%, Alfa Aesar). The $p2$ catalyst exhibits the lowest onset potential for MOR, the highest current densities, and enhanced tolerance to intermediate methanol oxidation products. Its activity is at least twice that of the commercial PtRu/C catalyst. Thus, the sequential introduction of precursors during synthesis enables the preparation of highly efficient PtRu/C catalysts, promising for application as anode materials in DMFCs.

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The Influence of Silicone Oil Viscosity on the Laser Cleaning Effects of A3003 Aluminum Alloy Surfaces

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A3003 aluminum alloy, widely recognized for its excellent corrosion resistance, is a key material for heat exchangers in the shipbuilding and automotive industries. Residual silicone oil, generated during manufacturing processes, can deteriorate the quality of subsequent processing, highlighting the necessity of environmentally friendly laser-cleaning technology. In this study, 1065 nm Q-switched fiber laser was employed to determine viscosity-dependent optimal cleaning parameters by systematically varying laser power, defocus distance, and overlap ratio. Experimental results showed that low-viscosity oil (100 cSt) was most effectively removed at 100 W laser power, a -2 mm defocus distance, a 45% overlap ratio, and four scanning passes. In contrast, high-viscosity oil (1000 cSt) appeared visually removed at 300 W with a 35% overlap ratio and three scans, but surface damage occurred. FTIR analysis, which enables the identification of residual oil through its characteristic infrared absorption spectrum, revealed that the C-H peak for the 100 cSt oil disappeared after four scanning passes but re-appeared after five scans. This result indicates that excessive laser irradiation can adversely affect cleaning efficiency. High-viscosity oil exhibits limited heat diffusion, making it prone to carbonization caused by localized heat accumulation; therefore, precise laser control is essential. These findings provide important guidelines for establishing sustainable laser-cleaning processes for heat-exchanger materials.

Fabrication of Membrane Structures Based on a GaAs/AlGaAs Heterostructure with an InGaAs Quantum Well Using Focused Ion Beam Processing and Selective Wet Etching

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A_3B_5 heterostructures are widely used for microscale light sources and integrated photonic systems, including membrane resonators [1]. Partial or complete release of structures from the substrate reduces optical mode leakage and modifies light confinement and extraction [2]. A promising route for fabricating membrane emitting structures is the combination of focused ion beam processing and wet etching, avoiding conventional lithography. Although this approach has already been studied for A_3B_5 systems [3], GaAs/AlGaAs heterostructures with an InGaAs quantum well remain insufficiently explored, especially in terms of preserving photoluminescent properties after FIB modification. In this work, the photoluminescent properties of microscale structures, fabricated on a GaAs/AlGaAs heterostructure with an InGaAs quantum well, were investigated. A sacrificial $Al_{0.7}Ga_{0.3}As$ layer was incorporated into the structure to enable membrane formation. To reduce the effect of Ga^+ ions, a SiO_2 layer was deposited on the surface prior to FIB processing. Ring-shaped and square microscale structures with a characteristic size of 10 μm , including structures with and without submicron bridges, were defined by focused ion beam processing. This was followed by step-by-step selective wet etching of the sacrificial layer in a 1% HF solution. After each etching step, the structures were characterized by photoluminescence spectroscopy. The signal from an unmodified region, measured at the corresponding stage, was used as a reference. The photoluminescent response during selective etching was found to be nonmonotonic. For square structures, the integrated photoluminescence intensity increased up to the fourth etching stage and then decreased at the fifth stage. For disk structures, the integrated photoluminescence intensity increased as the sacrificial layer was progressively removed. At the final stage, all studied structures exhibited a photoluminescence signal comparable to or higher than the corresponding reference. The initial decrease in intensity is likely related to incomplete release from the substrate, so that part of the optical mode still leaks into it, while the influence of side surfaces already starts to increase. The subsequent increase in photoluminescence may be associated with reduced substrate-related losses and redistribution of the optical mode as a more pronounced membrane geometry is formed. The decrease observed for square structures at the fifth stage may be due to their stronger sensitivity to edge effects and to the surface condition after removal of the protective oxide layer. A red shift of the photoluminescence peak was observed for all studied structures. The maximum shift reached 10 nm relative to the initial reference value of 1019 nm and was recorded after the final etching stage. This shift is likely associated with changes in the local strain state, caused by partial relaxation of elastic stresses, arising from the lattice mismatch between the quantum well and the surrounding matrix. Thus, a method has been developed for fabricating membrane microscale structures based on a GaAs/AlGaAs heterostructure with an InGaAs quantum well, using focused ion beam processing and selective wet etching. It is shown that this approach

preserves the photoluminescent properties after FIB modification and is promising for fabricating emitting microscale structures based on GaAs/AlGaAs heterostructures.

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Graphene Metamaterials on Silicon Carbide for W-band Automotive and Industrial Applications Metamaterials, Formed on the Surface of Silicon Carbide

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The growing demand for high-precision sensing in autonomous vehicles and industrial automation has intensified the search for materials and structures capable of manipulating electromagnetic waves at millimeter-wave frequencies. Metamaterials, with their engineered sub-wavelength structures, offer unprecedented control over wave propagation, but their practical deployment requires fabrication techniques that are both precise and compatible with robust, high-temperature substrates. This study investigates the formation and characterization of metamaterials based on a conductive, graphene-like layer, directly synthesized on a silicon carbide (SiC) substrate through a laser ablation process, targeting the W-band (75-85 GHz) [1]. The core of this research is the development of a fabrication method that leverages the physical properties of SiC. Upon exposure to a focused laser beam, the silicon component on the surface of a semi-insulating 6H-SiC crystal preferentially evaporates due to its lower sublimation point. This process leaves behind a carbon-rich layer, which, under optimized laser parameters, forms a stable and highly conductive film resembling the properties of graphene. For this study, the laser patterning was conducted using a 1060 nm wavelength source with a 20 μm spot size, scanned at a speed of 400 mm/s over a $700 \times 700 \mu\text{m}$ area. By precisely controlling the pulse frequency between 20 and 160 kHz and maintaining a line density of 60 lines per mm, a uniform conductive layer with a thickness of approximately 7 μm was achieved. This direct-writing approach allows for the simultaneous creation of the metamaterial pattern and its conductive component [2]. The primary objective of this work is to design, simulate, and experimentally validate a zero-index metamaterial (ZIM) unit cell, fabricated using this laser-induced graphitization technique. The unit cell, consisting of the conductive layer, etched into a 250 μm thick SiC wafer, was modeled, using full-wave electromagnetic simulation software (ANSYS HFSS). The design was specifically optimized for industrial and automotive radar applications within the 75 – 85 GHz frequency range. The

simulation results demonstrate excellent performance, with a reflection coefficient (S11) better than -20 dB across the target band. Furthermore, analysis of the effective medium parameters revealed a near-zero index of refraction, with an extracted effective permittivity below 0.35, confirming the metamaterial behavior. This research successfully demonstrates the feasibility of fabricating functional, graphene-based metamaterials on SiC substrates, using a single-step laser ablation method. The results highlight a promising pathway for creating robust, all-carbon metamaterial structures that are well-suited for high-frequency applications, including automotive short-range and long-range radar (SRR/LRR) as well as industrial fluid level sensing systems, where thermal stability and performance are critical.

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Features of the Formation of Ohmic Contacts to Graphene Obtained by Plasma-chemical Etching of SiC

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Graphene, with its unique electrical properties, is one of the most promising materials for post-silicon electronics. However, its practical implementation is hampered by the difficulty of creating reliable low-resistance metal-graphene contacts, since contact resistance often limits device performance. The traditional method of producing graphene on SiC via high-temperature annealing requires heating to significant temperatures, which is poorly compatible with existing silicon technology. However, the use of plasma etching allows graphene to be synthesized at significantly lower temperatures, paving the way for the integration of graphene electronics into standard production cycles. At the same time, as noted in the review by Aslanidou et al., the study of epitaxial graphene on SiC and its contacts with metals remains a pressing task for achieving low contact resistance values. In this regard, there is a need for a comprehensive study of contacts specifically to graphene, formed by the plasma method, since such graphene may have a different morphology, degree of defects, and type of doping, compared to thermally grown graphene [1]. The plasma-chemical treatment of a substrate can influence the formation of a buffer layer and charge transfer across the metal-graphene interface, necessitating the study of fundamental current transport mechanisms and the identification of dominant processes, namely thermionic, tunneling, or hopping conduction. Furthermore, the creation of commercially viable devices such as Hall sensors requires stable and reproducible contact parameters. Therefore, establishing a correlation between the plasma etching conditions of SiC and the electrical characteristics of the resulting structures is an important scientific and technical challenge [2]. Thus, the study of metal-graphene contacts to

graphene obtained by plasma etching on a SiC surface lies at the intersection of surface physics, materials science, and nanoelectronics technology. Its solution will advance the development of energy-efficient, high-frequency graphene devices compatible with the modern semiconductor industry. The aim of this work was to conduct experimental studies on the formation of an ohmic contact between metal and graphene, obtained by plasma etching of SiC substrate. The experimental methodology was as follows: various metals were deposited onto a graphene layer grown on the SiC surface, using magnetron sputtering. The ohmic resistance of the metal-graphene and metal-graphene-metal structures was then studied. Aluminum, copper, tantalum, titanium, and chromium were selected as the primary metals used. The adhesion properties of the above-mentioned metal-graphene contacts were also studied. As a result of these experimental studies, the dependencies of the metal-graphene ohmic resistance on the sample temperature were obtained. Chromium proved to be the most suitable metal for contact formation in terms of adhesion and electrical conductivity parameters in our metal substrate. Therefore, chromium, which exhibits the best adhesive and electrical conductivity properties, will be selected for the formation of sensor device structures to provide ohmic contact between graphene and metal.

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The High-temperature Synthesis on the PtPdCo/C Catalyst for Low Temperature Fuel Cells

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The development of highly efficient catalysts for low-temperature fuel cells remains one of the most pressing challenges in modern hydrogen energy. The currently widespread catalysts, based on platinum nanoparticles, have a high cost, which hinders the widespread adoption of low-temperature fuel cells. In this regard, a promising strategy to reduce their costs, as well as to increase their activity and stability, is the use of bimetallic or trimetallic platinum-based catalysts. Trimetallic catalysts are of the greatest interest, as they have the potential to surpass bimetallic counterparts in electrochemical performance. However, the synthesis of trimetallic catalyst nanoparticles on carbon support is a complex task, requiring not only the formation of small particles uniformly distributed over the surface of the carbon support, but also the obtainment of homogeneous alloy from different metals. A range of methods is used to produce trimetallic catalysts, among which an approach, based on impregnating the initial support material with metal salts, followed by high-temperature reduction in an inert atmosphere with the addition of hydrogen, is of particular interest. It is worth noting that the characteristics of the resulting catalyst during the high-temperature synthesis are significantly

influenced not only by the thermal treatment conditions (temperature and composition of the reducing atmosphere), but also by the characteristics of the initial Pt/C or PtM/C precursor material and the impregnation method used. Consequently, the following objective was set: to investigate the influence of the cobalt deposition method (as hydroxide by alkalizing the suspension and the wet-synthesis using NaBH_4) onto the initial PtPd/C precursor material, followed by high-temperature treatment at 600 °C in an Ar atmosphere with 5% H_2 , on the microstructure and electrochemical properties of the ternary PtPdCo/C catalyst. XRD analysis established that the obtained PtPdCo/C catalysts contain a single metallic phase, which possibly confirms the formation of nanoparticles with an alloy structure. The trimetallic catalysts demonstrated a highly electrochemically active surface area. For the sample, prepared by the alkaline method, the value was 61 m^2/g (PGM), while for the catalyst synthesized using borohydride it was 53 m^2/g (PGM). Despite the smaller active surface area, the sample, prepared by the borohydride method, demonstrated higher mass activity in the oxygen reduction reaction, reaching 368 A/g (PGM) at a potential of 0.9 V, which exceeds the activity of the commercial Pt/C benchmark. Thus, the proposed synthesis strategy is an effective approach for producing promising trimetallic catalysts. It is shown that the method of liquid-phase reduction with borohydride followed by thermal treatment is preferable for application in low-temperature fuel cell cathodes, as it provides higher mass activity.

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Experimental Investigation of Acoustic Fields Generated by Focusing Ultrasound Transducers

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Advances in physical acoustics, imaging and signal processing techniques, piezoelectric materials, and ultrasonic transducer designs have led to the development of novel methods and equipment for ultrasound diagnostics, therapy, and aesthetic medicine [1]. High-Intensity Focused Ultrasound (HIFU) remains a promising approach for minimally invasive therapeutic procedures [2]. This work presents experimental results on the influence of various defects and non-uniformities in the shape and dimensions of focusing piezoceramic elements, as well as structural features of HIFU transducers, on the characteristics of the generated acoustic fields. The spherical focusing elements of the HIFU transducer, fabricated from hard porous piezoceramics, had the following dimensions: outer diameter was 90 mm, radius of curvature was 75 mm, central aperture diameter was 50 mm, and piezoelement thickness was 1.2 mm. The central aperture was designed to accommodate an ultrasound imaging transducer. Various intentional defects, such as a radial crack, non-uniform thickness, and similar imperfections, were introduced into the spherical focusing piezoelectric element to evaluate their impact on the characteristics of the HIFU transducer's acoustic field. The HIFU transducer was driven

by a sinusoidal signal with an amplitude ranging from 0 to 10 V, generated by a digital function generator (Agilent 33521B). The excitation frequency was set to either the resonant or anti-resonant frequency of the HIFU transducer (~ 1.6 MHz) and could be varied in discrete steps to investigate the influence of the operating frequency on the acoustic field parameters. Acoustic field measurements and mapping were performed, using the UMS3 scanning ultrasound tank, equipped with calibrated needle-type PVDF hydrophone probes, an integrated broadband amplifier, and a DC power supply. The experimental data were compared with finite-element simulations of the vibration mode profiles of porous piezoelements, carried out, using the ANSYS software package. The study demonstrates that any deviations in the geometry or dimensions of the focusing piezoceramic element, fluctuations in operating frequency, and specific design aspects of the transducer significantly affect the parameters of the acoustic field. *Ex vivo* experiments on biological tissues, and acoustic phantoms confirmed the validity of both the measured and simulated results.

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Numerical Investigation and Comparison of Effective Elastic Properties of Regular Porous Structures

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The rapid development of additive technologies in recent years has significantly expanded the possibilities of designing highly porous materials with a controlled geometric structure. Unlike classical stochastic foams, such materials have a strictly regular geometry which opens new prospects for the targeted control of their effective mechanical properties. Therefore, the development of universal numerical models and approaches that predict effective material properties is a relevant problem. In this research, a generalized computational approach to the analysis and optimization of elastic properties of regular highly porous structures is proposed. It is based on the finite element method and the homogenization of the representative volume. This study continues previous works [1, 2] and complements them with consideration of new types of cells and lattices, based on them. The construction of the computer model, finite element meshing and numerical experiments were performed in the ANSYS package. The proposed model considers six boundary value problems (three tensile and three shear). Due to this, a complete set of effective elastic constants is obtained. Therefore, the proposed model can estimate the anisotropy of materials, occurring from the geometry of the structure. The validation of the proposed finite element model was carried out on the Gibson-Ashby cell. The

numerical results obtained with a porosity of over 70% correspond to the analytical and numerical results of other authors. Therefore, this model can be used to study a wide class of regular porous structures. Further comparative analysis was performed for four types of cells: Gibson-Ashby, cuboctahedron, tetrakaidecahedron and octet truss cells. To determine the effective moduli of these cells and lattices, both kinematic uniform boundary conditions and periodic boundary conditions were applied. Numerical analysis has shown that the structure, based on Gibson–Ashby cells, has the lowest stiffness moduli. At the same time, the highest values of the relative Young's modulus are achieved in cuboctahedral and octet lattices. The cuboctahedral configuration also provides highest value of the shear modulus. The anisotropy estimation, performed using the Zener coefficient, showed that only the tetrakaidecahedral structure saves isotropic behavior while anisotropy is observed for other lattices. The Gibson–Ashby model is simple and convenient for estimating the effective Young's modulus of highly porous heterogeneous materials; however, this study confirms that the geometry of regular structures has a significant impact on their mechanical properties.

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Formation of an Information Database for Describing the Characteristics of Ship Metal Structures

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Currently, over 12,000 vessels operate on the inland waterways (IWW) of Russia. A key issue facing the industry is the critical aging of the fleet: the average age of vessels exceeds 40 years, and 60% of them have already exceeded their standard service life. Over the past two decades, the fleet size has decreased by 35%, with over 1,000 vessels being decommissioned annually. The main reason for decommissioning is the accumulation of fatigue and operational damage in hull structures. The existing inspection system, based on surveys by classification societies, is aimed at identifying only critical defects (holes, water leaks). Less serious damage, but affecting strength (dents, bulges, corrugations), often goes unaddressed for long periods. This leads to a reduction in the overall load-bearing capacity of the hull. Consequently, there is an urgent need to develop new methods for assessing the impact of accumulated damage on the strength of hull structures. The aim of the work is to improve the existing method of defect detection and to build databases by considering pitting corrosion of the outer plating of the vessel. As part of the study, defects were systematized and a database of operational damage

to the hulls of inland and mixed-sea vessels was created [1]. Based on an analysis of classification society regulatory documentation, an improved defect detection method was proposed that, unlike the traditional approach, considers the presence of continuous pitting corrosion. Experimental studies of samples, removed from areas of intense wear, allowed for the construction of graphical dependencies of yield strength and ultimate tensile strength. The results obtained served as the basis for classifying outer plating sheets with continuous pitting wear as elements, requiring mandatory replacement. Based on the results of the study, practical recommendations were formulated for adjusting defect detection methods and strengthening the quality control of welded joints. An analysis of the obtained results showed that the existing defect detection methodology does not adequately assess the reduction in the load-bearing capacity of hull structures in the presence of continuous pitting wear of the plating and welded joints. Information databases can be used within the framework of the implementation of software packages [2, 3]. Experimental studies, including uniaxial tensile testing of specimens according to Russian GOST 1497-84, revealed a significant decrease in the strength properties of the material (yield strength and tensile strength), compared to the original, construction parameters. The improved defect detection approach proposed in this study ensures an increased level of operational safety and enables more informed decisions regarding the future operation of ship hulls.

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Implementation of Additive Technologies (3D Printing) in the Manufacturing Process of Structural Elements

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During the research, an analysis of the technological aspects of manufacturing machine parts and marine structures was conducted [1]. This resulted in the design of a mechatronic device for cleaning curbstones as part of a road maintenance project. The design phase included computer modeling, the creation of a sample database, and virtual strength testing under loads, exceeding operational loads. FDM printing technology was used to create a physical

prototype, using ABS plastic on Creality K1 Max equipment. Frame strength calculations for the device demonstrated a safety factor of 7.2 with a deformation of no more than 0.05 mm. As part of the development, technical requirements for the control system were defined, an algorithm for its operation was created, and a fault-tolerance analysis was conducted (including the brush drives, chassis, and vacuum system), which was used to develop a maintenance and repair procedure.

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Welding Technologies for Localized Ship Hull Repairs Outside the Dock

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Localized ship hull repairs outside the dock are of significant practical interest for the rapid restoration of a vessel's operability without its long-term decommissioning. Under these conditions, welding technologies are particularly important, allowing for repairs to be performed directly afloat or at the berth while maintaining strength, watertightness, and safety requirements. The aim of this study is to assess the feasibility of using welding technologies for localized ship hull repairs outside the dock. The repair process is based on an assessment of typical hull damage that makes localized repairs possible outside the dock: cracks, holes, corrosion damage, and deformations of individual sections of the plating and framing. Preparation of tooling and equipment for welding and surfacing, metal preparation requirements, access restrictions to the repair area, and the impact of humidity, seam motion, temperature, and surface conditions on the process are also considered. An important approach is the selection of welding consumables, welding modes, temporary reinforcements, and quality control methods when performing out-of-dock repairs. One of the most important procedures is ensuring compliance with safety requirements, including fire prevention measures, leak testing, equipment protection, and work organization in the confined shipboard environment. Ensuring the effectiveness of out-of-dock localized hull repairs is determined by the choice of welding technologies, the quality of preparation of the repair area, consideration of external operational factors, and strict adherence to safety requirements.

Laboratory Rig for Studying Propeller Parameters during Ship Repair and Modernization

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During ship repair and modernization, propeller replacement and refurbishment impacts thrust, torque, efficiency, cavitation, noise, and vibration. Therefore, a laboratory rig, capable of measuring key propeller parameters under controlled conditions and comparing the original, repaired, and refurbished conditions, has practical value. Research shows that measurements of thrust, torque, rotational speed, and associated hydrodynamic effects provide the basis for assessing a propeller's suitability for further operation. In practice, propeller repair and modernization are often assessed based on geometry, visual inspection, and indirect performance indicators, while changes in actual performance characteristics after refurbishment or refurbishment may remain insufficiently studied. This complicates an objective assessment of the effectiveness of repair measures, especially when there is a risk of thrust loss, increased drag torque, and cavitation [3]. The aim of this work is to develop a laboratory rig for studying propeller parameters and determine its capabilities in assessing the effectiveness of ship propulsion repair and modernization. The propeller is a key component of the propulsion system, and its technical condition directly impacts on the efficiency and reliability of the vessel. During repairs and upgrades, it is necessary not only to restore the propeller's geometry but also to experimentally confirm changes in its performance. A laboratory rig is designed to study the thrust, torque, rotational speed, power consumption, and derivative coefficients of the propeller under specified conditions. These types of rigs allow for the acquisition of reproducible data in open water or near-open water conditions and the use of this data to compare different propeller configurations. The key parameters, determined during rig operation, are thrust, torque, efficiency, the dependence of performance on rotational speed, and flow conditions. The rig enables comparison of the parameters of the original propeller model, the repaired propeller, and the propeller after upgrade, using a unified set of criteria. This allows one to determine whether the performance has recovered after the cavitation damage has been repaired, whether the thrust and torque levels have changed, and whether the upgrade is justified based on performance criteria. This is especially important for cases where repairs are aimed at eliminating cavitation wear or improving the propeller's hydrodynamic performance. The laboratory rig serves as a tool for objectively assessing the technical condition of propellers. Its use allows for the transition from visual and geometric assessments to measuring actual operating parameters, which is particularly important when making decisions about repair, modernization, and recommissioning of the propeller.

Design of Efficient Interchangeable Functional Modules for a Modular Unmanned Vehicle

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A modular approach allows one to adapt a single UAV platform to various missions by swapping out payloads and functional subsystems. However, the use of interchangeable modules impacts weight, balance, power consumption, aerodynamics, autonomy, and control stability. Therefore, the key challenge lies not in creating the modular design itself, but in assessing the impact of module replacement on the UAV's performance under real-world operating conditions. The goal of the study is to determine the effectiveness of using interchangeable modules in UAV design and how their installation affects its operation, power consumption, and overall capabilities. To achieve this, the following tasks must be addressed: (i) to understand how modular UAVs are designed; (ii) to determine the types of interchangeable modules and their purposes; (iii) to select metrics for evaluating the effectiveness of such a design; (iv) to assess how module replacement affects the UAV's weight, power consumption, stability, and payload, (v) to determine the conditions under which the modular design performs best. The effectiveness of a modular unmanned aerial vehicle (UAV) architecture is determined by the balance between functional flexibility and the associated tradeoffs in weight, power consumption, integration complexity, and control stability. Structurally, such a UAV consists of a base platform and replaceable modules (sensor, measurement, cargo, communications, and computing). A key requirement is compatibility in terms of mechanical interface, power supply, data transmission channels, and software. A modular architecture increases the versatility of an UAV, but its effectiveness is determined by the balance between functional flexibility and tradeoffs in weight, power consumption, integration complexity, and control stability. A modular UAV comprises a base platform and replaceable modules, namely sensor, measurement, cargo, communications, computing, or specialized modules. A key requirement is module compatibility in terms of mechanical fastening, power supply, data exchange interfaces, and software integration. Modularity provides a gain in versatility, but simultaneously changes the UAV's weight, load distribution, flight time, permissible payload, and control algorithm requirements. Therefore, the effectiveness of modules should be assessed not only by their functional benefit but also by their impact on the overall performance of the platform [1]. Modular UAVs are a promising solution that allows one to adapt a single aircraft to different tasks, using interchangeable equipment. However, the effectiveness of such a design depends not only on the number of possible missions but also on how the modules affect weight, energy consumption, flight stability, and ease of use. Therefore, modules must be selected wisely, assessing both their usefulness for a specific task and their overall impact on the performance of the entire aircraft.

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Effect of Changes in the Sharpness of the Grid Electrode Angle in a Planar Field Emission Cell on the Distribution of Electric Field Strength

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Currently, there is a rapid development in the world of vacuum micro- and nanoelectronics devices, based on the effect of field electronic emission. Field emission cathodes can be used as electronic sources in various devices such as microfocus X-ray tubes, electron microscopes, and mass spectrometers [1]. Due to the technological possibility of forming nanoscale air gaps between electrodes, field emission structures with a nanoscale quasi-vacuum conduction channel have become particularly promising. In the cell under study, the quasi-vacuum channel is 65 nm, which reduces the likelihood of ionization of the residual gas in the interelectrode space and allows the creation of field emission structures that do not require vacuuming and vacuum casing. Field electron emission from nanoscale surfaces due to ballistic electron charge transfer in a quasi-vacuum gap can provide high performance (in the THz-range) and stability in high temperature and radiation conditions [2]. Currently, there are problems with vacuum nanoelectronics that need to be solved. Among them, we can point out the selection of materials for the emission surface and the uneven distribution of electric field strength, which requires optimization of geometric parameters. A planar field emission cell, based on silicon carbide and graphene, is studied by physical and mathematical modeling. The study examined the effect of changes in the sharpness of the grid electrode angle in a planar field emission cell on the distribution of electric field strength. A field emission planar cell is considered, consisting of cathode and anode electrodes, located opposite each other with potentials of -10 V and 0 V, respectively, as well as two grid electrodes, located on the sides of the cathode. The effect of a change in the angle of a grid electrode adjacent to the cathode in the range from 90 to 50° in combination with a change in its potential from -10 V to -5 V on the distribution of electric field strength in the space between cathode and anode has been studied. The results showed that with a decrease in the angle to 80° , the local field strength increases on the grid from 106.4% to 106.8% and decreases on the cathode from 86.4% to 80.6% of the electric field strength on a uniform section of the cathode at a grid potential of -8 V. Thus, the best performance was achieved at an angle of 80° and a potential of -8 V. These results should be considered when developing and designing planar field emission devices.

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First-principles Calculation of the Work Function of a Field Emission Cathode with Different Coating Types

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Currently, there is a rapid development of vacuum micro- and nanoelectronics devices, based on the effect of field electronic emission in the world. Field emission cathodes can be used as electronic sources in various devices such as microfocus X-ray tubes, electron microscopes, and mass spectrometers. One of the key parameters, determining the energy efficiency of vacuum electronic devices is the operation of the cathode output, which affects the magnitude of the potential barrier at the boundary with the vacuum medium and the value of the field emission current. This parameter is crucial for minimizing the operating voltages of vacuum microelectronic devices (electron guns, vacuum diodes and triodes, etc.). One of the ways to reduce the output of the emission surface of the cathode is to apply thin films of materials to the cathode that have a lower output than that of the substrate material. Due to the small thickness of the film, the crystal lattice is deformed at the boundary with the substrate material, because of which its characteristics change, compared to the bulk material.

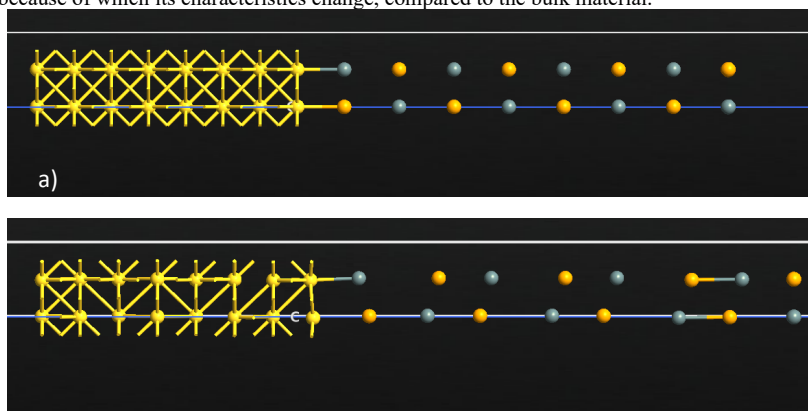


Fig. 1. Field emission structure of a SnSe-coated Au cathode: (a) before and (b) after the optimization process; yellow balls represent Au atoms, orange balls represent Se atoms, and gray balls represent Sn atoms.

To predict the operation of the output, a first-line approach, based on the theory of the density functional was applied, considering the deformations that occur at the interface of the layers. The calculation results were obtained for the crystal structure of a coated cathode, a typical example of which (Au/SnSe) is illustrated in Fig. 1a before optimization. In the process of calculations, the theory of the density functional with the basis of wave functions in the form of a linear combination of atomic orbitals, the PseudoDojo (Medium) pseudopotential and the

Purdue – Burke – Ernzerhof (PBE) exchange correlation functional was used. When solving the Poisson equation along the x - and y -axes, a periodic boundary condition with a periodicity of 2 atoms along each axis was taken together with the Dirichlet boundary condition along the z -axis, and the Neumann boundary condition on the left. The Dirichlet boundary condition determines that the potential is zero at the right boundary of the cell to simulate the presence of a vacuum at the boundary with the emission surface of the cathode. Due to non-periodicity in the z - direction, the Neumann condition is used to require that the potential gradient vanishes on the left side of the system. The optimization of the structure was carried out, using an automatic algorithm for minimizing system energy and mechanical stresses. The calculation of the output operation was carried out for the structure after optimization (see Fig. 1b). For other coating materials, a structure, like the one shown in Fig. 1, was used. Ghost atoms (atoms with zero potential) on the right boundary of the structure are required for correct modeling of the attenuation of the wave function during the transition of electrons into vacuum and obtaining an adequate value of the output operation, respectively. The results of the first-principal calculation of the yield for various types of coatings are shown in Table 1. From comparison with experimental results, one can see a good agreement between theory and experiment. The results obtained can be applied in the design of metal vacuum nanoparticles using cathode coating materials with low output performance.

Table 1. Comparison of calculated and theoretical values of the work function of an emitter with different types of coating.

Material	Calculated work function (eV)	Experimental work function (eV)
LaB ₆ (film) on Si	(2.4)	2.7 [1, 2]
TiN (film) on Si	(3.3)	3.2 [3]
SnSe (film) on Au	(3.83)	3.9 [4]

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Study of the Influence of the Composition of Trimetallic IrPtRu Catalysts on Their Functional Characteristics in the Oxygen Evolution Reaction

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The development of “green” hydrogen energy is hindered by the high cost of anode catalysts for proton exchange membrane electrolyzers (PEMEL, PEMWE) due to the use of expensive iridium. As an alternative, this study investigates IrPtRu electrocatalysts with a reduced Ir content, combining the high activity of Ru and the stability of Ir. A series of catalysts with different metal ratios (Ir₃₅Ru₃₅Pt₃₀, Ir₄₀Ru₃₀Pt₃₀, Ir₅₀Ru₂₀Pt₃₀) was synthesized by the liquid-phase reduction method. Local analysis of the materials performed using EDX revealed the compositional heterogeneity of the trimetallic catalysts. In the Ir₄₀Ru₃₀Pt₃₀ sample, the content of Ir and Ru is underestimated (probably due to incomplete reduction), while in Ir₅₀Ru₂₀Pt₃₀ an excess of Ir is observed. The presence of oxygen indicates the existence of oxides. Elemental mapping data confirms the uneven distribution of metals: Ir is predominantly localized at the edges of agglomerates, which may indicate the formation of several types of nanoparticles (either rich in Ir or depleted of it), see Fig. 1. The activity of the catalysts in the OER was investigated by linear voltammetry. At 1.53 V, the highest currents were shown by Ir₅₀Ru₂₀Pt₃₀ (7.9 mA/cm²) and Ir₄₀Ru₃₀Pt₃₀ (7.4 mA/cm²). All IrPtRu catalysts are more active than the commercial analogue. The mass activity increases in the order: Ir-COM < Ir₅₀Ru₂₀Pt₃₀ < Ir₃₅Ru₃₅Pt₃₀ ≤ Ir₄₀Ru₃₀Pt₃₀. The obtained results determine the pathways for further reduction of iridium loading in the anodes of PEM electrolyzers.

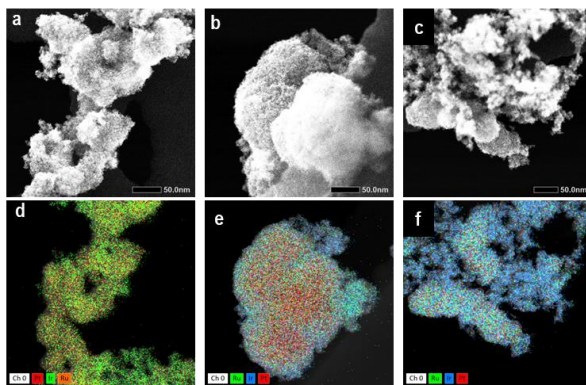


Fig. 1. SE images of Ir₃₅Ru₃₅Pt₃₀ (a), Ir₄₀Ru₃₀Pt₃₀ (b), Ir₅₀Ru₂₀Pt₃₀ (c) and EDX mapping (d, e, f) from the corresponding areas.

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Formulating the Development of Software Modules for a Fighting Game on the Unity Platform Using C#

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In the modern gaming industry, the success of digital projects is determined not only by their visual style but also by the reliability of the software implementation of game mechanics. For fighting games, the following are particularly important: accurate player action registration; predictability of the combat system; animation stability; and high performance in dynamic scenes. The Unity platform and C# language enable the creation of flexible and scalable solutions, but a well-thought-out modular architecture and optimization of key components are essential for a high-quality product. The goal of this work was to develop and optimize software modules for the fighting game "Brain for Brainrot" in Unity using C#. The plot centers on the player's confrontation with out-of-control artificial intelligence. The player controls a digital fighter, completes PvE challenges, battles bosses, unlocks new characters, and participates in PvP battles. Key tasks in creating the game platform: (i) designing the combat system architecture; (ii) implementing modules for controlling characters and combat states; (iii) creating subsystems for leveling up and interacting with characters; (iv) optimizing performance for rich gameplay. The solution's implementation consisted of the following. Development was conducted in Unity, using object-oriented and component-based approaches. The project integrated the following: (i) movement and input processing modules; (ii) combat logic (hits, blocks, combos); (iii) damage and stats calculation system; (iv) passive skill and progression subsystem; and (v) game state management module (coordinating transitions between PvE, PvP, story episodes, and boss battles). This approach provided a convenient decomposition, simplified the addition of new characters, customization of their parameters, and further expansion of the game's content.

The Influence of the Operating Temperature of the Gas Sensor on the Temperature of Its Housing

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The operating temperature of the gas sensor reaches 200 – 400 °C. However, the gas sensor housing should not become excessively hot. Therefore, it is important to understand the effect of a gas sensor microheater, heated to 268 °C. The microheater, which is based on a 1.5 × 1.5 mm² aluminum oxide substrate with a metal oxide gas-sensitive film, has the sensor housing temperature. In this study, the gas sensor microheater was heated to 268 °C. The temperature of the sensor housing, its contacts, and the retaining manifold were then measured. A

HIKMICRO HM-TP23-10VF portable thermal imaging camera was used for the study. A gas sensor in a TO-39 housing was used as an experimental sample. The experiment was conducted at an ambient temperature of 22.7 °C and a humidity of 24.6 %. The sensor microheater was powered using an adjustable laboratory power supply with a voltage of 1.924 V and a current consumption of 82 mA. The calculated temperature of the sensor microheater was 268 °C. After 20 minutes, a thermal imaging scan of the detector surface was taken in open air. Figure 1 shows the temperature reliefs of the sensor microheater (Fig. 1a), the side part of the housing (Fig. 1b) and the back side of the sensor housing after its placement in an aluminum manifold (Fig. 1c). Studies have shown that the front of the sensor exhibits a pronounced thermal profile of the heated chip and its conductive contacts. The maximum temperature on the side of the housing was no more than 33.5 °C. The maximum temperature (41.5 °C) was recorded at the contact group exit. After placing the sensor in an aluminum manifold without forced air circulation, the rear of the housing reached a maximum temperature of no more than 29.1 °C. Thus, measurements have shown that while the sensor heats up to 268 °C, the housing of the TO-39 detector does not exceed 41.5 °C, significantly expanding the range of materials used for detector holders and sealing the detector in the holder.

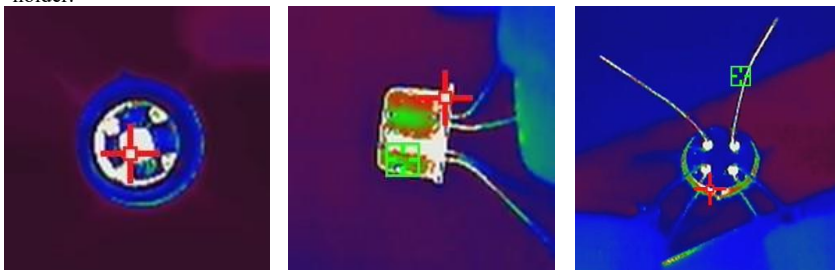


Fig. 1. Temperature reliefs of the sensor microheater (a), side part (b) and back side of the sensor housing (c)

Features of the Formation of Acoustic Waves in Elastography

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Viscoelastic models assume that soft tissue is a solid (single-phase) medium and do not account for fluid motion within the tissue. Alternatively, tissue can be considered as consisting of a porous solid phase and a fluid phase that resides within the pores of a solid matrix. This approach to elastography, called poroelastography, is based on the poroelastic model developed by Biot [1]. In general, an isotropic mechanical body can be characterized by the spatial distribution of its viscoelastic parameters. In viscoelastic tissue, there is a time delay between the application of a force and any resulting displacement. In a dynamic regime, when a force is applied over time, the evolution of stress over time provides information about viscosity. This requires knowledge of the relationship between the time course of stress application and the time constants of the tissue response [2]. The relevance of studying the

propagation of transverse (shear) waves in layered structures is driven by the development of shear wave elastography (SWE) methods. Biological tissues such as skin, vessel walls, or parenchymal organs with capsules often have a layered structure, where mechanical properties change abruptly with depth [1, 3]. Reconstructing the elastic modulus requires considering the influence of layer interfaces on wave dispersion [3]. Let us consider the problem of propagation of a harmonic shear wave in a packet of NN horizontal layers. The coordinate system is chosen such that x-axis is directed along the wave propagation direction, and z-axis is perpendicular to the layers (depthwise) [4]. Within the framework of the linear theory of elasticity for an isotropic medium, motion is described by the Navier-Cauchy equation. For a transverse wave, polarized along the y-axis (SH wave), the displacement vector has the form $\mathbf{u} = (0, u_y(x, z, t), 0)$ [5].

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Analysis of the Propagation Processes of Transverse Waves in Bio Tissues Considering the Nonlinear Strain

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Most diseases in the human body that result in structural changes in organs and tissues are currently not susceptible to early diagnosis. The organs are most susceptible to cell replacement include the liver, pancreas, mammary glands, and thyroid gland. Changes in organ structure can result from dysfunction of body systems, and the changes themselves can also disrupt normal organ function. Furthermore, over time, structural changes can become malignant. For example, fibroadenoma of the breast occurs in approximately 35% of women under 35, and breast cancer is one of the three most common types of cancer [1]. Acoustic methods are the most harmless non-invasive diagnostic methods. The main problems with early disease diagnosis stem from the fact that these methods are based on the principles of linear acoustics and have several shortcomings. The most important of these is the low information content of these methods in the early stages of the disease [2]. Using nonlinear

effects, arising from the propagation of acoustic waves in biological tissues, can improve the accuracy of tumor detection and localization. In this case, in addition to linear characteristics, the acoustic nonlinear parameter of the medium serves as an information parameter. Our study examines the propagation of a low-frequency transverse acoustic wave in biological tissue, as well as the formation of harmonic components, depending on changes in the nonlinear parameter in the medium [3]. One promising acoustic method for studying the structure of human organs and tissues is elastography, which is based on assessing changes in the propagation velocity of a transverse acoustic wave due to changes in tissue stiffness [4]. To assess the degree of nonlinear properties of various biological tissues, we will examine the propagation of a low-frequency transverse acoustic wave and its interaction with the third harmonic [3]. To describe the processes of propagation of transverse waves in solids from the viewpoint of nonlinearity, it is necessary to begin with the consideration of viscoelastic models of biological tissues and their conversion to a form, containing elements that exhibit nonlinearity of deformation processes [3, 5].

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Development of Large-Area Flexible CsPbBr₃ Perovskite Quantum Dot LEDs

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The development of lightweight and design-flexible display technologies has become an important trend, driven by the growing demand for portable and wearable electronics [1]. Perovskite quantum dots (PQDs) have emerged as a promising material for next generation displays due to their high colour purity, wide colour gamut, and high carrier mobility [2]. In this study, Zn²⁺-doped quantum dots were synthesised via a hot-injection method, combined with ligand exchange and surface passivation strategies. This resulted in high-quality emissive materials with a photoluminescence quantum yield (PLQY) of up to 90% and a narrow full width at half maximum (FWHM) of 20.1 nm. The fabrication of all-inorganic CsPbBr₃ perovskite quantum dot flexible light-emitting diodes (FPQLEDs) was achieved by utilising polyethylene naphthalate (PEN) as the flexible substrate. The resultant devices exhibited both high efficiency and excellent mechanical stability, with a maximum luminance of 33,308 cd/m² and an external quantum efficiency (EQE) of 1.29%. Mechanical reliability was verified, using a self-developed automated bending test system, where the devices retained 68% of their initial EQE after 5,000 bending cycles at a bending radius of 10 mm. In addition, large-area flexible devices with an emitting area of 4 cm² were demonstrated, highlighting the significant potential of this fabrication approach for future large-area flexible display applications (Fig. 1).

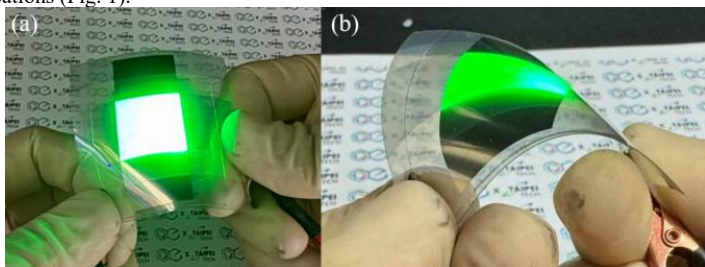


Fig. 1. Photograph of large-area flexible device: (a) without bending (b) after bending.

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Correlation of Ultrasonic Velocity with Plastic Deformation Stages in Metals

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According to the results of recent studies conducted on Rayleigh and Lamb waves [1], the acoustic wave velocities in metals have been found to be significantly affected by plastic deformation [2, 3]. The verification of these relationships using bulk waves was performed. Experimental data on the velocities of bulk longitudinal and transverse acoustic waves were obtained under uniaxial monotonic tension of the aluminum specimens. Stage-like wave velocity behavior, corresponding to the stages of plastic deformation of the metal was observed. The stages of strain hardening, necking, and fracture were identified, using ultrasonic measurements. Systematic errors, arising during ultrasonic testing were analyzed. To correct them and to ensure correct interpretation of acoustic diagnostic results, a calculation algorithm was developed. It makes it possible to determine the propagation time of acoustic wave packets through the thickness of prismatic metal specimens. The obtained results can be used to investigate plastic deformation in metals by nondestructive testing, using bulk shear and longitudinal waves.

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Modeling the Acoustoelastic Effect on Linear Viscoelastic Materials

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The acoustoelastic effect, which is used for the determination of the stress state of metals, is traditionally described, using the Murnaghan nonlinear elastic model and equations of nonlinear elasticity theory [1]. However, theoretical estimates, obtained using this approach, are found to be an order of magnitude lower than those observed in rolled metals [2]. For the correct interpretation of nondestructive testing results, a mathematical description of the experimental observations is required. The work is devoted to the application of viscoelastic models of nonlinear material mechanics for the description of the acoustoelastic effect. In this approach, the dependence of wave velocities on the magnitude of applied strains is found to be a first-order function, which corresponds to experimental values. The problem of propagation of longitudinal and transverse acoustic waves was solved for different rheological models. Relationships were obtained for the phase and group velocities of wave packets, simulating propagation of ultrasonic signals through the thickness of the diagnosed material. The obtained equations can be used to estimate the influence of stresses and strains on the change in acoustic wave velocities against a background of other factors, such as material damage or inhomogeneity of mechanical properties [3].

Acknowledgement. The research was carried out with the financial support of the Russian Science Foundation, Project No. 25-29-01480.

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Game Mechanics for the Adventure Game "Roots" in Unreal Engine 5

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Developing horror games requires special attention to how the player interacts with the virtual world. Unlike action or puzzle games, where mechanics are aimed at overcoming obstacles, horror projects must simultaneously instill a sense of anxiety, insecurity, and curiosity in the player. Unreal Engine 5 provides developers with a wide range of tools to achieve this from photorealistic graphics, powered by Lumen and Nanite to a flexible visual scripting system.

However, the simplicity of implementing individual features does not guarantee a high-quality result: the key factor is the careful design of the connections between mechanics, their balancing, and their adaptation to the player's psychological perception. The objective of this research is the design and software implementation of a set of game mechanics for the adventure horror game "Roots," running on Unreal Engine 5. Developed mechanics should create an atmosphere of suspense, encourage exploratory behavior, and generate tension through the character's limited capabilities and the need to avoid direct confrontation. The following tasks were addressed during the research: (i) analyzing existing solutions in the field of horror mechanics; (ii) creating an architecture for interaction with environmental objects; (iii) developing enemy behavior, focused on searching and pursuing the player; (iv) implementing an event system managing the story context; and (v) evaluating the performance and optimization of the developed solutions. Development was carried out in Unreal Engine 5.6. The logic of the mechanics is implemented in C++ and using Blueprints. NPC behavior is built on Behavior Trees in conjunction with the Environment Query System (EQS), which enabled adaptive player search, based on the level's terrain. Assets from the Quixel Megascans library and built-in landscape design tools were used to create the environment. Version control was maintained via Git with the Git LFS extension for large binary files. The developed mechanics were tested on a group of three players with experience playing horror games. Testing showed that the combination of limited player options (lack of weapons) and adaptive enemy behavior creates a sustained sense of tension. The average uninterrupted play session lasted 45 minutes, indirectly demonstrating a high level of engagement. In surveys, participants noted that the greatest fear was not caused by jump scares and loud noises, but by moments when the player realizes they could have just been spotted. This confirms the effectiveness of the developed stealth system. During this work, a set of mechanics was created for the adventure horror game "Roots," running on Unreal Engine 5. Systems for environmental interaction, stealth with adaptive AI, and narrative control through the environment were implemented. The optimization ensured stable performance on the target platform (80 FPS at a resolution of 1920×1080). The results obtained can be used as a basis for further development of a full-fledged game product, as well as teaching material for courses related to the design of game logic and artificial intelligence in video games.

Shape Memory Effect of Cu-Al-Ni Ion Plasma Coatings under Sliding Friction

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Alloys with a shape memory effect (SME) have been actively studied for the past several decades. However, due to the complex mechanisms of phase transitions and their dependence on several external and internal factors, research into this effect remains relevant. Metals with SME do not exist, and the same alloy can be produced, using various technologies, not just by fusing components. In this regard, one of the important factors determining SME is the alloy creation technology. Such a specific technology as ion-plasma synthesis automatically brings into consideration the size factor, since it forms an alloy in the form of a micrometer-thick

coating, typically with an ultrafine or nanocrystalline structure. This work investigates vacuum ion-plasma coatings of the Cu–Al–Ni system with SME under sliding friction conditions for the effect of SME on coating wear. Thus, this study considers a three-parameter problem, including the influence on the SME of: (i) vacuum ion-plasma deposition technology; (ii) the dimensional factor of coating structure; (iii) complex coating loading conditions during sliding friction tests. The studied coatings with a thickness of 6.5 – 7.4 μm , manufactured of a copper-based alloy with 14 wt.% Al and 4 wt.% Ni, were formed by vacuum ion-plasma synthesis on a substrate of 40CrNi medium-carbon low-alloy structural steel. The coating structure was studied, using a high-resolution dual-beam scanning electron microscope with the production of cross-sections in the coating surface. The mechanical properties of the coatings were determined by continuous indentation, which also revealed the presence of a shape memory effect in the studied coating. Tribological characteristics, namely friction coefficient μ and wear intensity J were chosen as a criterion for assessing the effect of the stressed state of the coating on the shape memory. Experimental values of μ and J were obtained in standardized sliding friction tests, using the ball-on-disk scheme. Based on the analysis of the results obtained, a very low friction coefficient μ for CuAlNi coatings was found, ranging from 0.15 to 0.30. However, their wear resistance was also low. In terms of this indicator, the studied Cu–Al–Ni coatings are an order of magnitude or more inferior to ion-plasma nitride or carbon diamond-like coatings [1 – 3]. This result does not allow us to recommend CuAlNi coatings for practical use in industrial friction units with stress in the contact zone, exceeding 500 MPa. Under such friction loads, the return of deformation due to the SME is insufficient to compensate for the deformation effect. In this case, the deformation in the CuAlNi coating rapidly accumulates during friction, and the coating experiences fatigue failure. The conducted studies have revealed another important result: the components of the CuAlNi coating demonstrate good compatibility during vacuum ion-plasma spraying. Since the SME is highly dependent on the chemical composition of the alloy, the compatibility of the components allows for their specified concentrations in the coating, which are necessary for the implementation of the SME using both magnetron and cathodic arc evaporation methods.

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Investigation of Energy Consumption for Preheating Oil Prior to Transportation

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The problem of transporting high-viscosity oils has acquired particular significance in recent years due to the depletion of light, low-viscosity oil reserves and the increasing development of heavy hydrocarbon fields. The high viscosity of such media leads to increased hydraulic losses during pipeline transportation. The most common method for reducing viscosity is preheating the oil before pumping it into the pipeline; it is characterized by substantial thermal energy costs. In this regard, it becomes necessary to justify the optimal temperature regime for transportation that minimizes total operating expenses [1, 2]. Within the framework of this study, an approximation was performed on calculated data obtained from a numerical experiment conducted in the Mathcad software to determine the thermal power, required to heat oil to a specified temperature before pumping it into the pipeline. The study was carried out for three oil fields, characterized by different physicochemical properties, which necessitates an individual approach to selecting their heating temperature during pipeline transportation. The fields considered were: Kotur-Tepe (Turkmenistan), Ozek-Suat (Russia), and Uzen (Kazakhstan). For each field, the kinematic viscosity of the oil was determined, using the Reynolds – Filonov formula, with the heating temperature varied in the range from 20 to 70 °C. Subsequently, the thermal power required to heat the oil was determined as

$W = \rho C_v Q \Delta T$, where ρ and C_v are the density and specific heat capacity of the fluid, Q is the oil flow rate, and ΔT is the difference between the initial ($T = 10$ °C) and final temperatures of the energy carrier. The calculated data were approximate in MS Excel using trendlines [3]. Five types of extrapolations were performed: linear, polynomial, logarithmic, exponential, and power. The reliability of each type, in terms of evaluating the results of the predictions made, was determined based on the value of the root-mean-square deviation. The approximation of the numerical experiment results showed variability in the more reliable type of extrapolation for the fields under consideration. The constructed trendlines, along with the indicated reliability values, provide a clear representation of the optimal energy costs that ensure a reduction in hydraulic losses when pumping viscous oils through pipelines.

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Research on the Dependence of Oil's Kinematic Viscosity on Its Heating Temperature

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Due to the depletion of light crude oil reserves, significant efforts have been made in recent years to develop heavy hydrocarbon fields [1]. However, transporting these hydrocarbons via pipelines involves considerable hydraulic losses because of the high viscosity of such oils. One of the most common methods for reducing viscosity is preheating the oil before pumping it into the pipeline. This method, however, requires substantial thermal energy, which necessitates the selection of an optimal temperature regime for transporting the energy carrier through pipelines to minimize operating costs [2]. Within the framework of this study, a numerical experiment was performed using the Mathcad software package to determine the required oil heating temperature needed to achieve a specified viscosity. The study was conducted for three oil fields, characterized by different physicochemical properties, namely Kotur-Tepe, Ozek-Suat, and Uzen. The calculation equations were derived based on the Reynolds – Filonov formula. The coefficient k reflects in this formula the individual properties of fluid; it was determined for oil from each field, using the equation [3]: $k = \frac{\ln(\nu_1/\nu_2)}{T_2 - T_1}$, where ν_1 and ν_2 are the experimental viscosity values of the oils from the fields under consideration at temperatures T_1 and T_2 , respectively. The calculation results are presented in the form of graphical dependencies, showing the change in heating temperature of the energy carrier, required to achieve a specified kinematic viscosity (in arbitrary units relative to the viscosity of the given oil at 10 °C). The constructed graphical dependencies make it possible to analyze various technological regimes for transporting the energy carrier through pipelines to minimize operating costs and ensure the operational reliability of pipeline systems.

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Unstrained Bond Model Analysis of PMN-Based Solid Solution Structures

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Lead magnoniobate (PMN) is a classic relaxor ferroelectric, whose order-disorder phase transition in the *B*-sublattice has a unique character due to the stoichiometry of the Mg^{2+} and Nb^{5+} cations (1:2 ratio). Minimizing the lattice elastic energy is key to analyzing the order-disorder phase transition in the *B*-sublattice of $A(B'B'')\text{O}_3$ perovskites within the framework of the relaxed-bond model. The relaxed-bond model is based on a comparison of ideal interatomic distances and actual distances in the crystal lattice. The idea behind the simulations, using the relaxed bond model is that the ionic system tends to achieve a cation distribution that minimizes the deviation of the $B' - \text{O}$ and $B'' - \text{O}$ bond lengths from their equilibrium values. It is well known that in disordered $A(B'B'')\text{O}_3$ systems, the cations in the *B*-position are initially distributed statistically (disorder). If the difference in ionic radius and/or charges of the cations in the *B*-sublattice is large, this creates strong local stresses in the lattice structure and initiates the conditions for the transition of the system to an ordered state. In PMN, the ionic radius of Mg^{2+} (0.72 Å) is significantly larger than that of Nb^{5+} (0.64 Å). Thus, ordering arises in the structure, which allows it to relax, alternating "large" and "small" BO_6 octahedra, with cationic centers at the *B*-sites of different radius. The change in the average radius of the *B*-site cations affects the stability of the entire ionic framework. Local distortions around different *B*-type cations can induce micro-ordering. A significant charge difference (for example, ions of Mg^{2+} и Nb^{5+}) in the *B*-site creates an electrostatic stimulus for ordering, which the relaxed-bond model interprets as minimizing Coulomb stresses, while the charge difference between the *B*-sublattice cations (+2 and +5) is enormous. Therefore, 1:1 ordering in nanoregions creates a local excess negative charge. To compensate for this charge, the boundaries of the nanoregions must be surrounded by an excess of Nb^{5+} ions. Thus, according to the relaxed-bond model, disorder in the *B*-sublattice leads to a "distribution" of $B' - \text{O} - B'' - \text{O}$ bond lengths. If the dispersion of these lengths exceeds a critical threshold, the system becomes thermodynamically unstable and either disintegrates or becomes ordered. The presence of oxygen vacancies in perovskites radically alters the energy of the cationic sublattice, as the $B - \text{O} - B$ -ionic chain is broken, and the vacancy allows ions in adjacent *B*-sites to shift away from the octahedra centers, minimizing local stress without requiring long-range ordering. The study subjects were $\text{Pb}(\text{Mg}_{1/2}\text{Nb}_{1/2})\text{O}_{2.75}$, $\text{Pb}(\text{Mg}_{3/4}\text{Nb}_{1/4})\text{O}_3$ and $\text{Pb}(\text{Mg}_{1/4}\text{Nb}_{3/4})\text{O}_3$ samples [1, 2]. In this work, we analyze possible actively discussed reasons for the formation of local superstructural ordering, discovered by many researchers on a scale up to 10 nm due to changes in the *B*-sublattice and the presence of oxygen vacancies in the structure [3].

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Modeling the Nanostructural Features of Cationic Lattices in Non-stoichiometric PMN-based Solid Solutions

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Compounds with the perovskite structure $\text{Pb}(B'B'')\text{O}_3$ are historically among the first perovskites, finding application in modern electronics due to their unique set of observed physical properties. As is known, the ferroelectric properties of oxygen-octahedral structures are determined by the presence of *d*-elements in the octahedral oxygen environment. This statement describes the classical model for the occurrence of spontaneous polarization in crystals with the perovskite structure and related compounds. However, the role of cations, occupying cuboctahedral positions in oxygen-octahedral structures is less well defined in the observed physical properties. Cations with sp^2 states determine the sp^2 hybridization of states in cation-oxygen systems. If a transition metal (e.g., Nb^{5+}) is located at the center of the oxygen octahedron, as in lead magnoniobate (PMN) and related materials, then it is «favorable» for this ion to shift from the center of the octahedron toward one of the oxygen ions, which causes an electric dipole. However, if the oxygen octahedral structure of perovskite contains vacancies, the displacement mechanism becomes more complex. In Pb^{2+} ions ($6s^2 6p^2$), the 6s-electron orbitals are more stable than the 6p-electron orbitals. The outermost $6s^2$ electron orbital has a relatively large radial extension, which increases the ionic radius and reduces the degree of overlap of the 6p orbitals with the orbitals of the nearest neighboring anions. This reduction in overlap leads to a decrease in the strength of the *A* – *B* cation bond in the *A*- and *B*-sublattices. The hybridization of the 6s and 6p orbitals, which involves the energy splitting of these orbitals, leads to polarization of the electrons in the outer orbitals, so that the effective ionic radius is significantly smaller on one side of the cations than on the other. This allows for the formation of a much stronger bond on one side of the cation, and the energy generated by this bond can be greater than the hybridization energy. Because of this reason, Pb^{2+} ions stabilize in most crystals with asymmetric anionic coordination. In this work, we analyze possible actively discussed reasons for the formation of local structural ordering, discovered by many researchers on a scale up to 10 nm due to crystal-chemical ordering of *B*-position atoms. The objects of this study are ferroceramic samples of non-stoichiometric PMN, which were obtained by solid-phase synthesis [1, 2]. All samples were studied at room temperature by X-ray diffraction analysis on a DRON-3M diffractometer (CuK_α radiation, Ni filter) with Bragg-Brentano focusing ($\theta - 2\theta$). Structural parameters were refined, using the PowderCell 2.4 software program.

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Implementation of a Digital Model of Thermal and Hydrodynamic Characteristics of a Horizontal Section of a Stopped Pipeline

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Computer modeling makes it possible to make well-founded design decisions through accurate assessment of the thermal and hydrodynamic characteristics of design objects. One of the effective tools for preliminary evaluation of these characteristics is simulation modeling within an engineering analysis system based on advanced digital solutions. This study presents a mathematical model of thermal and hydrodynamic processes in a stopped pipeline, including the heat conduction equation, the hydrostatics equation, as well as initial and boundary conditions for temperature and pressure distribution [1, 2]. The ANSYS Workbench software is used to implement the model; it is a universal finite element analysis system that allows building a three-dimensional geometry of the pipeline, considering insulation layers, pipe material, properties of the fluid inside it, and simulating transient cooling processes under the influence of ambient temperature (soil, air, water) [3, 4]. As a result of the computer-based solution, using SpaceClaim and Extrude procedures, a two-dimensional axisymmetric model of the pipeline section and graphs of changes in fluid pressure with variations in the temperature of the energy carrier in the range from 35 °C to 50 °C were obtained. The performed computer modeling, together with a numerical experiment, carried out in the Mathcad environment, provides a detailed understanding of the process under consideration. This makes it possible to scientifically manage technological processes of oil and petroleum product transportation to ensure energy efficiency and reliability of pipeline transport systems.

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Angle-Resolved Phase-Sensitive SPR Sensor Based on Four-Step Phase-Shifting Interferometry for Goos-Hänchen Shift Detection

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Surface plasmon resonance (SPR) is a label-free optical sensing technique highly sensitive to refractive-index variations at the metal–dielectric interface. To further enhance phase-resolved sensitivity, this work integrates four-step phase-shifting interferometry (PSI) into an angle-resolved SPR configuration (see Fig. 1) for analyzing the Goos-Hänchen (GH) shift.

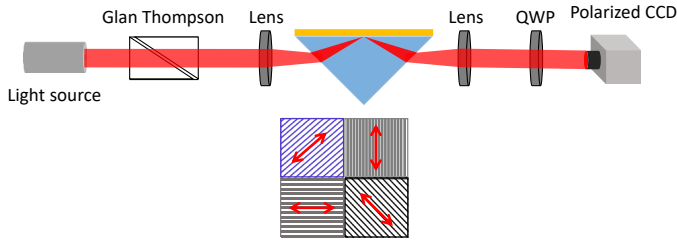


Fig. 1. Schematic of the PSI-based SPR setup integrating polarization camera for single-frame phase acquisition

The proposed homodyne interferometric system employs a polarization camera that simultaneously captures four phase-shifted interference images in a single measurement, enabling one-shot phase reconstruction without mechanical scanning. The reconstructed phase spectra, fitted with a complex Lorentzian model, reveals sharp phase jumps at the SPR resonance and a corresponding GH shift peak, validating the phase-gradient amplification effect. Experimental results show a linear GH response to refractive-index variations up to $\Delta n \approx 2.8 \times 10^{-4}$. In addition, a proof-of-concept biosensing experiment using miRNA hybridization confirms that molecular interactions can be directly monitored through GH shift variations. This PSI-based SPR system provides a compact, stable, and phase-sensitive approach for real-time optical and biosensing applications.

Adaptive Control of a Robotic Manipulator with Nonlinear Dynamics Using Hybrid Neural Network Control Loops

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Current research in the field of manipulator robot control aims to account for the high degree of nonlinearity of dynamic processes, parametric uncertainty, and the influence of external disturbances. This study is focused on adaptive control systems that integrate high-performance neural network models into the classical PID control law to capture the temporal dynamics of tracking errors and perform adaptive correction of control signals, thereby compensating for the effects of nonlinearities and unmodeled disturbances. The control objects considered are rigid multi-link manipulators, characterized by nonlinearities in their mathematical models and influenced by distortions of the control torque due to sensor noise and mechanical factors, such as slipping. The goal of control is to accurately track a complex trajectory represented by a linear combination of harmonics at different frequencies. The proposed solutions follow the principle of function separation: a baseline PID loop with fixed coefficients ensures the stability of the closed-loop system, while a neural network add-on compensator generates additive corrections in the PID controller channels. The parameters of these hybrid controllers were tuned, using metaheuristic optimization algorithms. Experiments evaluate different input data structures and neural network compensator architectures. The study identifies optimal learning algorithm settings that ensure stable, efficient controller performance within the manipulator control loop.

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Development of an Automated System for Monitoring and Sorting Vietnamese Fruits, Using Processed Signal from Integrated IR and RGB Colour Sensor

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This research paper discusses the development of an automated system for monitoring and sorting Vietnamese fruits, using integrated IR sensors, RGB colour sensor. Unlike complex and costly image processing methods that require high performance configuration, the

proposed system employs a TCS3200 sensor to convert the colour of light reflected from object into a frequency signal. This is a more cost-effective and simplified approach that maintains high accuracy in colour recognition. Additionally, the system incorporates automatic weighing and counting, enabling fruit size estimation based on specific gravity. The design includes a 3D-printed dark box to minimize environmental light interference while ensuring adaptability for customization and upgrades in diverse practical applications.

Development and Implementation of Visual Components for a Horror Game

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In the modern computer games industry, visual style plays a decisive role in creating atmosphere, especially in the horror genre. For 2D projects, the most expressive solution is hand-drawn graphics, in which every element from background to characters is created by hand and maintained in a consistent artistic style. Unlike technologically intensive approaches, this approach emphasizes linework, color schemes, frame composition, and frame-by-frame animation, allowing for a unique mood without the use of complex visual effects. The goal of this work is to develop and implement a set of visual solutions for a 2D horror game, ensuring the creation of an atmospheric, recognizable look for the project through hand-drawn graphics, animation, and minimalist effects. The tasks included (i) creating characters, enemies, and backgrounds in a unified, signature style; (ii) developing frame-by-frame animation for key objects; (iii) implementing simple visual effects (particles, color filter overlays, sprite transformations), synchronized with game events; and (iv) optimizing the graphics for stable performance. Development was carried out, using standard 2D graphics tools. All visual content was created by hand: background, characters, enemies, environmental objects, and interface elements were drawn. The total number of visual components exceeded 25, including sprite sets for animation and effects. All elements are united by a single artistic language, namely a dark, slightly grotesque style with an emphasis on contrasting silhouettes, shading, and a muted color palette, creating a sense of unsettling, almost fairytale-like menace. Simple yet effective techniques were used to develop the visuals for the key gameplay mechanic, that is the cyclical enemy appearances. A few seconds before the enemy appears, the screen gradually darkens with a translucent dark mask, causing sprites to shimmer slightly and a film-like grain effect appears. The moment of the enemy's appearance is accompanied by a short animation of the transformation of the sprite and the appearance of a cloud of particles, namely simple circles, scattering in all directions. The intensity of these visual cues varies, depending on the current stress level, creating an escalating tension without the need for complex technology.

Microstructural Features and Complex Electromechanical Parameters of Lead-Free Ferroelectric Ceramics

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Interest in lead-free piezoelectric ceramics is primarily driven by growing environmental and public health concerns, associated with currently used lead-containing piezoceramic compositions, such as PZT (lead zirconate titanate), PT (lead titanate), and lead metaniobate. Changes in environmental legislation over the past two decades have stimulated intensive research into alternative lead-free materials [1]. However, it appears highly unlikely that a new lead-free piezoceramic system, comparable to PZT in terms of the diversity of crystal structures and solid-solution compositions and possessing piezoelectric properties close to those of the PZT system, will be discovered soon. Therefore, current research efforts are focused on identifying and optimizing more efficient piezoelectric compositions, based on established lead-free systems, as well as conducting detailed investigations of properties critical for practical applications to enable the mass production of lead-free piezoceramics [2]. Among currently known alkali niobate-based lead-free ceramics, solid-solution ceramics, based on sodium-lithium niobates (Na, Li)NbO₃, exhibit the greatest practical interest for high-frequency applications. This work presents the results of an experimental study of microstructural features, as well as the complex dielectric, elastic, and piezoelectric parameters of ferroelectric piezoceramics, based on (Na, Li)NbO₃ solid solutions. The samples of lead-free ferroelectric piezoceramics with the composition Na_{0.86625}Li_{0.12375}Sr_{0.01}Nb_{0.988}O₃ were prepared, using the hot-pressing method. To evaluate phase distribution, grain structure, and ferroelectric domain structure, X-ray diffraction analysis and piezoresponse force microscopy (PFM), supplemented by scanning electron microscopy (SEM), were employed. A complete set of complex elastic, dielectric, and piezoelectric parameters was measured and analyzed, using the PRAP automatic iterative method. The frequency dependencies of the complex electromechanical parameters of the experimental samples were measured over a frequency range up to 90 MHz. Microstructural and domain structure studies confirmed the high quality of the piezoceramics structure. As a result of this comprehensive investigation, a full set of complex elastic, dielectric, and piezoelectric parameters was obtained. It was demonstrated that the lead-free piezoceramics possess a unique combination of electromechanical properties and are characterized by low attenuation and minimal dispersion of ultrasonic waves across a broad frequency range, making them highly suitable for high-frequency ultrasonic transducers in medical equipment and non-destructive testing applications.

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Investigation of the Effect of Ultrasonic Treatment on the Viscosity Characteristics of Heavy Oils

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Currently, heavy oil fields account for many global oil reserves; however, the share of heavy oil in total oil production remains relatively low, less than 20%. This is primarily due to challenges, associated with the extraction, transportation, and refining of heavy crude oils, which stem mainly from their high viscosity. Various methods are employed to reduce the viscosity of heavy oils, including hot water flooding, cyclic steam stimulation, steam-assisted gravity drainage (SAGD), solvent injection, and *in-situ* combustion [1]. One promising approach for reducing the viscosity of heavy oil is low-frequency ultrasonic treatment [2]. Under ultrasonic exposure, certain intermolecular bonds within the high-molecular-weight compounds, presenting in heavy oil, are disrupted, resulting in a significant reduction in oil viscosity. This study presents the results of an experimental study on the effect of ultrasonic treatment on the kinematic viscosity of highly viscous petroleum products, conducted via direct measurements. Fuel oil samples were subjected to direct exposure to high-intensity ultrasound at varying power levels and durations. Their kinematic viscosity was measured before and after treatment. Additionally, the viscosity relaxation behavior of the treated samples was monitored over a period of 10 days. Kinematic viscosity measurements were performed, using a calibrated VZ-246 viscometer. Ultrasonic radiation was generated by Langevin transducers, operating in the frequency range of 20 – 40 kHz. The transducers were excited by continuous sinusoidal signals of variable power, produced by a Tektronix AFG 3022B signal generator and amplified by a PA 400-5 amplifier (Precision Acoustics LTD). The study established dependencies of viscosity on ultrasonic exposure duration at fixed power levels, revealing a nonlinear and non-monotonic character of these relationships. It has been demonstrated that intense ultrasonic treatment of highly viscous petroleum products can reduce their viscosity by several times. Moreover, for most ultrasonic treatment regimens, reported in this work, the viscosity relaxation time of the treated petroleum products exceeds 10 days. This indicates that the application of high-intensity ultrasound can substantially mitigate the challenges, associated with the extraction and transportation of heavy crude oils, which are primarily caused by their high viscosity. The obtained results can be applied to optimize ultrasonic treatment parameters for the development of enhanced oil recovery systems and for improving the transportation efficiency of heavy crude oils and petroleum products.

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Space-Time Symmetries and Gauge Invariance in the Geometric Theory of Evolving Defects: A Noether Current Approach to Configurational Forces

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The mechanical behavior of advanced materials and microdevices is often dominated by their defect microstructure. Dislocations, vacancies, and grain boundaries not only determine strength and ductility but also evolve under external stimuli such as mechanical load, temperature, and irradiation, leading to creep, fatigue, and degradation. The geometric theory of defects offers a profound continuum framework for describing such microstructures by introducing a non-Euclidean geometry on the material manifold, namely the metric and connection encoding local lattice spacings and incompatibilities, respectively. A key kinematic object in this description is the *implant field*, which maps the local stress-free configuration of a defective crystal to a fixed reference. While powerful for static analyses, the classical geometric theory lacks a first-principles dynamic law for how the material geometry (and hence the implant field) evolves under driving forces. In parallel, *configurational mechanics* identifies the Eshelby stress tensor and its divergence, that is the configurational force, as the thermodynamic conjugate to changes in material structure, such as defect motion or phase boundary propagation. However, the relations between these forces and the underlying geometric variables often remain phenomenological. Recently, a variational formulation for *static* incompatible elasticity was developed, where the implant field is included as an independent variable in the action, and Noether's theorem yields balance laws and conservation laws. This approach beautifully recovers the Eshelby stress as the canonical momentum conjugated to material translations. A natural and open question is: *Can this framework be extended to dynamics, providing a unified variational origin for both equilibrium equations and the kinetic laws of defect evolution?* To get closer to answering this question we develop a space-time (3+1)-dimensional formalism for the material manifold, treating time as an additional material coordinate. Within this framework, we construct a covariant action principle whose fields include both the deformation mapping and the time-evolving implant field. Application of Noether's theorem to the symmetries of this action yields conservation laws that naturally embody the dynamics of defects. Specifically, invariance under material space-time translations generates the canonical energy-momentum tensor, whose spatial divergence gives the standard Eshelby (configurational) stress tensor, while its time component governs energy balance, including the defect field's energy. Furthermore, we identify a gauge symmetry, associated with specific transformations of the implant field, reflecting the freedom in describing locally stress-free states. This symmetry leads to a novel conservation law, interpreted as the balance of defect flux. As a central result, the evolution equation for the implant field emerges not as a separate phenomenological postulate but as a component of the unified Euler–Lagrange equations in (3+1) dimensions.

The theory is applied to the problem of a spherical nanoshell, subjected to radially symmetric irradiation, where the buildup of point defects is modeled as an evolving field of material non-metricity. We compute the corresponding Noether currents and show how the radial configurational force drives the expansion of the damaged zone. This work establishes a fundamental link between the variational symmetries of a defective material and the thermodynamic forces, governing its microstructural evolution.

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Classical and Molecular Dynamics of Nanoscale MEMS Elements

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The miniaturization of electronic components towards micro and nanoscales has fundamentally shifted the paradigm of device design. While classical microelectronics often treats mechanical deformation as a negligible side effect, the integrated mechanical and electrical components in micro- and nano-electro-mechanical systems (MEMS/NEMS) operate in a regime, where these fields are intrinsically coupled. Phenomena such as stress-induced changes in charge carrier mobility, electromagnetic noise, generated by mechanical vibrations, and the significant energy dissipation from these interactions can no longer be ignored. This strong thermo-electro-mechanical coupling, negligible at macroscopic scales, becomes a dominant factor, determining the performance, reliability, and power efficiency of modern hybrid systems from strain-engineered transistors and MEMS sensors to adaptive diffraction optics. Accurate modeling in this multi-physics landscape is a formidable challenge. Continuum-based approaches, reliant on numerous empirically determined tensor constants, fail to capture the atomistic origins of these scale-dependent phenomena. At the other extreme, purely *ab initio* quantum mechanical methods, while fundamental, remain computationally prohibitive for systems of engineering relevance. Molecular Dynamics (MD) emerges as a powerful intermediary, offering a pragmatic yet physically rigorous pathway. Unlike continuum mechanics, MD describes the system through a concise set of scalar interatomic potentials, providing a unified framework that derives complex macroscopic behavior, including the coupled multi-physics effects mentioned above, namely from the collective dynamics of particles. This work is dedicated to exploring the potential of this MD-based approach for analyzing the nanoscale behavior of hybrid material systems under operational stresses. While MEMS components are typically modeled as linear-elastic structures (a valid approximation for small displacements and low-cycle fatigue) their behavior fundamentally changes under finite deformations and dynamical loading. In these operational regimes, structures exhibit significant dissipative properties and complex non-linear dynamics, leading to a drastic alteration of their mechanical response, including a phase lag between stress and strain, and eventual performance degradation or failure. Accounting for these effects is paramount for the design of high-energy microdevices such as actuators, micromirror arrays, and diffraction gratings. Furthermore, these micro-objects are inherently hetero-structures, whose analysis must consider not only the atomistic nature of each material but also critical interfacial phenomena, such as lattice mismatch. This work specifically

addresses these issues by investigating the non-linear response and the evolution of phase-space dynamics in a silicon-aluminum heterostructure under dynamical loading, with a focus on the interplay between atomic-scale interface properties and macroscopic dissipative behavior. In the main body of this work, we focus on the results of an MD analysis, based on the Embedded Atom Method, of the dynamic response of a circular aluminum membrane on a silicon substrate under dynamical loading. The characteristic diameter of the membrane is three orders of magnitude larger than the lattice parameter, while its thickness exceeds it by approximately one order. The analysis of the obtained results will assess the influence of the non-linear nature of deformation and the accumulation of irreversible changes in the atomistic structure at oscillation amplitudes close to the ultimate limits. This will thereby characterize the limiting operational regimes. An important point for discussion is the evolution of the system's phase portrait, which demonstrates the system's dissipative nature in an integral sense, despite the local preservation of Hamiltonian dynamics.

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Designing Audiovisual Style and User Experience in a Store Management Simulator

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The current indie game market demonstrates a steady interest in the store management simulator genre. Projects such as Shop Titans, Moonlighter, and Recettear demonstrate that audiences value not only economic depth but also atmosphere, emotional feedback, and high-quality visuals. This study examines key approaches to designing audiovisual style and interfaces for the development of "No Time to Stop!", a robot rental and assembly store simulator. The author (K.G. Sandul) contributed graphic assets, UI/UX solutions, sound design, and musical score. The first key objective is to develop a coherent visual style that supports the player's imagination. Unlike many simulators, where graphics are utilitarian, "No Time to Stop!" developed a store prototype block, including models of spare parts (20+ variants), a basic robot, shelving, arena tables, and four customer types. Visual effects accompany key events: reputation changes, repairs, breakdowns, and achievements. This allows the player to intuitively read the state of the game world without relying on text cues, reducing cognitive load and increasing immersion. A second important aspect is the design of an auditory layer as the means of feedback and emotional reinforcement. An analysis of player personality types according to Bartle and BrainHex revealed that the leading personality types for the store management simulator genre are the "Achiever" and "Collector." For these players, auditory confirmation of actions (sounds of movement, interaction, receiving money, and rent expiration) is a significant anchor for engagement. The game features voice lines for each customer type (Elite Collector, Budget Seeker, Speed Racer), dynamic music that changes, depending on the store's reputation level, and SFX for breakdowns, repairs, and rewards. Experience from projects like Moonlighter shows that high-quality audio can significantly increase player retention.

Piezoelectric Properties of "Porous Piezoceramic – Polymer" Composites, Fabricated by Ultraviolet Stereolithography

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The additive manufacturing technology for 3D printing via ultraviolet (UV) stereolithography can be adapted to fabricate piezoelectric elements from "piezoceramic – polymer" composite materials. However, producing such composites involves several challenges. In this approach, a UV-curable resin serves as the non-piezoelectric matrix, while particles of porous piezoceramic act as the piezoelectric component. These particles are opaque to UV radiation; therefore, ensuring sufficient UV penetration depth into the composite is critical. This is achieved by optimizing the concentration of piezoceramic particles and incorporating UV-transparent particles into the polymer matrix, which promote uniform UV propagation throughout the entire matrix volume via multiple scattering of the radiation on the particles. The aim of this work was to investigate the feasibility of developing a piezoelectric composite, based on a UV-curable resin and macroscopic porous piezoceramic particles, suitable as a functional material for 3D printing of piezoelectric elements via UV stereolithography. Composite elements were fabricated, using UV-curable resin as the polymer matrix and porous piezoceramic particles (characteristic size is 1 mm) as the piezoelectric component. Porous piezoceramic was selected due to its advantages over conventional dense ceramic: superior acoustic impedance matching with the polymer matrix, tunable properties through porosity control, and enhanced machinability [1]. The fabricated elements had a diameter of 20 mm, and a thickness of 2 mm. Conductive paste electrodes were applied to both faces of the elements. Electromechanical characterization revealed that the longitudinal piezoelectric modulus of the composite elements reaches up to 75% of that of the initial porous piezoceramic. Simultaneously, the elements exhibit no pronounced resonant electromechanical behavior. This combination of properties makes them suitable for non-resonant acoustic applications, such as ultra-wideband ultrasonic receivers and pulsed ultrasonic transducers.

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Leakage Currents of Pt/Ba₂NdFeNb₄O₁₅/SrRuO₃(001)/MgO(001) Heterostructure

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When applying thin-film materials, conduction currents and heat losses play an important role. In this regard, it is important to study the mechanisms of electrical conduction to understand the sources of conductivity and minimize them. This work presents the results of the electrical conduction mechanisms study of a Pt/Ba₂NdFeNb₄O₁₅/SrRuO₃(001)/MgO(001) thin layer heterostructure. The thin film was deposited by high-frequency cathode sputtering technique. The obtained dependences (see Fig. 1) show that the resulting heterostructure exhibits mechanisms such as ohmic conduction, a current, limited by a spatial charge, and Poole–Frenkel emission. The characteristics obtained at low fields are discussed.

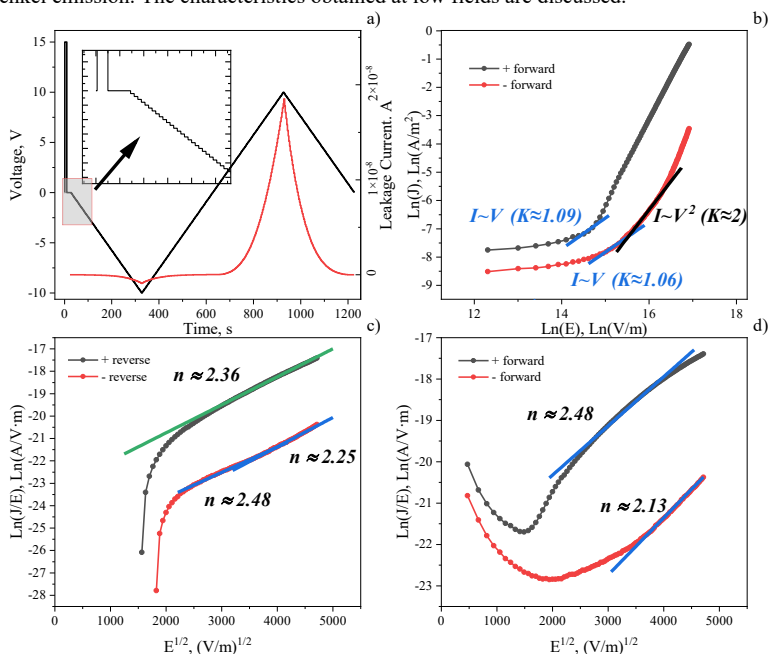


Fig. 1. Applied DC voltage and response of the BNFNO thin film (a), experimental data in space charge limited current (b), Poole–Frenkel (c, d) coordinates

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Designing Game Logic and Decision-Making Systems in the Roguelike Game "The Sinner's Dice"

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The roguelike genre has established a strong position in the computer game development industry due to its ability to provide high replay ability and gameplay variability. One of the key elements of such projects is the player's decision-making system under uncertainty. A key goal of game design is not eliminating randomness, but rather its intelligent integration into gameplay so that it enhances interest rather than diminishes player control. The goal of this work is to design game logic and a decision-making system for the roguelike game "The Sinner's Dice" that ensures a balance between randomness and control, creating a robust and engaging gameplay loop. To achieve this goal, the following tasks were defined: analyzing the genre's characteristics and existing solutions, developing core combat mechanics, designing a progression structure, creating an economic and rewards system, and integrating all elements into a coherent gameplay system. During the process, an analysis of games in a similar genre was conducted, which allowed us to identify several key factors, influencing player engagement: (i) the presence of meaningful decisions, (ii) limited resources, (iii) variability in progression, and (iv) clarity of core mechanics. Based on this, a project concept was developed that focuses on player interaction with a system of random events through limited control tools.

Comparative Experimental Electrodynamic Analysis of the Conducting Properties of Microwave Transmission Lines, Containing Chiral-Dependent Gammadion Pairs with Different Symmetries

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This study presents a brief analysis of chiral-dependent surface gammadion configurations, deposited on the reverse side of a conducting strip of a coplanar transmission line [1]. Two types of such structures were studied, namely with axial and point symmetry. The aim of these experimental studies was to compare their resonant frequencies, transmission and reflection coefficients, and determine their optimal applicability [1]. Fig. 1a shows a photo of the section of the transmission line with gammadion pair symmetry relative to the axis running between them perpendicular to the transmission stripe, while Fig. 1b shows the same pair but with point symmetry. Device characterization was performed on an Agilent Technologies N5230C analyzer. The results of key parameter measurements for these layouts are presented on Fig. 2. Based on the results obtained, the following conclusions can be drawn: (i) the resonant frequencies of these two designs are virtually identical (8.149 GHz and 8.363 GHz), but the

attenuation of the transmission coefficient S_{21} for the second design is 14.7% higher, i.e., a notch filter, based on this configuration, would be preferable; (ii) the first design with axial symmetry yields the best value for the input reflection coefficient S_{11} near the resonant frequency (8.005 GHz), demonstrating a slight advantage over the second design (since it differs from the resonant notch frequency by only 5.5%).

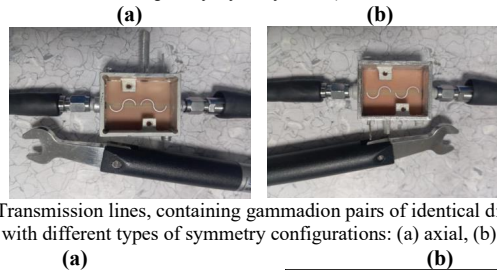


Fig. 1. Transmission lines, containing gammadion pairs of identical dimensions but with different types of symmetry configurations: (a) axial, (b) point

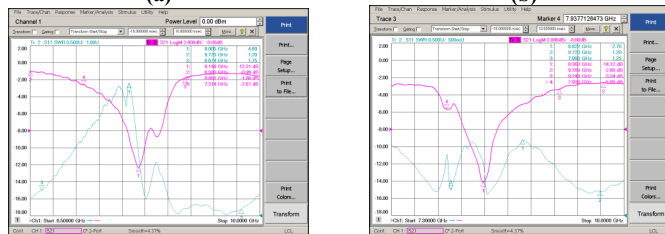


Fig. 2. Measurements of the transmission coefficient S_{21} (pink lines) and reflection coefficient S_{11} (green lines) for different configurations: (a) axial and (b) point symmetry

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Improving the Efficiency of Nitrogen Production with Required Purity Based on Automatic Control of Compressed Air Pressure Parameters

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In all modern systems, pressure stabilization is essential, regardless of the process complexity or type of production. It is necessary to reduce negative hydraulic resistance, namely at low pressure values, the process performance deteriorates, while at high pressure values, an emergency occurs, such as tank depressurization or complete rupture. Furthermore, many

sources indicate [1] that the primary parameter (over 40% of all emergencies) that causes spontaneous combustion, fires, and fire-explosion hazards in production is excess pressure [2]. In other words, the higher the pressure, the more potentially hazardous the system becomes and requires more careful operation and attention to both the possibility of ignition and the potential consequences of an explosion [3]. Therefore, based on the above, monitoring system pressure parameters is not only mandatory but also a complex production task. Thus, the relevance of this study is due to the introduction of an automatic air pressure stabilization system into a nitrogen production plant, in addition to reducing labor costs for maintenance and increasing reliability. It can provide a high technical and economic effect due to the optimization of the technological process and ensure the production of nitrogen with the required purity at the output [4].

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Environmentally Safe Hydrogel-Hydrochar Composites: from Synthesis to Practical Application

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In the context of ongoing climate change, water scarcity has become a critical constraint for agricultural productivity in arid and semi-arid regions. This study addresses the urgent need for innovative materials capable of optimizing the soil water regime. The main objective of this work is to develop environmentally safe hydrogel–hydrochar composite materials, designed to enhance soil moisture retention and regulate water availability under drought conditions. The synthesis of the composite material is based on the use of a biodegradable hydrogel. Gelatinization of starch (1:10 in water, 80 °C, 40 min) was followed by citric acid cross-linking at 50 °C (5 h, OS40-PRO Stirrer), ethanol washing/dehydration, and final vacuum drying at 60 °C to constant mass. The hydrogel was combined with hydrochar, derived

from alder wood chips waste and obtained, using a bench-top reactor 4520. The production conditions included a temperature of 200 °C, an exposure time of 90 minutes, and a water-to-biomass ratio of 1:10 (w/w). The base component is an environmentally friendly hydrogel, characterized by high biodegradability, non-toxicity, and excellent water-holding capacity. The formation of the polymer network in the composite is based on the creation of stable ester bonds between starch molecules and citric acid, which ensures a robust three-dimensional structure. During the cross-linking stage, hydrochar is introduced into the hydrogel, resulting in a hydrogel-hydrochar composite with an optimal component ratio of 1:1. This composite combines the high water-holding capacity of the base hydrogel with the sorption characteristics of the hydrochar. Due to the synergistic combination of the hydrogel's water-retention capacity and the sorption properties of hydrochar, the composite provides effective regulation of the soil water regime. It reduces evaporative moisture losses, maintains stable soil moisture throughout the experimental period, and creates favorable conditions for plant growth under arid conditions.

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GPU-based Block-sparse Solvers for Systems of Linear Equations, Arising from Finite Element Method

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Finite element method is widely used in multiple areas of modern engineering. Static problems are usually discretized into systems of linear algebraic equations (SLAE). Depending on the problem, matrices with different properties may arise. Mechanical problems produce at least positive semi-definite matrices, which can be solved using well-known methods. Discretization of coupled problems, combining mechanical and electrical properties, leads to semi-definite matrices that require some modifications in methods to achieve proper results. The size of matrices is also an issue since finite element models may produce large matrices with $10^5 - 10^6$ rows and high sparsity, which leads to direct methods, being highly inefficient, and renders iterative methods with preconditioning the most appealing approach. Preconditioners may sometimes perform partial inversion of the matrix, while maintaining the sparsity structure or may build upon the ideas of algebraic or geometric multigrid methods. In this study, we performed a series of numerical experiments with finite element models, obtained from ACELAN-COMPOS [1] package. Both 2D and 3D cases with different types of finite elements and combination of boundary conditions and physical properties were considered. The goal of the study was to implement and evaluate the set of operations, tailored specifically for working with block-sparse matrices on GPUs. These operations include matrix-vector multiplication and matrix-matrix multiplication. The data are organized into sets with atomic elements, being dense blocks of arbitrary size. The performance of these basic operations was measured and compared with modern CPU and GPU implementations for sparse matrices. For solving systems of linear equations, three methods were implemented: BiCGStab [2] (Biconjugate Gradient Stabilized method), GMRES [3] (Generalized Minimal

Residual method) and classical CG (Conjugate Gradient method) with different preconditioners. We also explored different approaches to the construction of the SLAE in ACELAN-COMPOS, described in [4], to evaluate the impact of nodal reordering and degrees of freedom grouping on the performance of the basic operations and overall solution process. Results were compared with well-known solvers and validated on a set of model problems.

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System-Analytical Approach to the Assessment of Composite Hazardous States under Unknown Group Composition of Objects

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In many complex technical and cyber-physical systems, hazardous conditions arise not from single components but from groups of objects, whose composition is not fully known in advance or changes over time. In such cases, traditional risk assessment methods, based on fixed system structure and isolated component analysis, may fail to identify composite hazardous states, especially when risk emerges from structural and functional interactions between objects rather than from their individual behavior [1, 2]. Previous work by the authors has introduced applied and system-analytical methods for failure risk assessment in control systems of complex objects and structurally uncertain cyber-physical control systems, with emphasis on handling indistinct, interval-valued, and partially observable input data [3]. Building upon these foundations, this report presents an extended system-analytical approach, specifically focused on the identification and evaluation of composite hazardous states under uncertainty in group composition. The system is represented as a multi-level structure comprising elements, groups, and a supersystem, where local object states, interaction links, and group-level configurations are jointly considered. Unknown or partially known group composition is treated as structural uncertainty and is modeled by sets of admissible group configurations, interval-valued estimates, and logical rules for reconciling incomplete

information. Within this framework, hazardous group states are defined as configurations in which the combined effect of objects and their interactions exceed a predefined safety threshold, even if individual objects remain non-critical when considered separately. The methodology includes the formalization of potentially hazardous configurations, the construction of group-level risk evaluation functionals, and an algorithm for detecting composite hazardous states under incomplete observability [4, 5]. The main contribution lies in the integration of structural uncertainty into hazard assessment at the group level, enabling more robust and interpretable risk evaluation for complex systems with dynamically changing group boundaries. The proposed approach is intended for application in decision-support systems for monitoring distributed technological installations, multi-component units, sensor networks, and other systems in which safety is determined by group configurations rather than by single components alone.

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Crystal Structure, Nanostructure and Dielectric Properties of the BiFeO₃/SrTiO₃/Pt/Al₂O₃(001) Bilayer Heterostructure

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Currently, research and development of multiferroic materials is a priority area of modern materials science. This interest stems from the significant potential of multiferroic materials for use in the development of non-volatile memory, spin-based devices, photovoltaic cells, and micro-electromechanical systems. Bismuth ferrite (BiFeO₃), which combines both ferroelectric and magnetic properties at room temperature, is considered one of the most promising multiferroics. Furthermore, in thin-film form, BiFeO₃ can withstand substantial strain, enabling property control through size effects. In this study, we consider the features of the crystal structure, nanostructure and dielectric properties of the two-layer heterostructure BiFeO₃/SrTiO₃, deposited by the RF cathode sputtering method on a Pt/Al₂O₃(001) substrate. According to X-ray diffraction data, the BiFeO₃/SrTiO₃/Pt/Al₂O₃(001) heterostructure was obtained without impurity phases, and the BiFeO₃ and SrTiO₃ layers were grown polycrystalline with a preferred orientation in the direction of the crystallographic axis [111]. Atomic force microscopy results showed that the sample surface is characterized by low roughness (~ 12.3 nm) despite the established polycrystalline structure of the BiFeO₃ film (Fig. 1). When studying the dielectric characteristics of a bilayer heterostructure, it was found

that the values of ε in the range of $T = 83 - 493$ K are 250 – 320, while the values of $\tan\delta$ are quite low (0.05 – 0.1).

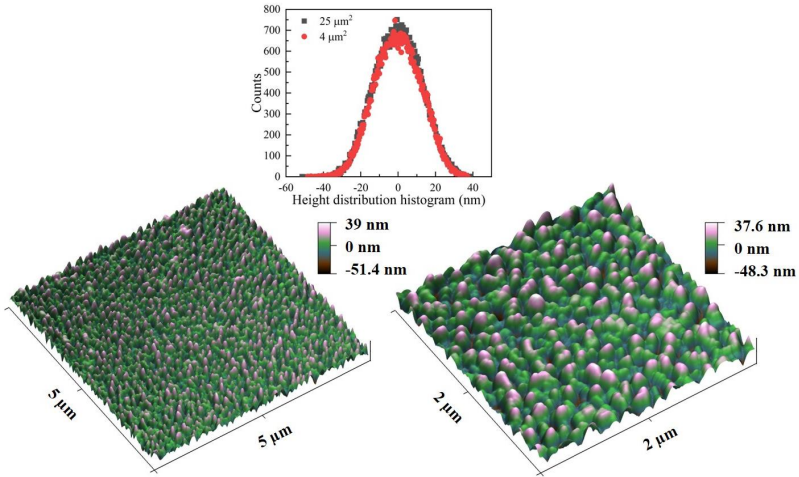


Fig. 1. Topography of BiFeO₃/SrTiO₃/Pt/Al₂O₃(001) surface areas of 25 μm² and 4 μm², as well as their surface height distribution histograms.

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Modulating Oxygen Vacancy Distribution to Enhance Switching Stability in Ag/ZrO₂/Ti/Pt RRAM Devices

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This research investigates the resistive switching behaviors of Ag/ZrO₂/Ti/Pt memory cells, fabricated on glass substrates. The active layer consists of a bilayer ZrO₂ (25nm/25nm) structure, deposited by RF sputtering at a power of 80 W and a working pressure of 5 mTorr. To optimize the device performance, the oxygen gas flow ratio during the sputtering process was systematically varied at 6%, 8%, 10%, and 12%. Experimental results indicate that the

oxygen content significantly modulates the switching parameters and stability of the RRAM devices [1, 2]. While the 6% and 8% samples exhibited larger fluctuations in switching voltages, the device fabricated with a 10% oxygen flow ratio demonstrated the most superior and stable resistive switching characteristics. Specifically, the 10% sample achieved a stable on/off ratio between 10^2 and 10^3 , with both set and reset voltages V_{set} and V_{reset} , maintained below 1 V. This stabilization is attributed to the balanced concentration of oxygen vacancies and the formation of robust Ag-based conductive filaments within the ZrO_2 matrix. These findings suggest that precise control of oxygen stoichiometry and sputtering pressure is essential for developing high-reliability, low-power ZrO_2 -based non-volatile memory.

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A Study on the Properties of Composites Using Vitrimer Resin Based on an Automated Intermediate Material Manufacturing Process

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In this study, CFRP UD composites, using vitrimer resin were fabricated, and their applicability was evaluated in terms of mechanical properties, thermal characteristics, and reprocessability. Vitrimer resins are thermosetting polymers capable of reprocessing through bond-exchange reactions upon heating and have attracted attention as materials that can overcome the recycling limitations of conventional thermoset resin-based composites. In the field of construction composites, increasing interest has been directed toward resin systems that can maintain mechanical performance while enabling reprocessability. Accordingly, the ability of vitrimer resin-based composites to secure sufficient material properties has become an important consideration. In addition, for practical structural applications, not only reprocessability but also tensile properties, interlaminar shear properties, and thermal stability at the composite level are required simultaneously. Therefore, this study aimed to examine both the process applicability and the feasibility of securing sufficient properties in vitrimer resin-based composites. Composite specimens were prepared based on an automated intermediate material manufacturing process, in which intermediate materials were produced at 100 °C for 30 min and subsequently molded by hot pressing. Mechanical properties were evaluated through tensile and interlaminar shear strength (ILSS) tests, while thermal characteristics were analyzed using DSC and DMA in terms of glass transition temperature (T_g), $\tan \delta$, and thermal behavior. The results showed that the vitrimer resin-based composites exhibited tensile strengths of approximately 1500 – 1900 MPa and interlaminar shear strengths

of approximately 60 – 72 MPa, depending on the fabrication conditions and resin system. In addition, DSC and DMA analyses confirmed the temperature range above the glass transition temperature of the vitrimer resin at which reprocessing was possible. Under the reprocessing conditions, shape change and rebonding capability were also confirmed, indicating functional characteristics differentiated from those of conventional thermoset composites. These results demonstrate that vitrimer resin-based composites can simultaneously achieve both mechanical performance and reprocessability. In future work, quantitative evaluation of property changes and retention behavior before and after reprocessing under varying molding conditions, resin types, and reprocessing conditions will be conducted to further expand the industrial applicability of vitrimer resin-based composites and their potential use in structural applications.

Influence of High-Temperature Isothermal Exposure on the Crystallization Behavior and Mechanical Properties of CF/PEKK Composites

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Thermoplastic composites are attractive for aerospace structures because of their excellent mechanical properties, thermal stability, and reprocessability. Carbon fiber reinforced polyetherketoneketone (CF/PEKK) composites are regarded as promising high-performance structural materials. During manufacturing and subsequent thermal processing, these materials can experience repeated high-temperature exposure, which may affect the crystallization behavior of the matrix and the resulting mechanical response of the composite. However, the effect of isothermal high-temperature exposure on CF/PEKK composites has not been fully clarified. In this study, the influence of high-temperature isothermal exposure on the crystallization behavior and mechanical properties of CF/PEKK composites was investigated. CF/PEKK laminates were fabricated from commercial prepreg and exposed at 380 °C for 30, 60, and 120 min. Differential scanning calorimetry (DSC) was used to analyze thermal behavior and crystallinity changes, while mechanical properties were evaluated by three-point bending and interlaminar shear strength (ILSS) tests. The DSC results showed that thermal behavior changed with exposure time, although the trend was not monotonic. The 60 min condition exhibited relatively higher crystallinity, suggesting enhanced structural rearrangement of the PEKK matrix at intermediate exposure time. In contrast, no clear degradation was observed in flexural properties within the investigated range, and the 120 min condition showed the highest average flexural values. These results indicate that high-temperature isothermal exposure affected the thermal response of CF/PEKK composites more clearly than the flexural mechanical response.

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Metal-Triggered Electrochromic Device with Gel Electrolyte

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Electrochromic devices (ECDs) enable reversible optical modulation and are widely applied in smart windows and low-power displays. However, conventional systems require external power sources and complex fabrication processes. To address these limitations, self-powered electrochromic systems have emerged as a promising alternative. PEDOT: PSS is a conductive polymer, widely used for electrochromic applications due to its tunable optical properties, solution processability, and reversible redox behavior. In this study, a metal-triggered electrochromic device is proposed, in which electrochemical potential differences between the metals and the electrolyte generate a built-in voltage, enabling voltage-free operation. A gel electrolyte composed of polyacrylamide, LiCl, and agarose is employed to improve ionic conductivity while preventing leakage. The incorporation of ethylene glycol enhances conductivity by improving polymer chain alignment and carrier mobility. This work focuses on optimizing material composition, film thickness, and metal triggering to achieve high performance and stability. The device employs a simple structure comprising an ITO substrate, a spin-coated PEDOT: PSS layer, and a LiCl-based gel electrolyte. Thinner films exhibited higher transmittance, while thicker films showed enhanced modulation. Al-triggered operation produced the highest optical modulation, attributed to strong redox interactions and built-in potential differences. This work presents a low-cost, scalable approach for energy-efficient electrochromic systems.

Microstructure and Ultraviolet Sensing Properties of Hydrothermally Grown Er-Doped ZnO Nanowires on *p*-Type Silicon Substrates

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In this study, erbium (Er)-doped zinc oxide ($\text{Zn}_{1-x}\text{Er}_x\text{O}$, $x = 0, 0.01, 0.03$, and 0.05) nanorods were successfully synthesized on *p*-type silicon (*p*-Si) substrates, using a hydrothermal

method. The effects of Er doping on the microstructure and optical properties of the ZnO nanorods were systematically examined. As the Er doping concentration increased, the nanorods exhibited an enhanced surface area but a decrease in nanorod density. X-ray diffraction (XRD) analysis confirmed the formation of a hexagonal wurtzite structure without any secondary phases, indicating successful incorporation of Er ions into the ZnO lattice. Photoluminescence (PL) spectra showed that increasing the Er doping concentration reduced defect-related emissions, indicating improved crystal quality. The $\text{Zn}_{1-x}\text{Er}_x\text{O}$ ($x = 0.03$) nanorods exhibited the highest performance in ultraviolet (UV) detection, achieving an on/off current ratio of 13000% at a bias of 5 V. These results suggest that Er-doped ZnO nanorods with optimized doping levels provide significant improvements in both structural quality and optoelectronic performance, making them promising candidates for UV photodetector applications.

Investigation Characteristics of Thermal Field in SiC Crystal Growth, Using PVT

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Silicon carbide (SiC) has emerged as a transformative material in the field of power electronics due to its superior electrical, thermal, and mechanical properties, enabling high-efficiency and high-power device operation under extreme conditions. With the ongoing demand for larger wafer sizes, the growth of large-diameter SiC single crystals has become a critical technological objective. However, as the crystal size increases, maintaining a well-controlled and spatially uniform temperature distribution within the growth crucible presents significant challenges, particularly for the physical vapor transport (PVT) method, where thermal gradients strongly influence crystal quality and growth stability. In this study, a comprehensive numerical simulation framework was developed to investigate the thermal field characteristics during SiC single-crystal growth, using a resistively heated PVT system. The model incorporates the coupled effects of heat conduction, radiation, and material properties to accurately capture the temperature distribution within the crucible. By systematically varying the relative position between the heating element and the crucible, the resulting temperature field under different configurations was analyzed in detail. The simulation results demonstrate that careful adjustment of the heater–crucible configuration can significantly improve temperature uniformity. Lowering the vertical position of the heating coil leads to a downward shift in the location of the maximum temperature, while maintaining the peak temperature of approximately 2500 K. This behavior provides a practical means of controlling the thermal field without compromising the required high-temperature conditions for crystal growth. Moreover, the temperature distribution near the seed crystal surface is found to be relatively uniform, which is essential for achieving stable and defect-minimized growth. At a position approximately 60 mm below the source powder, the temperature difference across the growth interface is maintained below 10 K, indicating a sufficiently small thermal gradient. Such conditions are advantageous for suppressing the formation of parasitic polycrystalline regions,

particularly near the edges of the crystal, thereby enhancing the overall crystalline quality. Overall, this study provides important insights into the thermal management of PVT-grown SiC crystals and offers practical guidance for optimizing heater design and process parameters. The findings contribute to the advancement of large-scale SiC crystal growth technologies and support the continued development of next-generation power electronic devices.

Determination of Non-stationary Impact by the Stress State in the Specified Area of Layered Cylindrical Construction

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Currently, to solve several practical problems, it is relevant to determine the non-stationary (impulsive) effect on the external and (or) internal surfaces of a cylindrical structure's layer package, given the known stress state in a specified area of the structure under consideration. Such problems, for example, include the tasks of confirming the reproducible probing non-stationary (impulsive) effect in *a priori* and *a posteriori* analysis of the results of diagnosing the state of materials in layered cylindrical structures. The purpose of this work was to develop methods and software for determining the impulse effect on the outer and (or) inner surfaces of a layered cylindrical structure with isotropic and (or) transversely isotropic layers, given the known stress state in a specified region of the structure. These methods were based on the constitutive equations and the matrix algorithm of the generalized method for scalarization of dynamic elastic fields in transversely isotropic media [1, 2]. The obtained results are most expedient to use in the process of diagnostics of the condition of materials of layered cylindrical structures in instrument engineering, mechanical engineering, aircraft engineering, shipbuilding, fuel and energy complex, etc.

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Modeling of the Stress-Strain State in the Power Elements of Constructions with Internal or External Coating

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In the practice of design, power cylindrical elements with an external and (or) internal protective coating are often used. At the same time, a wide variety of isotropic and

transversally isotropic materials are applied both for the marked power elements and for protective coatings. In this case, to carry out quality control of the marked elements of structures during production and diagnostics of their condition during operation, the methods and software for modeling of the specified processes are relevant. Methods and software have been developed for determining the stress-strain state in cylindrical force elements with external and (or) internal protective coatings, made of isotropic and (or) transversely isotropic materials. The methods are based on the constitutive equations of the generalized method of scalarization of dynamic elastic fields in transversely isotropic media [1, 2]. The obtained results are most expedient to use in *a priori* and *a posteriori* analysis of the results of diagnostics of the state in instrumentation, mechanical engineering, aircraft engineering, shipbuilding, fuel and energy complex, etc.

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Tension and Pressure Sensors with Various Film Architectures

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The development of carbon nanomaterials contributes to the creation of new highly sensitive and elastic sensors that reproduce the mechanical and sensory functions of human limbs and organs. Single-walled carbon nanotubes (SWCNTs), multi-walled carbon nanotubes (MWCNTs), and graphene are recognized among the most promising candidates capable of replacing traditional silicon and metal systems due to their exceptional electrical and mechanical properties [1]. In this work, flexible stretch and pressure sensors, based on thin carbon films were developed, and three-dimensional and two-dimensional sensor architectures were formed. The effect of nanosecond laser radiation on the electrical properties of architecture is investigated. For the formation of films, dispersions of SWCNTs, MWCNTs and reduced graphene oxide (rGO) in organic solvents with the addition of surfactants were studied. Carbon films were obtained by spray deposition on silicon substrates with the following parameters: the nozzle diameter of the spray head is 0.3 mm, the distance from the nozzle to the substrate surface is 13 cm, the operating pressure was maintained in the range of 1 – 3.5 kg/cm², which made it possible to control the flow rate of the dispersed medium in the range of 0.03 – 0.05 ml per pass. The speed of movement of the spray head was 1 cm/s. Three-dimensional architectures were obtained by sequentially depositing 1000 layers of MWCNTs, followed by 56 layers of rGO. As a result, spherical globular structures with a size of 23.5± 0.9 μm were formed on silicone substrates, evenly distributed over the entire surface. Flexible pressure sensors were formed, based on these three-dimensional architectures. The measured sensitivity coefficient of sensors with three-dimensional architecture was 1.61 ± 0.4 kPa⁻¹.

Exposure to laser radiation at an energy density of 0.12 J/cm^2 resulted in a 2-fold decrease in the resistance of carbon architectures. With an increase in energy density above 0.3 J/cm^2 , the destruction of the carbon network was observed. Two-dimensional sensor architectures for stretch sensors were obtained on silicon substrates, using laser lithography on thin films of MWCNTs. Mathematical modeling, using the finite element method, has shown the formation of mechanical stress concentrators during deformation of such sensors. Due to the redistribution of voltage in the carbon film, the strain sensitivity of such sensors increased by 5 times. The sensitivity coefficient of sensors with a two-dimensional architecture was 110 ± 4 . Using laser radiation with the parameters: a wavelength of 1064 nm, a pulse duration of 100 ns, a frequency of 30 kHz, a spot diameter of $\sim 35 \text{ }\mu\text{m}$, an energy density of 0.12 J/cm^2 , a 2-fold decrease in sensor resistance was achieved, as well as a 2-3-fold decrease in hysteresis during stretching and compression. The achieved result is significant in the field of flexible sensor development, since a decrease in the thickness of film sensors and an increase in their sensitivity usually leads to an increase in hysteresis [2].

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Dielectric Spectra, Magnetic Capacity and Conductivity Mechanisms of (Na, K, Bi)(Nb, Fe)O₃ Solid Solutions at Low Temperatures from 10 K to 300 K

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The research presents the results of an experimental study of solid solutions along the quasi-binary cross-section of the $(1-x)(\text{Na}_{0.5}\text{K}_{0.5})\text{NbO}_3 - x\text{BiFeO}_3$ system in the composition range of $0.85 \leq x \leq 0.95$. The investigations were carried out over a wide range of low temperatures, from 10 K to 300 K. During the study, data on the microstructure of the ceramic samples were obtained, the temperature-frequency dependencies of the dielectric permittivity were constructed, and the characteristics of the magnetic capacitance in external fields were investigated. It was established that the dielectric losses in the low-frequency range are caused by a significant contribution of intergranular conductivity. The analysis of the temperature dependencies of electrical conductivity revealed that abnormally low activation energies (0.003 – 0.005 eV) are characteristic of all investigated compositions. Such small values indicate the dominance of mechanisms of quantum charge carrier tunneling and hopping conduction between ions along grain boundaries. The key result of the work was the observation of a pronounced magnetocapacitive effect (MCE = 0.157 at 77 K) in the composition with $x = 0.95$. This effect is explained by the combined influence of Maxwell-Wagner polarization and the presence of mixed valence states of iron ions, which facilitate

magnetoelectric coupling. For other compositions, a significant magnetocapacitive response was not recorded within the measurement error. The obtained data expand the fundamental understanding of charge transport processes in multiferroics and open prospects for the use of these materials in low-temperature microelectronics and spintronics devices.

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Strength Evaluation of Dissimilar-Material Butt Joints Based on Singular Stress Field

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Many studies have investigated the strength evaluation of adhesive joints, and it has been established that adhesive strength can be rationally evaluated, using the Intensity of Singular Stress Field (ISSF). However, these findings have mainly been obtained from adhesive specimens, made of identical materials, and the influence of different adherends on adhesive strength has not yet been fully clarified. In our previous study, carbon steel (S35C) was used as the adherend, and experiments were conducted, using JIS standard butt joints (ABA butt joints) bonded with an epoxy adhesive. The results showed that the adhesive strength of JIS standard butt joints is strongly affected by the singular stress field at the joint ends, and that the strength can be expressed by a constant ISSF. In the present study, dissimilar-material joints (ABC butt joints) were prepared, using carbon steel (S35C) and aluminum alloy (A5052) to investigate the effect of adherend materials. The adhesive strength of JIS standard butt joints was measured, and their fracture behavior was examined. As shown in Fig. 1, the adhesive strength of the ABC joints was lower than that of the ABA joints.

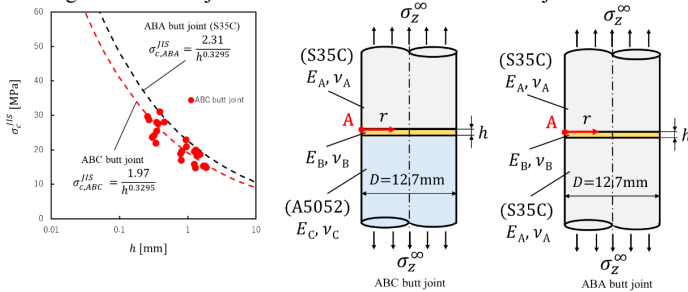


Fig. 1. Comparison of adhesive strength between ABC butt joint (steel/epoxy/aluminum) and ABA butt joint (steel/epoxy/steel) for JIS specimen

Furthermore, related experiments were conducted on protruding butt joints without singular stress fields, and their adhesive strength characteristics were compared.

Numerical Homogenization of PZT-Thin Metal Layer-Air and PZT-Air Composites, Using Periodic Boundary Conditions

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Homogenization is important for predicting the effective material properties of piezoelectric composites. It enables linking microstructure to macroscopic performance for efficient sensor and actuator design. This work extends our previous studies on porous piezoelectric composites with metalized pore surfaces (PZT-Thin Metal Layer-Air or PZT-TML-Air) by introducing periodic boundary conditions (PBCs) into the numerical homogenization framework. Earlier analyses, based on linear essential boundary conditions (Dirichlet-type), impose uniform fields on the representative volume element (RVE), which may lead to inaccurate estimation of effective electromechanical properties due to artificial constraints. In contrast, periodic boundary conditions provide a physically consistent representation of infinite periodic media by enforcing compatibility of displacement and electric potential fluctuations across opposite faces of the unit cell. This is particularly important for PZT-TML-Air structures, where strong local field interactions arise due to high material contrast and electromechanical coupling. The homogenization problem is formulated for coupled mechanical and electrical fields, governed by piezoelectric constitutive relations. The representative unit cell is assumed to be periodically repeated in space, leading to periodicity conditions on displacement and electric potential fields. Periodic boundary conditions are implemented in ANSYS APDL, using constraint equations that link corresponding nodes on periodic boundaries, ensuring continuity of fluctuations and anti-periodicity of tractions and electric fluxes. Repeated unit cells with cubic and spherical pores are analyzed for both ordinary porous systems (PZT-Air) and PZT-TML-Air configurations, considering different porosity levels. Effective elastic, dielectric, and piezoelectric coefficients are obtained by solving standard cell problems under mechanical and electrical loadings. A comparison was made of solutions for problems with essential and periodic boundary conditions for individual cells and for the lattices, composed of these cells. Additionally, to implement periodic boundary conditions in RVEs, three-dimensional finite element meshes with identical corresponding 2D meshes on opposite outer faces were used. The present study provides a systematic assessment of the influence of periodic boundary conditions on the effective electromechanical properties of porous piezoelectric composites. Various porosity levels are analyzed. The simulations evaluate effective elastic moduli, dielectric permittivities, and piezoelectric coefficients, as well as some important figures of merit relevant to sensing and actuating performance. Special attention is given to evaluating how the choice of boundary conditions affects the estimation of transverse and shear piezomoduli, as well as dielectric permittivities, especially in the presence of high porosity and strong material heterogeneity. The proposed framework also allows for a detailed investigation of the potential enhancement

in transverse actuation performance of PZT-TML-Air structures. This study highlights the critical role of boundary conditions in homogenization and provides a robust computational framework for the design and optimization of piezoelectric composite materials with extreme contrast parameters of different phases.

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Study of Structure Characteristics of BiFeO₃ and YMnO₃ Multiferroics Thin Films Sputtered on Al₂O₃(0001) Substrates

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Due to the current trend toward miniaturization of device components and using nanomaterials, thin film studies are actual studies. Their potential applications lie in information processing and storage (non-volatile memory), high- and low-temperature sensors, optoelectronics, and nano- and microsystems devices, including microwave devices. This work is devoted to the study of the obtaining possibilities of BiFeO₃ (BFO) and YMnO₃ (YMO) multiferroics thin films on sapphire substrates Al₂O₃(0001). The deposition was carried out, using the RF-sputtering cathode method in an oxygen atmosphere. The conditions were selected, using a buffer layer of strontium titanate (SrTiO₃, STO) on the “Plasma 50 SE” facility (ELITTEKH LLC, Russia). As a result, BFO/STO/Al₂O₃(0001) and YMO/STO/Al₂O₃(0001) heterostructures were obtained. X-ray phase analysis showed that the films are grown without the formation of impurity phases. The reflection of the BFO/STO/Al₂O₃(0001) heterostructure corresponds to the [111] direction for the pseudo cubic perovskite structure. For the YMO/STO/Al₂O₃(0001), diffraction pattern shows a reflection that most likely corresponds to the (022) reflection of orthorhombic YMO. Note that the target from which the film was deposited has a hexagonal structure. Microscopic analysis of the surface of both BFO/STO/Al₂O₃(0001) and YMO/STO/Al₂O₃(0001) heterostructures shows classical block growth by the Volmer-Weber mechanism. The films are homogeneous, with no pores, cavities, or other irregularities. For BFO/STO/Al₂O₃(0001), the islands are distributed almost densely, but discreetly, across the entire surface. The quite large blocks (approximately 320 – 380 nm) have predominantly oval shape. For YMO/STO/Al₂O₃(0001), the size of the formed blocks is approximately 120 – 150 nm. The blocks themselves are divided into individual islands, where they partially merge. Thus, oriented growth of BFO and STO films on the Al₂O₃ substrate is observed with the [111] crystallographic axes of both layers are out-of-plane (parallel to the [001] axis of Al₂O₃). In the YMO/STO/Al₂O₃(0001) heterostructure, layers are grown in an oriented manner. For the STO sublayer the [111] axis is out-of-plane, while for YMO layer the [022] axis is out-of-plane. Most likely, conjunction with the hexagonal structure of the Al₂O₃ substrate occurs along these planes in YMO, since the Y and Mn atoms have a threefold rotation axis in this plane.

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Nonlinear Asymptotic Models of Elastic Band Stretching for Direct and Inverse Problems

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In biomechanics, rectangular small-sized specimens are often used to study the mechanical properties of biological tissues, e.g. tendons, ligaments, bone tissue, etc. Due to size limitations, the length-to-width ratio of such specimens is not always sufficiently large for the application of classical rod theories. Moreover, many biological materials exhibit strongly nonlinear behavior even under moderate strains. Therefore, it is relevant to develop refined applied models that account for specimen geometry, boundary conditions, and nonlinear deformation behavior. The exclusive use of numerical methods is not always appropriate for solving inverse problems of parameter identification. In the present work, within the framework of generalized plane stress, a nonlinear problem of stretching an elastic rectangular strip ($|x_1| \leq a/2$, $0 \leq x_2 \leq H$) is considered. The strip is rigidly clamped at the lower end ($x_2 = 0$) and subjected to a distributed load at the upper end. A first-order Kantorovich hypothesis is employed: the longitudinal and transverse displacements are represented as $u_2 = w(x_2)$ and $u_1 = x_1\varphi(x_2)$, respectively, where φ and w are unknown functions. Based on the Lagrange variational principle for the Saint-Venant – Kirchhoff constitutive law and using the nonlinear Green – Lagrange strain tensor $\boldsymbol{\varepsilon} = \frac{1}{2}(\nabla \mathbf{u} + (\nabla \mathbf{u})^T + (\nabla \mathbf{u})^T \cdot \nabla \mathbf{u})$, a geometrically nonlinear boundary value problem is formulated, consisting of two second-order differential equations. An alternative formulation in terms of first-order equations is derived, using first integrals of the system, relying on the constancy of the generalized longitudinal force and the conservation law of generalized energy. An asymptotic approach is employed to analyze the problem. A regular expansion in terms of the strain amplitude δ is carried out, with $\gamma = a/H$, remaining a free parameter, thereby extending the applicability of the model to specimens with arbitrary aspect ratios. Linear approximations, which include exponentially decaying boundary layers, are constructed. The first nonlinear corrections are also obtained; their structure includes additional terms, expressed via exponentials. The solutions are compared with finite element simulations, showing excellent agreement over a wide range of geometric parameters (from thin to moderately thick specimens). It is shown that deviations from linear theory become noticeable at finite strains and should be considered in precision calculations. An inverse problem for determining the elastic constants λ^* and μ is considered, using additional displacement information, measured at several points on the specimen edge. A system of linear algebraic equations is constructed, the solution of which yields the material parameters. Numerical reconstruction experiments confirm the effectiveness of the proposed approach. The developed models can serve as a basis for non-destructive testing methods of elastic properties of materials, including biomechanical applications.

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Sensitivity Analysis of the Coefficients of the Cowin-Nunziato Model for an Inhomogeneous Poroelastic Rod

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Currently, functionally graded porous materials are attracting increasing attention from researchers and engineers because they possess a predetermined distribution of properties and combine high strength with low weight. The development of additive technologies, particularly 3D printing, has opened new prospects for manufacturing such products. For the mathematical description of the deformation of porous bodies, the micro-dilatation theory of Cowin-Nunziato is often applied. In contrast to the classical theory of elasticity, this model introduces an additional kinematic variable in the form of a micro-dilatation function, which represents the change in the volume fraction of the material matrix at a given point in the medium. The constitutive relations of this theory under static loading contain several classical parameters (elastic moduli) and non-classical parameters (pore diffusion modulus, coupling modulus, pore stiffness modulus). At present, theoretical and experimental methods for determining the parameters of the Cowin-Nunziato model have been developed only for homogeneous porous bodies. Solving coefficient inverse problems for heterogeneous porous bodies is required, the first stage of which is a sensitivity study. Sensitivity analysis is an investigation of how changes in input parameters (material properties) affect the output data of an experiment. This is key to understanding the stability of the inverse problem and for experiment planning. The problem under consideration is the static deformation of a heterogeneous porous rod, with one end fixed and tensile load, acting on the other, while the micro-dilatation flux at both ends is zero. The input information consists of displacements, measured along the length of the rod. Based on Fréchet derivatives and the adjoint state method, sensitivity characteristics for the Cowin-Nunziato model for a rod are introduced, boundary value problems for the sensitivity functions are formulated, and computational experiments are conducted for various heterogeneity laws. It was found that the most influential parameter for the heterogeneous porous rod is Young's modulus. Its variation strongly changes the displacement field. The coupling parameter manifests as a scaling factor for the influence of porosity on displacement. The pore stiffness modulus affects the displacement through the amplitude of the porosity field. Its identification requires high accuracy in measuring the displacement field. The pore diffusion modulus is the least sensitive. It influences the spatial distribution of porosity and, through it, the displacement. Data from zones of high gradients are needed to determine this parameter.

The Effect of Friction on the Axial Compression of a Transversely Isotropic Porous Cylinder

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Modeling the mechanical behavior of modern structural and biological materials, such as laminated composites, trabecular bone, and porous ceramics, is a complex interdisciplinary problem. These materials are characterized by a complex internal heterogeneous structure that determines their macro mechanical properties. Unlike classical continuous media, their deformation behavior depends significantly on the features of the microstructure, such as the presence of pores, inclusions, and anisotropy, as well as on the conditions of interaction with external devices, primarily friction in the contact zones. Uniaxial compression remains one of the key methods for determining their mechanical characteristics, yet the interpretation of its results is often carried out within the framework of classical rod models. This leads to large systematic errors in the estimation of elastic module. Therefore, the creation of accurate analytical models that simultaneously account for porosity, anisotropy, and friction is a critically important task for ensuring the validity of mechanical tests and the reliability of engineering calculations. In the present work, an improved analytical model for the axial compression of a transversely isotropic porous cylinder is developed and investigated within the framework of the micro-dilatation theory of Cowin-Nunziato, taking contact friction into account. For transversely isotropic material, independent coupling moduli are introduced for transverse and axial deformations, respectively. Contact friction is modeled through an integral parameter, expressed as the ratio of the generalized tangential and normal forces at the ends. The original three-dimensional boundary value problem is reduced to a system of ordinary differential equations, using the first-order Kantorovich method in combination with the Lagrange variational principle. An analytical solution in closed form is obtained, representing a superposition of a rod-type part and exponentially decaying boundary-layer components. A comprehensive parametric analysis is conducted, quantitatively assessing the influence of friction, the degree of anisotropy, and porosity parameters on the stress-strain state. It is established that friction reduces radial displacements and increases the apparent elastic moduli, while anisotropy amplifies the effect of friction; the coupling parameters determine the extent of the mechanical load's influence on the restructuring of the pore structure. Based on three criteria (smallness of porosity change, smallness of deformations, and strength condition), the permissible loads for porous ceramics are calculated, and practical recommendations for planning experiments are given. The fundamental possibility of determining the coupling moduli is demonstrated, provided that experimental data on the change in local porosity are available, for example, obtained by computed tomography methods.

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The Influence of Bonding Technology Parameters on the Quality of Overlap Seams on Knitted Fabrics

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Sew-free garment products have been experiencing strong growth in recent years due to their advantages, including liquid resistance, durability, good appearance, lightness, and softness. Many types of bonding tape and machine were developed to ensure quality of seam on sew-free garments. This article presents the results of research on the simultaneous effects of bonding parameters on quality of overlap seams on a 69% Nylon and 31% Lycra knitted fabric sample for sportswear. The technological parameters were investigated including bonding temperature, bonding time, and pressure settings on the bonding machine. The study area for the technological parameters included a bonding temperature of 123 – 207 °C, a bonding time of 8 – 42 seconds, and a pressure of 0.10 – 0.60 mPa. Common overlap seam quality parameters on sew-free garments are attended and selected for this study including peel strength and stretch recovery of the seam. The overlapping seams were made in three different directions: horizontally, along the course, and diagonally at a 45°. Experimental design methods with the assistance of Design Expert software were used to design the bonding technological parameter options and analyze the results. Rotatable central composite design was used for these experiments. The results of experiments show that the peel strength of seam samples varied considerably in three directions with the same bonding technology parameters, with a coefficient of variation of 1.2 – 33.8 %. Meanwhile, the stretch recovery was similar, with a variation coefficient of 0.3 – 4.4 %. The effects of these bonding parameters on the average peel strength and average stretch recovery on this fabric sample follow incomplete quadratic regression models. Analysis results show that bonding temperature and time parameters have a major influence on both the peel strength and the stretch recovery. The pressure factor within the investigated range does not cause significant changes to either of the two seam quality parameters. These research results contribute to improving the production technology of sew-free garments and promote the development of these products in the future.

An End-to-End Simulation Framework for Piezoelectric Transducer Systems in Underwater Acoustic Communication

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Amidst the era of advanced materials, development in piezoelectric materials has facilitated the design and implementation of advanced transducers, applied in acoustic sensor systems as well as underwater communication systems. The transducers act as interfaces between electrical signals and acoustic waves, thereby affecting the performance of acoustic modems in complex acoustic propagation environments. Indeed, multiphysics simulation software like COMSOL Multiphysics is widely used to simulate piezoelectric ceramics, while MATLAB is commonly employed for electronic circuit modeling and signal processing. Nevertheless, such techniques are usually utilized for each individual sub-module separately, and there is still no general approach that would incorporate all of them into a coherent signal transmission-reception chain. Therefore, it becomes hard to replicate the whole conversion process from the digital stimulation of a signal up to its acoustic emission and then back to the digital reconstruction of the same signal in one consistent setup. In this research, a technique for modeling the complete function of a piezoelectric transducer-based underwater acoustic modem is developed. This technique involves building a simulation pipeline that starts by processing a digital input signal in MATLAB, then uses it as an electrical source for amplification and filtering possible before feeding it into a piezoelectric transducer, simulated in COMSOL Multiphysics. The obtained signal is again transformed into an electrical response, processed in MATLAB for digital signal reconstruction. The proposed framework realizes all steps from input digital signal to output digital signal within a coupled electrical and acoustical domain under realistic conditions. Specifically, it is realized by a single computational model of the transmission-reception process, but provides access to intermediate states, comprising voltage responses, acoustic field pressure distributions, wave attenuation, and received response. In this way, this capability enables analyzing the effects of transducer properties, electronic stages, and environmental factors on the system's performance. As a result, the proposed model enables system-level analysis of signal processing techniques, as well as material-configuration-level analysis of piezoelectric materials and transducer circuits.

Physical and Mechanical Properties of Thin AlN Coatings with Different Stoichiometric Compositions

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Aluminum nitride (AlN) is a promising functional material, characterized by a unique combination of properties, including excellent piezoelectric behavior, a wide bandgap, a low coefficient of thermal expansion, high thermal conductivity, high electrical resistivity, and good dielectric properties. Owing to these characteristics, AlN is widely used in electronic and optoelectronic devices and is compatible with silicon-based microelectronic technologies. Additionally, AlN coatings serve as wear-resistant and impact-resistant dielectric layers in electronic components. A particularly important application of AlN involves multilayer coatings, for example in combination with CrN. Alternating layers of varying thickness create a gradient in atomic and electronic structures due to phase transformations, which enhances the overall performance of the material. However, expanding the use of AlN coatings in microdevices requires a comprehensive understanding of their behavior in microcontacts. To achieve this, probe-based characterization techniques are employed, including atomic force microscopy for microstructural analysis and nanoindentation for evaluating mechanical and microtribological properties. The aim of this study was to investigate the influence of the stoichiometric composition of AlN coatings, deposited by reactive magnetron sputtering, on their microstructure, mechanical and tribological properties, as well as specific electrical resistivity. As a result of this work, two groups (the first group of coatings was sputtered at 100 °C, the second one – at 20 °C) of AlN coatings with different stoichiometric compositions were obtained, using the reactive DC magnetron sputtering method with the variable nitrogen flow in the chamber.

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Application of Mobile Resonant Chiral-Dependent Modules for Practical Adjustments of the Microwave Transmission Lines Conductive Parameters

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In recent years, in the development of radio electronics, research has intensified in the field of introducing several chiral-dependent structures that are used as part of strip-type transmission lines [1]. Thus, it was found that the surface structure in the configuration of a double concentric annular split resonator (DCASR) has unique properties of notch filtration when positioned on the reverse side of the conductive strip (Fig.1).

At the same time, notch filtering was obtained at resonant frequencies at various substrate parameters and resonator sizes (Fig. 2). The authors found [1] that the rotation of this DCASR around the central point in its center also provides a restructuring of the resonant notch frequency (Fig. 3) and the attenuation coefficient of the filter (Fig. 4).

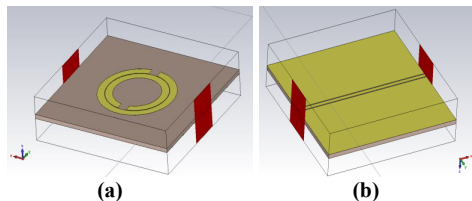


Fig. 1. Two sides of the three-dimensional image of the printed circuit board of the conductive section of the transmission line with DCASR

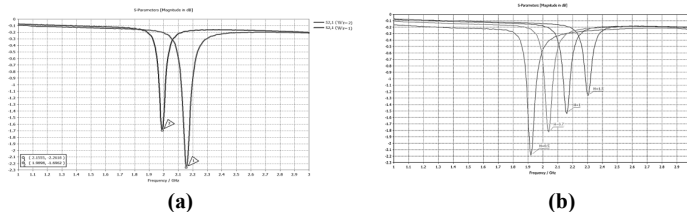


Fig. 2. Frequency characteristics of the transmission coefficient S_{21} of an annular resonator at different widths of the ring strip (a) and different values of the plate thickness (b)

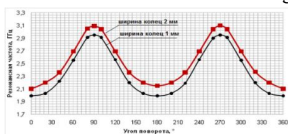


Fig. 3. Dependence of the resonant frequency of the notch filter on the angle of rotation of the DCASR

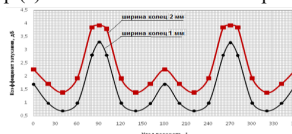


Fig. 4. Dependence of the attenuation coefficient of the notch filter on the angle of rotation of the DCASR

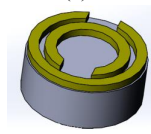


Fig. 5. Three-dimensional model of the mobile rebuilding module

Thus, it is possible to manufacture a frequency adjustment module, consisting of a separately rotating substrate with a strip DCASR, applied on it, which could be placed in a convenient

place of the transmission line above the section of the conductive strip and, by rotation, carry out both the tuning of the resonant frequency of the power absorption and the attenuation coefficient of such a notch (reject) filter. A three-dimensional model of the proposed mobile rebuilding module is shown in Fig. 5.

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Atomistic Mechanism of Friction-Force Independence on the Normal Load and Other Friction Laws for Dynamic Structural Superlubricity

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We explore dynamic structural superlubricity for the case of a relatively large contact area, where the friction force is proportional to the area (exceeding $\sim 100 \text{ nm}^2$) experimentally, numerically, and theoretically. We use a setup, composed of two smooth molecular incommensurate surfaces: graphene-covered tip and substrate. The experiments and molecular dynamic simulations demonstrate independence of the friction force on the normal load for a wide range of normal loads and relative surface velocities. We propose an atomistic mechanism for this phenomenon, associated with synchronic out-of-plane surface fluctuations of thermal origin, and confirm it by numerical experiments. The physical nature of these fluctuations is shown in the schematic sketch in Fig. 1. By incorporating this mechanism, we develop a comprehensive theory for this specific superlubricity regime. The model demonstrates that the friction force increases linearly with both temperature and relative velocity once a specific threshold velocity is surpassed. Our molecular dynamics results show a fair agreement with these theoretical predictions, providing a robust framework for understanding the fundamental friction laws in dynamic structural superlubricity.

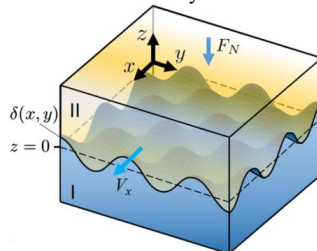


Fig. 1. Schematic sketch of synchronic thermal fluctuations

Black-box Optimization Techniques for Modelling New Materials

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Modern modelling of new materials is increasingly based on computationally expensive finite-element and multi physics simulations. In such settings, the objective function is often available only as the output of an external solver, while analytical gradients are missing, noisy, or too expensive to obtain. The computational package presented in this implements a practical black-box optimization framework that combines evolutionary search, batch evaluation, caching, and parallel execution for simulation-driven design tasks. The main contribution of the implementation is an integrated workflow that connects optimization methods directly to finite element packages (COMSOL Multiphysics, ACELAN-COMPOS [1]) and performs parameter optimization or shape optimization. This dual support is important for new materials modelling, where both constitutive parameters and geometric features can influence final performance. The core scenario for modelling new material consists of generating representative volume elements (RVEs) [2] geometry, evaluating its response under certain loading conditions, and then optimizing either the material parameters or the shape of the geometry to achieve desired properties. We developed robust derivative-free local improvement strategy, tailored to expensive external simulations based on multi-start gradient search and a genetic optimization pipeline which includes elite preservation, adaptive tournament selection, mutation rate adaptation, and diversity-aware crossover. We performed modeling of piezoelectric composites with 3-3, 3-1 and 3-0 connectivity by building both random and predefined methods of generating representative volumes in ACELAN-COMPOS package, using three types of the finite elements. The design variables were structured as a set of parameters (inclusion or pore size, material filling percentage, thickness of inclusion) for predefined RVEs generators and a vector of values, where each value represents the control variable for each micro-level element for randomized methods. For the first type of structures, two methods of evolutionary search were used; for the second type, specific modification of topology optimization approach was implemented. Designed materials were used on macro-level to evaluate their quality for different types of piezoelectric transducers to make the whole design-response loop for creating material for a specific transducer design was automated.

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Automated Monitoring and Control System for the Extrusion Plant

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Extruders are the primary equipment for plastics processing worldwide, ensuring high product quality and reducing costs. To improve efficiency and transparency, companies are implementing comprehensive monitoring systems, based on the industrial Internet of Things (IoT). These systems are built on a four-layer architecture: sensor level (sensors), controller level, operator level (SCADA), and analytical level (IoT platform) [1]. The central control element of the extrusion unit is the programmable logic controller (PLC), which acts as a "brain" of system. It continuously processes incoming information from all sensors and generates control signals to actuators, ensuring precise adherence to the process conditions. Based on the received data, the controller implements extruder control algorithms, maintaining the stability of all key processes. The temperature control circuit is equipped with three high-precision thermocouples, evenly distributed across the heating zones, ensuring optimal thermal conditions for processing polymer feedstock. Additional temperature monitoring is performed at the inlet and outlet of the screen exchanger, where separate sensors are installed to track thermal changes in the material during the filtration process. This solution ensures strict adherence to specified process parameters and prevents unwanted temperature fluctuations. Completing the monitoring system is a set of precision pressure sensors, placed at critical points along the melt line; they provide continuous monitoring of hydrodynamic characteristics and enable the prompt detection of any deviations from standard parameters. The operator control level is implemented, using a SCADA system and HMI panels, which serve as a single interface for personnel interacting with the process. Through this interface, the operator receives a complete and visual overview of the extrusion system's operation in real time, monitoring all key parameters on mnemonic diagrams and graphic screens: heating zone temperatures, melt pressure, screw speed, and throughput. If necessary, the operator can remotely change setpoints, adjust operating modes, and start or stop individual mechanisms without leaving the control panel. The visualization system also performs an important alarm function: if any parameter exceeds acceptable limits, warnings and audible alerts immediately appear on the screen, drawing the attention of personnel to the situation. All operator actions and system events are automatically recorded in a log, ensuring complete control transparency and creating the basis for subsequent analysis of equipment operation. Thanks to the intuitive interface and well-designed screen structure, managing a complex process becomes not only efficient but also safe, reducing the likelihood of human error [2]. The IoT wireless communication module performs the important function of establishing a data transmission channel between the PLC and the dispatcher's computer. It converts industrial protocols into a format suitable for transmission over wireless networks, ensuring the integrity and reliability of information. This approach enables centralized dispatch control of multiple extrusion machines simultaneously from a single workstation.

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The Problems of Integrating Heterogeneous IoT Devices into a Single Monitoring Circuit for Water Consumption during Digitalization of Land Reclamation

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The implementation of integrated monitoring and automated irrigation network management systems enables significant water savings through the transition to precision irrigation, as well as reduced operating costs through the automation of technological processes. An indirect but significant advantage is the increase in crop yields, achieved through optimal water management. However, addressing these challenges requires the implementation of modern systems, based on real-time big data transmission, which poses a key challenge, namely ensuring stable communications and long-term battery life in vast areas with poor cellular coverage and limited power infrastructure [1]. Integrating disparate devices into a single system is impossible without unified data exchange protocols and platforms capable of collecting data from any sensor, regardless of manufacturer or transmission method. Dedicated gateways play a key role here, that is they convert signals and perform primary telemetry processing directly at the equipment installation site, reducing the load on central servers and minimizing communication bandwidth requirements. To correctly interpret readings from soil moisture, water flow, and meteorological sensors, a unified semantic data model is required to ensure the consistent operation of all system components. As the infrastructure scales, cybersecurity becomes a priority, namely a unified authentication and encryption policy must be implemented for all types of connected devices to prevent an expanding attack surface. Creating such a unified environment lays the foundation for the application of artificial intelligence methods, which can identify hidden relationships in disparate data streams and independently generate optimal irrigation control algorithms [2]. The practical implementation of integrating heterogeneous IoT devices in irrigation networks is based on the use of LoRaWAN and NB-IoT protocols, which provide energy-efficient communication over long distances, as well as MQTT for reliable telemetry exchange in unstable communication channels. Cybersecurity of the heterogeneous infrastructure is ensured by a combination of measures: traffic encryption using the TLS 1.3 standard, end-to-end encryption at the application level, and the use of hardware trusted boot modules (TPM) for secure storage of cryptographic keys in critical nodes. The development prospects for IoT are linked to the transition to autonomous adaptive systems and the widespread adoption of edge computing, which allows data processing to be offloaded directly to peripheral gateways. Digital twin

technologies will further develop, enabling predictive modeling of water consumption based on the integration of data from IoT sensors, satellite monitoring, and meteorological models. The final stage of this evolution will be the formation of self-organizing mesh networks from heterogeneous devices capable of automatically rebuilding their topology when individual nodes fail, ensuring an unprecedented level of reliability and autonomy in water resource management [3].

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Study of the Duration of the Transient Process Establishment on A Gas Pipeline Section

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Transient processes in gas pipelines occur when the gas transportation mode changes, accompanied by a redistribution of pressure, flow rate, and temperature along the pipeline section over time. The relevance of this study stems from the need to ensure the reliability and energy efficiency of gas transmission systems under variable operating conditions typical of modern networks with complex configurations [1]. The mathematical description of unsteady gas flow is based on a system of partial differential equations, including the equations of continuity, flow, and heat influx. Considering some simplifying assumptions regarding the flow velocity of the energy carrier, the system of equations, defining the transient process is reduced to a single partial differential equation of the heat conduction type with corresponding boundary conditions, representing a mathematical model of the process under consideration. The constructed mathematical model is implemented analytically and numerically in the Python programming language [2]. The effect of a stepwise increase in pressure at the beginning of a gas pipeline section on the time, required to establish a new steady state, was studied. The calculation results are presented as graphical dependencies, reflecting the relationship between changes in inlet pressure and the duration of the transient process. The resulting graphs provide a clear understanding of the impact of process parameters on the time, required to establish a new stationary regime, and allow for the quantification of system response times under various disturbances.

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Study of the Dynamics of Changes in Gas Consumption in the Transient Process

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The preferred method of delivering gas to consumers today is via pipelines, which helps reduce the cost of transporting gas fuel over long distances. However, when transporting energy by pipeline, so-called transient processes inevitably occur, associated with the transition from one mode of natural gas transportation to another. The relevance of this research topic is driven by the need to improve the energy efficiency, reliability, and operational safety of pipeline gas transportation systems. This paper examines the dynamics of natural gas flow rate propagation along a gas pipeline section during a sudden change at the beginning of the section. The mathematical model of the problem is presented as a partial differential equation of the heat conduction type with respect to the specific gas flow rate, with corresponding initial and boundary conditions, considering that the new gas flow rate, established at the beginning of the section, is maintained constantly. It was assumed that the time at which the gas flow rate reaches a certain pipeline cross-section is the point in time when the change in flow rate at cross-section x is 1% of the initial change [1, 2]. The problem was solved numerically, using the grid (finite difference) method with an implicit scheme in Python software. The grid method is based on discretization of the continuous domain of the desired function (mass flow rate) in spatial and temporal coordinates. When developing Python software for simulating transient processes in a gas pipeline, the implicit scheme is implemented in several stages, including creating a structure and populating a matrix, based on a finite difference approximation [3, 4]. The matrix coefficients depend on pipeline parameters such as diameter, roughness, and flow regime. Boundary conditions such as end-of-pipe pressure and valve operation are also considered. The grid method was implemented in Python using the NumPy and SciPy libraries for matrix operations and solving systems of algebraic equations. An analysis of the impact of discretization parameters on the accuracy and speed of calculations was conducted. It was found that reducing the spatial step size to 5 km and the time step size to 30 s allows for acceptable accuracy when simulating transient processes in gas pipelines up to 200 km long. Furthermore, computational costs remain within acceptable limits for engineering applications. The graphical dependencies of the mass flow distribution along the gas pipeline route at different points in time, constructed based on the calculation results, make it possible to visualize the propagation of gas flow waves and determine the time for establishing a new steady state regime.

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Fabrication and Properties of $\text{SrFe}_{2/3}\text{W}_{1/3}\text{O}_3/\text{Si}(001)$

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Multiferroics, in which electric and magnetic orders coexist at temperatures above room temperature, have been intensively studied in recent decades due to the prospects for their application in microelectronics and microwave technology. $\text{SrFe}_{2/3}\text{W}_{1/3}\text{O}_3$ (SFW) is one of the most interesting representatives of this group of materials, as it combines ferrimagnetic and ferroelectric properties at $T_m < 400$ K. This work presents the results of studies on the fabrication and dielectric properties of $\text{SrFe}_{2/3}\text{W}_{1/3}\text{O}_3/\text{Si}(001)$ films, which we obtained for the first time. X-ray diffraction studies of the $\text{SrFe}_{2/3}\text{W}_{1/3}\text{O}_3/\text{Si}(001)$ structure showed polycrystalline and pure growth of the SFW film (both reflexes (001) and (002) and (110) are present on the X-ray diffraction pattern). The measured dependencies $J(U)$ of the $\text{Pt}/\text{SrFe}_{2/3}\text{W}_{1/3}\text{O}_3/\text{Si}(001)$ heterostructure are shown in Fig. 1. It has been established that three main mechanisms of electrical conductivity are clearly manifested in the $\text{Pt}/\text{SrFe}_{2/3}\text{W}_{1/3}\text{O}_3/\text{Si}$ heterostructure, such as ohmic conductivity ($E = 1 - 13$ MV/m), space charge limited current (SCLC) ($E = 13 - 50$ MV/m) and the coexistence of SCLC and Poole–Frenkel emission in the range $E = 22.7 - 32$ MV/m. It is assumed that the high conductivity of SFW is explained both by the intrinsic conductivity of the material (ohmic conductivity) and by strong injection from the near-electrode region at the $\text{Pt}/\text{SrFe}_{2/3}\text{W}_{1/3}\text{O}_3$ interface. The reasons for the revealed patterns and their influence on ferroelectric properties are discussed.

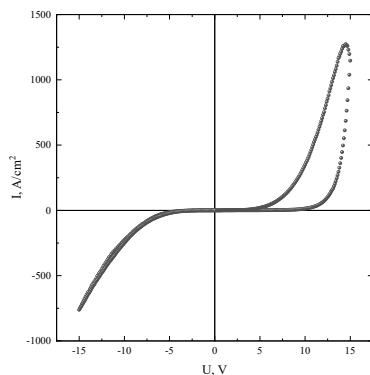


Fig. 1. Dependence of leakage current density on voltage of SFW thin film at room temperature

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Dielectric Properties of SrTiO₃(111)/Al₂O₃(001) Thin Films

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Strontium titanate (SrTiO₃, STO) is a prominent representative of a group of materials with a perovskite-type structure and currently is of interest in the form of nanoscale films. This work presents the results of dielectric properties studies of the SrTiO₃(111)/Al₂O₃(001) films. It is shown that the film is grown epitaxially, while compressive strains of the unit cell ($\approx 1\%$) occur in the plane of interface with the substrate and there are practically no deformations in the direction normal to the surface of the substrate, compared with bulk STO. An interdigitated planar capacitor structure was formed by the electron beam lithography, which made it possible to study the properties of the STO film in the $[11-2]_c$ direction (the direction of the $[100]_{\text{Al}_2\text{O}_3}$ substrate) at temperatures of $T = 77 - 73$ K (Fig. 1). It is shown that as the temperature decreases, anomalies in the behavior of $\varepsilon(T)$, associated with phase transitions of various nature, are observed in the heterostructure, and dielectric losses decrease against the background of an increase in k from 14.07% to 46.74%. Repeated cycling with an alternating electric field at room temperature did not reveal degradation of the film characteristics up to 10^{11} cycles.

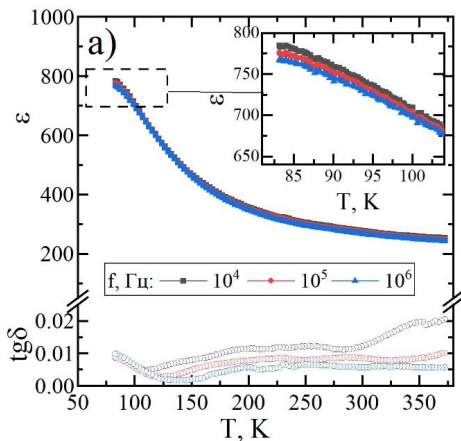


Fig. 1. $\varepsilon(T)$ and $\text{tg}\delta(T)$ dependencies of the STO/Al₂O₃(001) heterostructure in the range of $T = 80 - 375$ K at frequencies of 10^4 , 10^5 and 10^6 Hz

Acknowledgement. This work was supported by the Ministry of Science and Higher Education of the Russian Federation as part of the state assignment projects of the Southern Scientific Center of the Russian Academy of Sciences (SSC RAS) (Projects No. 125011400232-3).

Structure and Properties of Heteroepitaxial Films 0.91NNO – 0.09SZO

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Antiferroelectrics are widely used in various microelectronic devices. The most studied antiferroelectric systems are compounds based on PbZrO_3 . However, the use of lead-containing materials is limited by environmental requirements, which stimulates the search for alternatives with similar characteristics. In this context, perovskite oxides based on NaNbO_3 , which have the ability to form an antiferroelectric state, are of particular interest. One of the effective ways to control the properties of NaNbO_3 is the formation of solid solutions with isovalent substitution, for example, the system $(1-x)\text{NaNbO}_3 - x\text{SrZrO}_3$ in the region of low concentrations x is characterized by stabilization of the antiferroelectric state and a change in the parameters of the induced phase transition. In this regard, the aim of this work is to study the characteristics of epitaxial thin films of the composition $0.91\text{NaNbO}_3 - 0.09\text{SrZrO}_3$ (NZNO-0.09), formed in the heterostructure $\text{Pt/NZNO-0.09/SrRuO}_3/\text{MgO}(001)$. The structures under study show good energy efficiency results (Fig. 1). The results of X-ray diffraction analysis showed that the films are pure and monocrystalline. The unit cell parameters in the tetragonal approximation for the 0.91NNO-0.09SZO and SrRuO_3 layers were: $c_{\text{NNZO}} = 0.3948(1)$ nm, $a_{\text{NNZO}} = 0.393(1)$ nm; $c_{\text{SrRuO}_3} = 0.3980(1)$ nm, $a_{\text{SrRuO}_3} = 0.395(3)$ nm. Dielectric measurements show that the film is in an antiferroelectric state.

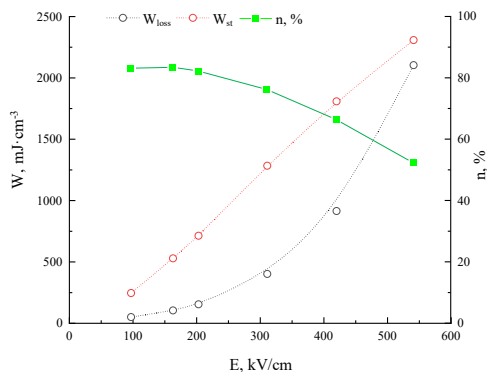


Fig. 1. Dependence of W_{st} , W_{loss} and n on E for the Pt/NNZO/SRO/MgO(001) heterostructure at a temperature of 293 K.

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Computer Simulation and Experimental Investigation of Ultrasonic Heating of Biological Tissues by Cylindrical Standing Waves

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The development of novel methods and devices for therapeutic treatment of large volumes of superficial tissues, using ultrasound energy in a more efficient and safer manner, is a key priority in modern aesthetic and regenerative medicine [1]. One promising approach involves the use of annular or cylindrical ultrasonic transducers, combined with vacuum-assisted tissue immobilization within the transducer cavity [2]. This study presents both theoretical modeling and experimental validation of ultrasonic heating in biological tissue, placed inside a hollow cylindrical piezoceramic element. The piezoelement was modeled, using linear elasticity theory, while the surrounding medium and biological tissue were treated as acoustic continua. Structural dynamics simulations were performed, using the finite element method (FEM), implemented in the ACELAN and COMSOL software packages. Transient thermal-acoustic heating was simulated, using FEM-based solvers in COMSOL and FlexPDE. In the physical experiment, biological tissue (bovine liver) was positioned inside a radially polarized hollow cylindrical piezoelement. The piezoelement was driven by a sinusoidal signal with an amplitude of 0 – 100 V at an excitation frequency of approximately 2 MHz, generated by a digital function generator (Agilent 33521B) and amplified, using an RF power amplifier (E&I 1040L). The tissue, positioned within the cylindrical ultrasonic standing wave (USW) field, experienced both thermal and/or mechanical effects, induced by ultrasound. It is important to note that, in contrast to a planar standing wave, the acoustic pressure distribution in a cylindrical standing wave does not follow a sinusoidal pattern but rather exhibits a Bessel function profile. An axial cross-section of the tissue sample allowed direct visualization of the resulting temperature distribution, which was subsequently compared with numerical simulations. The experiments demonstrated that the spatial pattern and magnitude of heat deposition depend strongly on the length of the cylindrical piezoelement, the ultrasonic intensity, and the duration of exposure. The results of the computer simulations demonstrate good agreement with the experimental data, confirming the validity of the proposed modeling approach for predicting ultrasonic heating patterns, generated by cylindrical standing waves.

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Microstructural Features and Anisotropy of Electromechanical Properties in Textured Piezoceramics, Based on Layered Bismuth-Containing Compositions

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Layered ferroelectrics, based on bismuth-containing compounds with a perovskite-like structure (BLSF – bismuth layer-structured ferroelectrics), have attracted considerable attention in recent years due to their interesting electromechanical and structural properties [1]. These compounds are characterized by high Curie temperatures; however, the piezoelectric activity of BLSF ceramics, fabricated by conventional ceramic processing, is not as high as might be expected, based on data from monocrystals. One reason for the low piezoelectric activity is related to the two-dimensional restriction on possible rotations of the spontaneous polarization vector within crystallites. To improve piezoelectric properties, the use of textured ceramics with a controlled degree of preferred crystallite orientation has been proposed [2]. One method for producing textured ceramics is hot pressing, i.e., sintering under uniaxial mechanical pressure. Textured sodium bismuth titanate (NBT) and its solid solutions, which exhibit high Curie temperatures and anisotropic electrical properties, are among the most promising compounds for developing new high-temperature piezoelectric materials. This work presents the results of an experimental study of microstructural features and complex electromechanical parameters of textured piezoceramics, based on solid solutions of the sodium bismuth titanate system. Textured piezoceramics of the composition $0.9\text{Na}_{0.5}\text{Bi}_{4.5}\text{Ti}_4\text{O}_{15} - 0.1\text{PbNb}_{0.5}\text{Cr}_{0.5}\text{O}_3$ were fabricated by hot pressing in the form of blocks with sizes of $110 \times 110 \times 20 \text{ mm}^3$. Microstructural investigations were performed on polished surfaces and fracture surfaces of the piezoceramic samples, using a scanning electron microscope (JEOL JSM-6390LA). The complex dielectric, piezoelectric, and elastic parameters of the NBT-based piezoceramics were measured and analyzed, using piezoceramic disks $\varnothing 8 \times 0.73 \text{ mm}$ with varying orientations of the surface normals relative to the pressure axis, applied during hot pressing. Experimental results demonstrate that textured NBT piezoceramics with the electric field, applied perpendicular to the poling direction ($E \perp P$), possess a unique combination of anisotropic electromechanical parameters, as well as low dispersion and low attenuation of ultrasonic waves over a broad frequency range. The unique combination of high and significant anisotropic electromechanical and piezoelectric characteristics, together with the high Curie temperature of the textured piezoceramics, enabled the development of ultrasonic transducers capable of operating at temperatures up to 770 K for acoustic monitoring systems.

Acknowledgement. This study was financially supported by the Ministry of Science and Higher Education of the Russian Federation (State Assignment in the Sphere of Scientific Activity, Project No. FENW-2026-0027).

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Quantitative Evaluation of Thread Consumption in Stitch Type 103 for Industrial Blind Hemming on Woven Fabrics

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Thread consumption significantly influences production cost estimation and material planning in garment manufacturing. While extensive studies have been conducted on lockstitch and chain stitch seam types, limited quantitative data are available for ISO 4915 stitch type 103 (single-thread blind stitch), which is widely used in hemming operations. This study experimentally determines the thread consumption coefficient of stitch type 103 under varying stitch densities and fabric weights. Two woven fabrics with different mass per unit area (240 g/m² and 374.5 g/m²) were selected. Sewing experiments were conducted using 100% polyester sewing thread (Tex 18), with stitch densities of 4, 4.5, and 5 stitches per inch (SPI). Seam lengths of 20 cm and 25 cm were tested, each repeated five times. Thread consumption was measured, statistically evaluated, and converted into consumption coefficients per meter of seam length. Results indicate that thread consumption coefficients ranged from 3.37 to 4.45 m of thread per meter of seam. Stitch density showed a clear increasing trend in thread usage, while fabric weight significantly influenced consumption levels. Seam length did not significantly affect the coefficient. The findings provide practical reference values for industrial thread consumption estimation in blind hemming operations.

Influence of PVA Binder and Processing Parameters on the Functional Performance of Ag-doped ZnO Coatings on Cotton Fabrics for Self-cleaning and Antibacterial Applications

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This study investigates the influence of polyvinyl alcohol (PVA) binder and key processing parameters, including solution concentration and padding pressure, on the functional

performance of Ag-doped ZnO (Ag-ZnO) coatings, applied to cotton fabrics. Ag-ZnO nanoparticles with an optimized doping concentration of 0.5 wt% were synthesized via a co-precipitation method and deposited onto cotton substrates, using a padding-dry-heat process, with and without the incorporation of PVA as a binding agent. The effects of processing parameters on deposition behavior were evaluated in terms of add-on percentage and surface loading, while coating morphology and elemental distribution were characterized by SEM and EDS analysis. Functional performance was assessed through photocatalytic degradation of methylene blue under UV and Xenon irradiation, and antibacterial activity against *Escherichia coli* and *Staphylococcus aureus*. Results show that both solution concentration (10 – 80 µg/mL) and padding pressure (70 – 100%) significantly affect nanoparticle loading, with optimal conditions, identified at 80 µg/mL and 80 – 90% pressure. The incorporation of PVA does not significantly increase the actual nano loading but markedly improves coating uniformity, adhesion stability, and functional durability. The optimized Ag-ZnO coated fabrics exhibit excellent self-cleaning performance ($\approx 99\%$ MB degradation) and enhanced antibacterial activity (ZOI up to 17.9 mm). The findings demonstrate that processing parameters primarily control nano deposition, whereas PVA binder plays a critical role in stabilizing the coating structure and enhancing functional performance. This study provides a practical strategy for optimizing durable multifunctional textile coatings.

The Bifurcation Analysis of the Cahn-Hilliard Equation

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The Cahn-Hilliard equation at a segment with the boundary condition is considered [1, 2]. By method of center manifold [3], the theorem on the existence and stability of spatially inhomogeneous stationary solutions $\varphi_1^\pm(x, \varepsilon, a)$, branching off from the zero solution with $\varepsilon^2 = 1 - 3a^2$ has been proved. The analysis conducted has shown that the asymptotic expansion of the solution $\varphi_1(x, \varepsilon, a)$ in the vicinity of $\varepsilon^2 = 1 - 3a^2$, obtained in the theorem is an approximate solution of the problem under consideration with the sufficiently wide range of the parameter ε^2 . The theorem assertions on the existence, shape and stability are of local as for the parameter ε^2 nature. For the construction and analysis of stationary solutions of slowly varying solutions, we use the Galerkin's approximations of the average dimensions (30 – 40). We should note that with sufficiently small ε^2 the function $\varphi_1(x, \varepsilon, a)$ is like a step function with values 1, –1 and one transition point. The solutions $\varphi_k(x, \varepsilon, a)$, $k = 2, 3, \dots$, are built being based on $\varphi_1(x, \varepsilon, a)$, using the principle of similarity [4]. In particular, the solution $\varphi_2(x, \varepsilon, a)$ has been built. We should emphasize that with small ε^2 the function $\varphi_2(x, \varepsilon, a)$ is the solution of the type of internal transition layer with two transition points. In particular, the solution $\varphi_3(x, \varepsilon, a)$ has been built. We should emphasize that with small ε^2 the function $\varphi_3(x, \varepsilon, a)$ is the solution of the type of internal transition layer with three transition points. The analysis conducted suggests that the use of the Galerkin's method and the method of center manifold in the problem leads to qualitatively and quantitatively correct results.

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Investigation of the Tribological Properties of Epoxy Resin, Modified with Micro-sized Al_2O_3 Particles

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Epoxy polymer composites are widely employed in tribology due to their excellent adhesion, chemical resistance, and potential for modification to enhance wear resistance [1]. The incorporation of micro-sized Al_2O_3 particles into an epoxy matrix substantially enhances the mechanical and tribological properties of the material, which is relevant for developing durable friction assemblies in various industrial sectors. Therefore, the objective of this study is to investigate the effect of the mass fraction of micro-sized Al_2O_3 particles on the tribological properties of a composite, based on ED-20 epoxy-diane resin, and to determine the optimal modifier concentration, based on the criterion of minimal mass wear. To achieve the set objective, samples of epoxy-diane resin, modified with Al_2O_3 particles at varying mass fractions (1%, 3%, 5% by mass), were prepared. The microstructure of the samples was investigated, using scanning electron microscopy; tribological properties were evaluated on a modified SMT-1 friction machine, according to the "roller-pad" scheme, with a 40 mm diameter counter body roller, made of 40CrNiMo6 steel, under a load of $N = 200$ N and a sliding speed of $V = 0.2$ m/s. The chemical analysis of the powder revealed Al_2O_3 particles with a composition of $\sim 49.8\%$ Al, $\sim 39.1\%$ O, and $\sim 11.2\%$ C, with sizes of $15 - 59$ μm , typical for micron-dispersed technical aluminum oxides, used in tribological and composite materials. The microstructure reveals a smooth, predominantly spherical or isometric morphology without branched forms, ensuring uniform distribution in the polymer matrix, reducing agglomeration due to lower specific surface area, and enhancing the wear resistance and thermal stability of composites, owing to the high density, hardness, and chemical inertness of the particles [2]. The conducted tribological studies established that samples with Al_2O_3 , added to the ED-20 matrix, exhibit a stable friction coefficient throughout the entire test duration, unlike the neat ED-20 sample. Samples with 1 and 3 mass % Al_2O_3 exhibit a stable friction coefficient in the range from 0.6 to 0.65, whereas at 5 mass %, it increases to 0.8 by the end of the test, accompanied by higher mass wear. Examination of the contact surface morphology after tribological tests indicates abrasive wear upon introduction of dispersed Al_2O_3 particles. The optimal modifier concentration is 1 mass %, providing minimal mass wear.

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Effect of Argon Ion Cleaning Parameters on the Surface State of 40CrNi Steel before PVD Coating Deposition

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For high-quality vacuum coatings, produced by physical vapor deposition, meticulous specimen preparation prior to coating deposition is required [1]. The surface quality of the specimens is a key factor that strongly affects the tribological performance of vacuum-deposited coatings. In physical vapor deposition (PVD) processes, the coatings replicate the initial substrate topography with high fidelity, and the presence of a complex microgeometry or significant roughness leads to intensive accumulation of internal stresses as the film thickness increases, ultimately resulting in crack formation and delamination [2]. During the deposition of vacuum coatings such as nitride, diamond-like, high-entropy alloy-based, and multilayer coatings, one of the critical stages of surface preparation for the deposition of an interlayer (Ti, Cr, etc.) or the main coating layer is ion cleaning with argon ions. Argon ion bombardment is carried out under high vacuum, which enables surface activation, removal of oxides and contaminants, and the achievement of excellent adhesion, while minimizing porosity and improving the coating microstructure. Ion cleaning of the 40CrNi steel specimen was carried out in a BRV600F chamber in two stages. In the first stage, the specimen was etched for 30 min in an argon (Ar^+) atmosphere at a pressure of 9.9×10^{-1} Pa (Ar content 50%) without applying a bias voltage. The etching conditions in the second stage were identical to those of the first stage (30 min, 50% argon, no heating). A distinguishing feature of this stage was the continuous application of a bias voltage of $U_S = 1000$ V to the specimen. To determine the elemental composition of the specimen surfaces, a Zeiss EVO MA 18 scanning electron microscope, equipped with an X-Max 50 energy-dispersive X-ray spectrometer, was used. The surface roughness (R_a , R_z) was measured, using a TR220 surface roughness tester. The conducted study demonstrated that argon ion cleaning (Ar^+) of the 40CrNi steel surface provided effective substrate preparation for vacuum coating deposition, reducing the carbon content from 5.1 at.% (after sample preparation) to 3.9 at.% (without U_S) and 1.6 at.% (at $U_S = 1000$ V), while simultaneously optimizing the surface topography. A decrease in R_a by 14.81% indicates selective smoothing of micro-irregularities, ensuring excellent adhesion of subsequent coatings, whereas an increase in R_z by 41.18% forms a functional microrelief with an increased contact area.

Acknowledgement. This work was supported by the Russian Science Foundation (grant No. 21-79-30007-II).

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Titanium Oxide Memristive Nanostructures Based on Electrochemical Oxidation

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One of the modern electronics objectives include techniques development for the memristive nanostructures fabrication, based on electrochemical oxides with adjustable resistive switching parameters [1]. To reproduce certain synaptic functions in hardware, a diverse set of resistive devices with varying properties is required, which can depend on the material of the memristive device and the thickness of its active layer [2]. The objective of this work is to study electrochemical oxidation voltage pulses duration influence on the thickness of the formed memristive nanostructures based on titanium oxide. The experimental studies utilized semi-insulating silicon Si/SiO₂ substrates, onto which a thin 20 nm titanium film was formed, using magnetron sputtering. The windows for electrochemical oxidation with a total oxidized surface area of 3550 μm² were exposed to the experimental samples surface by photolithography, using an Olympus IXplore automated micropatterning system. The working and auxiliary electrodes of the electrochemical cell were made of titanium and were 20 mm apart. The samples were pressed with its active part against the auxiliary electrode and faced the working electrode. A citric acid solution with 150 ppm particle concentration was used as the electrolyte; measurements were performed, using a Soeks Ecovisor F4 tester. To create a potential difference between the two electrodes, a GW Instek GPS-3303 DC power source was used. As a result of oxidation, arrays of TiO₂ structures were formed on the titanium surface. The obtained memristive nanostructures geometric parameters were studied by atomic force microscopy, using Solver P47. Experimental studies were conducted at the following voltage pulse durations: 20, 30, 40, 50, 60, and 70 seconds. The oxidation voltage was constant and amounted to 5.2 V. As a result of statistical data processing, the dependence of the oxide nanostructure thickness on the applied voltage pulses duration was obtained, which averaged 1.75 nm for 20 s, 3.75 nm for 30 s, 5.5 nm for 40 s, 7 nm for 50 s, 8 nm for 60 s, and 9 nm for 70 s. Accordingly, this study investigated the formation modes of memristive TiO₂ nanostructures, obtained by electrochemical oxidation, controlled by the duration of voltage pulses. The obtained results can be used to manufacture memristive TiO₂-based structures, for the hardware implementation of promising neuromorphic systems, neural networks that use

synaptic plasticity principles, and artificial intelligence systems that mimic the human brain functioning.

Acknowledgement. The study was supported by the grant of Russian Science Foundation № 22-79-10215-P, at the Southern Federal University.

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The Study of Biomedical Elements Formed by Additive Technologies

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The rapid development of additive manufacturing is opening new possibilities in the field of tissue engineering and bringing us closer to solving key challenges in modern biomedicine, related to the creation of artificial biological structures, whose properties closely resemble those of human organs, tissues, and the vascular system. Among additive technologies, one of the most promising areas is two-photon polymerization lithography, which enables the formation of structures with submicron resolution. This method allows for the creation of complex three-dimensional micro- and nanostructures, such as capillaries, with high geometric precision and characteristics close to those of natural biological counterparts. Traditional manufacturing methods lack precision, required to reproduce the complex hierarchical architecture of biological systems. In contrast, two-photon polymerization lithography provides a high level of control over the geometry, structure, and properties of the material and allows for the creation of three-dimensional structures with submicron resolution, which is critical for modeling the cellular environment and biological tissues. This work investigates the possibility of creating biomedical components, using two-photon polymerization lithography. Figure 1 shows a fragment of a capillary, formed by two-photon polymerization lithography, using SZ2080 resist. Studies of its structure and mechanical properties were conducted, using atomic force microscopy. The results demonstrate that additive technologies, in particular two-photon polymerization lithography, allow for the fabrication of complex biomedical elements with high spatial resolution and specified structural characteristics. The resulting microvascular structures possess geometries and properties similar to those of natural biological systems.

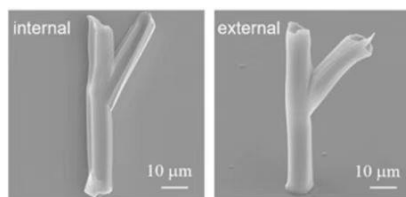


Fig. 1. Section of a capillary, formed by two-photon polymerization lithography, using SZ2080 resist

Optimization of the Production Process of an Oil Refinery According to the Cost Criterion

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The sustainable functioning of any branch of industrial production is based on increasing the efficiency of technological processes, reducing production costs and maximizing profits. The possibility of optimizing production processes of various directions includes the introduction of digital linear programming tools, statistical analysis and algorithmic strategies to find the most effective solution to the problem. The research paper presents a mathematical model of the distribution of heterogeneous resources, using the example of one of the oil refineries producing five brands of gasoline with different octane numbers. Light distillates, kerosene fractions, additives and additives are needed for production, the reserves of which are known and limited to certain values [1]. The values of the consumption rate and the profit received by the enterprise from the sale of each ton of a certain type of product are known. The initial data was presented in the form of a technological matrix, containing complete information about the resource requirements of production. The optimal production plan is built, using the simplex method in the MS Excel software [2, 3]. The optimal allocation of resources obtained, which ensures maximum of target functions according to the cost criterion, involves the production of two types of products, namely A-95 and A-95+ gasoline, therefore, additional conditions were introduced into the mathematical model of the problem, regarding the required minimum volumes of each type of product, and a new optimal solution was built. The resulting reference plan ensures rational production planning to maximize profits from the sale of manufactured products with optimal allocation of available resources. The effectiveness of the introduction of digital optimization tools for decision-making tasks in the production sector of the oil and gas industry was noted.

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Development of a Three-phase Pump Motor Control System for an Automated Oil Collection, Preparation, and Transportation System in the Field

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Improving the overall level of the automation of oil collection, preparation, and transportation in the field is a pressing issue today [1]. Three-phase asynchronous motors form the basis of these systems. One of the most important elements of the overall modernization of the oil and gas complex is the replacement of obsolete motor drives in automation systems for oil collection, preparation, and transportation, and refining in the field [2]. The scope of application of electric drives in industry, transport, and everyday life is constantly expanding. Currently, more than 60% of all electrical energy generated worldwide is consumed by electric motors. Consequently, the effectiveness of energy-saving technologies is largely determined by the efficiency of the electric drive. The development of high-performance, compact, and energy-efficient drive systems is a priority area for the development of modern technology [3]. The automation system for oil collection, preparation, and transportation in the field is designed to control the process of a booster pump station (BPS), as well as maintain optimal oil and gas treatment and water discharge conditions, monitor process parameters, protect BPS pump units from overheating, monitor the process, generate and issue reporting and archival documentation, and diagnose measuring equipment. This study describes a power thyristor-capacitor current source with switched capacitors for driving a three-phase asynchronous AC motor at a structural level.

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Acid Profile as a Predictor of Developmental Stage-Dependent Resistance of Weeds to a Marine Biotoxin: A Multivariate Regression Framework

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The utilization of marine biotoxins as targeted bioherbicides requires a transition from empirical dose-response assessment to predictive susceptibility modeling. While the crude venom of *Rhizostoma pulmo* demonstrates phytotoxic efficacy against invasive species like *Ambrosia artemisiifolia*, the inherent variability in plant resistance, particularly across distinct developmental phenophases, remains a critical knowledge gap for practical application. This study proposes a computational framework linking the biochemical composition of the target plant to its predicted vulnerability to pore-forming toxins. Building on preliminary mortality data, we hypothesize that the resistance of a plant to venom-induced cellular lysis is governed by the specific amino acid (AA) composition of its cell wall and membrane proteins, and that this relationship is modulated by the developmental stage (Seed vs. Adult Plant). We introduce a multivariate modeling approach wherein the response variable (Mortality Rate, %) is predicted by a feature vector of normalized AA concentrations (e.g., Proline, Hydroxyproline, Lysine) and a categorical interaction term for phenological phase. The core of the model is a regularized regression structure that allows for the quantification of stage-specific biochemical barriers. By parameterizing this model, using existing public metabolomic databases and literature-derived venom efficacy data, we generate a predictive heatmap of weed vulnerability. This framework moves beyond descriptive toxicology towards mechanism-informed bioproduct optimization, essential for designing precision application strategies in sustainable ecosystem management.

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Light-Assisted Stabilization of Al/InAlGaO/Pt RRAM via a Photo-Responsive Two-Dimensional SnS₂ Insertion Layer

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Resistive random-access memory (RRAM) based on multi-component oxide semiconductors, such as InAlGaO, is a highly promising candidate for next-generation non-volatile memory.

However, utilizing a reactive aluminum (Al) top electrode frequently leads to uncontrolled oxygen extraction, generating excessive oxygen vacancies at the interface. This overabundance of defects severely degrades switching reliability, manifesting as severe fluctuations in SET/RESET voltages and the problematic high resistance state (HRS) floating effect. To address these critical challenges, we propose a novel optoelectronic memory architecture that embeds a two-dimensional (2D) tin disulfide (SnS₂) insertion layer within the Al/InAlGaO RRAM structure. Leveraging the pronounced photo responsive characteristics of the 2D SnS₂ layer under 550 nm wavelength illumination, we introduce a light-assisted modulation mechanism to regulate the resistive switching process. During operation, 550 nm light exposure generates electron-hole pairs within the SnS₂ layer, which dynamically modulates the internal electric field and localizes the migration path of oxygen ions. This photo-gating effect effectively restricts the random overgrowth and lateral diffusion of conductive filaments. Our experimental results demonstrate that the SnS₂ insertion layer, coupled with 550 nm optical stimulation, significantly sharpens the conductive filament formation and rupture processes. Consequently, the operating SET and RESET voltages are highly stabilized, and the HRS floating phenomenon is successfully suppressed. This work provides an effective, light-modulated defect-engineering strategy to overcome the inherent limitations of Al-electrode RRAMs, paving the way for reliable optoelectronic memory applications.

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The Influence of Electric Field on the Pyroelectric Properties of PbFe_{1/2}Nb_{1/2}O₃ and 0.91PbFe_{1/2}Nb_{1/2}O₃ Ceramics

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Like solid solutions of other complex perovskites, PbFe_{1/2}Nb_{1/2}O₃-based compositions exhibit very large dielectric, piezoelectric and pyroelectric responses. The field dependencies of the permittivity, dynamic pyroelectric coefficient, and differential and effective inverse piezoelectric modulus d_{33} of PbFe_{1/2}Nb_{1/2}O₃ (PFN) ceramics and the 0.91 PbFe_{1/2}Nb_{1/2}O₃ – 0.09 PbTiO₃ (PFN – 0.09PT) solid solution were studied in the temperature range of 20 – 160 °C. Figure 1 shows the temperature dependencies of the dynamic pyroelectric coefficient γ for PFN and PFN – 0.09PT ceramics, measured in the heating mode FH at different values of the constant electric field strength E . The $\chi(T)$ dependencies for both PFN and PFN – 0.09PT

exhibit a diffuse maximum $T_{m\gamma}$ at a temperature approximately on 10 K below the temperature of permittivity maximum T_{mc} for PFN ceramics and approximately coinciding with T_{mc} for PFN – 0.09PT ceramics. The large difference between the T_{mc} and $T_{m\gamma}$ values is due to the stronger diffuseness of the $\varepsilon'(T)$ dependence maximum in PFN ceramics. The diffuseness parameter W of the $\varepsilon'(T)$ and $\chi(T)$ dependence maxima was determined as the half-width of the $\varepsilon'(T)$ maximum at 2/3 of its height at $T > T_{mc}$. With increasing field E values, an increase in the blurring parameter W is observed, however, in the case of PFN ceramics, the blurring of the maxima of both $\varepsilon'(T)$ and $\chi(T)$ dependencies increases more strongly than in PFN – 0.09PT ceramics ($W_{m\gamma}$ at $E = 0$ is twice as large as in PFN – 0.09PT (6.2 K and 2.9 K, respectively), and with increasing field E values, this difference somewhat decreases (to 22.8 K and 13.1 K, respectively). In PFN, in the heating and cooling modes, an anomaly in the region of the monoclinic-tetragonal phase transition was observed on the temperature dependencies of the dynamic pyroelectric coefficient $\gamma(T)$, while for PFN – 0.09PT no anomalies were observed.

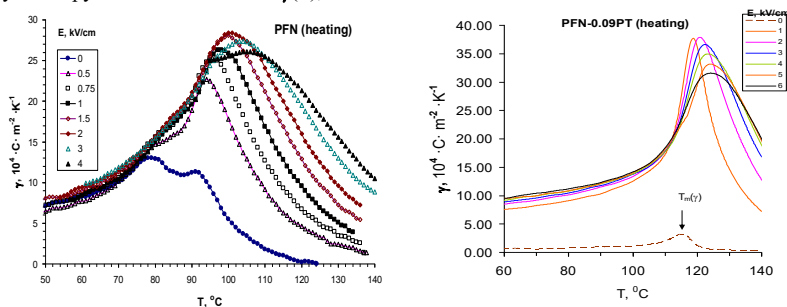


Fig. 1. Temperature dependences of the dynamic pyroelectric coefficient γ for PFN and PFN–0.09PT ceramics, measured in the FH-heating mode under the different values of the constant electric field strength E

Thermally Expanded Graphite from Acceptor Graphite Intercalation Compounds: Microstructure, Morphology and Physicochemical Properties

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Acceptor graphite intercalation compounds have a unique ability to expand (increase in volume) under conditions of rapid heating to high temperature [1]. Therefore, such compounds are widely used for thermally expanded graphite (TEG) synthesis on a laboratory and industrial scale. In our research, TEG was obtained from acceptor graphite intercalation compounds by the thermal shock mode of heating at 900 °C (Fig. 1). The structural features,

microstructure, morphology and quality of the obtained thermally expanded graphite were studied by powder XRD, scanning electron microscopy, transmission electronic microscopy, and Raman spectroscopy. TEG is a hydrophobic crystalline material and has a unique nanoporous structure. Such structural features determine its physicochemical properties. TEG, obtained from acceptor graphite intercalation compounds [1], has a remarkable mix of unique properties. It is a promising component for the development of multifunctional materials, which can be used for a wide scope of applications. TEG is a well-known sorbent for various eco-toxicants such as oil and oil products, organic compounds and heavy metals. Therefore, it is a promising component of effective sorbent materials. Model systems for a comprehensive study of the adsorption properties of TEG with respect to organic compounds, using experimental and computational methods, are discussed.

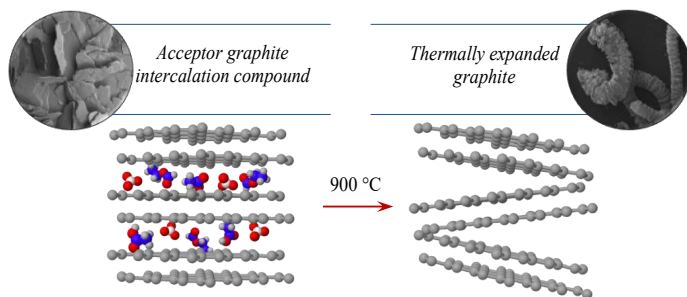


Fig. 1. Scheme of the thermally expanded graphite synthesis from acceptor graphite intercalation compounds

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Interface-Edge Singular Stress Fields in Notched Lap Joints

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This study focuses on the influence of notch position on the strength of the singular stress field at the interface end of lap joints, with the aim of improving adhesive strength. To identify an effective notch position, a small crack was assumed at the interface end, and the magnitude of the singular stress field was evaluated by analyzing its stress intensity factor. Figure 1 shows a simple lap joint model, used in the analysis. By providing a semicircular notch near the interface end, the singular stress field was reduced. When the distance C between the interface end and the notch tip is 2.0 mm or more, the stress intensity factor hardly changes, indicating that the influence of the notch on the singular stress field is small. Furthermore, as the semicircular notch approaches the interface end, K_1/K_{1*} and K_2/K_{2*} decrease at almost the same rate. When the notch is in contact with the interface end ($C = 0$), the stress intensity factor was

found to decrease by about 70%. In addition, tensile tests were performed on the lap joint to investigate the influence of the notch on the fracture load.

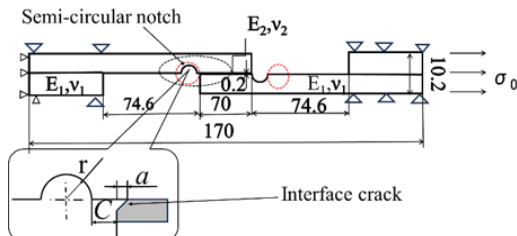


Fig. 1. Single lap joint with a semi-circular notch near the interface end

The Importance of Calcium-Carbonate Balance for the Functioning of River Ecosystems

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One of the fundamental principles underlying the functioning of natural waters is the carbonate system (or calcium-carbonate equilibrium). Under natural conditions, the pH of river water is controlled by reactions, involving the carbonating system. The carbonate system covers a range of acid-based reactions in river water, including carbon dioxide dissolution, carbonic acid dissociation, hydrolysis of alkali metal carbonate and bicarbonate salts, calcium carbonate precipitation, and more. The buffering properties of river water are largely determined by the ratio of sodium carbonate and sodium bicarbonate concentrations which ensures certain stability in the chemical composition of the water. In addition to its theoretical significance for the hydrochemistry of natural waters, research into the carbonate system has several practical applications and can be used in related geosciences, including oceanography, hydrobiology, hydrogeology, and other sciences directly or indirectly associated with the study and use of natural waters. The calcium-carbonate equilibrium has been extensively explored for marine and ocean waters, especially its variability in the river and sea waters mixing zone as a part of estuarine hydrological and hydrochemical processes research. Much less research has been conducted on river waters, reservoirs and lakes. The main applied areas of carbonate system research are related to the following: (i) the predictive analysis of water salt composition and water hardness during the construction of large reservoirs especially in arid climate; (ii) the assessment of the carbon dioxide aggressiveness of water and forecast of the corrosive properties of river water during the construction of hydraulic structures; (iii) using water as a source of drinking water supply, for irrigation or technical purposes (assessing the probability of scaling in heating systems and other technical equipment); (iv) studying the probability of microelement sorption on calcium carbonate crystals, formed in water followed by precipitation in river sediments; (v) assessing the direction of biological processes in reservoirs and in the "natural water-soil" system under conditions of calcium carbonate dissolution and precipitation in water. For the southern regions of the European part of Russia,

including the steppe zone of the Rostov region, where a shortage of fresh water supply occurs, there is an increasing need to study the carbonate-calcium balance in river waters to assess the possibility of using brackish water including underground mine waters as alternative sources of water supply for industrial enterprises. The solubility of calcium carbonate in water can be quantitatively calculated for any acid-based conditions. There are established relationships between pH changes and carbonic acid concentrations in river water. However, in most cases, in natural river water, it is not the concentrations of carbonates, bicarbonates, or carbonic acid that depend on pH but rather their ratio that determines the pH of the environment. The main factors, influencing the calcium-carbonate balance in river water, are carbonic acid (regulating the solubility of bicarbonates) and calcium ions (limiting the solubility of calcium carbonate and the concentration of carbonate ions). As we continue our study of the chemical composition of river water in the Rostov Region, we plan to conduct a detailed study of the carbonate system to assess the suitability of the water for irrigation and technical purposes.

A Novel Combined Approach for Non-Invasive Treatment of Superficial Tissues in Body Contouring and Aesthetic Applications

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Therapeutic modalities, employing electromagnetic fields (EMFs) and ultrasound for surgical, therapeutic, or aesthetic interventions in targeted human tissues are well established [1]. Among these, high-intensity focused ultrasound (HIFU) has emerged as a particularly effective technique for non-invasive tissue modification [2]. However, conventional radiofrequency (RF) and HIFU approaches for superficial tissue treatment suffer from several limitations: limited treatment volume, risk of epidermal injury, suboptimal energy efficiency, prolonged procedure times, and restricted applicability to certain anatomical regions, primarily due to complex body contours, thin adipose layers, and the proximity of bones or vital organs. To overcome these challenges, this study introduces an innovative, synergistic method for non-invasive treatment of superficial tissues on virtually any body area. The approach integrates three complementary physical mechanisms: cylindrical ultrasonic standing waves (CUSW), radiofrequency (RF) energy, and vacuum-assisted massage. The proposed combinational therapy relies on the sequential or simultaneous application of constructively interacting biophysical stimuli. Unlike conventional HIFU or unfocused ultrasound systems, CUSW deliver acoustic energy parallel to the skin surface, fully confined within the target zone and conforming to the body's curvature. This configuration achieves therapeutic efficacy comparable to HIFU while significantly expanding the treated tissue volume. The developed therapeutic module comprises an electronic control unit, a vacuum system, and a multifunctional treatment head, integrating both CUSW and RF transducers. This head features a vacuum suction cup, a central plunger that compresses tissue and ensures optimal acoustic coupling, a cylindrical piezoceramic element that generates CUSW within the captured tissue volume, and metal RF electrodes, positioned on both the cup's outer rim and the plunger surface. *Ex vivo* experiments on biological tissues confirm the high selectivity, efficacy, and safety of the proposed method and device architecture. Critically, this multimodal interaction lowers the cavitation threshold, enhances local blood perfusion,

accelerates clearance of cellular debris, and enables real-time monitoring and control of the treatment process. These advantages make technology a very promising platform for next-generation non-invasive aesthetic and therapeutic applications.

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On the Causes of Destructive Phenomena in Niobate Ferroelectric Ceramics

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The study examines the main causes of destructive phenomena in ferroelectric ceramics based on sodium, potassium, and lithium niobates (niobate ferroelectric ceramics). First of all, it is (1) the secondary intermittent recrystallization of type I, which causes the growth of individual crystallites to a critical size ($\sim 14 \mu\text{m}$), above which the integrity of the samples is compromised; (2) the secondary intermittent recrystallization of type II, associated with the presence of a fluorine-containing liquid phase in niobate ferroelectric ceramics, which is a matrix for the excessively rapid growth of single crystals to gigantic sizes both in the edge regions ("crust" effect) and in the center of the sample; using various experimental techniques (determination of strength, fracture toughness, etc.), it was found that the maximum permissible concentration of fluorine that does not lead to destructive phenomena in niobate ferroelectric ceramics is $< 0.2 \text{ wt.}\%$; an increase in the fluorine content leads to a deterioration in mechanical properties, suppression of the piezoelectric state, as well as an undesirable increase in dielectric constant by 50% for niobate ferroelectric ceramics; (3) the heterogeneity of the solid solutions under study, caused by the simultaneous existence of crystalline and liquid phases during the sintering process, each with a different composition; (4) the rheological characteristics (high caking and low flowability) of the original powders, leading to non-uniform density and, subsequently, to low sintering activity, which causes the formation of the centers with a more (less) dense structure and non-uniform microstructure, which are sources of internal stress; (5) the existence of critical values of the specific surface area of Nb_2O_5 particles of various qualifications, above which the strength of the niobate ferroelectric ceramics decreases sharply ($550 - 650 \text{ m}^2/\text{kg}$ for Nb_2O_5 in NbO-Pt ; $950 - 1000 \text{ m}^2/\text{kg}$ for special purity grade; $2500 - 3500 \text{ m}^2/\text{kg}$ for a type of special purity grade). The methods for minimizing destructive phenomena in niobate ferroelectric ceramics have been selected, based on high strength and fracture toughness indicators: (i) a modification with

cationic additives, in particular, oxides Cr_2O_3 , TiO_2 , and MnO_2 , selected based on comprehensive studies and leading to strengthening by 1.5 – 2 times; (ii) a modification with glass additives, which leads to crystallographic matching of interphase boundaries, increasing strength properties, and improving the electrophysical parameters of the niobate ferroelectric ceramics.

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Resistive Switching of TiO_2 /Graphene Memristor

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Traditional von Neumann architecture, which relies on separation of memory and processing units, exhibits fundamental limitations in throughput and power efficiency due to the intensive data exchange between these components. Memristors are resistive memory elements that enable the development of neuromorphic computing systems with architectural similarities to the biological brain. Metal oxide memristors have been extensively studied owing to their compatibility with CMOS technology [1, 2]. However, their filamentary switching mechanism introduces stochastic behavior, resulting in high variability of switching parameters and precluding precise analog computation. During the reset operation, localized Joule heating reaches several hundred degrees Celsius, causing thermally induced diffusion of the electrode material and irreversible degradation of the oxide layer. The integration of two-dimensional materials, particularly graphene, has been proposed to address these limitations. The thermal conductivity of graphene is $\sim 5000 \text{ W}/(\text{m}\cdot\text{K})$, which facilitates heat dissipation and reduces defect diffusion and uncontrolled filament growth. The graphene film also functions as a diffusion barrier, limiting ion migration between the metal electrode and dielectric. In the present work, a planar memristor structure, comprising ITO/ TiO_2 /graphene, is experimentally investigated. The graphene layer was synthesized via chemical vapor deposition on a copper substrate and serves as a bottom contact, enabling lateral charge transport within the 10-nm-thick oxide film during the transition to a low-resistance state. The graphene film was predominantly monolayer. Two upper ITO contacts are separated by $170 \mu\text{m}$. The deposited ITO films have a thickness of 100 nm. Electrical characterization of the fabricated memristor structures was performed at room temperature under ambient conditions, using a probe station with tungsten tips with a diameter of approximately 100 nm. The fabricated planar memristor demonstrates stable bipolar resistance switching over 10^3 cycles, with high-resistance state and low-resistance state values of $260 \pm 10 \Omega$ and $115 \pm 13 \Omega$, respectively, yielding an $R_{\text{off}}/R_{\text{on}}$ ratio of 2.25. These results demonstrate that graphene electrodes increase the reliability of TiO_2 -based planar memristors for applications in neuromorphic computing systems, non-volatile memory, and bioinspired robotic systems.

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Dielectric Properties of Ferroelectric Solid Solutions Based on $\text{Bi}_{0.5}\text{Na}_{0.5}\text{TiO}_3$ under the Influence of a Constant Electric Field

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Ferroelectric materials are an important class of functional materials, exhibiting spontaneous polarization, nonlinear response, and hysteresis properties. They are widely used in modern electronics, including piezoelectric transducers, sensors, memory elements, and varactors. Therefore, studying their dielectric characteristics in alternating and direct electric fields is of great importance. The aim of this study is to investigate the dependence of the real ϵ'/ϵ_0 and imaginary ϵ''/ϵ_0 parts of the permittivity on the electric field strength for ceramic ferroelectric solid solutions of various compositions. The objects of study were ceramic solid solutions of the systems: $(1-x)\text{Bi}_{0.5}\text{Na}_{0.5}\text{TiO}_3 - x\text{BaTiO}_3$, $(1-x)\text{Bi}_{0.5}\text{Na}_{0.5}\text{TiO}_3 - x\text{PbZr}_{0.52}\text{Ti}_{0.48}\text{O}_3$, and $(1-x)\text{Bi}_{0.5}\text{Na}_{0.5}\text{TiO}_3 - x\text{PbZr}_{0.95}\text{Ti}_{0.05}\text{O}_3$ with $x = 0.03$ and 0.06 , synthesized by a two-stage solid-state method. The samples exhibited a relative density of about 95%, indicating high-quality ceramics. The dependencies of the real (ϵ'/ϵ_0) and imaginary (ϵ''/ϵ_0) parts of the relative permittivity on temperature were obtained, using an automated setup, based on an Agilent 4263B LCR- meter in the frequency range of $(10^2 - 10^5)$ Hz. X-ray diffraction analysis revealed that the studied materials crystallize in a perovskite structure. For the $(1-x)\text{Bi}_{0.5}\text{Na}_{0.5}\text{TiO}_3 - x\text{BaTiO}_3$, decomposition into two solid solutions with similar cell parameters was observed, due to a mismatch in the isomorphism conditions. In systems with $\text{Bi} \leftrightarrow \text{Pb}$ substitution, the formation of continuous solid solutions was observed. A study of the $\epsilon'/\epsilon_0(E)$ and $\epsilon''/\epsilon_0(E)$ dependencies revealed the formation of characteristic "butterfly" loops with hysteresis, reflecting domain structure rearrangement processes. It was established that the shape of the loops, the magnitude of the hysteresis, and the position of the ϵ' maxima depend significantly on the material composition and the concentration of the substitution component. Increasing concentration leads to a shift of the ϵ' maxima toward lower electric fields, which is associated with changes in the mobility of domain walls and coercive fields. The obtained results indicate the possibility of targeted control of the dielectric properties of the studied ferroelectric materials by changing their composition and are of interest for use in nonlinear electronic devices.

Acknowledgements. This study was supported by the Ministry of Science and Higher Education of the Russian Federation (State Assignment in the Sphere of Scientific Activity, Project No. FENW-2026-0022). The equipment of the Shared Use Center of the Southern Federal University's Physics Research Institute "Electromagnetic, Electromechanical, and Thermal Properties of Solids" was used.

Photocatalytic Activity of Nanocrystalline La-modified Titanium Dioxide Films

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Thin titanium dioxide films are widely used today in various scientific fields. TiO₂-based materials possess unique physical and chemical properties, making them suitable for use in a variety of applications, including wastewater treatment and non-invasive disease diagnostics. Pure titanium dioxide has a wide band gap (3.2 eV) and exhibits photocatalytic activity when exposed to ultraviolet radiation. One way to improve the material is by alloying it with other elements that can alter its crystal lattice and electron-band structure. Rare earth metals, including lanthanum, are considered promising elements for alloying. Currently, various synthesis methods exist that allow one to obtain a material that meets the specified criteria. The main synthesis methods include sol-gel synthesis, anodic oxidation, magnetron sputtering, and microarc oxidation. However, these methods have a few drawbacks, so chemical synthesis methods, one of which is oxidative pyrolysis, are gaining popularity in the modern world. In this study, thin titanium dioxide films, modified with lanthanum ions, were obtained, using oxidative pyrolysis, as described previously [1]. Thermal treatment of the films was carried out at 600 °C. Thus, the nanocrystalline titanium dioxide films with a content of 1, 3, 5, and 10 mol % La³⁺ were obtained. X-ray diffraction analysis (ARL X'TRA diffractometer, CuKα1 radiation) showed that the resulting material crystallized predominantly in the anatase phase with some rutile. The photocatalytic properties of the synthesized material were studied, using a model reaction of methylene blue dye photodegradation upon irradiation with UV light (wavelength 280 – 300 nm) for a specified time (0 – 90 minutes). The residual methylene blue concentration was determined spectrophotometrically (KFK-2MP spectrophotometer). All the resulting films exhibited photocatalytic properties and degraded methylene blue by more than 60 % in 90 minutes. Photocatalytic activity was shown to depend on the percentage of lanthanum ions. The titanium dioxide film modified with 5% La³⁺ exhibited the highest photocatalytic properties: 90 % of the methylene blue was degraded in 90 minutes. Thus, thin nanocrystalline La-modified titanium dioxide films were obtained, using oxidative pyrolysis and demonstrated exhibiting photocatalytic properties.

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Numerical Simulation and Experimental Study of High-Intensity Ultrasonic Fields in a Cylindrical Piezoelectric Transducer

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Considering the declining production of light crude oil due to the gradual depletion of its reserves, interest in the development of heavy oil fields has significantly increased. However, heavy oil extraction faces numerous challenges, primarily attributable to its elevated viscosity. Conventional methods for viscosity reduction during extraction involve heating the oil-bearing formations and applying solvents [1]. These approaches, however, are often costly and pose environmental risks. An alternative method capable of reducing the viscosity of heavy crude oils and highly viscous petroleum products is high-intensity ultrasonic treatment [2]. This technique is environmentally benign and has the potential to lower extraction costs. Consequently, there is growing interest in ultrasonic methods for enhancing oil recovery. A key component of ultrasonic activators is the high-intensity ultrasonic transducer, capable of operating under heavy oil extraction and transportation conditions, either independently or in combination with solvents, catalysts, or steam stimulation. This work presents the results of analytical and finite-element modeling, as well as an experimental investigation of high-intensity ultrasonic fields inside a hollow cylindrical piezoelectric transducer filled with a viscous liquid. Finite-element modeling of the cylindrical transducer was performed in a two-dimensional axisymmetric formulation, using the ANSYS software package. The study demonstrates the feasibility of generating a high-intensity ultrasonic field of standing cylindrical waves within a liquid-filled cylindrical piezoelectric transducer by exploiting its radial, longitudinal, and thickness vibration modes. Based on the simulation results, it was established that generating a standing ultrasonic wave in the oil, contained within a pipe whose radius corresponds to that of real-world pipelines, requires piezoelectric materials with relatively high sound velocities. The results obtained and the developed cylindrical transducers have been applied in experiments on ultrasonic treatment of viscous fluids and heavy crude oils. In the physical experiments, the cylindrical transducer filled by viscous fluid was driven by a sinusoidal signal with an amplitude of 0 – 100 V at an excitation frequency of approximately 2 MHz, generated by a digital function generator (Agilent 33521B) and amplified, using an RF power amplifier (E&I 1040L). Nodal patterns of cylindrical standing waves in the fluid were mapped, using calibrated needle-type PVDF hydrophone probes and observed visually on the liquid surface. The results of the computer simulations demonstrate good agreement with the experimental data, confirming the validity of the proposed method and transducer design for ultrasonic treatment of heavy oils by cylindrical standing waves.

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Influence of Pathological Alterations on the Complex of Characteristics of Natural Human Enamel and Dentine

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Dental caries remain a major global public health burden and is widely recognized as the most prevalent non-communicable disease worldwide. Despite decades of research, the mechanisms governing caries initiation and progression at multiple spatial scales, namely from molecular alterations to macroscopic tissue degradation, are not yet fully elucidated. A critical barrier to advancing both preventive and restorative dentistry lies in the limited availability of integrative studies that simultaneously assess the physical-mechanical properties, microstructural organization, and molecular composition of dental tissues across clearly defined stages of natural caries development. In this context, the present study aims to provide a comprehensive, multiscale characterization of human enamel and dentine, affected by various forms of natural carious and non-carious pathological processes. Emphasis is placed on establishing correlations between structural heterogeneity and functional mechanical response. To achieve this, a unified multimodal analytical framework is implemented, combining (i) high-resolution computed X-ray microtomography for three-dimensional assessment of mineral density distribution and lesion architecture; (ii) atomic force microscopy for nanoscale evaluation of surface topography and mechanical properties; (iii) scanning electron microscopy for detailed visualization of microstructural features; (iv) Raman spectroscopy for chemical and molecular profiling and (v) complementary optical imaging techniques for mesoscale characterization. Such an integrated methodology enables the identification of subtle transitions in tissue properties that are not detectable, using single-modality approaches. The results demonstrate that caries progression is accompanied by pronounced spatial heterogeneity in mineral content, crystallographic organization, and mechanical stiffness, with distinct patterns, observed between enamel and dentine due to their differing hierarchical structures. Importantly, microstructural features are shown to play a decisive role in modulating local biomechanical behavior and susceptibility to demineralization. Furthermore, the study reveals that pathological alterations do not occur uniformly but rather follow complex, stage-dependent pathways, influenced by both intrinsic tissue architecture and external factors. This underscores the limitations of conventional average metrics and highlights the necessity of adopting a nuanced, multiscale assessment strategy that integrates mechanical, structural, and compositional datasets. The findings have direct implications for several domains of dental science. From a clinical perspective, improved understanding of tissue heterogeneity and lesion progression can enhance diagnostic accuracy and inform minimally invasive treatment planning. In the field of biomaterials, the insights gained may guide the development of restorative materials with mechanical and structural properties better matched to those of native tissues. Finally, the proposed multimodal framework provides a robust platform for future studies, aimed at evaluating

preventive interventions and therapeutic strategies, ultimately contributing to more effective management of dental caries.

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Deposition of Cu₂O Thin Films by RF Magnetron Sputtering for Optoelectronic Memristive Devices

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Memristive structures are promising non-volatile resistive memory devices, featuring high performance, long-term and multi-level data storage, and low power consumption [1]. Of particular interest are optoelectronic memristive structures, which combine the properties of resistive memory with photosensitivity and can be used in neuromorphic machine vision systems for visual perception and image processing. Copper oxide (Cu₂O) is a *p*-type semiconductor material with a band gap of 2.1 – 2.2 eV, which ensures high light absorption in the ultraviolet and visible spectral regions and opens the possibility of creating optically controlled memristive structures for optoelectronic machine vision systems [1, 2]. This study examines the effect of radiofrequency (RF) magnetron sputtering power in an oxygen-free environment on the structural properties of Cu₂O thin films for use in non-volatile resistive memory devices and machine vision systems. The study involved depositing Cu₂O films on glass substrates, using magnetron sputtering at room temperature, and VSE-PVD-DESK-PRO equipment. The sputtering power varied from 25 to 100 W, and the operating argon pressure in the vacuum chamber was set at 5×10^{-3} mbar. The deposition time varied from 4 to 55 min, during which the Cu₂O film thickness was 90 ± 6 nm. Figure 1 shows SEM and AFM images of the Cu₂O film surface, obtained at a sputtering power of 75 W. All Cu₂O films were found to have a uniform nanocrystalline structure without significant defects, with a characteristic columnar structure visible on the cross-section cleavage, aligned perpendicular to the substrate plane. The grain size in the Cu₂O film increases from 8 ± 2 to 29 ± 3 nm with an increase in sputtering power from 25 to 75 W, which is due to a higher deposition rate and a higher density of crystalline phase nucleus. However, at a sputtering power of 100 W, no further grain growth occurs; instead, their size decreases slightly to approximately 24 ± 3 nm. The resulting Cu₂O films have a relatively smooth surface with an average roughness ranging from 4.5 ± 0.6 to 5.9 ± 0.9 nm at sputtering powers from 25 to 100 W. Thus, the most promising power for creating memristive structures is a magnetron sputtering power of 75 W, at which the Cu₂O film has the largest grain size, a uniform and relatively smooth surface, which can facilitate a

more controlled formation of a nanoscale conductivity channel in it for stable resistive switching by reducing the density of grain boundaries.

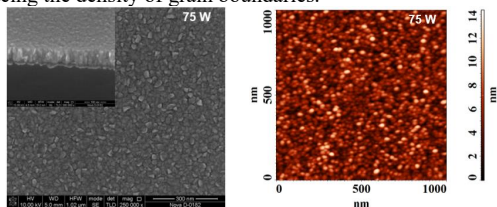


Fig. 1. SEM and AFM images of the Cu₂O film surface

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Using Blueprint in Developing Game Mechanics for the Unreal Engine Roguelike Game "The Sinner's Dice"

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Modern computer game development requires tools that enable the efficient implementation of complex game mechanics while maintaining the flexibility of the project architecture. One of such tools is the Blueprint visual programming system, part of the Unreal Engine game engine. Blueprint allows one to describe the behavior of game objects, using a graphical structure, simplifying the development process, increasing the clarity of logic, and speeding up project changes. During the development of the game mechanics for The Sinner's Dice, the Blueprint visual programming system, a built-in tool of the Unreal Engine game engine, was extensively used. Blueprint allows one to implement game logic, using graphs, consisting of nodes and the connections between them, to clearly describe the behavior of game objects and their interactions. Using this tool has accelerated the process of creating mechanics prototypes, reduced the time required to implement changes, and simplified the interaction between the programmer and the game designer. Blueprint was used to implement key gameplay elements, including processing player actions, interacting with objects, activating game effects, and managing the sequence of events during the gameplay loop. The visual representation of the logic allowed for faster analysis of the mechanics' structure and the identification of potential errors early in development. This allowed for rapid testing of various game system behaviors and the selection of the most appropriate solutions in terms of balance and ease of use. One of the advantages of using Blueprint is its rapid iteration. Changes to logic can be made without the need to completely compile the project, which is especially important when developing

games with experimental mechanics. This allowed for flexible configuration of game system parameters, including effect activation conditions, interactions between entities, and the sequence of actions. This approach increased the efficiency of the development process and enabled the rapid implementation of new ideas. When designing game mechanics, Blueprint was used in conjunction with an object-oriented approach. Logic was distributed among separate classes and components, which allowed for a more convenient organization of the project structure. Separating functionality minimizes coupling between different parts of the system and simplifies future expansion of mechanics. This resulted in an architecture that allows for the addition of new gameplay elements without the need for significant reworking of existing code. Despite its ease of use, Blueprint requires adherence to certain graph organization principles. As the number of nodes increases, the structure can become complex, complicating project maintenance and development. To address this issue, logic was decomposed into individual functions, macros, and components, preserving the system's readability and structure. This approach balanced the clarity of visual programming with the project's scalability requirements. As a result, Blueprint enabled the implementation of game mechanics with sufficient flexibility and the ability to expand them further. This tool has proven highly effective in prototyping and implementing game object interaction logic. The use of visual programming, combined with a well-thought-out architecture, accelerated development and improved the quality of game system implementation.

Interaction between Palladium (Pd) and Carbon Nanotubes (CNT) (8,0) Studied through First Principles DFT Calculations

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The interaction between carbon nanotubes (CNT) (8,0) and palladium (Pd) atoms was investigated, using first principles of Density Functional Theory (DFT) calculations. The study demonstrates that palladium significantly enhances the interaction with the CNT, leading to a transformation of the nanotube from a semiconducting to a conducting state. Four adsorption sites were considered for the Pd atom: atomic, axial, chiral, and hexagonal, and their effects on the electronic and geometrical properties were analyzed. Key parameters including band structure (BS), density of states (DOS), energy gap (EG), binding energy (BE), and charge transfer (Q_t) were evaluated. Additionally, geometric changes such as bond length, bond angle, and binding distance were calculated. The results showed that the Pd adatom attaches to the carbon nanotube via a covalent bond with a bond length of 2.18 Å. The optimized properties of the highest occupied molecular orbital (HOMO) and lowest unoccupied molecular orbital (LUMO) were also analyzed, revealing the potential of CNT-Pd interactions. The study suggests that these interactions can be exploited for surface coating applications, offering enhanced durability and long-term performance for various materials and devices.

Tuning Nonlinear Optical Response and Energy Thresholds in Photopolymer Composites with Graphene and Carbon Nanotubes

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The application of hydrogel coatings on metal stimulating electrodes makes it possible to solve the problems of mechanical mismatch with biological tissues and an increase in impedance, caused by tissue mobility. To create such coatings by two-photon polymerization, it is necessary to ensure a reproducible effect at each point of irradiation when using a scanning system with a given trajectory. In this study, nonlinear absorption cross-sections and exposure thresholds were determined, which were used to select the optimal laser irradiation mode. Prolonged implantation of metal electrodes causes a reaction of the nervous system (encapsulation) and an increase in impedance due to tissue movement [1]. To solve these problems, an electrically conductive hydrogel [2] was developed, formed by a point-by-point scanning laser system. Control of the optical properties of the photo-cured composition is necessary to assess its suitability for photopolymerization under specified energy conditions. The nonlinear optical properties of a composite, based on bovine serum albumin, collagen, chitosan, eosin Y, single-layer carbon nanotubes, and reduced oxide graphene, have been studied. The nonlinear absorption cross-section $\sigma = 640$ GM was determined by the Z-scan method. The threshold pulse energy is 0.6 μ J with an incident pulse energy of 12.5 μ J. The beam radius at the focus is 22 μ m, and the sample thickness is 1 mm. Optical characteristics alone are not enough to adjust the parameters of the scanning system. The temperature change during the thermochemical reaction from laser irradiation on the developed setup is investigated. With a power of 195 mW, a frequency of 15 kHz and a pulse duration of 120 ns, the temperature increased from 27.1 °C to 28.2 °C for 25 seconds. During the photo-curing process, an increase in nonlinear absorption was observed with a decrease in the normalized transmission from 1 to 0.27. During scanning, the beam moves at a speed of 240 mm/s. The exposure time is regulated by the number of passes. The optimal number of passes is determined from the heat balance equation is equal to 12 with a power of 560 MW and a frequency of 30 kHz. The layer thickness did not exceed 350 μ m. A 6×6 mm² photopolymer structure with a specific electrical conductivity of about 70 mS/cm was obtained.

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Effect of Concentration on Nonlinear Optical Parameters of Ni-Phthalocyanine Containing Phosphazene

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Comparison of parameters of nonlinear optical materials is often difficult due to differences in the concentration of the active substance. Existing models estimate the absorption coefficient without considering the effect of dye concentration. This work presents a developed mathematical model that considers concentration effects. The model was validated, using the example of Ni-phthalocyanine with a phosphazene fragment at specified concentrations. To date, there is no nonlinear optical material for laser radiation limiters that simultaneously have all the necessary characteristics: linear absorption coefficient α , nonlinear absorption coefficient β , attenuation coefficient, irradiation threshold and dynamic range [1]. Traditional models allow estimating the nonlinear absorption of a substance, but do not take into account concentration effects [2]. In this study a method for determining the nonlinear molar absorption coefficient is proposed. The application of this model will facilitate comparative analysis and search for effective phthalocyanines for use in nonlinear optical limiters. The values of traditionally used parameters, characterizing the nonlinear optical response were determined for Ni-phthalocyanine with a phosphazene fragment [1]. The linear and nonlinear molar absorption coefficients were quantified, using the developed model and calibration curves. The Z-scanning method [1] was used at a total pulse energy of 500 μJ , a pulse duration of 20 ns, and a wavelength of 532 nm to determine the values of α and β . Calibration curves were constructed for five samples at different concentrations of C_m (Fig. 1) in tetrahydrofuran (THF). Linear molar absorption coefficient amounted $\varepsilon_\alpha = 5.2 \text{ (M}^{-1}\cdot\text{cm}^{-1}\text{)}$ and non-linear molar absorption coefficient $\varepsilon_\beta = \varepsilon_{\beta 1} C_m^2 + \varepsilon_{\beta 2} C_m + \varepsilon_{\beta 3} \text{ (cm}\cdot\text{GW}^{-1}\cdot\text{mm}^{-1}\text{)}$, where $\varepsilon_{\beta 1} = -484 \text{ (cm}\cdot\text{GW}^{-1}\cdot\text{mm}^{-3}\text{)}$, $\varepsilon_{\beta 2} = 315 \text{ (cm}\cdot\text{GW}^{-1}\cdot\text{mm}^{-2}\text{)}$, $\varepsilon_{\beta 3} = -45 \text{ (cm}\cdot\text{GW}^{-1}\cdot\text{mm}^{-1}\text{)}$. At high concentrations, the effect of agglomeration is observed (the coefficient $\varepsilon_{\beta 1}$ has a negative value), which leads to a deviation from the linear dependence. The presence of $\varepsilon_{\beta 3}$ determines the error. The obtained values of linear and nonlinear molar absorption coefficients are important for constructing Z-scan curves and modeling the transfer characteristics of optical limiters.

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Micromechanics-based Modeling of Electrical Conductivity in CNT-reinforced Cementitious Composites

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Conductive cementitious composites have attracted attention for structural health monitoring, electrical heating, and electromagnetic interference shielding [1, 2]. The incorporation of electrically conductive fillers facilitates the formation of conductive networks within the cement matrix, thereby enhancing the composite's electrical conductivity [2]. Consequently, significant research efforts have been directed toward predicting their electrical conductivity, among which micromechanical approach has emerged as an effective analytical approach [3, 4]. Due to their heterogeneous pore structure and complex filler–matrix interactions, accurate prediction of electrical conductivity necessitates a micromechanical approach [3, 4]. Therefore, this study adopts a micromechanical modeling framework to predict the electrical conductivity of CNT-reinforced cementitious composites [5].

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Development of an Exoskeleton Model to Replace the Load on the Human Body

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To address the problem of partially or completely replacing the load on the human body, the construction of a structure made of rod elements, which together constitute an exoskeleton, is

being considered (Fig. 1). The proposed design will include load and strain sensors, as well as an automated load compensation system. The estimated lifting load is planned to be 150 kg.

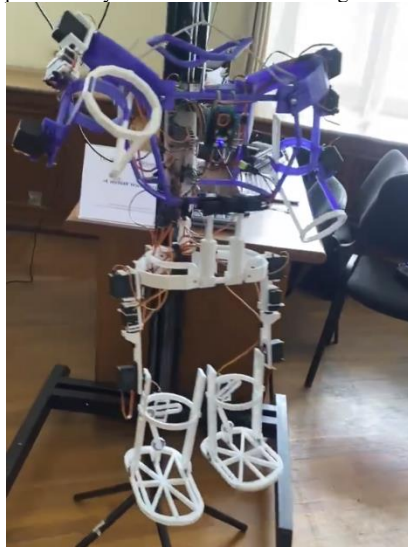


Fig. 1. Model of the exoskeleton.

The exoskeleton being developed is designed to increase human load-bearing capacity and protect them from harmful industrial factors. As a part of this solution, a load control system will be built. The sensors for the control system are located on plates attached to specific end points. The structure is made of PETG plastic. The preliminary weight of the finished experimental exoskeleton model is up to 5 kg with dimensions of $702 \times 489 \times 271 \text{ mm}^3$. Assembly time, including stages of production and preparation for installation, is 42 hours. The developed design is a mock-up of the exoskeleton, intended to demonstrate the mobility and functionality of the structure. The exoskeleton can be equipped with various modules and devices to perform specific tasks without changing the supporting structure. The exoskeleton arm consists of a set of simple hinges that ensure unimpeded movement of the structure, anatomically identical to the human body. Specifically, the shoulder joint is designed to lift and support the entire arm, two pivot points are designed to rotate similarly to the anatomical angle of the arm, and an elbow element is designed to flex the arm at the elbow.

On the Necessity of Studying the Physical and Mechanical Properties of Decorative Concrete

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The modern market for construction materials is characterized by high competition, rapid technological advancements, and increasing consumer demands. Enhancing the competitiveness of products has become a key challenge for manufacturers. One effective direction is the expansion of the range of construction materials, including the introduction of decorative concrete and products made from it. Today's consumers are focused not only on strength and durability but also on aesthetic qualities. There is a growing demand for original, non-standard solutions that allow for the creation of unique architectural objects and interior spaces. This trend stimulates the development of decorative types of concrete. It can be noted that decorative concrete has already proven itself, for example, in the Loft style. Decorative concrete represents a group of materials that combine structural and aesthetic functions. They can be classified into colored (by the introduction of pigments), textured (imitating natural materials), polished, architectural (for facades and small architectural forms), translucent (containing optical fiber elements that allow light to pass through), and fluorescent (capable of accumulating light and emitting it in the dark). Thus, translucent and fluorescent concrete can be used in the production of facade panels for buildings, interior partitions, landscaping, architectural lighting, and so on. Despite the promising nature of these materials, their widespread implementation requires a thorough study of their physical and mechanical properties. This necessity is related to ensuring the strength and durability of structures, resistance to climatic effects, wear resistance, operational safety, and compatibility with traditional construction technologies. Thus, expanding the range of construction materials, using decorative concrete, is an important tool for enhancing the competitiveness of building materials. However, their widespread implementation requires comprehensive scientific justification, based on the study of physical, mechanical, and operational characteristics. This work presents an analysis of existing developments in the field of translucent concrete. The analysis shows that several countries hold leading positions in the study of translucent concrete. Russian researchers are currently focusing mainly on technological schemes for producing the material and individual laboratory experiments. This indicates that more extensive studies of the physical, mechanical, and operational properties at the level of serial products are needed to justify the widespread implementation of the material in Russian practice. Large-scale systematic testing is needed for frost resistance, water absorption, durability of the "matrix-fiber" interface, fire resistance, and operational reliability.

Adaptive Management of Computing and Network Resources under Limited Connectivity for Industrial Monitoring Systems

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Industrial monitoring and control systems increasingly rely on distributed sensing, geospatial analytics and AI-based decision support, deployed across heterogeneous edge and cloud infrastructures. In many application scenarios, for example remote industrial sites, linear infrastructure or construction areas, communication channels are characterized by limited bandwidth, intermittent connectivity and strict reliability constraints, which leads to unstable data flows and suboptimal utilization of computing and network resources. This study addresses the problem of adaptive management of computing and network resources in such constrained environments and proposes a systems-analysis-based approach to designing resource-aware architectures for industrial monitoring platforms [1, 2]. The proposed approach combines three key elements: (i) a multi-layer system model that explicitly represents edge, fog and cloud nodes together with their computing and communication capabilities; (ii) an adaptive control loop that selects local *versus* offloaded execution strategies based on online measurements of network quality, workload intensity and latency constraints; and (iii) optimization-based and learning-based policies that allocate CPU, memory and communication slots to incoming tasks while satisfying application-specific quality-of-service requirements. The control loop operates under intermittent connectivity conditions by using predictive models of link availability and buffering strategies for critical data flows [3]. Simulation experiments on a model industrial monitoring scenario demonstrate that the proposed adaptive resource management methods reduce average task completion time and communication cost, compared to static allocation schemes, while maintaining acceptable performance during prolonged connectivity degradation. The results indicate that even lightweight adaptation mechanisms, when embedded into the architecture of industrial monitoring platforms, can significantly improve robustness and efficiency of computing and networking under realistic constraints. The approach is particularly relevant for industrial and construction applications, where distributed sensing, geospatial analytics and AI-based diagnostics must operate reliably despite limited network connectivity [4].

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Physics-Informed U-NET for Label-Free Stress Analysis in 3D Lattice Structure Design

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The exceptional mechanical performance of lattice structures is fundamentally derived from their periodic unit cell architecture. While finite element analysis (FEA) is the standard tool for predicting these mechanical behaviors, its integration into the generative design process often leads to prohibitive computational costs due to the requirement for repeated high-fidelity simulations. To address this, machine learning-based surrogate models have been introduced; however, they are largely constrained to low-dimensional geometric parameters and global performance metrics, such as stiffness and strength. This limitation restricts the design space and fails to capture detailed local responses, such as stress concentrations. In this study, we propose a U-Net-based framework capable of predicting full-field displacement and stress distributions for voxel-based lattice structures, effectively serving as a high-speed alternative to conventional FEA. By incorporating physics-based operators and equilibrium residuals, our U-Net model achieves self-supervised learning capabilities. This allows the model to maintain robust predictive accuracy across diverse structural variations (even in scenarios with limited labeled data) by enforcing physical consistency through the minimization of equilibrium residuals. We show that our proposed model accurately predicts the mechanical responses of lattice structures across a wide design space, significantly accelerating the overall design and optimization process.

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Investigation of the Memristive Properties of N-doped Carbon Nanotubes for the Development of Next-generation Strain Sensor

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Currently, next-generation strain sensors are being developed, characterized by the ability to simultaneously detect and store external stimuli [1]. A promising approach in the field of non-volatile memory, particularly for sensor devices, is the use of memristive structures [2]. At the same time, an important challenge is the search for materials capable of simultaneously providing detection of external mechanical effects and stable resistance switching under the influence of an external field. Preliminary studies indicate the potential of carbon-based materials for solving this problem [3]. In this work, the dependence of the resistive switching process in nitrogen-doped carbon nanotubes (N-CNTs) on the magnitude of the external force was investigated. The N-CNT sample was grown by the plasma-enhanced chemical vapor

deposition in streams of ammonia and acetylene at a temperature of 575 °C. The aspect ratio of the nanotubes' length to their diameter was 25. The nitrogen concentration was approximately 10%. A 100 nm thick molybdenum film served as the bottom contact.

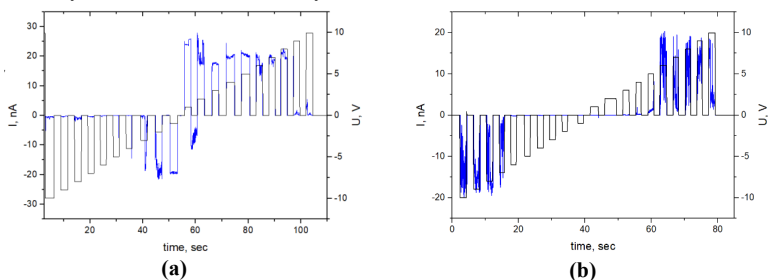


Fig. 1. Experimental current–time characteristics of the current, flowing in the “lower contact – N-type semiconductor – AFM probe” system at an applied force of 2 μN (a) and 1.8 μN (b).

The investigations were carried out, using atomic force microscopy (AFM) with a Pt-coated conductive probe. During the measurement, the AFM probe applied pressure to the tip of the N-CNT and a series of rectangular pulses with an amplitude ranging from 0 to 10 V and back was applied. The AFM probe was grounded. The results of the experimental studies are presented in Fig. 1. The results show that the conductivity of N-CNTs depends on the force applied by the probe to the sample. At a probe force of 2 μN and under negative voltage pulses ranging from -10 to -3 V, the N-CNT remained in a high-resistance state (HRS). In the “lower contact – N-CNT – AFM probe” system, the current was close to zero, which can be explained by the formation of an internal electric field in the nanotube, induced by deformation. In the range of negative pulses from -2 to 0 V and in the range of positive pulses up to 8 V, a current proportional to the applied electric field was observed, indicating a transition of the N-CNT to a low-resistance state (LRS). When a 9 V voltage pulse was applied, the system switched back to the HRS (Fig. 1a). Then, upon reducing the contact force to 1.8 μN , a conduction current flowed in the “lower contact – N-type semiconductor – AFM probe” system in the voltage ranges from -10 to -7 V and from 6 to 10 V, which is attributed to a decrease in the internal electric field of the N-CNT (Fig. 1b). At the same time, in the region of lower voltages (less than ± 6 V), the N-CNT was also in the HRS, which is associated with deformation of the N-CNT under the probe force. As a result, it has been demonstrated that the resistive switching process in N-CNTs depends on the magnitude of the external stimulus, which can be used in the development of next-generation strain sensors.

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Solution of an Edge Crack in a Semi-infinite Plate of General Anisotropy, Subjected to a Self-equilibrating Loads at a Crack Face

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The elastic field for an anisotropic semi-infinite plate with an edge crack perpendicular to a free surface, subjected to self-equilibrating forces, applied at upper and lower crack faces simultaneously, is derived by using a complex variable method, combined with an iterative procedure. The current problem corresponds to a situation where a pair of concentrated forces act on the crack faces, either attempting to open or shear them. By integrating the points of application of the concentrated forces along the crack line, it becomes possible to easily determine the SIFs of edge crack in an anisotropic semi-infinite plate, subjected to various surface forces. Although the expressions of the obtained SIFs are not mathematically exact, they are organized in the form of polynomials that are highly valuable for many engineering applications.

SH Waves on the Surface of Heterostructures with Lithium Niobate

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Lithium niobate (LiNbO₃), along with lithium tantalate, is widely used as an active element in integrated microelectronic devices. Due to its high piezoelectric properties and stability of properties, this material is used as a substrate for devices, based on surface acoustic waves (SAWs). New methods for transferring thin single-crystal wafers [1, 2] onto substrates at low temperatures allow for the orientation of the single-crystal wafers to utilize the directions of the most efficient excitation. The efficiency of wave excitation depends on the magnitude of wave localization in the ferroelectric layer, which is associated with the propagation velocity and, consequently, the material of the dielectric part of the substrate. Therefore, for each heterostructure, an analysis of the SAW excitation efficiency as a function of the orientation and thickness of the active layer and the substrate material is necessary. Such an analysis for a lithium niobate/silicon heterostructure was performed in [3]. The paper presents the results of numerical analysis of the SH SAW excitation efficiency for a lithium niobate/sapphire

heterostructure with a fused silica intermediate layer. The results of 3D numerical simulation of the excitation of shear SAWs on the surface of the $\text{LiNbO}_3/\text{SiO}_2/\text{Al}_2\text{O}_3$ heterostructure are also presented. The calculations were performed using the Comsol Multiphysics package. For the heterostructure without a SiO_2 interlayer (at $h/\lambda = 0.5$), the maximum electromechanically coupling coefficient (EMCC) value reaches 0.51 at an angle β (lithium niobate crystal cut orientation) of 75° . Inclusion of an additional 200 nm thick SiO_2 dielectric layer into the heterostructure leads to an increase in EMCC. The highest EMCC, equal to 0.525, is exhibited by a heterostructure with a lithium niobate plate thickness of 1.25 μm at an angle of $\beta = 65^\circ$. The depth distribution of the elastic energy density of a shear wave was analyzed. Calculations revealed a significant dependence of the energy density distribution on the heterostructure parameters. Additional consideration of electrodes leads to a decrease in the EMCC. S -parameter calculations were performed for the heterostructure with the highest EMCC.

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Atomic and Molecular Structure of Pollutants in Soil Matrices: A Spectroscopic Study of a Model Quartz–goethite System

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In the modern world, which is experiencing the consequences of nuclear testing, chemical weapons trials, and the natural degradation of soil horizons, there is a growing need for the efficient use and rehabilitation of land resources. One of the key challenges is soil contamination with heavy metal ions and their subsequent removal. Impurity ions are retained in soil matrices through interactions with organic matter, iron oxides, clays, and quartz, being the main constituents of soils. Each of these sorbents possesses distinct physicochemical sorption characteristics and warrants individual consideration. For instance, sorption on clays occurs predominantly through the fixation of ions with strictly defined radii at their "frayed edge sites," representing a specific case. The study of sorption by organic matter is complicated by its dual role as both a sorbent and a desorbent. Therefore, to elucidate sorption and remediation mechanisms, such complex soil systems should be decomposed, and each component should first be examined individually. In this context, the quartz–goethite system represents a convenient model due to its ease of synthetic reproduction and widespread occurrence in nature. As an example, soil samples were collected from mine tailings of the Donets Coal Basin. These formations were selected, based on the assumption that, due to their

geological origin, they are depleted in organic matter and thus suitable for studying sorption under realistic conditions following investigations of model systems. X-ray diffraction (XRD) analysis identified α -quartz (SiO_2) with reflections at $2\theta = 20.68^\circ$, 26.45° , 49.97° , and 59.79° , as well as crystalline goethite ($\alpha\text{-FeOOH}$). The full width at half maximum (FWHM) of the goethite (130) reflection is 0.180° , corresponding to a crystallite size $> 20 - 30$ nm. The absence of reflections from other crystalline phases confirms that the system is predominantly two-phase (quartz – goethite) within its crystalline component. ATR-FTIR spectroscopy confirmed the absence of significant organic matter: no C–H stretching vibrations were detected in the $2800 - 3000\text{ cm}^{-1}$ region. Diagnostic Si – O bands ($1000, 798, 779\text{ cm}^{-1}$) and Fe – O bands ($476, 395, 338\text{ cm}^{-1}$) unambiguously indicate the presence of quartz and iron-bearing phases. Thus, the absence of reflections from other crystalline phases in the diffractograms allows the system to be considered predominantly two-phases with respect to its crystalline component; the contribution of the amorphous fraction requires additional characterization. In future work, this model system or its synthetic analogues will be used for controlled experiments involving the introduction of target pollutants (U and Pb) and the study of their coordination environment by *in situ* FTIR spectroscopy, structural changes by XRD, and spatial distribution by SEM-EDS. This approach will enable a quantitative description of the mechanisms, governing the localization of impurity ions in weakly ordered condensed media.

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Change in the Strength of Slag-alkaline Binding Agent over Time

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The key characteristic of most hydraulic binders is their reactivity, which is expressed as their compressive strength. This value is determined by using standard methods, such as Russian GOST 310.4-81 (2003), at a standard age of 28 days of curing under normal conditions. To determine the activity of slag-alkali binders, a method based on the Russian GOST 310.4-81 (2003) standard was used, but with modifications proposed by V.D. Glukhovskiy. Strength indicators were recorded after the samples reached the standard age of 28 days. Concrete structures last much longer than a standard strength test. Although the binder's strength is determined after 28 days, its hardening does not stop there. On the contrary, the material only gets stronger over time, reaching strengths beyond its design strength. To test how the strength of the slag-alkali binder changes over time, several identical batches of samples were produced. After stripping the formwork, the $40 \times 40 \times 160\text{ mm}^3$ beam samples, manufactured according to the amended Russian GOST 310.4-81 method, were stored in water until their testing time. These beam samples were stored in water and tested for strength at different ages: after 28 days (standard), as well as after 84, 169, 252, and 364 days. The results revealed that the material's strength increased significantly for one year, namely by 52%, compared to the initial value.

Methods of Corrosion Protection of Reinforced Concrete Structures

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Reinforced concrete is characterized by high durability and resistance to aggressive environmental influences. Its dense, low-permeability structure ensures reliable protection of steel reinforcement from corrosion. However, practical experience with reinforced concrete structures shows that damage, caused by corrosion of both the concrete itself and the reinforcing elements, can occur during service. There are two main scenarios for reinforced concrete failure. In the first case, the reinforcement begins to rust only after the concrete protective layer has already been damaged. In the second case, the concrete provides no protection from the start. The rust that forms on the reinforcement grows and literally tears the concrete apart from the inside. This typically occurs in structures that are constantly exposed to moisture or are regularly exposed to wet and dry conditions. Concrete can fracture from the inside due to chemical reactions. For example, alkalis, formed during cement hardening or special additives, can react with silica contained in the aggregate. Concrete is also adversely affected by aggressive environmental substances, such as sea salt, de-icing agents, and soil salts. Due to their effects, the structure can begin to deteriorate in the range from 5 to 20 years after construction. Detecting this problem is difficult: it requires constant monitoring and sophisticated laboratory equipment. Therefore, it is much more effective to implement corrosion protection methods during the construction stage. Measures to protect concrete from corrosion in this case include reducing cement consumption and limiting the alkali content to 2.5 – 2.7 kg/m³. This is achieved by using Portland cement with acidic mineral additives, introducing lithium salts into the concrete mixture, as well as air-entraining and gas-forming additives. The second type of internal corrosion of reinforced concrete is caused by concrete carbonation. This process is faster the less protected the concrete is from external influences. The risk increases if the concrete has a low water resistance rating. There is a third type of corrosion, in which harmful crystals (hydrosulfoaluminates and gypsum) form in the concrete pores. The rate of this process depends on how easily water, containing sulfates, penetrates the concrete and how vigorously the concrete reacts with them. To protect the structure, it is necessary to use special sulfate-resistant cement and various additives (for example, pozzolanic or microsilica-containing ones). Substances that make the concrete dense and impermeable to water (water-reducing and hydrophobic agents) also help. Concrete with very low permeability (grades W16 – W20) has the best resistance to this type of corrosion.

Automation and Mathematical Modeling of the Primary Oil Treatment Process

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A modern oil production enterprise is a complex set of process facilities that produce, transport, initially process, store, and pump oil and gas, as well as perform reservoir pressure maintenance processes [1]. The dispersal of process facilities over large areas has led to the need and economic feasibility of developing and implementing telemetry systems and organizational structures for the remote monitoring and control of process facilities and processes. At the same time, the production, transportation, storage, and refining of oil (as well as the consumption of finished products, such as motor fuel and lubricants) are accompanied by extremely negative consequences for the environment and human health. The products, coming from oil and gas wells, are not pure oil and gas, respectively. Along with oil, wells also produce a formation of water, associated (petroleum) gas, and solid particles of mechanical impurities (rocks, hardened cement). Forming water is a highly mineralized medium with a salt content of up to 300 g/l. The content of water, formed in oil, can reach 80%. Mineral water causes increased corrosion of pipes and tanks; solid particles entering the oil flow from the well cause wear of pipelines and equipment. Associated (petroleum) gas is used as a raw material and fuel [2]. It is technically and economically feasible to subject oil to special treatment before feeding it into the main oil pipeline for the purposes of its desalination, dehydration, degassing, and removal of solid particles; therefore, the task of automating the processes of oil production, preparation, and transportation is extremely relevant [3]. This work is devoted to a relevant topic, namely, the automation of the technological process of primary oil preparation and its mathematical modeling [4].

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Electrochemical and Dielectric Properties of Anticorrosive Organic Films

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The protective effect of an organic imidazole compound against the corrosion of low-alloyed steel St-3 in 1M H₂SO₄ was investigated as a function of experimental time ($t = 1 - 4$ days) and the concentration of surfactant SAS-6 (a surface-active substance, SAS, organic salt of SAS⁺Cl⁻), which was varied within the range of $C_{SAS} = (1 - 4) \times 10^{-3}$ mol/l. Besides this individual surfactant, a composite inhibitor was studied, consisting of a benzimidazole derivative and KBr. The KBr concentration was maintained at a constant 0.01 mol/L. An increase in the concentration of the organic compound promotes enhanced protection of steel against corrosion in a sulfuric acid environment. The use of a composite inhibitor significantly enhances the protective effect of the surfactant. According to [1], this is primarily due to the process of recharging the positively charged [2] steel surface in an acidic environment because of electrostatic adsorption of bromide anions. The adsorption of the SAS⁺ cations onto the negative steel surface increases, leading to an enhanced protective effect. The braking coefficient K for an individual SAS initially increases by more than 1.7 times as t grows from 1 to 2 days. Following this, it monotonically decreases with further increases in t up to 3 and 4 days. For the investigation of steel corrosion inhibition mechanism, galvanostatic polarization measurements were carried out in the background solution and in the presence of the tested additives. It has been determined that the additives act as a cathodic-anodic type inhibitor, retarding both the cathodic reaction of hydroxonium cation reduction and the anodic-reaction of surface iron atom oxidation. Elevated surfactant concentrations in the investigated inhibitors along with the application of SAS+KBr composition result in increased inhibition of coupled electrochemical reactions, a finding fully consistent with gravimetric measurements. Using a scanning laser microscope and applying the confocal method for obtaining micrographs, the surface morphology of films with a granular (cellular) structure, depending on C_{SAS} and t , was investigated. The application of a combined inhibitor and an increased adsorption time contributes to the reduction of defects and the formation of a relief with larger elongated grains. The frequency dependencies of the negative capacitance C' of deposited films were determined within the frequency range of $(2.5 - 3 \times 10^6)$ Hz. In the spectral dependencies of $C'(f)$ of films under weak external mechanical stresses, a blurred resonant dielectric dispersion and two relaxation-type dispersions are observed. The values of electrical capacity and conductivity of films depend on the concentration of surfactants and the film formation time. Mechanisms of dielectric dispersion and the nature of conductivity of the obtained films are being discussed.

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Using Leontiev's Intersectoral Balance Model to Implement the Planning Task in the Oil and Gas Industry

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The analysis of the economic development of any industry is based on intersectoral models, while planning and forecasting calculations are carried out, production and distribution balances are determined. The intersectoral balance makes it possible to analyze the production relationships between different industries, manifested in the mutual influence of prices, production volumes, capital investments and incomes, and to solve the problems of forecasting the main macroeconomic indicators (gross and final product output, net output, material costs, production consumption, etc.) [1]. The model of intersectoral balance, developed by V. Leontiev, is notable for the fact that it can construct an ideal economic process, based on the algebra of matrices and the matrix analysis apparatus to calculate the relationships between industries. The intersectoral balance equation can be used to calculate the vector of final consumption, based on a known vector of gross output, as well as for planning purposes of gross output, based on a known vector of final consumption of the past period [2]. This research considers the problem of determining gross output for a planned period, with a known change in the final consumption of producing industries, in relation to four branches of the oil and gas industry: transportation, energy, chemical and processing, each of which produces its own homogeneous products. According to the known data on the execution of the balance sheet for the reporting period, the required volume of output of each industry has been determined, with variations in the final consumption values of other industries included in the analysis. The use of the mathematical apparatus, developed by V. Leontiev for a specific economic model, makes it possible to predict changes in the planning period to determine rational strategies for managing the socio-economic development of various industries.

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The Effect of Impregnation of Grinding Wheels with Surfactants on the Performance of the Fine Grinding Process

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The main indicators of the grinding process are productivity and quality, which are largely determined by the nature of the chip formation process, which is the result of the interaction

of the abrasive grain and the processed material. The nature of this interaction, in turn, depends on the processing modes, the used lubrication cooling technological means (LCTMs) and the characteristics of the abrasive tool. The degree of influence of transverse and longitudinal feeds, as well as the speed of the part on cutting capacity, tool consumption and surface roughness are approximately the same [1, 2]. As the cutting speed increases, the cutting capacity increases and the cutting force decreases, which in turn reduces the consumption and surface roughness for medium grain circles but increases for fine-grained ones. In addition to the characteristics of the abrasive tool and the processing modes, the composition and method of using LCTMs have a significant impact on the grinding process. As research has shown (see Table 1) for fine and fine grinding, LCTMs containing surfactants are the most effective.

Table 1. Influence of the composition of cooling liquids on the performance of grinding process

The composition of the LCTM	Processed material (hardened steel)	Process indicators		
		Cutting capacity $Q_m, \frac{mm^3}{s}$	Tool consumption $Q_a, \frac{mm^3}{s}$	Surface roughness $R_a, \mu m$
$H_2O + 3\% Na_2CO_3$	STB4	6.0	8.6	0.115
	X160CrMoV12-1	5.3	8.3	0.15
$H_2O + 0.6\% NaH_2PO_4 + 0.3\% NaNO_2$	STB4	6.3	9.0	0.10
	X160CrMoV12-1	5.8	0.11	0.10
$H_2O + 3\% Na_2CO_3 + 1\% C_{17}H_{33}COOH$	STB4	5.6	8.0	0.08
	X160CrMoV12-1	5.0	8.6	0.09
$H_2O + 3\% Na_2CO_3$	SNCM447	50.6	21.1	1.24
Sulfurized oil	SNCM447	59.2	3.5	0.88

Table 2. Effect of wheel impregnation on the parameter of grinding process

Brand of the grinding wheel	The impregnation material of the grinding wheel	Process indicators		
		Cutting capacity $Q_m, \frac{mm^3}{s}$	Tool consumption $Q_a, \frac{mm^3}{s}$	Surface roughness $R_a, \mu m$
63CF500J6B	Without impregnation	2.0	2.1	0.17
	Paraffin	2.4	1.3	0.16
	Stearin	2.,3	1.2	0.14
63CF500K6B	Without impregnation	1.2	3.2	0.08
	Paraffin	1.4	1.8	0.10
	Stearin	1.5	1.7	0.06

Despite the significant influence of surfactants on the grinding process with fine-grained wheels, their use is associated with a set of difficulties. Compounds, containing the COOH group in molecules, which include higher fatty acids (oleic acid, stearic acid, palmitic acid, etc.), have the greatest surface activity. However, their use as additives to LCTMs is complicated because they do not form aqueous solutions at normal temperatures, and when neutralized with alkalis, soaps are formed, the surface activity of which is significantly less than the acids themselves. One of the effective surfactant methods, which allows one to overcome these difficulties is the impregnation of the grinding wheels before its operation. To assess the effect of impregnation on the performance of the fine grinding process, 63CF500J6B and 63CF500K6B the grinding wheels were tested. The degree of impregnation

by weight of the circles with a hardness of K was equal to 5.8%, circles with a hardness of J was equal to 9.1%. Samples made of STB4 steel were ground on a BUA16 machine with a change in all the elements of the mode. The average data on cutting capacity, surface roughness and tool consumption are shown in Table 2. Stearin impregnation of circles is the most effective, causing the increase by 22% of cutting ability of the circles, and the decrease by 30% of surface roughness. When the circles are impregnated with paraffin, the removal of metal increases, but the surface roughness does not decrease. When grinding SUS304 steel with impregnated circles, their wear decreases by 2 times, and the surface roughness decreases by 1.3 times.

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Numerical Investigation of Placement and Geometry Effects of PZT Patches on MEMS Cantilever Electromechanical Behavior

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Cantilever-based Micro-Electro-Mechanical Systems (MEMS) have emerged as highly efficient platforms for sensing and actuation due to their high sensitivity, simple structure, and ease of integration into miniaturized devices. These systems are widely used in applications such as chemical sensing, biological detection, and energy harvesting. In such devices, piezoelectric (PZT) patches are commonly employed to enable both sensing (direct effect) and actuation (inverse effect) through electromechanical coupling. In this study, a cantilever-based MEMS sensor integrated with a PZT patch is investigated, with particular emphasis on the effect of PZT placement along the beam. Three configurations are considered, wherein the PZT patch is positioned near the fixed end, at the mid-span, and near the free end of the cantilever beam. A direct piezoelectric effect analysis is carried out by applying a mechanical load of 0.001 N, and the resulting electric potential is evaluated. Further, the inverse piezoelectric effect is analyzed by applying an electrical input of 10 V. Findings clearly establish that placing the PZT patch near the fixed end is the most effective configuration for both direct and inverse piezoelectric effects. Additionally, different geometric profiles of the PZT patch are evaluated to identify the optimal design. The study highlights the importance of strategic placement and geometric optimization in enhancing the performance of cantilever-based MEMS devices.

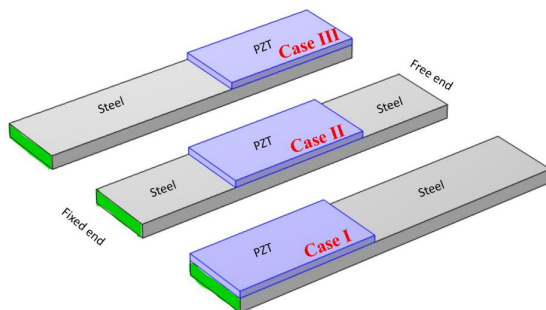


Fig. 1. Cantilever beam configurations with PZT attachment at fixed end (Case 1), midspan (Case 2), and free end (Case 3).

Computer Simulation and Experimental Investigation of Ultrasound Fields Generated by a Sectorial Focusing Transducer

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High-intensity focused ultrasound (HIFU) systems are widely employed for surgical, therapeutic, and cosmetic procedures in biological tissues [1]. Phased array transducers, based on direct acoustic field synthesis, offer significant advantages over single-focus HIFU devices, particularly when treating large tissue volumes. Among various array configurations, sectorial spherical transducers represent a promising implementation [2]. This study presents both numerical modeling and experimental characterization of the ultrasound fields, generated by a sectorial spherical focusing transducer under different excitation schemes specifically, by applying signals with controlled phase shifts or distinct frequencies to individual sectors. Simulations were carried out, using the Vortex software package implemented in MATLAB, which enables calculation of the acoustic pressure distribution in any cross-sectional plane of the transducer's field when driven by sinusoidal signals with arbitrary frequencies and phase offsets. Experimental validation was performed in water and oil tanks, as well as on *ex vivo* biological tissue samples. Biological tissue samples were placed in an oil bath and exposed to focused ultrasound. Preliminary experiments to detect cavitation activity were also conducted, using thin aluminum foil, immersed in the same oil bath. The transducer sectors were excited by continuous-wave or radiofrequency burst sinusoidal signals with varying frequencies or phase shifts, generated by a custom-designed multi-channel arbitrary waveform generator. The results confirm the accuracy of the computational model and demonstrate the feasibility of advanced beam-shaping techniques. Based on these investigations, a novel method of dynamic focusing has been developed and tested. This approach involves the sequential, continuous, and cyclic generation of focal regions with predefined size, shape, and spatial location, operated at an optimal repetition rate and ultrasonic energy level. Dynamic focusing is

achieved by introducing tailored phase delays across the transducer sectors or by simultaneously driving different sectors at slightly detuned frequencies. The proposed method significantly enhances both thermal and cavitation effects of ultrasound while enabling treatment of substantially larger tissue volumes, compared to conventional static focusing. This advancement holds considerable potential for improving the efficacy and versatility of HIFU-based therapeutic and aesthetic applications.

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Spatial and Temporal Localization of Ultrasonic Heating in Biological Tissues Using an Ultrasonic Transducer with a Cooled Surface

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Ultrasonic methods are currently employed in virtually all areas of medical practice and represent one of the most promising approaches for diagnostics and therapeutic treatment [1]. High-Intensity Focused Ultrasound (HIFU) therapy is a rapidly evolving technology that is expanding into new medical applications due to its high efficacy, minimal side effects, and cost-effectiveness [2]. However, one limitation of the HIFU method when treating superficial tissues and nearby organs is the small size of the ultrasonic exposure region and the large focal distance. Realizing the potential of new ultrasonic technologies requires the development of novel, more effective, and safe methods for influencing biological tissues, as well as advanced ultrasonic hardware. The aim of this work was to develop a novel method, alternative to focused ultrasound, for the spatial and temporal localization of ultrasonic therapeutic exposure. This method utilizes various combinations of ultrasonic and thermal fields for comprehensive ultrasonic therapy of superficial tissues or adjacent organs. This study presents the results of numerical simulation and experimental investigation of ultrasonic heating of biological tissues, using a planar ultrasound transducer with a cooled surface. The simulation of biological tissue heating by planar acoustic waves was performed, using two software packages: k-Wave for MATLAB (acoustic simulation) and FEniCS (thermal simulation). The k-Wave package implements a pseudo-spectral method for solving coupled first-order acoustic equations. The FEniCS software package enables the calculation of medium heating by solving the classical heat conduction equation, using the Finite Element Method (FEM). Temporal temperature distributions within the biological tissue were obtained, accounting for transducer surface cooling and thermal conductivity, at various frequencies and ultrasonic intensities. Designs were developed, and prototype models of planar ultrasonic transducers with adjustable emitting surface temperature were fabricated. Experimental

validation of the simulation results was conducted, using tissue-mimicking phantoms and *ex vivo* biological tissue samples. It was demonstrated that the developed design ensured effective superposition of ultrasonic heating fields and external cooling of both the transducer surface and the object under study. This leads to the spatial and temporal localization of ultrasonic therapeutic exposure in biological tissues.

Acknowledgement. The study was financially supported by the Russian Science Foundation Grant No. 24-72-10128, <https://rscf.ru/project/24-72-10128/> at the Southern Federal University.

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Anomalous Elastic Dispersion in Porous Piezoceramics

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In recent years, the functional requirements for ultrasonic and piezoelectric transducers, and the underlying materials, have evolved significantly due to the expanding scope of their applications, including medical diagnostics and therapy, energy harvesting, underwater acoustics, non-destructive testing, and so on [1]. Among emerging materials, porous piezoceramics, based on various compositions, have demonstrated considerable promise for advanced ultrasonic devices [2]. This work presents a comparative study of the microstructure and frequency-dependent complex elastic properties of porous and dense PZT-based piezoceramics with identical chemical composition. The analysis of the frequency response of porous piezoceramics revealed distinct regions of anomalous elastic dispersion, manifested as characteristic variations in the real and imaginary parts of the complex elastic modulus, sound velocity, and attenuation of resonant vibrations. It was found that the anomalous dispersion in porous piezoceramics, specifically, the linear decrease in thickness-mode sound velocity (V_t^D) in piezoceramic disks, is caused by an increasing contribution from quasi-rod structural elements of the ceramic framework. This leads to a gradual transition toward the longitudinal sound velocity typical of a bulk piezoceramic rod (V_{33}^D) at higher frequencies. This enhanced contribution arises from the changing ratio between the characteristic length scale of spatial heterogeneity in the coral-like piezoceramic skeleton and the wavelength of resonant oscillations as frequency increases. With rising frequency, the acoustic wavelength shortens, thereby amplifying the influence of mesostructured quasi-rod domains (aggregates of crystallites preferentially aligned along the direction of remnant polarization) on the overall complex electromechanical response of the porous piezoelement. These findings enable the identification of optimal operational frequency bands for porous piezoceramic components that ensure high electromechanical efficiency in ultrasonic transducers. The investigated

materials exhibit a unique combination of functional properties, making them highly promising for applications in ultrasonic sensors, medical imaging and therapeutic transducers, and even high-intensity focused ultrasound (HIFU) systems.

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Electrophysical Properties of a Series of (BaTiO₃)_x/LSMO_(0.95-x)/(GeO₂)_{0.05} Composites

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The study of new composite materials, exhibiting unique properties, distinct from their constituent components, is currently of great interest due to their manifold applications. Composite materials are widely used as magnetic field sensors, in energy harvesting devices, next-generation memory, spintronic devices, microwave devices such as microwave phase shifters, electromagnetic wave modulators, and miniature antennas, as well as radio-absorbing materials [1]. Novel ceramic multiferroic composites of the formula (BaTiO₃)_x/LSMO_(0.95-x)/(GeO₂)_{0.05} have been synthesized in this study. These composites are based on lanthanum strontium manganite (La_{0.7}Sr_{0.3}MnO₃, LSMO) and barium titanate (BaTiO₃), with varying proportions of these components, and incorporate germanium oxide as a matrix element. The mass percentage of x ranges from 60% to 95%. The research specimens were cylindrical, with a 12 mm diameter and a 2.5 – 3 mm height. Silver electrodes were applied to the end surfaces of the samples at a temperature of 550 °C. The structural parameters of the barium titanate crystal lattice have been determined in various ceramic samples. It was found that with an increase in the LSMO content in the composite, the structural parameters of BaTiO₃ (BT) decrease from 4.029 to 3.972 Å along the c -axis and from 3.990 to 3.970 Å along the a -axis at $t = 20$ °C. The $B(H)$ magnetic hysteresis loops of the samples were studied. A significant enhancement of ferromagnetic properties was observed in the composites with increasing x . For instance, the 85%BT / 15%LSMO composite sample exhibits a coercive force $H_c = 500$ Oe, significantly higher than the $H_c = 30$ Oe, observed in pure LSMO. This increase in H_c is likely due to the increased defectiveness of barium titanate [2]. Temperature dependencies of the dielectric permittivity of the composites were obtained, exhibiting different degrees of phase transition blurring in BaTiO₃. In the frequency range of 3 – 12 GHz, the absorption spectra of microwave energy of synthesized samples were studied using the measurement technique [3]. Composites with concentrations of $x = 80$ and 75% are characterized by the highest radar absorption capacity. Their resonance-type spectra contain 2-3 large absorption maxima, reaching the level of –(25-30) dB at $t = 20$ °C. Heating of samples significantly shifts the absorption maxima in the spectra to the region of lower frequencies. After cooling, the

absorption spectra of the composites restore their original shape. The electrical and magnetic energy emission spectra of the samples were studied in the same frequency range. As with absorption, two- and three-mode spectra with maximum emission energy are characteristic of composites with concentrations of $x = 80$ and 75%. The interpretation of the results obtained is given.

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The Effect of Temperature on the Conductivity and Capacitance of Organic Films

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The influence of temperature, ranging from room temperature to 120 °C, on the conductivity and capacitance of protective organic films, deposited on the surface of St-3 rolled steel in an inhibited sulfuric acid solution was studied. As corrosion inhibitors, a new organic compound of the imidazole class surface-active substance SAS-5 and its mixtures with potassium chloride were used. The correlation between the protective properties and the morphology of the resulting organic anticorrosion films was studied in relation to their formation time t and the potassium chloride concentration C_{KCl} in the electrolyte. The concentration dependencies of the calculated steel corrosion inhibition coefficient (K) and the measured thickness (h) of deposited films showed good agreement within the C_{KCl} concentration range of 10 – 40 mM/l for films, formed over 4 days with a composite inhibitor. Frequency-dependent dielectric capacitance and conductivity measurements of the films were performed in the frequency range of (20×10^6) Hz at different temperatures. Upon heating the films to 120 °C, the real parts of their complex conductivity G' and the magnitudes of negative capacitance $|C|$ increase over a wide frequency range. The increase in G' is apparently due to the rise in the effective mobility of charge carriers and their concentration with increasing film temperature. The increase in $|C|$ is caused by an increase in the dielectric permittivity of the films. In polar materials, the dielectric permittivity grows due to increased dipole mobility with rising temperature, which facilitates their orientation in an external alternating electric field. In the frequency dependencies of the films' capacitance $C'(f)$, dielectric dispersion is observed in the high-frequency range ($10^5 - 10^6$ Hz), the center of which shifts by an order of magnitude to lower frequencies with a 100 °C increase in temperature. The method of impedance spectroscopy was utilized to determine the link between temperature-related changes in conductivity, capacitance, and the shift of the dielectric dispersion center of the films. To

describe the frequency dependencies of negative capacitance in films, an equivalent circuit of the sample's impedance model was utilized. This model incorporated thermal ionic polarization in internal fields with inverse field strength and featured a capacitor with negative capacitance [1]. The frequency dependencies of $C''(\omega)$ and $G''(\omega)$ were calculated and found to practically coincide with experimental dependencies for various temperatures by fitting the parameters of the electrical circuit elements. The Seebeck thermoelectric effect has established that the investigated films exhibit n -type conductivity. Based on the characteristic temperature dependence of conductivity $G(T)$, the calculated values of specific electrical conductivity σ , and the observed decrease in G' with increasing one-dimensional compression of the films [2], it is concluded that the investigated films exhibit semiconductor properties.

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Mathematical Modeling and Optimization of Bimorph Piezoelectric Plates with Spatially Inhomogeneous Properties

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The development of highly efficient piezoelectric elements requires targeted control of their dynamic characteristics, particularly their natural frequencies. One promising approach is the use of functionally graded materials, which allow for varying physical, mechanical, and electromechanical properties within the structure. This opens additional opportunities for optimizing the parameters of piezoelectric systems within given geometric constraints. This work formulates the optimization problem for a piezoelectric bimorph plate with functionally graded properties, varying in the plane of the structure. The mathematical model is constructed within the framework of thin-plate theory, considering electroelastic interaction and spatially inhomogeneous material properties. Maximizing the first natural frequency of bending vibrations is considered as the objective function, which is fundamental for improving efficiency. For numerical implementation, a finite element model was developed in the FreeFem++ environment, providing an adequate description of both mechanical and electrical fields in the inhomogeneous structure. Attention was paid to correctly approximating the gradient distribution of the bimorph plate properties. Based on this model, an optimization algorithm is proposed for the repeated solution of spectral problems with varying the spatial

distribution of the material's effective parameters. The calculations yielded optimal distribution laws for material properties in the class of quadratic functions, ensuring an increase in the first natural frequency of oscillations, compared to homogeneous analogs. It is shown that rational variation of the parameters in the plane of the plate allows for a significant influence on the dynamic response of the system without changing its geometry. These results can be used in the design of piezoelectric devices for various applications, including sensors, actuators, and elements of energy harvesting systems, where specified frequency characteristics and improved operational efficiency are critical.

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Optimization of Output Characteristics of Piezoelectric Bimorphs with Split Electrodes

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Piezoelectric transducers occupy an important place in modern engineering, enabling the conversion of mechanical energy into electrical energy and *vice versa*. In recent years, the development of low-power autonomous energy sources that utilize the dissipated energy of structural vibrations has attracted particular interest. Creating highly efficient devices of this class requires both the development of theoretical models and the refinement of design solutions. This work proposes an approach to optimizing the characteristics of piezoelectric bimorph elements, based on the analysis of their transverse bending vibrations. Both planar and axisymmetric structures are considered under various types of boundary conditions, including rigid clamping, hinged support, and free edges. Depending on the transducer's functional purpose, various optimality criteria are formulated: (i) for actuator mode, maximizing the amplitude of steady-state forced vibrations or the power emitted into the acoustic environment; (ii) for sensor and energy generation modes, increasing the electric potential at the electrodes or the power transmitted to the external load. A key area for improving efficiency is the alignment of the transducer's electric fields with the spatial distribution of the mechanical fields. In this regard, two approaches are being explored: (i) the use of piezocomposite materials, including functionally graded ones, and (ii) the optimization of the electrode coating configuration. The latter approach is based on accounting for the non-uniform distribution of stresses and strains, determined by both the boundary conditions and the oscillation mode. It is assumed that the inner electrode completely covers the interlayer interface, while the outer electrodes are segmented. For several modes, including rigid fixation

and higher bending modes, alternating zones of tension and compression are formed along the element's length, requiring the alignment of the electrode segment boundaries with these regions. To solve the optimization problem, an applied theory of oscillations of multilayer piezoelectric plates has been developed, allowing for the presence of regions with different electrical potentials on the outer electrodes. This enables efficient numerical calculations within optimization procedures. As a result, the positions of the electrode separation lines are determined, coinciding with the areas where the sign of longitudinal mechanical stresses and deformations changes. For axisymmetric plates, optimization is reduced to finding the cutting radius, while for free-form plates, it is reduced to constructing the corresponding separation lines.

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Synthesis and NO₂ Gas Sensing Properties of 2D SnS₂ Thin Films, Derived by SnO Precursor

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In this study, two-dimensional (2D) layered tin disulfide (SnS₂) thin films were successfully fabricated on sapphire substrates, using RF sputtering, followed by a post-sulfurization process. The research focuses on the impact of oxygen flow rates (0%, 10%, and 20%) during the deposition of SnO precursors on the subsequent sulfurization behavior. Experimental results indicate that an increase in oxygen content significantly elevates the energy barrier for sulfurization, raising the threshold temperature from 320 °C to over 400 °C. This phenomenon is attributed to the higher bond energy of Sn–O compared to the reaction energy between metallic tin and sulfur. Regarding gas sensing, the response characteristics of 2D SnS₂ with varying thicknesses toward NO₂ were investigated. A 5 nm-thick sample exhibited a significant response of 26% to 10 ppm NO₂. Compared to ultrathin, discontinuous island-like films, the 5 nm quasi-continuous 2D layered structure provides more stable electron transport channels and an optimal Debye length modulation space. This work demonstrates that the phase quality of 2D SnS₂ can be precisely controlled by tuning precursor oxygen content and sulfurization parameters, enabling high-performance NO₂ detection at low temperatures with great potential for flexible electronics and wearable sensor applications [1, 2].

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Influence of the Quality of Medical Data Markup on the Effectiveness of Neural Network Training: Theoretical Foundations and Experimental Verification

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When training neural networks, the quality of medical data markup affects the effectiveness of training, and, subsequently, the accuracy of recognition by neural networks of various pathologies on 2D images in medicine [1]. This is due to the markup, forming the ground truth, in other words, the "correct answer" for the neural network, that is, the neural network takes as the truth the data, on which it is trained. If there are inaccuracies or errors in the data, then the neural network is trained on erroneous data, and as a result it gives the same erroneous result. In this study, special attention is paid to the quantity of qualitative data. It has been established that it is preferable to use from 30,000 thousand data [2]. However, there are exceptions when using 15,000 thousand data and special algorithms when writing a neural network, it is possible to partially compensate for the lack of a large amount of data. The more qualitative data is used in training, the more accurate the predictions are [3, 4]. However, it is also necessary to consider the representativeness of the sample, in this case a wide range of patients with different individual characteristics. After training and testing the neural network, experimental verification was performed, which is the process of confirming the reliability of the research results or the correctness of the methodology by conducting experiments, which is necessary when working with a neural network and checking how reliable this model is. Thus, high-quality data markup made it possible to ensure correct training of the neural network, increase the accuracy of model predictions, and create a reliable intelligent decision support system that reduces the likelihood of diagnostic errors and automates the diagnostic process.

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The Volume and Length of the Mixture of Petroleum Products Formed in the Contact Zone During Their Sequential Pumping Through the Pipeline

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Sequential pumping of light oil products in the same pipe is characterized by the different-grade fuels combined in batches of several thousand tons are pumped into the pipeline sequentially one after the other, with each batch displacing the previous one in the pipeline and, in turn, being displaced by the next one. The advantage of this method of pumping petroleum products is cost-effectiveness, due to the use of a single pipe for transportation, while the disadvantage is the inevitable formation of a mixture in the contact area of batches with different physical-chemical properties [1]. This study investigates changes in the volume and length of a mixture of the same name and dissimilar petroleum products, formed in the contact zone during their sequential pumping through a pipeline. When solving the problem, two cases were considered: petroleum products of the same type (two grades of gasoline or two grades of diesel fuel) are pumped, which differ slightly in density and viscosity, and petroleum products of different types (gasoline and diesel fuel) are pumped, which differ significantly in density and viscosity. For each case, the volume of the mixture, formed in the contact zone of petroleum products, was determined, using the appropriate equations, that consider the rheological properties of the transported media. The main parameter included in the formulas that determines the mixing process of petroleum products in their contact is the longitudinal mixing coefficient, for which several formulas are known. The study used a modified formula by J. Taylor's model, obtained by him based on averaging the spatial equations of impurity propagation in a turbulent flow of liquid, moving in a pipeline, and adjusted to consider the industrial data of the oil product pumping process [2, 3]. The length of the area, formed in the contact zone of the mixture of petroleum products was determined by dividing the volume of the mixture V_c by the cross-sectional area of pipeline S : $l_c = V_c/S$. The calculations were carried out in the Mathcad software, the results of the numerical experiment were presented in the form of graphical dependencies of changes in volume and length of a mixture of the same and dissimilar petroleum products, formed in the contact zone along the length of the pipeline. An analysis of the results of solving the problem shows that the growth rates of the volume and length of the mixture, formed in the contact zone of petroleum products vary along the length of the pipeline and do not depend on the types of media in contact.

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Sustainable PFAS-Free Water-Repellent Silicone Textile Coatings

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Stringent environmental regulations on per- and polyfluoroalkyl substances (PFAS) restrict the use of conventional fluorine-based water-repellent technologies, necessitating sustainable and eco-friendly alternative strategies. This study integrates polar functional groups into an organo-alkoxysilane inorganic hybrid material and employs a silicone-based sol-gel process to develop a high-performance fluorine-free coating. Among the tested configurations, conventional fluorine-free repellents exhibited poor durability, whereas the developed hybrid structure demonstrated enhanced water repellency and printability due to maximized coating stability (see Fig. 1). Lab-scale gravure coating and contact angle measurements were conducted to investigate the dispersibility stability and film-forming properties of the synthesized materials. The TEOS and PDMS-SiO₂-based systems significantly outperformed conventional acrylic and wax-based approaches by forming a uniform coating layer and improving overall durability. Enhanced water-repellent characteristics were strongly correlated with the introduction of the organo-alkoxysilane structure, validated through application to lightweight tent fabrics. These findings confirm that the sol-gel process and hybrid material composition are critical to the performance of eco-friendly textile coatings and support the development of sustainable materials for global outdoor applications

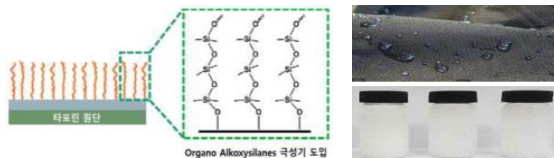


Fig. 1. Schematics of organo-alkoxysilane-based water-repellent coating on textile substrate

A Novel Method for Multifunction Filter Synthesis Using Integrator and Differentiator

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This study presents a synthesis method that can realize multi-function second-order filter circuits, including high-pass, low-pass, and band-pass filter functions. The theoretical design of multi-function filter circuits is based on the transfer function of conventional filter circuits [1 – 4]. The feedback loops use functional blocks, such as integrator and differentiator, to construct the multi-function circuit. We use PSpice simulator software to verify the obtained filter functions of the synthesized circuit. Simulation result reveals the workability of the derived filter. Thus, the feasibility of the proposed method is confirmed.

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Design and Analysis of Piezoelectric Energy Harvester for Bicycle Road Excitations

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Historically, the bicycle has been one of the most efficient and accessible modes of short-distance transportation for individuals. In modern times, bicycles are increasingly integrated with various electronic components, including sensors, speedometers, and communication

devices. Additionally, mobile phones and smartwatches, now essential tools for daily life, require a consistent power supply. These devices typically consume low power, which is often provided through batteries or dynamos. However, batteries are not environmentally friendly and require regular replacement upon depletion. Dynamos, on the other hand, demand additional pedaling effort due to frictional contact with the bicycle wheel, generate operational noise, and produce electricity intermittently rather than continuously. While in motion, a bicycle is subjected to dynamic loads and mechanical vibrations caused by uneven terrain and rider movement. These mechanical inputs, if properly harnessed, offer an opportunity for energy harvesting. Moreover, to enhance the durability and performance of bicycles, continuous structural and performance monitoring is essential [1]. Wireless sensors are increasingly used in structural health monitoring and enhancing the reliability of bicycles. With the advancement of low-power electronic components, it has become feasible to power such systems using energy harvesting techniques, reducing or eliminating the need for conventional batteries. Among various energy harvesting methods, piezoelectric energy harvesters are particularly attractive due to their simplicity, compact size, and ability to efficiently convert mechanical vibrations into electrical energy. While other transduction mechanisms such as electromagnetic and electrostatic harvesters also exist, they generally exhibit lower energy conversion efficiency and are less commonly implemented in bicycle-related applications [2].

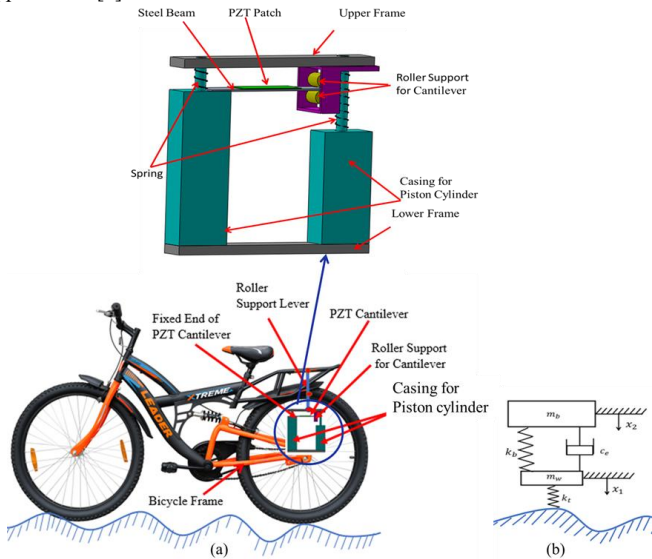


Fig. 1 (a) Bicycle model with piezo energy harvesting device, (b) schematic view of the spring-damper system dual-mass

In this study a novel design for a piezoelectric energy harvester is tailored for bicycle applications. The device harnesses the mechanical vibrations generated during cycling and efficiently converts them into electrical energy. Uniquely, the proposed harvester also functions as a shock absorber, mitigating the impact of road-induced disturbances. It is strategically installed between the bicycle's wheel and chassis and is conceptualized as a dual-

mass spring-damper system. A comprehensive mathematical model has been developed to predict the energy output based on dynamic systems, incorporating parameters such as road surface roughness, structural geometry, and material properties.

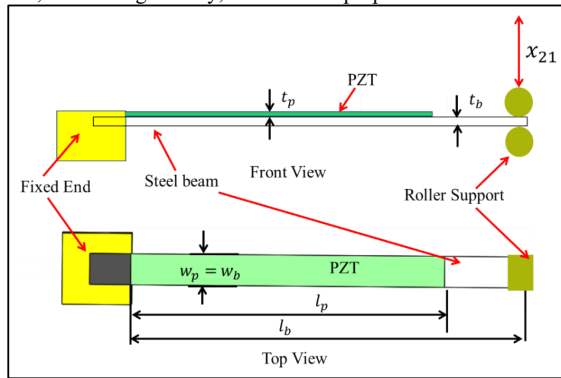


Fig. 2. Piezoelectric cantilever with roller end support

The electrical power generated was evaluated under rough road conditions, with variations in piezoelectric (PZT) patch length, bicycle speed, and electrical load. Experimental analysis revealed a maximum output power of 3.59 mW at a cycling velocity of 15 m/s, using a single PZT patch of 35 mm in length, 25 mm in width, and 0.267 mm in thickness for measurement, under conditions of high surface roughness. The working principle and configuration of the piezo energy harvesting device to harness the energy from the bicycle during the cycling is depicted in Fig. 1a and 1b. The piezo energy harvester with d_{31} working mode is mounted with rear wheel support of the bicycle as shown in Fig. 1a. The main parts of the device are the piezoelectric cantilevers, upper frame relates to rider frame of bicycle, lower frame relates to rear wheel frame of the bicycle, casing for piston-cylinder and roller support to ends of the piezoelectric cantilevers as shown in Fig. 1a. A CAD model of the bicycle, equipped with a piezoelectric harvester, is shown in Fig. 1a. The configuration illustrates that the device is mounted between the back-wheel frame, ensuring direct transmission of vibrations from the rear wheel to the harvester. Rider frame is connected through a lever to the upper frame of the device. Cantilever is constructed, using a PZT patch bonded to a steel beam, as depicted in Fig. 2.

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Reassessment of Adhesive Strength in Notched Butt Joints, Using Minimum Cross-Sectional Area

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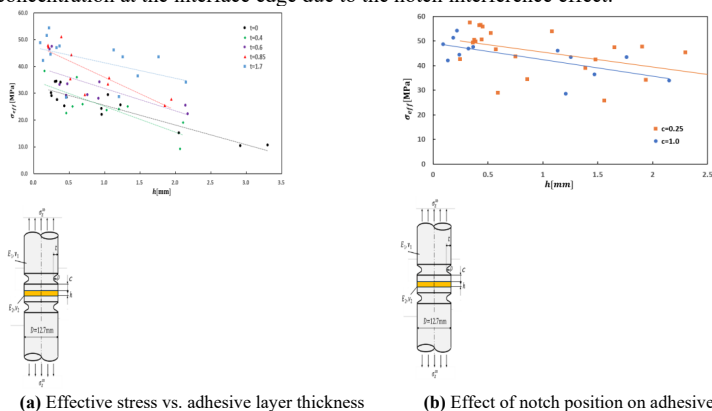
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In a previous study on notched butt joints, joints with various notch depths were compared with conventional JIS butt joints without notches. Although the introduction of notches reduced the singular stress field at the interface edge, only a limited improvement in adhesive strength was observed. In the present study, it is hypothesized that fracture is governed by the stress at the center of the interface rather than by the singular stress at the edge. Based on this assumption, an evaluation method, focusing on the minimum cross-sectional area is proposed. The effective stress is defined as $\sigma_{eff} = 4P_c/\pi d^2$, where P_c is the critical failure load, and d denotes the minimum cross-sectional diameter. Using this definition, as shown in Fig. 1(a), we obtained results, showing that adhesive strength of notched butt joint improves with increasing notch depth. This result supports the validity of the proposed evaluation method, based on the minimum cross-sectional area. Furthermore, experiments were conducted with a notch position of $c = 0.25$ mm, and the results were compared with those from a previous study with $c = 1.0$ mm. As shown in Fig. 1(b), the case of $c = 0.25$ mm exhibited higher adhesive strength than that of $c = 1.0$ mm. This improvement is attributed to the reduction in stress concentration at the interface edge due to the notch interference effect.



(a) Effective stress vs. adhesive layer thickness (b) Effect of notch position on adhesive strength
Fig. 1. Effective stress σ_{eff} vs. adhesive layer thickness h for various notch depths t [mm] (a), and comparison of adhesive strength for notch positions $c = 0.25$ mm and $c = 1.0$ mm (b).

Building the Dimensions System for Clothes of Female Students at the Hanoi University of Science and Technology

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Vietnam's garment industry has been developing dynamically; however, the lack of a standardized sizing system for specific target groups remains a significant challenge. This study focuses on developing an anthropometric sizing system for female students at Hanoi University of Science and Technology (HUST). The necessity of this research arises from the practical demand at HUST, which has approximately 35,000 students, of whom females account for about 40% (approximately 12,000 – 15,000 students). Moreover, the university is implementing a diverse uniform system, ranging from summer and winter uniforms to national defense education and physical education attire, along with a substantial demand for uniforms for student organizations and clubs. Preliminary observations indicate that female students in engineering disciplines possess distinctive morphological characteristics, with body stature, tending to be smaller than that of the general Vietnamese youth population, possibly due to the specific academic intensity of technical programs. Therefore, it is necessary to conduct an anthropometric survey and establish a clothing sizing system for university students in general and female students in particular to obtain an appropriate anthropometric dataset and proactively support the production of student uniforms at the university. The study conducted direct measurements on a sample of 165 female students with a confidence level of 99.9%, collecting 43 anthropometric dimensions categorized into five groups: body weight, height, length measurements, breadth/thickness measurements, and girth measurements in accordance with the Vietnamese standard TCVN 5781:2009 [1 – 14]. The data were processed using SPSS 20.0 software, applying Principal Component Analysis (PCA) to identify key body dimensions and Pearson's correlation test to verify the relationships among variables. The results established an optimized sizing system that not only supports accurate uniform production for HUST students but also provides a foundation for extending future research to male students and proposing anthropometric recommendations for Vietnamese female students, in general.

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Synaptic Plasticity in Nanocrystalline ZnO Films for Artificial Nociceptors

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Today, one of the most promising areas of development is intelligent robotic systems, the complexity and diversity of which have rapidly increased in recent decades [1]. In particular, the global scientific community is devoting considerable attention to the development and creation of biosimilar adaptive prosthetic systems that replace and/or restore impaired motor functions. Research is also actively underway to develop and create an artificial nociceptor, namely a primary afferent neuron, activated by painful stimuli that damage or potentially damage body tissue [2]. The development of such a device opens vast possibilities for the creation of promising limb sensing systems for robotic systems and bionic prostheses. Analysis of literature has shown that structures based on binary metal oxides, particularly nanocrystalline zinc oxide (ZnO), obtained by pulsed laser deposition, are promising. However, the creation of artificial nociceptors based on nanocrystalline ZnO films currently requires the solution of problems, related to the experimental study of synaptic plasticity: pair-pulse potentiation (PPF) and pair-pulse depression (PPD). Zinc oxide films were obtained on the Si/SiO₂/TiN substrate by pulsed laser deposition at the Pioneer 180 unit (Neocera LCC, USA) under the following conditions: a substrate temperature of 300 °C, a distance between the target and the plate of 55 mm, a O₂ pressure of 1 mTorr, a pulse energy of 270 mJ, a laser-pulse repetition rate of 10 Hz, and number of laser pulses of 21,000. Electrical measurements were carried out using a TH2690 semiconductor parameter measurement system (Techmize, China) and an MS-4 probe station with tungsten probes with a tip diameter of 100 nm. The TiN bottom contact was grounded during the electrical measurements. Analysis of the obtained results showed that increasing the number of pulses from 0 to 100 leads to an increase in postsynaptic current from 0.16±0.02 mA to 0.37±0.04 mA for an interpulse interval of $t_{INT} = 0.5$ ms, from 0.12±0.02 mA to 0.29±0.04 mA for a pulse width of $t_{INT} = 5$ ms, and a decrease in postsynaptic current from 0.13±0.03 mA to 0.09±0.01 mA for $t_{INT} = 10$ ms, from 0.14±0.02 mA to 0.07±0.01 mA for $t_{INT} = 20$ ms. The result obtained can be explained by the

accumulation of space charge in the case of small values of t_{INT} , which leads to an increase in postsynaptic current (PPF), and by the resorption of space charge for t_{INT} greater than 10 ms, which leads to a decrease in postsynaptic current (PPD).

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Effects of Phase Coexistence and Non-180° Domains on Energy-storage Characteristics in Ferroelectric $(\text{Ba}_{0.85}\text{Ca}_{0.15})(\text{Zr}_{0.10}\text{Ti}_{0.90})\text{O}_3 - x\text{Gd}_2\text{O}_3$

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Modified ferroelectric (FE) $(\text{Ba}_{1-x}\text{Ca}_x)(\text{Zr}_{1-z}\text{Ti}_z)\text{O}_3$ ceramic materials are of great interest due to their high piezoelectric activity and large energy-harvesting, energy-storage (ES) and other parameters. The ES parameters that predetermine applications of FE materials are energy density W_{rec} and ES efficiency η [1]. These parameters depend on the coercive field E_c and the difference between the maximum (or saturated) polarisation P_{max} and remnant polarisation P_r , i.e. characteristics of the hysteresis loop of FE. The characteristics of the hysteresis loop and ES parameters of $(\text{Ba}_{0.85}\text{Ca}_{0.15})(\text{Zr}_{0.10}\text{Ti}_{0.90})\text{O}_3 - x\text{Gd}_2\text{O}_3$ (BCZT- x GO) ceramics were studied [1] for $0 \leq x \leq 0.05$, at the coexistence of the tetragonal and rhombohedral phases ($P4mm$ and $R3m$). In the present work, we analyse an effect of heterophase structures and non-180° domains (or mechanical twins) on ES in BCZT - x GO ceramics at room temperature. The heterophase and non-180° domain structures are studied within the framework of a model [2], where two-phase regions and interlayers coexist, and conditions hold for complete stress relief. Based on this model, we evaluate the optimum volume fraction $n_{T,opt}$ of the 90° domains in the tetragonal phase and the relevant volume fraction v_R of the rhombohedral phase (that can be single-domain) in heterophase BCZT - x GO. Relations between the volume fractions $n_{T,opt}$ and v_R (heterophase structure) and the $P_{max} - P_r$ difference (ES parameter) are shown in Fig. 1. The largest $P_{max} - P_r$ difference, recoverable energy density W_{rec} and ES efficiency η are achieved in BCZT - 0.04GO for which the condition $v_R = 1 - n_{T,opt}$ holds with an accuracy of several percent.

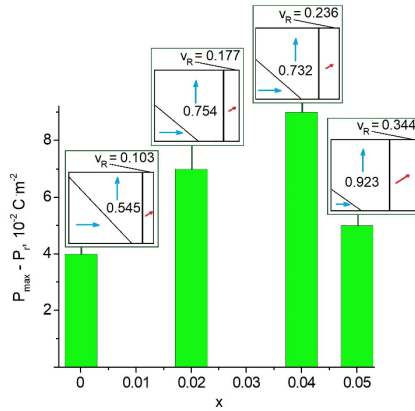


Fig. 1. Relations between the optimum volume fraction $n_{T,opt}$ (see the value under the vertical arrow in each domain fragment), the volume fraction v_R , and the $P_{max} - P_r$ difference (after experimental data [1]) in heterophase BCZT – Xgo; domain orientations are shown with arrows.

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Influence of the Matrix Subsystem on the Performance of Highly Anisotropic Piezo-active 1–1–3 Composites Containing Auxetic Polymer

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Recent studies on advanced lead-free 1–1–3 composites containing two ferroelectric (FE) components show that these composites exhibit the large piezoelectric coefficient g_{33}^* , electromechanical coupling factors (ECFs) k_{33}^* , k_t^* etc. [1]. The composite contains two systems of FE rods (the first and second components) and polymer (the third component) [1]. To date, fibrous structures ‘FE – auxetic polymer’ with 1–3 connectivity were not yet analysed for any of the 1–1–3 composites. The aim of the present work is to highlight an effect of the 1–3 FE ceramic / auxetic polymer matrix on the piezoelectric properties and ECFs of the 1–1–3 composites. The first component is $[001]_c$ textured BCZT ceramic [2] (from the FE $(\text{Ba}_{1-x}\text{Ca}_x)(\text{Zr}_{1-y}\text{Ti}_y)\text{O}_3$ system) with the moderate piezoelectric anisotropy and volume fraction m in the 1–1–3 composite. The second component is chosen among conventional lead-free FE ceramics (BaTiO₃, KNLNS–BZ etc.), and its volume fraction is m_c in the 1–3 matrix. The third component is auxetic PET or PLA [3]. The second and third components form the 1–3 matrix. Its piezoelectric coefficient $d_{31}^{(1-3)}$ and elastic compliances $s_{12}^{(1-3),E}$ and $s_{13}^{(1-3),E}$ change sign at variations of m_c . Condition $d_{31}^* = 0$ holds at $m = m^*$ (Fig. 1) in the range where the elastic compliance $s_{13}^{*E} \rightarrow 0$ due to the sign-variable behaviour of $s_{13}^{(1-3),E}$ at variations of m_c .

Anisotropy factors of the composite obey conditions $\zeta_d^* = d_{33}^* / d_{31}^* \rightarrow \pm\infty$, $\zeta_k^* = k_{33}^* / k_{31}^* \rightarrow \pm\infty$ and $\zeta_{kt-p}^* = k_t^* / k_p^* \rightarrow \pm\infty$ due to the change of $\text{sgn } d_{31}^*$ in the presence of auxetic polymer in the 1–3 matrix. The volume fractions m^* and m_c (Fig. 1) suggest that the very large anisotropy of the piezoelectric coefficients and ECFs is achieved at the prevalent volume fraction of auxetic polymer. The relatively small difference between the m^* values for the 1–3 composites containing different auxetic polymers (cf. curves 1 and 2 in Fig. 1) is accounted for by the large difference between the elastic properties of FE ceramic and polymer [2, 3] irrespective of their chemical compositions. The effective parameters make the highly anisotropic lead-free 1–3 composites competitive in transducers, sensors and related applications operating in a longitudinal oscillation mode.

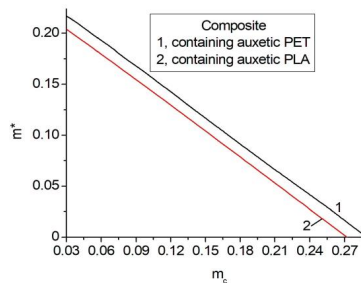


Fig. 1. Volume fractions m^* of BCZT in the 1–3 BCZT / KNLNS–BZ / auxetic PET composite (curve 1) or in the 1–3 BCZT / KNLNS–BZ / auxetic PLA composite (curve 2).

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Strain-Dependent Poisson's Ratio from the Incompressibility Condition

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In the theory of linear elasticity, material properties are characterized by several mechanical constants, including Poisson's ratio, Lamé constants, Young's modulus, and shear modulus. Poisson's ratio is defined as the negative ratio of transverse strain to longitudinal strain. This work focuses on the incompressible deformation regime, where volume conservation is assumed. There are nonlinear elasticity studies in which Poisson's ratio varies with strain [1]. Thus, some nonlinear experimental effects, such as acoustoelasticity, can be described, using its linear dependence on strain [1]. In this work, Poisson's ratio was derived by imposing the volume conservation constraint, yielding its functional dependence on axial strain. Similar results were reported in experimental studies by G. Wertheim [2] and J. F. Bell [3], who investigated materials, exhibiting near-incompressible behavior, such as rubber-like materials

and metals under large plastic strains. Using the obtained relation under the volume conservation assumption, the dependencies of longitudinal and transverse wave velocities on axial strain were expressed as linear functions. These results agree with the experimental data and confirm that several previously known effects can be described, using simplified relations [3].

Acknowledgement. The research was carried out with the financial support of the Russian Science Foundation, Project No. 25-29-01480.

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Metal Decorated BiVO₄ with Improving Photocatalytic Performance

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Bismuth vanadate (BiVO₄) is a promising visible-light-driven photocatalyst, owing to its narrow bandgap and suitable band structure; however, its performance is hindered by rapid charge recombination and sluggish surface kinetics. Metal decoration (Ag, Pd, Pt) has emerged as an effective strategy to address these limitations. This study presents a comprehensive overview of synthesis strategies and photocatalytic applications of metal-decorated BiVO₄ systems. The enhanced performance is attributed to synergistic effects, including surface plasmon resonance, Schottky junction formation, and improved charge separation and transfer. Notably, Ag/BiVO₄ achieved ~94% ethylparaben degradation under 40 W LED irradiation within 240 min. Facet-engineered Pt/PtOx/BiVO₄ ({040}) exhibited ~1.5 times higher sulfamethoxazole (SMX) degradation than randomly decorated counterparts and ~23 times higher than bare BiVO₄. Similarly, Pd – BiVO₄ enabled 98.8% SMX removal after 210 min, compared to only 36.3% for pristine BiVO₄. These findings provide valuable insights for designing efficient and sustainable BiVO₄-based photocatalysts.

Features of Fine-Grained Concretes Based on Local Aggregates

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Currently, one of the priorities for the development of the building materials industry is the production of fine-grained concrete and products made from them. The relevance of the development lies in obtaining high-quality material, using local raw materials. Fine-grained concrete has several advantages. As a rule, fine-grained concrete has higher physical and mechanical characteristics, as well as greater durability, compared to heavy concrete. A decrease in the diameter of pores and capillaries, characteristics of fine-grained concretes, and an increase in the uniformity of their distribution lead to increased frost resistance of the material and, ultimately, its durability. This reduces the material consumption of structures and increases the reliability of their operation. The accelerated kinetics of hardening of products, made from particularly harsh mixtures, reduces the duration of heat and moisture treatment. However, the disadvantages of fine-grained concrete should also be noted, because of which there is a slow pace of its production and use in construction. First, they are caused by the structure of concrete, which is characterized by high uniformity and fine grain, high content of cement stone, absence of a rigid stone skeleton, increased porosity and specific surface area of the solid phase. In fine-grained concretes, shrinkage deformations can be 1.5 – 2 times higher than in equal-strength concretes with coarse aggregate, and the production of products from fine-grained concrete involves high binder consumption, which entails a significant increase in the cost of the product at relatively low strength classes. Many publications note the importance of using high-quality sands with well-chosen granulometry. Research by domestic and foreign scientists has shown that sand, as the main carrier of surface area, mainly affects the consumption of cement in concrete. The Rostov region has a rich selection of deposits of building materials. The territorial balance of common minerals in the Rostov region as of 01.01.2025 includes 217 deposits (sites) of construction sands or 431 million m³. 126 deposits (sites) are in operation. Sands are used in building mortars, in the manufacture of concrete, silicate bricks, as a softener in brick production, for locomotive sandboxes, railway track ballasting and highway repairs. The sands of the Rostov region, modulo their size, belong to the group of small and very small. The use of such aggregates leads to an increase in the water consumption of concrete mix due to the large specific surface area of the grains, which, in turn, leads to an increase in cement consumption, a deterioration in technological performance and an increase in the price of finished products. The development of compositions of fine-grained concretes of the required properties is associated with solving several tasks. Increased total specific surface area of aggregates, on the one hand, improves the uniformity of the structure and allows obtaining high-strength concrete, compared with conventional concretes, but on the other hand, the increased water consumption of such mixtures leads to an increase in cement consumption to ensure the desired consistency of the cementing agent. The main solutions, namely an analysis of the grain composition of the natural sands of the Don region has shown that they belong to the group of very small ones and their use is possible in conjunction with high-water-reducing additives. It is also possible to replace 30% of natural sand with large fractions of rock crushing screening. The enrichment of very fine natural sands with large fractions of rock crushing in an optimal amount leads to an increase in the proportion of strong grains in the structure of fine-grained concrete and an

increase in its strength, as well as to a decrease in intergranular voidness and a decrease in water consumption of the mixture, while ensuring its high fluidity and reliable adhesion to reinforcing elements.

Electrophysical Properties of Ferroelectric Materials PCR-35 Modified with BiFeO₃ under the Influence of Temperatures

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Ferroelectric materials based on sodium lithium niobate (NLN) systems, including PCR-35 piezoceramics, are considered a promising lead-free alternative to widely used PZT compounds. However, the practical use of such materials is limited by their poor electrical properties and anomalous behavior with increasing temperature. Modifying PCR-35 with bismuth ferrite (BiFeO₃), a multiferroic with a high Curie temperature (~1100 K), opens the possibility of targeted control of phase boundaries, domain structure, and dielectric relaxation mechanisms, which determines the scientific and practical significance of this study. The objects of the study were ceramic samples of the composition (1 - x)PCR-35 - xBiFeO₃ (x = 0.005 - 0.025), obtained by two-stage solid-phase synthesis, followed by firing at $T = 1463 - 1478$ K. The dependencies of the real (ϵ'/ϵ_0) and imaginary (ϵ''/ϵ_0) parts of the relative permittivity on temperature were obtained, using an automated setup based on an Agilent 4980A LCR-meter in the frequency range of (20 - 10⁶) Hz. Relative elongation ($\Delta L/L$) was studied on an original setup with a Micron-02 device and an Agilent 34401A digital nanovoltmeter with a reading resolution of 0.01 μm . It was found that the introduction of BiFeO₃ into the PCR-35 matrix leads to a decrease in the maximum permittivity temperature (from 572 K to 515 K), a change in the nature of the frequency dispersion of $\epsilon'/\epsilon_0(T)$ and $\epsilon''/\epsilon_0(T)$, and a change in the temperature anomalies in the relative elongation curves. Characteristic temperature regions were identified, containing extrema, inflection points, and a sharp change in the rate of increase/decrease in dielectric parameters. Analysis of the frequency dependence of losses indicates the presence of relaxation processes, associated with domain rearrangements and thermal activation of charge transfer, the contribution of which significantly depends on the concentration x. The conducted studies demonstrate that the introduction of a small amount of BiFeO₃ enables effective control of the electrophysical properties over a wide temperature range.

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Process-Window Analysis of p-GaN Etch Depth in E-Mode AlGaIn/GaN HEMTs

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This work presents a calibrated TCAD study of etching-depth variations in enhancement-mode (E-mode) *p*-GaN gate AlGaIn/GaN HEMTs under experimentally defined ICP conditions [1, 2]. Three cases are examined: nominal depth, residual *p*-GaN (under-etch), and over-etch into the AlGaIn barrier. In the residual regime, remaining *p*-GaN forms a *p-i-n*-like electrostatic configuration that modifies the vertical field and partially depletes the two-dimensional electron gas (2DEG). As the residual thickness increases, both the threshold voltage (V_{th}) and ON resistance (R_{ON}) rise rapidly and then saturate, revealing strong sensitivity to small thickness variations. In contrast, over-etching reduces the effective AlGaIn barrier thickness, weakens band bending, and lowers 2DEG density due to reduced carrier confinement. This leads to simultaneous increases in V_{th} and R_{ON} through degraded channel conductivity and redistributed voltage drop. Using a $\pm 0.2V_{th}$ tolerance, a quantitative process window approximately from -0.8 to $+0.5$ nm around the nominal depth is defined to ensure stable E-mode operation. These results clarify the electrostatic origin of etch-depth-induced performance shifts and provide practical guidance for *p*-GaN HEMT process optimization.

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Sound Design Development for the Horror Game "Dark Forest" on the Unity Platform

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In the game development industry, sound design plays a crucial role in creating a game's atmosphere, especially in the horror genre. Much of the tension is created through sharp, high-quality sounds that are sometimes difficult to distinguish from real ones. Modern engines, such

as Unity, offer ample opportunities for high-quality sound design implementation; most developers go beyond pre-made assets, creating an atmosphere from scratch. To achieve deep and atmospheric immersion in a project, it is necessary to carefully create a sound environment that adapts to the player's actions, influencing their psychological perception and the accuracy of information acquisition. The goal of this work is to develop and implement atmospheric sound design for the horror game "Dark Forest" on the Unity platform. The soundtrack should provide high psychological pressure at the right moments and engage the player. The tasks included creating an interactive audio system in Unity, designing sound concepts for the project's various locations, implementing psychological impact mechanisms, and evaluating their impact on the gameplay experience. Development was conducted in Unity 2022 and FMOD Studio to ensure flexibility and interactivity. Over 20 events were created and grouped into categories. All audio was recorded and processed, using Reaper and Audacity. Initially, a selection of the necessary sounds was conducted to match the game's concept. Each sound was organized into a separate category to simplify the process and define the task. Professional audio equipment was used to achieve this goal, specifically the Maono PD400X microphone, a multifunctional dynamic microphone with a cardioid polar pattern and XLR connectivity. The Focusrite Scarlett Solo 3rd Gen is the third generation of professional external sound cards with analog preamplifiers. This compact solution for transmitting audio signals to and from a computer offers cleaner, higher-quality audio. The Maono armature is designed to secure the microphone, adjust its height, and suppress vibrations from external equipment near the microphone. The Maono pop filter is an acoustic filter, installed in front of the microphone to minimize plosive consonants. The developed sound system has proven effective in creating the atmosphere and supporting the project's gameplay. Using FMOD enabled flexible sound control without overloading the project, resulting in optimized performance. Synchronizing audio distortions with visual effects presented a particular challenge. A solution was found using global FMOD parameters, ensuring precise synchronization of effects and achieving a high level of ambiance in the game. Player feedback indicates that sound is highly important for emotional connection and conveying the atmosphere of a game, especially in the horror genre. Scenes stood out where the entity's distorted voice gradually became clear, creating an effect of mystery and a gradual understanding of what was happening, enhancing the player's immersion. This confirms the hypothesis that sound may not simply be a background and a means of obtaining information, but an independent mechanic. During the project, the sound design for the game "Dark Forest" was successfully created, using Audacity and Reaper, and the soundtrack was fully integrated into the project, using Unity and FMOD. The system includes multiple sound events, the implementation of psychological pressure mechanisms, and adaptive content. Testing confirmed a significant increase in player immersion with the developed sound design. The results obtained can be applied to other horror projects, as well as for educational purposes where studying the management of the user's emotional state is required.

ZnO-Based Memristors in Physical Unclonable Functions Application

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Today, the number of IoT devices used in both households and businesses, as well as in large factories and plants, is steadily increasing every year. These include smart speakers, various household appliances, smart traffic lights, machine sensors, and drones. The importance of such devices in people's lives cannot be overstated because they significantly improve people's daily lives and have a positive impact on business processes in large enterprises and factories. The development of new technologies is accompanied by the emergence of serious security challenges. Attackers use IoT devices to infiltrate the networks to which they are connected, with the aim of causing harm to both the devices themselves and critical processes across the entire network. Existing software-based security methods, particularly stored access keys, are vulnerable to copying, extraction, and spoofing. Therefore, there is a strong need for more advanced methods of securing IoT devices, such as hardware-based digital access keys based on the physical properties of the device itself (PUF). The use of memristors as PUFs holds great promise. The electrical properties of memristors depend on the film material, defects, and switching characteristics, making them well-suited for the construction of PUFs. [1, 2]. Simulations of the physical processes in a ZnO film were performed, and the effect of film thickness on the HRS/LRS ratio, as well as on the U_{SET} and U_{RESET} voltages, was investigated. Analysis of the simulation results for the dependence of the LRS/HRS ratio on film thickness showed that increasing the thickness from 10 to 80 nm leads to an increase in LRS/HRS from 16.7 to 434.81, an increase in U_{SET} from 0.35 to 2.6 V, and a decrease in U_{RESET} from -0.15 to -1.2 V. The simulation results show that the thickness of the ZnO film significantly affects the memristor's current-voltage characteristic. Based on this, variations in the film parameters can be considered as one of the factors, determining the uniqueness of the memristor structure's response. This confirms the potential for using such devices in PUF systems.

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Thermophysical Properties of the Ceramic Solid Solutions of the Composition PCR-35, Modified by NiO ($x = 0.005 - 0.025$)

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Ferroactive sodium lithium niobate solid solutions, being the basis of the industrially sought-after PCR-35 material, are of significant interest as a lead-free alternative to PZT systems for piezoelectric applications. One of the most important parameters, determining the thermomechanical reliability of ceramic elements, is the coefficient of thermal expansion (CTE) α , whose behavior during phase transitions is anomalous. In the present work, a systematic investigation of the temperature dependencies of the relative linear elongation ($\Delta L/L$) and the coefficient of thermal expansion $\alpha(T)$ of ceramic samples of the composition $(1 - x)\text{PCR-35} - x\text{NiO}$ ($x = 0.005 - 0.025$) is carried out in the range of (300 – 723) K. The measurements were performed on a specially designed dilatometric setup, including a Micron-02 device for checking end gauges of length with a reading resolution of 0.01 μm and an Agilent 34401A digital nanovoltmeter for digitizing the analog signal. The design of the measuring chamber with a quartz base and two inductive sensors (A and $-B$) ensures compensation for thermal expansion of the substrate, using the algebraic summation method. The heating rate was 1 K/min; the data, obtained in the cooling mode, were used to calculate the thermophysical parameters. It was established that in zones of structural instability, corresponding to phase transitions, pronounced anomalies are observed in the $\Delta L/L(T)$ and $\alpha(T)$ dependencies, namely the sharp changes in the expansion rate, kinks, and extremes. The nature and intensity of the anomalies depend on the concentration of the modifying NiO additive. Varying x leads to a change in the temperatures of the CTE anomalies. The relationship between the identified thermal expansion features and the rearrangement of the domain structure and the thermal activation of defect processes is discussed. The results are compared with dielectric measurement data (ϵ' , ϵ'') for the same compositions, allowing for a comprehensive assessment of the material's behavior in the phase transition region. The obtained data can be used in the design of multilayer piezoelectric structures, where matching the CTE of various components is a critical reliability factor.

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Circular Model in Construction: Extending Life Cycles and Recovering Resources

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The concept of sustainable development, currently being implemented by most countries, calls for a transformation of approaches to environmental management across all economic sectors. One of the key mechanisms for achieving sustainable development goals is the circular economy, based on maximizing the added value of resources through their reuse. In this context, the development of resource-efficient and environmentally friendly construction at all stages of the real estate lifecycle is particularly important. The construction industry is the largest consumer of natural resources and a major waste generator, accounting for approximately half of all extracted materials and generating a third of the global waste. A critical issue is the lack of models for the recycling of building materials at the design stage after a facility's use. As a result, most of the construction and demolition waste (C&D) generated is not recycled. A paradoxical situation has arisen, in which the high resource potential of C&D is ignored due to the inefficiency of existing waste management systems. A fundamental condition for the transition to a circular economy in the construction sector is extending the service life of buildings and structures. This is achieved through: (i) modernization and reconstruction of existing buildings; (ii) implementation of new design approaches, focused on the subsequent recycling of structural elements and materials (design for demolition). Modern architectural practice demonstrates a steady trend toward designing buildings with a long-life cycle. International eco-efficient design standards (BREEAM, LEED, etc.) play a significant role in this process, establishing strict requirements for the energy efficiency and durability of buildings. The economic feasibility of this approach is supported by empirical data: the application of ecodesign principles enabled European Union countries to reduce energy consumption in 2021 by €120 billion [1]. Renovation of existing buildings is no less promising. The use of modern renovation technologies allows for a significant extension of the life cycle of buildings, while the material intensity of such work is 40 – 80 times lower than that of new construction. In the spectrum of eco-friendly building materials, wood, with its fully biodegradable and renewable properties, occupies a special place. A comparative analysis of thermal insulation properties shows that this material is 12 times better than concrete and 350 times better than steel. In addition to energy efficiency, the use of wood contributes to a significant reduction in the carbon footprint at all stages of a building's life cycle. In summary, the transition to a circular economy in the construction sector is not only an environmental imperative but also an economically sound strategy. Modern technological solutions and international standards already make it possible to significantly reduce the consumption of primary resources and minimize anthropogenic impacts. Integrating material reuse principles into the design phase and transitioning from a linear "resource-product-waste" model to closed resource consumption cycles is an urgent necessity. Overcoming the current paradoxical situation with construction and demolition waste disposal is only possible through an integrated approach that ensures synergy between environmental safety and economic efficiency.

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BIM Technologies as a Tool for the Economic Efficiency of Circular Architecture

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As one of the largest sectors in terms of resource consumption and waste generation, the construction and architecture industry increasingly recognizes the need to improve materials, processes, and systems to create a more sustainable environment. Despite the structural and technological barriers that complicate transformation within the sector, innovative approaches and modern technologies, developed both within the industry and beyond, can facilitate these changes. The professional and academic communities actively promote the implementation of circular economy principles in the construction sector. Within this framework, construction activity is considered a new model for preserving resource value and preventing the use of primary raw materials and waste generation, not only through recycling and reuse, but primarily by reducing overall resource demand. The implementation of circular economy principles involves the design and construction of buildings and structures with consideration for reparability, renewability, and suitability for reuse and disassembly. Such an approach preserves the maximum value of resources and minimizes waste generation within closed material cycles. A significant role in this process is played by Building Information Modeling (BIM), which facilitates the application of circular economy principles in construction not only by simplifying architectural design processes, but also by ensuring long-term asset management [1]. BIM can be defined as an integrated process, based on the collaborative work of project stakeholders, to create a virtual building model, aimed at ensuring effective management at all stages of the asset's life cycle. In the context of circular architecture, the building information model functions as a database that enables various types of comprehensive analysis. BIM technology serves as a valuable tool for conducting economic assessments as well as analyzing the potential for reuse of materials and structural components, thereby forming the foundation for closed-loop resource cycles. The implementation of BIM technologies in design and construction processes creates conditions for long-term economic performance. The economic effect is reflected not only in the reduction of direct costs for materials and labor, but also in the improvement of design quality, the shortening of project implementation periods, and risk mitigation. According to expert estimates, the adoption of information modeling technology significantly increases the accuracy of cost and quantity estimations and reduces construction costs. Long-term economic benefits are also achieved through reduced operational expenses, namely the BIM model enables the optimization of maintenance processes, resulting in lower total expenditures throughout the entire life cycle of the facility [2]. Thus, BIM technologies function as an instrument for ensuring the economic efficiency of circular architecture by integrating the principles of reuse and resource conservation into a system of economic decision-making. In the context of ongoing digital transformation, the potential of BIM to reduce total life-cycle costs will continue to grow, thereby strengthening the economic efficiency of the industry under conditions of sustainable development.

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Digital Transformation of Construction in the Context of Resource Constraints: Strategic Priorities

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In contemporary conditions, the construction sector operates within an environment of increasing resource constraints and heightened requirements for the environmental performance of economic activities. The persistence of a linear logic of material resource use results in waste accumulation, rising project costs, and a decline in the long-term sustainability of companies. This problem is systemic in nature, as it affects not only technological processes but also the principles, governing the management of material flows throughout the entire life cycle of capital construction projects. The circular model is regarded as an instrument of structural modernization of the industry, aimed at preserving resource value, reintegrating materials into economic circulation, and reducing negative environmental impacts. For construction organizations, this implies a transition from fragmented management of the design, construction, and operation stages to their integration within a unified management system. Of particular importance is the ability to forecast the future trajectory of structural elements at the project design stage. At the same time, the practical implementation of circular principles encounters a range of institutional and informational constraints. The absence of systematized data on the characteristics of applied materials, the fragmented interaction among participants in the investment and construction process, and the insufficient technological capacity of companies create barriers to closing material loops. Under these conditions, the formation of a digital management environment becomes a key driver of transformation [1]. Digital tools enable end-to-end resource traceability, enhance planning accuracy, and provide a foundation for decision-making aimed at the reuse and recycling of construction materials. The application of building information modeling technologies, automated accounting systems, analytical platforms, and facility condition monitoring tools facilitates the integration of fragmented information flows into a unified system. In this way, the infrastructural basis for the transition to a circular economic model is established. The development of a digital transition strategy presupposes the consistent implementation of organizational and technological changes. At the initial stage, material flows and the enterprise's level of digital readiness are assessed; subsequently, individual solutions are introduced and piloted. This is followed by the integration of information systems into key business processes. The final stage involves the development of digital interaction between the company and external stakeholders. Such an approach considers differences among companies in terms of scale and resource capacity, thereby reducing transformation costs. Digital transformation becomes the

structural foundation for the transition to a circular model, enhancing resource efficiency and the resilience of construction organizations within the context of the economy's environmental modernization. Moreover, the implementation of digital tools contributes to increased transparency of business processes and improves lifecycle management of construction projects. This enables companies to adapt more effectively to regulatory changes and sustainability requirements, thereby generating long-term competitive advantages.

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Roadmap for the Digital Transition of the Construction Industry to a Circular Model

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The development of a roadmap for the transition of Russian construction companies to a circular economy represents a strategic direction for industry transformation amid intensifying environmental and resource constraints. The concept of the circular economy (CE) presupposes the extension of asset life cycles, the reuse of resources, and the minimization of waste. The key prerequisite for its implementation is digitalization, which ensures transparency and manageability of processes at all stages of a building's life cycle. The purpose of this study is to substantiate the role of digitalization in the development and implementation of a roadmap for the transition of Russian construction companies to a circular economy and to identify the principal directions of digital transformation within the industry. The contemporary construction industry is characterized by high material intensity and significant volumes of waste while largely maintaining a linear economic model. The predominance of primary resource consumption persists, whereas the reuse of materials remains limited. Ongoing urbanization increases pressure on natural resources, necessitating a shift toward more efficient management of material flows [1]. Under these conditions, the development of a phased roadmap becomes an essential instrument for the systemic transformation of companies. The roadmap structures the transformation process, determines the sequence of digital solution implementation, mitigates risks, and ensures effective governance of the transition to a circular model. Digitalization functions as the foundational mechanism for implementing this strategy. The application of Building Information Modeling (BIM), digital material passports, ERP systems, IoT sensors, digital platforms, and digital twin technologies enables the collection and analysis of data on material composition, waste volumes, and reuse potential. The integration of digital tools creates a unified information environment necessary for establishing closed material loops. The transformation of construction companies is implemented through four stages: preparation, piloting, scaling, and integration. At the initial stage, a basic digital infrastructure is established, and material flows are assessed. Subsequently, circular solutions are tested at selected facilities, followed by the integration of BIM, ERP, and IoT into a unified resource management system. The final stage

involves the development of digital interaction with recyclers, suppliers, and partners based on platform-based solutions. The analysis demonstrates that without digital support, the implementation of circular economy principles remains fragmented. Digital technologies ensure transparency of material flows, reduce information asymmetries, and enhance resource efficiency, thereby creating conditions for the development of service-oriented and circular business models. Therefore, the transition of construction companies to a circular economy is not feasible without comprehensive digital transformation, which serves as a system-forming factor for the sustainable and competitive development of the industry under conditions of environmental and resource constraints.

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Digitalization as a System-forming Factor in the Transition to a Circular Economy: Global Experience and Prospects

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In recent years, global economic development has taken place against the backdrop of growing environmental challenges, depletion of natural resources, and increasing anthropogenic pressure on the environment. The linear economic model that has been used for a long time and is based on the principle of “produce – use – dispose” is gradually losing its effectiveness under conditions of resource scarcity and the growing emphasis on sustainable development. In this context, the concept of a circular economy is gaining increasing importance, as it is aimed at creating closed production and consumption cycles, reducing waste generation, and preserving the value of resources throughout all stages of the product life cycle [1]. Digitalization plays a significant role in the practical implementation of these principles, exerting a noticeable influence on the transformation of economic processes. Within the framework of digital transformation, particular importance is attached to technologies that support the management of material flows and resource use. The application of the Internet of Things (IoT) makes it possible to continuously monitor the condition of products and equipment, thereby contributing to the development of predictive maintenance and extending the operational life of assets. The use of big data analytics (Big Data) allows for more informed planning, helps to reduce overproduction, and improves the quality of managerial decision-making. At the same time, digital platforms create opportunities for the development of the sharing economy, industrial symbiosis mechanisms, and service-oriented models, focused on the reuse and recovery of products. A distinctive feature of international practice is the integrated use of digital solutions at different stages of the product life cycle. At the design and production stages, digital tools contribute to reducing material intensity and improving product reparability, while during the used phase they help extend product lifespans through service- and platform-based models. In the field of waste management, digital technologies increase the transparency of secondary resource flows and facilitate their more efficient

reintegration into economic activity, thereby enhancing the overall effectiveness of circular practices. An analysis of foreign experience shows that the most tangible results in the development of a circular economy are achieved by countries that follow a comprehensive approach, combining digital solutions, government regulation, and active involvement of businesses and the population. The European Union has developed a systematic model of circular development, based on regulatory requirements, extended producer responsibility, and the introduction of digital product traceability tools. China demonstrates the effectiveness of large-scale government programs and digital platforms that actively engage the population in waste separation and resource-saving practices. The experience of Germany and the Netherlands confirms the economic feasibility of circular business models through the integration of Industry 4.0 technologies and intelligent resource management systems. The analysis conducted allows the conclusion that digitalization serves as a system-forming element in the transition to a circular economy. Coordinated interaction between the state, business, and society, supported by digital tools, creates conditions for sustainable socio-economic development, reduces environmental risks, and increases resource efficiency.

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Mathematical Modeling of a System for Monitoring Oil Pumping Conditions in Main Pipelines

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To create and maintain pressure in a pipeline sufficient to ensure the transportation of oil, oil pumping stations are required [1]. The main purpose of each oil pumping station is to take oil from a low-pressure pipeline section, increase this pressure, using pumps, and then inject the oil into a high-pressure pipeline section [2]. The main elements of an oil pumping station are pumping units, tanks, supply and distribution pipeline systems, metering units, devices for receiving and starting treatment devices and flow diagnostic tools, as well as lubrication systems, ventilation, heating, power supply, water supply, automation, telemetry, etc. Mathematical models of oil flow have existed for a very long time [3]. However, recently there has been an increasing need to build a model in real time. The model proposed by the authors will allow for complete control of the processes, occurring inside the pipeline, as well as transmit up-to-date information on the pumping status to the dispatcher [4]. Operational measurements of parameters (pressure and volumetric flow at various points in the pipeline), as well as equipment operating parameters, can be used as initial data.

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EDX Analysis of BaTiO₃ Thin Film, Fabricated by PLD under Different Substrate Temperature, for Neuromorphic Applications

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Due to the unique combination of physical and chemical properties, barium titanate (BaTiO₃), providing high operating speed, moderate energy consumption, and high data storage density in neuromorphic structures, is widely used in AI systems [1]. Since BaTiO₃ films are multicomponent oxides, their physicochemical parameters depend on precise observance of the stoichiometric composition and structure, which in turn is determined by the conditions of their synthesis [2]. Thus, the purpose of this work is to study the influence of substrate temperature under PLD on BaTiO₃ composition. Figure 1 shows EDX spectra of BaTiO₃ films, fabricated by PLD under different substrate temperatures. The obtained EDX spectra indicates the presence of barium, titanium, and oxygen in all BaTiO₃ films, obtained in the temperature range from 300 °C to 600 °C. The decrease in the oxygen content in the films with increasing substrate temperature may be due to the onset of oxygen vacancy formation in the films being formed. Furthermore, films, obtained at 300 °C, are characterized by low adatom mobility during deposition, leading to the formation of a fine-grained structure with a non-uniform metal distribution. As the substrate temperature increases to 600 °C, kinetic energy allows cations to occupy the lattice sites, bringing the Li/Nb ratio closer to 1. In addition, at 600 °C, light impurities are more effectively desorbed from the substrate surface, which makes the chemical composition of the film cleaner compared to films, obtained at lower temperatures. The obtained results can be used for controlled formation of oxide layers in the manufacture of in-sensing computing systems for artificial intelligence.

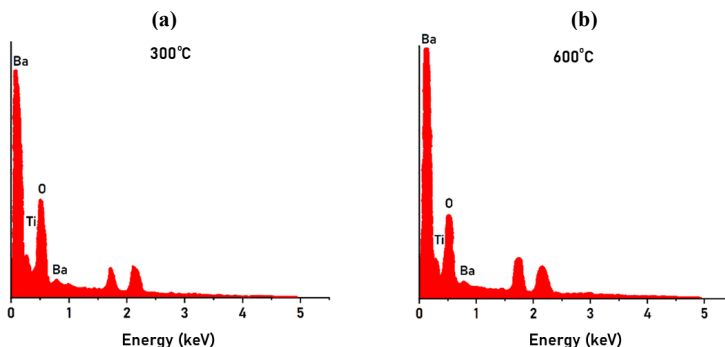


Fig. 1. EDX analysis of BaTiO₃ films, obtained by PLD at different substrate temperatures: (a) 300 °C and (b) 600 °C

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The Automation of Residual Gas Afterburning in the Process Flow Chart for Obtaining Gaseous Sulfur

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This study addresses a pressing issue, namely automation of the third stage of a Claus plant's process flow diagram, specifically the process gas after burning stage. The gas, generated during the removal of acidic components from hydrocarbon gas, is hydrogen sulfide gas, which is converted into elemental sulfur [1]. The Claus process, or its various modifications, is used for this operation. Currently, sulfur-containing compounds in exhaust gas must not exceed 0.5 mg/m³; therefore, process gases must be purified before being discharged into the atmosphere, as an integral part of the Claus process [2]. Numerous Claus plant process diagrams exist, and their improvement is a pressing scientific and technical challenge [3]. Several modified Claus plants were analyzed, and a diagram that includes a sulfur combustion stage was identified. Part of the process gas is mixed with air and then enters the combustion chamber. The remaining gas enters the combustion chamber through bypass lines. An additional burner is installed in the combustion chamber, which burns a portion of the resulting sulfur to stabilize the required combustion chamber temperature. If the required temperature

is still not reached, additional fuel gas is fed into the combustion chamber [4]. The analysis conducted allowed us to conclude that the process of SO₂ production from sulfur offers the best economic performance. It is also worth noting that the process with preheating of the process gas appears the most preferable when oxygen is expensive.

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Analysis of the Effect of Friction on the Recovery of Elastic Parameters of a Cylindrical Specimen

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In recent years, there has been a notable increase of interest in inverse problems, concerning the recovery of elastic characteristics of materials (including variable ones), which is driven by the widespread use of materials, exhibiting inhomogeneity of elastic properties. Traditionally, beam-type models such as the Timoshenko model are employed in the interpretation of experimental data; however, this leads to significant errors due to the absence of consideration of the actual boundary loading conditions that give rise to local features of the stress-strain state. Within the framework of the linear theory of elasticity, several problems concerning the compression of elongated cylindrical specimens by non-ideal rigid plates have been considered. The construction of approximate models of various orders was carried out by employing hypotheses on the representation of the displacement field as a linear combination of radial polynomials of various orders with unknown coefficient-functions. Two types of loading were considered (type 1: the axial compression under the action of normal end loads; type 2: the compression of the specimen by means of an end load with a fixed base; in both types, the lateral surface is free of loads), where the effect of friction at the loaded ends was accounted for by introducing a certain distribution law of shear stresses in an auxiliary problem. By means of the Lagrange variation principle, based on the Kantorovich method, the problems were reduced to systems of ordinary differential equations with the corresponding

boundary conditions, which include certain integral characteristics of normal and shear stresses. Analytical solutions are presented for the homogeneous case. The nature of the displacement functions and the values of the friction parameter in the case of inhomogeneity along the axial coordinate are analyzed. Based on the constructed models, inverse coefficient problems for the recovery of the inhomogeneity laws from additional information on the displacements of points on the lateral surface of the specimen have been formulated. The input data consisted of displacement values at a set of points on the lateral surface. Due to the absence of information on the value of the friction parameter, the problems were classified as ill-posed, and their solution was therefore carried out, using the Tikhonov regularization method. Polynomials were used as basic functions for the approximation of the sought functions. In the case of a homogeneous cylinder, an inverse problem for the determination of the elastic constants of the material and the friction parameter has been formulated, and the reconstruction results are presented.

Acknowledgement. The study was supported by the Russian Science Foundation (project No. 22-11-00265-P) at the Southern Federal University.

Towards the Estimation of Elastic Properties of Complex-shaped Rods Employing Frequency-dependent Dispersion Curves of Elastic Guided Waves

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Metallic beams or rods with complex-shaped cross-section such as I- and T-shaped bars are widely used in various engineering constructions to enhance their load-bearing capacities. During their long-term service such structures could deteriorate through fatigue, wear, and breakage, caused by various external factors. Consequently, monitoring their health status is vital for ensuring the overall safety of the considered engineering construction. While elastic moduli of materials from which such rods or beams are manufactured are among the key parameters, which reflect structural residual strength, they are essential as well for calibrating conventional non-destructive testing methods, such as acoustic emission or ultrasonic systems. Along with the standardized fatigue tests, elastic modulus of such elongated structures could be evaluated in a nondestructive and *in-situ* manner by employing elastic guided waves (EGWs), which dispersion properties depend strongly on material and geometric features of corresponding waveguides. Although being well-established for structures with simple geometry, e.g., plates or pipes, the implementation of such approaches for complex-shaped waveguides requires additional research efforts. Main challenges arise here due to the presence of multiple propagating EGWs even at low frequencies, which sufficiently complicates the selection of optimal normal modes, being sensitive to specific elastic constants and their selective excitation and sensing with respect to the available testing equipment. In this report, considering an I-shaped beam and a hollow-square rod, made from construction steel as examples, peculiarities of EGW application to the estimation of corresponding elastic moduli are discussed. At the first step, dispersion curves and mode shapes of propagating EGWs in

such structures are evaluated employing semi-analytical finite element method (SAFE). Such calculations allow investigating the influence of waveguide elastic properties on specific normal modes and selecting the most suitable among them. Afterwards, both numerically and experimentally utilizing laser Doppler vibrometry the capability to reliably extract dispersion curves of such EGWs from measured probe signals with respect to the load application region and the location of measurement points relative to the waveguide cross-section is estimated. The problem of elastic moduli evaluation is further reduced to the numerical minimization of discrepancies between the theoretically calculated and experimentally measured EGW dispersion characteristics for the specific normal modes during variation of input elastic constants in the corresponding SAFE-based computer model. To validate the obtained results, they are compared with the values of standard elastic constants of steel grades from which the considered specimens are manufactured. Moreover, dispersion curves of other normal modes, which were not employed in the reconstruction procedure, being evaluated with the estimated elastic moduli, are compared with their experimental counterparts revealing fair coincidence among each other.

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Study of Electrical Switching of Pixels in Active Gradient Amplitude THz Diffraction Grating Based on VO₂/TiO₂/LiNbO₃

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Active metasurfaces for emerging THz flat optic devices are establishing a basis for variety of novel optical instruments. Recently, several approaches have been proposed for creating active THz metasurfaces, using phase-change materials. Among them are (1) materials that switch between two states, using heat, current, and/or light [1]; (2) devices with hybrid metal-graphene metaatoms that are adjusted simultaneously with common electric gate bias [2]; (3) programmable liquid crystal matrices [3]; (4) Si-based metasurfaces, controlled by “global” illumination by powerful femtosecond laser pulses [4]; (5) Fresnel amplitude band plates made of carbon nanotubes in a deformable polymer matrix [5] and so on. All electric control active metasurfaces are highly desired but still challenging and the advanced and expensive multi-step lithography microprocessors level fabrication processes are used for fabrication [6]. Recently, we discovered an electrically controlled gradual conductivity alteration in VO₂/TiO₂ films, grown on LiNbO₃ substrates [7] that is very different from the abrupt and uncontrolled insulator-to-metal transition in traditional VO₂ films on Al₂O₃ or SiO₂/Si substrates. Such unique behavior of VO₂/TiO₂/LiNbO₃ composites enables the design of all electric tuning the phase and amplitude of reflected THz and middle IR waves, which opens a broad avenue for a new class of active metasurfaces. In this work, we study the electrically induced gradual switching of pixels in an active amplitude-THz reflective diffraction grating to identify the

device's tuning modes for use as an amplitude-sinusoidal grating and a binary grating with actively variable period.

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Nd-modified TiO₂ as Visible Light Photocatalyst for Organic Synthesis

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Photocatalysts, used in organic synthesis, contain expensive noble metals and organic compounds that are not recyclable. Therefore, replacing them with cheaper and safer metal oxide catalysts is highly promising for achieving sustainable development goals. Density functional theory calculations have shown that one promising inorganic photocatalyst composition is Nd/TiO₂, which has demonstrated high efficiency for converting CO₂ to methanol [1]. In this study, nanoscale TiO₂ photocatalysts, doped with 3 mol.% Nd³⁺, were synthesized, using a sol-gel method from the inorganic precursor titanium tetrachloride. The materials were studied using X-ray powder diffraction analysis and transmission electron microscopy. All synthesized samples are nanosized spherical polycrystallites with an average particle size of 12 nm. Their photocatalytic properties were also examined, using model dyes (methylene blue and methyl orange). Doping with Nd³⁺ ions was shown to significantly increase the photocatalytic activity of the material, compared to the pure titanium dioxide. Thus, Nd-TiO₂ has been shown to be a promising catalyst for organic synthesis due to its ability to utilize sunlight and ability to suppress charge recombination, and its increased adsorption capacity for organic molecules.

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CNN-based Automated Pipeline for Quantitative Analysis of Nanoparticles in TEM Images: Segmentation, Stability, and Clustering

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Accurate preliminary analysis, segmentation, and quantitative morphological assessment of nanoparticles in Transmission Electron Microscopy (TEM) images remain a challenging task due to low contrast, particle overlap, and operator subjectivity [1]. The actual work presents an automated pipeline, utilizing a Convolutional Neural Network (CNN) for TEM image segmentation, integrated with Test-Time Augmentation (TTA) procedure to evaluate results' stability. The developed pipeline encompasses image preprocessing (denoising and contrast enhancement), CNN-based segmentation, and comprehensive morphological assessment of the extracted nanoparticles. The resulting optimized binary masks enable the calculation of morphological parameters, including equivalent diameter, circularity, aspect ratio, and other descriptors. Principle Component Analysis (PCA) and k-means clustering were applied to the obtained features to identify morphological groups. The results demonstrated highly reproducible segmentation output with an average TTA stability score of approximately 0.85 and revealed three statistically significant clusters: larger, slightly elongated particles with mean diameter 23.5 nm; smaller, compact particles with mean diameter 17 nm; and rare anomalous outliers. The proposed approach outperforms traditional thresholding and watershed algorithms by ensuring objective and reproducible segmentation, even for overlapping aggregates. The adaptive implementation of the pipeline ensures scalability for various nanosystems and shows the significant acceleration of costly quantitative TEM studies in the field of catalysis [2]. The segmentation results, as was shown, demonstrate the effectiveness of the CNN-based approach with a color-coded probability map, indicating high confidence in particle boundary detection.

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Electrical Modeling of Microtriodes in a Vacuum Microwave Integrated Circuit

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This study presents an algorithm and results for formalizing nonlinear electrical processes in a vacuum microwave integrated circuit resistant to radiation and heat [1]. The formalization of electrical processes is based on a model of specific matter, containing moving electrons and an electromagnetic field that interact with each other. The theoretical study of such electronic components, containing an "open" set of microtriodes, is relevant due to the need to develop electronic and computer hardware. The electronic components of such hardware must be compatible with the supporting platform for wireless power supply systems in space. A charge change prediction was conducted in a fragment of the vacuum integrated circuit [1]. This fragment is formed by a pair of interacting microvacuum electronic apparatus, connected into a single unit by power conductors and heat-dissipating components. These electronic components, together, form building blocks of analog and digital vacuum microelectronics products for electrical engineering applications. The basis for creating the graphical and analytical operators of the coherent microtriode theory is a set of models of an electron as a particle with a negative elementary charge and characterized by a "geometric" radius of $\sim 10^{-22}$ m and a "field" radius of $\sim 10^{-15}$ m. Furthermore, the Maxwell and Lorentz integral-differential equations in the monochromatic approximation are correctly transformed into algebraic relations, suitable for synthesizing vacuum integrated circuits, using electrical and radio engineering methods. These methods are supplemented by the theory of microwave electronic circuits, but without using the superposition principle when summing the signals of electronic components. The summation of microwave signals from electronic components leads to diffraction and interference of the combined electromagnetic field in electronic and computing equipment. From an engineering perspective, the steady-state and unstable electrical conditions of a structural unit are calculated, using the Tellegen-Kirchhoff formulas. These relations collectively characterize the laws of conservation of energy and charge in the temporal and spatial domains of a microtriodes system, operating in saturation mode. Vacuum integrated circuit design issues include analyzing the influence of contact potential difference and the electron work function of electrode materials, as well as the electrical conductivity and configuration of the metal, semiconductor, and dielectric anode and grid connections. The connections are coupled to power supplies via interconnections that simultaneously transmit the signal. For example, when designing vacuum integrated circuits, the effect of minimizing the electron transit time during field emissions from a tip cathode, made of various materials (diamond, tungsten, etc.), is considered. The minimization effect takes place due to the absence of a negative space charge, created by unexpected heating. This theoretical study of a microwave vacuum microelectronics product allows us to create a correct model of the interaction between electromagnetic field sources and the topology of the generalized current circulation path. This model is necessary for reliable optimization of the product's energy

consumption, using equivalent circuits and complex amplitudes, harmonic linearization and balance, and the theorems of Thevenin and Norton.

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Investigation of the Stress-Strain State of Downhole Head Components

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Column heads are designed for strapping casing strings of gas and oil wells. The design of the column head should provide [1 – 4]: (i) reliable sealing of the inter-column spaces; (ii) pressure control in the inter-column space; (iii) fast and reliable fastening of the casing columns; (iv) versatility, i.e. the possibility of attaching casing columns of different diameters to one column head; (v) protection of the mouth of the casing columns from increased wear during drilling tool operation; (vi) the possibility of vertical movement of the casing strings at high temperatures in the well; (vii) high reliability of the suspensions and sealing assemblies during drilling and long-term operation of the well; (viii) the lowest possible height; (ix) sufficient strength, taking into account the effects of various loads. To study the effect of the structural parameters of the head on the stress-strain state of the structural parts, using the Compass CAD system, a parametric solid-state model of the borehole head was designed. The model is used to study the compression process of the casing and check the strength of the structural parts. The type of research is defined as nonlinear, static and axisymmetric. Only one cross-section of the head is considered, assuming a symmetrical distribution of circumferential stresses and deformations over the entire volume of the model. The material of the body, the production column, the lower and upper rings is structural steel. The material of the packer ring and the wedge sleeve is rubber. The upper clamping ring moves to a height, which corresponds to tightening the flange connection of the column head. The model uses the following contact conditions for mating parts: (i) upper ring – packer; (ii) lower ring – packer; (iii) wedge sleeve – pipe; (iv) wedge sleeve – housing; (v) lower ring – wedge sleeve; (vi) lower ring – housing. Contact conditions are defined with default parameters, without penetration. The Mises stress diagram is present on Fig. 1. A numerical experiment was planned and implemented to study the effect of several parameters of the structure studied on the contact force Y_1 acting on the production column, the maximum stress in the parts of the head Y_2 , and the weight of the head Y_3 . These parameters include: X_1 is the displacement of the pressure ring, X_2 is the cone angle of the wedge sleeve, X_3 is the height of the packer ring. As a result of data processing by the method of multifactorial regression analysis, empirical dependencies describing the behavior of the target parameters were obtained. It is determined that the direction and degree of influence of each variable factor is ambiguous. Therefore, the optimization problem of minimizing the weight of the column head was proposed and solved with restrictions on the permissible rigidity and strength of the structure. As a result of optimization, an 18% reduction in the weight of the structure was achieved.

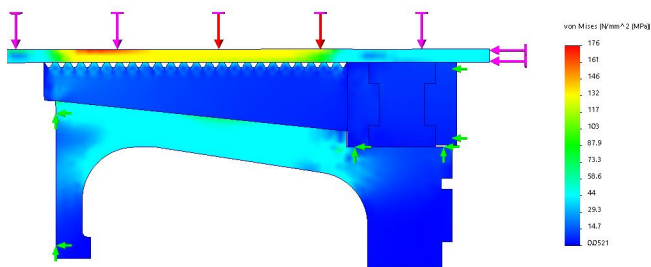


Fig. 1. Mises stress diagram in the details of the borehole head column

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The Effect of Synthesis Time on ZnO Nanorods, Obtained on Nickel Coatings via Chemical Deposition Method

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In this work, the dependence of ZnO nanorod morphology, deposited by chemical bath deposition (CBD) on nickel-coated substrates [1], on synthesis time was investigated. Polycor substrates with Ni stripes (0.12 – 0.13 μm thick, deposited by vacuum thermal evaporation) were precoatd with a seed layer from 0.1 M or 0.01 M $\text{Zn}(\text{CH}_3\text{COO})_2 \cdot 2\text{H}_2\text{O}$ ($\text{Zn}(\text{Ac})_2$) in ethanol: ultrasonication for 30 min at 35 $^\circ\text{C}$, aging for 24 h, spin-coating, and annealing for 20 min at 240 $^\circ\text{C}$. ZnO synthesis was performed by chemical bath deposition at 85 $^\circ\text{C}$ for 30 or 60 min from a solution of 0.025 M $\text{Zn}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$ and 0.05 M hexamethylenetetramine (HMTA); substrates were rinsed with water and air-dried. The samples were examined using a scanning electron microscope (SEM, Nova Nanolab 600, 10 kV). Studies showed that 30

min deposition resulted in complete ZnO – NR coverage of the entire substrate surface. SEM images revealed nanorods growing from seed centers and those formed in the solution bulk that chaotically settled on the substrate. At 60 min deposition, predominantly ZnO – NR grew from seed centers. ZnO – NR grew equally on both polycor substrate and nickel film. Figure 1 shows histograms of nanorod diameter distributions by size. Analysis revealed that at 0.01 M seed layer concentration and 30 min deposition, 80% of ZnO – NR had uniformly distributed transverse dimensions in the 80 – 176 nm range (Fig. 1b). Extending deposition to 60 min (Fig. 1c) led to greater growth of ZnO – NR with a diameter of 120 ± 12 nm (36.4%). At a seed layer concentration of 0.1 M and 30 min deposition time (Fig. 1a), about 30% of ZnO – NR have a diameter of 111 ± 12 nm. Extending deposition to 60 min (Fig. 1c) reduces ZnO – NR diameters to 91 ± 12 nm (36.5%). This is because ZnO – NR growing from seed centers have a smaller diameter.

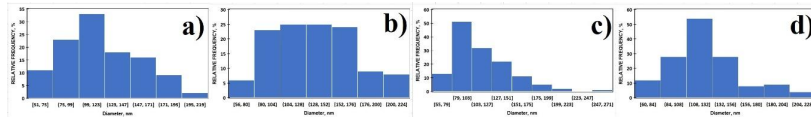


Fig. 1. Results of statistical analysis of SEM images of synthesized ZnO nanorods at Zn(Ac)₂ concentrations of 0.1M (a, c) and 0.01M (b, d), and synthesis times of 30 min (a, b) and 60 min (c, d).

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Suppression Strategy for Crack-Tip Stress Concentration in Lip-Type Cracks under Coupled Mechanical and Electrothermal Loading

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Thermoelectric materials in semiconductor packaging and energy conversion devices are often subjected to coupled thermal and electrical loading, leading to complex thermomechanical stresses and crack initiation. This study presents an analytical investigation of symmetric lip-type cracks in *n*-type Bi₂Te₃ thermoelectric materials under combined mechanical and electrothermal loading at arbitrary orientations. Based on complex variable thermoelastic theory, stress intensity factors (SIFs), full-field stress distributions, and crack initiation angles are evaluated for various loading directions and crack geometries. The results show that thermoelectric coupling significantly amplifies crack-tip stress concentration, which can be effectively mitigated by applying appropriate vertical compressive or horizontal tensile preloads, and the corresponding critical suppression conditions are identified. When complete suppression is not achieved, the strain energy density criterion is employed to predict fracture initiation and propagation

direction. The proposed framework provides both stress suppression strategies and fracture prediction capability for thermoelectric materials under multiphysics loading.

Automated Optical Inspection Platform for Micro-LED Matrices Integrating Embedded Control and Deep Learning

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With the growing demand for high-efficiency and high-consistency inspection in micro-LED array applications, conventional manual inspection methods are increasingly limited by low throughput, operator dependence, and inconsistent judgment. To address these issues, this study presents an automated optical inspection system for matrix-arranged micro-LED samples by integrating embedded control, machine vision, and deep learning into a unified platform. The proposed system combines automated stage movement, image acquisition, sample positioning, and defect evaluation to achieve a more stable and efficient inspection workflow. A three-axis motion platform is used to perform automated scanning of the target sample, while a PC-based interface provides system control, monitoring, and result management. In addition, image-based analysis is employed to support target localization and inspection tasks, reducing the reliance on manual alignment and visual observation. To further improve defect detection capability, a deep learning-based image analysis approach is introduced to distinguish normal and abnormal sample patterns from captured images. The developed system demonstrates the feasibility of integrating embedded systems with intelligent visual inspection for micro-LED samples. It can improve inspection consistency, reduce human workload, and provide a practical foundation for future expansion toward more advanced, scalable, and application-oriented automated optical inspection systems.

Verification of Vibration Mode and Acceleration Spectrum to Suppress the Print Circuit Board in a Fan-driven Power Supply

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The internal printed circuit boards (PCBs) of a power supply unit were investigated on vibration transmission from fan excitation. Four distinct measurement methods, including Laser Doppler Vibrometry (LDV), Scanning LDV (SLDV), oscilloscope-transferred frequency (Scope FFT), and Time-frequency Analysis from scope time signal, are

comparatively evaluated to establish a benchmark measurement technique. PCB's natural frequencies and mode shapes are identified through various experimental data. Using the mass-point setup with the kinematics and structural coupling constraints to consider the electronic components, a finite element analysis (FEA) model was constructed to validate experimental results. Driven fan-induced vibrations are characterized by the acceleration at the electrode pads. By integrating natural frequency, mode shape, and excitation acceleration, key parameters, influencing electrode-pad vibration amplitude, are identified. A systematic simulation framework is developed to determine optimal vibration suppression, positioning in the complex PSU structures.

Experimental Characterization and Finite Element Modeling of Vibration Behavior in Ferroelectric BaTiO₃ Plates

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Barium titanate, BaTiO₃, is a representative lead-free ferroelectric ceramic with a good electromechanical coupling, making it attractive for piezoelectric applications. This study investigates the vibration behavior of BaTiO₃ plates under electrical excitation and mechanical loading, focusing on resonant frequencies and mode shapes. Because the mechanical and electrical properties of BaTiO₃ are highly sensitive to processing conditions and microstructures, the parameters, reported in literature, are insufficient for accurate prediction and design analysis. To address this, the elastic, dielectric, and piezoelectric constants of BaTiO₃ plates were experimentally measured and incorporated into a finite element piezoelectric-coupled model, using ABAQUS. Under different excitation conditions, they were then compared with experimental measurements to validate the simulation modeling approach. Results show that simulations, based on the experimentally determined material constants, achieve good agreement with measured vibration responses, demonstrating reliable predictive capability. This work provides a practical framework for integrating experimental characterization with finite element modeling, enabling more accurate analysis and design of ferroelectric BaTiO₃-based components.

Enhancement of Conductive Filament through RTA Technique Based on Cu-Doped Gallium Oxide RRAM

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Resistive Random Access Memory (RRAM) devices are gaining attention for next generation non-volatile memory technology due to their straightforward design, rapid switching speed, low power consumption, long data retention, and excellent durability [1, 2]. The fundamental operation of RRAM is based on resistive switching within a metal – insulator – metal (MIM) structure. These devices switch between high resistance state (HRS) and low resistance state (LRS) when subjected to external stimuli like an electric field. The formation and rupture of conductive filaments are the primary methods for transitioning RRAM between HRS and LRS. This process is driven by the creation of oxygen vacancies or the diffusion of active metal ions from the electrodes into the active layer under a strong electric field. In this work, we have studied the resistive switching characteristics of gallium oxide-based RRAM with different device structures. This study sheds light on the influence of Cu nanoparticles on the resistive switching mechanism. To prove our theory, we fabricated gallium oxide-based RRAM, then we doped copper into gallium oxide to form the insulation layer. Furthermore, we introduced RTA technique to make copper diffuse into insulation layer and become Cu nanoparticles, which can significantly improve the conductive mechanism of RRAM device. The measurement result shows that the device with Cu-doped has better resistive switching characteristics than traditional MIM structure device, which shows 10^5 on/off ratio and excellent endurance for over 2000 switching cycles.

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A Physical Blanking Mechanism for Improving Energy Efficiency in Reconfigurable Convolution Engines

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Hardware architectures for extreme environments, such as space exploration and nuclear monitoring, require structural resilience to enable self-repair and ensure mission continuity. Thanks to the emergence of edge computing, edge devices are now widely deployed in these extreme sectors for real-time image recognition and sensing tasks that demand high-throughput capabilities to execute convolutional neural networks (CNNs). However, these devices operate under constrained power resources, creating a dilemma of balancing performance, energy consumption, and structural resilience. Traditional static hardware architecture struggles to manage energy in advanced processes. Regarding energy optimisation, existing CNN architectures often neglect static power consumption at the physical level. For instance, in the fixed array proposed in our previous work [1], processing elements at the end of the array remain idle when executing small convolution kernels (e.g., 3×3), which are prevalent in edge tasks. At the same time, the common approach for reducing dynamic power via clock gating presents its own limitations. Conventional clock gating and RTL-level clock enable (CE) to mask the signal rather than halting the clock toggling. Consequently, the clock tree continues to dissipate power. Moreover, clock gating on FPGA platforms is notably less efficient than in ASICs. FPGA implementations typically rely on global clock buffers or RTL-level clocks enable signals. Global clock buffers are generally utilised to govern an entire region of the FPGA, offering a granularity that is far too coarse for precise power management. These inherent limitations make traditional logic gating insufficient for power-constrained edge devices. Given these inherent limitations, dynamic partial reconfiguration (DPR) emerges not merely as an alternative but as a requisite for energy optimisation on FPGA platforms. This research utilises a reconfigurable streaming convolution engine to implement a “physical blanking” technique. By dynamically loading blanking bit streams into idle processing element (PE) regions, defined by the architecture, the internal logic is physically erased, equivalent to constructing virtual power switches within the FPGA to intercept static leakage at its source. This approach demonstrates that the architectural integration of DPR provides a more fundamental intervention than the superficial masking of conventional logic gating. The effectiveness of the proposed mechanism was validated on an edge-based FPGA platform. Experimental results show that switching to physical blanking mode via the reconfigurable architecture, implemented by DPR, reduces total power by 11.11%, dynamic power by 26.67%, signal power by 31.25%, and clock-tree dissipation by 28.57%. These results confirm that leveraging DPR-based physical blanking to implement architectural power switches provides a robust and viable solution for energy-constrained edge devices in extreme environments, effectively overcoming the limitations of conventional logic gating.

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Thermal Processes in Laser-assisted Turning

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Conventional machining of high-strength materials, due to the limited use of low cutting speeds, is slow and inefficient. To improve the efficiency of machining difficult-to-machine materials, a new innovative method, called laser-assisted turning, can be used [1]. This method combines traditional mechanical machining methods with laser technology. The laser acts as a source of heat, which is concentrated on the material. Under the influence of laser radiation, the material softens, reducing cutting force, extending tool life, and reducing machining time. Optimizing laser-assisted machine depends on controlling laser heating [2]. This requires the development of a comprehensive mathematical model that describes the laser and thermomechanical heating processes [3]. The amount of heat, generated during laser-assisted cutting, is determined by the formula:

$$Q = Q_1 + Q_p \quad (1)$$

Based on the work [1], when considering only laser heating, the temperature field can be determined by solving the heat conduction equation:

$$Q_l(x, y, z, t) = T_0 + \frac{8P_a \sqrt{a}}{\lambda_T \pi^{3/2}} \int_{\sqrt{t-\tau}}^{\sqrt{t}} \frac{\exp \left[-4 \frac{\left[x - V_x(t-u^2) \right]^2 + y^2}{d^2 + 16\alpha u^2} - \frac{z^2}{4\alpha u^2} \right]}{d^2 + 16\alpha u^2} du \quad (2)$$

Where T_0 is the initial temperature, $a = \lambda_T / (c\rho)$ is the thermal diffusivity, c is the heat capacity; ρ is the specific gravity of the material; P_a is the absorbed laser power, λ_T is the thermal conductivity, d is the laser beam diameter, V_x is the laser beam velocity along x -axis direction. The cutting temperature during turning can be determined, using S.S. Silin's formula:

$$Q_p = \frac{0,95 \tau_p \left(\frac{va_1}{a} \right)^{0,375} \left(\frac{a_1}{p_1} \right)^{0,055} \operatorname{erf} \sqrt{\frac{va_1 B}{4a}}}{c\rho B^{0,625} \left(\frac{\lambda_p}{\lambda} \beta \varepsilon \right)^{0,15} \left(\frac{a_1}{b_1} \right)^{0,045} (1 - \sin \gamma)^{0,65} \sin^{0,03} \alpha} \quad (3)$$

where τ_p is the resistance of the material, being processed to plastic shear, a_1 is the thermal diffusivity of the material being processed. Substituting expressions of Q_1 and Q_p in (1), we obtain a generalized dependency for determining the total amount of heat, released during laser-assisted processing:

$$Q = \left(T_0 + \frac{8P_a \sqrt{a}}{\lambda_r \pi^{3/2}} \int_{-\tau}^{\tau} \frac{\exp \left[-4 \frac{[x - V_s(t-u)]^2 + y^2}{d^2 + 16au^2} - \frac{z^2}{4au^2} \right]}{d^2 + 16au^2} du \right) + \frac{0,95 \tau_p \left(\frac{va_1}{a} \right)^{0,375} \left(\frac{a_1}{p_1} \right)^{0,055} \operatorname{erf} \sqrt{\frac{va_1 B}{4a}}}{c \rho B^{0,625} \left(\frac{\lambda_2}{\lambda} \beta \varepsilon \right)^{0,15} \left(\frac{a_1}{b_1} \right)^{0,045} (1 - \sin \gamma)^{0,65} \sin^{0,03} \alpha} \quad (4)$$

Thus, the study yielded a two-stage analysis. The first stage involved calculating the thermal linear-volume laser heating. The second stage involved coupling the thermomechanical cutting process. To obtain more precise relationships, experimental studies on different types of material are necessary.

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A Switched Capacitor Regulator with Low Input Voltage for Energy Harvesting System

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A switched capacitor regulator with low input voltage for an energy harvesting system is proposed in this study. Energy harvesting is a method of capturing energy from external sources in the environment. However, the voltage, generated by this method, is typically too low, which may result in the abnormal activation of the power converter during the power conversion process. In this study, circuit architecture is proposed to minimize the effect of lower input voltage on system operation. In addition, the conversion efficiency can be improved by clock signal frequency optimization controller. The chip is realized by the TSMC 0.25 μm HV CMOS process with an area of 2.24 mm^2 . Experimental results show that the peak voltage conversion efficiency is more than 97%.

An Enhanced Ripple-Based Regulator with Master-Slave RS Control and Dual-Loop Feedback

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This paper proposes an advanced power regulator, fabricated in TSMC 0.18 μm CMOS process, specifically optimized for energy harvesting systems with low input voltage requirements. To address the challenges of abnormal activation and efficiency degradation in low-voltage environments, a novel Ripple-based Control (RBC) architecture is implemented. The proposed controller utilizes a Master-Slave RS Flip-Flop configuration to ensure robust logic switching and immunity against high-frequency switching noise. An innovation is the integration of dual-loop enhancement, incorporating both the output voltage ripple and the inductor current sensing into the feedback path. This dual-loop RBC mechanism significantly improves transient response and eliminates sub-harmonic oscillations commonly found in traditional asynchronous controllers.

Role of Pt Thickness and Nanoparticles in Liquid-Nitrogen-Enabled Nitrogen Incorporation for *p*-Type ZnO Thin Films

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In this work, ZnO thin films were deposited, using a non-balanced magnetron sputtering system, and a practical nitrogen incorporation route, inspired by conventional metal-processing concepts, was explored. Instead of introducing nitrogen through complex plasma chemistries or high-temperature treatments, liquid nitrogen (LN_2) was employed as a nitrogen source to enable doping under relatively simple processing conditions. To clarify how nitrogen species can be incorporated into the ZnO lattice and to improve the doping efficiency, platinum (Pt), a noble metal with high catalytic activity, was introduced onto the ZnO surface. The Pt layer was designed to evaluate whether noble-metal-assisted catalysis plays a key role in facilitating nitrogen incorporation and activation. XPS was used to examine the chemical states and depth-related signatures, associated with nitrogen in the ZnO films, confirming that nitrogen-related components are detectable after LN_2 -assisted processing. Electrical properties were further evaluated by Hall-effect measurements, where the treated films exhibited *p*-type transport behavior, indicating successful conductivity conversion under selected conditions. In addition, the influence of Pt configuration was investigated. A continuous Pt layer with excessive thickness was found to hinder nitrogen incorporation, likely due to blocking or

limiting the interaction between nitrogen species and the ZnO surface. In contrast, Pt nanoparticles provided a more favorable catalytic interface while maintaining accessible diffusion pathways, leading to improved *p*-type response. These results suggest that surface catalytic design, particularly the use of nanoscale Pt rather than thick continuous Pt films, can be a critical factor in enabling LN₂-assisted nitrogen doping for *p*-type ZnO.

Distribution of Mode-I Thermal Stress Intensity Factor along a Front of Three-dimensional Surface Crack due to an Instantaneous Internal Point Heat

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This study evaluates mode-I thermal stress intensity factor (SIF) distributions along the crack front of a three-dimensional surface crack perpendicular to the free surface in an isotropic elastic solid, subjected to instantaneous internal point heating. The quantitative evaluation of thermal SIFs for surface cracks is essential for thermal laser separation and stealth dicing, where localized heating governs thermal stress fields in brittle materials. The thermal stress field is formulated using Goodier's thermoelastic displacement potential, and the crack problem is solved using a boundary integral formulation with discretization based on the body force method. With only the crack surface discretized, the present formulation enables efficient and accurate evaluation of mode-I thermal SIFs under transient thermal stress conditions. A detailed parametric study was conducted, using the normalized SIF, defined by a representative length, heat input, Young's modulus, and the coefficient of thermal expansion. The results show that the normalized mode-I thermal SIF distribution is significantly affected by Poisson's ratio and heat-source depth, particularly near the free surface.

Machine Learning Approach for Stationary State Problems of One-dimensional Schrödinger Equation in Self-rectifying Memory Array

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Resistive switching memory has emerged as a leading contender for next-generation memory and computing systems, enabling diverse applications, such as storage-class memory, multilevel storage, and neuromorphic computing. A one-dimensional steady-state model of the Schottky barrier at the platinum/strontium manganite (Pt/SMO) interface is presented, using a Schrödinger equation-based approach. This model quantitatively captures the formation of stationary interface states and rectifying barriers in a metal – semiconductor – metal structure. Ultraviolet photoemission spectroscopy (UPS) measurements were used to determine the interfacial band alignment and estimate the Schottky barrier heights, and the pronounced rectifying behavior was confirmed by the current–voltage (I–V) characteristics. The model is calibrated with these UPS and I–V data, allowing it to accurately reproduce the asymmetric I–V response, observed in Pt/SMO/Pt devices. In addition, a machine learning framework (decision tree and random forest algorithms) was leveraged to model the rectifying process, providing an explainable fitting of what interface parameters influence device performance. The integrated physics-based and data-driven approach offers insights into the optimization of two-terminal selector devices. The results highlight the potential of engineered Pt/SMO Schottky interfaces for self-rectifying selectors in high-density memristor arrays and provide a solid foundation for its application in neuromorphic computing and artificial neural networks.

An Investigation into the Impact of Environmental Factors on the Stability of Remote Monitoring Systems in Animal Shelters Using Open Meteorological Data

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This study deployed a cloud video-stream + OpenWeatherMap monitoring architecture in the dog-and-cat area of Shelter A in Zuozhen, Tainan. Hardware consisted of a Raspberry Pi Zero 2 W paired with a 1080P IP camera that handled live streaming and link-failure detection. On the software side, a Flutter application invoked the OpenWeatherMap One Call 3.0 API every hour to fetch ambient temperature and relative humidity, synchronizing these readings, together with local connection logs, to Google BigQuery. During a 30-day trial the system collected 720 environmental observations and 1243 disconnection events. Using BigQuery

Standard SQL functions CORR and ML.LINEAR_REG, the research computed real-time correlations between environmental factors and communication quality. Results confirm that edge devices plus open weather data are sufficient to quantify communication risk in a semi-outdoor shelter setting. The work demonstrates the feasibility of completing real-time correlation and regression analysis, threshold derivation, and automatic dispatch entirely inside native BigQuery SQL, and proposes a closed-loop workflow, namely “data streaming → cloud computation → threshold push → effect evaluation”. The approach offers a quickly replicable upgrade path for budget-constrained shelters and establishes a statistical baseline for future multi-site, multi-season extensions aimed at reducing caregiver workload, increasing public visibility, and enhancing animal welfare without additional hardware cost.

SrMnO₃-based Self-rectifying Memristor Crossbar Arrays

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Conventional charge-based memory technologies, including dynamic random-access memory (DRAM), static random-access memory (SRAM), and flash memory, are approaching their scaling limits due to exponentially increased leakage currents and the reduced electron storage capability as device dimensions shrink. To address these challenges, embedded three-dimensional (3D) structures have been explored as a new approach to overcome scaling limitations. Meanwhile, resistance random-access memory (RRAM), which offers high cell density in both two-dimensional (2D) and 3D-stacked CMOS/RRAM hybrid structures, has gained increasing attention in both scientific and technological communities over the past decade. Additionally, crossbar arrays, based on two-terminal memristors, provide a simple and effective method to achieve high-density memory architectures by reducing the cell size to $4F^2$ (where F is the minimum feature size). However, misreading problems in crossbar arrays, caused by crosstalk interference from sneak-path currents through neighboring memristors remain a critical issue. In this study, cubic SrMnO₃ (SMO), a complex metal oxide, commonly used as a ferromagnetic or thermoelectric material, is fabricated into a Pt/SMO/Pt structured cell, demonstrating forming-free resistive switching behavior. Moreover, the SMO-based memristor exhibits good endurance and a remarkable self-rectifying effect in the low-resistance state (LRS). The Schottky barrier at the Pt/SMO interface is investigated, using ultraviolet photoemission spectroscopy (UPS). This device effectively suppresses sneak-path currents, enabling the integration of high-density memory arrays. The reset process is quantitatively analyzed through machine learning, applied to electrical transport characteristics, while the high-resistance state (HRS) is accurately described, using the

Poisson–Boltzmann formalism. Finally, a 2×2 square crossbar array is designed to mitigate misreading issues, realizing a self-rectifying crossbar SMO RRAM array device.

Quantum Transport in Simple Structure Based Neuromorphic Memristor via Machine Learning

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For enabling neuromorphic computation, resistive random-access memory (RRAM) is considered a promising device due to its significant advantages in power consumption and large storage density. Despite numerous studies have highlighted that the importance of achieving ideal linearity in simulated artificial synapses, effectively controlling oxygen vacancy diffusion and preventing the switching process from being affected by the formation and dissolution of hypoxic filaments remain challenging, as this can lead to unpredictable variations. In this study, Ag/SiO₂/Pt based memristor under positive and negative pulse sequences, can perfectly mimic the enhancement and inhibition behaviors of biological synapses because it exhibits tunable resistance modulation. Based on electrical characteristically model analyses, the charge transport behavior follows the trap-controlled space charge limited conduction (SCLC) mechanism, which can be concluded that it is the controlled formation and rupture of Ag filaments that are responsible for the resistive switching while exhibiting a switching ratio of ~ 100 along with a good endurance and stability suitable for nonvolatile memory applications. Additionally, we investigated spike-timing-dependent plasticity (STDP) to demonstrate the feasibility of our memristor synapse in neuromorphic applications. During the process, the linearity of the changes in long-term potentiation (LTP) and long-term depression (LTD) weights is observed to reveal the performance of electronic synapses. Finally, a model between electronic synapses and triggers is built via machine learning. This new modeling memristor may enable the development of nonlinear nonvolatile memory and support precise multi-level modulation when applied as an artificial synapse in neuromorphic computing.

Electrostatic Discharge Susceptibility of DDR5 DIMM, Analyzed via Electromagnetic Simulation

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As Double-Data-Rate fifth generation (DDR5) Synchronous Dynamic Random-Access Memory (SDRAM) modules are used in high-performance computing and consumer

electronics, the higher bandwidth and signal integrity requirements make electrostatic discharge (ESD) protection more challenging [1 – 4]. If transient electrical surges on the power or ground rails are not properly suppressed, these may cause permanent damage to the memory circuitry. However, the design and fabrication of DDR5 Dual In-line Memory Modules (DIMM) should meet JEDEC constraints, which limit the selection of ESD protection methods. In this study, the ESD susceptibility of DDR5 DIMM is analyzed and simulated by using electromagnetic commercial software, according to the specification of IEC 61000-4-2. The different capacitor configurations are present with additionally specific capacitors, located between the power and ground rails on DDR5 DIMM to evaluate the ESD susceptibility and protective properties. In addition, it is necessary to ensure that specific capacitors do not affect the normal operation of the DDR5 DIMM. The result shows that the suitable capacitor configurations could reduce the ESD induced transients and improve the ESD protective properties of DDR5 DIMM. These results could provide practical guidance of ESD protection for DDR5 DIMM.

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Efficiency Optimization in Perovskite/Lead Sulfide Quantum Dot Heterojunction Photodetectors

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A heterojunction photodetector based on FAPbBr₃ perovskite quantum dots (PQDs) and PbS quantum dots (QDs) is developed, with PCBM and a ~10 nm MoO₃ thin film, serving as the electron and hole transport layers, respectively, to optimize carrier transport and device stability. The PQD/PbS heterojunction effectively suppresses carrier injection and interfacial recombination under dark conditions, leading to a significant reduction in dark current [1 – 4].

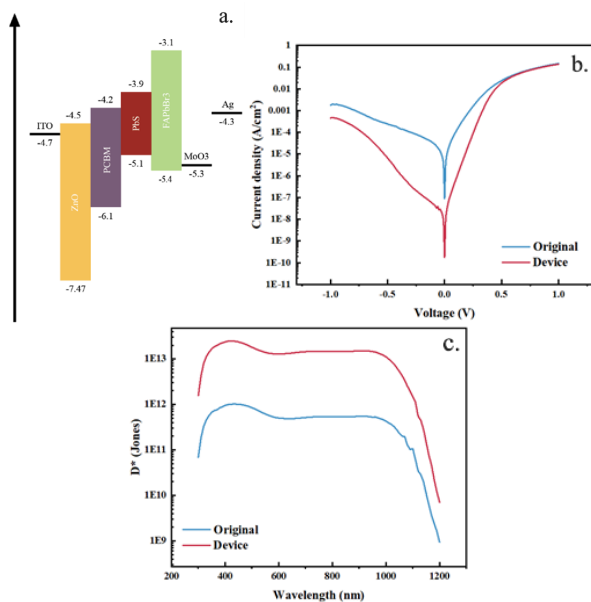


Fig. 1. (a) Energy Level Diagram of the photodetector; (b) dark current of photodetector without FAPbBr₃ PQDs and with FAPbBr₃ PQDs; (c) detectivity of photodetector without FAPbBr₃ PQDs and with FAPbBr₃ PQDs

The device achieves an external quantum efficiency (EQE) of 12.15% at 980 nm and a high detectivity (D^*) of 1.28×10^{13} Jones. Additionally, it exhibits a stable photoresponse over a broad spectral range from 300 to 900 nm, along with an ultralow dark current of 1.75×10^{-10} A/cm² under zero bias. These results demonstrate that the ZnO/PCBM/PbS QD/FAPbBr₃ PQD/MoO₃/Ag structure enables low-noise, high-sensitivity, and broadband photodetection, highlighting its strong potential for near-infrared sensing applications.

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Influence of ZnO Doping Concentration and Resistive Layer Thickness on Switching Characteristics and Conduction Mechanisms of Flexible RRAM Devices

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This study fabricates resistive layers with various thicknesses by incorporating different solid contents of ZnO powder into a silica sol matrix for application in flexible Resistive Random Access Memory (RRAM) devices. A systematic investigation was conducted to evaluate the effects of ZnO doping concentration and film thickness on the electrical characteristics and reliability of the devices, along with an analysis of the underlying current conduction mechanisms. The experimental results demonstrate that all devices exhibit bipolar resistive switching behavior. As the ZnO solid content increases, the operating voltage shows a decreasing-then-increasing trend. Among the investigated conditions, the device with 10% ZnO solid content and a thickness of 300 nm exhibits optimal electrical performance, featuring the lowest Set/Reset operating voltages, reduced power consumption, and an ON/OFF ratio of up to nine orders of magnitude. In addition, the resistance state distribution is highly concentrated, and the memory window is significantly improved. However, when the ZnO content is excessively high, the operating voltage increases, while the retention and endurance performance degrade. Regarding thickness dependence, when the resistive layer becomes excessively thick, the set voltage increases, while the switching ratio, retention performance, and endurance all exhibit a declining trend. Conduction mechanism analysis reveals that the low-resistance state (LRS) follows Ohmic conduction behavior, whereas the high-resistance state (HRS) conforms to the space-charge-limited current (SCLC) mechanism, indicating that the switching behavior is primarily governed by trap-controlled carrier transport and oxygen-vacancy-induced conductive filament formation. By properly tuning the ZnO doping concentration and resistive layer thickness, the oxygen vacancy distribution and film microstructure can be effectively optimized, thereby enhancing the controllability of conductive filament formation and rupture. The optimized fabrication conditions proposed in this work enable flexible RRAM devices with low operating voltage, high switching ratio, and improved reliability, demonstrating significant potential for applications in low-power non-volatile memory and flexible electronic devices.

A Finger-worn Responsive Bio-inspired Controller, Utilizing a Silver-ink Force Sensing Resistor

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A force sensing resistor (FSR) is widely used for measuring static and dynamic forces, applied to a contact surface, owing to their compact size, low cost, and ease of integration. However, a FSR consists of conductive ink printed on a flexible substrate, whose resistance varies with applied force. Despite advantages such as flexibility and affordability, FSRs suffer from nonlinear response, limited durability, and low integration density, which restrict broader industrial adoption. In this study, we investigate the feasibility of using finger-mounted FSR sensors for activity recognition and prosthetic hand control. For dexterous prosthetic hands with multiple degrees of freedom (DOF), reliable extraction of control signals from human muscle activity is essential for intuitive motion control. To address these challenges, we present a sensor-driven 3D-printed prosthetic hand, actuated by an FSR-based sensing and control module. The relationship between external force and FSR resistance is monitored within the linear region by a control module that forms a closed circuit using an Arduino microcontroller, the FSR, a battery, and a reference resistor. Additionally, the servomotor is directly driven by the control module, with its angle of rotation dependent on the linearly calibrated FSR signal. Finally, the finger joint synchronizes with the servomotor and FSR signal, utilizing the calibration curve to translate the external force detected by the FSR into a control signal that drives the servomotor to rotate the finger joint structure. These results highlight the potential of FSR-integrated control modules for next-generation bionic robotic systems and provide a foundation for applications in human-machine interaction and artificial intelligence-assisted prosthetics.

Synergistic Enhancement of Indium-Tungsten-Gallium Oxide TFTs via Dual-Channel Architecture and Al_2O_3 High- k Dielectrics

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This research presents a systematic investigation into the electrical performance and interfacial properties of amorphous indium–tungsten–gallium oxide (IWGO) thin-film transistors (TFTs), specifically focusing on the integration of high- k gate dielectrics to achieve superior switching characteristics. The IWGO active layers were deposited via radiofrequency (RF)

magnetron co-sputtering at room temperature, where tungsten (W) doping was strategically employed to suppress excessive oxygen vacancy formation due to its high bond dissociation energy with oxygen (W–O). To overcome the performance bottlenecks, associated with conventional SiO₂ dielectrics, such as high subthreshold swing and limited capacitive coupling, a 100-nm-thick Al₂O₃ high-*k* dielectric layer was incorporated using atomic layer deposition (ALD). The ALD process provided a highly conformal and pinhole-free dielectric film, which is essential for reducing interface trap density and gate leakage current. Benefiting from the high dielectric constant ($k = 9.5$) and the exceptionally wide bandgap ($E_g = 8.7$ eV) of Al₂O₃, the fabricated IWGO TFTs demonstrated a remarkable enhancement in electrical stability and efficiency. Experimental results confirmed that the Al₂O₃-based devices achieved a high I_{on}/I_{off} ratio of 1.73×10^7 and a significantly reduced subthreshold swing (SS) of 111.88 mV/dec. Furthermore, the interface trap density was successfully lowered to $5.17 \times 10^{10} \text{ cm}^{-2} \cdot \text{eV}^{-1}$. The synergy between tungsten-doped channels and ALD-deposited high-*k* dielectrics enables high-performance, low-power transparent electronics [1, 2].

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ECHO LOG: A Study on Sonic Visualization and Interactive Experience of Delphinid Cetaceans in Taiwan Waters

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This research project, "ECHO LOG," focuses on the diverse species of the family Delphinidae in the waters surrounding Taiwan. Addressing the perceptual gap between underwater bioacoustic data and public understanding, this study proposes a multimodal sensory translation system. The core of the research lies in transforming abstract acoustic signals, namely whistles, burst pulses, and clicks, into tangible "Sonic Forms" through visual language and interactive installations, achieving a cultural and data-driven visualization of marine bioacoustics. In terms of data processing and contextual interpretation, the study collected acoustic samples from 16 common cetacean species, covering a historical span from late 20th-century records to contemporary recordings. The research categorizes three major sound systems into ten distinct acoustic patterns, including signature whistles, social whistles, continuous whistles, agonistic burst pulses, social burst pulses, mixed burst-pulses, calls (FM pulses), echolocation clicks, high-speed terminal buzzes, and social clicks. By integrating

habitat characteristics, foraging habits, and behavioral traits, these patterns are translated into intuitive "emotional narratives." This process is not a literal linguistic translation, but an ethological interpretation, grounded in acoustic structure and ecological context, enabling audiences to perceive the emotional and existential states of cetaceans through interaction. At the visual translation level, acoustic parameters were utilized for parametric modeling. By analyzing spectral morphology, variables such as wave density, amplitude, and flow were parameterized to establish unique "acoustic fingerprints" for each species. A chromatic ripple system was also developed, where hue represents frequency bands and saturation maps echo intensity, precisely visualizing the energy flow within the central frequency bands and secondary echoes. Regarding interactive technology, the project developed physical installations integrated with NFC (Near-Field Communication) sensing (see Figs. 1, 2). The hardware utilizes parametric design to reconstruct biological features, while the software employs mobile devices as control nodes. Through NFC triggers and cloud-based web commands, the system synchronizes multimedia output across multiple displays. When users interact with physical modules, the system provides real-time feedback, including acoustic explanations, ecological videos, and emotional dialogues, achieving a synchronized sensory experience of sight, sound, and touch. Supported by 11 academic and research institutions across Taiwan, Hong Kong, and the USA, this project offers a novel medium for cross-disciplinary marine environmental education [1 – 12]. This research demonstrates that Design Translation effectively enhances public engagement with ecological data and provides an innovative technical pathway for the digital archiving and interactive display of bioacoustics.

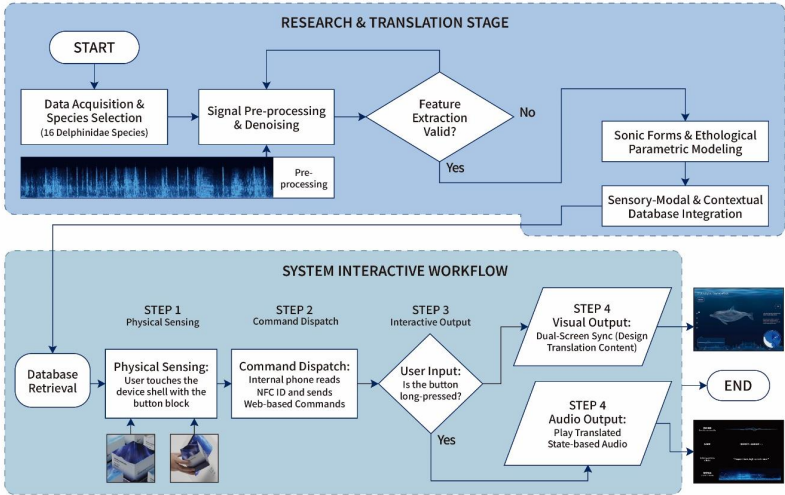


Fig. 1. "ECHO LOG" project development and interaction workflow

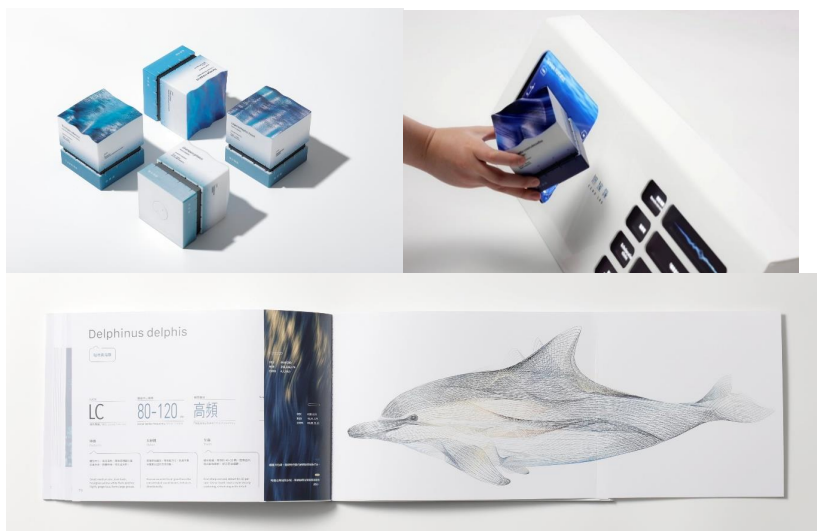


Fig. 2. Physical exhibits in the “ECHO LOG” project

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Citric Acid Synthesis of Pt/C Electrocatalysts: Effect of Carbon Support Type on Nanoparticle Formation and Functional and Electrochemical Characteristics

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Proton exchange membrane fuel cells are key devices in hydrogen energy. To improve their power characteristics and service life, electrocatalysts with optimal electrochemically active surface area (ESA), oxygen reduction reaction (ORR) activity, and stability are required. The most common and commercially available are Pt/C materials, namely Pt nanoparticles (NPs), anchored and distributed on the surface of a carbon support (CS). The use of different CS makes it possible to modify the functional characteristics of the resulting catalysts; however, recommendations on the use of supports with specific properties for creating highly active and stable catalysts are still lacking. The aim of this study is to establish correlations between the characteristics of CS and the catalysts, obtained on their basis, to identify the most effective CS that provide high ESA, ORR activity, and stability. For this purpose, the influence of supports, characterized by different specific surface areas, defectiveness, and degrees of graphitization, namely Vulcan XC72 (V), ECS-002402 (PJ), Ketjenblack EC-300J (KB), and an N-doped analog (KB_N), on the kinetics of Pt nanoparticle formation was studied. The functional characteristics of the catalysts were investigated. It was found that during citric acid synthesis, a homogeneous nucleation mechanism of Pt prevails, followed by sorption of the formed NPs onto the support, regardless of the CS. According to electron microscopy results, the average Pt NP size in all samples is about 2.5 – 2.8 nm. An increase in ESA and ORR mass activity values is observed in the series $V < PJ \leq KB = KB_N$. Given the similarity of NP sizes, these differences can be explained by varying degrees of their aggregation, which decreases in the indicated sequence. The KB_N-based sample is characterized by an ESA of 72 m²/g (Pt) and a mass activity of 398 A/g (Pt), which is 1.2 – 1.4 times higher than the characteristics of the commercial counterpart JM40 (58 m²/g (Pt), 276 A/g (Pt)). The most stable supports are ECS-002402 and N-doped Ketjenblack EC-300J; this correlates with the stability of the PJ and KB_N catalysts, obtained on their basis. Improved catalyst stability is achieved by using CS with a surface area, exceeding 400 m²/g, a high degree of graphitization, and nitrogen doping. The combination of these features allows uniform distribution and strong anchoring of NPs on the CS surface, thereby slowing down catalyst degradation. In prototypes of real fuel cell devices, the PJ and KB_N materials demonstrated at least 5% higher power, compared to the commercial counterpart JM40. Thus, the PJ and KB_N materials are promising for use in proton exchange membrane fuel cells.

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Impact of Hole-Transport Layers on Low-Voltage, High-Efficiency PbS Photomultiplication Photodetectors

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PbS CQDs show great potential for infrared photodetection but suffer from intrinsic limitations in long-wavelength regions due to low photon energy [1, 2]. Theoretical calculations indicate that the maximum external quantum efficiency (EQE) of a 150 nm PbS film at 1440 nm is only ~30%. Unlike conventional photodiodes, photomultiplication-type photodetectors utilize a gain mechanism, which trapped carriers (typically holes) in the transport layer prolong carrier lifetime, leading to localized charge accumulation and energy band bending at the electrode interface, thereby forming a current gain loop that enables EQE to exceed 100%. In this work, four-hole transport layers (HTLs), namely TAPC, BCP, M-CBP, and BcZPh are systematically investigated (Fig. 1). Devices with TAPC exhibit the best performance, achieving a maximum EQE of 255.87 %. This improvement is attributed to hole trapping in TAPC, which induces band bending at the PbS CQDs/Ag interface, reduces the Schottky barrier, and facilitates continuous electron injection via tunneling.

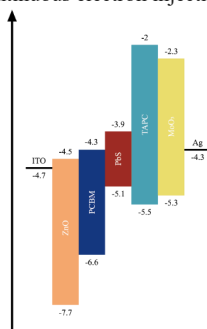


Fig. 1. Band energy diagram devices with different HTLs

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Temperature Behavior of Optical Transmission Spectra in $\text{SrFe}_{2/3}\text{W}_{1/3}\text{O}_3$ Thin Films

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Transition metal-based complex oxides are of great interest to contemporary materials science, thanks to their exceptional electronic, magnetic, and optical properties. Among these compounds, ferrotungstates hold a distinctive position, as they integrate the crystalline architecture of tungstates with the magnetic properties conferred by iron. $\text{SrFe}_{2/3}\text{W}_{1/3}\text{O}_3$, known as strontium ferrotungstate, is a multiferroic material in this family whose promising characteristics are attributed to the joint presence of iron and tungsten ions within its lattice [1, 2]. Understanding its optical behavior is both fundamentally important and practically relevant for the creation of next-generation functional materials in optoelectronics, photonics, and spintronics. This work presents a study of the spectral transmission characteristics of thin single-crystal films of strontium ferrotungstate with the stoichiometric composition $\text{SrFe}_{2/3}\text{W}_{1/3}\text{O}_3$, deposited on $\text{MgO}(001)$ substrates, at various temperatures. The aim of the study was to investigate the influence of temperature conditions on the optical properties of these multiferroic materials, which is important for their future applications in various fields of science and technology. $\text{SrFe}_{2/3}\text{W}_{1/3}\text{O}_3$ films were produced by RF cathodic sputtering on pre-treated MgO substrates. The study methodology included spectroscopic measurements, using a dedicated system, comprising an SF-56 spectrophotometer and an LN-121-SPECTR optical cryostat. The temperature range varied from room temperature to 180 °C, allowing for a systematic study of the evolution of the optical properties of $\text{SrFe}_{2/3}\text{W}_{1/3}\text{O}_3$ thin films upon heating. The analysis of the obtained transmission spectra revealed significant changes in the optical properties of the $\text{SrFe}_{2/3}\text{W}_{1/3}\text{O}_3/\text{MgO}$ films, depending on temperature. Specifically, an increase in the visible transmittance was observed with increasing temperature, indicating thermally induced structural changes in the material, which may be associated with a phase transition or thermal expansion of the crystal lattice.

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Dielectric Properties of 0.05BiFeO₃ – 0.95PbFe_{0.5}Nb_{0.5}O₃ Ceramics with the Addition of GeO₂

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Currently, multiferroics, namely a class of materials in which ferroelectric and ferromagnetic ordering coexist are being studied in detail. This is due to the possibility of their application in devices, enabling the mutual control of magnetic and electric parameters [1, 2]. The most well-known and studied representatives are bismuth ferrite (BiFeO₃, BFO) and lead ferroniobate (PbFe_{0.5}Nb_{0.5}O₃, PFN). However, their use is limited by high leakage currents. This problem arises from increased electrical conductivity, associated with oxygen defects and the formation of parasitic phases in solid solutions. The creation of multicomponent materials based on BFO and PFN with a stabilized structure makes it possible to mitigate these drawbacks. Attention is paid to the modification of these compounds, which not only improves the final properties but also enhances their manufacturability, for example, by reducing the synthesis and sintering temperatures of the ceramics. The present work describes the results of studying the effect of the GeO₂ additive on the dielectric parameters of the 0.05BFO – 0.95PFN ceramics solid solutions, modified super stoichiometrically in amounts of 0.5 – 1.0 wt. %. The samples were obtained by the method of solid-phase reactions, followed by sintering, using conventional ceramic technology. Measurements of the relative complex permittivity $\varepsilon^*/\varepsilon_0 = \varepsilon'/\varepsilon_0 - i\varepsilon''/\varepsilon_0$ (ε' and ε'' are the real and imaginary parts of ε^* , respectively, ε_0 is the dielectric constant) were made in the frequency range of $f = 20 - 2 \times 10^6$ Hz in the temperature range of 20 – 650 °C on an automatic measuring setup, based on an Agilent E4980A LCR-meter and a Varta TP703 temperature controller. The modification of the compositions leads to a change in the dielectric characteristics, compared to the base solid solutions. An explanation for the changes observed is provided.

Acknowledgements. The study was carried out with the financial support of the Ministry of Science and Higher Education of the Russian Federation (State task in the field of scientific activity. Project No. FENW-2026-0022: “Ferro (magnetic) ordered systems with high polarizability and dielectric (magnetic) controllability, multicaloric and pyroelectric effects, and stored energy density based on heterogeneous non-toxic media of various solid-state architectures with nanoscale distortions for the creation of an electronic component base”). The equipment of the Center for Collective Use of the Research Institute of Physics of the Southern Federal University «Electromagnetic, electromechanical and thermal properties of solids» was used.

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Tone Injection PAPR Reduction Techniques for Underwater OFDM Signals Applying to Band-Limited Acoustic Transducer

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The most important feature of the peak-to-average power ratio (PAPR) reduction techniques for OFDM signals is keeping the signals generated, using IFFT in the linear region of the transmitter power amplifier. When OFDM signal applies to underwater communication, the acoustic transducer has much limited bandwidth compared to that of the power amplifier. It implies that frequency out of the band of the transducer can be used to reduce the PAPR. The most intuitive scheme, following this idea, is the tone injection. After adding additional signals to the bands outside the transducer, but within the ranges of the power amplifier, the PAPR of the transmitted signal is determined between the power amplifier and the transducer. Since the injected signals out of the transducer driving band are filtered and do not affect the receiving signal, the proposed scheme can keep the same error-rate performance after PAPR has been reduced (see Fig. 1).

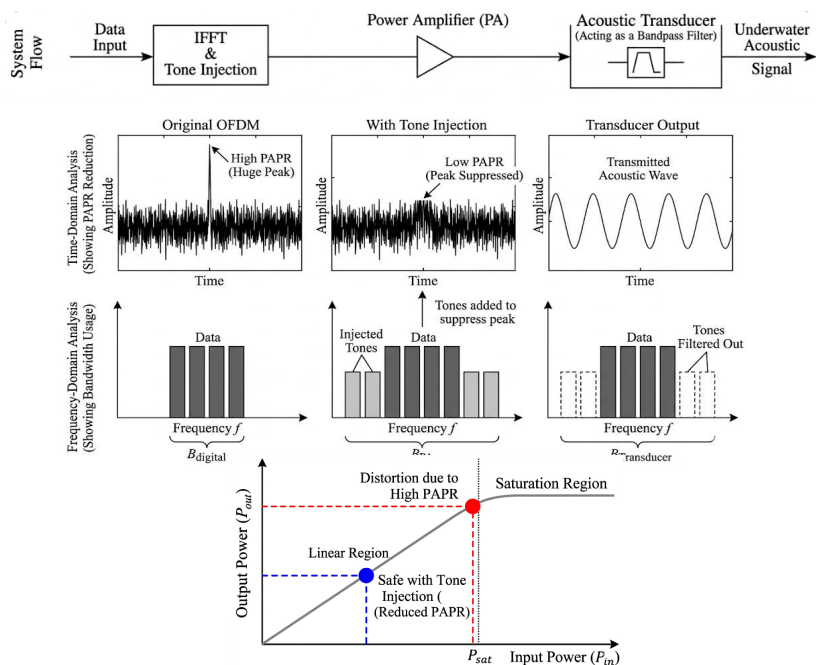


Fig. 1. Proposed scheme

Ligand-Assisted Halide Exchange in FAPbI_{3-x}Br_x Perovskite Quantum Dots for Color-Tunable Light-Emitting Diodes

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While formamidinium lead iodide (FAPbI₃) perovskite quantum dots (PQDs) possess exceptional optoelectronic properties, tuning their emission stably into the visible spectrum remains challenging [1 – 4]. We report an efficient post-synthetic ligand engineering strategy utilizing tetraoctylammonium bromide (TOAB) to induce anion exchange, precisely regulating the halide composition in FAPbI_{3-x}Br_x PQDs. This TOAB-mediated substitution of iodide with bromide triggers a significant photoluminescence (PL) blue shift from 785 nm to 536 nm. Analyses of carrier dynamics and crystal structures reveal that while optimal TOAB loading preserves optical integrity, concentrations, exceeding 0.6 mmol, induce compositional imbalance, degrading both photoluminescence quantum yield (PLQY) and carrier lifetime. Furthermore, we successfully integrated these TOAB-modified PQDs into light-emitting diode (LED) architectures, achieving an electroluminescence (EL) blue shift from 783 nm to 630 nm (Fig. 1). The pristine baseline LED device delivered a notable external quantum efficiency (EQE) of 8.8% and a radiant emittance of 21 mW/cm². This ligand-assisted halide modulation demonstrates a versatile and robust approach for advancing color-tunable optoelectronic devices.

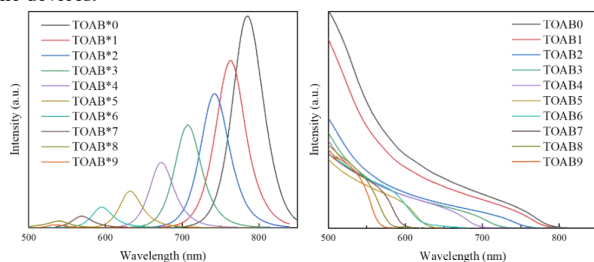


Fig. 1. PL and UV-vis absorption spectra of FAPbI_{3-x}Br_x PQDs

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Crystal Structure, Piezo- and Dielectric Properties of a New Series of Solid Solutions $\text{SrBi}_2\text{Ta}_{2-x}\text{Nb}_x\text{O}_9$ ($x = 0.0, 0.2, 0.4, 0.6, 0.8, 1.0$)

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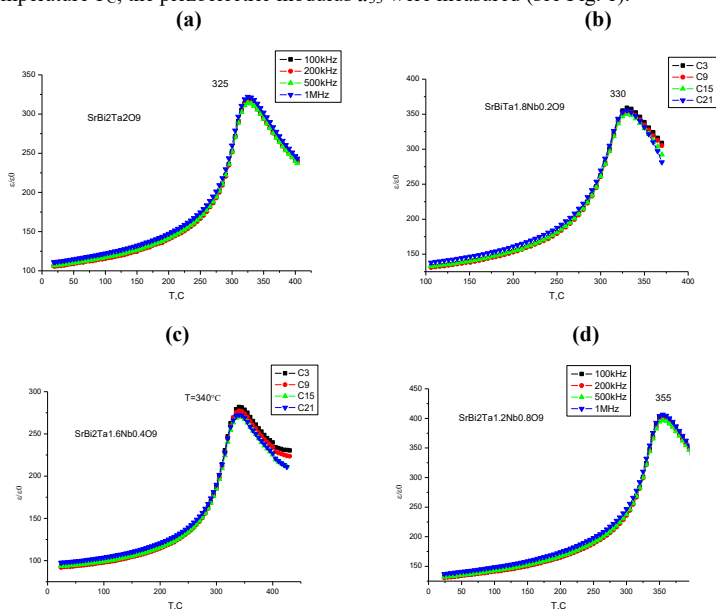
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Aurivillius-Smolensky (AS) ceramics $\text{SrBi}_2\text{Ta}_{2-x}\text{Nb}_x\text{O}_9$ ($x = 0.0, 0.2, 0.4, 0.8, 1.0$) with the number of perovskite-like layers of $n = 2$, was synthesized ($x = 0.2, 0.4, 0.6, 0.8, 1.0$) by the conventional solid-phase reaction method [1 – 5]. According to the X-ray powder diffraction data, it was found that all the compounds are single-phase with the structure of the AS phases with an orthorhombic crystal lattice (space group $A2_1am$). The crystal lattice parameters a , b , c were calculated, the relative permittivity $\varepsilon/\varepsilon_0(T)$, the dielectric loss tangent $\tan\delta$, the Curie temperature T_C , the piezoelectric modulus d_{33} were measured (see Fig. 1).



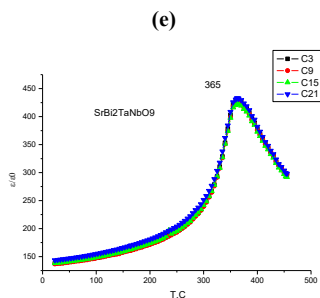


Fig. 1. Temperature dependence of the dielectric permittivity $\varepsilon/\varepsilon_0(T)$: (a) $\text{SrBi}_2\text{TaNbO}_9$, (b) $\text{SrBi}_2\text{Ta}_{1.8}\text{Nb}_{0.8}\text{O}_9$, (c) $\text{SrBi}_2\text{Ta}_{1.6}\text{Nb}_{0.4}\text{O}_9$, (d) $\text{SrBi}_2\text{Ta}_{1.2}\text{Nb}_{0.8}\text{O}_9$, (e) $\text{SrBi}_2\text{Ta}_2\text{O}_9$

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Features of the $\text{SrBi}_{1.9}\text{Y}_{0.1}\text{Nb}_2\text{O}_9$ Structure Formation, Depending on Annealing Conditions

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A polycrystalline sample of $\text{SrBi}_{1.9}\text{Y}_{0.1}\text{Nb}_2\text{O}_9$ was synthesized by solid-phase reaction of the corresponding oxides Bi_2O_3 , Y_2O_3 , SrCO_3 , and Nb_2O_5 . All starting compounds were of analytical grade. X-ray diffraction patterns were recorded on a Rigaku Ultima IV diffractometer with a Cu X-ray tube. $\text{CuK}_{\alpha 1, \alpha 2}$ radiation was isolated from the overall spectrum, using a Ni filter. X-ray diffraction patterns were measured over a 2θ range from 10 to 60° with a scanning step of 0.02° and a scanning speed of $0.5^\circ/\text{min}$. X-ray diffraction pattern analysis, line position determination, line indexing (hkl), and structure refinement were performed, using the Rietveld method in FullProf Suitt software. To refine the structure, the

SrBi₂Nb₂O₉ structural model from Crystallography Open Database #1531753 was used. To accurately refine the cell parameters, the stoichiometry of the composition was considered.

Table 1. SrBi_{1.9}Y_{0.1}Nb₂O₉ structure parameters

<i>a</i> , Å	<i>b</i> , Å	<i>c</i> , Å	<i>V</i> , Å ³	<i>I</i> _{Nb-O1} , Å	<i>I</i> _{Nb-O2} , Å	<i>I</i> _{Nb-O4} , Å	<i>I</i> _{Nb-O5} , Å
5.506	5.506	25.00	758	2.142	1.885	1.925	2.068

The model parameters are presented in Table 1 with orthorhombic phase group #36, unit #4 A21am. The structure of the compound corresponds to the known perovskite-like oxide of ASP SBN. All peaks were indexed based on orthorhombic cells, associated with space group A21am, which corresponds to crystallography database card #1531753. A comparative analysis of X-ray diffraction profiles (Fig. 1) was performed for a SrBi_{1.9}Y_{0.1}Nb₂O₉ ceramic sample, prepared with a Bi₂O₃ backfill and annealed for 2 hours. The SrBi_{1.9}Y_{0.1}Nb₂O₉ ceramic sample, prepared with a 5% Bi₂O₃ excess and annealed for 4 hours, showed that structure formation occurs in all cases. The top sample on Fig. 1 exhibits the highest degree of texturing: the relative ratio of the (020) and (00.10) reflections is close to the calculated relative intensities, which characterize a uniform distribution of crystallites in all directions only in the sample at the lower part of Fig. 1. The ratio of the relative intensities of reflections (02.10) and (11.13) also indicates a decrease in the degree of texturing in the sample with excess Bi₂O₃ and an increase in annealing time. The absolute intensities of the sample annealed without excess Bi₂O₃ are the lowest, but the integrated intensities in all samples remain the same for each group of reflections, which may indicate some structural disorder in the samples, which decreases with the addition of backfill and an increase in annealing time. The annealing temperature for all samples was 1100 °C. The lattice parameters of all samples coincided within three decimal places, meaning that the formation of the crystal lattice does not depend on the annealing conditions.

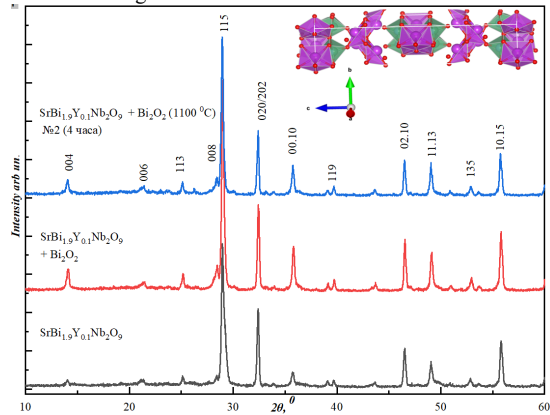


Fig. 1. XRD patterns of SrBi_{1.9}Y_{0.1}Nb₂O₉, obtained from ceramic samples with different annealing conditions

The Influence of Isovalent Substitution in the *B*-sublattice of Ti Atoms for Zr Atoms on the Dielectric Properties of Bi₃TiNbO₉

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The chemical structure of Aurivillius-Smolensky phases (ASPs) can be described by the general formula $A_{m-1}B_mO_{3m+3}Bi_{m-1}$ [1 – 3]. The crystal structure of ASPs consists of alternating fluorite-like layers $(Bi_2O_2)^{2+}$, between which there are perovskite-like layers $(A_{m-1}B_mO_{3m+1})^{2+}$, where m is the number of layers. It is known that fluorite-like layers $(Bi_2O_2)^{2+}$ have a compressive effect on the oxygen octahedra, located between them. Dielectric properties of ASP Bi₃TiNbO₉ are present on Fig. 1. ASP Bi₃Ti_{0.85}Zr_{0.15}O₉ with $m = 2$, was synthesized by the solid-phase reaction method. Due to the X-ray powder diffraction data, the compound is single-phase with the ASP structure and orthorhombic crystal lattice (space group A2₁am). The parameters a , b , c of crystal lattice were calculated, and the relative permittivity $\epsilon/\epsilon_0(T)$, the dielectric loss tangent $\text{tg}\delta$ (see Fig. 2), the Curie temperature T_C were measured.

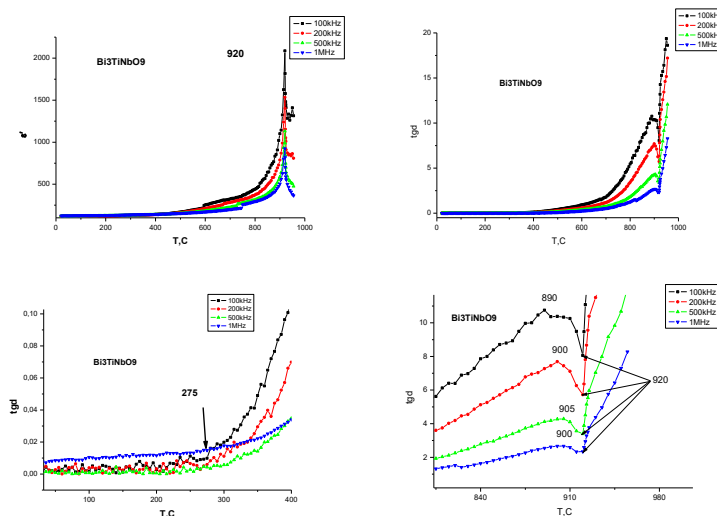


Fig. 1. Dielectric properties of Bi₃TiNbO₉ and the detail fragments of these plots.

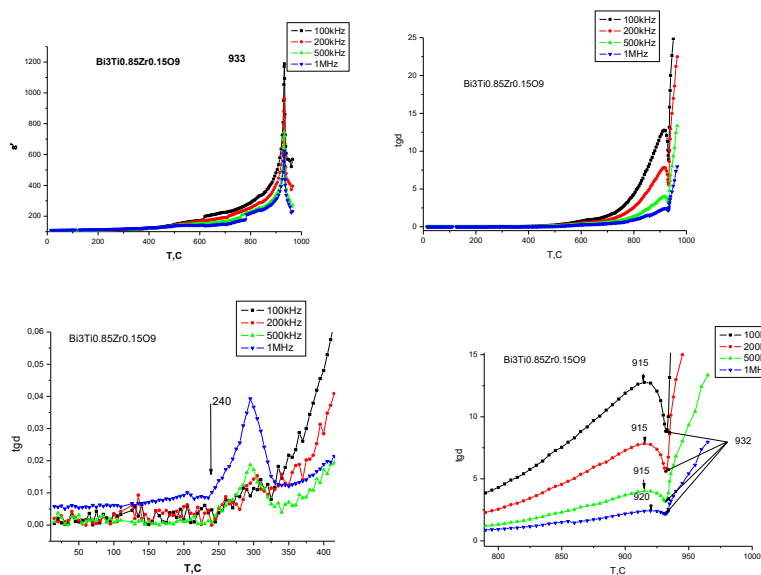


Fig. 2. Dielectric properties of $\text{Bi}_3\text{Ti}_{0.85}\text{Zr}_{0.15}\text{NbO}_9$ with the detail fragments of these plots.

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The Influence of Polarization on the Dielectric Properties of $\text{Bi}_3\text{Ti}_{1.5}\text{ReO}_9$

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Aurivillius-Smolensky (AS) ceramics $\text{Bi}_3\text{Ti}_{1.5}\text{ReO}_9$ [1, 2] were synthesized by the conventional solid-phase reaction method. According to the X-ray powder diffraction data, it was found that all the compounds are single-phase with the structure of the AS phases (the

number of perovskite-like layers $m = 2$) with an orthorhombic crystal lattice (space group $A2_1am$).

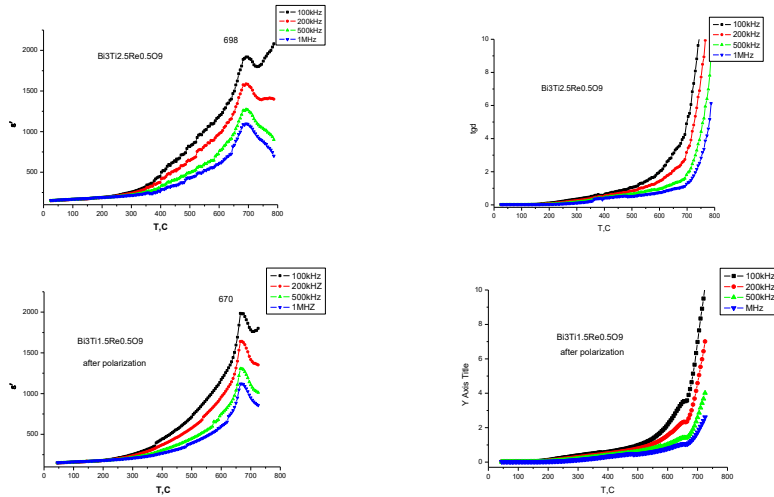


Fig. 1. Dielectric constant and dielectric loss tangent of $\text{Bi}_3\text{Ti}_{1.5}\text{ReO}_9$ before and after polarization. The crystal lattice parameters a , b , c were calculated, and the relative permittivity $\varepsilon/\varepsilon_0(T)$, the dielectric loss tangent $\text{tg}\delta$, the Curie temperature T_C were measured. After polarization, the permittivity ε was measured again. The Curie temperature decreased by 30 °C. The dielectric loss tangent $\text{tg}\delta$ after polarization has a clearly defined maximum and minimum in the region of the Curie temperature T_C , which is characteristic of the phase transition in AS phases.

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Effect of Composition and Crystal Structure on Magnetic Properties of Pr-doped Bismuth Ferrite

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Bismuth ferrite (BiFeO_3) is a multiferroic material that retains ferroelectric and antiferromagnetic ordering at relatively high temperatures ($T_C \approx 830$ °C, $T_N \approx 370$ °C).

However, its practical application is limited by thermodynamic instability, which promotes the formation of impurity phases. Doping BiFeO₃ with rare-earth elements, on one hand, stabilizes the crystal structure and reduces impurity phase concentration; on the other hand, it enhances magnetic properties through the emergence of weak ferromagnetism. This study investigates the structural and magnetic properties of ceramic solid solutions in the Bi_{1-x}Pr_xFeO₃ system ($x = 0.10 - 0.26$, $\Delta x = 0.02$). A series of samples was synthesized via a two-stage solid-state reaction method ($T_1 = 550$ °C, $T_2 = 830$ °C), followed by sintering ($T = 890 - 920$ °C). Structural parameters were determined by X-ray powder diffraction (DRON-3 CoK α radiation); microstructure was examined, using scanning electron microscopy (Carl Zeiss EVO 40); and magnetic characteristics were measured at room temperature, using a vibrating sample magnetometer (LakeShore VSM 7404). It was established that substitution of Bi³⁺ ions with Pr³⁺ induces a structural phase transition from rhombohedral to orthorhombic symmetry at a critical concentration of $x \approx 0.14$. In the composition range $0.14 \leq x \leq 0.22$, a morphotropic phase boundary is observed, characterized by the coexistence of both phases; for $x > 0.22$, a single-phase orthorhombic structure is formed. A key finding is the nonlinear evolution of magnetic properties. In the rhombohedral phase ($x < 0.14$), samples exhibit characteristics typical of antiferromagnets ($M_s \approx 0.09 - 0.12$ emu/g, $H_c < 400$ Oe). Upon entering the morphotropic region, a sharp enhancement in magnetization is observed: M_s increases to 0.206 emu/g ($x = 0.20$), while H_c reaches 4979 Oe. Of particular interest is the composition $x = 0.22$, where the formation of a single-phase orthorhombic structure coincides with a maximum saturation magnetization of $M_s = 0.530$ emu/g, 5.7 times higher than that of the lightly doped sample. The remanence-to-saturation ratio (M_r/M_s) increases from 0.013 to 0.407 ($x = 0.24$), indicating a transition toward a more ordered magnetic structure with enhanced anisotropy [1]. The observed magnetic enhancement is attributed to the combined effect of two factors: (i) distortion of Fe–O–Fe bond angles and weakening of antiferromagnetic super exchange interactions, consistent with Goodenough – Kanamori rules [2]; and (ii) suppression of the spiral cycloidal spin modulation and reorientation of spins along the c -axis upon transition to the orthorhombic phase [1]. The abrupt increase in M_s at $x = 0.22$ correlates with the complete suppression of the cycloid in the single-phase orthorhombic structure.

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2026 International Conference on “Physics and Mechanics of New Materials and Their Applications” (PHENMA 2026), Busan, South Korea, July 15 – 18, 2026

SCHEDULE

PHENMA & AMPD 2026		
Day 2 (July 16, 2026) - Thursday		
Main hole (Room1)		
10:40-12:00	Opening Chair: Prof. Yun-Hae Kim Co-chairs: Prof. Shun Hyung Chang, Prof. Mikito Yasuzawa, Prof. Ivan A. Parinov	
10:40-11:20 (40 min)	The Wave of Silicon: Past, Present, and Future of the Semiconductor Industry. (Prof. Chai-Sheng Wen)	Keynote Speech I (Taiwan)
11:20-12:00 (40 min)	Effective approaches for enhancing the Photocatalytic activities of Bismuth Halide-Based Nanocomposites (Prof. Pankaj Koinkar)	Keynote Speech II (Japan)

Day 2 (July 16, 2026) - Thursday		
Room 1		
Oral details (12 min presentation / 3 min Q&A)		
13:20-14:25 (65 min)	Parallel Sessions (Invited and Oral Presentations) (Session chair: Dr. Se-Yoon Kim, Dr. Antonio Nakagaito)	Nanoscience
13:20-13:40 (20 min)	Molding of all-cellulose plates by filtration of nanofiber aqueous suspension (Antonio Norio Nakagaito, Japan)	Invited speaker (17 min presentation / 3 min Q&A)
13:40-13:55 (15 min)	Spin-state Manipulation of Fe Single Atom Catalysts for Enhanced Bifunctional ORR/OER Performance (Yongfang Zhou, New Zealand)	Oral 1
13:55-14:10 (15 min)	Reduction of carbon dioxide using electrodes modified with copper hydroxide nanosheets incorporating fatty acid ions (Masashi Kurashina, Japan)	Oral 2
14:10-14:25 (15 min)	Environmentally Safe Hydrogel-hydrochar Composites: from Synthesis to Practical Application (Margarita Getman, Ekaterina Kravchenko, Tatiana Minkina, Dariya Privizentseva, Russia)	Oral 3
14:25-14:40 (15 min)		Tea Break
14:40-15:45 (65 min)	Parallel Sessions (Invited and Oral Presentations) (Session chair: Dr. Kyo-Moon Lee, Dr. Huang-Chang Lee)	Nanoscience
14:40-15:00 (20 min)	Metal-Triggered Electrochromic Device with Gel Electrolyte. (Min Yen Yeh, Ming Jia Liu, Yun-Shiuan Yeh, Jin-Hau Yeh, Chi-Da Yang, Yu-Hung Chen, Shun Hsyung Chang, Taiwan)	Invited speaker (17min presentation / 3min Q&A)
15:00-15:15 (15 min)	β-Ga₂O₃ Nanorod EGFET for Portable pH Sensing with Embedded Readout (Cheng-Xiang Yan, Hao-Ting Hsu, Jin-Wei Chang, Jia-Cheng Wu, Ching-Ho Tien, Taiwan)	Oral 1

15:15-15:30 (15 min)	Role of Pt Thickness and Nanoparticles in Liquid-Nitrogen- Enabled Nitrogen Incorporation for p-Type ZnO Thin Films (Yi-Jing Chen, Han-De Chen, Xu-Yi Jie, Jun-Ting Wu, Lin-Wei Yang, Jian-Fu Tang, Taiwan)	Oral 2
15:30-15:45 (15 min)	Synergistic Integration of Plasmonic Au and MoS ₂ Co-Catalyst in TiO ₂ for Hydrogen Evolution Under Visible Light (Minhaz Md Hussain, Japan)	Oral 3

Day 2 (July 16, 2026) - Thursday		
Room 2		
Oral details (12 min presentation / 3 min Q&A)		
13:20-14:25 (65 min)	Parallel Sessions (Invited and Oral Presentations) (Session chair: Prof. Kei-ichiro Murai, Dr. Sung-Won Yoon)	Structure
13:20-13:40 (20 min)	Suppression of Hygroscopicity in Y-Substituted In₂Mo₂O₁₂ Negative Thermal Expansion Materials by K⁺ Incorporation (Keiichiro Murai, Japan)	Invited speaker (17 min presentation / 3 min Q&A)
13:40-13:55 (15 min)	Engineering yttrium distribution in spray pyrolyzed yttrium aluminum silicate glass particles with bioactivity and cytotoxicity evaluation <i>in vitro</i> (Yu Jen Chou, Taiwan)	Oral 1
13:55-14:10 (15 min)	Morphology-Tuned Fe ₂ O ₃ -Based Heterostructures for Sustainable Photocatalytic Degradation (Niloy Paul, Japan)	Oral 2
14:10-14:25 (15 min)	Preparation and evaluations of photo-curable 2-(methacryloyloxy)ethyl choline hydrogen phosphate bio-printing scaffold (Yumeng Zhao, Taiwan)	Oral 3
14:25-14:40 (15 min)		Tea Break
14:40-15:45 (65 min)	Parallel Sessions (Invited and Oral Presentations) (Session chair: Dr. Seong-Yeol Ba, Dr. Chih-Yuan Hsu)	Structure
14:40-15:00 (20 min)	Optimization of SAE 8620 Steel 3D Printing Mold Processes and Evaluation of Physical Foaming Formability for Enhanced Elastomeric Performance of Industrial Foams (Jin-Woo Lee, Korea)	Invited speaker (17 min presentation / 3 min Q&A)
15:00-15:15 (15 min)	Comparison of Joining Characteristics of Aluminum/Thermoplastic Composite Hybrid Joints According to Surface Treatment Methods (Ji-Yeol Kim, Korea)	Oral 1
15:15-15:30 (15 min)	Influence of High-Temperature Isothermal Exposure on the Crystallization Behavior and Mechanical Properties of CF/PEKK Composites (Min-Jun Kim, Korea)	Oral 2
15:30-15:45 (15 min)	Modified Fields–Backofen Constitutive Modelling of Cold Deformation Behaviour for 10B38 Boron Steel (Hong-Thao Pham, Thanh-Cong Nguyen, Quang-Cherng Hsu, Taiwan)	Oral 3

Day 2 (July 16, 2026) - Thursday		
Room 3		
Oral details (12 min presentation / 3 min Q&A)		
13:20-14:25 (65 min)	Parallel Sessions (Invited and Oral Presentations) (Session chair: Prof. Hitoshi Mizuguchi, Dr. Chang-Wook Park)	Analysis

13:20-13:40 (20 min)	Chromatographic Signatures of Electrochemical Reversibility in HPLC with Multi-THEME Detection (Hitoshi Mizuguchi, Japan)	Invited speaker (17min presentation / 3 min Q&A)
13:40-13:55 (15 min)	Effects of Surface-Modified Starting Powders on the Sintering Properties of $(\text{Mg}_{0.2}\text{Ni}_{0.2}\text{Zn}_{0.2}\text{Co}_{0.2}\text{Mn}_{0.2})_2\text{SiO}_4$ Ceramics (Shao-Ju Shih, Taiwan)	Oral 1
13:55-14:10 (15 min)	Computational Schemes for Determining Parameters of Nonlinear Elastic Materials (S.A. Egorova, M.I. Karyakin, Russia)	Oral 2
14:10-14:25 (15 min)	Sensitive Determination of PET and PC in Airborne Particulate Matter by Thermochemolysis-GC/MS (Ogawa Tomoya, Japan)	Oral 3
14:25-14:40 (15 min)		Tea Break
14:40-15:45 (65 min)	Parallel Sessions (Invited and Oral Presentations) (Session chair: Prof. Sung-Min Yoon, Prof. Shao-Ju Shih)	Analysis
14:40-15:00 (20 min)	Magnet Reduction and Efficiency Limit Analysis of a Small External Rotor BLDC Motor for Precision Applications (Chun-Yu Hsiao, Yu-Pei Cai, Taiwan)	Invited speaker (17 min presentation / 3 min Q&A)
15:00-15:15 (15 min)	Hydrochar as a Waste Product with Added Value (Dariya Privizentseva, Ekaterina Kravchenko, Margarita Getman, Russia)	Oral 1
15:15-15:30 (15 min)	Electrostatic Discharge Susceptibility of DDR5 DIMM Analyzed via Electromagnetic Simulation (Yu-Lin Chiu, Jyh-Liang Wang, Taiwan)	Oral 2
15:30-15:45 (15 min)	Effect of bias voltage on X-ray elastic constant and residual stress in titanium nitride films (Kazuya Kusaka, Japan)	Oral 3

Day 2 (July 16, 2026) - Thursday		
Room 4		
Oral details (12 min presentation / 3 min Q&A)		
13:20-14:25 (65 min)	Parallel Sessions (Invited and Oral Presentations) (Session chair: Dr. Weison Li, S.A. Egorova)	Sensing & Architecture
13:20-13:40 (20 min)	MXene Based Self-Powered Monitoring of Environmental Pollutants and Biomarkers (Aman Mahajan, India)	Invited speaker (17 min presentation / 3 min Q&A)
13:40-13:55 (15 min)	Fabrication and Evaluation of a Continuous Glucose Monitoring Sensor Using bacterial cellulose (Makuto Gaki, Japan)	Oral 1
13:55-14:10 (15 min)	Fractional Hypersingular Diffusion Layer for Robust Signal Denoising on Metric Graphs (Yu. E. Drobotov, Russia)	Oral 2
14:10-14:25 (15 min)	Polycarbonate Transfer Technique for 2D Semiconductor Devices (Meng-Lin Tsai, Taiwan)	Oral 3
14:25-14:40 (15 min)		Tea Break
14:40-15:45 (65 min)	Parallel Sessions (Invited and Oral Presentations) (Session chair: Dr. Chiao-Yun Chang, Dr. Masashi Kurashina)	Sensing & Architecture

14:40-15:00 (20 min)	SrMnO₃-based Self-rectifying Memristor Crossbar Arrays (Yu-Hao Chen, Cheng-Yu Wu, Yu-En Huang, Ting-Hsuan Tsai, Hsin-Ti Chiu, Yueh-Wei Chen, Yu-An Chiu, Chen-Fang Kang, Taiwan)	Invited speaker (17 min presentation / 3min Q&A)
15:00-15:15 (15 min)	Architecture-Optimized Ag–CsPbI ₃ Platforms for PIERS Detection (Chih-Yi Liu, Jih-Yan Guo, Dian Luo, Shun-Wei Liu, Taiwan)	Oral 1
15:15-15:30 (15 min)	A Stable and High-Efficiency Boost Converter LED Driver with PWM Control for High-Voltage Applications (I-Wen Chang, Yi-Chieh Hsu, Taiwan)	Oral 2
15:30-15:45 (15 min)	A Multi-Mode 24 GHz mm Wave Radar Sensing System for Privacy-Preserving Home Security Applications (Chun-Yu Hsiao, Jao-Yi Lin, Yichao Wang, Taiwan)	Oral 3

Day 2 (July 16, 2026) - Thursday		
Room 5		
Oral details (12 min presentation / 3 min Q&A)		
13:20-14:25 (65 min)	Parallel Sessions (Invited and Oral Presentations) (Session chair: Dr. Chun-Yu Hsiao, Chih-Tsung Chang)	AI
13:20-13:40 (20 min)	Deep Learning-based Feature Extraction for 40 Hz SSVEP Recognition in Flicker-Free Neuromodulation Systems (Hong-Ming Lin, Chih-Tsung Chang, Taiwan)	Invited speaker (17min presentation / 3min Q&A)
13:40-13:55 (15 min)	Neuromorphic Memristor via Machine Learning (Yu-Cheng Wang, Ya-Ge Huang, Guan-Lin Li, Yu-Kai Shen, Taiwan)	Oral 1
13:55-14:10 (15 min)	Quantum Transport in Simple Structure Based Neuromorphic Memristor via Machine Learning (Yu-Hao Chen, Ting-Hsuan Tsai, Yu-En Huang, Hsin-Ti Chiu, Cheng-Yu Wu, Chen-Fang Kang, Taiwan)	Oral 2
14:10-14:25 (15 min)	Machine Learning Approach for Stationary State Problems of One-dimensional Schrödinger Equation in Self-rectifying Memory Array (Yu-An Chiu, Yueh-Wei Chen, Ting-Hsuan Tsai, Yu-En Huang, Chen-Fang Kang, Taiwan)	Oral 3
14:25-14:40 (15 min)		Tea Break
14:40-15:45 (65 min)	Parallel Sessions (Invited and Oral Presentations) (Session chair: Dr. Yi-Chieh Hsu, Dr. Sung Won Yoon)	Sensing & Architecture
14:40-15:00 (20 min)	Influence of ZnO Doping Concentration and Resistive Layer Thickness on Switching Characteristics and Conduction Mechanisms of Flexible RRAM Devices (Yuan-Nan Tsai, Chen-Jui Yang, Taiwan)	Invited speaker (17min presentation / 3min Q&A)
15:00-15:15 (15 min)	An Enhanced Ripple-Based Regulator with Master-Slave RS Control and Dual-Loop Feedback (Yi-Chieh Hsu, Yi-Cheng Lai, Taiwan)	Oral 1
15:15-15:30 (15 min)	GaN Based UV Photodetector Application as Optical Communication with Biorobot Control. (Cheng-Yu Wu, Dung-Sheng Tsai, Taiwan)	Oral 2
15:30-15:45 (15 min)	Green Graphene-Based Flexible Sensors for Wireless and Real-Time Pulse Monitoring. (Chiao-Deng Yeoh, Chen-Fang Kang, Dung-Sheng Tsai, Taiwan)	Oral 3

Day 3 (July 17, 2026) - Friday		
Main hole (Room 1)		
	Chair: Prof. Pankaj Koinkar	
10:00-10:40 (40 min)	Distribution of Mode-I Thermal Stress Intensity Factor along a Front of Three-dimensional Surface Crack due to an Instantaneous Internal Point Heat. (Prof. Akihide Saimoto)	Keynote Speech III (Japan)
10:40-11:20 (40 min)	Building an Optimal Radar Sequence of Binary Phase-manipulated Signals as a Discrete Optimization Problem and Various Heuristic Approaches to its Solution (Prof. Boris Melnikov, Bo Zhang, Elena Melnikova)	Keynote Speech IV (Russia)
11:20-11:30 (10 min)		Tea Break
11:30-12:10 (40 min)	Joining characteristics of Aluminum/Thermoplastic composite hybrid joints according to surface treatment methods and recent composite studies (Prof. Yun-Hae Kim)	Keynote Speech V (Korea)

Day 3 (July 17, 2026) - Friday		
Room 1		
Oral details (12 min presentation / 3 min Q&A)		
13:30-14:20 (50 min)	Parallel Sessions (Invited and Oral Presentations) (Session chair: Dr. Chih-Yi Liu, Dr. Tsia)	AI
13:30-13:50 (20 min)	Automated Optical Inspection Platform for Micro-LED Matrices Integrating Embedded Control and Deep Learning (Wei Cheng Chen, Tzu Hsun Kao, Min Yen Yeh, Taiwan)	Invited speaker (17 min presentation / 3 min Q&A)
13:50-14:05 (15 min)	Adaptive Control of a Robotic Manipulator with Nonlinear Dynamics Using Hybrid Neural Network Control Loops (N.K. Litvinov, Yu. E. Drobov, Russia)	Oral 1
14:05-14:20 (15 min)	An Investigation into the Impact of Environmental Factors on the Stability of Remote Monitoring Systems in Animal Shelters Using Open Meteorological Data (Yu-Cheng Wang, Taiwan)	Oral 2
14:20-14:30 (10 min)		Tea Break
14:30-15:35 (65 min)	Parallel Sessions (Invited and Oral Presentations) (Session chair: Dr. Kyo-Moon Lee)	Structure
14:30-15:20 (20 min)	Black-box Optimization Techniques for Modelling New Materials (P.A. Oganetsyan, E.I. Fomenko, S.A. Gorshkov, A.V. Vissarionova, Russia)	Invited speaker (17 min presentation / 3 min Q&A)
14:50-15:05 (15 min)	Prediction and Validation of Mechanical Properties of Fiber-Reinforced Composites Using Physics-Based Modeling and Machine Learning (Soonmin Hong, Korea)	Oral 1
15:05-15:20 (15 min)	A Study on the Properties of Composites Using Vitrimer Resin Based on an Automated Intermediate Material Manufacturing Process (Min-Ji Koo, Korea)	Oral 2
15:20-15:35 (15 min)	Microstructure and Electrical Properties of RF Magnetron Sputtered MoC Thin Films for Precision Resistor Applications	Oral 3

Day 3 (July 17, 2026) - Friday	
Room 2	

Oral details (12 min presentation / 3 min Q&A)		
13:30-14:20 (50 min)	Parallel Sessions (Invited and Oral Presentations) (Session chair: Prof. Boris Melnikov, Dr. Jin-Woo Lee)	Structure
13:30-13:50 (20 min)	Film Structure and Corrosion Protection Mechanisms of Film-Forming Amines: Role of Surface Oxidation State and Hydrophobicity (Ken Yoshida, Japan)	Invited speaker (17 min presentation / 3 min Q&A)
13:50-14:05 (15 min)	Suppression Strategy for Crack-Tip Stress Concentration in Lip- Type Cracks under Coupled Mechanical and Electrothermal Loading. (Wan-Yu Xua, Yi-Lun Liaob, Ching-Kong Chaoa, Yu-Hsi Huangb, Taiwan)	Oral 1
14:05-14:20 (15 min)	Atomistic Mechanism of Friction-Force Independence on the Normal Load and Other Friction Laws for Dynamic Structural Superlubricity (Nikolay Brilliantov, Russia)	Oral 2
14:20-14:30 (10 min)		Tea Break
14:30-15:35 (65 min)	Parallel Sessions (Invited and Oral Presentations) (Session chair: Prof. Kazuya Kusaka, Dr. A. S. Kornievsky)	Analysis
14:30-14:50 (20 min)	Hypersingular Integral Inversion of Mean-Field Potentials for Non-Destructive Mapping of Defect Distributions in Advanced Materials (Yu. E. Drobotov, Russia)	Invited speaker (17 min presentation / 3 min Q&A)
14:50-15:05 (15 min)	Numerical Investigation and Comparison of Effective Elastic Properties of Regular Porous Structures (A.S. Kornievsky, A.V. Nasedkin, Russia)	Oral 1
15:05-15:20 (15 min)	Modified Fields–Backofen Constitutive Modelling of Cold Deformation Behaviour for 10B38 Boron Steel (Quang-Cherng Hsu, Taiwan)	Oral 2
15:20-15:35 (15 min)	Analysis of the Friction–Wear Correlation of Tire Tread Compound Considering Strain-Dependent Nonlinear Viscoelastic Properties (Hyunseung Kang, Korea)	Oral 3
15:35-15:50 (15 min)	Metal Decorated BiVO ₄ with Improving Photocatalytic Performance (Trinh Duy Nguyen, Vinh Huu Nguyen, Que-Minh T. Doan, Truc Thai Thanh, Oanh T.K. Nguyen, Taeyoon Lee, Vietnam)	Oral 4

Day 3 (July 17, 2026) - Friday		
Room 3		
Oral details (12 min presentation / 3 min Q&A)		
13:30-14:20 (50 min)	Parallel Sessions (Invited and Oral Presentations) (Session chair: Prof. Toshihiro Moriga)	Analysis
13:30-13:50 (20 min)	Influence of Silicone Oil Viscosity on Laser Cleaning Effects of A3003 Aluminum Alloy Surfaces (Sunghwan Kim, Korea)	Invited speaker (17 min presentation / 3 min Q&A)
13:50-14:05 (15 min)	Analysis of Re-solidified Metal Layer Formation during Underwater Laser Cutting of Stainless Steel for Nuclear Decommissioning (Jaecook Jeon, Korea)	Oral 1
14:05-14:20 (15 min)	ECHO LOG: A Study on Sonic Visualization and Interactive Experience of Delphinid Cetaceans in Taiwan Waters (Wang Yun-Han, Xu Ruo-Zhen, Luo Yu-Ching, Qiu Xiang-En, Chen Cheng-Huan, Lan Wei-Hsien, Chang Shun-Hsyung, Wen Chai-Sheng, Lu Shi-Ming, Taiwan)	Oral 2

14:20-14:30 (10 min)		Tea Break
14:30-15:50 (80 min)	Parallel Sessions (Invited and Oral Presentations) (Session chair: Dr. S.A. Lychev, Mr. Sung Uk Yoo)	Analysis
14:30-14:50 (20 min)	A Fast and Accurate Quasi-atom Method Hybrid Model for Simultaneous Atomistic and Continuum Simulation of Solids (Artem Chuprova, Egor Nuzhin, Nikolay Brilliantov, Russia)	Invited speaker (17 min presentation / 3 min Q&A)
14:50-15:05 (15 min)	Space-Time Symmetries and Gauge Invariance in the Geometric Theory of Evolving Defects: A Noether Current Approach to Configurational Forces (S.A. Lychev, Russia)	Oral 1
15:05-15:20 (15 min)	Solution of an Edge Crack in a Semi-infinite Plate of General Anisotropy Subjected to a Self-equilibrating Loads at a Crack Face (Yohei Sonobe, Japan)	Oral 2
15:20-15:35 (15 min)	Dry-Jet Wet-Spun Bamboo-Derived Continuous Cellulose Fibers for Composite Applications (Eunseok Lee, Korea)	Oral 3
15:35-15:50 (15 min)	Micromechanics-based Modeling of Electrical Conductivity in CNT-reinforced Cementitious Composites (Seoyoung Moon, Korea)	Oral 4

Day 3 (July 17, 2026) - Friday		
Room 4		
Oral details (12 min presentation / 3 min Q&A)		
13:30-14:20 (50 min)	Parallel Sessions (Invited and Oral Presentations) (Session chair: Dr. P. A. Oganasyan, Dr. Ken Yoshida)	Sensing & Architecture
13:30-13:50 (20 min)	Increasing Diamond Ore Beneficiation Process Efficiency with LMS-driven Production Simulation and VR/AR-approaches (V.A. Afanasyev, S.A. Tyasto, Russia)	Invited speaker (17 min presentation / 3 min Q&A)
13:50-14:05 (15 min)	A Switched Capacitor Regulator with Low Input Voltage for Energy Harvesting System (Yi-Chieh Hsu, I-Wen Chang, Yu-Cheng Liang, Yi-Cheng Lai, Taiwan)	Oral 1
14:05-14:20 (15 min)	Detector influence in X-ray elastic constant measurement of polyphenylene sulfide (Itsuki Takahata, Japan)	Oral 2
14:20-14:30 (10 min)		Tea Break
14:30-15:50 (80 min)	Parallel Sessions (Invited and Oral Presentations) (Session chair: Prof. Daisuke Yonekura)	Sensing & Architecture
14:30-14:50 (20 min)	A Finger-worn Responsive Bio-inspired Controller Utilizing a Silver-ink Force Sensing Resistor (Yueh-Wei Chen, Yu-An Chiu, Cheng-Yu Wu, Hsin-Ti Chiu, Chen-Fang Kang, Taiwan)	Invited speaker (17 min presentation / 3 min Q&A)
14:50-15:05 (15 min)	Development of Large-Area Flexible CsPbBr ₃ Perovskite Quantum Dot LEDs (Kuan-Yu Kea, Wu-Kai Tsuib, Yin-Ting Hsua, Sih-An Chenc, Lung-Chien Chena, Zong-Liang Tsengb, Shun-Hsyung Changd, Taiwan)	Oral 1

15:05-15:20 (15 min)	Rapid UTI Diagnostics using ITO EGFET with LAMP techniques (Chun-Ming Albert Wang, Taiwan)	Oral 2
15:20-15:35 (15 min)	Physics-Informed U-NET for Label-Free Stress Analysis in 3D Lattice Structure Design (Seunghyun Kim, Korea)	Oral 3
15:35-15:50 (15 min)	An AI-Driven Dynamic Questionnaire System to Streamline Pre-Consultation for the Elderly (Chih-Fu Yang, Taiwan)	Oral 4

Day 3 (July 17, 2026) - Friday		
Room 5		
Oral details (12 min presentation / 3 min Q&A)		
13:30-14:20 (50 min)	Parallel Sessions (Invited and Oral Presentations) (Session chair: Dr. Chen-Fang Kang and Prof. Yohei Sonobe)	Analysis
13:30-13:50 (20 min)	Green Synthesis of β -Tricalcium Phosphate Particles from Waste Eggshells: A Comparative Study of Different Processes for Radiative Cooling (Yang Yu Hsuan, Taiwan)	Invited speaker (17min presentation / 3min Q&A)
13:50-14:05 (15 min)	Distribution of Mode-I Thermal Stress Intensity Factor along a Front of Three-dimensional Surface Crack due to an Instantaneous Internal Point Heat (Yohei Sonobe, Shinichi Kubota, Takuichiro Ino, Atsuhiko Koyama, Akihide Saimoto, Japan)	Oral 1
14:05-14:20 (15 min)	An End-to-End Simulation Framework for Piezoelectric Transducer Systems in Underwater Acoustic Communication (Nhut Thang Le, Cong Toai Truong, Ngoc Hung Nguyen, Quang Huy Cao, Huy Hung Nguyen, Tan Tien Nguyen, Van Tu Duong, Vietnam)	Oral 2
14:20-14:30 (10 min)		Tea Break
14:30-15:50 (80 min)	Parallel Sessions (Invited and Oral Presentations) (Session chair: Dr. Sung Youl Bae)	Structure
14:30-14:50 (20 min)	A Portable Double-Acting Piston Pump for Biomedical Applications: Design, Modeling, and Experimental Evaluation (Cong Toai Truong, Trung Dat Phan, Huy Hung Nguyen, Tan Tien Nguyen, Van Tu Duong, Vietnam)	Invited speaker (17 min presentation / 3 min Q&A)
14:50-15:05 (15 min)	A Study on the Mechanical-Thermal Properties of Reformed Perlite Cores and BF/HDPE Sandwich-Structured Composites (Hyeon-Mok Jung, Korea)	Oral 1
15:05-15:20 (15 min)	Development of Ti-Zr alloys with various pore structures and their mechanical properties for load-bearing implant materials (Seok-June Seo, Tomoyuki Fujii, Yoshinobu Shimamura, Japan)	Oral 2
15:20-15:35 (15 min)	Comparative Study of TiC and TiN Reinforced CoCrFeNiAl High Entropy Alloy Composites Fabricated by Laser Powder Bed Fusion (Juwon Kim, Korea)	Oral 3
15:35-15:50 (15 min)	Flame-Retardant Self-Reinforced PET Composites for Circular Automotive interior Panel (Se-Yoon Kim, Korea)	Oral 4

Poster Presentation List

Room 4-6 AMDP/PHENMA 2026		
No.	Paper title	Name
1	Improvement in Strength Variation of Bi-Zn Solder/Glass Joints Bonded Using Ultrasonic Soldering Method	Yuuto Nakanishi
2	Synthesis and Electronic Structure Characterization of Nanostructured Fe–Co–Ni Phosphides for Hydrogen Evolution	Sheng-Chang Wang
3	Interfacial Reactions Between Multi-walled Carbon Nanotubes-reinforced Sn-3.0 wt.%Ag-0.5 wt.%Cu Composite Solder with Cu	Yi-Pin Lin
4	In Situ Polymerization of HCl-doped Polyaniline on PET Fabrics for Robust, and Flexible Humidity Sensors	Cheng-Ho Chen
5	Effect of Polyaniline Content on the Performance of Humidity Sensors Based on Self-Fabricated Flexible Interdigitated Electrodes	Tzu-Yi Lin
6	Designing Single Atom Catalysts for the Hydrogen Oxidation Reaction in Proton-exchange Membrane Fuel Cells	Jing Wang
7	Enhanced NO₂ Sensing Performance of Ga₂O₃/CuO Bilayer Thin Films via p–n Heterojunction Engineering	Yu-Jen Hsiao
8	Phase-Field Simulation of Polar Nano-Regions in Relaxor Ferroelectrics	Yuanqi Chen
9	In situ Monitoring of Flow-Accelerated Corrosion Inhibition by Film-Forming Amines in a High-Temperature and High-Pressure Loop Test	Mayu Jobe
10	Investigation Characteristics of Thermal Field in SiC Crystal Growth Using PVT	Ming-Hsien Shih
11	Rice Quality Identification via Multimodal Physical Feature Analysis: An Optical Inspection System	Chih-Yuan Hsu

12	Effect of bias voltage on X-ray elastic constant and residual stress in titanium nitride films	Kazuya Kusaka
13	Detector influence in X-ray elastic constant measurement of polyphenylene sulfide	Itsuki Takahata
14	Effect of Heat Input on Deformation and Residual Stress in Multi-pass Welding of Shipbuilding Thick Plates	Jisung Kim
15	Preparation and Properties of Environmentally Friendly Epoxy Resin-Ammonium Dihydrogen Phosphate Coconut Shell Ash Flame-Retardant Composite Material	Chin-lung Chiang
16	Rapid UTI Diagnostics using ITO EGFET with LAMP techniques	Chun-Ming Wang
17	Fabrication and Evaluation of a Continuous Glucose Monitoring Sensor Using bacterial cellulose	Gakuto Maki
18	Rheological Behavior of 76S Bioactive Glass/Collagen Composite Bioinks with Varying Solid Loadings	Ji-Yan Li
19	Influence of Solid Contents on the Rheological Behaviors of Bioactive Glass/Collagen Composite Bioinks	Ji-Yan Li
20	Verification of Optimized Component Design for Double Vacuum Piping in Liquid Hydrogen Transport	Sung-won Yoon
21	Verification of Optimized Design for Large Composite Structures Considering Marine Environment Motions	Sung-won Yoon
22	Tailored Anionic Regulation in Ternary MoSSe for High-Performance Energy Conversion and Storage Applications	Poonam Lakhiwal
23	First-Principles Investigation of a Novel Two-Dimensional Penta-SiBN Monolayer for Hydrogen Storage	Sangeeta Meena
24	Chemical Mechanical Polishing Research for Hybrid Bonding Application	Cheng-Yu Lin
25	Evaluation of Characteristic Failure Stress (CFS) Based on First Ply Failure for Composite Structures in Wind-Assisted Propulsion Systems	Chang-Wook Park

26	Evaluation of Surface Characteristics and Tensile Behavior of Industrial Fibers under Acidic and Alkaline Environments	Chang-Wook Park
27	Preparation and evaluations of photo-curable 2-(methacryloyloxy)ethyl choline hydrogen phosphate bio-printing scaffold	Yumeng Zhao
28	Advancing Safer Nuclear Decommissioning through Advanced Laser Technologies	Su-jin Lee
29	Surface Modification of Substrates Using Phosphate-Terminated Zwitterionic Polymers and Their Functional Evaluation	Maruyama Junya
30	Mo₃C₂T_x MXene Based Efficient Material for Hydrogen Generation and Supercapacitor Applications	Akshidha Singla
31	Influence of thermal annealing on the performance of microcrystalline silicon thin film solar cell fabricated from fluorinated precursors by two-step growth PECVD technique	Yu-Hung
32	Grain Refinement of Industrial Pure Iron by Electron Beam Alloying with Ti and Nb	Aoi Arima
33	Fretting Fatigue Damage Behavior of Cr/CrN Multilayer Coatings with Different Numbers of Layers	Izuru Tasaki
34	Effect of Particle size on Erosion Properties of Cr/CrN Multilayer Coating	Osuke Nakatani
35	Surface Modification of Substrates Using Phosphate-Terminated Zwitterionic Polymers and Their Functional Evaluation (Junya Maruyama)	Junya Maruyama

Room 8~9 PHENMA 2026

No.	Paper title	Name
35	Numerical Modeling of Gas Velocity Dependence in a Gas Sensor.	Ya.A. Abdullaev, V.V. Petrov.
36	Nano Piezo Digital-analog Actuator for Mechatronics.	S. M. Afonin.

37	Dielectric Properties in the Microwave Range of Dispersed-Crystalline Powders of BaTiO₃ Modified with NiO.	M.A. Ambartsumyana, I.N. Andryushinaa, K.P. Andryushina.
38	Low-Complexity Transversers with Square Wave Carrier for Band-Limited Acoustic Transducers.	An-Zhe Yeh, Yu-Lin Lin, Huang-Chang Lee.
39	Study of the Dielectric Response of Dispersed-crystalline Powders of the Composition Pb(Zr_{0.80}Ti_{0.20})O₃ in the Microwave Range.	K.P. Andryushinab, M.A. Ambartsumyana, I.N. Andryushinaa.
40	The Influence of Temperature and Mmicrowave Power on the Dielectric Properties of the Ceramic Solid Solution PbZr_{0.94}Ti_{0.06}O₃.	I.N. Andryushinaa, M.A. Ambartsumyana, K.P. Andryushinab.
41	Research on Application of Lean Manufacturing in Sewing Line for Multi-layer Blazers at the Services Production Center Hanoi Industrial and Trade University.	Anh Nguyen Thi Thao, Thao Phan Thanh.
42	Computer Optimization of Shear Piezoelectric Transducers for Application as Energy Harvesting Devices.	Arkadiy N. Soloviev, Mariia S. Germanchuk.
43	Optimization of the Finite Element Model of a Semi-passive Bimorph with an Active Layer Made of Porous Piezoceramics, Taking into Account the Choice of Non-uniform Porosity in the Plane of the Piezoelectric Layer.	Arkadiy N. Soloviev, Mariia S. Germanchuk, V.A. Chebanenko.
44	Optimization of the Output Characteristics of Functionally Gradient Plate Transducers by Varying the Porosity and Thickness of Piezoelectric Layers for Different Boundary Conditions and Vibration Modes.	Arkadiy N. Soloviev, Mariia S. Germanchuk, V.A. Chebanenko.
45	Optimization of a Semi-passive Bimorph with an Active Layer Made of Porous Piezoceramics under Different Mechanical Boundary Conditions to Increase the Output Potential in the First Bending Mode.	Arkadiy N. Soloviev, Mariia S. Germanchuk, V.A. Chebanenko.
46	Identification of the Damaged State of Extended Elements Based on the Solution of a Non-stationary Problem of the Theory of Elasticity.	Arkadiy N. Soloviev, Mariia S. Germanchuk, Okbazghi K. Abraha, Nikolay E. Piun.
47	Applied Theory for Calculating Transverse Vibrations of a Layered Structure with Polymer Matrices and Inclusions of Porous Piezoceramic Rods Located along the Layer.	Arkadiy N. Soloviev, Mariia S. Germanchuk, Pavel A. Oganetsyan.
48	Mathematical Modeling of the Interaction of a Rigid Lensotome Tip with an Amorphous Lens Substance and the Selection of the Optimal Destruction Option with Maximum Efficiency.	Arkadiy N. Soloviev, Mariia S. Germanchuk, Regina A. Bardakova, Aleksandr N. Epihin.
49	Control of Liquid-phase Synthesis Parameters to Enhance the Functional Characteristics of Iridium-containing Catalysts.	Ya.V. Astravukh, A.S. Pavlets, E.A. Moguchikh, A.A. Alekseenko.
50	Resistive Switching Properties of Hafnium Oxide Memristor Structures for Neuromorphic Systems.	A.A. Avakyan, A.V. Saenko, V.A. Smirnov.

51	Synaptic Plasticity Simulation of Titanium Oxide Memristor Nanostructures.	V.I. Avilov, N.I. Polupanov, V. A. Smirnov.
52	Influence of the Molecular Beam Epitaxy Conditions on the Growth of InAs Quantum Dots on the Patterned GaAs(111)B Surfaces.	S. V. Balakirev, D. V. Kirichenko, N. E. Solodovnik, N. A. Shandyba, D. D. Dukhan, M. M. Eremenko, M. S. Solodovnik.
53	Mechanical Properties of Polyester Resin Modified with Carbon Fibers.	O.A. Belyak, V.V. Lis, M.M. Chetverik.
54	Game Design and Narrative Development for a Fighting Game on the Unity Platform.	R.A. Bespalov, A.V. Maistrenko.
55	Analysis of Thermodynamic Processes in a Casing String during Combustion of a Thermite Mixture at the Bottom Hole Based on a Simulation Model.	S.I. Bespalov, V.N. Stepanov, S. O. Kireev, M.V. Korchagina.
56	An Effective Identification Method in Problems of Low-frequency Defectoscopy.	O. V. Bocharova, I. E. Andjiovich.
57	On the Identification of Parameters of Fractional-order Viscoelasticity Models.	I.V. Bogachev.
58	Ensuring the Absence of Thermal Defects when Grinding Ball Screw Gears.	V. B. Bogutsky, L. B. Shron.
59	Dielectric Relaxation in SBN50-La.	A.L. Bulanova, A.V. Pavlenko, N.V. Makinyan.
60	Changes in the Surface Structure and Technological Properties of Natural Spodumene Treated with a Dielectric Barrier Discharge	I. Zh. Bunin, I. A. Khabarova, E. V. Koporulina
61	Influence of Man-made Raw Materials on the Physical and Mechanical Properties of Lightweight Concrete.	N. I. Buravchuk, O.V. Guryanova, E. P. Putri.
62	Use of Technogenic Raw Materials for the Liquidation of Mined-out Areas.	N. I. Buravchuk, O.V. Guryanova, E. P. Putri.
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68	Information-Based Framework for Assessing Building Damage in Dynamic Studies.	A.V. Cherpakov, A.S. Brezkin, D.G. Tumanyan.
69	Conducting Work on Training a Neural Network to Assess Damage to a Triangular Structure Based on Dynamic Response Analysis.	A.V. Cherpakov, Yu. E. Drobotov, V.E. Yakovlev.
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167	Microstructural Features and Complex Electromechanical Parameters of Lead-Free Ferroelectric Ceramics.	M.A. Lugovaya, A.N. Reznichenko, I.A. Shvetsov, A.P. Turygin, A.N. Rybyanets.
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194	Application of Mobile Resonant Chiral-Dependent Modules for Practical Adjustments of the Microwave Transmission Lines Conductive Parameters.	E.V. Nikolaev, I.V. Malyshev, N.V. Parshina.
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203	Microstructural Features and Anisotropy of Electromechanical Properties in Textured Piezoceramics Based on Layered Bismuth-Containing Compositions.	E.I. Petrova, I.A. Shvetsov, N.A. Shvetsova, Yu. A. Kuprina, M.A. Lugovaya, A.N. Rybyanets.
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