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1 SESSIONS

Thermal Conductivity of Double Polymorph Ga_2O_3 Structures

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Keywords: gallium oxide, phase transformation, thermal transport, phonons, time-domain thermoreflectance, polymorphs, molecular dynamics, ion irradiation.

Recently discovered double polymorph γ/β-Ga_2O_3 structures [1] constitute a novel class of advanced materials providing an option to modulate functional properties across interfaces without changing the chemical composition of materials, in contrast to that in conventional heterostructures. In this work, we investigate thermal transport properties in such structures having variable γ-layer thicknesses (350-1000 nm) fabricated by a self-organized polymorph β-to-γ transformation upon reaching a certain disorder threshold induced into β-substrates by ion irradiation [2]. The cross-plane thermal conductivity was measured by time-domain thermoreflectance, effectively obtaining depth profiles of the thermal conductivity across the γ/β-Ga_2O_3 structures. The thermal conductivity of γ-Ga_2O_3 was measured in the range of 1.84÷2.11 $Wm^{-1}K^{-1}$, independently of the initial β-substrates orientations, consistently with the cubic spinel structure of the γ-phase. The molecular dynamics simulations demonstrated good agreement with the experimental results in γ-phase when residual biaxial strain was applied to γ-Ga_2O_3 lattice. In its turn, the thermal conductivity of monoclinic β-Ga_2O_3 showed a distinct anisotropy, with values ranging from 10 $Wm^{-1}K^{-1}$ for [201] to 20 $Wm^{-1}K^{-1}$ for [010] orientations. Thus, for double polymorph γ/β-Ga_2O_3 structures formed on [010] β-substrates, there is an order of magnitude difference in thermal conductivity across the interface, which potentially can be exploited in thermal energy conversion applications.

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Приложение 1

High-performance p-type V2O3 films by spray pyrolysis for transparent conducting oxide applications

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Keywords: p-type transparent conductive oxides, V2O3, spray pyrolysis, opto-electric properties, electron correlation.

P-type transparent conductive oxides (TCOs) have promising applications in technologies such as solar cells, organic light-emitting diodes, and transparent thin-film transistors. However, unlike their n-type counterparts, current p-type TCOs suffer from inadequate transparency and carrier mobility, limiting their commercial viability. Achieving high-performance p-type TCOs is essential for enabling transparent p-n junctions and improving devices such as photovoltaic cells and water-splitting systems that require efficient p-type electrodes.

Recent work by Hu et al. [1] demonstrated that pulsed laser deposited (PLD) V2O3, a strongly correlated oxide, can function as a p-type TCO. In such materials, strong on-site Coulomb interactions influence the valence band structure, enabling p-type conductivity and pushing screened plasma energy below the visible range, which improves optical transparency. Despite these promising findings, research on V2O3 synthesized through more accessible methods remains limited.

In this study, we report the successful synthesis of high-quality p-type V2O3 thin films on c-plane Al2O3 substrates using spray pyrolysis, a low-cost, non-vacuum, and scalable method. Structural, optical, and electrical properties of the films were thoroughly characterized. The films show epitaxial alignment with the substrate, and their properties vary with thickness, doping, and growth conditions. The V2O3 films exhibit resistivity ranging from 0.026 to 0.0037 Ω·m, optical transparency between 20–70%, and thicknesses from 30–200 nm. While the figure of merit (FOM) of these films is slightly lower than that of PLD-grown counterparts, spray pyrolysis offers a practical route for large-scale exploration and optimization of doping strategies.

This work highlights spray pyrolysis as a viable technique for fabricating promising p-type TCOs and underscores the potential of V2O3 in next-generation transparent electronic and energy devices.

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Rheology of Fullerene-Containing Composites

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Keywords: polyurethane, fullerene, isocyanate, rheology, thermal properties

The effect of different contents of fullerene on the properties of polyurethane resins (PUs), including rheology properties, was investigated. The results showed that the rheology properties of the prepared PU resins depend on the type of isocyanates and fullerene used.

The synthesis of fullerene C60 and C70 was carried out in the plasma of an electric arc discharge [1]. In the experiment, graphite rods were used as a carbon source. The synthesis process consists of two stages. At the first stage, annealing of graphite electrodes is carried out by resistive heating with continuous pumping of air from the chamber to a vacuum value of 10^{-3} Torr. In this case, the temperature of the heated electrode can reach 10,000 K due to the high electrical current of 180 A that passes through the graphite electrodes. During annealing, the residual gases, water vapor, and hydrocarbons are desorbed from the pores of the graphite electrodes. In this case, water evaporation occurs at a temperature of 433.15 K, oxygen-containing groups decompose at 473.15 K, and residual impurities are removed at higher temperatures. At the second stage, after the resistive heating of the electrodes, high-purity helium gas is injected into the chamber up to a pressure of 200 Torr. Further, the electrodes are disconnected and moved to a distance of 1-2 mm from each other, while the values of the direct current and voltage reach 90-200 A and 60-80 V, respectively. After the formation of an electric arc, the voltage stabilizes to the value of 20-30 V due to the constant electrode distance. Thus, carbon vapor is obtained, which is converted into fullerene soot during synthesis. The resulting carbon black dissolves in benzene or toluene. The solution is left for several hours. Then the extract is separated from the insoluble component by filtration. The resulting soluble mixture is evaporated at a temperature of 413.15 K.

The effect of the share rate on the shear stress of PUs [2] mixed with fullerene is shown in Figure. The shear stress increased with increasing the shear rate of PUs-fullerene. Also, the shear stress is the highest in the case of 3-fullerene and the lowest in the case of 2-fullerene at the same shear rate. However, the shear stress of PUs is higher than that of PUs-fullerene. The flow curves are convex to the shear stress axis and represent the state of increasing the shear rate because PUs and PUs-fullerene behave as non-Newtonian shear-thinning fluids.

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Synthesis and characterization of Pd-doped perovskite / Vulcan XC-72 carbon nanocomposite for sustainable supercapacitor technology

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Keywords: Energy storage; Nanocomposite; Perovskite; Supercapacitor electrode; Vulcan carbon

Due to the lower equivalent series resistance compared to other types of energy storage devices, supercapacitor electrodes can therefore be an ideal choice for energy storage. In this study, a perovskite-based metallic compound, La0.6Sr0.4Fe0.9Pd0.1O3 was synthesized by the sol-gel method and combined with carbon Vulcan XC-72 to create an effective nanocomposite-based modifier for the development of mini supercapacitor. Morphological studies of the obtained compounds were carried out using a variety of characterization techniques including X-ray Diffraction (XRD), Energy Dispersive X-ray Spectroscopy (EDX), Fourier-transform infrared spectroscopy (FT-IR), and Field Emission Scanning Electron Microscope (FE-SEM) and X-ray Photoelectron Spectroscopy analysis (XPS). On the other hand, the electrochemical feasibility of the synthesized nanocomposite and the developed La0.6Sr0.4Fe0.9Pd0.1O3/Vulcan XC-72 -based supercapacitor was demonstrated by applying various approaches including cyclic voltammetry (CV), galvanostatic charge/discharge (GCD), and electrochemical impedance spectroscopy (EIS). The La0.6Sr0.4Fe0.9Pd0.1O3/Vulcan XC-72 shows the highest specific capacitance (329 F/g) with a power density of 750 W/kg and an energy density of 4.8 Wh/kg at a current density of 0.01 mA/g. In order to evaluate the stability of the designed supercapacitor, long charge/discharge cycles were also carried out. After 5000 charge/discharge cycles, the specific capacity reached about 76.47% of its original value. The present results show that the La0.6Sr0.4Fe0.9Pd0.1O3/Vulcan XC-72 nanocomposite can be efficiently used as a potential material for energy storage, which may be promising for the future.

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Microdischarge dynamics of volume DBD-plasma under the natural convection airflow

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Keywords: Dielectric barrier discharge, microdischarge, convective flow, Comsol simulation, PIV.

Dielectric barrier discharge (DBD) at room conditions, when air is used as the plasma-forming gas, typically exists as randomly distributed thin microdischarge (MD) channels. These channels exhibit complex collective behavior, including spatial self-organization and temporal memory effects. While such phenomena have been widely studied in quiescent or externally forced gas environments [1,2], the influence of self-induced natural convection remains insufficiently explored. This work presents a systematic investigation of the filamentary dynamics in volume DBDs under conditions where convective airflow arises solely from thermal gradients generated by the discharge itself [3]. The study focuses on the DBD behavior in a 3 mm air gap between a copper electrode and a dielectric-covered ITO-glass electrode, using both quartz material as dielectric layer. A sinusoidal voltage is applied, and discharge evolution is tracked over time. In the absence of external flow, local heating from the repetitive ignition of MDs induces buoyancy-driven gas motion. Over sustained operation, this natural convection modifies the discharge structure, leading to a progressive vertical drift of microdischarge channels. High-speed visualization reveals that discharge filaments, initially randomly distributed, begin to exhibit coherent upward motion synchronized with the thermal flow field. Comparative measurements indicate that this motion correlates with the development of thermal gradients across the interelectrode volume. The average MD drift velocity increases with discharge temperature, confirming the coupling between gas heating and filament displacement. Simultaneously, the temporal evolution of discharge current and voltage waveforms remains stable, suggesting that the observed transport is not externally forced but results from convective entrainment of surface charges and pre-ionization regions. To complement the optical diagnostics, numerical modeling was conducted using COMSOL Multiphysics. Results show the development of a steady upward convection roll, with peak flow velocities approaching 0.5 m/s near the central axis. These simulated velocities are consistent with the experimentally observed rates of filament motion. The flow structure remains symmetric and stable over the discharge timescale, confirming that natural convection is sufficient to generate organized transport in DBD configurations of this scale.

In conclusion, this study demonstrates that self-induced thermal convection can play a dominant role in shaping the spatiotemporal behavior of microdischarges in volume DBDs.

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Dust forming nonequilibrium plasma for building blocks synthesis for Nanoscience and Nanotechnology

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Silicon nanoclusters were extensively studied during the last two decades for their outstanding properties. However never before has their permanent electrical dipole moment been exploited for any application. Research conducted on dusty plasmas was focusing on the understanding of their formation mechanisms and on the induced problems in low-pressure plasma tools and surface processing technologies.

These studies on physics and chemistry of dusty plasmas resulted in the discovery of fascinating scientific and technological domains[1]. It is still an important item with regards to the nanoscience and nanotechnologies developments[2].

The experimental measurement of the strong permanent electric dipole moment of 1 nm nontetrahedral and ultra-stable silicon nanoclusters (SiNCs) formed in low pressure cold plasmas open the way to many possible applications. The aim of this contribution is to give an overview on the main aspects of the problem. The first one concerns a short presentation of the nucleation and growth mechanisms of the nanoparticles occurring in low pressure plasmas underlining the evolution of the discharge and plasma characteristics[3 - 7]. In the second part, the new insights on the dust particle properties will be presented. The third part of the contribution is devoted to the use of the SiNCs for the modification of the work function of different materials.

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Development of the Technological Process for the IGR Reactor's Highly-Enriched Irradiated Uranium-Graphite Fuel Immobilization

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Keywords: conversion; down blending; immobilization; highly-enriched uranium-graphite fuel; IGR reactor.

The safe immobilization of irradiated highly enriched uranium (HEU) fuel is a key priority in both nuclear waste management and global non-proliferation initiatives. In Kazakhstan, the National Nuclear Center places particular emphasis on handling legacy HEU fuel from research reactors. A notable example is the IGR research reactor, whose original core – comprising irradiated uranium-graphite HEU fuel—was in operation from 1961 to 1966 and subsequently removed during reactor upgrades. This legacy fuel now necessitates a robust and secure immobilization solution.

This study outlines the development of a technological process designed to reduce the uranium-235 enrichment level of the irradiated HEU fuel to below 20%. The approach involves blending the HEU with depleted uranium, followed by encapsulation in a Portland cement matrix. Full-scale experiments were conducted to evaluate the homogeneity of uranium distribution within the matrix.

The method is based on a set of specific criteria: prior down-blending of HEU to low-enriched uranium (LEU) levels, strict control of uranium-235 content within the cement matrix (limited to 50 g/t), and achieving uniform distribution of fuel particles throughout the matrix.

To reduce enrichment, HEU was dry-mixed with depleted uranium dioxide, then immobilized within a Portland cement matrix. The optimal uranium concentration was ensured by carefully adjusting the fuel-to-matrix ratio. Experimental results confirmed a uniform particle distribution of approximately 93%, supporting both the mechanical integrity and long-term stability of the solidified waste form.

The technological process was further refined through the design and implementation of two dedicated systems: a grinding and mixing unit, and a cementation unit, both tailored for full-scale application.

This immobilization technology provides a reliable solution for the long-term containment of nuclear materials from the IGR reactor and has potential for adaptation to other types of radioactive waste. Future work will explore its applicability to the immobilization of uranium-zirconium HEU fuel, as well as to the immobilization of liquid radioactive waste.

Experimental results demonstrate the viability and effectiveness of the proposed method, ensuring compliance with international standards, including those set by the IAEA, as well as national regulatory requirements. The outcomes support ongoing efforts to tailor immobilization techniques for the safe and long-term management of spent fuel from research reactors.

The main results are presented in the article "Development of the technological process for the IGR reactor's highly-enriched irradiated uranium-graphite fuel immobilization" (Kuanysh K. Samarkhanov, Yuliya Yu. Baklanova, Olga S. Bukina, Viktor V. Baklanov, Yerbolat T. Koyanbayev, Ivan M. Kukushkin, Igor M. Bolshinsky, Kenneth J. Bateman, Journal of Nuclear Materials, Volume 610, 2025, 155801, ISSN 0022-3115, https://doi.org/10.1016/j.jnucmat.2025.155801).

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Optical vortex rings

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Keywords: optical vortex rings, paraxial laser beams, topological transformations

Historically, vortex rings were studied as the smoke rings in hydrodynamics by Helmholtz [1]. In the context of optics, first appearance of vortex rings is linked to the study of Airy rings [2]. Rings can undergo various topological transformations, and the basic topological reactions include the birth and death of loops and reconnection of vortex nodal lines [3].

We analyze theoretically a simple system consisting of a fundamental Gaussian beam and a plane wave in a superposition. Destructive interference of co-propagating waves results in the formation of optical vortex rings - closed-loop structures characterized by a rotational flow of electromagnetic energy around the nodal line. Nucleation of a single ring and annihilation of a pair can be observed in radially symmetric beams [4]. Breaking symmetries of the beam profile introduces novel types of topological reactions – birth of a pair and reconnections [5].

Our model describes propagation of laser beams in vacuum governed by the Schrödinger-type paraxial wave equation for slowly varying envelope of the electric field E:

$$4i\frac{\partial E}{\partial t}+\frac{\partial^2 E}{\partial x^2}+\frac{\partial^2 E}{\partial y^2}=0 \tag{1}$$

here the dimensionless coordinates x and y are scaled according to the units of beam width w_0 and "time" t is normalized by the diffraction length $z_R=\pi w_0^2/\lambda$. The fundamental solution to Eq. 1 is the 1D Gaussian beam:

$$E(x,t;w_0,t_0)=\frac{w_0}{\sqrt{w_0^2+i(t-t_0)}}\exp\left(-\frac{x^2}{w_0^2+i(t-t_0)}\right), \tag{2}$$

with the focal plane (beam waist) located at $t=t_0$. A product of two 1D solutions with different w_0 and t_0 for x- and y-directions creates a beam with elliptic transverse profile: $E(x,y,t)=E_x(x,t;w_x,d/2)E_y(y,t;w_y,-d/2)$. Total destructive interference corresponds to the nodes of the superposition of the beam and the plane wave with relative amplitude P and relative phase ϕ, thus we look for the solutions of the following equation:

$$E(x,y,t)=Pe^{i\phi} \tag{3}$$

To reduce the parameter domain, we introduce the beam ellipticity parameter ϵ s.t. $w_x = \sqrt{2}\cos\epsilon$ and $w_y = \sqrt{2}\ \sin\epsilon$. In the simplest case of the radially symmetric beam ($\epsilon = \pi/4, d = 0$), the phase $\arg E(x, y, t)$ describes infinite planes that are arranged perpendicular to the optical axis [4]. Consequently, the rings appear to be circular arranged flat on the transverse plane. Two distinct topological reactions appear in this case: the birth/death of a single ring on the optical axis ($r = 0$) and nucleation/annihilation of a pair of counter-propagating rings. The latter is exclusive to the radially symmetric case.

In elliptic beams [5], breaking the radial symmetry creates rings that are deformed in 3D space. This introduces two additional types of topological events: the birth of a pair off-axis and reconnections, resulting from the decomposition of the mutual nucleation/annihilation of a pair. We categorize beams into three according to the parameters that govern the shape: elliptic ($\epsilon \neq \pi/4, d = 0$), astigmatic ($\epsilon = \pi/4, d \neq 0$) and elliptic-astigmatic ($\epsilon \neq \pi/4, d \neq 0$). Mechanism for the birth of a pair off-axis remains consistent across all three types, but the nature of reconnections varies case-by-case.

In general, we distinguish reconnections that do not change the number of rings (e.g. $3 \rightarrow 3$), and those that do (e.g. $3 \leftrightarrow 1$ and $2 \leftrightarrow 4$). Some of the reconnections involve the "flat" rings that appear in the symmetry planes of beams, such as the $3 \rightarrow 3$ reconnection in elliptic beams and $2 \leftrightarrow 4$ in elliptic-astigmatic beams depicted in Fig. 1 (a) and (c). These rings appear on special points along t where $r \rightarrow \infty$: $t = 0$ for elliptic and $t = -d/(2\cos 2\epsilon)$ for elliptic-astigmatic.

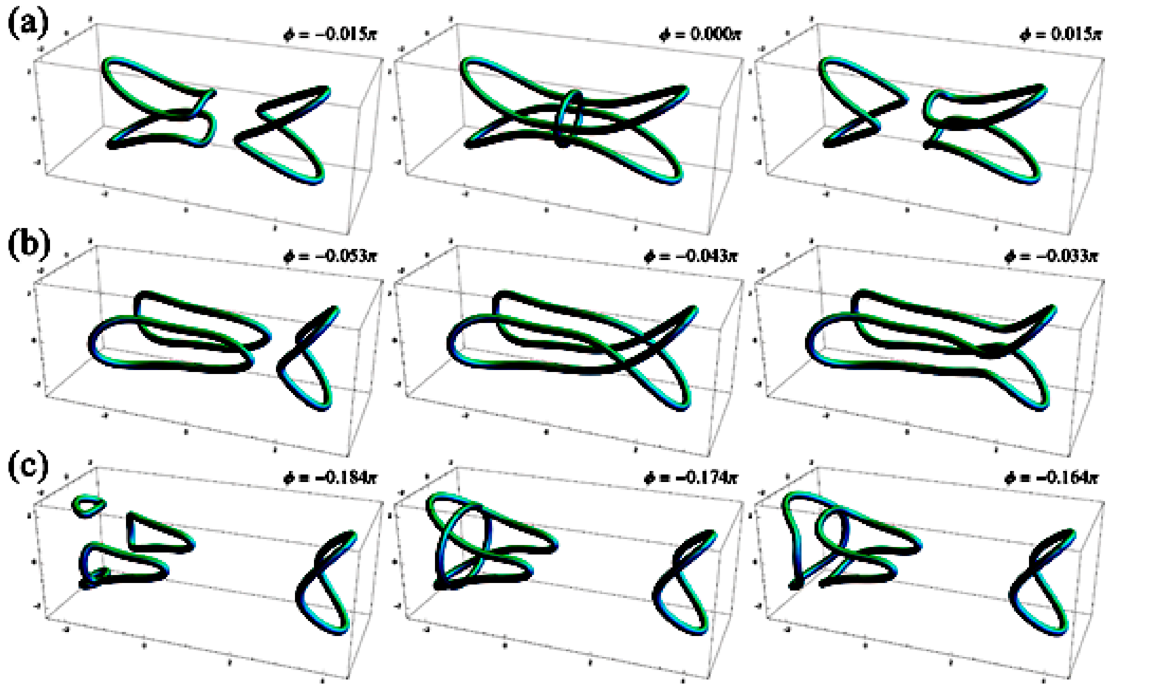

Fig. 1. Reconnections of vortex rings in: (a) elliptic beam $(\epsilon, d) = (\pi/5, 0)$ at $P = 1/4$, (b) astigmatic beam $(\pi/4, 1)$ at $P = 1/4$, and (c) elliptic–astigmatic beam $(\pi/5, 1)$ at $P = 1/5$. Images featured in [5].

To summarize, we have investigated and analyzed several distinct topological transformations of vortex rings. We identified four separate types of topological events: nucleation of a single ring, mutual annihilation of the counter-rotating pair, birth of a pair off-axis and reconnections. Annihilation is only possible in radially symmetric beams, while the latter two are the product of elliptic asymmetries induced into the beam shape.

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Simulation of Transport Properties of 2D, 3D charged systems and warm dense Be plasma

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Keywords: Yukawa systems, dipole systems, molecular dynamics, quantum molecular dynamics, beryllium, transport properties, shear viscosity, thermal conductivity, diffusion, strongly coupled plasmas.

We present a unified analysis of the transport properties in two-dimensional (2D) and three-dimensional (3D) strongly coupled systems, combining results from four recent studies. For 2D systems, non-equilibrium molecular dynamics (NEMD) simulations were used to investigate the heat transfer parameters in Yukawa systems under homogeneous magnetic fields, and the shear viscosity in dipole systems was calculated using both NEMD and Green–Kubo approaches. Additionally, the impact of finite particle size was introduced through a novel force-field model, allowing molecular dynamics simulations to account for hard-sphere collisions and avoid unphysical overlaps in complex (dusty) plasmas.

Moving to 3D systems, we evaluated the applicability of the Yukawa one-component plasma (Yukawa–MD) model and the Chapman–Enskog approach against benchmark quantum molecular dynamics (QMD) simulations of heated beryllium at metallic density. Using QMD-derived radial distribution functions (RDF), we adjusted the Yukawa model parameters to match the ion structure and then compared the resulting transport properties, such as diffusion coefficients, across corresponding temperatures.

Our combined results highlight the limits of classical interaction potentials, such as screened Coulomb (Yukawa) and dipole–dipole forces, in predicting the transport properties of real materials under extreme conditions. They also underline the necessity of validating classical and semi-analytical approaches, like the Chapman–Enskog method, against ab initio quantum benchmarks, particularly for high-temperature metallic systems. This work contributes to the understanding of where classical plasma models succeed and where they require quantum corrections, offering insights applicable to strongly coupled plasmas, warm dense matter, and dense astrophysical environments.

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Ultra-High Thermal Rectification in Asymmetric Graphene Monolayer

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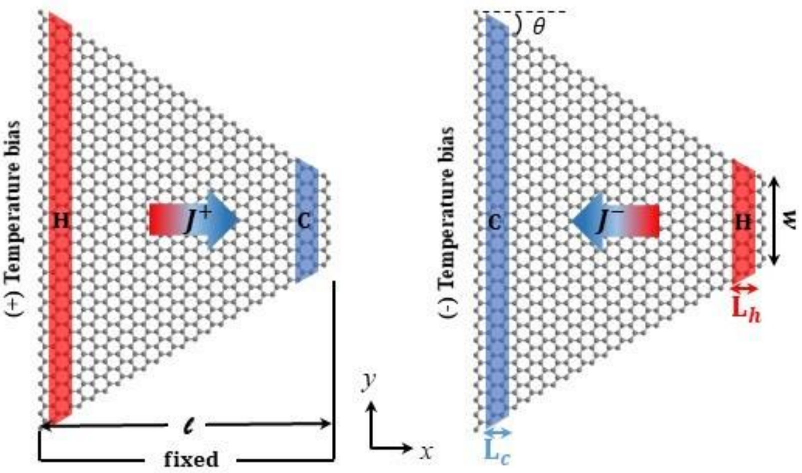
In this study, using non-equilibrium molecular dynamics (NEMD), we discovered infinite thermal rectification and negative thermal conductivity in geometrically asymmetric graphene monolayers. We conduct simulations under two temperature difference biases: one with the hot bath on the left side, denoted as (+), and the other with the hot bath on the right side, denoted as (-), as depicted in the figure.



We also identified a critical temperature difference between the heat baths, at which the thermal conductivity becomes zero (ΔT_{tp}), resulting in no heat current across the system. Our research makes significant strides in the field of nanoscale heat transfer, unveiling several key discoveries in trapezoidal-shape graphene monolayers:

1. Spontaneous Heat Current (SHC): We observed SHC in this asymmetric structure, where, intriguingly, the system shows a heat current even in the absence of a temperature difference. This finding enables energy generation without conventional fuel.

2. Infinite Thermal Rectification: *Our most groundbreaking discovery* is infinite thermal rectification for for $\Delta T < \Delta T_{tp}$. Prior studies have reported only minimal rectification ratios, insufficient for practical applications. Achieving infinite thermal rectification marks a critical breakthrough with potential applications in thermoelectric devices, thermal logic, and advanced thermal management systems.

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Stable Photodiode Performance under Ionizing Radiation Enabled by a Self-Adaptive Nanostructured CNWs/CdZnTe Heterojunction

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Keywords: Carbon nanowalls, CdZnTe, Ionizing radiation, Optoelectronic devices, Radiation-resistant photodiodes,

The rapid advancement of the aerospace industry, nuclear power, radiation medicine, and particle physics – fields where systems must operate in environments with high levels of ionizing radiation – necessitates the development of radiation-resistant optoelectronic devices for accurate sensing, communication, and control. Photodetectors, including photoconductors, photodiodes, phototransistors, avalanche photodetectors, and quantum well detectors, play a crucial role in these applications [1,2].

Carbon nanowalls (CNWs), a unique form of carbon allotropes composed of vertically aligned graphene sheets forming a 3D network, have emerged as promising materials due to their compatibility with various substrates (metals, semiconductors, insulators) and diverse synthesis methods [3,4]. In recent years, CNWs have found applications in a range of optoelectronic devices, including solar cells, LEDs, and sensors [1–4].

In this study, we propose self-adaptive nanostructured CNWs/cadmium zinc telluride (CdZnTe) heterojunction photodiodes capable of stable operation across the UV-VIS-NIR spectrum under ionizing radiation. We investigated the effects of 1.5 MeV proton irradiation at a fluence of 10^{12} protons/cm^2 on the structural, electronic, and optoelectronic properties of CNWs, CdZnTe, and their heterojunction. Using advanced characterization techniques, we observed that key photodiode parameters—responsivity and detectivity—not only remained stable but in some cases slightly improved after irradiation, attributed to the radiation-induced self-adaptive behavior at the CNWs/CdZnTe interface. These results demonstrate the robustness and potential of CNWs/CdZnTe heterojunction photodiodes for long-term deployment in radiation-intense environments such as outer space and nuclear facilities.

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Theoretical studies of light nuclei structure and reactions involving light nuclei at the Institute of Nuclear Physics

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During several decades the theoretical studies of various nuclear reactions are being carried out at the Institute of Nuclear Physics. The most part of the works has been done under the direct participation of the professor Elena Ibraeva, and the researcher Pavel Krassovitskiy. One of the main directions of studies is the correct account for nuclei structure. For this purpose, the nuclear models reproducing spectroscopic characteristics are chosen: radii, binding energies, spectra of low-lying levels of nuclei, magnetic and quadrupole moments.

The significant part of the works was devoted to a study of the halo-structure of the excited states of positive parity in ^{9}Be nucleus [1, 2]. The study of this phenomenon in Kurchatov Institute revealed that the ground state of ^{9}Be nucleus does not manifest the halo-structure. In our calculations the halo-structure in the ground state of ^{9}Be nucleus was also not observed. However, as we showed for the first time such a structure is observed for the excited states of positive parity in ^{9}Be nucleus. We obtained that in the ground state the valence neutron is at a distance of about 3 fm from the αα-core, while in the excited states this nucleon is removed up to the distances of 15-18 fm!

We have also considered the structure of ^{7}Li in αt- and ^{8}Li in αtn-models. Based on these models a successful calculation of ^{7}Li (n, γ) ^{8}Li reaction has been done for the first time, which is of great astrophysical interest since it allows to resolve a gap with A = 8 in the chain of fusion reactions of CNO-elements in the non-standard models of nucleosynthesis [3]. A number of our fundamental studies was devoted to one-nucleon spectroscopy of light nuclei where it was shown for the first time that the potential cluster models can be successfully applied for description of spectroscopic and dynamic characteristics of one-nucleon channels of light nuclei fragmentation [4].

For ^{6,7}Li nuclei a calculation of cross sections of real and virtual α-particles capture reactions has been done [5, 6]. The real α-particles were captured in (α, γ)-reactions, and virtual – in lithium reactions of pick-up like ^{6}Li (^{6}Li, d) and ^{7}Li (^{7}Li, t). It turned out that in the chosen range of excitation of the forming nuclei ^{10,11}B the cross sections for the real and virtual α-particles differ sharply. The capture in (α, γ)-reaction has a resonance structure. The resonance levels in this case lead to a formation of α-particles of a certain energy of several MeV. An observation of these α-particles could serve for the diagnostics of ion component of a DT-plasma.

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Investigation of the effect of HVOF deposition modes on the microhardness of Cr_3C_2-NiCr coatings on zirconium alloy E110

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This article examines the structural, phase, and physico–mechanical characteristics of Cr_3C_2–NiCr composite coatings deposited with high-speed oxygen fuel on zirconium alloy E110. The HVOF method was chosen to create coatings with high adhesion to the substrate and excellent performance properties.

Keywords: HVOF; Cr_3C_2-NiCr coating; E110 zirconium substrate

Modern industry and science are faced with the need to develop and use new materials capable of providing high reliability and efficiency in extreme operating conditions. Coatings based on Cr_3C_2-NiCr are particularly relevant, which are widely used in industry due to their ability to protect surfaces from wear and exposure to high temperatures [1]. This makes them in demand in industries such as aviation, energy, metallurgy, and mechanical engineering [2]. Zirconium, which is widely used in nuclear power due to its unique properties, can be significantly improved by applying Cr_3C_2-NiCr coatings, which makes it possible to increase the protective properties of fuel cells in the event of an emergency loss of coolant. This solution opens up new prospects for the development of innovative technologies aimed at improving nuclear safety and improving the operational efficiency of nuclear reactors [3].

The purpose of this work is to study the process of coating based on Cr_3C_2-NiCr by high-speed oxygen-fuel (HVOF) spraying onto the surface of zirconium grade E110, followed by an analysis of the microhardness and phase composition of the coatings obtained.

A study performed using a nanoscale powder based on Cr_3C_2-NiCr and HVOF technology at the Thermika-3 facility. Spraying was performed with the following parameters as shown in Table 1, and Cr_3C_2-NiCr powder was used as the sprayed material.

Table 1. Coating parameters

№	Distance, mm	Fuel, bar	Air, bar	Oxygen, bar
Sample a	350	1,7	2,2	2,8
Sample b	350	1,7	3,3	2,8
Sample c	350	1,7	3,7	2,8
Sample d	350	2,4	3,3	2,8

After spraying, the microhardness of the coatings was measured on an HL V1 DT device operating on the principle of pressing a diamond pyramid into the test material under a load of 0.10 N, followed by measuring the diagonal of the print.

X-ray diffraction analysis (XRD) was performed using an XpERT-PRO Panalytics diffractometer equipped with a copper anode (Cu) and a Ka radiation source (λ = 1.5406 Å).

The cross-sectional microhardness varied in the range from 1190 to 1280 HV, which is due to differences in the application parameters. The microhardness of zirconium alloy E110 is about 380 HV, which is significantly lower than the values for coatings. These differences are due to the thermal effects during spraying and subsequent operation of the coatings, which emphasizes the need for strict control of thermal conditions during their formation.

The phase composition of the sprayed coatings, studied by X-ray diffraction analysis, revealed several key phases. A solid solution of carbon in chromium ($Cr_{23}C_6$) with a cubic lattice (Fm-3m group) and parameters a=10.6600 Å was found. The Cr_3C_2 phase with a rhombic lattice and parameters a=5,5400 Å, b=2,8330 Å and c=11,4940 Å has also been identified, which has excellent mechanical and physical properties, which makes it valuable for industrial applications. In addition, the $CrNi_3$ phase with a cubic lattice (Fm3m group) and parameter a=3.5400 A, known for its high melting point, corrosion resistance, thermal conductivity, and strength, has been identified. However, the $NiCrO_4$ phase with a tetragonal lattice and parameters a=5,5380 Å, b=5,5380 Å, and c=8,4350 Å was not detected in the initial powders [3].

This paper presents the results of a study of the mechanical characteristics of Cr_3C_2-NiCr composite coatings deposited by the HVOF method on zirconium alloy E110. Composite coatings based on Cr_3C_2-NiCr have significantly higher microhardness compared to the target substrate, which is largely due to the formation of carbides (Cr_3C_2, $Cr_{23}C_6$).

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Increasing wear resistance of ploughshare by electrofriction treatment

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Keywords: surface treatment; electrofriction hardening; wear; microhardness; ploughshare

The surface layers of agricultural machinery components are subject to intensive abrasive wear during operation, which leads to accelerated degradation and reduced service life. To improve the wear resistance of tool surfaces, induction cladding using wear-resistant materials such as 'Sormait-1' is widely employed. However, to achieve optimal mechanical performance, additional post-treatment is required. Electrofriction treatment (EFT) is an effective hardening method in which the surface undergoes localized melting under electric arc discharge, resulting in significant microstructural changes and enhanced surface properties.

This study investigates two types of surface treatments applied to L53 steel: (1) induction cladding with 'Sormait-1' and (2) combined induction cladding followed by EFT. The coatings were characterized and compared with the substrate based on microstructure, phase composition, microhardness distribution, and tribological behavior. Induction cladding resulted in the formation of a dendritic structure, while the subsequent EFT refined this structure and led to increased surface hardness. The average hardness after EFT reached 786 $HV_{0.1}$—more than three times higher than the base steel.

Abrasive wear resistance was evaluated according to ASTM G65. Field tests were carried out using plough shares treated with and without EFT. Each blade was scanned using a structured-light 3D scanner before and after use in actual soil conditions. Based on the scan data, wear was quantified by calculating linear wear, volume loss, and mass reduction. The results showed that EFT-treated blades exhibited a 12%–14% longer service life compared to those processed with induction cladding alone.

These findings confirm the advantages of combining induction cladding and electrofriction treatment to improve the durability of tillage machine components, providing a promising solution for extending equipment lifetime in abrasive environments.

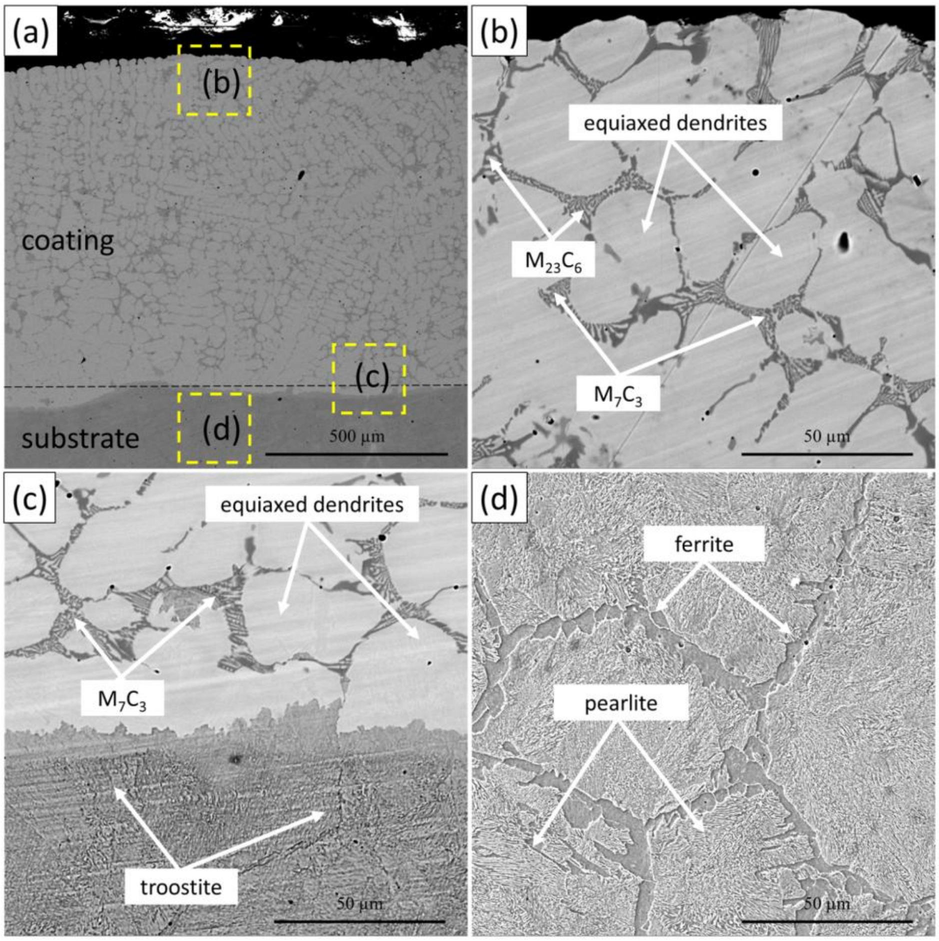

Figure 1. SEM images of the cross section of induction cladding 'Sormait-1':
(a) general view; (b) coating surface; (c) transition layer; (d) initial material (steel L53).

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Effect of neutron irradiation in helium and hydrogen atmosphere on structure and embrittlement of austenitic structural steel

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Keywords: austenitic structural steel, neutron irradiation, WWR-K research reactor, helium and hydrogen atmosphere, mechanical test, microhardness, strength, plasticity, embrittlement.

Investigation results of structure and mechanical properties studies of austenitic structural steel $C_{0.12}Cr_{18}Ni_{10}Ti$ irradiated with neutrons in helium and hydrogen atmosphere at ~1000 K are presented. For irradiation, hermetically sealed ampoules of C0.12X18H10T stainless steel, filled with helium and hydrogen were made. Helium and hydrogen pressure were 30 kPa at room temperature. Irradiation was carried out for 7 twenty-day companies (3254 h) in the channel of the WWR-K research reactor of the Institute of Nuclear Physics in Almaty. Irradiation fluence was $8.9 \cdot 10^{19}$ n/cm^2 for "fast" neutrons with E> 0.11 MeV. Structure and mechanical properties (microhardness, density, strength, plasticity), were studied by optical metallography (OM), scanning electron microscopy (SEM), thermodesorption spectroscopy and mechanical testing.

The study results of synergetic effects of helium atmosphere and neutron irradiation allow us to draw the following conclude:

- Neutron irradiation in a helium environment at high temperatures leads to the accumulation of helium in the material. Helium is located predominantly on structural defects with low capture energy - grain boundaries, dislocations, helium-vacancy complexes;
- Helium release from irradiated steel occurs in the low-temperature region (~ 0.3 Tm);
- Changes in the mechanical characteristics of steel irradiated with neutrons in a helium environment indicates high-temperature radiation embrittlement, specific to FC metals in the presence of helium.

Study of synergetic effects of hydrogen atmosphere and neutron irradiation shows:

- Austenitic steel X18N10T is inclined to embrittlement in the low-temperature range;
- Increasing the test temperature to 450 °C leads to changingin fracture mechanism from ductile to ductile-brittle;
- Large number of the carbide precipitates MeC, Me3C Me23C6 type are formed in austenitic steel 12X18H10T during irradiation.

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Effect of a Wake-Field on the Dissociation of Quarkonium in Collisional Quark–Gluon Plasma

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Keywords: dissociation energy; quarkonium; quark–gluon plasma; wake-field; Cornell potential

The Quark-gluon plasma (QGP) is a highly dense state of matter that exists at extreme temperatures. It is made up of strongly interacting quarks and gluons which are governed by quantum chromodynamics (QCD). Scientists can create QGP by carrying out experiments involving the collision of heavy ions at high speeds, such as those conducted at CERN SPS and BNL RHIC. One of the indicators of the formation of QGP during these experiments is the suppression of quarkonium [1], which is a meson consisting of a pair of heavy quarks of the same flavor, namely charm and bottom quark. These quarks are of particular interest because they form very compact bound states compared to ordinary matter baryons and mesons. These bound states can survive the QGP phase transition, while the latter undergo deconfinement due to the Debye screening length. As the temperature and density of matter increase, the J/ψ and

Y mesons [2] also dissociate. The effective confined potential in a non-relativistic model can be used to study these bound states [3].

The ground state energies depending on Debye mass and temperature for charmonium and bottomonium were calculated using numerical method for solving Schrodinger equation with potential modified for dynamical screening case [4]. In the paper [5] wake effects on the dissociation of heavy quarkonia states J/ψ and Y by introducing an in-medium modification to the inter-quark potential. The wakes in the quark–gluon plasma were modeled using linear response theory using a dynamic dielectric function obtained from kinetic theory (Boltzmann equation) with a Bhatnagar–Gross–Krook (BGK) collision term [6-8]. The in-medium modified potential was used to investigate the dissociation character depending on various parameters such as the velocity of quarkonium moving through the medium and the collision frequency. The critical values of the dissociation temperature have been also calculated. Modifications of the dissociation energy due to wake-field effects were found.

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Microporous aerogel based on microcrystalline cellulose as a sorbent for use as a gas capacitor

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Keywords. mesoporous materials, hydrogen (H_2) storage, sunflower seed husk (SFH), microcrystalline cellulose (MCC), biopolymer scaffolds, electrochemical energy.

Cellulose-based composite materials have attracted increasing interest among scientists working on developing energy-storage materials with unique properties. In the present study, an aerogel was synthesized from sunflower seed husk (SFH) to form microcrystalline cellulose (MCC), the hydrogen (H_2) sorption potential of which was then investigated. The effect of MCC concentration on the nitrogen sorption capacity of the aerogel samples obtained was assessed based on comparison with other like materials. As per the results of BET analysis, the aerogel with an MCC concentration of 3% was determined to be microporous, with a specific surface area of 3000 cm^2/g, average pore diameter of 29.7 nm, total pore volume of 0.44 cm^3/g, density of 166 kg/m^3, and porosity of 95%. It was found that at a temperature of 77K and up to 1 bar, MCC_3/PAm aerogel can sorb up to 0.8% hydrogen. Additionally, the results of SEM analysis revealed a microporous surface morphology, while FTIR analysis showed that the hydroxyl groups in the MCC molecule and the amino groups in the polyacrylamide (PAm) molecule form hydrogen bonds with each other. The results of the research indicate that such an aerogel has potential for use as a material for H_2 storage, and appears to be more ecologically friendly than the metal hydrides used in many H_2 fuel cells and storage containers, the end-of-life processing of which remains a relatively unexplored issue. Generally, cellulose is considered to be a highly desirable material from both ecological and economic perspectives.

Опыт АО «УМЗ» в исследованиях и разработке новых материалов для ядерных и термоядерных реакторов

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Опыт эксплуатации бериллия в качестве отражателя/замедлителя/размножителя нейтронов в ядерных реакторах деления, а также значительный объем экспериментальных и расчетных данных позволил установить пределы его эксплуатационных способностей и ограниченную возможность применения в ядерных и проектируемых термоядерных реакторах.

Предельные бинарные интерметаллические соединения бериллия (бериллиды) типа MBe_{12} обладают отличительными характеристиками по жаропрочности, устойчивости к окислению при высоких температурах, значительно более низким распуханием в результате воздействия нейтронного облучения по сравнению с чистым бериллием. По этой причине бериллиды имеют потенциал применения в ядерной и термоядерной энергетике, авиакосмической отрасли, в качестве окон в мощных источниках рентгеновского излучения и других отраслях промышленности.

АО «УМЗ» проводит исследования в направлении развития и внедрения технологий промышленного получения заготовок и изделий из различных бериллидов, а также по проведению их испытаний и изучению физико-механических свойств до и после нейтронного облучения.

В настоящей статье представлена информация об имеющихся к настоящему времени результатах развития технологий получения заготовок и изделий из бериллидов титана $TiBe_{12}$ и хрома $CrBe_{12}$ а также полученных к настоящему времени результатах исследований свойств бериллида титана $TiBe_{12}$.

Experience of UMP JSC in research and development of new materials for nuclear and thermonuclear reactors

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Experience in the operation of beryllium as a reflector/moderator/neutron multiplier in nuclear fission reactors, as well as a significant amount of experimental and calculated data allowed us to establish the limits of its operational capabilities and the limited possibility of using it in nuclear and designed thermonuclear reactors.

Limit binary intermetallic compounds of beryllium (beryllides) of the MBe_{12} type have distinctive characteristics in terms of heat resistance, resistance to oxidation at high temperatures, and significantly lower swelling as a result of exposure to neutron irradiation compared to pure beryllium. For this reason, beryllides have potential for use in nuclear and thermonuclear power engineering, the aerospace industry, as windows in powerful X-ray sources and other industries.

UMP JSC conducts research in the direction of development and implementation of technologies for industrial production of blanks and products from various beryllides, as well as their testing and study of physical and mechanical properties before and after neutron irradiation.

This article presents information on the currently available results of the development of technologies for the production of blanks and products from titanium beryllides $TiBe_{12}$ and chromium $CrBe_{12}$, as well as the currently obtained results of studies of the properties of titanium beryllide $TiBe_{12}$.

The ACAST Project: Green Transition and Novel Economy of Central Asia via the prism of Research, Certification and CRMs

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The Almaty Centre for Advanced Science and Technology (ACAST) is a proposed research and innovation hub developed by Cantabrigia Advisors Ltd. and Kazakh British Technical University (KBTU) to support the green transition and knowledge-based economic growth in Central Asia. Anchored in the *Algebra of Development* framework, ACAST seeks to integrate fundamental research—

particularly in quantum materials and critical raw materials (CRMs)—with industrial application.

Addressing systemic gaps in laboratory infrastructure and technical capacity, the initiative outlines scalable investment models and collaborative pathways with institutions such as the University of Cambridge. Scientific priorities include spin-based technologies, superconductivity, and multifunctional composites, offering novel solutions for energy and environmental challenges. ACAST aspires to create a fully integrated science-industry ecosystem to drive sustainable development in the region.

Technology of gas-thermal spraying of steel coatings

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Keywords: arc spraying, steel coatings, microstructure, Vikkers hardness, porosity, thickness.

Arc spraying method is one of the most effective and economical thermal spraying technologies for creating high quality protective coatings [1]. In this paper, the influence of various parameters of arc spraying process on the characteristics of steel coatings is discussed. The parameters such as gas pressure, wire feed rate and distance from the gun to the substrate surface were varied during the experiment. The studies included evaluation of coating properties such as roughness, thickness, porosity, structure and hardness [2]. The methods used for analysis were profilometry to measure roughness, scanning electron microscopy (SEM) to study structure, Vickers hardness measurement, and optical microscopy to determine porosity and coating morphology [3].

The results showed that the arc spraying parameters significantly affect the coating properties. Thus, the coatings obtained under different modes have a layered structure and different thicknesses [4]. The analysis of the coating structure revealed defects such as unmelted particles, voids and delaminations in the coating interface [5]. Thickness and porosity studies showed that increasing the wire feed rate and decreasing the distance between the gun and the substrate favors the production of thicker and denser coatings [6]. Increasing the wire feed speed from 2 to 12 cm/s was found to reduce the porosity from 12.59% to 4.33% and increase the coating thickness to 699 μm [7]. The study of surface roughness showed that a comprehensive approach is important to optimize this parameter. Increasing the wire feed rate to 12 cm/s can increase the roughness Ra, but the gas pressure has a significant effect on this index, reducing the roughness from Ra=18.63 μm at a pressure of 6 MPa to Ra=15.95 μm at a pressure of 8 MPa [8]. It was also found that changing the arc spraying parameters affects the hardness of the coating, which was higher than the substrate hardness in all modes [9].

Thus, optimization of these parameters makes it possible to achieve the best combination of mechanical and structural properties of the coating. The results of the study can be useful for improving arc spraying technologies and expanding their application in various industrial fields [10].

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Investigation of the High-Temperature Resistance of Ni-Cr-Al Coatings Obtained by the Detonation Spraying Method

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Abstract: The high-temperature oxidation behavior of Ni-Cr-Al coatings with both homogeneous and gradient structures, deposited by detonation spraying, was investigated. To evaluate their oxidation resistance, cyclic thermal tests were conducted at 1000 °C for 50 cycles. Visual inspection revealed that both homogeneous and gradient Ni-Cr-Al coatings-maintained surface integrity without visible degradation after exposure to elevated temperatures. Microstructural analysis after cyclic oxidation revealed a stable oxide-rich structure with low porosity (~1%), increased coating thickness, and a distinct aluminum gradient in the gradient coatings compared to the homogeneous ones.
Keywords: Ni-Cr-Al coatings; gradient coating; detonation spraying; high-temperature resistance; oxidation.

Ni-Cr-Al coatings are widely used as bonding layers or protective coatings for gas turbine components operating in high-temperature, oxidative, and hot corrosion environments in both power generation and aerospace industries [1]. In our previous work [2], we proposed a method for fabricating gradient Ni-Cr-Al coatings via detonation spraying. The novelty of this method lies in achieving the desired gradient structure by adjusting the barrel gas filling volume during spraying, which allows precise control of the distribution of the Ni-Cr-Al composite powder from the substrate to the surface of the coating. The main objective of this study is to investigate the high-temperature oxidation behavior of both homogeneous and gradient Ni-Cr-Al coatings produced using this technique.

In this study, the coatings were subjected to 50 thermal cycles at 1000 °C in an air environment. Each cycle consisted of 1 hour of heating followed by 20 minutes of cooling at room temperature. After the tests, the morphology of the coating cross-sections was analyzed using backscattered electrons (BSE) on a JSM-6390LV scanning electron microscope (Jeol, Tokyo, Japan).

A microstructural analysis of the coatings was carried out following high-temperature cyclic oxidation testing. Elemental mapping and line scans for Ni, Cr, Al, and O were performed for both homogeneous and gradient coatings (Figure 1). Figure 1a illustrates that in the homogeneous coating, aluminum content increases toward the substrate, with a relatively uniform elemental distribution within the top 100 µm of the coating. Depletion of aluminum beyond this depth accounts for further compositional changes, which are supported by SEM and EDS results. Figure 1b clearly demonstrates a graded distribution of aluminum from the substrate to the coating surface, indicating a higher aluminum concentration near the surface. As shown in the images, the average thickness of the coating after testing was 140–160 µm, compared to 90–110 µm prior to testing [2]. No cracks or delamination were observed after high-temperature cyclic oxidation. The coatings exhibited high oxide content and low porosity (~1%). The complete results of the study on the high-temperature oxidation resistance of homogeneous and gradient Ni-Cr-Al detonation coatings were published in our previous article [3].

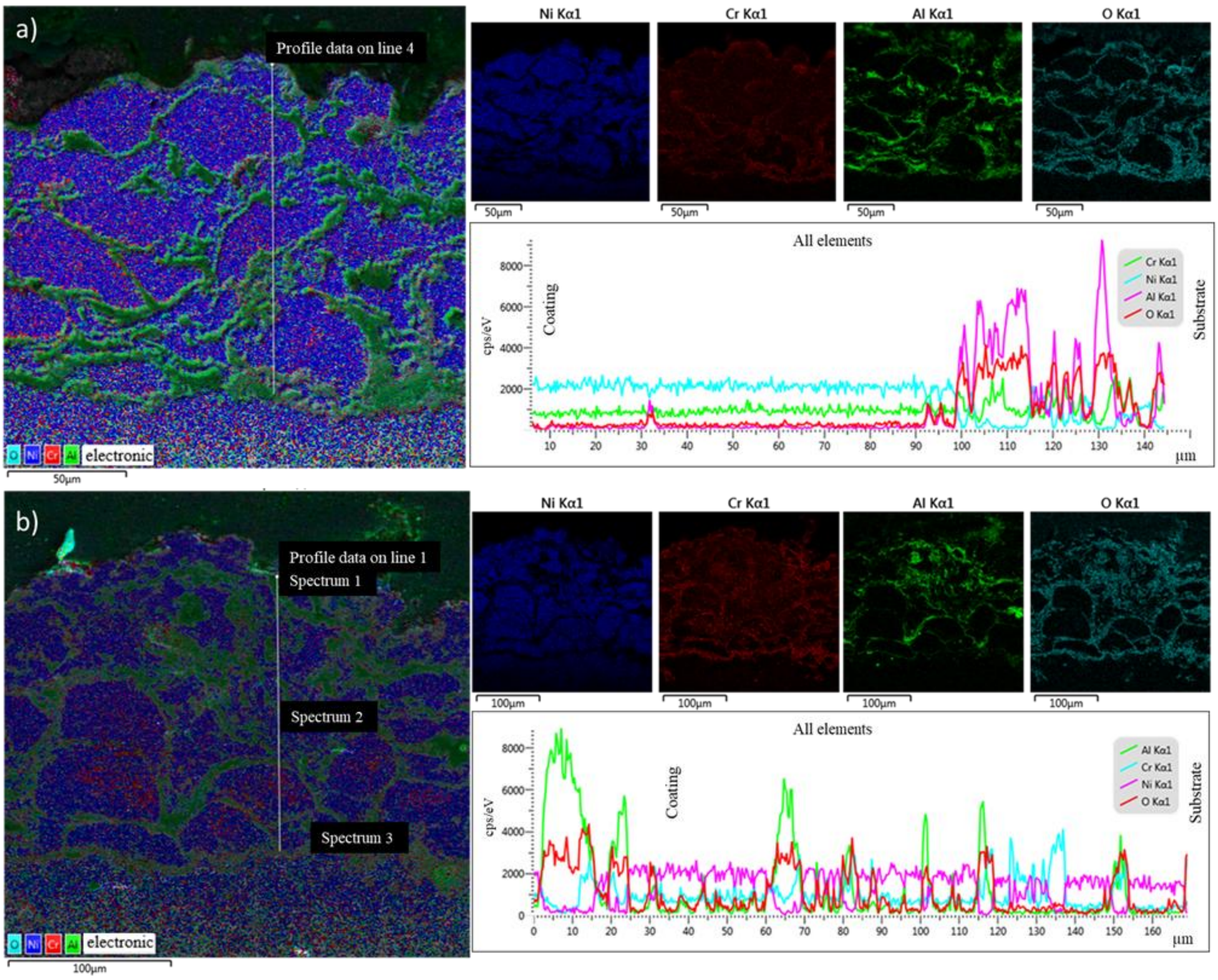

Figure 1. Elemental mapping analyses and a corresponding EDS line-scan analysis of the home-genouse (a) and gradient (b) Ni-Cr-Al coatings after 50 cycles of high-temperature oxidation testing.

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Ionic Core effect on Microscopic and Dynamic Properties of Dense Plasmas

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Dense plasmas are generated in modern high-energy-density-plasma science facilities such as NIF, GSI, Sandia National Laboratory, where the dense plasmas are created by compressing and heating a target by a laser or intense charged particle beams. In this work, we present the results of calculations of the transport and thermodynamic properties of dense plasma at ICF parameters. It is known that the interaction potentials between particles are also of importance for correctly calculation of plasma properties taking into account peculiarities and parameters of investigated plasma. Transport and thermodynamic properties are studied on the basis of screened electron-ion interaction potentials [1-4]. A pseudopotential approach was used to study the effect of an ionic core on the electron-ion scattering in dense plasmas. Screening of the ion charge is taken into account using the density response function in the long wavelength limit. Additionally, the effect of electronic non-ideality is included using the compressibility sum-rule connecting the local field correction and the exchange correlation part of the electronic free energy density.

Using screened pseudopotential, we have computed electron-ion scattering phase shifts, the total elastic scattering cross section, and the transport cross section. It is found that the ionic core leads to the strong decrease of the scattering cross sections, transport, relaxation properties. Additionally, it is shown that the transport cross section has a non-monotonic dependence on the variation of the ionic core field parameters. To investigate thermodynamic properties, there was solved the integral Ornstein–Zernike equation in the hypernetted chain approximation. To show the correctness of the model, its results are compared with the results of MD and QMD simulations.

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Size-tailored Gd^{3+}-doped carbon dots for bioimaging application

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Keywords: carbon dots, Gd^{3+}-doping, fluorescence, proton relaxation time, bio-imaging,

Carbon dots (CD) were synthesized by a one-step solvothermal method and as precursors urea, citric acid and 3-(trifluoromethyl)aniline were used [1]. After synthesis, the purified CDs were fractionated into sizes ranging from 3 kDa to 100 kDa using various filter membranes. The chemical composition and optical properties of the obtained samples were studied by energy dispersive X-rays (EDX), Fourier-transform infrared spectroscopy (FTIR), dynamic light scattering (DLS), proton relaxation time measurements, ultraviolet-visible spectroscopy and fluorescence spectroscopy. A comparison of the CDs' optical properties revealed a strong correlation with their size. In vitro studies demonstrated the biocompatibility and cytotoxicity of these CDs with cells, suggesting potential applications in biomedicine, particularly for magnetic resonance imaging and red fluorescent cell or tissue imaging.

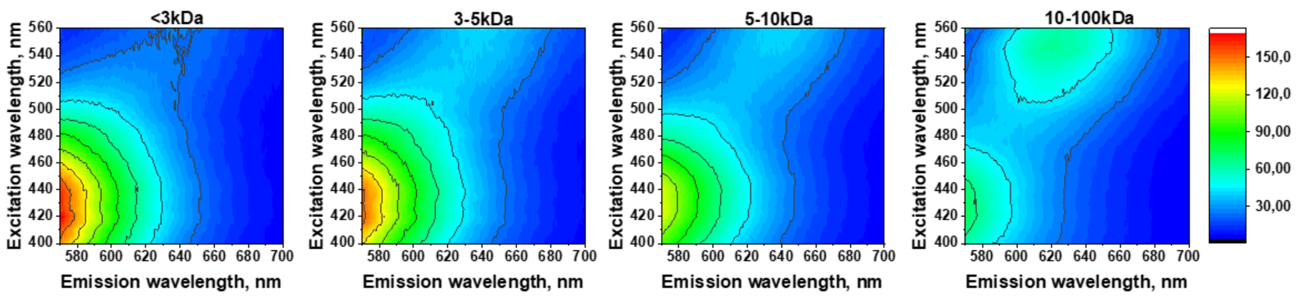

Figure 1. FL excitation/emission maps in the visible region

Figure 1 presents fluorescence (FL) maps of different sizes of CDs upon excitation in the 400–560 nm range. In these maps, except for CDs in the 10-100 kDa range, the highest FL intensity is centered around an excitation wavelength of 430 nm. This dominant FL peak, most pronounced in small particles (<10 kDa), diminishes as nanoparticle size increases. This suggests that FL in the spectral region excited between 400 and 470 nm, with emission below 600 nm, is characteristic of smaller CDs. Conversely, the intensity of red fluorescence of CDs excited at a wavelength of 540 nm increases and becomes maximal for larger particles (10-100 kDa). Therefore, it can be concluded that the optical properties of these CDs depend on their size.

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High-Precision Non-Born–Oppenheimer Calculations of BH and BH^+ Molecules: Towards Benchmark Accuracy in Multi-Electron Systems

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Keywords: BH, BH^+, Variational Method, explicitly correlated Gaussians, Non-Born–Oppenheimer calculations, relativistic effects, quantum electrodynamics corrections.

I will report a high-accuracy variational study of the ground states of the BH molecule, which is generally viewed as one of the “workbenches” of quantum chemistry, as well as its cation, BH^+. In this work, the wave functions of the eight-particle (BH) and seven-particle (BH^+) systems are expanded in terms of all-particle explicitly correlated Gaussian (ECG) basis functions and without resorting to the Born–Oppenheimer (BO) approximation regarding the separability of the electronic and nuclear motion. Each basis function incorporates both electronic and nuclear degrees of freedom, ensuring a fully coupled treatment of the internal motions of the particles forming the system. We have used the resulting nonrelativistic wave functions to compute leading-order relativistic and quantum electrodynamics (QED) corrections within the framework of the perturbation theory. I will present the total, ionization, and dissociation energies whose accuracy surpasses the previous theoretical predictions.

The present calculations demonstrate the capability of the non-BO approach that, when combined with expanding the wave function of the system in terms of ECGs, delivers high-precision descriptions of diatomic molecules. I will also show that the results not only establish new benchmarks for the BH and BH^+ species but also lay the groundwork for extending non-BO techniques to larger molecular systems with potential applications in precision spectroscopy and future advancement of quantum chemistry methods.

Structural and Property Modification of Oxide-Beryllium Ceramics Induced by Electron Irradiation

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Abstract. This work presents the results of a study on the effects of electron irradiation on the structure and properties of composite beryllium ceramics modified with micro- and nanopowders of titanium dioxide. X-ray phase analysis and scanning electron microscopy with elemental microanalysis were employed. It was established that electron irradiation induces structural and phase transformations in the ceramics, along with homogenization of the chemical composition. Magnetic measurements revealed the emergence of ferromagnetic properties in the absence of ferromagnetic impurities, presumably due to changes in the electronic density of states. The obtained results expand the understanding of the potential for targeted modification of beryllium ceramics for use in specialized electronic systems.
Keywords: beryllium ceramics, electron irradiation, titanium dioxide, microstructure, X-ray phase analysis, ferromagnetism.

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Obtaining superhydrophobic coatings by plasma treatment at atmospheric pressure

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Keywords: hydrophobicity, contact angle, PECVD method, RF-discharge, nanofilms.

Superhydrophobic coatings are applied to the surfaces of objects to provide water-repellent properties. Currently, superhydrophobic surfaces are being actively studied by various research groups due to their unique characteristics, such as self-cleaning, anti-icing, anti-fogging, low friction, and oil–water separation capabilities.

The superhydrophobic surface repels water so that a spherical drop easily rolls over the surface. It is usually characterized by a high contact angle (> 150°) and a low angle of inclination or hysteresis with a small contact angle (< 10°).

Although there are several methods for producing hydrophobic surfaces that differ in surface modification techniques, these processes are generally technologically complex and poorly reproducible. As a result, most industrial methods are expensive and applicable only to small, flat surfaces or a limited range of materials [1].

This study focuses on a comprehensive investigation of superhydrophobic surfaces obtained using PECVD (Plasma-Enhanced Chemical Vapor Deposition) in RF-discharge plasma with gas mixtures (Ar/HMDSO and Ar/TEOS) [2-4]. The synthesized superhydrophobic coatings were deposited onto silicon and glass substrates. Experimental results showed that the contact angle ranged from 140° to

165°, depending significantly on the plasma parameters. It was found that increasing the number of particle deposition cycles led to an increase in the contact angle.

Additionally, the change in contact angle over time under normal temperature and pressure conditions was investigated. The experimental results showed that films obtained in Ar/TEOS plasma began to lose their hydrophobic properties 10 months after deposition, with the contact angle decreasing to 130° after 18 months. In contrast, the samples produced using Ar/HMDSO plasma demonstrated significantly higher stability, with the contact angle decreasing from 160° to 145° over a 24-month period.

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Magnetoelectric coupling and Prospects for Quantum Multifunctional Materials for Solid State Refrigeration

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We began to realise the potential of Magneto and Electro Caloric Effect while studying ferroelectric quantum criticality and consolidating this field in its modern form as described in our recent publications [1,2,3] where we illustrate discovery and the first quantitative verification of a quantum critical point in an incipient ferroelectric. This field is an exciting new arena for discovery and leads us to broader field of multiferroic criticality [4], where spin order can be tuned by application of an electric field or charge order by a magnetic field. The materials that show the novel quantum critical behaviour at low temperatures are also the same class of materials that could be used for magnetocaloric or electrocaloric cooling, or even a combination of both.

Therefore, the background in quantum criticality and novel states of matter is in fact synergetic with the investigation and implementation of the electrocaloric effect.

We envisage the commonplace use of cooling and refrigeration systems based on the Electrocaloric effect in scientific, industrial and technological settings being operated over a wide temperature range. This solid-state, cryogen free technology promises compact, efficient, safe and environmentally friendly refrigeration with potential for use in many existing fields and markets as well as enabling new and exciting opportunities.

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The role of the WWR-K reactor in the development of HTGR technologies

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Keywords: Nuclear fuel, TRISO, HTGR, in-pile testing, WWR-K.

Since 2010, the Japan Atomic Energy Agency (JAEA) and the Institute of Nuclear Physics (INP) have been collaboratively developing fuels and materials for High Temperature Gas-cooled Reactors (HTGRs) using the WWR-K reactor, within the framework of the International Science and Technology Center (ISTC) [1,2]. Utilizing the experimental infrastructure of the WWR-K reactor, in-reactor tests of both fuel and structural materials have been conducted under representative operational conditions [3].

Specifically, irradiation experiments have been performed on TRISO fuel and HTGR fuel compacts incorporating a silicon carbide (SiC) matrix, as well as on TRISO fuel mock-ups. One key irradiation test is targeted at high burn-up HTGR fuel, achieving a burn-up level of 94 GWd/t. Fuel integrity was confirmed through monitoring of the Kr-88 release rate. The measured release rate correlated with surface uranium contamination from the fabrication process and the early failure of two particles. These observations led to the conclusion that no additional failures occurred during irradiation. Post-Irradiation Examination (PIE) of the high burn-up fuel enabled the extension of the thermal conductivity design curve. Additionally, the feasibility of a new matrix material composed of a mixture of natural and artificial graphite was demonstrated [4-6].

Research and development (R&D) efforts also focused on HTGR fuel with a SiC matrix. Two categories of SiC-based samples were investigated: pure SiC samples and SiC samples incorporating TRISO fuel particle simulators. In the simulators, the fuel kernel was replaced by SiC, which was coated with two layers of high-density pyrolytic carbon (PyC), separated by a SiC layer. Both types of samples were irradiated in an inert gas atmosphere and high temperature in the WWR-K reactor. Subsequent PIE included measurements of compressive strength, hardness, Young's modulus, dimensional stability (swelling/shrinkage), and the coefficient of thermal linear expansion.

Additionally, R&D was conducted on oxidation-resistant graphite, produced by applying a SiC coating to the graphite surface. The structural integrity of these samples under irradiation conditions was verified through surface inspections after irradiation [7-9].

The WWR-K reactor serves as a versatile multipurpose research facility and plays a pivotal role in the advancement of HTGR technology. This paper presents the testing conditions and achieves performance characteristics for each experimental test. Furthermore, it illustrates the influence of neutron irradiation and other environmental factors on the behavior of the tested materials and outlines the current experimental capabilities of the WWR-K reactor in the context of ongoing upgrades to its experimental and analytical systems.

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High-Luminosity Gridless Cylindrical Energy Analyzer with Axisymmetric Electrostatic Focusing

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Keywords: cylindrical mirror analyzer, axisymmetric electrostatic field, gridless design, second-order focusing, electron optics, energy dispersion, particle trajectory simulation, conformal mapping

Abstract:

We present a novel design of a cylindrical mirror energy analyzer (CMEA) for charged particles that operates without input/output grids. The analyzer employs an axisymmetric electrostatic field, providing high luminosity and second-order focusing in the detector plane. This gridless approach minimizes potential distortions at the particle entrance and exit, enhancing the energy resolution.

The electrostatic potential distribution within the analyzer is calculated using conformal mapping techniques and complex variable function theory. The field configuration was optimized to create a low-field region near the electrode ends, allowing particle transmission without the use of fine-structured grids. Numerical integration of the equations of motion and Monte Carlo simulations were employed to model particle beam trajectories with varying energy spreads.

Simulation results demonstrate that the analyzer achieves significant linear dispersion along the cylinder axis (~0.6 per 100% energy change) and strong focusing properties. The proposed configuration combines compact geometry, high transmission efficiency, and precise energy selection, making it suitable for electron spectroscopy applications in solid-state physics.

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Physical model for testing structural materials of fusion reactors under plasma and thermal impact

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Keywords: plasma, beryllium, thermal load, microstructure, ion fluence

The choice of plasma-facing construction materials is still important engineering issue in designing of a fusion reactor (FR). The current choice of plasma-facing materials has been made at the ITER through a compromise between a number of physical and operational requirements: minimal impact of impurity contamination on plasma performance and operation, maximum operational flexibility, and minimal fuel retention for the operation in the deuterium-tritium reaction phase.

Recently, over many decades it was supposed to use beryllium as the material of the first wall (FWP) of the ITER, and tungsten as the diverter lining. Although to date it has been decided to replace beryllium with tungsten in the ITER, this material or its compounds are still used in other TOKAMAKs [1] and may be used in the future inside the FR vacuum chamber.

This paper contains the results of beryllium tests after simulating possible thermal and plasma impacts in the FR. The key idea of the research is the possibility of conducting similar studies for any structural material according to the developed algorithm of the physical model. The main research stages are analysis, computer modeling, preparing the test object, irradiation in a plasma beam installation (PBI) [2] and a set of methods of materials science research.

Based on the results of the references analysis, heat fluxes of 2 MW/m^2 (normal) and 4.7 MW/m^2 (elevated) were determined depending on the location of the PBI in the ITER chamber and a calculation model was built in the Autodesk CFD software package. The temperature distribution in the FWP structural materials has been obtained (Figure 1) and its maximum values for beryllium testing have been determined at a normal heat flow of 360 °C, with an increased heat flow of 735°C.

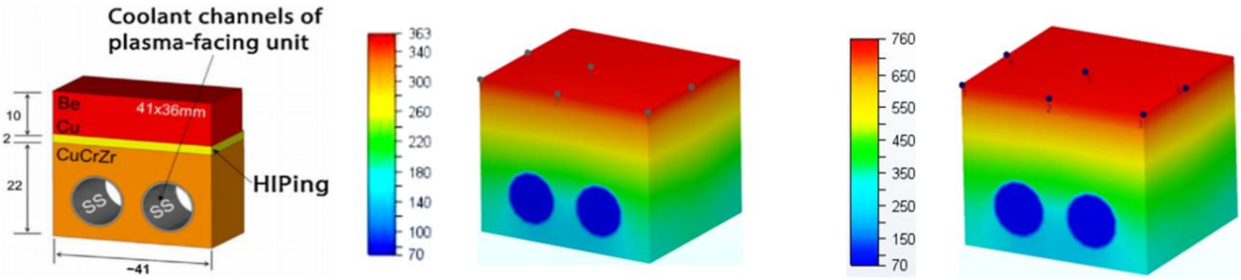

Figure 1 – Temperature distribution in structural materials of the FW

For testing the material, TGP-56 beryllium samples were prepared with a perpendicular cutout to the material surface to simulate the effects of plasma and heat flow not only on the surface, but also on the edge between the FWP gaps. The samples were alternately tested in the PBI under the irradiation with hydrogen plasma with maintaining the calculated temperatures.

The measurement, calculation and recording of the technological parameters of the experiments were carried out using a set of measuring instruments, proprietary techniques and developed data calculation programs. The PBI has been equipped with an automated complex of plasma diagnostics based on Langmuir probes, optical spectroscopy, mass spectrometry, pyrometry, etc. This complex allows obtaining the plasma parameters (temperature, concentration, flow, fluence of charged particles) in real time mode. The irradiation process, the beryllium sample, and the PBI are shown in Figure 2.

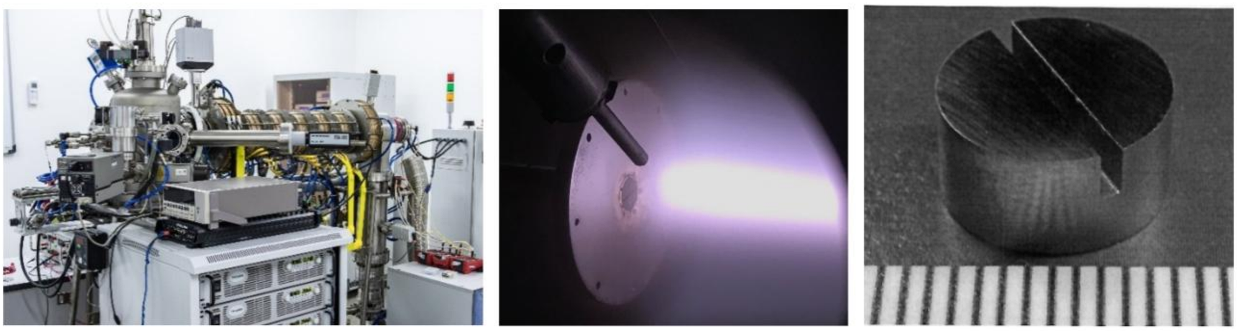

Figure 2 – PBI appearance and the process of the beryllium sample plasma irradiation

The following experimental research methods were used: microanalysis, X-ray diffraction analysis, transmission electron microscopy, determination of microhardness to study the changes in the microstructure and structural-phase states of the beryllium surface as a result of the tests. The images of the surface and fine structure of some samples are shown in Figure 3.

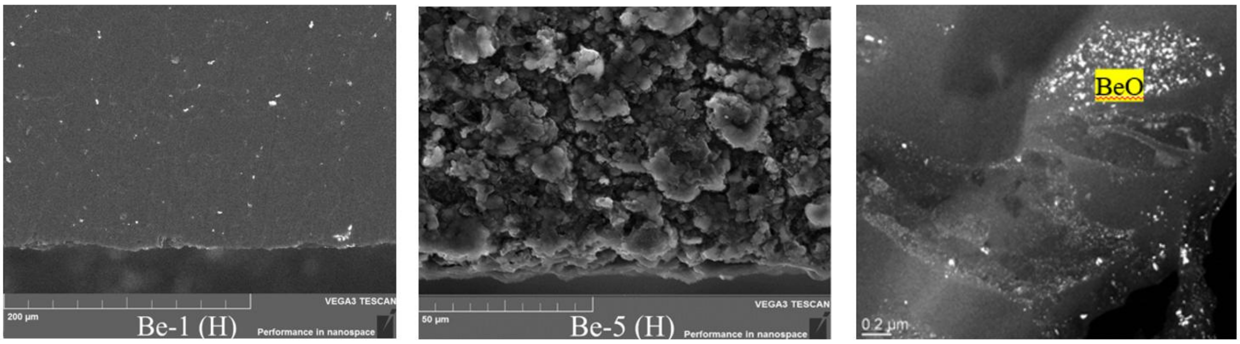

Figure 3 – SEM images of the initial beryllium Be-1(H) surface after the irradiation of plasma Be-5(H) with $3.56 \cdot 10^{26}$ H^+ fluence and fine structure of Be-5(H) after 50 000 s at 760 ° C

The effect of the hydrogen plasma and thermal loads did not have a critical effect on the structural change and destruction of the surface and edges of the beryllium samples after 50 000 seconds (100 pulses of 500 s each). An increase in the number of the irradiation cycles leads to an increase in linear pore sizes. According to the results of the phase analysis, BeO phases were detected in addition to beryllium, which is confirmed by the TEM results. Thus, this material has a high resource for its use in the FR. The physical model of simulating the experiments is used to study tungsten, beryllium, and titanium and can be used to evaluate the operational properties of any structural materials of the fusion installations.

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Synthesis of nickel-graphite nano- and micro-sized powders by liquid-phase arc discharge

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Keywords: micro- and nanoparticles; graphene encapsulation; X-ray diffraction; Raman spectroscopy; scanning electron microscopy

The synthesis of metals encapsulated in a carbon nanoshell by the method of electric arc synthesis in a liquid medium will allow not only to obtain a wider range of materials than a similar process in the gas phase, but will also allow to give the material additional physical and chemical properties.[1] In obtaining the composite material, different electrode materials and composition of liquid medium can be used, it will contribute to the ability to control the necessary material parameters. The relevance of this topic is the possibility of remote control of composite ferromagnetic particles in the liquid, which will allow high-quality separation, as well as for the use of the obtained nano- and micro-powders in alternative energy, including the production of hydrogen.

The liquid-phase electric arc synthesis unit consists of a reaction chamber, two electrodes arranged vertically along the chamber axis, an alternator, and a liquid-phase medium that acts not only as a coolant but also as an additional chemical reagent [2]. The materials of the upper and lower electrodes consist of nickel and graphite, respectively. The upper electrode is movable and oscillates relative to the lower electrode. Thus, the electric circuit between the electrodes closes and opens, forming an arc discharge plasma.

The synthesis of encapsulated nickel nanoparticles was performed in three different liquids (distilled water, alcohol, and toluene) under the same conditions. The obtained solutions with microparticles were subjected to separation and examined on analytical instruments. The sizes of the obtained nanostructures were determined using a scanning electron microscope (Fig. 1); the results showed that the nanostructures range in size from 100 nm to several microns. The phase composition of nickel particles immobilized in a carbon nanoshell was investigated by X-ray phase analysis. The analysis was performed using a Rigaku MiniFlex 600 X-ray spectrometer. To remove the amorphous carbon and the resulting nickel carbide, an annealing in an inert environment was performed.

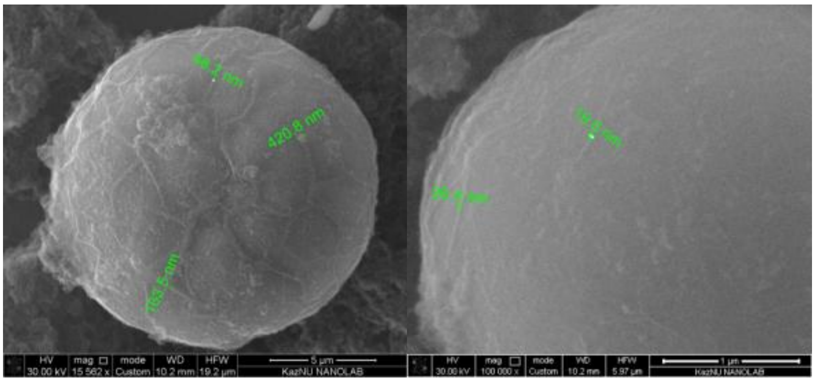

Fig. 1 Micrographs of microstructures of nickel particles in a carbon shell

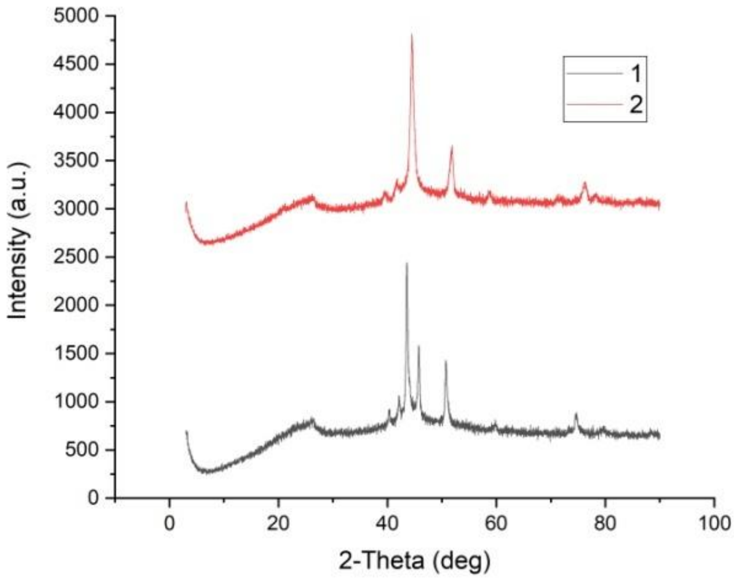

Fig. 2 X-ray phase analysis of encapsulated nickel particles obtained in toluene before annealing (1) and after (2)

According to the results of the experiments, it was found that, regardless of the liquid medium, the particles have a spherical shape, the particles synthesized in toluene were more homogeneous in size. The composition of the carbon shell was determined by X-ray analysis. In the liquid phases distilled water and alcohol the shell had graphite composition, in toluene the shell composition was graphene.

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Research to justify the safety of advanced nuclear reactors

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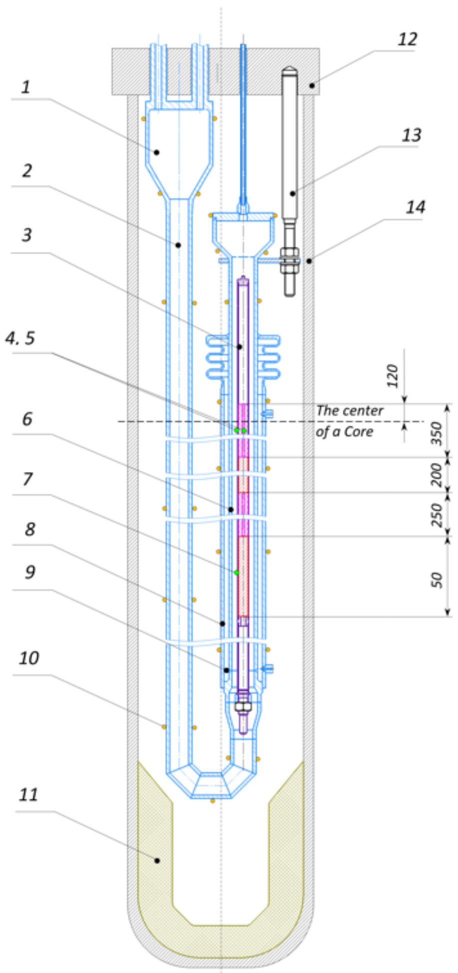
Keywords: Impulse Graphite Reactor, in-pile experiment, heterogeneous fuel rod, sodium coolant, fuel rod failure.

This research presents the results of an experiment conducted in the IGR (Impulse Graphite Reactor) to study the behavior of a heterogeneous fuel rod under loss-of-flow conditions [1]. A heterogeneous fuel rod is one of the options under consideration for the layout of a core of fast reactors [2]. The fuel rod consists of two zones of enriched fuel, separated by a fuel zone with low content of uranium-235. During the experiment, conditions were provided that correspond to the expected operating conditions of a fuel rod in a fast reactor at a nominal power, including the level and distribution of energy release throughout the height of a fuel rod and the temperature of an ambient sodium. The experiment results allowed evaluating the state of fuel pellets subjected to thermal impact, typical for the initial phase of an Unprotected Loss-of-Flow (ULOF), in which there is a decrease in heat removal from fuel rods, heating of fuel pellets up to the melting temperature and destruction of the fuel cladding. The methodological approaches and obtained experimental data will be used in preparation and conduction of experiments with model heterogeneous fuel assembly (FA) when simulating the ULOF. General view of the experimental device presented in the Figure 1.



1 – buffer tank with sodium;
2 – sodium feeding path;
3 – heterogenous fuel rod;
4,5 – thermocouples TT1, TT2;
6 – inner case of the test section;
7 – thermocouple TT3;
8 – outer case of the test section;
9 – nitrogen cooling path;
10 – electrical cable heaters;
11 – ampoule trap;
12 – ampoule lid;
13 – rod;
14 – ampoule vessel.

Figure 1 – Experimental device with heterogeneous fuel rod

The neutronic characteristics of the IGR research reactor provide an opportunity to study the behavior of fuel assemblies of various types of reactors, consisting of several dozen fuel rods containing up to 8 kg of uranium dioxide, in transient and accident modes of operation.

Starting from 2013, based on the IGR, the feasibility of an in-pile experiment to study the behavior of FAs of a fast reactor with two-component core under severe accident conditions was studied. Such a core may include an inner zone consisting of FAs which are heterogeneous in height, and an outer zone consisting of FAs which are uniform in height. This principle of core separation, together with an improved FA configuration, might it possible to reduce the positive sodium void effect of a nuclear reactor reactivity, which ultimately increases its safety level.

At the stage of integrated experiment preparation with a heterogeneous FA, an in-pile experiment with a heterogeneous fuel rod was conducted. This experiment provided preliminary data on a sequence of events that can take place in the fuel rods of a heterogeneous FA at the initial phase of ULOF, and to assess the behavior of fuel pellets subjected to thermal effects which are typical for this phase of the accident. In addition, the experiment made it possible to check methodological approaches that will be used in preparation of integrated in-pile experiments with a heterogeneous FA.

Based on the results of the implemented studies, it can be concluded that the in-pile experiment to study the heterogeneous fuel rod of a sodium-cooled fast reactor behavior during the initial phase of ULOF and to assess the state of fuel pellets subjected to thermal effects typical for this phase was carried out at the IGR reactor, which is preparatory for the integrated experiment with a heterogeneous FA. As the result, the predetermined conditions were obtained in the experimental device, the expected sequence of the events in the experimental device was provided. It was determined that with an integrated energy release of 1.56 kJ/gUO_2 in a heterogeneous fuel rod the degradation of fuel pellets and the fuel rod as a whole is observed. At the lower fission zone, degradation is insignificant and consists in partial melting of the fuel cladding, the appearance of cracks in the direction perpendicular to the pellet axis. At the upper fission zone, the fuel cladding was completely melted, the grain size was 20–40 μm. The graininess was mostly pronounced at the ends of the pellets, as well as near large cracks oriented in a direction parallel to the ends of the pellets, which could be caused by thermal etching. Also, at the upper fission zone, signs of pellet melting were observed, which is explained by the absence of micron porosity in the body of material grains and a change in the initial inner diameter of the pellet.

Comparison of the calculated and experimental values of the test parameters shows that the designed computational models (neutronics and thermohydraulic) and the applied approaches make it possible to predict the state of the heterogeneous fuel rod during testing with satisfactory accuracy and can be used as the basis for the development of a computational model and methods necessary for estimating the energy release and thermal state of a heterogeneous FA which is planned to be tested at the IGR.

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Surface Damage of Tungsten under Pulsed Plasma Exposure

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Keywords: pulsed plasma accelerator, tokamak, tungsten, brittle to plastic transition, pulsed plasma flow, microcracks, thermonuclear fusion

This paper investigates the cracking of a tungsten plate after exposure to a pulsed plasma stream. Tungsten, used as the first wall material of fusion reactors, is susceptible to brittle fractures at temperatures below the brittle to plastic transition (DBTT) [1, 2]. Exposure to high-energy fluxes caused by plasma disturbances and ELMs can induce significant thermomechanical stresses leading to the formation of microcracks [3-5]. The most intense cracking is observed when the material is cooled after it has been heated to high temperatures. Studies confirm that the initial temperature of a tungsten plate significantly affects its fracture pattern. Control of temperature conditions allows us to reduce the risk of surface damage and increase the reliability of the structure.

Experiments on the tungsten plate were carried out on a PW-7 pulsed plasma accelerator [6, 7] with the number of pulses 13, 26, and 39. Before each discharge, the plate was heated to a temperature of 823 K, which exceeds the temperature of the transition of tungsten from the brittle to the plastic state. The vacuum chamber was filled with hydrogen after pumping air to a pressure of 10^{-3} Torr; the capacitor voltage was 4 kV, and the gas pressure was 30 mTorr. Plasma parameters: velocity ~27 km/s, energy ~1.1 MJ/m², pulse duration ~200 µs. The surface morphology was investigated by scanning electron microscopy (SEM), the structure by X-ray diffraction (XRD), and the composition by EDS-analysis. In all experiments, rolled polycrystalline tungsten (99.96%) of size 15×15×2 mm uniformly irradiated with plasma was used. Before the experiments, the samples were sanded with sandpaper and electropolished, then washed in alcohol and deionized water to remove contaminants.

During the experiments, a pulsed plasma flow was applied to preheated polycrystalline tungsten plates. The temperature of the plates before each pulse was 823.15 K (±5%), which exceeds the temperature at which tungsten transitions from the brittle to the plastic state. After exposure to 13, 26 and 39 pulses with an energy density of ~1.1 MJ/m², a duration of ~200 µs and a plasma speed of ~27 km/s, the formation of morphological changes on the surface was observed. SEM analysis showed the formation of spots of different sizes containing nickel impurities, the origin of which is associated with heating and erosion of the fastening elements of the installation. These impurities contributed to a local change in morphology, causing the appearance of blisters and cracks. According to EDS data, the original surface consisted exclusively of tungsten, but after exposure, nickel-containing areas appeared. The formation of blisters is explained by the diffusion of hydrogen under thin films of impurities and its accumulation in thermal stress zones, which confirms previously obtained data on the effect of the coating on the intensity of the blister formation process.

Preheating of the plates showed a positive effect: the crack width decreased significantly from 7-10 μm (according to previous work for unheated samples [8] and other works [9, 10]) to 300-315 nm. Changing the number of pulses (13, 26, 39) did not lead to a significant increase in damage, but a slight reorientation of the cracks and a change in their shape associated with the redistribution of thermal stresses were observed. The total crack area according to ImageJ was 7.4 μm^2 (1%) after 13 pulses, 12 μm^2 (1.6%) after 26, and 11.65 μm^2 (1.56%) after 39, indicating saturation of the destruction process. XRD analysis showed a shift of the diffraction line (321) towards higher angles, indicating the occurrence of compressive stresses in the surface layer. The calculations showed a stress value of the order of 125.6 MPa. A broadening of diffraction lines was also observed, indicating an increase in dislocation density. Increasing the number of pulses had no significant effect on the stress level, which emphasizes the importance of temperature preparation of the material.

In addition, it was found that craters caused by unipolar arcs similar to those observed on the surface of the T-10 tokamak were formed on rough areas, especially in crack zones. These craters had a hemispherical shape and indicated the action of explosive electron emission. It is important to note that when using preheating, the formation of tungsten dust and droplets was significantly reduced, in contrast to previous studies, where such defects were intense. Thus, heating the plate above the transition temperature of tungsten to the plastic state allows for effective control of surface destruction and minimization of erosive effects under thermal plasma loading.

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Characterization of Nanomaterials Synthesized in Ar/C2H2 DC Glow Discharge Plasma

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Keywords: Plasma-Kristall experiment, nanoparticle synthesis, PECVD, plasma luminescence, particle motion

In this report we present an experimental result on the study of dusty plasma characteristics with carbon nanoparticles as dust component in the plasma environment of Ar/C2H2 gas mixture of a DC glow discharge in an experimental setup consisting of a П-type glass tube (according to PK-4 facility at ISS). Experimental results revealed that the growth of nanoparticles occurs by the generations.

The phenomenon of cyclic nanoparticle growth occurring during intervals of plasma cessation was observed, consistent with the characteristic nanoparticle synthesis within plasma environments discernible by direct observation [1]. In addition, it was found that the presence of nanoparticles in the positive column of the glow discharge has a significant effect on the plasma luminescence intensity, as shown in Figure 1 [2,3]. In addition, the dependence of the time interval between nanoparticle generations on the discharge voltage was observed during the experiments.

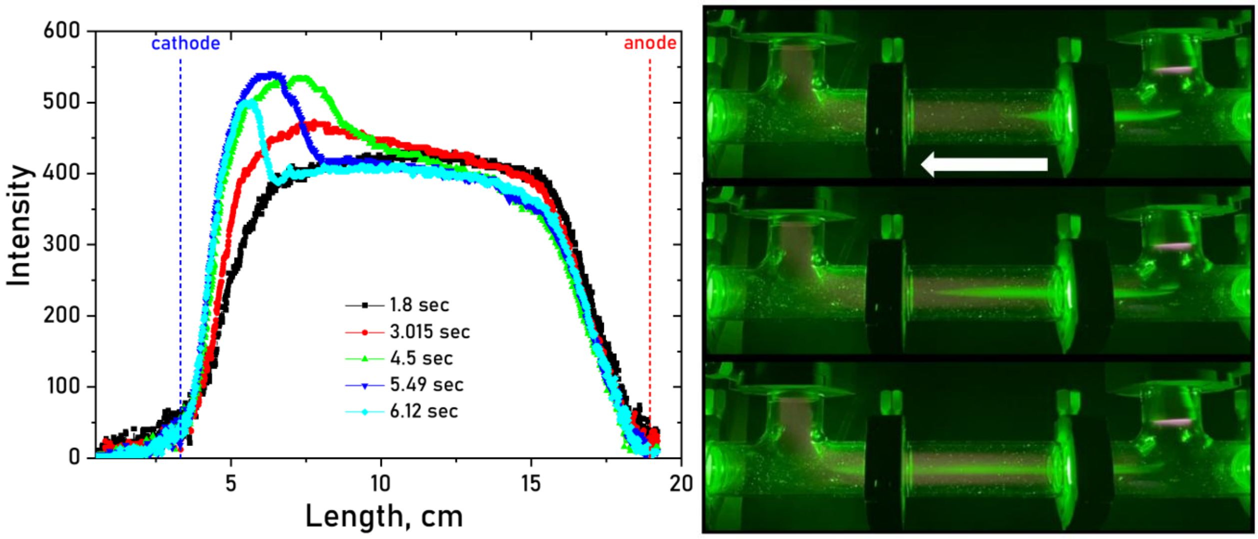

Fig. 1. Change of plasma luminescence intensity during the dust particle motion

Additionally, during the experiments, a correlation of the time interval between nanoparticle generations and the discharge voltage was observed. It was found that as the discharge voltage rises, the time between nanoparticle generations decreases [4,5].

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Nitrogen-Doped Carbon Nanowalls as Efficient Platforms for Hydrogen Peroxide Detection

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Keywords: Carbon nanowalls, Hydrogen peroxide, Biosensor, H_2O_2 detection, RI-PECVD, Nitrogen doping

The development of miniaturized, low-cost, and enzyme-free sensors based on nanomaterials using advanced fabrication techniques holds significant promise for biological detection applications. Among various nanomaterials, carbon-based electrochemical sensors have shown excellent sensitivity for detecting trace levels of analytes [1,2]. One particularly promising material is carbon nanowalls (CNWs)—vertically oriented, interconnected graphene sheets [3] – which have attracted growing interest due to their high electrical and thermal conductivity, large surface area, excellent electrocatalytic activity, and sensitivity toward various analytes.

In this study, nitrogen-doped CNWs were synthesized and employed in the fabrication of electrochemical sensors for hydrogen peroxide (H_2O_2) detection. The CNWs were grown on $Ti/SiO_2/Si$ substrates using the radical-injection plasma-enhanced chemical vapor deposition (RI-PECVD) method, with varying nitrogen concentrations introduced during synthesis. Structural and morphological properties were characterized using Raman spectroscopy, X-ray photoelectron spectroscopy (XPS), and electron microscopy.

Electrochemical performance was evaluated through cyclic voltammetry and chronoamperometry. Nitrogen doping was found to significantly enhance the electrochemical properties of CNWs. In particular, the sample synthesized at a high nitrogen flow rate (N_2: 20 sccm) exhibited the highest amperometric response, excellent electrocatalytic activity for H_2O_2 reduction, and a wide linear detection range from 1 μM to 250 μM. It also demonstrated a low limit of detection (LOD) and high sensitivity of 679.6 $\mu A \cdot mM^{-1} \cdot cm^{-2}$.

These results demonstrate a promising strategy for tailoring the electrochemical properties of CNWs via nitrogen doping, paving the way for the development of cost-effective, metal-free, and high-performance biosensors for hydrogen peroxide detection.

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Contribution of the Institute of Nuclear Physics to the strategic and sustainable development of Kazakhstan through scientific research, development and implementation of the world-wide technologies for peaceful atomic energy

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Institute of Nuclear Physics of the Republic of Kazakhstan

In the present abstract the main achievements of the team of authors from the Institute of Nuclear Physics (INP) are designated for the period of 2009-2024 in field of use of atomic energy for peaceful purposes both in fundamental research and high technological products, also submitted for the Al-Farabi State Prize of the Republic of Kazakhstan in field of Science and Technology in 2025.

On the base of light nuclei structure models developed at the INP calculations of great interest for nuclear astrophysics and thermonuclear fusion energy development have been carried out [1]. The studies on development of new materials with specified properties for atomic industry as well as radiation-resistant materials with enhanced reliability and resourse being carried out at the INP are also directed toward the aim with fusion energy. A set of works has been carried out on studies of materials of blanket-breeder of thermonuclear reactors. At the WWR-K reactor the works on testing and studies of generation processes and release of tritium and helium out of lithium ceramic (Li_4SiO_4, Li_2TiO_3) under the neutron irradiation have been carried out. The applied results of investigations are the unique data on testing materials of high temperature gas-cooled reactors, which have been used when projecting commercial small modular reactors.

The development of strategically important field in the state, the atomic energy, was facilitated by the works on conversion of research nuclear WWR-K reactor and critical assembly facility with transition to low enriched fuel. As a result of these works the parameters of the reactor have been enhanced which influenced positively the ongoing studies and expansion of a spectrum of new scientific problems. An invaluable contribution to the development of healthcare system in the state is being made by the radiopharmaceuticals produced at the INP which are used in diagnosing and therapy of cancer diseases. There has been established a production of industrial radionuclide sources which are used in radiography of welded joints of oil and gas pipelines as well as inspection of atomic reactors construction designs [3]. Furthermore, the active participation of INP specialists in works on projecting of virtually all centers of nuclear medicine established in Kazakhstan and new objects for use of atomic energy at the sites of the INP contributes significantly to the development of this strategically important direction in the state.

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Continuous spectra of light charged particles from interaction of 22 and 30 MeV energy protons with nuclei

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Keywords: nuclear reaction, cyclotron, cross section, exciton model, detector

Working out the preequilibrium decay mechanism in nuclear reactions remains an actual problem of the nuclear reaction theory. The problem is largely connected with obtaining the new experimental data on double-differential cross sections in (*p,xp*), (*p,xd*), etc., reactions with different proton energies. These reactions play a role in the applied researches on secure and wasteless nuclear power system creation accelerator subcritical reactor.

Reviews on available experimental data of reactions with nucleons are presented in [1, 2]. Several experiments on double-differential cross sections measurements have been performed at energy about 30 MeV [3–9]. More over at this energy many channels of reactions are open, and the total cross section of the reactions for nuclei of such mass region reaches its maximum.

The experimental cross-section measurements of (*p,xp*) reaction were carried out on a beam of accelerated protons at the energy of 22 and 30 MeV on the isochronous cyclotron, U-150M, at the Institute of Nuclear Physics by using a self-supporting targets of different elements which have been chosen as the objects of our investigation since they are the construction elements of a hybrid nuclear energy plant and experimental data on which are necessary for the development of ADS systems.

Many different theoretical approaches have been used to describe the preequilibrium reaction data over a wide range of incident energies. The analysis of the experimental results of reactions (p,xp) at E_p = 22 and 30.0 MeV was performed in the framework of the exciton model of nuclear decay [10] describing the transition of the excited system to the equilibrium state. The Griffin exciton model is a statistical model, which describes the excited levels of the intermediate system in terms of the single-particle shell model, i.e., characterized by the number of the excited particles (above the Fermi level) and holes (below the Fermi level). In the two-component exciton model, proton and neutron degrees of freedom are taken into account separately [11] and it is assumed that the nucleus is characterized by the parameters p_π, h_π, p_ν and h_ν, where *p* and *h* denote particle and hole, and π and ν are proton and neutron degrees of freedom, respectively.

Theoretical calculations were performed using the Talys code optimized for the case under consideration. We chose the $(p_\pi, h_\pi, p_\nu, h_\nu) = (1,0,0,0)$ particle–hole configuration as our starting point. The normalization coefficient K_g was taken to be

15 MeV. The square of the matrix elements was parameterized using the normalization constants $K_{\pi\pi}$*:* $K_{\pi\nu}$*:* $K_{\nu\nu}$*= 2200:900:900 МэВ*^{2}.

It follows from a comparison of the experimental and theoretically calculated integral spectra that the main contribution to the formation of the integral cross section for (p,xp) reactions comes from the preequilibrium mechanism.

This experimental study is very important for the extension of the preequilibrium experiments in this direction to see the mechanism of the reaction and the level of energy dependence. It is also important to observe the adequacy of the above-mentioned theoretical models to explain the measured experimental data.

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CO_2 Detection Using Carbon Nanowall-Based Gas Sensors

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Keywords: Carbon nanowalls, gas sensors, CO_2

Carbon nanowalls (CNWs) have garnered significant interest for gas sensing applications due to their outstanding material properties, including a large specific surface area, high electrical conductivity, porous nano-/microstructure, and excellent charge carrier mobility [1-2]. In this study, CNW films were synthesized and employed in the fabrication of gas sensors for carbon dioxide (CO_2) detection [3].

The CNWs were synthesized using an inductively coupled plasma (ICP) plasma-enhanced chemical vapor deposition (PECVD) method. Their structural and morphological properties were analyzed using Raman spectroscopy and electron microscopy. Two sensor fabrication approaches were explored: (1) direct synthesis of CNWs onto interdigitated gold (Au) microelectrodes on quartz substrates, and (2) transfer of pre-synthesized CNW films onto interdigitated Au microelectrodes on glass substrates.

The CO_2 sensing performance of the fabricated devices was evaluated across various gas concentrations and operating temperatures. Results showed a linear increase in sensitivity with both CO_2 concentration and temperature. Notably, devices with maze-like CNW structures demonstrated superior performance compared to those with petal-like morphologies. A maximum sensitivity of 1.18% was recorded at a CO_2 concentration of 500 ppm and a temperature of 100 °C.

These findings highlight the potential of CNW-based sensors as a promising platform for the development of efficient, scalable, and low-cost gas sensing devices for environmental monitoring and toxic gas detection.

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2 POSTER SESSION

Synthesis of Carbon Nanomaterials PECVD in DC Discharge Plasma

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Keywords: Dusty plasma, electron temperature, PECVD, plasma with nanoparticles, optical spectroscopy.

In modern science and technology, the demand for nanomaterials is growing rapidly. In particular, carbon-based nanoparticles – such as nanotubes, nanofibers, and nanowalls – with controllable structure and properties are widely used in the fields of electronics, energy, and sensor devices. One of the most effective methods for synthesizing such materials is plasma-enhanced chemical vapor deposition (PECVD), a technology that enables controlled growth of nanostructures from the gas phase.

The study is focused on the synthesis of a diamond-like carbon (DLC) film in an Ar-C_2H_2 plasma under a direct current (DC) glow discharge, as well as the investigation of its chemical composition and properties. The experimental parameters were as follows: pressure – 1 torr; voltage – 1 kV; and a gas mixture of 98% Ar and 2% C_2H_2 [1,2]. Plasma was ignited at various time intervals, and the resulting products were analyzed using Atomic Force Microscopy (AFM), Raman Spectroscopy, X-ray Photoelectron Spectroscopy (XPS) methods.

During the experiment, a diamond-like carbon (DLC) film was synthesized on the surface of a negatively charged electrode. The thickness of the deposited layers was investigated using atomic force microscopy (AFM). Structural features of the synthesized film were examined via Raman spectroscopy, providing essential information on the formation of the diamond-like phase. The T, D, and G peaks were identified, and the dispersion of the G peak was analyzed. The chemical composition of the material, specifically the sp^2 and sp^3 hybridized states, was studied using X-ray photoelectron spectroscopy (XPS) (Figure 1). The obtained data allowed for the identification of chemical bonds involving carbon, oxygen, and nitrogen elements.

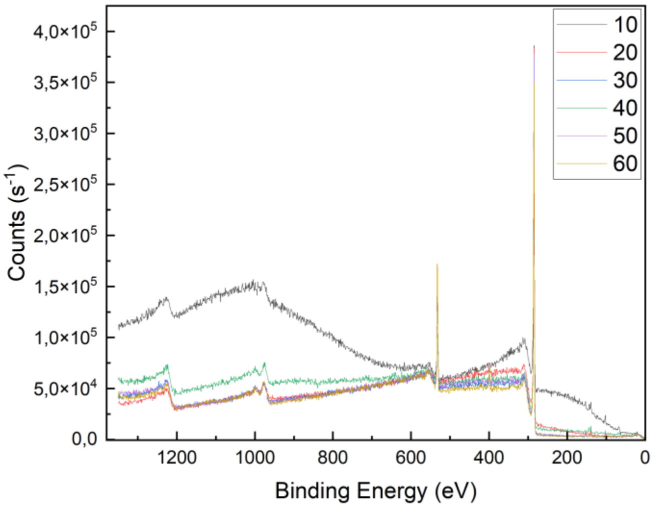

Figure 1 – XPS analysis of the synthesized samples.

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Synthesis of Chondrule-like particles in a plasma environment

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Keywords: Chondrules, Chondrites, Protoplanetary disc, Plasma synthesis, RF discharge, Fe-Si nanoparticles, Crystallization, Pulsed plasma, Meteorite analogues, Mössbauer spectroscopy.

Chondrites are primitive meteorites containing rounded structures, chondrites, which are considered to be among the oldest solid formations in the solar system. They are composed of silicate and metallic components, indicating complex thermal and physicochemical processes during their formation. According to existing hypotheses, chondrites were formed as a result of rapid heating and melting of dust particles in the protoplanetary disc, followed by their rapid cooling and aggregation. Despite numerous studies, the exact mechanism of their origin remains controversial, and laboratory reproduction of these conditions requires special experimental approaches. In this work, we performed laboratory synthesis of Si-Fe-based chondro-like particles under HF discharge conditions, which allowed us to reproduce the key stages of their formation in the protoplanetary disc. The experiments produced nanoparticles of 50-500 nm in size, composed of silicon and iron, with characteristic spherical and aggregated morphologies. XRD and Mössbauer spectroscopy confirmed the presence of amorphous and crystalline Fe-Si phases characteristic of natural chondrites. In addition, the synthesised particles were exposed to a pulsed plasma discharge (T > 1500 K), which led to their partial melting and recrystallisation. The formation of crystalline structural phases such as $FeSi2$ (β -FeSi2 - low-temperature; α -FeSi2 - high-temperature), similar to the textures of chondrites in meteorites, was observed. The results obtained allow us to reproduce in laboratory conditions the processes of aggregation, melting, and crystallisation of dusty material, which confirms the hypothesis about the possible formation of chondrites in the conditions of plasma processes in the early Solar System.

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On the phase and group velocity in quark–gluon plasma

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Keywords: phase velocity; group velocity; quark–gluon plasma; dispersion relation; waves in quark-gluon plasma

The quark-gluon plasma (QGP) is a special state of matter under extreme conditions, which is formed at high temperatures and energy densities [1]. Such conditions occur naturally in the cores of massive celestial bodies [2], as well as in the early stages of the development of the Universe. Moreover, such a state of matter under controlled parameters can be obtained in particle collision experiments at ultra-relativistic velocities. Such experiments are carried out at the LHC and RHIC.

The scope of this investigation is the collective effects of the new state of matter, particularly the optical properties of the matter. Since the formation of QGP is predicted, the dielectric function of the matter has been studied. Using the dielectric function, one can calculate the dispersion relation of the waves in medium and at the boundary of QGP. It will provide the information on the refractive index of the medium in the linear response theory approach.

Two theoretical models of QGP have been used: the collisional QGP and the viscous QGP. The first model is derived from Boltzmann transport equation that includes pair collision operator of BGK in scope of kinetic theory [3-4]. Here, QGP is considered to behave like weakly coupled gas with binary collisions. The second model is derived from relativistic hydrodynamics equations in scope of QCD [5]. The model describes strongly coupled system with small shear viscosity, because the last experimental data from RHIC predicted ideal fermi liquid behavior of QGP. Dispersion relation of these two models describes the propagation of waves in media, from weakly coupling to the strong correlation limit [6]. The collisional model corresponds to low temperature and high baryonic density regime that can occur in core of massive compact objects, whereas the viscous model corresponds high temperature and low baryonic density regime that can occur in the matter of Early Universe. Phase and group velocity can be calculated from dispersion relation, and provide new information about the state of matter [7].

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The influence of fillers on the structure and properties of ultra-high molecular weight polyethylene

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Keywords: UHMWPE, DB, acid stability, IR analysis, X-ray diffraction analysis

This paper presents the results of a study of a composite coating made of ultra-high molecular weight polyethylene (UHMWPE) with a diabase filler obtained by flame spraying. Diabase of 10 wt.%, 20 wt.%, 30 wt.% and 40 wt.%. was chosen as a filler. The polymer coating was applied to the St3 metal substrate by temperature control in a conventional flame spraying process. The coating was studied by scanning electron microscopy, X-ray phase analysis, infrared spectroscopy, abrasive wear resistance, microhardness testing and determination of the friction coefficient. It has been shown that diabases do not have a negative effect on the initial chemical structure of UHMWPE and it is not subjected to destruction during flame spraying. The

introduction of diabase into the composition of UHMWPE with a content of 10-40% of the total mass does not adversely affect the crystalline structure of the coating. It has been established that with an increase in the volume of the diabase filler, the wear resistance of the composite coating based on UHMWPE increases. It has been determined that with the addition of diabase, the microhardness of the coatings increases.

Various studies have shown that the incorporation of inorganic fillers into the structure of ultra-high molecular weight polyethylene significantly enhances its mechanical, tribological, thermal, and corrosion-resistant properties [1–4].

This work was carried out within the framework of the following projects: the fundamental research project of the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan, IRN No. AP09259925 “Development and implementation of a high-performance technology for applying an anti-corrosion coating based on ultra-high molecular weight polyethylene” (2021–2023), and IRN No. AP19679461 “Development and implementation of a radiation- and corrosion-resistant protective composite material based on ultra-high molecular weight polyethylene with fillers” (2023–2025).Основные результаты работы опубликованы в следующих статьях:

1 Skakov, M.; Bayandinova, M.; Ocheredko, I.; Tuyakbayev, B.; Nurizinova, M.; Gradoboev, A. Influence of Diabase Filler on the Structure and Tribological Properties of Coatings Based on Ultrahigh Molecular Weight Polyethylene. Polymers 2023, 15, 3465. https://doi.org/10.3390/polym15163465;

2 Skakov, M.; Ocheredko, I.; Tuyakbayev, B.; Bayandinova, M.; Nurizinova, M. Development and Studying of the Technology for Thermal Spraying of Coatings Made from Ultra-High-Molecular-Weight Polyethylene. *Coatings* 2023, *13*, 698. https://doi.org/10.3390/coatings13040698

3 Skakov, M.; Bayandinova, M.; Kozhakhmetov, Y.; Tuyakbaev, B. Microstructure and Corrosion Resistance of Composite Based on Ultra-High Molecular Weight Polyethylene in Acidic Media. Coatings 2025, 15, 89. https://doi.org/10.3390/coatings15010089

Based on the analysis of previous research results, the idea emerged to enhance the physical and mechanical properties of ultra-high molecular weight polyethylene by introducing mineral filler particles. It is assumed that the incorporation of a mineral filler in the form of diabase into UHMWPE will promote the formation of an optimized coating structure, leading to improved physical-mechanical, tribological, and corrosion-resistant properties.

It is worth noting that diabase, as a mineral raw material similar to basalt, possesses good mechanical properties, chemical resistance to aggressive environments, affordability, and environmental friendliness. Diabase is a volcanic igneous rock, whose main component is well-preserved plagioclase—colorless and transparent—with rare occurrences of pyroxene. Its melting temperature ranges from 1005 to 1250°C.

However, in our opinion, the effect of diabase as a filler on the structure and properties of UHMWPE-based composites has not yet been sufficiently studied. For this reason, conducting systematic research on the influence of diabase—a mineral filler—on the structure of UHMWPE, as well as on its mechanical, tribological, and corrosion-resistant properties, is of considerable scientific and practical interest. Based on the results obtained:

1 the regularities of the influence of diabase—a mineral filler—on the structural-phase state of UHMWPE-based composite coatings obtained by flame spraying have been established. The incorporation of diabase in the amount of 10–40 wt.% into UHMWPE does not significantly affect the crystallinity of the coating or its chemical structure.

2 the role of diabase mineral filler in improving the physical and mechanical properties of UHMWPE-based composite coatings has been identified and quantitatively assessed. The enhancement of these properties strongly depends on the diabase content. For instance, the microhardness of pure UHMWPE coating is 5.34 Hv, while for coatings with 10 wt.% diabase it increases to 5.67 Hv, with 20 and 30 wt.% diabase—6.15 Hv and 6.95 Hv, respectively, and reaches 7.27 Hv at 40 wt.%. The wear resistance of the UHMWPE-based composites increases as the matrix is filled with higher amounts of diabase, more than doubling at 40 wt.% compared to pure UHMWPE. Surface roughness also rises from 1.237 to 4.311 μm. Furthermore, the addition of diabase significantly reduces the coating's coefficient of friction: from ~0.17 for pure UHMWPE to ~0.14, ~0.09, ~0.06, and ~0.05 for coatings with 10, 20, 30, and 40 wt.% diabase, respectively.

3 the resistance of UHMWPE-based composites with diabase mineral filler to aggressive environments has been established. Samples made of pure UHMWPE and UHMWPE with 10 wt.% diabase exhibited the highest chemical stability in acidic media. After chemical exposure, the crystallinity of the pure UHMWPE coating decreased by 22%, while that of the UHMWPE composite with 10 wt.% diabase decreased by only 18%.

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ANTIBACTERIAL NANOCOMPOSITE MATERIAL BASED ON BENTONITE CLAY

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Bentonite clays are natural minerals characterized by unique physical and chemical properties, including high adsorption capacity, ion exchange capacity and gel formation potential. These qualities make bentonite widely applicable in various fields. In medicine, bentonite clay is used as an adsorbent for detoxification, in the treatment of gastrointestinal disorders, and in dermatology for skin care and the treatment of inflammatory conditions. Research shows that bentonite clays have potential antibacterial and anti-inflammatory properties, which opens up new possibilities for their use in medical and biomedical fields. These features make them a promising resource for the development of innovative therapeutic agents and treatment approaches.

In this context, the physical and chemical properties of local bentonite clays were analyzed to determine the most suitable type for wound healing application. Bentonite clay from two horizons of the Taganskoye deposit, which is located in Eastern Kazakhstan, was selected as optimal in terms of its properties, which correspond to the pharmacopoeial article. Based on these results, wound healing films were developed using gelatin and bentonite clay, incorporating different concentrations of zinc oxide nanoparticles and plant extract. These films were thoroughly evaluated for antibacterial properties and physicochemical characteristics, demonstrating their potential effectiveness for wound healing.

Keywords: bentonite, montmorillonite, medicine, Tagan deposit.
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Developing research skills in prospective physics educators through STEM-based education

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Keywords: STEM, aspiring physics educator, laboratory activities, research expertise.

Research competencies among students, particularly future physics teachers, have a significant impact on the quality of education. As a result, considerable attention is given to studying methods for developing these competencies, including the implementation of modern educational technologies such as STEM. For instance, Kin et al. (2022) examine the development of research competencies in the Education 4.0 era, emphasizing the urgent need to address this issue.

A number of studies propose various approaches to solving this problem, particularly through the use of digital technologies (Howard et al., 2021; Fernández-Batanero et al., 2022; Berikkhanova et al., 2023). Other approaches include STEM leadership training (Yilmaz, 2022; Widiyanto et al., 2021), an ecological approach (Bukusheva et al., 2023), project-based learning combined with STEM (Imbert Romero et al., 2024; Hattie, 2011), and the integration of digital technologies with STEM learning (Qiuhui & Thitinant, 2023; Maulana, 2020).

However, a review of the existing literature shows that the problem of developing research competencies is rarely considered from the perspective of using available scientific equipment and instruments. Meanwhile, most universities possess experimental analytical devices (e.g., TEM, SEM, XRF, EPR, NMR, IR spectroscopy) operating based on various physical principles. In particular, electron and X-ray diffraction are widely used in instruments such as transmission electron microscopy (TEM), scanning electron microscopy (SEM), and X-ray diffractometry. Despite their extensive use in scientific research, these instruments are rarely incorporated into the educational process to enhance students' research competencies.

Some studies have attempted to integrate wave optics phenomena, such as interference and diffraction, into the training of future physics teachers to develop their critical thinking skills (Saprudin et al., 2019; Mešić et al., 2021). Researchers highlight that the wave optics section in general physics courses requires additional attention in teacher preparation, as it not only strengthens methodological training but also deepens students' understanding of the subject (Aragón et al., 2019).

Furthermore, according to Bunaciu et al. (2015), X-ray diffractometry, as one of the most rapidly developing experimental-analytical methods for material research, plays a direct role in shaping research competencies. However, an analysis of university curricula reveals a lack of methodology for conducting laboratory work on topics such as "electron diffraction" and "X-ray diffraction."

The integration of X-ray diffractometers into the educational process, in combination with STEM education and other innovative technologies, appears to be a promising direction for fostering scientific and research competencies among future physics teachers.

As a result, this paper proposes a methodology for developing research skills in future physics teachers through the study of the "X-ray Diffraction" section of the physics curriculum. The approach includes carefully designed tasks and laboratory experiments aimed at fostering research abilities. The study confirms the effectiveness of this structured system of tasks and its corresponding methodology.

An analysis of psychological, pedagogical, and methodological literature has identified the theoretical foundations necessary for preparing future educators for research activities. It is established that research skills are a crucial component of professional training for physics teachers. The study highlights the role of STEM education in developing these competencies and justifies the selection of criteria for assessing the levels of research skills in future physics teachers.

The proposed model has demonstrated its versatility and can serve as a framework for other disciplines within the natural and mathematical sciences. The research shows that physics students' research competencies—characterized as a combination of sustained motivation for scientific inquiry and proficiency in applying physical research methods—can be effectively cultivated by integrating STEM education into laboratory work on "X-ray Diffraction." The results indicate that incorporating STEM elements into physics lab exercises, particularly in diffraction studies, significantly enhances students' research skills, better preparing them for independent research in their senior years. This, in turn, improves the overall research competence of future physics teachers.

The study has also defined the structural components of research competencies in future physics teachers, along with key indicators of their development. These indicators include strong motivation for research activities, an active interest in scientific literature, initiative in identifying and solving research problems, systematic execution of research processes, critical analysis of research outcomes, logical assessment of findings, clear and structured presentation of results, and a strong inclination to integrate research into their professional career. Based on these indicators, a diagnostic framework was developed to evaluate the formation of research competencies in future physics teachers.

The findings suggest that combining STEM-based teaching techniques with traditional methods in the laboratory practicum on X-ray diffraction effectively enhances research competencies in future physics educators.

The study led to several key conclusions. A survey assessing the current state of research competencies among future physics teachers revealed that their competency levels are relatively low and require urgent improvement through well-structured methodological training in universities. To address this, a methodological framework was developed to enhance research competencies (Skakov M., Dalabayev, T. 2024). A pedagogical experiment validated the effectiveness of this approach, showing a 22.5% improvement in knowledge acquisition. Based on these findings, a model for developing research competencies in future physics teachers, grounded in STEM education, was formulated and confirmed as an effective educational strategy.

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A TECHNOLOGY FOR MAKING DETONATION COATINGS ON POWER EQUIPMENT PARTS

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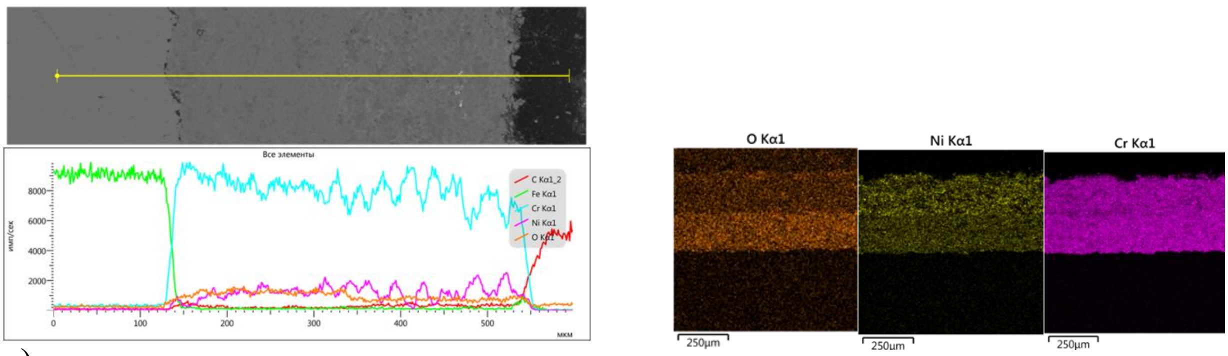
Abstract: This paper presents a comparative study of Cr3C2-NiCr coatings and 12Kh1MF steel under corrosive, erosive, and high-temperature conditions. Coatings were applied by detonation spraying at various oxygen/propane flow rates and distances. The study assessed high-temperature oxidation and corrosion resistance of uniform and gradient coatings versus uncoated steel. An erosion test apparatus was developed, allowing temperature control up to 650°C and particle velocities of 25 m/s under varied conditions. Results show porosity greatly affects corrosion and wear resistance. The combined corrosion-erosion analysis offers insights for component design.
Keywords: detonation-spraying method, Cr3C2–NiCr,, heat-resistant steel, wear resistance, thermal power industry, thermal power plants, reliability.

1. Introduction. In the Republic of Kazakhstan, more than 79% of electricity is produced by coal combustion, and it should be noted that more than half of thermal power plants (TPPs) have an average service life of more than 30 years. The majority of their equipment items have worked out their design and standard service life, a factor that causes degradation of their operational reliability. The problem of preventing failures of the existing equipment caused by accumulation of its internal and external damages remains of issue. Currently, improving the reliability and increasing the service life of components whose performance characteristics are governed by the properties of their working surfaces is a topical issue. One of most promising methods of improving the performance proper ties and increasing the service life of components is to apply functional coatings on their surfaces by using various spraying technologies [2, 3].

2. Materials and Methods. This paper presents a comparative study of Cr3C2-NiCr coatings and 12Kh1MF steel under corrosive, erosive, and high-temperature conditions. Coatings were applied by detonation spraying at various oxygen/propane flow rates and distances. The study assessed high-temperature oxidation and corrosion resistance of uniform and gradient coatings versus uncoated steel. An erosion test apparatus was developed, allowing temperature control up to 650°C and particle velocities of 25 m/s under varied conditions. Results show porosity greatly affects corrosion and wear resistance. The combined corrosion-erosion analysis offers insights for component design.

3. Results. We analyzed the surface morphology by scanning electron microscopy (SEM). The cross-section SEM images (Figure 2) shows the Cr3C2-NiCr coatings with the EDS analysis results. The gradient coating based on Cr3C2-NiCr was synthesized by progressively reducing the barrel filling volume from 73% to 57% with an explosive gas mixture. This specific spraying mode was selected based on prior experimental results, with the objective of producing coatings wherein the distribution of carbide phases in the gradient Cr3C2-NiCr coating progressively increases from the substrate to the surface. As a result, a substantial number of carbide phases uniformly augment from the substrate to the coating surface. It is posited that the Cr3C2-based carbide, which forms on the surface at a barrel filling volume of 57% with an explosive gas mixture, enhances wear resistance and hardness. Conversely, the CrNi3 phase formed in proximity to the substrate ensures the coatings' high adhesive strength.



a) b)

Fig.1. SEM images of cross-section and elemental depth distribution of Cr3C2-NiCr gradient coating.

Table 1 shows the measured characteristics of the gradient coatings. According to the elemental analysis data, the element distribution by the coating thickness can be seen along the line (Figure 3.12). The EDS analysis along the lines was carried out in the direction from the surface to the substrate. According to the EDS analysis results, it can be seen that the Cr coating (which has a dark shade) gradually increases from the substrate to the coating surface, and the Ni content decreases. The results of measuring the microhardness of the Cr3C2-NiCr coatings showed a smooth decrease in hardness from the surface to the substrate. On the coating surface, the microhardness has a value of 11.9 GPa and closer to the substrate, it has a value of 10.1 GPa.

The results obtained (see Fig. 5) indicated that Sample #2 exhibited a more stable weight increase. This is likely due to the Cr3C2-NiCr coating successfully protecting the sample.

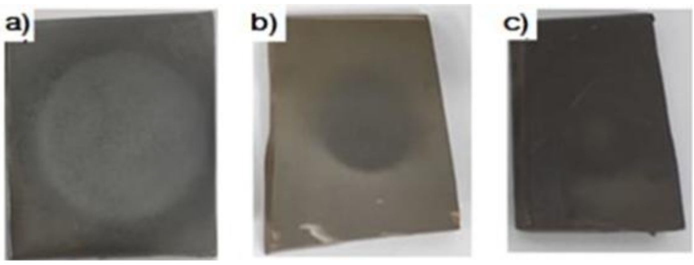


Fig.2. Result of rig tests of samples. a) Sample #1; b) Sample #3; c) Sample #2

The resistance of samples with gradient coating, uniform coating, and no coating to high-temperature oxidation was investigated. The experiments were conducted according to GOST 6130-71 at a temperature of 900°C, with 50 cycles. After holding at the specified temperature for 1 hour, the samples were cooled in air for 20 minutes. This procedure constitutes one cycle of high-temperature oxidation. After each cycle, the mass of each sample was measured (Figure 3).

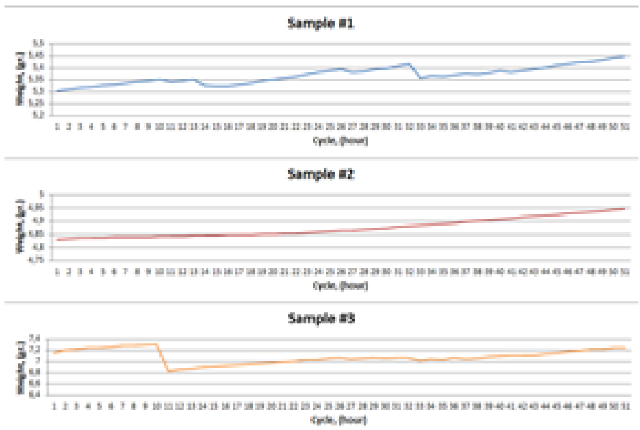


Fig.6. Mass change graph of the samples during high-temperature oxidation tests, 50 cycles.

Conclusions. The oxide scale of Samples No. 1 and No. 3 showed a tendency to crack and flake off during high-temperature oxidation tests. In contrast, Sample No. 2 demonstrated positive results, as the coating proved to be resistant to oxidation during the experiments..

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Link to the original article:
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Stability of the structure and phase composition of the intermetallic compound of beryllium and titanium - TiBe12 under neutron irradiation

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Keywords: Stability of the structure, titanium beryllide, neutron irradiation, phase composition, WWR-K.

Intermetallic compounds of beryllium and titanium (TiBe12) are often considered as an alternative material for neutron multiplier in thermonuclear blanket designs. Compared to metallic beryllium, TiBe12 has a higher operating temperature, is resistant to oxidation, accumulates less tritium and is compatible with stainless steels [1]. Today, the Ulba Metallurgical Plant in Kazakhstan has mastered and implemented technology for manufacturing TiBe12 blocks on an industrial scale, suitable for use in thermonuclear facility [2]. The uniqueness of this material is its single-phase structure - TiBe12. The aim of the work is to study the radiation resistance of the titanium beryllide TiBe12, industrially produced by Ulba Metallurgical Plant. Neutron irradiation of titanium beryllide samples was carried out at the WWR-K reactor at the Institute of Nuclear Physics of the Republic of Kazakhstan up to fluences of 4 and 5 x1020 cm-2, at a fast neutron flux density of 2.4 x 1013 cm-2 s-1 [3]. Irradiation was carried out in an argon atmosphere at a temperature of ~ 80 °C. The work presents data on the stability of structure and phase composition under neutron irradiation.

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PREPARATION OF HIGHLY POROUS ACTIVATED CARBON WITH HIGH SPECIFIC SURFACE AREA FROM AGRICULTURAL WASTES

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Keywords: agricultural waste, activated carbon, pyrolysis, activation, KOH.

The rising quantity of agro-industrial waste in Kazakhstan provides an environmental issue and an opportunity for sustainable resource exploitation. This study investigates the valorization of rice husk, soybean husk, and sunflower husk by converting them into high-performance activated carbon (AC) via chemical activation using potassium hydroxide (KOH). The synthesis procedure involved pyrolysis followed by activation at 750 °C in an inert nitrogen environment. The produced activated carbons were extensively characterized using BET surface area analysis, SEM-EDS, XRD, TGA, and DSC techniques. The generated activated carbon exhibited a specific surface area of 2363.7 m^2/g, indicating the presence of meso- and macropores. XRD study proved the amorphous structure with restricted graphitic ordering, while TGA-DSC indicated improved thermal stability. The results show that agricultural by-products can serve as sustainable precursors for producing activated carbon with customized porous architectures appropriate for environmental remediation, energy storage, and catalytic uses. This study advances circular economy ideas and sustainable materials in Kazakhstan.

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Intense Pulsed Ion Beam for Modification of Functional Materials

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Intense pulsed ion beam (IPIB) irradiation has emerged as a powerful tool for modifying material properties by inducing ultrafast heating and fast cooling cycles [1]. This study explores the effects of IPIB irradiation on various materials, with a focus on noble metal nanoparticles and metal oxide thin films.

High-current IPIB irradiation was employed to induce solid-state dewetting of magnetron-sputtered silver films, leading to the formation of spherical nanoparticles with enhanced sphericity compared to conventional rapid thermal annealing. The superfast heating (10^9 K/s) and subsequent cooling provided by IPIB irradiation played a critical role in shaping the nanoparticles, demonstrating its potential for precise morphological control. Experimental results confirmed improved crystallinity and shape uniformity, which are beneficial for plasmonic applications [2].

Additionally, IPIB irradiation was applied to tungsten trioxide thin films to enhance their photoelectrochemical performance. The process led to the formation of a sponge-like porous structure on the WO_3 surface, increasing its active surface area and improving light absorption. As a result, an ~80% enhancement in photocurrent generation was observed compared to non-irradiated samples. The rapid phase transformation induced by IPIB irradiation facilitated the crystallization of amorphous WO_3, further contributing to its improved PEC activity [3, 4].

These findings highlight the significant potential of IPIB irradiation as a novel technique for the controlled modification of material structures at the nanoscale. Its ability to induce rapid, high-temperature annealing processes without prolonged thermal exposure opens new avenues for applications in nanotechnology, photonics, and energy conversion devices.

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Investigation of a Pulsed Plasma Thruster Using Graphite as Propellant

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Keywords: Pulsed Plasma Thruster, Graphite Propellant, Ignition Discharge, Coaxial Electrode Configuration, Electric Propulsion

In this work, a prototype of a solid-state pulsed plasma thruster (PPT) was developed. The thruster features a coaxial configuration consisting of a central anode, an outer cathode, and an ignition electrode, which also serves as a solid graphite propellant. Additionally, the design includes an electromagnetic component responsible for generating the impulse.

Experimental studies were carried out using a main storage capacitor with a capacitance of 2 μF, and discharge voltages ranging from 2 to 3.5 kV. Discharge currents were measured using a Rogowski coil. The maximum discharge current, recorded at 3.5 kV, reached 7 kA. A high-speed camera was used to capture sequential images, allowing for visualization of plasma channel formation and the ejection of a plasma plume. Based on the video data, the velocity of the plasma jet was estimated. The effective ignition voltage required on the igniter electrode for reliable discharge initiation was also determined.

The second part of the study focused on investigating the combustion process of the ignition spark discharge, which is critical for initiating the main plasma pulse. For this purpose, a separate test bench was designed to vary the parameters of the ignition system. A series of experiments led to the determination of the effective breakdown voltage and optimal capacitance for the ignition circuit. These optimizations enabled stable ignition of the graphite propellant and consistent formation of the plasma channel.

The combined results confirmed the effectiveness of the proposed solid-fuel PPT configuration and enabled further optimization of the ignition system to improve discharge reliability and repeatability. The data obtained are expected to support the future development of compact propulsion systems for small spacecraft.

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EFFECT OF PULSE-PLASMA TREATMENT ON THE PROPERTIES OF CR3C2-NICR DETONATION COATINGS

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Abstract: In this study, Cr3C2-NiCr based detonation coatings which have been subjected to pulse-plasma treatment were studied. The study showed that IPO reduced the surface roughness by 48%, reduced the coating friction coefficient by about 2 times, increased the hardness of the coatings from the original 12 GPa to 16.2 GPa and improved their wear resistance by 2 times compared to untreated coatings.. Pulse-plasma treatment provides qualitative formation of coatings from metal-ceramic material of Cr3C2-NiCr system with complex heterogeneous structure-phase state, where the layered structure of areas of carbide particles and matrix metal in immediate proximity from "carbide-matrix" border with selections in matrix of dispersed secondary carbides is revealed.
Keywords: ceramic metal coatings, detonation spraying, pulse-plasma treatment, coating modification, hardness, wear resistance.

1. Introduction. Improvement of the qualitative characteristics of carbide-based metal-ceramic coatings is possible by external high-energy impact. The most effective technology is a complex pulse-plasma treatment, including surface modification by: magnetic field, electric current (flow of charged elementary particles), high gradient thermal stream (plasma), containing metallic and nonmetallic alloying elements.

Pulse-plasma treatment (PPT) provides a rapid heating (heating time 10-3 - 10-4 s) of a surface layer followed by its intense cooling by heat removal into the volume of a product. High speed (up to 107 K/s) of melting and crystallization of surface layers contribute to formation of nanodisperse crystal structure and high density of dislocations. Impulse heat influence, elastoplastic deformation of processed material structure in combination with electromagnetic influence are carried out. Due to pulse current (up to 10 kA/cm2) flowing through the surface layers of the coating, physical and chemical processes as well as heat and mass transfer are intensified.

The purpose of this work is to study the possibility of increasing the complex of physical and mechanical properties of the coating material made of Cr3C2-NiCr powder with the use of modern methods of cumulative-detonation coating deposition and subsequent pulse-plasma treatment.

2. Materials and Methods. Powder of Cr3C2-NiCr (75/25) (H.C. Starck: AMPERIT® 584.054) with a dispersion of 10-45 µm was used as the spraying material. The coatings were applied to 12Cr1MF steel samples by detonation spraying (DS) on a multichamber detonation apparatus. To modify the resulting detonation coating on the surface of the product, a pulsed plasma technology (PPT) was used. Pulsed plasma generation was carried out at the "Impulse-6". The phase composition of DS and DS/PPT coatings was studied using X-ray diffractometer X'PertPRO. The surface morphology was investigated by scanning electron microscopy (SEM) using backscattered electrons (BSE) on a JSM-6390LV scanning electron microscope. Tribological tests for sliding friction were performed on a TRB^3 Anton Paar Srl tribometer, using the standard "ball-on-disk" technique (international standards ASTM G 133-95 and ASTM G99). Microhardness of cross-section of samples was measured according to GOST 9450-76 (ASTM E384-11) on Metolab 502.

3. Results. Figure 1 shows the results of measuring the surface roughness of the Cr3C2-NiCr based coating material, according to which it was found that the surface has a non-uniform structure with the presence of pores. The Ra value, which is the arithmetic mean deviation of the profile, was chosen as the main parameter for assessing the surface roughness of the coatings. The roughness parameter of the coatings obtained before the PPT has a value of Ra = 11.2 (Fig.1a), and after the PPT has a value of Ra = 5.31 (Fig.1b). The twofold decrease in the roughness parameter is caused by pulse plasma melting of the protruding fragments and pores of the coating roughness, which contributed to a decrease in the surface roughness value by ≈ 48% as compared to the coating roughness parameters before PPT.

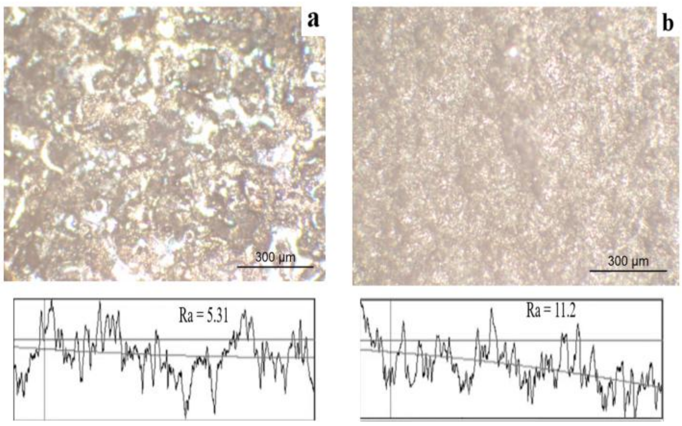

Figure 1. Micrograph of topography and surface roughness of Cr3C2 coatings before (a) and after the PPT

Figure 2 shows the diffractograms of the coating surface before and after the pulsed plasma treatment (PPT). The following phase components were detected in the coatings before the pulse-plasma treatment: Ni-Cr-Fe, Cr3C2,Ni-Cr-Fe/ Cr7C3 and Cr7C3 phases (Fig. 2a). Cr2O3 chromium oxide phases were found on the surface after PPT (Fig. 4b). Thus, after an PPT on the diffractogram it is observed growth of intensity of peaks of chrome carbide Cr3C2, (Fig. 2b), the reason for which is short-term activization of a surface of a covering from behind a pulse plasma where the plasma containing active carbon and oxygen causes course of two mutually exclusive chemically thermal processes of oxidation and carburization. The combination of solid phases of chromium oxide and carbide in the hardened metal matrix significantly increases the durability of the resulting material in conditions of abrasive wear.

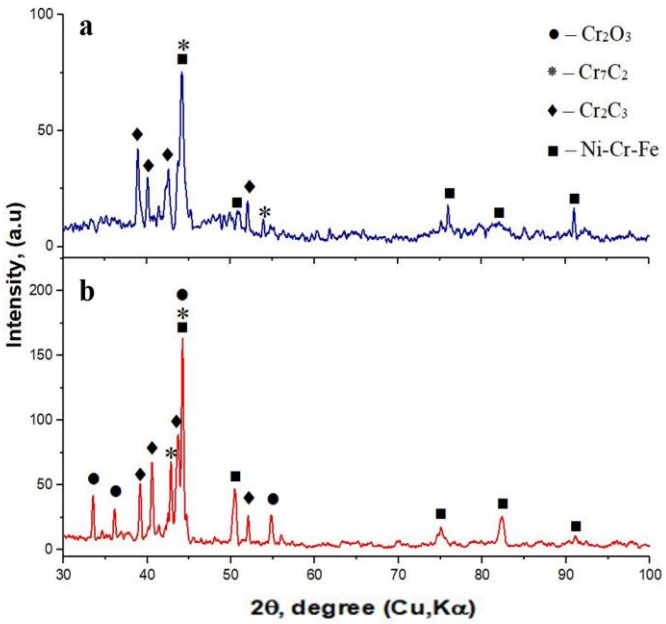

Figure 2. Surface diffractograms of Cr3C2-NiCr coating material before (a) and after (b) pulse plasma treatment

Conclusions. Detonation coating technology and subsequent pulse-plasma processing provide, formation of quality coatings from ceramic-metal powder on the basis of Cr3C2-NiCr with complex heterogeneous structural-phase state, where the layered structure of carbide particles and matrix metal areas in the immediate vicinity of the "carbide-matrix" border with allocation of dispersed secondary carbides in the matrix is revealed. Detonation spraying and subsequent pulse-plasma treatment, can be recommended as an optimal way to protect the surfaces of parts operating in extreme wear conditions.

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Study of plasma discharge of tokamak KTM

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Keywords: Tokamak, plasma diagnostics, KTM, plasma current, Thomson scattering, electron temperature

The Kazakhstan Material Science Tokamak (KTM) is a magnetic confinement facility designed to generate high-temperature plasma. The primary research objectives of the KTM tokamak include testing first wall materials for future fusion reactors and studying plasma physics phenomena [1].

This paper presents an overview of the diagnostic complex of the KTM tokamak, developed for plasma physics investigations. The composition of the diagnostic systems, their technical specifications, and installation features are discussed [2]. In addition, key results obtained during experimental campaigns using these diagnostics are provided, particularly in relation to plasma discharge generation on the KTM tokamak.

Plasma discharges on KTM were performed in the ohmic heating mode [3]. During the experimental campaigns, the first plasma discharges were obtained with parameters approaching nominal values, and valuable operational experience was gained. The acquired data and achieved discharge parameters will enable further experiments aimed at reaching the design performance of plasma discharges.

This paper also presents the conceptual design of a Thomson scattering diagnostic system (TS) for the KTM tokamak. This system will allow for real-time monitoring of plasma temperature and density profiles, and the collected data can be integrated into the plasma discharge control loop. Accurate measurement of radial profiles of electron density and temperature is essential for achieving the design discharge parameters [4]. Therefore, development of the TS diagnostic is currently underway, as it is one of the most reliable and accurate tools for measuring these key plasma parameters.

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Properties of FeCrAl coatings obtained by plasma-spraying method

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Keywords: coatings; plasma spraying; intermetallic; wear resistance; microhardness.

The development of power engineering requires the introduction of new materials and technologies to improve the quality and durability of products. One of the promising directions is the creation of heat protective coatings for the protection of working surfaces of turbine blades of gas turbine engines operating at temperatures up to 1000-1200°C. Intermetallic coatings based on iron aluminides (Fe_3Al, FeAl) have high resistance to oxidation due to the formation of an oxide layer Al_2O_3 [1, 2]. However, their application is limited by brittleness, which can be reduced by alloying with e.g. chromium due to the so-called third element effect. In this work the processes of formation of Fe-Al-Cr intermetallic coatings produced by air-plasma spraying and the mechanisms affecting their stability at high temperatures are investigated. Experimental studies included the analysis of microhardness, wear resistance and corrosion resistance of coatings, as well as their phase composition and microstructure. The results showed that the optimization of sputtering parameters, especially at FrCrAl (30_33) mode, promotes the formation of a coating with improved tribological and anticorrosion characteristics, which is associated with its dense and uniform structure. These data have an important practical significance for the creation of wear-resistant and corrosion-resistant coatings applicable in power engineering [3, 4].

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Green synthesis of graphene-like structures by electrochemical exfoliation

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Keywords: Graphene; graphene oxide; electrochemical exfoliation; Hummer's method; carbon materials; green synthesis; graphite rods

Recently, demand on and graphene-like structures (GLS) has increased due to its widespread use in sensors, water purification and anti-corrosion materials. Therefore eco-friendly, and cost-effective way of GLS synthesis is needed. This study examines the synthesis of GLS from graphite rods by electrochemical exfoliation (EE). We discovered that this method yields GLS which include few-layered graphene and graphene oxide. The EE method implies the use of graphite rods in ammonium sulfate electrolyte solution because it was shown in many previous works done by various researchers that sulfate ions are most effective in exfoliation of graphite. Throughout the whole experiment, which lasted for ~5 hours, certain voltage and power were maintained. Furthermore, we conducted two additional variations of experiment, one in combination with ultrasonic treatment and one in combination with Hummer's method (HM) specifically to produce graphene oxide (GO). Ultrasound assisted in exfoliation and oxidation of graphite, and reagents from HM, although not effectively, oxidized graphite. For control, we synthesized GO by classical HM. Next, we performed several tests to confirm the obtainment of GO and to compare GOs. Titrimetric analysis showed presence of oxygen-containing groups, FT-IR analysis confirmed the presence of these groups and other characteristic features of GO. XRD showed that our samples were mostly few-layered graphene. UV-Vis confirmed the presence of graphene and GO. Raman spectroscopy showed defects in final products. Overall, the yield of GO was lower than in HM, and final mixture was not pure due to presence of graphite flakes and few-layered graphene.

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Electrophysical Aspects of Current Density Distribution and Its Role in Electrolyte Boiling and Surface Hardening During Electrolytic Plasma Processing

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Keywords: electrolytic plasma processing, current density, Laplace equation, boiling time, cathode, numerical modeling, electric discharge, gas-vapor shell.

The present work investigates the electrophysical foundations of the boiling process and surface hardening in cathodic electrolytic plasma processing (EPP), focusing on the role of current density distribution. Two interrelated aspects are considered: (1) the time required to achieve electrolyte boiling in a conical-anode cylindrical-cathode system, and (2) the effect of current concentration on the nonuniformity of steel surface hardening.

In the first part, the Laplace equation is solved in spherical coordinates to derive analytical expressions for electric potential and current density. These solutions enable an energy balance estimate for the time required to heat the near-cathode electrolyte layer to boiling point. The boiling times were calculated both analytically and numerically (Elcut 6.6 program) for 50 V and 200 V cases. High-speed video analysis validated the predictions, confirming good agreement at higher voltages. However, at lower voltages, deviations increase due to neglected heat removal and convective effects, highlighting the limitations of simplified models.

The second part presents a study of current density in practical EPP configurations using COMSOL Multiphysics. Simulations revealed that sharp corners of treated steel samples exhibit more than tenfold increases in local current density, as also confirmed by visual observations of discharge initiation. Microhardness mapping post-treatment showed enhanced hardening in these regions, indicating a direct link between current concentration and thermal effect. Local irregularities in hardness distribution were attributed to electrohydrodynamic instabilities, including Tonks–Frenkel and Kelvin–Helmholtz mechanisms.

This integrated approach—combining electrostatic modeling, numerical field simulations, and experimental validation—demonstrates that control over current density distribution is critical both for ensuring plasma formation and for achieving

uniform mechanical modification. The results provide a foundation for optimizing electrode geometry and process parameters in industrial EPP applications, especially for diffusion surface treatment (carburizing, nitriding) of complex steel parts.

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Effect of electrolytic-plasma hardening on the microstructure hardness and tribological properties of 45 steel

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Keywords: electrolytic plasma hardening; 45 steel; hardness; wear resistance, microstructure.

This study presents the findings on the impact of electrolyte plasma hardening (EPH) on the microstructure, phase composition, and tribo-mechanical properties of medium-carbon structural steel 45, a material widely employed in tool and machine component manufacturing. The hardening process was performed using an EPH system with electrolytes based on varying concentrations of sodium carbonate (Na_2CO_3) in distilled water (15%, 20%, and 25%). A uniform heating duration of 4 seconds during quenching led to significant structural-phase transformations within the surface layers of the steel. Specifically, the initial ferrite-pearlite structure was transformed into martensite, resulting in a substantial increase in surface microhardness to 506–690 HV0.1 – approximately 2.5 to 3.5 times higher than that of the untreated steel.

Table 1. Parameters of EPH regimes for steel 45.

Sample	Electrolyte composition	Electrolyte flow rate (L/min)	Voltage (V)	Anode area (cm^3)	Anode-cathode distance (cm)	Current density (A/cm^2)	Time (s)
No. 1	15% Na_2CO_3 + 85% water	100	300	500	10	36	4
No. 2	20% Na_2CO_3 + 80% water	100	300	500	10	44	4
No. 3	25% Na_2CO_3 + 75% water	100	300	500	10	44	4

The hardened layer reached a depth of up to 3.2 mm. Moreover, wear resistance improved markedly, with wear volume decreasing by a factor of 1.3–1.5, as evidenced by values ranging from 2.01×10^{-4} to 2.26×10^{-4} m³. These results demonstrate the effectiveness of electrolyte plasma hardening in enhancing the structural integrity and durability of steel 45, making it a promising approach for extending the service life of critical and heavily loaded machine parts.

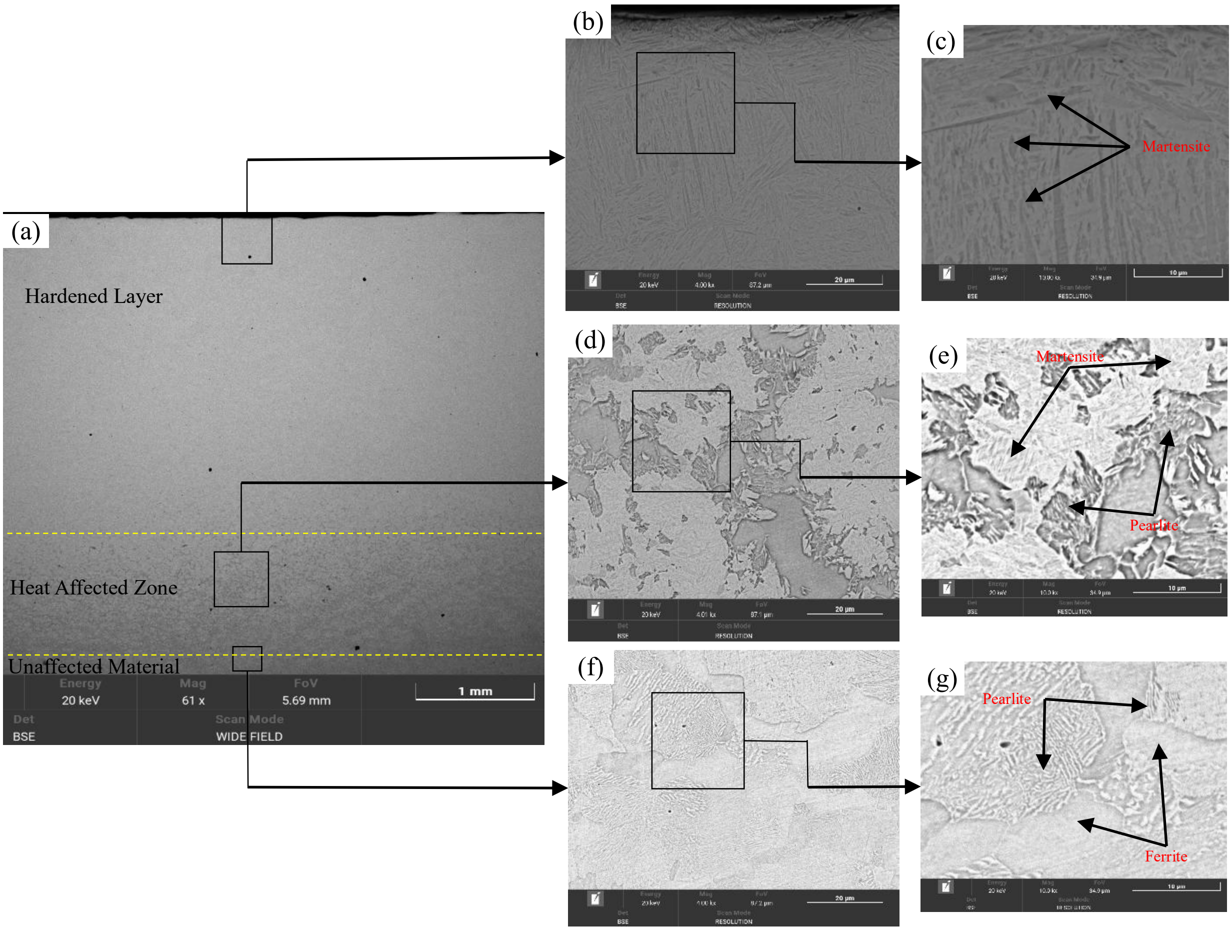

Figure 1. SEM images indicating the microstructure of sample No. 2 in cross-section: microphotography at ×60 (a), hardened layer at ×4000 (b) and ×10000 (c), heat affected zone at ×4000 (d) and ×10000 (e), original material at ×4000 (f) and ×10000 (g).

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STUDY OF PHYSICAL PROPERTIES OF SUPERHYDROPHOBIC SURFACE OBTAINED BY PLASMA JET

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Keywords: atmospheric discharge plasmas; contact angles; hexamethyldisiloxane; plasma polymerisation; superhydrophobic surface

Recent studies have led to the development of superhydrophobic coatings exhibiting water contact angles exceeding 150°. These coatings are of considerable interest due to their remarkable features, such as water repellency, self-cleaning ability, resistance to corrosion, anti-fogging performance, ice removal properties, protection from biological fouling, and low-friction behavior, among others [1]. Owing to these properties characteristics, hydrophobic films hold significant promise for implementation across various fields, including energy, construction, healthcare, marine and aerospace industries, and textile manufacturing [2].

This work presents the results of a comprehensive investigation into superhydrophobic surfaces obtained by plasma jet treatment at atmospheric pressure

[3]. The surface roughness essential for superhydrophobicity was achieved by generating nanoparticles within a plasma stream composed of argon and hexamethyldisiloxane (HMDSO). A correlation between the water contact angle and key processing parameters—namely, discharge power and treatment duration—was established. The maximum contact angle measured was 168±2°. Analytical techniques such as Scanning Electron Microscopy (SEM), Atomic Force Microscopy (AFM), X-ray Photoelectron Spectroscopy (XPS), and UV-Vis spectroscopy were employed to characterize the coatings. The resulting films demonstrated excellent chemical resistance, thermal stability, durability under UV radiation, and robustness against various environmental factors. These findings suggest broad applicability, particularly in areas where self-cleaning and corrosion resistance are critical. The superhydrophobic surfaces are specifically engineered to prevent water interaction, hinder droplet accumulation, and block the adhesion or infiltration of mercury.

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INVESTIGATION OF STRUCTURAL-PHASE AND MECHANICAL-TRIBOLOGICAL CHARACTERISTICS OF THERMAL PROTECTIVE COATINGS BASED ON NiCrAlY/ZrO_2-Y_2O_3

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Abstract: This paper presents the results of investigation of multilayer gradient heat protective coatings of NiCrAlY/YSZ system formed by detonation spraying. The coatings consisting of alternating layers of NiCrAlY and YSZ were obtained with a gradient thickness distribution, which was achieved by using two dispensers in the barrel of the detonation apparatus. X-ray phase analysis, measurements of

microhardness, surface roughness, and tribological characteristics of the obtained coatings were carried out.
Keywords: thermal protection coating, NiCrAlY/YSZ, multilayer gradient structure, detonation spraying, wear resistance.

1. Introduction. During the operation of structural elements in aviation, power and space engineering the problem of increasing the thermal resistance and reliability of materials is acute. Multilayer ceramic coatings based on NiCrAlY and YSZ effectively protect against thermal and oxidative wear, but are susceptible to flaking due to the formation of oxides at the boundary of layers during oxygen diffusion [1-2]. The solution to this problem is the creation of gradient coatings with a smooth change in composition. One of the most promising approaches is the detonation spraying method using two powder dispensers, which allows controlling the composition of the coating during the spraying process. This approach provides a gradual change in the physical and chemical characteristics of the coating, reduces thermal stresses and increases oxidation resistance. In addition, detonation spraying is characterized by high coating density, bond strength with the substrate and low porosity, which is critical for parts operating in aggressive environments. The aim of the study is to investigate the structural-phase, mechanical and tribological characteristics of NiCrAlY-YSZ coatings.

2. Materials and Methods. In this work, multilayer gradient thermal protection coatings applied by detonation spraying on a 12Kh18N10T stainless steel substrate (size 20×15×3 mm) pre-treated by sandblasting were investigated. NiCrAlY (PNX20K20YU13) powders for the metal sublayer and YSZ (Metco 233B) powders for the ceramic coating were used as starting materials. The formation of the gradient structure was carried out using two powder dispensers to ensure a smooth transition from the metallic to the ceramic layer. The spraying was carried out on a CCDS2000 machine with varying gas mixture parameters and number of shots to obtain two gradient deposition regimes. The deposition technique and parameters of detonation spraying regimes are described in detail in publications [3]. The microstructure was investigated using SEM (TESCAN MIRA3), and the microhardness, roughness, and tribological properties of the coatings were determined in accordance with current standards.

3. Results. Figures 1 shows the cross-sectional microstructural images of the detonation coatings. Microstructure analysis confirms the successful preparation of multilayer gradient coatings consisting of a NiCrAlY layer (binder coating), a YSZ layer (top coating), and gradient intermediate layers containing a mixture of NiCrAlY and YSZ. As can be seen in the figures, the light areas correspond to the ceramic YSZ phase and the dark (gray) areas correspond to the metallic NiCrAlY phase. It is important to note the absence of visible cracks, defects and signs of delamination in all samples. The coatings obtained by detonation spraying are characterized by a dense microstructure with low porosity (Table 1).

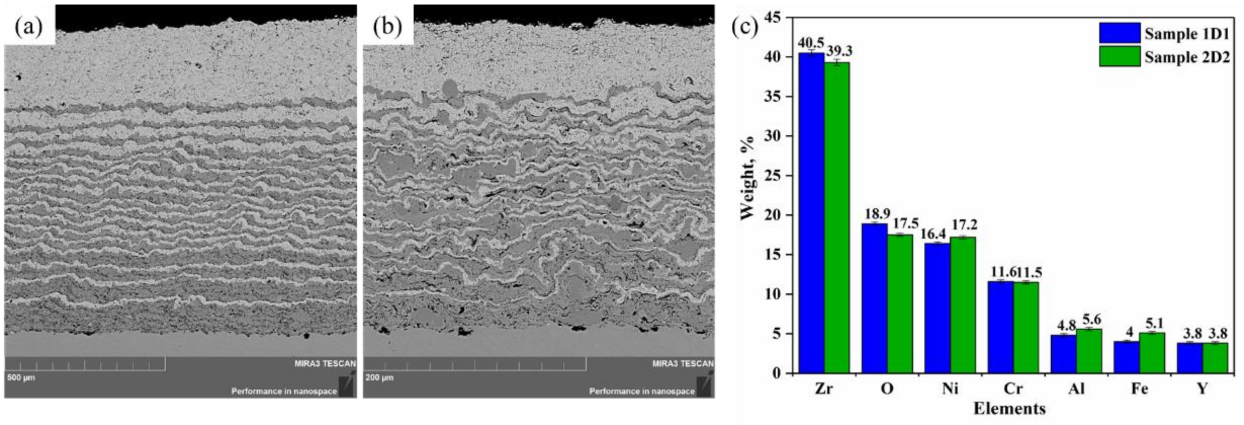

Figure 1. Cross-sectional BSE images of samples 1D1 (a) and 2D2 (b) with visible layered structure, as well as a histogram of the distribution of elements (Zr, O, Ni, Cr, Al, Fe, and Y) by their content in percentage (c).

Table 1 shows the measured characteristics of the multilayer gradient coatings. Sample 1D1 is characterized by a higher surface roughness (Ra = 3.76 µm) compared to sample 2D2 (Ra = 1.21 µm), which is probably due to the presence of unmelted particles and the inhomogeneity of the structure. The microhardness of coating 1D1 (8396 MPa) exceeds that of sample 2D2 (7365 MPa) by about 1.14 times. This may be due to both structural features of the coating and increased roughness, contributing to the redistribution of load during measurements. In terms of tribological properties, sample 1D1 was found to have a significantly lower coefficient of friction (0.125) compared to 2D2 (0.584), indicating better wear resistance and stability of the 1D1 coating under contact loads.

Table 1 - Structural-mechanical and tribological characteristics of NiCrAlY/YSZ gradient coatings obtained by detonation spraying method

Sample	**Porosity, %**	**Thickness of coatings, µm**	**Ra, µm**	**HV, MPa**	**Coefficient of friction**
1D1	2.31±0.11	963.67 ± 13.59	3.76±0.24	8396±332	0.125±0.048
2D2	3.28±0.13	273.72 ± 1.26	1.21±0.11	7365±221	0.584±0.130

Conclusions. NiCrAlY-YSZ coatings obtained by detonation spraying have a dense structure, high microhardness and low friction coefficient. Sample 1D1 showed better wear resistance compared to 2D2. The gradient structure ensures the stability of the coating.

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Link to the original article:
https://www.mdpi.com/2079-6412/14/7/899

Developing digital educational content on tribology and integrating it into the professional training of future physics educators

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Keywords: Educational program, Digital educational material, Physical fundamentals of tribology, Future physics teacher, Professional competence.

In this work, electronic textbooks for the elective course «Physical Foundations of Tribology» have been developed and introduced into the educational process of educational programs «Physics» in the preparation of future physics teachers. It is shown that the level of creativity and a positive attitude towards innovative educational activities of students in these programs turned out to be high, and they are sufficiently prepared to use digital educational materials for this course (M = 3.89). Electronic textbooks have been developed and introduced into the educational process: «Physical Foundations of Tribology»; «Electronic methodological guide for performing laboratory work on the physical foundations of tribology»; «Electronic methodological guidelines for practical classes in the discipline physical foundations of tribology» for the elective course «Physical Foundations of Tribology» (Figure 1).

a) b) c) d)

Figure 1.

Interfaces of electronic manuals (a, b) and, accordingly, their Certificates of Entry into the State List of Rights to Objects Protected by Copyright of the Ministry of Justice of the Republic of Kazakhstan (c, d).

In order to start performing laboratory work, each student must study theoretical material (lectures, diagrams, instructions and memos); perform practical work on the topic (get a positive assessment); take a test with theoretical questions and small practical tasks (get a positive assessment for this course using a developed electronic textbook on physical foundations tribology.

The pedagogical experiment showed the effectiveness of the developed electronic educational material for the development of students' professional competence in the field of tribology. About 75% of the students in the experimental groups showed a high and sufficient level of professional knowledge and skills at the end of the experiment, and the proportion of students with a high and sufficient level of knowledge in tribology in the control groups was 60%. The proportion of respondents with a high level of needs and motives for tribological activity is higher by 6.74%; with sufficient, higher by 8.26%; with average, lower by 9.39%; and with low, lower by 5.61% compared with the results of the control groups. Thus, this paper shows the necessity and expediency of developing digital educational materials on tribology and their application in the process of training future physics teachers in order to increase their level of professional competencies.

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Estimation of electron temperature as a function of the discharge parameters at DC gas discharge plasma of Ar and Ar/C2H2 mixture

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Keywords: Dusty plasma, electron temperature, PECVD, plasma with nanoparticles, optical spectroscopy.

Complex (dusty) plasma is a quasi-neutral electric medium containing, in addition to electrons and ions, also densely bound microparticles. The first experiments with microparticles were conducted in laboratory conditions, but the resulting structures did not have a volumetric character [1]. This was due to the action of gravity. As a solution, it was proposed to conduct research in microgravity, i.e. in orbit. However, conducting such experiments in space requires significant resources, which makes the search for alternative methods in ground-based laboratories particularly relevant.

Ground-based experiments with nanoparticles allow more precise control of parameters such as pressure and gas composition, which plays an important role in the study of nanoparticle growth mechanisms, dynamics and interaction with plasma [1-3].

Based on the work [4], the results of the study of electron temperature in argon-acetylene argon-acetylene DC glow discharge plasma are provided. The optical-emission method was used to determine the main parameter of the complex plasma. The dependence of the electron temperature on the operating pressure, voltage, and discharge time was determined from the intensity of spectral lines. The source voltage varied from 1kV to 1.5kV, and the pressure was maintained between 0.1-1 torr. As a function of time, the electron temperature was calculated every 20 seconds during a 200-second discharge.

The results showed that in argon plasma, as the pressure increases, the electron temperature decreases up to a pressure value of 0.4 torr, subsequent increase leads to an increase in temperature. Also, with the increase in source voltage, a decrease in electron temperature within the error limits is observed. In addition, in dusty plasma (PECVD in Ar-C2H2), the electron temperature as a function of pressure and source voltage showed a trend similar to that observed in argon plasma. However, the electron temperature in dusty plasma increases as a function of time at the initial moment, after which it decreases sharply with time.

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Synthesis of nanocomposite based on modified nanocellulose

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Keywords: microcrystalline cellulose, cellulose nanofibers, nanocomposite, oxidized starch, biofilm.

Cellulose-based biopolymers, derived from renewable resources, offer a sustainable alternative to plastic packaging. They are biodegradable, versatile, and increasingly cost-effective, though challenges remain in improving their properties [1]. Modified nanocellulose are widely used in the food and pharmaceutical industry as a reinforcing agent, improving the iscosity and rheological behavior of emulsions, suspensions, and pastes. This study focused on developing a biodegradable biofilm from cellulose nanofibers and oxidized corn starch and carboxymethylcellulose, using succinic anhydride as a crosslinker. [2, 3].

The biofilm's mechanical strength, water absorption, and biodegradability were evaluated. The biofilm exhibited a strength of 0.78 MPa, absorbed 0.21% water, and had a biodegradability rate of 0.008%. The results demonstrated that the addition of cellulose nanofibers significantly enhanced the mechanical properties of the nanocomposites. These findings suggest that the biofilm has significant potential for industrial applications, particularly in the biofilms and bioplastics sector.

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Interaction of atmospheric pressure plasmas with the water surface

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Keywords: plasma-liquid interactions, streamer dynamics, water surface deformation, optical emission spectroscopy, plasma diagnostics

Streamer discharges in gases are complex phenomena triggered by rapid intensification of the electric field and sustained through collisions with neutral molecules. These discharges are crucial across various applications, including atmospheric-pressure plasma generation, environmental remediation, and medical treatments. While most studies on streamer discharges interacting with water have focused on plasma jets and their effects on the liquid surface [1,2], our research takes a different approach: the discharge is directed straight at the water surface without any assisting gas flow.

This study investigates the dynamics of streamer channels in atmospheric-pressure plasmas interacting with water and characterizes the physical processes at the water–plasma interface. Specifically, we examine how different discharge regimes—weak discharge, streamer formation, and stable streamer channel—affect the water surface. Each regime is analyzed by estimating the dominant acting forces, including electrohydrodynamic forces, surface tension, and gravity [3]. This approach offers insights not covered in prior studies using plasma jets.

The experimental setup consists of a high-voltage metallic tip as the upper electrode and a copper plate submerged in distilled water as the lower (liquid) electrode. By varying the applied voltage, three distinct discharge stages are observed: the initial pre-discharge stage, the formation of small and large branched streamers, and the development of a stable streamer channel.

In the initial stage, where discharge activity is minimal, the nonlinear deformation of the water surface with increasing voltage is attributed to a gradual reduction in surface tension caused by the strengthening electric field. This leads to accelerated liquid deformation. At this stage, gravitational and electric forces are dominant.

The next stage of the discharge, occurring at higher voltages (10.5–12 kV), marks a transition in discharge behavior. The intensified electric field causes rapid ionization of air molecules and water vapor, with collisions between electrons and gas molecules producing both optical emission and a characteristic discharge sound. At this stage, the discharge branches into multiple filaments, large and small streamer channels, identified by the oscillatory features in the current waveform. The increased deformation of the water surface is attributed to the growing influence of electrohydrodynamic forces.

As the discharge fully develops, the current significantly increases, leading to a stable regime where a continuous plasma channel forms. In this phase, the plasma reaches a conductive steady state through thermal ionization, and the discharge burns uniformly. Thermal effects and plasma pressure play a dominant role, and this stage is characterized by the simultaneous formation of multiple streamers and frequent current impulses, clearly visible in current waveform data.

Optical emission spectra from the second and third discharge stages were recorded and analyzed using the "MassiveOES" software [4]. This allowed for the calculation of rotational and vibrational gas temperatures. Optical Emission Spectroscopy (OES), which measures the emission from excited atoms and molecules, is a powerful diagnostic tool for determining key spectral parameters—such as wavelength and intensity—and is widely used to assess gas temperatures in plasma environments. In the obtained spectra, the most intense part corresponds to the nitrogen (N_2) spectrum in the range of 337–400 nm, where the strongest intensity peak of the N_2 (C–B) transition (at 337 nm) can be observed (Figure 1).

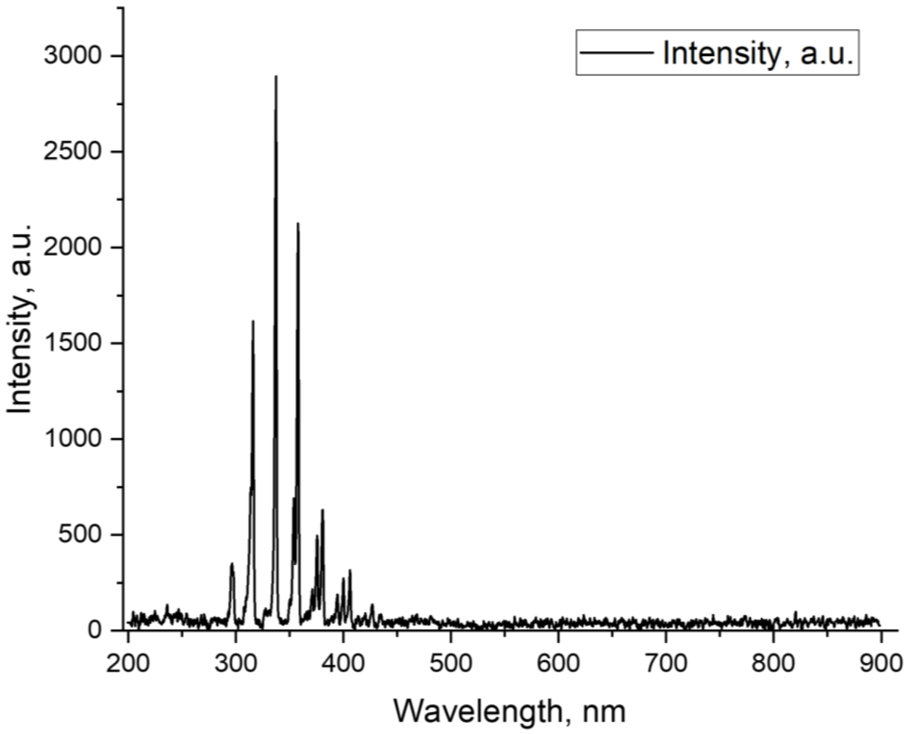

Figure 1. Experimental spectra of the gas discharge

The research findings can serve as a foundation for developing new methodological approaches in fields such as water purification, environmental safety, and modeling of atmospheric phenomena.

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Plasma diagnostics during studies of plasma–material interactions on a plasma-beam facility

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Keywords: ITER, KTM, Tokamak, PBI, BPD, H plasma, Langmuir probe, Plasma parameters

When studying the processes of plasma interaction with the surface, there is a need to determine the exposure parameters and the installation operating modes. The goal of this work is to measure the plasma parameters on a plasma beam installation (PBI) using an automated probe diagnostics system developed by us.

The plasma diagnostic and monitoring system at PBI is based on the use of a cylindrical Langmuir probe. The software has been developed for measuring, recording and processing the probe voltage characteristic (I-U curve) in real time and a movable probe input for measuring the radial distribution of the plasma parameters (plasma concentration, electronic temperature). The measurements were carried out under different operating modes of the PBI with a variation in the parameters of the accelerating voltage of the electron beam and the pressure of the working gas. The nature of changes in the plasma parameters in the radial direction in a hydrogen medium has been established. The obtained results are in good agreement with the similar work in the study of the plasma parameters in the radial direction at the linear plasma installations.

The got dependences make it possible to analyze and establish a correspondence between the parameters of plasma action on materials and the nature of processes on their surface and in volume. The presented engineering idea will be proposed to complement the diagnostic complex of the plasma KTM tokamak.

Chektybayev B.Zh., Skakov M.K., Tulenbergenov T.R., Sokolov I.A., Miniyazov A.Zh., Zhanbolatova G.K., Nauryzbayev R.Zh. Measurement of plasma parameters in the PBI using the Langmuir probe // Fusion Engineering and Design.– August 2024.– Vol. 205.– 114546.– https://doi.org/10.1016/j.fusengdes.2024.114546

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Concept of the UCN Source at the WWR-K Reactor (AlSUN)

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A concept is presented for an ultracold neutron (UCN) source with a superfluid helium converter placed in the thermal column of the WWR-K research reactor (Almaty, Kazakhstan). Similar source designs are employed in the existing TRIUMF project (Vancouver) [1] and the proposed project at the WWR-M reactor (Gatchina) [2]. The main distinguishing features of our concept are more efficient systems for accumulating UCNs in the source and transporting them to experimental facilities. This is achieved by separating the heat and UCN fluxes from the source, as well as by lowering the temperature of the helium converter below approximately 1 K.

In this work, we build on the parameters of UCN source concepts from existing projects that involve accumulating UCNs in superfluid helium, and we aim to refine these parameters for developing a UCN source at the WWR-K reactor. We perform an assessment of the achievable UCN density both in the source and in the experimental setup. We also discuss the challenges that must be resolved to justify the feasibility of such a project and to achieve the highest possible performance of the source.

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Enhancing students' research skills through innovative STEM education methods

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Keywords: Research abilities, students, STEM education, ionization chamber protype, skills.

In the modern era of science education, the demand for educational methodologies that bridge the gap between theoretical instruction and hands-on practice has intensified. One of the core challenges facing STEM (Science, Technology, Engineering, and Mathematics) education is the limited capacity to engage students in authentic scientific inquiry [1]. Addressing this challenge, the present study introduces an innovative educational model that integrates ionization chambers into STEM curricula as a practical and research-driven instructional tool, specifically in the context of atomic physics [2,3].

The research is grounded in constructivist and experiential learning theories, emphasizing student-centered approaches where learners build understanding through direct experience, reflection, and experimentation. Drawing on Kolb's experiential learning cycle and inquiry-based learning principles, the study encourages active participation in scientific processes [4]. The use of ionization chambers—typically reserved for specialized laboratory research—is proposed here as a cost-effective, accessible, and pedagogically powerful method to enhance STEM students' engagement and research competencies [5,6].

The study was conducted at Khoja Akhmet Yassawi International Kazakh-Turkish University, involving 120 third-year students enrolled in physics-related STEM programs. A quasi-experimental design was adopted, featuring pre- and post-assessments in both control and experimental groups. Prior to the 15-week intervention, no significant differences were observed between the two groups ($t(118) = 0.7749$, $p > 0.05$). However, post-intervention analysis revealed a statistically significant improvement in the experimental group that had engaged with ionization chambers ($t(118) = 7.8335$, $p < 0.05$). These findings confirm the hypothesis that integrating ionization chambers into STEM education enhances research-related outcomes.

In addition to the experimental study, a meta-analysis was performed to contextualize the findings within broader educational research. Scientific literature from databases such as Mendeley, Scopus, and ERIC was reviewed, focusing on key terms like «ionization chamber», «STEM education», and «research skills». The meta-analysis supported the experimental results by demonstrating a consistent positive effect size across multiple related studies (common effect size = 4.093, CI = 4.085–4.101), validating the educational impact of combining practical tools with STEM pedagogy.

The theoretical contributions of this study are multifaceted. First, it situates the use of ionization chambers within well-established educational paradigms, thereby operationalizing abstract learning theories through a tangible tool. Second, it offers a scalable framework for developing students' critical thinking, experimental design, data analysis, and problem-solving capabilities—key skills in any modern STEM field. Finally, it provides evidence that even resource-constrained environments like Kazakhstan can implement high-impact, low-cost educational innovations without dependence on advanced laboratory infrastructure.

Practically, this research carries significant implications for educational policymakers, curriculum designers, and teacher educators. By demonstrating how relatively simple scientific instruments can be used to foster deep learning, this study calls for a reevaluation of current science teaching methods. It proposes the integration of ionization chambers into national STEM curricula and preservice teacher training programs as a strategy to enhance scientific literacy and cultivate a research-oriented mindset among students.

In conclusion, this study not only underscores the educational value of ionization chambers as effective instructional tools but also contributes to the global discourse on evidence-based STEM education reform. By providing students with the means to explore invisible physical processes—such as radiation—in a controlled, meaningful way, this research supports the development of scientifically literate, research-capable individuals who are prepared to meet the challenges of the 21st century.

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Development of a synthesis technology for zirconia-based composite ceramics and its influence on the phase composition, microstructure, and physico-mechanical properties

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Keywords: zirconium dioxide, powders, ceramics, sintering, physico-mechanical properties, structure, phase composition

Yttria-stabilized zirconia (YSZ) ceramics represent one of the most promising classes of structural and functional materials, widely used in various industrial sectors. This is due to their unique combination of high strength, hardness, thermal resistance, wear resistance, chemical inertness, and high ionic conductivity [1–4]. Studies have shown that the addition of HfO_2 to YSZ helps reduce grain size and increase flexural strength compared to undoped YSZ [5]. The incorporation of Al_2O_3 enhances the microhardness of ceramics [6]. Thus, combining YSZ, HfO_2, and Al_2O_3 into a single composite can create a synergistic effect, significantly improving mechanical and performance properties. However, successful implementation of this approach requires precise optimization of component ratios and processing parameters.

The aim of this study is to investigate the effect of sintering temperature on the phase structure and physico-mechanical properties of 6YSZ–Al_2O_3–HfO_2 composite ceramics.

Commercial powders of yttria-stabilized zirconia (6YSZ), aluminum oxide (Al_2O_3), and hafnium oxide (HfO_2), with an average particle size of up to 20 μm (CAS 1314-23-4, Shandong Xuke Chemical Technology Co., Ltd., China), were used. The powders were mixed in the ratio: 85 wt.% 6YSZ + 10 wt.% Al_2O_3 + 5 wt.% HfO_2 at 60 rpm for 48 hours. A binder based on a 10% polyvinyl alcohol solution mixed with glycerol (ratio 7:3) was used to produce the press mass. The samples were shaped via uniaxial semi-dry pressing under a load of 1000 kg/cm^2 with a dwell time of 30 seconds. Sintering was carried out in vacuum at temperatures of 1400–1600° C.

X-ray diffraction analysis revealed a transformation of the monoclinic ZrO_2 phase into a metastable tetragonal phase with increasing temperature, with the t-ZrO_2 content reaching 63–68% at 1600° C. Aluminum oxide transitioned into its hexagonal α-Al_2O_3 form, while the Y_2O_3 and HfO_2 phases remained monoclinic. The optimal properties were observed at 1600 °C: relative density — 5.8 g/cm^3, open porosity — 0.19%, water absorption — 0.07%, microhardness — 12.1 GPa, and fracture toughness (K_1C) — 6.0 MPa·m$^{1/2}$ [7].

Thus, increasing the sintering temperature promotes the formation of a denser and stronger microstructure with a predominance of the tetragonal phase, classifying the resulting material as TZP-type ceramics with superior performance characteristics.

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Ionization potential lowering in the framework of the generalized chemical model

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Keywords: generalized Poisson-Boltzmann equation, Helmholtz free energy, effective interaction potentials, Saha equation, ionization potential lowering.

Over the past few decades, plasma physics has increasingly focused on the study of warm dense matter (WDM), a unique state of matter characterized by moderate to high temperatures and densities that fall between the regimes of ideal plasmas and condensed matter. Unlike classical plasmas, where particles are weakly coupled, or solid-state systems dominated by quantum effects, WDM represents an intermediate domain where both quantum degeneracy and strong interparticle interactions play significant roles. This hybrid nature makes WDM an object of fundamental interest, offering valuable insights into complex many-body interactions under extreme conditions.

The sustained interest in WDM research is largely driven by its relevance to various astrophysical and planetary phenomena. Understanding the behavior of matter in this regime is essential for accurately modeling the internal structure and evolution of giant planets, such as Jupiter and Saturn, as well as the dense cores of stars during different evolutionary stages. Additionally, the atmospheres of exoplanets, particularly those subjected to intense stellar radiation, often exhibit WDM-like conditions, making it imperative to develop precise models for interpreting observational data. Beyond astrophysics, WDM can be experimentally realized in controlled laboratory environments through high-power laser pulses or energetic ion beams, which compress and heat matter to extreme states, thus providing a valuable platform for validating theoretical predictions and exploring new physical phenomena.

Accurately describing WDM remains a significant theoretical challenge. The primary difficulty arises from strong Coulomb interactions between charged particles within media that often contain a complex mixture of species. Even under high-temperature and high-density conditions, a considerable fraction of neutral atoms and molecules persists, requiring careful consideration, especially when analyzing the electrodynamic properties of the system [1].

The diverse physical phenomena associated with WDM necessitate a robust and consistent theoretical framework. To address this, a generalized chemical model was developed, as detailed in [2], providing an efficient and reliable method for predicting the thermodynamic and compositional properties of plasmas comprising both charged and neutral constituents. This model captures essential processes such as pressure ionization and molecular dissociation by systematically exploring their behavior across a wide range of temperatures and densities. Particular emphasis is placed on deriving analytical expressions for ionization potential depression and dissociation energy shifts, formulated through microscopic interaction potentials and validated across various plasma conditions.

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MAGNETRON TECHNOLOGY FOR PREPARATION OF TAPE SUPERCONDUCTORS WITH Nb3Ge COATING

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Superconducting materials based on niobium are widely used in modern technology: Nb-Ti alloy and Nb3Sn superconducting intermetallic compound. The Nb-Ti alloy is used to produce magnetic-resonance imaging scanners, and the superconducting Nb3Sn intermetallic compound is used to produce superconducting magnets in the large accelerator complexes. Use of such mega-installations as the Large Hadron Collider (LHC) in modern science has shown that superconducting materials, used in LHC construction, can lose superconductivity upon reaching the limit values of load in terms of the current and field. In this regard, an urgent task is to search for new technologies for obtaining superconductors suitable for upgrading such installations as the LHC [1].

At present, mainly low-temperature superconductors (LTSC) operating at liquid helium temperatures are used in the technology [2].

Among the superconductors listed in Table 1, two hard superconductors of the second kind are mainly used [3]. One of them, a niobium-titanium alloy with a body-centered cubic structure (50 wt.% Nb and 50 wt.% Ti in Russia and 47 wt.% Nb and 53 wt.%, Ti, in the USA, respectively), exhibits the critical transition temperature to the superconducting state that is equal to 9.6 K, and the critical current (3-8)*10^8 A/m^2 in a magnetic field of 5 Tl.

The second superconductor that is used is the Nb3Sn intermetallic compound with a body-centered cubic crystal lattice (A15 structure), produced by the diffusion of tin into niobium at 800-900°C, with the critical transition temperature of 18.3 K at zero magnetic field and current.

LTSC based on the niobium-titanium alloy, despite its relatively low critical characteristics, has taken a leading position due to simple technology of its production and the products from it. Methods for superconducting state stabilization to avoid the problem of SC destruction due to various reasons (thermal, mechanical, magnetic, electrical influences, instability of magnetic flux in the SC, excess current-carrying capacity, etc.) and return to the normal conductivity, which was encountered at the beginning of applied research, have been developed. The latter has led to the fact that the design of superconducting winding materials consists of a large number of thin strands of the superconductor, which are placed in a matrix of normal material with high electrical and thermal conductivity (aluminum, copper). Usually, the SC occupies 30-50% of the wire cross section. Taking into account the features of the SC production described above, as well as the deformability of the Nb-Ti alloy, the method of plastic processing turned out to be the most technologically advanced. Studies of physical properties of niobium-titanium alloys and changes in their processing conditions [4, 5, 6] intended for increasing their critical characteristics, did not lead to significant results.

A similar manufacturing method is used for SC production based on brittle niobium stannide with an inclusion of intermediate heat treatments to provide the diffusion of tin into niobium and formation of the Nb3Sn intermetallic compound. The scheme for preparation of a conductor with a composite structure in both cases includes several dozen operations without taking into account the production, preparation and processing of high-purity raw materials [7].

Tape or wire superconductors coated with niobium stannide are prepared using the diffusion of liquid tin into niobium and by pulling the long-size products through a bath of molten tin in several temperature zones (750-800ºC, 950-1100ºC and 750-800ºC) [8]. Another option [15] implies the high-temperature tinning of a niobium tape followed by the heat treatment of the tape in a long furnace to form a layer of niobium stannide with the A15 structure. Both options are characterized by the difficulties associated with accumulation of niobium impurities in liquid tin and the multi-operation scheme for carrier cleaning.

Preparation of niobium stannide by the decomposition of tin and niobium chlorides from the gas phase on a heated surface [10, 11] of a tape or a wire substrate made of noble metals at 800-1000°C is accompanied by the preparation of a superconductor that does not form cracks during bending for a 3 cm diameter, used for production of superconducting devices based on the printed circuit principle.

In work [12], studies were completed on the preparation of the niobium-tin coatings by the electrolytic method, resulted in establishment of the fundamental capability of niobium stannide production in the electrolysis process. However, presence of cracks was noted in the coating due to several reasons: difference in the expansion coefficients of the substrate and coating, absence of the heat-removing layer, storage conditions and cutting.

Despite the large number of studies and technological works performed, the most optimal way for production of the niobium A15 stannide is the solid-phase diffusion using niobium and bronze in preparation of semi-finished products by plastic deformation followed by the high temperature annealing (about 800 °C). The methods to form superconductors in the coatings that would be acceptable for industrial application, have not been developed until now.

At the same time, the ion-plasma processes to form the ultrafine metal particles of various sizes in island films and their technical design open up new capabilities for the production of new materials and alloys based on the phenomenon of thermal fluctuation melting.

At present, stranded wire conductors from intermetallic compounds and niobium alloys, prepared by drawing through a thin die, are mainly produced and used. The main disadvantage of commercially used superconductors based on the intermetallic compounds is manufacturing electrical products from a semi-finished component and the subsequent synthesis of the compound that is already in the product with all its structural elements at a high temperature (above 900 °C), when the intermetallic compound is formed via the diffusion of tin into niobium, and, as a result, the impossibility of rejecting conductors at the preliminary stage.

In 1975, L.R. Testardietal published a paper [13], which describes magnetron production of the Nb3Ge compound, measurement of its critical transition temperature, and analysis of the effect of various technological parameters on the properties of the resulting compound. We will refer to this paper many times in the discussion of our results. At the same time, the chamber design, described in [15], is not suitable for preparation of tape superconductors coated with Nb3Ge.

As according the Nb3Ge superconducting compound is the most perspective one for application in the accelerator technologies, we made an attempt to develop a magnetron technology for preparation of a tape superconductor coated with niobium germanide. In addition, stability of this technology, simultaneously with the technology development, was tested against such negative factors as insufficiently pure feedstock and insufficiently clean vacuum.

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The effectiveness of using STEAM projects in teaching physics: on the example of increasing interest in solar energy

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In today's global context, the demand for professionals in physics and engineering is steadily increasing. However, the declining interest of students in physics in recent years has become a matter of concern not only in Kazakhstan but also worldwide. One effective approach to addressing this issue is the integration of STEAM projects into the educational process. This study aimed to explore the impact of applying the STEAM methodology to the physics curriculum, specifically in the context of teaching solar energy, on students' interest in the subject and their research engagement.

The reviewed scientific literature related to the research topic highlights that scholars often explore STEAM knowledge within the context of individual disciplines. In developed Western European countries, the focus is placed on educational equity and systematic integration, whereas developing nations tend to prioritize pedagogical practices. In contrast, Eastern countries underscore humanistic leadership and the incorporation of cultural elements in STEAM education [1–3]. Although many educators express interest in STEAM-integrated approaches, they frequently lack sufficient preparation for effective implementation [4]. The effectiveness of the STEM model in fostering critical mathematical thinking among primary school students is largely determined by comprehensive problem-based learning (PBL) strategies [5]. A deeper understanding of STEAM education reveals its foundation in the synergistic effects of problem-based and project-based learning methodologies [6]. Consequently, STEAM education not only enables students to apply their physical knowledge, skills, and experience, but also encourages the creation of qualitatively new outcomes—STEAM products [7].

The experiment involved 212 second-year students from Khoja Akhmet Yassawi International Kazakh-Turkish University and M. Auezov South Kazakhstan University. Participants were evenly divided into control and experimental groups. The control group received traditional instruction, while the experimental group took the course "Alternative Energy Sources" fully integrated with STEAM projects. Over the 15-week course, students explored topics such as energy generation using solar panels, the photoelectric effect, angular influence, and panel efficiency.

During the experiment, students developed various projects and constructed functional devices. Specifically, they created solar panels that automatically track sunlight, Arduino-based irrigation systems, and fully operational models using mechanical components produced with a 3D printer. In the process, students utilized tools such as Arduino, servo motors, light-dependent resistors (LDRs), and 3D modeling software. A key advantage of the STEAM approach is its integration of science and technology, which simultaneously fosters students' creativity, engineering skills, and mathematical competencies.

The results of the study were analyzed using Google Forms questionnaires and SPSS software. The survey outcomes indicated a significant increase in students' interest in the subject. In the experimental group, the average interest score rose from 3.5 before the course to 4.4 after it ($t(105) = -10$, $p < 0.001$). In contrast, the control group showed only a marginal increase—from 3.3 to 3.4. This difference confirms the substantial impact of STEAM projects on the experimental group.

The STEAM methodology not only makes the subject more engaging but also cultivates essential life skills in students—such as critical thinking, teamwork, and creative problem-solving. It should be regarded not merely as a teaching strategy for physics but also as an effective tool for career orientation in emerging fields like solar energy.

In conclusion, the study's findings confirm the effectiveness of STEAM projects in enhancing educational quality, fostering student interest in the subject, and preparing future energy specialists. Broad implementation of such integrative methods represents a meaningful investment in the future of science and education.

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The fourth Annual Conference of the Kazakh Physical Society on June 4-7, 2025, ABSTRACTS OF REPORTS

Басуға жауапты Ислямова С.А.

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Таралымы 500 дана	Тапсырыс 596

С. Аманжолов атындағы ШҚУ «Берел» баспасы
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