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# Polymeric Materials: in Search of a Balance Between Utility and Environmental Concerns

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Nowadays, the human society is aggressively challenged by pollution and scarcity of resources for the future industrial development dramatically augmented by the geopolitical instability. To create the needed new and sustainable technologies, products, services, markets and business models, two main transition directions, ecological and digital, doubled by a strong involvement of the whole society are considered. To lay the foundations of a clean, competitive industry, to reduce the pressure on limited resources and costs of production, and to create new jobs, the key elements could be represented by design by thinking sustainable products, increased selected collection and recycling of raw materials, as well as a functioning market for secondary raw materials (circularity) among many others.

Synthetic polymers, plastics, known as soft materials are one of the materials responsible for the actually increasing negative impact on the environment. They are present alone or in combination with inorganic hard materials (metals, oxides…) in almost all economic sectors (textiles, packaging, constructions, electronics, cosmetics, household objects and devices, toys…) bringing with them the undesired polluting.

This work aims to put plastics and the derived materials under socio-economic, but also scientific and technological scrutiny. Some solutions on plastics replacing with materials from renewable resources of use in clean energy production, electronics, biomedicine, and environment protection or efficient recycling and reuse are detailed, as developed by the authors’ institutions.

**Keywords:** Raw materials; Plastics; Environment; Circularity; Sustainability.

# Next-Generation Polymer Composites Based on Emerging 2D Materials

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Hydrogen is central to the development of clean and sustainable energy systems, yet its widespread use is hindered by challenges such as leakage from storage systems and the embrittlement of metal components. To address these issues, polymer composites reinforced with two-dimensional (2D) materials are emerging as effective materials.

This work presents a novel and scalable method, Temperature-Induced DElamination (TIDE), for exfoliating $Ti_3C_2T_x$ MXene into large-area, defect-free nanosheets. Based on molecular dynamics simulations, which showed a significant weakening of interlayer interactions above 7.2 Å spacing, TIDE exploits the reversible expansion of ethanol/water mixtures to drive solvent intercalation. After five cycles, the method achieved efficient MXenes delamination, producing flakes >10 µm in size, with minimal defects, high conductivity (~6000 S/cm), and a yield of 61 wt%.

These high-quality MXenes were then integrated into HAVOH/PAA polymer matrices to produce hydrogen barrier coatings with enhanced resistance to water humidity. The optimized film demonstrated outstanding hydrogen barrharalier performance, exceeding previously reported systems. Additionally, the films, after laser treatment, enabled real-time hydrogen detection and pressure sensing (0–200 bar), supporting applications in smart sensing technologies.

In summary, this study proposes a green, efficient exfoliation route for MXene production and showcases their multifunctional role in hydrogen barrier and sensing applications, offering valuable solutions for next-generation hydrogen energy systems.

**Keywords:** MXenes; Polymer Composites; Barrier Properties; Multifunctionality; Sustainable energy;

# Nanotechnology Research in the Republic of Moldova: The Role of the Technical University of Moldova

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Nanotechnology represents one of the emerging priority fields of research in the Republic of Moldova, with applications spanning advanced materials, energy, environment, health, food industry, microbiology and biotechnology. The Technical University of Moldova (UTM) plays a leading institutional role in consolidating national capacities in this area by coordinating interdisciplinary research and providing access to modern infrastructure. A decisive step in advancing nanotechnology research was the creation of the National Center for Materials Study and Testing (NCMST) in 2001, marked by the acquisition of electron and atomic force microscopy systems, which provided new opportunities for nanoscale investigation and innovation. Through its network of research centers, institutes and laboratories, UTM fosters a strong environment for scientific innovation, education, and technology transfer, serving as a platform for both fundamental studies and applied projects. Today, advanced studies and applications are carried out in key areas such as nanostructured materials, porous semiconductor templates, metal nanotube networks, electrochemical sensors, novel functional coatings, renewable energy, environmental protection, nanoelectronics, biomedical engineering, food industry, microbiology and biotechnology contributing to the development of advanced materials and technologies. This institutional framework not only strengthens Moldova’s research capacity but also positions the Technical University of Moldova as a national leader and regional reference point in nanotechnology research and innovation.

**Keywords:** Research centers; National capacity; Advanced materials; Scientific collaboration; Technology development.

# Mechanical Properties Study and Blation Tests of Hot Pressed and Manufactured under High Pressure Ultrahightemperature $HfB_2$ and $HfB_2$-SiC Ceramics

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Ultrahigh-temperature, corrosion-resistant materials based on $HfB_2$ (melting point of $HfB_2$ - 3380 °C) have high thermal conductivity, high level of mechanical characteristics, high corrosion resistance in oxidizing atmosphere due to the ability to form protective, oxidation-resistant scales at elevated temperatures. They are promising for many ultrahigh-temperature applications, for example, for the manufacture of nozzles for aircraft and rocket engines that are in contact with aggressive gases at high temperatures, as well as for the manufacture of wing edges and fairings for supersonic aircraft, etc. It is known that the addition of SiC to $HfB_2$ can increase the mechanical properties of composite. The results of present investigations showed that on the densification, mechanical characteristics and resistance toward ablation important role play sizes and quality of SiC initial powder used as addition. Such effect we observed both for the composites prepared under hot pressing conditions (30 MPa pressure) and conditions of high pressure (2 GPa) – high temperature. Our previous studies have shown that the use of high pressures and temperatures and hot pressing, and the addition of SiC to $HfB_2$ allowed us to achieve a level of mechanical properties of the resulting ceramic materials that, in terms of hardness and crack resistance, surpass the best world analogues. It was also shown that the addition of SiC significantly reduces the melting point and accelerates the oxidation kinetics upon heating. The microhardness, $H_V$, and fracture toughness, $K_{1C}$, (at an indentation load of 9.8 N) of the $HfB_2$-30 wt.% SiC(5-10 μm) composite material which was hot pressed (under 30 MPa) were $H_V = 38.6 \pm 2.5$ GPa and $K_{1C} = 7.7 \pm 0.9$ MPa $m^{0.5}$ when specific density 6.54 g/$cm^3$ (and near zero porosity) was attained. For $HfB_2$-30 wt.% SiC(30-50 μm) porosity was about 17 % and $H_V = 28.1 \pm 11.3$ GPa and $K_{1C} = 6.1 \pm 2.2$ MPa $m^{0.5}$. Hot-pressed HfB2 without additives exhibits $H_V = 18.9 \pm 0.1$ GPa and $K_{1C} = 7.65 \pm 0.6$ MPa·$m^{0.5}$, porosity 2.4% and specific density 10.79 g/$cm^3$. Ablation tests in air of the samples of ultrahigh-temperature hot-pressed ceramics based on $HfB_2$ and $HfB_2$-SiC when heated with a gas burner (into which an $O_2/C_2H_2$ mixture was fed, and the distance to the sample surface was 13 mm) showed that $HfB_2$ ceramics with an additive of 30% by weight of SiC with a grain size of 30-50 μm and 5-10 μm turned out to be significantly more stable (up to 2066-2080 °C, respectively, at an internal mass of 0.25 mg/s) than ceramics with $HfB_2$ without the additive (cracked at 1870 °C).

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# Some Peculiarities of Obtaining Gradient Materials with High Interlayer Adhesion, Structural Features and Phase Composition Based on Ceramic and Metal-Ceramic Systems by SHS Compaction Technology

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Hard alloys are distinguished by their excellent physical and mechanical properties, which makes them highly desirable for many technological applications. However, their widespread use is limited due to intrinsic brittleness and their low resistance to impulsive shock loads. This drawback can be overcome through the development of **gradient materials, fine-grained (nanostructured) systems,** and **phase-stress engineering,** which allow dissipation and accumulation of destructive energy under dynamic loading, thereby enhancing material durability. To achieve this, the **Self-propagating High-temperature Synthesis (SHS)** method has been employed. For SHS to proceed, it is sufficient that the initial components, once initiated by a thermal impulse, interact exothermically, enabling a self-sustaining synthesis front through heat transfer within the material. The aim of this study is to identify the compositional and structural factors necessary for producing gradient materials with high resistance to intense dynamic loads via **SHS compaction technology.** Specifically, the objective is to obtain materials whose **interlayer adhesion strength** is comparable to that of their individual ceramic or metal-ceramic components. This requires a **smooth transitional interface** between layers, avoiding sharp boundaries to ensure strong bonding. The research presents the structural features of the synthesized gradient materials, analyzes their phase composition, and demonstrates strategies for improving interlayer adhesion. The results confirm the potential of these materials for applications under high-intensity dynamic loading conditions.

**Keywords:** Gradient materials, Structure, SHS

# On the Possibilities of Applications of New Inorganic Polymer – Double Condensed Cyclooctaphosphate of Potassium-Gallium

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The significant properties of condensed phosphates, such as the high thermal stability and important content of phosphorus have caused their application as raw components for manufacture of phosphates glasses; the use of crystalline and/or amorphous non-crystalline ultraphosphates in quantum electronics are determined by their significant properties. Among a diversities of condensation schemes taking place in phosphoric anions one of them leads to the arrangement of cyclic, oligomeric or polymeric compounds formation. Very interesting inorganic polymeric compound - double cyclooctaphosphate of potassium-gallium $K_2Ga_2P_8O_{24}$ is synthesized by us, during investigation of poly-component system $K_2O$-$Ga_2O_3$-$P_2O_5$-$H_20$. The temperature range of the experiments was up 50° C to the 600 °C. The optimum range for the synthesis of new cyclic inorganic polymer was determined: up to 300° C to the 420° C, with initial molar ratios of phosphorus, gallium and potassium ranging from 16/1/4.5 to 16/1/8. The structure studied demonstrated the presence of long empty hollow channels. Given the structural arrangement of the compound in question, i.e. the fact that its open worked octa-cycle has structurally quite large, infinitely long cavities with diameters of around 5.2 Å to 5.4 Å, it was expected to have “zeolitic properties”, which would enable us to use it as an adsorbent. To this end, the catalytic properties of $K_2Ga_2P_8O_{24}$ were investigated at the Analytical Center "Geoanalitika". It was established that the inorganic polymeric compound of potassium-gallium possesses an interesting and important property: it is characterized by high catalytic activity in the model reaction of dehydration of n-butyl alcohol (n-Butanol). The overall conversion rate is 52% to 65%. It was also determined that this sample is comparable in activity to $BPO_4$, which in turn has a characteristic of around 50%. It is as active as the well-known catalyst $Bi(PO_3)_4$ and, above all, it is more active than the zeolitic catalyst NaZr-A (32%), which was tested under the similar conditions. During the tests it was determined that the reaction products – olefins C4 hydrocarbons - were best obtained and treated with the catalyst under the experimental conditions. K-Ga cyclooctaphosphate is very good catalysts in reactions to obtain C2-C6 olefin hydrocarbons/diolefins - which has been confirmed in specific studies - for the separation of low molecular-weight gases.

**Keywords:** Cyclooctaphosphate; Catalyst; Inorganic polymer; Gallium; Phosporus.

# The Influence of Ozonated Water on Some Components in Wine Materials of Saperavi from Ancient Region of Georgia – Bolnisi

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**Introduction:** The purpose to reduce the use of chemical phytosanitary treatments in viticulture means that various methods are being tried in search of more sustainable alternatives that have a lower impact on the environment. One such method is the use of ozone to protect grapes. The main advantages of using ozone for processing grapes are the treatment of downy mildew and powdery mildew of grapes, increasing the yield, and increasing the shelf life of products. Ozone application for grape processing is an environmentally friendly and highly effective method. Ozone does not harm the environment, does not accumulate in the soil and plant products, helps to increase crop yields, and increases the shelf life of products.

The aim of this work for the first time is to determine some mineral macro- and microcomponents, organic acids and preliminary identification of main phenolic antioxidants – resveratrol, quercetin and rutin in Georgian red wine Saperavi, and in wine materials, repeatedly treated with ozonated water.

**Objective:** Georgian red wine "Saperavi", kindly provided by the wine enterprise "Dzmebis marani" from Bolnisi.

**Methods:** The analyzes were carried out using GC/MS (instrument Agilent 1290 Series UHPLC coupled with 6450 Accurate Mass-Q-TOF-LC-HRMS), HPLC, photocolorimetry, spectrophotometry, conventional chemical analysis methods. As eluents, acetonitrile with 99.9% purity, acetic acid, bidistillate water were used.

**Results:** Ozone affects the chemical composition of grapes differently: short-term ozone treatment causes a decrease in the total free VOC (volatile organic compounds) content in fresh grapes. The concentration of tartaric acid in Saperavi was 8.3 g/dm$^3$, and malic acid was 4.8 g/dm$^3$ to compare with control samples – 5.8 g/dm$^3$ and 4.1 g/dm$^3$ accordingly. At the same time, stronger and longer ozone treatment induces the synthesis of some compounds, such as free (+)-4-carene and 4-terpineol. Exposure to ozone causes a decrease in the content of citric and tartaric acids compared to control samples. Also, grapes exposed to ozone stress may contain volatile substances associated with lipid peroxidation. The macro- and microcomponent composition of both must and wine did not change during ozone treatment. The content of resveratrol, quercetin and rutin also did not change compared to the control samples.

**Conclusion:** The ozone treatment practically didn't change the chemical content of wine Saperavi and wine materials.

**Acknowledgements:**
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# Ne Cryocrystals: Prediction of Thermal Expansion Based on the Correlation with Heat Capacity

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The low-temperature dependence of the heat capacity of Ne cryocrystals has a hump that appears as a local maximum in the heat capacity curve as shown in $C/T^3$ vs $T$ at $T_{max}$. The $T_{max}$ shifts to lower temperatures from 8.11 to 6.72 K with the change of the molar volume from 12.39 cm$^3$/mole to 13.39 cm$^3$/mole [1]. A universal empirical relation Δ* described the excess (non-Debye) heat capacity at low temperatures. The value of the universal function Δ* independent of molar volume for Ne cryocrystals. In the close vicinity of $T_{max}$ the left and the right branches of Δ* for all sets of Ne cryocrystals are almost symmetrical and can be well described by a quadratic dependence. At low frequencies, the phonon spectrum rises proportional to $\omega^2$ as formulated in the Debye model. At higher frequencies, the real spectrum of crystals exhibits van Hove singularities, where the spectrum changes discontinuously, which leads to the appearance of the hump in the heat capacity dependence $C/T^3$ vs. $T$. All frequencies of the real spectrum are proportional to the frequency $\omega_{vH}$ of the first van Hove singularity, the magnitude of which depends on the volume [2].

Correlation between thermal expansions ($T$) and heat capacity $C$ ($T$) of atomic Ne crystal was analyzed. The proportional correlation $(\beta/\beta*) \sim (C_V/R)$ with the parameter $\beta*$ for the bulk thermal expansion coefficient for Ne cryocrystals is observed in the temperature range from the lowest experimental to temperatures where $C_V/R \approx 2$. This study provides new information about the origins of such a correlation between thermal expansions $\beta(T)$ and heat capacity $C(T)$ of Ne crystals as a manifestation of the first van Hove singularity.

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[2] M.S. Barabashko, A.I. Krivchikov, R. Basnukaeva, O.A. Korolyuk, A Jeżowski, (2023). Proportional correlation between heat capacity and thermal expansion of atomic, molecular crystals and carbon nanostructures. Condensed Matter Physics, 26(3).

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**Keywords:** heat capacity; thermal expansion, first van Hove singularity.

# Thermoelectric Generator Based on SiGe Alloys

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Among high-temperature thermoelectric materials, silicon-germanium (SiGe) alloys are considered among the most promising due to their high efficiency and thermal stability. These materials can potentially achieve energy conversion efficiencies exceeding 10% in the temperature range of 1100–100 °C. Moreover, SiGe alloys demonstrate stable performance in vacuum, inert gas atmospheres, and even in air up to 1000 °C, making them highly suitable for practical thermoelectric generator (TEG) applications.

The thermoelectric generator presented in this work is based on both n-type and p-type $Si_{0.9}Ge_{0.1}$ alloys. These materials were synthesized via mechanical alloying—specifically, joint grinding of constituent elements in a planetary ball mill (RETSCH PM-100 CM)—followed by vacuum hot pressing to compact the resulting ultrafine powder. Bulk samples were fabricated using a high-temperature induction vacuum pressing system developed at the Sukhumi Institute of Physics and Technology. The grain size and phase composition of both powder and consolidated samples were characterized using a DRON-3M X-ray diffractometer and a Nikon optical microscope.

The generator consists of four monolithic thermoelectric modules connected in series. Each module includes 16 thermoelectric legs (8 n-type and 8 p-type) made from SiGe alloys, connected in series. The cross-sectional area of each leg is $0.5 \times 0.5$ cm$^2$ with a height of 1.5 cm. The modules were assembled using a vacuum induction furnace to ensure material integrity and thermal contact.

Thermoelectric performance was evaluated using a gas heater to simulate high-temperature conditions and a water-based cooling system. In the temperature range of 600–100 °C, individual modules generated an output voltage of approximately 1 V and power of 2 W, while the complete generator produced 4 V and 7 W accordingly. These results highlight the potential of SiGe-based systems for efficient, high-temperature power generation in a range of operational environments.

**Keywords:** Silicon-Germanium Alloys, Thermoelectric Generator, High-Temperature Energy Conversion, Mechanical Alloying.

# Photocatalytic Activities of Borides on the Antibiotic Wastes

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The increasing discharge of pharmaceutical residues, particularly antibiotics, into aquatic environments has raised serious concerns due to their persistence, potential to induce antimicrobial resistance, and limited removal by conventional treatment methods. Among these pollutants, compounds such as tetracycline, levofloxacin, ciprofloxacin, and other antibiotics from similar structural groups are frequently detected in wastewater streams. In this study, the photocatalytic degradation efficiency of selected boride-based materials—specifically titanium diboride ($TiB_2$), zirconium diboride ($ZrB_2$), and boron carbide ($B_4C$)—was investigated for the treatment of antibiotic-contaminated waters. The synthesized photocatalysts were tested under controlled UV-visible irradiation conditions at varying pH levels to evaluate their ability to degrade target antibiotics. Degradation kinetics, reaction pathways, and removal efficiencies were systematically analyzed. Results demonstrated that all three boride materials exhibited significant photocatalytic activity, with $TiB_2$ showing the highest performance in the breakdown of complex antibiotic molecules. The enhanced activity is attributed to their strong chemical stability, high surface area, and efficient charge separation under irradiation. These findings suggest that boride-based photocatalysts hold substantial potential as effective and sustainable alternatives for the removal of pharmaceutical micropollutants, offering a promising approach in advanced wastewater treatment technologies.

**Keywords:** Borides, Photocatalysis, Tetracycline, Pharmaceutical wastewater, Antibiotic degradation.

# Ferromagnetic Nanosystems and Magnetically Activated ATP Reactions

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Ferromagnetic nanosystems represent a transformative frontier in biomedicine, leveraging their unique magnetic properties for diverse therapeutic and diagnostic applications. This paper explores groundbreaking phenomena – magnetically activated adenosine triphosphate (ATP) reactions – to elucidate the role of iron and manganese oxide nanosystems in enhancing electrodynamical and biomagnetophysical processes.

Ferromagnetic nanoparticles can be exposed to alternating magnetic fields (AMF) or static magnetic fields. The oscillations of magnetic nanoparticles in these fields may result in localized heating, mechanical agitation, or altered molecular dynamics. These effects can influence the rate of ATP hydrolysis in the following ways:

Localized Heating: A magnetic nanoparticle can absorb energy from the applied magnetic field and release it as heat. This localized heating can speed up ATP hydrolysis reactions, which are temperature-dependent, by increasing the kinetic energy of the reactants and the ATPase enzymes involved in these reactions.

Magnetic Actuation: When subjected to an external magnetic field, ferromagnetic nanoparticles may undergo changes in orientation or shape, leading to mechanical vibrations that could potentially disrupt or accelerate the interaction between ATP molecules and ATPase enzymes (like ATP synthase or ATPases involved in muscle contraction or ion transport).

Enhancing Enzyme-Substrate Interactions:

The presence of ferromagnetic nanoparticles could influence the conformation and activity of enzymes involved in ATP hydrolysis, such as ATPases, by altering their microenvironment or through direct interactions.

Parallelly, our work investigates ATP activation via magnetic impurities ($Fe^{2+}$, $Mn^{2+}$), employing vibrational spectroscopy (Raman/IR) to probe how these ions modulate ATP hydrolysis kinetics and energy transfer mechanisms. The interplay between magnetic nanoparticles and ATPase-driven phosphorylation reactions is analyzed, offering insights into cellular energy manipulation and potential therapeutic applications.

By bridging material science, biophysics, and clinical innovation, this work underscores the potential of ferromagnetic nanosystems to revolutionize oncology and bioenergetics, while highlighting future directions for low-toxicity, high-efficiency nanotherapies.

**Keywords**: ferromagnetic nanoparticles, iron and manganese oxides, ATP hydrolysis, vibrational spectroscopy.

# Innovative Magnetron Reactor for Forming Monodisperse Nanomaterials

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Innovative magnetron reactor is a Planar-Rotational Magnetron Sputtering Device based technique-technology, which we present for receive of nanomaterials includes the formation of a flow of macrodroplets in the active zone of erosion and their cascade fission in the area of the magnetron plasma of a toroidal shape. The formation of macrodroplets on the surface of target proceeds under the action of intense ion bombardment between the inputs and outputs of closed magnetic field lines. As the sputtered atoms and molecules, also macrodroplets fly out from the target surface and enter the volume of the toroidal magnetron plasma. The sputtered atoms and molecules of the target material freely pass through the high intensive toroidal magnetron plasma, but macrodroplets from the target material in the volume of the toroidal magnetron plasma are recharged. Further, as a result of the development of the process of Rayleigh or capillary instability in plasma, makrodroplets start cascade fission. Final product of this procesis are monodisperse nanomaterials. The cooling and solidification of nanoparticles occurs outside the plasma region in the vacuum space. Presented by us Innovative magnetron reactor opens up new possibilities for obtaining in vacuum monodisperse nanoparticles.

# Gallium Oxide Based Memory Switching Device

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This paper discusses the production of gallium oxide ($Ga_2O_3$) by reactive magnetron sputtering technology and its use in a memory device - memristor, as an active layer. Various technological conditions are selected to obtain the best physical, electrical, structural and optical parameters of gallium oxide. Volt-Faradic, Volt-Siemens, Volt-Amperic, X-ray diffraction, light transmission spectra and Kelvin methods of measurement are used. The ratio of low resistance and high resistance is shown, calculated from the volt-amperic characteristic of the memristor.

**Keywords:** oxide, magnetron, technology, memory, memristor.

# Possibilities of Using Cu(II) Ions in Oncology: The Role of PAMAM Dendrimers and NIR Radiation

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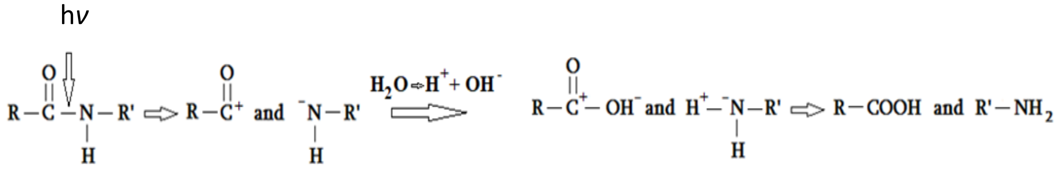
For non-invasive treatment of cancer with metal ions, Cu(II) and Cu(I) ions are most suitable, because they are capable to cause UV spectroscopically manifested self-consistent double proton transfer in DNA through the $H^+$ tunneling effect. The consequence of this is keto-enol and amino-imino tautomeric changes in guanine, cytosine, and adenine, leading to point mutations [1].

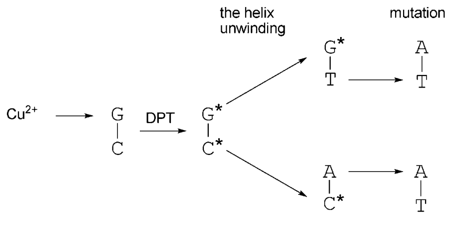
The aim of this work is the possible use of Cu(II) ions and highly toxic Cu(I) ions in oncology. Cu(II) and Cu(I) ions, having fulfilled their role, can be easily removed from the organism with the help of ceruloplasmin, which is synthesized by liver cells. For these purposes, we think it is good to use PAMAM (Polyamidoamine) dendrimers, which can bind Cu(II) and Cu(I) ions and deliver them to the nuclei of cancer cells. Hydrolytic enzymes found in lysosomes can release Cu(II) and Cu(I) ions from PAMAM dendrimers. Additionally, on the other hand, the process of ion release can be facilitated by using NIR (Near infrared) radiation of the line spectrum of an argon glow discharge lamp (700-1800 nm, 1.7-0.7 eV) [2].

This radiation can be used primarily for the amide bonds G4NH$_2$ of PAMAM dendrimers. A mandatory condition for hydrolysis of chemical bonds is the dissociation of water molecules into H$^+$ and OH$^-$ ions and overcoming the energy barrier (~1 eV) in bonds subject to hydrolysis.

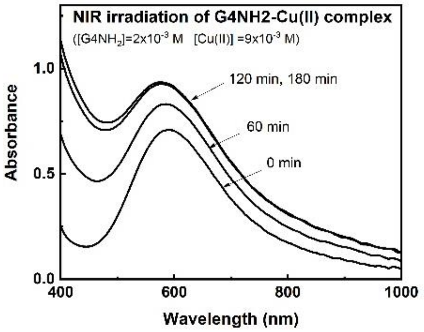


$$R-\overset{O}{\overset{\|}{C}}\overset{h\nu}{\downarrow}\underset{H}{\underset{|}{N}}-R' \Rightarrow R-\overset{O}{\overset{\|}{C}}{}^{+} \text{ and } {}^{-}\underset{H}{\underset{|}{N}}-R' \xrightarrow{H_2O \Leftrightarrow H^+ + OH^-} R-\overset{O}{\overset{\|}{C}}{}^{+}-OH^{-} \text{ and } H^{+}-{}^{-}\underset{H}{\underset{|}{N}}-R' \Rightarrow R-COOH \text{ and } R'-NH_2$$

Hydrolysis of amide groups



* rare tautomeric form of bases



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**Keywords:** DNA, Copper ions, PAMAM dendrimers, NIR

# Resonance Scattering Spectra Analysis of Core-Shell Structured Particles

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Knowledge of spectroscopic properties, scattering, and absorption spectra of particles is essential for the development of modern detection systems of aerosol and viral particles, as well as harmful agents. The simulation study of the optical characteristics of particles with different structures, shapes, and compositions enables the discovery of new composite materials for biomedical and nanotechnology applications. Scattering and absorption properties of particles revealed in an electromagnetic (EM) field depend on EM wavelength, particle size and shape, composition, and electric and magnetic properties of the environment and materials. Relay, Mie scattering, and geometrical optics approximation are well-known methods describing the particle's behaviour in the EM field. Ultraviolet (UV), Visible-Infrared (Vis-IR) and Raman spectroscopy are successfully developed for experimental study of materials and particles. The focus of the research is on the optical properties of particles observed within resonance wavelength ranges. These properties are estimated using modelling and simulation methods, resolving electrodynamics boundary problems in cylindrical or spherical coordinate systems in line with particle models that correspond to their specific shapes and structures. A study of resonance scattering properties of particles with structural similarities to viral particles is proposed. A virion, a complete nano-sized viral particle is composed of core (RNA/DNA) and shell (proteins), and the morphology of viruses is mostly icosahedral or helical. The elaborated concept, resonance scattering (RS) method and graphical interpretation for analyzing the resonance scattering spectra of core-shell structured virus-like particles (VLPs) are presented. Research has shown that the ratio of the volumes of the core to the shell of VLPs, along with their corresponding electric and magnetic parameters and shape, determines the resonance wavelength range. It could be predicted using a theoretical approach and estimating the so-called “electric” radii. The resonance scattering regions of viral particles typically fall within the UV range in most cases. The proposed method could be applied to studying the resonance scattering spectra of particles similar to VLPs.

Work is supported by Shota Rustaveli National Science Foundation of Georgia [Grant № FR-23-4069].

**Keywords:** Scattering; Spectra; Modelling; Simulation; Virus-like particles.

# Explosion Fabrication of High Entropy Alloys in Fe-W/WC-Al-Ti-Ni-B-C System

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High-Entropy Alloys (HEAs) are the alloys that contain at least 5 principal metallic elements with equimolar concentration, or where the presence of principal elements varies between 5-35%. The configurational mixing entropy of multicomponent system is varied as well depending on number (N) and concentration (n) of basic elements. The calculated mixing entropy is higher than the conventional alloys. High mixing entropy supports formation of HEA with stable solid solutions of disordered structures, in difference the conventional metallic alloys, that are form mainly complex intermetallic structures. Four core effects: high configurational entropy, sluggish diffusion, lattice distortion and cocktail effects provides to HEA’s the complex of unique special properties, in particular high hardness, wear-resistance, significantly high strength, structural stability, good corrosion and oxidation-resistance and etc.

The FeWAlTiNiBC multicomponent system was selected to fabricate HEA in the presented study. The high potential to form stable solid solutions and intermetallic compounds in wide spectrum of structural modification, as well as attractive properties for practical application were main motivation for selection of composition. Ball milling technology was applied to obtain multicomponent ultrafine powder reaction mixture for future consolidation and syntheses of bulk HEA’s. Due to his adiabatic nature, the explosion compaction (EC) technology was used for consolidation of mechanically alloyed (MA) powders.

The technological regimes of MA and EC of fabrication of HEA’s and some structure-properties obtained within research are discussed in the paper.

**Keywords: HEA,** Nanocomposites, Solid solutions; Mechanical Alloying, Explosion consolidation.

# Synthesis of Properties of Epoxy-Resol Copolymers

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The unique properties of epoxy polymers have led to their wide application in various fields of modern technology. Of particular interest are the works devoted to the synthesis and curing process of epoxy- resol resins.These polymers are characterized by increased physical and mechanical parameters. Taking into account the chemical structure of polycyclic bisphenols of the norbornane type, it could be expected that the epoxy-resol copolymers obtained on their basis would also have high performance characteristics, given the fact that in this case both components, such as diglycidyl ether, and the oligomer of the resol component were obtained on the basis of polycyclic bisphenols of the norbornane type. To obtain epoxy-resol copolymers, glycidyl ethers and methylol derivatives of the following polycyclic bisphenols were used: 4,4′-(2-norbornilidene)diphenol, 4,4′-(hexahydro 4,7-methylenindane-5-ylidene)diphenol, 4,4′-(decahydro-1,4,5,8-dimethylennaft-2-ylidene) diphenol. The reaction of the formation of epoxy-resol type copolymers based on glycidyl ethers and methylol derivatives of bisphenols proceeds due to the interaction of reactive epoxy groups with phenolic hydroxyls and methylol groups. The optimal ratio of the initial components was established by the example of the interaction of derivatives, 4.4′-(hexahydro-4,7 methylenindane-5-ylidene) diphenol. Thermomechanical studies have shown that the copolymer with the highest heat resistance is obtained with a molar ratio of the initial components of 1:1. An increase in the amount of methylene derivative in the initial mixture greater than the above does not lead to an increase in the thermal resistance of the copolymer, and when it decreases, the heat resistance of the polymer, on the contrary, decreases. The copolymer obtained on the basis of glycidyl ether and a methylol derivative of 2,2-bis (4-oxyphenyl)propane is significantly inferior in heat resistance to polymers obtained on the basis of polycyclic bisphenols. In terms of thermal resistance, copolymers based on the initial components of different structures do not differ markedly from each other. All of them are characterized by high thermal resistance. It seemed appropriate to use epoxy-resol copolymers as binders in the development of antifriction materials reinforced with thermal resistant carbon fiber. Carbon fabric with high temperature resistance, strength and self-lubricating properties was used as a reinforcing base. Physico–mechanical and friction studies have shown that epoxy-resol copolymers can be successfully used as binders for the manufacture of antifriction materials.

**Keywords:** Polymer; Copolymer; Epoxy; Resol; bisphenol.

# Effect of Ceramic Composite Nanopowders on Waste Water Treatment

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Advanced nanostructured materials have attracted considerable interest in recent years owing to their exceptional physicochemical properties, including high specific surface area, tunable porosity, and enhanced surface reactivity. These characteristics render them highly suitable for environmental remediation, especially in wastewater treatment where removal of persistent inorganic and organic pollutants remains a critical challenge. This study investigates the application of ceramic-based composite nanopowders, including carbides and borides, as multifunctional agents for improving the efficiency of wastewater purification processes. Batch adsorption and catalytic degradation experiments were performed under systematically varied conditions, including pH, nanopowder dosage, and contact time, to evaluate their removal efficiencies against model contaminants. The results demonstrated a significant improvement in both adsorption capacity and catalytic activity compared to single-component materials, which is primarily attributed to the synergistic effects arising from the composite structure and heterojunction interfaces facilitating charge separation. This enhanced performance underscores the potential of ceramic composite nanopowders as promising candidates for sustainable and effective wastewater treatment technologies, contributing to reduced environmental pollution and improved water quality.

**Keywords:** Wastewater treatment; Nanopowders, Composite materials, Adsorption, Environmental technologies.

# Multifunctional nanocomposite in the $B_4C$-SiC-Si-Al-$Al_2O_3$ – Carbon fiber System

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SIALON is a general name for a large family of Silicon nitride-based ceramic alloys, it was first adopted in the beginning of 1970. β-Sialon is the most well-known phase. Its chemical formula $Si_{6-Z}Al_ZOZN_{8-Z}$ (z=0–4.2) and its hexagonal crystal structure are similar to the structure of β-$Si_3N_4$. SiALON is distinguished by: high hardness, strength, wear resistance. It retains these properties under high temperature conditions. Composites working at high temperatures should be characterized by high density, hardness, thermal resistance and should retain these properties when working at high temperatures. Composites obtained from highly refractory oxide ceramics retain their hardness at high temperatures but are characterized by a high coefficient of thermal expansion and therefore low thermal resistance. Carbide-based ceramics have a relatively high coefficient of thermal expansion, but they are oxidized easily when working at high temperatures. Because of this, science has turned its attention to obtain super high-strength composites – SiALON’s. In this work Our Goal was - to obtain SiALON containing composites by reactive sintering method in SiC-$B_4C$-Si-Al-$Al_2O_3$ system. Using this method of synthesis, it became possible to obtain composites with different percentages of SiALON. Our task was also to study the phase composition in the SiC-$B_4C$-Si-Al-$Al_2O_3$ system.

**Keywords:** Composite; electron microscope; Phase composition; β-SIALON.

# Electrochemical synthesis and corrosion resistance of $Zn@Al_2O_3$ composite coatings

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A thin layer of metal, alloy or composite coating protects the product surface from damage. Coatings containing zinc, zinc alloys and various composites are used in various aggressive environments due to their good corrosion resistance and low cost [1,2].

To obtain a galvanic coating, an electrolysis process is used, $\gamma Al_2O_3$ is added to the zinc matrix as a filler to increase the corrosion resistance of the coating.A composite coating of $Zn@\gamma Al_2O_3$ is obtained from ammoniacal and sulfate electrolyte solut ions. The stability characteristics of the $\gamma Al_2O_3$ suspension are established through the zeta potential. The effect of $\gamma Al_2O_3$ content in the electrolyte on zinc current output and corrosion stability at different current densities is determined.

Corrosion potential, corrosion current density and corrosion rate are determined from the polarization curves of coatings obtained in sulfate and ammonia solutions containing different concentrations of $\gamma Al_2O_3$. Impedance spectroscopy is additionally used to study the corrosion processes, which provides a lot of information about the processes taking place at the electrode/electrolyte boundary. Based on the impedance spectroscopy determined the optimal content of $\gamma Al_2O_3$ in the case of ammonical electrolyte is 2÷10 g/l, and for sulfate electrolyte it is 5-10 g/l.

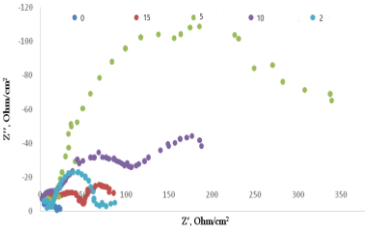

**Figure 1**.Sulfate electrolyte

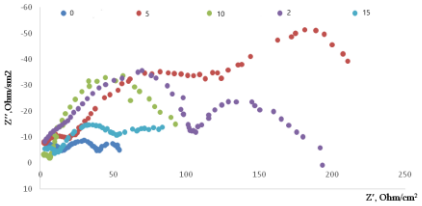

**Figure 2**. Ammonical electrolyte

**Keywords:** Electrochemical Coating, Composite, Corrosion, Impedance.

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# Study of Cathode Materials in Electrolytic Purification of Quarry and Industrial Wastewater from Heavy Metal Ions

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The task of cleaning quarry and industrial wastewater from heavy metal ions, due to their negative impact on the environment and human health, was and remains very relevant. This problem is also relevant for Georgia, in particular, for cleaning quarry waters of the Madneuli sulphide ore deposit from heavy metal ions, which pose a certain danger to the environment and at the same time are an important technological raw material.

The issues of heavy metal extraction from dilute solutions for their disposal, as well as solution neutralization, are given much attention. Different methods are used for this. The most promising is the use of the electrolysis method, which ensures minimal costs for their further processing and creates the possibility of implementing resource-saving and low-waste processes. However, electrochemical methods for extracting metals from such solutions have not been used until recently due to the relatively low productivity of existing industrial electrolyzers.

We studied the electrolysis process when purifying wastewater from copper(II) ions, which are highly toxic and are one of the main sources of pollution of the hydrosphere.

For the extraction of copper with a high degree and with a high current yield from dilute solutions ($Cu \leq 1 g/l$), we have developed a special design of an electrochemical reactor with radially located flat stainless steel cathodes, allowing the so-called "channel" electrolysis to be carried out at a high speed of liquid movement along the electrodes under conditions of maximum cathode current density. The reactor has achieved a significant improvement in the intensity of forced convection and a solution to the problem of removing copper powder from the cathodes. Large-scale laboratory tests have shown that a cascade arrangement of two such reactors, one of which operates at high current values (with copper extraction up to a concentration of 0.16 g/l), and the other at lower values (with copper extraction from 0.16 to 0.05 g/l), allows for a total extraction of up to 95.4% copper from quarry water with a current efficiency of 54.9% and a specific energy consumption of 4175 kWh/t, which corresponds to 5-10% of the cost of copper.

As the research results have shown, the bottleneck in the design of a reactor with flat steel electrodes is the electrolytic extraction of copper at a concentration of ≤ 0.16 g/l.

To solve the problem of intensifying the electrolysis process of copper extraction from highly dilute sulfate solutions, we designed an electrochemical reactor with a flow-through three-dimensional electrode made of carbon-graphite fibrous material with a highly developed reaction surface and high physical, mechanical and operational properties.

It has been experimentally established that when using an electrolyzer with flat steel cathodes from highly diluted solutions ($Cu \leq 0.16$ g/l), copper extraction in 1 hour is 19.6% with an extraction rate of 7.8 $g/h \cdot m^2$, while in an electrolyzer with carbon-graphite cathodes, all other things being equal, the extraction is 83-84% with a copper extraction rate of 176.6 $g/h \cdot m^2$, as a result of which the process intensity increases by 28 times. Specific energy consumption decreases by 1.6 times.

**Keywords:** Electrolysis; Cathode; Copper; Reactor.

# Theoretical Study of Zinc Tetracarboxy-Phthalocyanine: Geometry Optimization and UV-VIS Properties

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Metal phthalocyanines are good macrocyclic photosensitizers with useful photophysical and photochemical properties for photodynamic therapy (PDT) applications. Motivated by these remarkable properties, this study investigates both experimentally and theoretically the properties of tetracarboxy ZnPc. The focus is on understanding how these properties make ZnPc-tetracarboxy suitable for PDT applications, and the research compares these findings to existing literature [1].

The aim of our work is the simulation of molecular structure and optical absorption properties using Gaussian 09 [2] software. The geometry of zinc tetracarboxy phthalocyanine $ZnPc(COOH)_4$ was optimized using the B3LYP functional and the def2-SVP Gaussian basis set within the framework of density functional theory (DFT). DFT calculations were used to optimize the structure by finding the minimum energy configuration. Based on the optimized structure, time-dependent DFT (TDDFT) calculations were performed to simulate the UV-VIS absorption spectrum. The relevant electronic transitions were identified in the range of 300–800 nm, and the corresponding oscillator strengths allowed the assignment of the main absorption bands. The most intense transitions were found at approximately 729.7 nm (HOMO → LUMO, 87%) and 656.0 nm (HOMO → LUMO+1, 85%). The HOMO–LUMO energy gap was estimated to be around 1.61 eV, indicating good electronic stability. The B3LYP-based calculated

absorption spectrum is in very good agreement with the experimental spectra of $ZnPc(COOH)_4$.
Thus, this study predicts the electronic transitions responsible for UV-VIS absorption, which can be useful for understanding the photophysical properties of the molecule.

**Keywords:** Tetracarboxy ZnPc; UV-VIS Spectroscopy; geometry; TDDFT.

**Acknowledgements:** This paper was supported financially by the Ministry of Education and Research of the Republic of Moldova, MSU, subprogram #011209, a project PN-IV-P8-8.3-ROMD-2023-0048 (DSUPRAMED), within PNCDI IV.

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# Introduction of Nanocomposites into Medical Technologies

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Anthelmintics are a group of antiparasitic drugs that paralyse or kill parasites in the body. The most widely used anthelmintics are benzimidazole derivatives, one of which is albendazole. We have synthesized a composite anthelmintic material _ albendazole with calcium phosphate: $C_{12}H_{15}N_3O_2S_xCa_3(PO_4)_2$

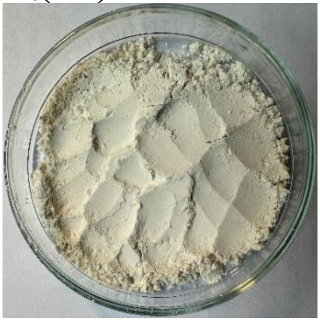

Fig. 1. Synthesized Anthelmintic Composite

The obtained composite differs from currently available medications of the albendazole class. It does not exhibit resistance and demonstrates improved side-effect profiles, including better tolerance, reduced rates of diarrhea and fatigue, and other related symptoms. The X-ray structure of the composite has been determined, revealing that calcium phosphate does not affect the structure of albendazole, as its content does not exceed 2%. X-ray fluorescence analysis was conducted to measure the quantitative content of calcium. The nanoscale size of the composite anthelmintic was determined to be 215 nm using a transmission electron microscope (NSX-100). The beam was directed only to the surface of the test sample, rather than to the entire mass. The physiological activity of the composite was studied using both microorganisms and lab mice, the latter assessed through the elevated plus-maze test. The effect of the composite on the central nervous system of mice was evaluated by monitoring their body weight. The physiological activity of the composite anthelmintic was determined by doses ranging from 100 to 200g (minimum-average-maximum). The obtained anthelmintic composite belongs to the class of antiparasitic agents and functions as a catalyst in the cellular oxidation process. It supports the immune system in animals, promotes growth and development, reduces the risk of waste accumulation in the body, and ensures the complete elimination of helminths. The nanocomposite we obtained is distinguished by its unique properties and high efficiency, offering both environmental safety and cost-effectiveness for agricultural use.

# ITE | Enabling Excellent Science

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Forschungszentrum Jülich is one of the largest interdisciplinary research centers in Europe and a founding member of the Helmholtz Association. Researchers from all over the world contribute their expertise here in the major future fields of energy, information and bioeconomy. In these socially highly relevant areas, we are looking for solutions to the challenges of the modern world. We conduct basic research with a globally unique infrastructure and develop practical applications.

The Institute of Technology and Engineering | ITE of Forschungszentrum Jülich is a multidisciplinary institute with world-class expertise, state-of-the-art laboratories and leading manufacturing technologies. Our aim is to develop innovative research devices, instruments and equipment in the form of unique products and demonstration facilities that push the boundaries of current technology and create solutions where no alternatives exist or are available.

Our research focuses on interdisciplinary topics based on mechanical engineering, automation, electronics and artificial intelligence. ITE has a special focus on low temperature technology, miniaturization, ultra-high vacuum technology, mechatronics and the development and implementation of advanced instrumentation. To successfully bring ideas to life, we closely integrate engineering and manufacturing technology, as well as the unique combination of diverse disciplines and state-of-the-art innovative technologies, equipment, complemented by the extensive experience and expertise of our staff.

In our presentation I will give examples of our work dealing with cryogenic moderator-reflector system for the European Spallation Source in Lund / Sweden, hydrogen storage systems for the German "energy transition" based on liquid organic hydrogen carriers, material and component development for the solid oxide fuel cell and solid oxide electrolyzer cell and some others.

**Keywords:** Spallation source; liquid hydrogen moderators; LOHC, SOC

# Intrinsic Peroxidase-like Activity of $MgFe_2O_4$/PVP Nanocomposites and Their Application in the Colorimetric Detection of $H_2O_2$

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It has been shown that nanoferrites are nanomaterials exhibiting intrinsic enzyme-like activity. Magnesium ferrite nanoparticles ($MgFe_2O_4$ NPs) have been effectively used as nanozymes; they have been shown to behave like a peroxidase in the oxidation of 3,3', 3,5'-tetramethylbenzidine (TMB). These materials have been used in various fields, such as biosynthesis, environmental protection, and bioelectronic sensor devices. In this paper, a method for synthesizing an $MgFe_2O_4$/PVP nanocomposite and studying it as a peroxidase enzyme mimetic has been described. The resulting nanocomposite has been characterized by X-ray powder diffraction (XRD), scanning electron microscopy (SEM), and FT-IR spectroscopy. The morphology of the $MgFe_2O_4$ NP powder has been studied by SEM; it has been shown that the $ZnFe_2O_4$–polymer NPs synthesized in the presence of a polymer have a spherical form and a size of 5–10 nm. Since the NPs have a high surface energy, they undergo a rapid interparticle interaction and coarsening and aggregate into spherical structures with a diameter of 80–120 nm. Composition has been determined by EDX with an Mg : Fe ratio of 1 : 2.5. Experimental results have shown that the $MgFe_2O_4$/PVP nanocomposites exhibit peroxidase-like activity in a linear range of 0.01–0.16 μM. In addition, the color change dependent on hydrogen peroxide concentration can offer a convenient approach to detecting $H_2O_2$ both with the naked eye and spectrophotometrically. Therefore, the $MgFe_2O_4$/PVP nanocomposites are a promising candidate for the colorimetric detection of $H_2O_2$, glucose, ascorbic acid, etc.

**Keywords:** Peroxidase Mimetic, $MgFe_2O_4$/PVP, Spinel Ferrite, $H_2O_2$ Sensing

**Acknowledgments.** This study was funded by Government of Republic of Moldova, Ministry of Education and Research, Research Subprogram 020201 “Nanostructures and advanced materials for implementation in spintronics, thermoelectricity and optoelectronics” and Research Subprogram 020101 ”InBioS - Innovative biotechnological solutions for agriculture, medicine and environment”.

## Laser-Driven Control of Optical and Electronic Properties in Quantum Dots

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The impact of intense structured laser fields - specifically Gaussian and Bessel beams - on the electronic and optical properties of InAs/GaAs quantum dots is investigated. The study focuses on vertically coupled cylindrical and strongly oblate ellipsoidal quantum dot systems, analyzing how non-resonant structured fields reshape confinement potentials, alter energy spectra, and influence carrier localization. Changes in linear and nonlinear optical responses, including absorption, refractive index modulation, and harmonic generation, are examined. Particular attention is given to excitonic complexes such as biexcitons, demonstrating the potential of structured light for tunable optical control in quantum nanostructures.

**Keywords:** Non-resonant structured light, Gaussian beam, Bessel beam, InAs quantum dot, optical properties.

# Obtaining New Composition Porous Materials by Self-Propagating High-Temperature Synthesis

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At present, vehicle exhausts are among the major factors of environmental pollution. This problem is particularly acute in developing countries, where the share of used cars is high because the catalytic converters in used cars are partially or often completely out of order, which leads to the increase of toxic substances in the air such as carbon monoxide, nitric oxides, and hydrocarbons. We used the SHS method to obtain a new type of catalytic substrate, in which precious metals (platinum, palladium, rhodium) can be partially or completely replaced with metals such as copper, nickel, chromium, etc. When obtaining the catalytic substrate by the SHS method, the correct selection of a chemical composition of the initial charging material of the reaction is a determining factor that ultimately leads to obtaining products with the desired properties. Due to the high degree of dispersion of additive metals (copper, chromium, nickel, etc.), they do not participate in the reaction, therefore, they do not form chemical compounds, and they are evenly distributed in the final product, which significantly increases the quality of their catalytic activity. The porosity of the obtained sample is significantly affected by the density of the initial sample. By changing the initial porosity of the sample, it is possible to vary the porosity of the final product from 5 to 45%. Application of the proposed technology reduces the neutralizer-catalyst's production cost and solves the problem of its scarcity. The obtained materials can be used in all types of vehicles with internal combustion engines, as well as in enterprises where catalytic purification of exhaust gases and liquids takes place.

**Keywords:** metal, SHS method, chemical composition, pollution, vehicle, exhaust.

# Superconductivity and Magnetism of Metal Coated GdBaCuO Tapes Exposed to Accelerated Proton and Electron Beams

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*Background* - The tendency of increasing energy losses in the expired world electricity grids, generators and transformers has made actual beneficial replacement of metals by superconductors (SC). Microfilms of yttrium- and gadolinium- barium cuprates have demonstrated the record SC current density. However, the open surface degrades, as any electric wire or contact. Besides, the nuclear particles accelerating facility accumulates self-irradiation induced structure defects under applied magnetic field.

*Objectives* - to study possibility of stabilizing SC function by specific irradiation conditions for SC with properly protected surfaces.

*Objects* – Industrial grade metal-coated superconducting microfilm on Ni-steel substrate micro-tape SuperOx were manufactured by S-Innovations (Russia, Japan). Three microlayers were deposited on $GdBa_2Cu_3O_{7-x}$ (GdBCO) crystal film: Ag for better contact and lowering AC losses, Cu for hermetization and current stabilization, outer PbSn alloy for fixing windings in solenoids. The tape has various interfaces: 1-metal-2-metal, metal-SC, SC-oxide insulator, insulator-metal, all of them are places for charge carrier separation, localization or scattering. These designs allowed one to increase the transport SC current > 200 A at 4.2 K in magnetic field >10 Tesla.

*Experimental methods* – Hall effect measuring system operated within 80-320 K at magnetic field 0.55 Tesla applied normal to the tape surface turned out highly effective for studying magnetic resistance, mobility of electrons and holes in this multilayered SC tape. The temperature range includes electronic and magnetic phase transitions, taking into account ferromagnetic Gd, Ni, Fe, antiferromagnetic Cu, and diamagnetic Oxygen. Cyclotron U-150 accelerated protons to 18 MeV in vacuum tor and projected on the water-cooled target with SC at the angle of $7^{o}$. Accelerator U-003 provided 4-5 MeV electrons at beam current 0.4-2 $\mu A/cm^2$, target cooled with LN to 160 K.

*Results* – electron fluencies $10^{14}$-$10^{15}$ $cm^{-2}$ resulted in the SC transition onset at 120 K magnetoresistance peak and mobility peak is at 80 K. Mobility minimum at 240 K correlates with peak of magnetoresistance attributed to Gd. Proton fluency of $<10^{14}$ $cm^{-2}$ induced α-β-γ-emitting radionuclides, generated tracks and shock waves on PbSn and Cu layer and sputtered them. Magnetoresistance had several peaks related to paramagnetic $O^-$ and $F^+$ defects and ferro-Gd,Ni.

*Conclusions* – the novelty of research is in finding moderate fluency of 9-18 MeV protons and 4-5 MeV electrons, when their tracks were suitable for trapping magnetic field and the distance between the tracks was enough to fit the supercurrent vortices, the coated SC layer was recrystallized by the absorbed irradiation energy. Peaks of carrier mobility and carrier localization correlate with minimal resistance in SC state and magnetoresistance peaks, respectively.

**Keywords:** cuprate superconductor; magnetoresistance; charge carrier mobility;

accelerated electron irradiation; cyclotron proton irradiation.

# Study of Carbon Nanotube/PDMS Polymer Nanocomposites

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The excellent properties of carbon nanotubes (CNTs), such as mechanical strength, high electrical and thermal conductivity, and remarkable flexibility, make them the most ideal and promising reinforcements for polymer/carbon nanotube composites. It is known, that properties of the composites are significantly influenced by interfacial interactions between nanotubes and polymer matrices. The challenge of the application of nanotubes in the composites is the uniform alignment of CNT reinforcements and forming proper interfacial bonding between matrix and CNTs during the mixing process of the composites. Therefore, it is very important to develop and study the technology for preparing polymer nanocomposites.

In this work, the main motive is to deagglomerate the CNTs and realize their uniform dispersion inside polymer matrix. For this purpose, CNT-polymer composites were synthesized using solution mixing method. Solution mixing involves dispersing CNTs in a solvent, followed by polymer addition and solvent evaporation. The choice of solvent is mainly governed by solubility of matrix polymer. For production of polymer nanocomposites, we used a polydimethylsiloxane as polymer matrix. The optimal parameters for composites synthesis, for uniform distribution of nanotubes in the matrix, is to process the solution with ultrasound at $30^oC$ for 30 minutes. The produced samples contain a percentage of CNT by mass: 0%, 5%, 10%, 15%. The synthesized materials were studied and identified by different methods.

**Keywords:** Carbon nanotube, Polydimethylsiloxane, composite

# Photostimulated Diffusion of P and B in Si from Phosporosilicate and Borosilicate Glasses

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In this work, photostimulated diffusion of P and B into Si is carried out using phosphosilicate or borosilicate glass, which is applied as a liquid onto a silicon wafer, and a 0.5 μm thick film is obtained on its surface by centrifugation. Pulsed photon irradiation (PPI) was performed on the original IMNE 9 setup [1], the design of which is based on the theoretical model of photostimulated processes in materials that we have developed [2]. Rapid thermal annealing has proven to be an effective means of defect elimination. Despite the efforts of researchers, it has not been possible evaluate such factors as high concentration of formed antibonded electron-hole pairs, selective absorption of photons by impurities and defects, changes in their charge state, etc., as well as other factors. These factors, in our opinion, play an important role in the processes of photostimulated crystallisation, annealing of defects, activation or diffusion of introduced impurities [2,3]. Depending on the technology in which these processes are used (to obtain a highly efficient solar cell, UV or IR sensor, etc.), PPI modes are determined, which vary in the irradiation range: spectrum 190÷4100 nm; pulse duration 5÷20 sec; power density 7÷160 W/cm$^2$; irradiation side - silicate glass, substrate, or both simultaneously. The study of the photoelectric properties of the structures obtained by the method of photostimulated diffusion was carried out on an original "Polychromator" device with optical filters [4]. Optimization of the PPI modes allows one to achieve the maximum sample heating temperature per pulse in the range of 200-600$^0$C. As a result, depending on the specific task, we obtain doped films in Si with a thickness of 0.05-0.4 μm at relatively short photon irradiation times and low temperatures, which is very important, especially for modern nanotechnologies.

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**Keywords:** Photostimulated proceses; Rapid thermal annealing; Pulsed lamp annealing; Pulsed photon irradiation.

# Ammonium Chloride-Assisted Synthesis of ZnO Nanomaterials

**A. Jishiashvili[1]**, E.Sanaia[2], Z. Shiolashvili[1], N.Makhatadze[1], A. Sichinava[2], K.Gorgadze[1], D. Jishiashvili[3]

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The nano-sized hexagonal ZnO possesses unique electrical, optical, and chemical properties, which, combined with its biocompatibility, contribute to its strong application potential and generate a high scientific interest. The chlorine ion ($Cl^-$) doping modifies the surface energy balance between different ZnO planes, promoting the rapid growth of specific facets and the development of diverse morphologies. The purpose of this work was to synthesize ZnO nanomaterials using the pyrolytic, ammonium chloride-assisted method and to investigate the effect of chlorine and process parameters on the morphology of the produced nanomaterials.

The powders of Zn, ZnO, and $NH_4Cl$ with different mass ratios were heated in the vertical quartz reactor. At 195°C, $NH_4Cl$ decomposed into $NH_3$ and HCl, which, after reacting with Zn and ZnO, produced volatile $ZnCl_2$. These species were reaching the Si substrate positioned above the sources, generating ZnO nanomaterial by interacting with residual gases. At relatively low substrate temperatures, up to 9 at.% chlorine was incorporated in ZnO, forming sheets and hexagonal disks with an average thickness of 70 nm. At temperatures exceeding 360°C, no chlorine was found in ZnO, and the morphology was transformed into a spherical aggregation of nanocrystals. However, under these conditions, intense HCl etching of ZnO nanomaterials was observed, depending on the mass ratio of $NH_4Cl$ to Zn.

Our preliminary results indicate that the addition of Si powder to the source allows for the synthesis of Si-doped ZnO nanomaterials. Additionally, when pure Si powder was used in conjunction with $NH_4Cl$ as a source, Si nanomaterials were produced. We propose that the developed ammonium chloride-assisted technology can be utilized for synthesizing some other metal-based compound nanomaterials. The results of this work clearly demonstrate that the application of $NH_4Cl$ in pyrolytic growth processes facilitates the formation of an active gaseous species, which subsequently produces volatile precursors for the growth of nanomaterials.

This work was supported by Shota Rustaveli National Science Foundation of Georgia (SRNSFG) [grant number YS-24-1927].

**Keywords:** ZnO; Ammonium chloride; Pyrolysis; Nanomaterials.

# An Efficient and Maximally Simple Optical Device for Multi-Junction Photovoltaic Elements

G. Kachlishvili, **Z. Melikishvili**, R. Kokhreidze

We have developed an optical device that, on one hand, concentrates solar radiation and, on the other hand, disperses the concentrated light into a spectrum (280 - 1750 nm). It is optimized to ensure the maximum efficiency of multi-junction photovoltaic elements by focusing each spectral region of optimally concentrated light onto the corresponding photovoltaic element.

The fundamental concept of the optical device developed by our group is defined by three key criteria:

1) To generate a continuous spectrum covering nearly the entire solar range (280–1750 nm) with minimal optical aberrations and a well-focused beam, enabling the efficient placement of photovoltaic elements operating within specific narrow optical bands.

2) To maximize the optical efficiency of the device itself, ensuring the highest possible transparency.

3) To minimize the cost per kWh of the generated energy

The optical device consists of three simple geometric components: a) A single-curvature parabolic mirror (concentrator), b) A single-curvature specialized mirror, c) A single-curvature specialized prism. Its schematic representation is shown in **Fig. 1.**

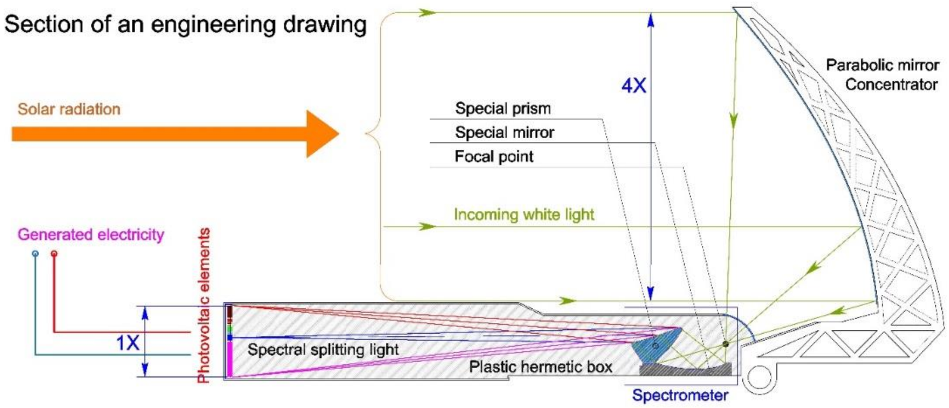

*Fig.1. Schematic representation of the optical device and photovoltaic elements optimized for a specific spectral range. In the given optimization, the ratio of the photovoltaic element area to the concentrator mirror area is 1:4.*

# UAV Detection and Tracking Device based on Novel Spectroscopic System

G. Kachlishvili, Z. Melikishvili, R. Kokhreidze, E.Sanaia, O. Kvitsiani, J. Markhulia

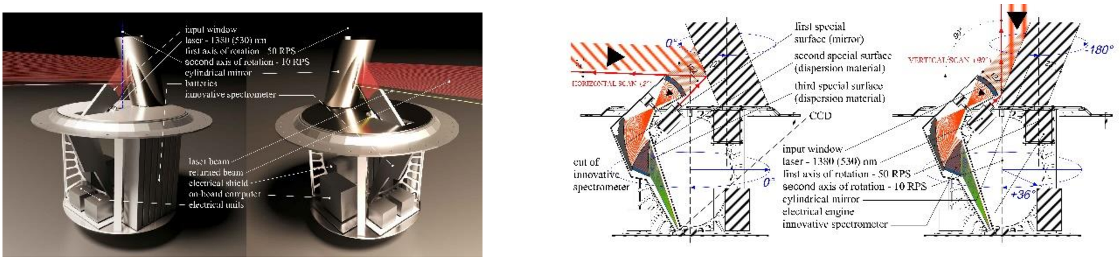

*Fig. 1: The left figure presents a 3D visualizationof the scanning system concepts, while the right figure depicts a cross-section.*

Recent events underscore the escalating threat posed by small drones, eluding detection and identification through conventional radar systems. Beyond the military context, small drones introduce potential threats in terms of terrorism and reconnaissance.

We have developed the theory of an innovative spectrometer[1]that can be optimized for a diverse range of optical and spectroscopic applications.One of these applications involves addressing the challenge of detecting small-sized and elusive FPV (First-Person View) drones at distances of approximately 500 m.On one hand, developing a real-time scanning device that surveys the sky within a 500 m radius using a specialized laser apparatus presents no significant challenges.On the other hand, several non-trivial problems emerge: a) The reflected signal from small and camouflaged objects is exceedingly weak; b) the solar background is significantly brighter; c) precise isolation of the faint reflected signal from the solar background is essential. For example, calculations indicate that utilizing a 1000 W (1380 nm) laser for hemispherical dome scanning, factoring in reflections from a drone with 4% reflectivity and an effective reflection area of 4 sq.mm within a 1/500-second interval, yields approximately 1/13,000,000,000 of the initial power, considering atmospheric absorption and scattering. Detecting these signals demands a sophisticated solution.

In theory,in the approximation of linear optics (which in turn implies both geometric and wave approximations), the innovative spectrometer has the highest possible transparency (sensitivity) and almost unlimited resolution, which allows it to be optimized for this kind of opticaltasks. The problem is that the correct interpretation of the signal in this spectrometer strongly depends on the collimations of the signal itself. The more the signal is collimated, the more correctly it will be identified. Fortunately, the smaller and farther the target is, the more collimated the reflected signal is.

**References**: [1] Master's thesis of George Kachlishvili, “Innovative Optical Spectrometer and its Application”, (2021).

# Electrical Properties of CNT/Polystyrene Composites

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In recent years, there has been great interest in conducting polymers, which may be used as electromagnetic wave absorbing shields in suitable systems.

Polymer nanocomposites offer significant advantages over traditional polymers, particularly in terms of lightness, high impact resistance, wear resistance, and chemical resistance.

Carbon nanostructures are materials that improve the mechanical, electrical, and thermal properties of polymer nanocomposites.

The aim of the work is to obtain two-component nanocomposites by mixing carbon nanotubes (CNT) in Polystyrene matrix. Polystyrene dissolved in chloroform and CNT are mixed using magnetic stirring at 25 - 30°C for 30 min. After evaporation of the solvent, samples with the desired shape are obtained, in which the CNT content is 1, 3, 5, 8, 10 and 12% by mass. The synthesized materials were studied and identified by different methods.

**Keywords:** Polystyrene, carbon nanotube, electromagnetic wave

# Solid State Fuel Based on Si and C Nano-Pico Particles

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Solid-state fuels based on nano- and pico-sized Si and C powders represent a promising frontier in energy and propulsion technologies. Their high energy density, tunable properties, and potential for reduced emissions make them attractive for a wide range of applications. However, significant research is needed to address challenges related to synthesis, combustion control, and safety. Advances in nanotechnology and materials science will play a key role in unlocking the full potential of these fuels.

Among the main advantages of Nano-Pico Si/C Fuels there are: High Energy Output – Silicon and carbon both release significant energy during oxidation; Controlled Reactivity – The use of nanoparticles allows for precise control over combustion properties; Reduced Emissions – Compared to traditional fossil fuels, Si/C-based fuels can produce fewer harmful byproducts, depending on the combustion environment; Compact and Lightweight – Solid-state fuels are easier to store and transport than liquid or gaseous fuels.

Our works include: Material Optimization – Developing advanced synthesis techniques (e.g. Laser induced Plasma) to produce Si/C nano- pico particles with precise size, shape, and composition; Combustion Studies – Investigating the ignition and combustion behavior of Si/C fuels under different conditions (e.g., pressure, temperature, and oxidizer concentration); Additive Integration – Exploring the use of additives (e.g., metals, oxides) to enhance combustion performance or stability.

Possible directions of application: Propulsion Systems – Nano-Si/C fuels can be used in solid rocket propellants or hybrid propulsion systems due to their high energy density and rapid combustion; Combustion Technologies – Nano Si/C fuels can be used in high-efficiency combustion systems for power generation or industrial processes; Space Exploration – Solid-state fuels are attractive for space applications due to their stability and high energy output.

**Keywords:** nano-pico, Si/C fuel, propulsion system, combustion technology, laser induced plasma.

# Ways to Improve Mercury-Sensitive Thin Films Adhesion to the Substrate

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When forming thin metal films on a solid dielectric substrate (Sital, Sapphire, mica, etc.), one of the main challenges remains obtaining high adhesion strength between the thin metal layer and the dielectric substrate. We encountered this problem when we developed a mercury-sensitive sensor with a thin gold sensitive layer. Although we tested solid dielectric substrates of various materials and different deposition methods and modes for the formation of this sensitive layer, the adhesion strength was very low (accurate measurement was not possible) and could not ensure stable operation of the sensing layer.

Continuing research led us to the idea that we should not apply a sensor film to a solid substrate, but, on the contrary, a dielectric substrate formed on a sensor layer. Polymer materials provide a relatively easy way to implement this technology. By subsequent polymerization of liquid varnish of these materials, it is possible to obtain solid substrates. The main task of this research was to select a polymer material that would meet the requirements that would be necessary for the subsequent proper operation of the sensor. Namely: after polymerization, it would be resistant to various aggressive environments (acids, alkalis, etc.), would have high temperature resistance (not less than $+400^0$C) and good adhesion to the sensitive layer of the sensor. Based on theoretical studies and our experience, we considered it appropriate to choose polyimide as the polymer material. In particular, we created a polymer base coat using polyimide varnish AD-9103 and its imidization.

The main goal of the presented research was to obtain the highest possible adhesion strength to the thin-film sensor layer by imidization and drying of polyimide varnish in various modes and with different thicknesses. This was achieved by conducting several stages of imidization and drying. The polyimide was applied using a centrifuge. The desired thickness was obtained by adjusting the rotation speed of the centrifuge. Before applying the polyimide, the structure was heated to a temperature of $100^0$C. This ensured the removal of moisture and accidentally introduced volatile substances from the surface to be applied. Measurements showed that the adhesive strength of the structure obtained with this technology between the sensor thin layer (gold thin film) and the formed polymer substrate was approximately $3.10^6$N/m$^2$, which is much higher than the adhesive strength of the same material vacuum-deposited on a solid substrate and fully meets the requirements for stable operation of the sensor.

**Keywords:** thin films; Adhesion; Polymer; substrate; sensor.

**Acknowledgment:** This work was supported by Shota Rustaveli National Science Foundation of Georgia. Grant number FR-24-4324.

# Wear Behavior Martensitic-Bainitic Ductile Iron During Different Dry Sliding Speeds

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This study explores the tribological behavior of high-strength cast irons with varying matrix microstructures—specifically martensitic-bainitic, bainitic-martensitic, and fully bainitic structures—under conditions of dry sliding friction. To evaluate performance, a series of controlled experiments were conducted using a standard pin-on-disc tribo-system. Tests were performed at two sliding speeds, 1.5 m/s and 2.1 m/s, under a constant normal load of 5 N and a continuous sliding distance of 1256 meters. The cast irons under investigation were subjected to various thermal and cryogenic treatmentsincluding cryogenic quenching, direct annealing, and isothermal annealing to develop distinct matrix structures. These treatment combinations enabled precise control over the formation and distribution of martensitic and bainitic phases, which are known to significantly influence mechanical and tribological properties. The study systematically correlates the observed frictional response with the underlying matrix microstructure, offering insight into how phase composition and transformation routes affect surface interaction during sliding. Among the materials tested, cast irons with a martensitic-bainitic structure demonstrated the most consistent frictional behavior across both sliding speeds, indicating enhanced thermal and mechanical stability under dry friction conditions. These findings contribute to the broader understanding of structure-property relationships in high-strength cast irons and support the development of wear-resistant materials for demanding engineering applications. The results may guide the selection and heat-treatment design of cast irons where frictional stability and durability are critical performance requirements.

**Keywords:** Tribology, coefficient of friction, wear resistance, dry sliding wear, microstructure.

# Effect of Concentration Profile Correction in InGaAs/InP Heterostructure on the Capacitance and Leakage Currents of PIN Mesa Photodiodes

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The subject of this work is IR PIN mesa photodiodes (PDs) based on $In_xGa_{1-x}As/InP$ ($x=0.53$) direct gap heterostructures. The focus is on studying the possibility of reducing the capacitance, C, and leakage currents $I_{leak}$ of PDs to improve their photoelectric and energy characteristics.

Reported is the implementation of a non-standard approach, according to which the values of C and $I_{leak}$ can be significantly reduced by adjusting the impurity concentration profile in the i-absorber of the PIN PDs. The latter is achieved by decreasing the dopant concentration in the contact $n^+$-layer by approximately an order of magnitude. The results are compared for structures of two types (I, II, and III) grown by the MOCVD method and distinguished by the presence (I, II) and absence (III) of an impurity concentration gradient in the i-absorber.

Mesa PDs had a circular configuration with different diameters of the active region, ∅ from 0.05 to 2.5 mm. The technology and measurement methods are described.

C(V) measurements showed that in the range of reverse biases $V_{rev}$ ~0÷2.5V the ratio C(II)/C(III) for each value of ∅ decreases approximately from 2.8 to 1.3 times. Interestingly, with a further increase in reverse voltage, $V_{rev}$ C(II)/C(III) tends to unity. Most likely, such an effect is associated with the cessation of the influence of the i-absorber concentration profile on the capacity.

With respect to $I_{leak}$ it turned out that for structure III, these values decrease several times, and, most importantly, their spread decreases.

Thus, the proposed variant of heterostructure optimization improves perceptibly photosensitivity, quantum efficiency, response time and specific detectability of PIN PDs. The described method does not require an increase in technology costs.

**Keywords:** IR PIN photodiode; i-absorber concentration profile; Capacitance; Leakage current.

# Transverse Thermoelectric Effect in Glass-coated Bi-Sn Microwires and Bi Films for Practical Application

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There is currently growing interest in developing efficient thermoelectric materials for use in energy conversion devices. The most commonly used elements today are thermocouples, which operate based on the Seebeck and Peltier effects. While these devices offer clear advantages, they also come with notable drawbacks. For example, to achieve the required output voltage, multiple thermocouples must be connected in series. Additionally, manufacturing reliable low-resistance contacts between the *n*-type and *p*-type legs poses technological challenges, which can compromise the overall reliability of the device. A promising alternative that avoids these limitations is the anisotropic thermoelectric element (AT). In crystals exhibiting anisotropy in thermal conductivity, electrical conductivity, and thermopower, an electric voltage can be generated perpendicular to the direction of heat flow - provided that the heat flux is oriented off-axis relative to the main crystallographic directions. This voltage is directly proportional to the temperature difference across the isothermal faces, the degree of thermopower anisotropy, and the length of the crystal, and inversely proportional to its thickness. An AT can be fabricated from a single crystal of appropriate size, without requiring thermoelectric junctions. Unlike conventional thermocouples, it eliminates the need for complex electrical interconnections.

We fabricated a sample using a 10-meter-long, glass-insulated, single-crystal tin-doped bismuth microwire (outer diameter - 20 μm; core diameter - 4 μm). A key factor in this process was the ability to grow the microwire as a single crystal, achieved through a laser-assisted recrystallization technique performed under a strong electric field. The microwire was coiled into a spiral, mounted onto a copper disk, and used in a series of experiments. The sample demonstrated a high sensitivity to heat flow, reaching up to $10^{-2}$ V/W, with a time constant of approximately 0.2 seconds. Also, polycrystalline bismuth films with thicknesses from 2 to 5 μm were deposited on mica substrates by vacuum thermal evaporation. Prototypes of heat flux sensors were fabricated from these films after recrystallization under the influence of laser heating and a strong electric field. The observed voltage dynamics at the output of these sensors in response to modulated heat fluxes is in good agreement with theoretical predictions for anisotropic thermoelectric elements.

**Keywords:** Anisotropic Thermoelement; Bismuth; Glass-insulated Single-crystal Microwire; Single-crystal Film, Heat Flux Sensor.

# To the Kinetics of Quantum Dissipative Systems: Quantum Brownian Particle Motion and Low Temperature Polaron Mobility Problem

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New, exact generalized quantum evolutionary (kinetic) equations for the equilibrium double-time correlation functions (Green‘s functions: advanced, retarded and causal) and statistical operator of a quantum dynamical system interacting with a phonon field were derived in the case of linear as to the Bose-amplitudes.

The random phase approximation has not been used to derive these equations. In the initial moment of time for the correlation functions a thermal initial conditions were used. The projection operator technique and generalized Bogolubov’s lemma for a dynamical system interacting with a boson field is proved and used for the excluding the dynamical variables of the phonon field from the derived evolutionary equations.

The derived kinetic equations are used to analyze the kinetic and linear transport phenomena in polar semiconductors and in exactly soluble model of the quantum dissipative system: A quantum Brownian particle dynamics of which is described by Caldeira-Legget Hamiltonian. It is asserted that there is no quantum regression theorem in the sense of Onsager. This is shown by explicit calculation of quantum Brownian motion of an oscillator. The specific form of kinetic equations of correlation functions and the mobility of Brownian particle were calculated.

As an application of this approach, the uniform theory of Froechlich’s polaron low-temperature mobility and conductivity - in the wide range of frequency of the weak external electric field – is developed as well. It reproduces the generalized Osaka result at low frequencies of external electric field and Feynman-Hellwarth-Iddings-Platzman result at high frequencies. Such an uniform theory of low-temperature polaron mobility was not yet developed until.

**Keywords:** kinetics, dissipative systems, correlation functions, polaron mobility.

# Graphene-based Nanocomposite Filament for 3D&4D printing: Manufacturing, Properties and Shape Memory Effects

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The new 4D printing technology is the next generation of additive manufacturing, which adds unique features to 3D-printed architectures under the influence of external stimuli. The concept of 4D printing requires smart materials with specific physical and mechanical properties, and sensitivity to external stimuli, as well as structural design with a selected 3D printing technique, which are necessary to unlock the potential for functionality for specific applications. Due to such complexity, no commercial smart material for 4D-printing is implemented so far. The current investigation is focused on the development of a thermo-responsive shape-memory bionanocomposite for 4D printing (FDM) manufactured of biodegradable polylactic acid (PLA)/polycaprolactone (PCL) blends incorporating graphene. Nanocomposites are prepared by melt extrusion technique allowing a homogeneous dispersion of graphene in the PLA/PCL matrix. The 3D printing (FDM) is applied for fabrication of test samples. The mechanical behavior is explored by tensile experiments. Electrical and thermal conductivities are tested and related to the structure and morphology. Joule heating was tested and optimized by the voltage and the temperature of heating. Results showed that the presence of PCL as soft segment contributed to an increment of toughness and elongation at ultimate strength of the polymer composite at expense of the maximum tensile stress and Young’s modulus. Conductive graphene nanofiller introduced additional functions and improved the properties and 3D-printability of the bionanocomposites making them electroactive and activating their thermally stimulated shape memory function. The bionanocomposite with graphene was proposed for manufacturing of an electroactive shape memory filament for 3D &4D printing.

**Keywords:** Bionanocomposite; Shape memory; Mechanical properties; Electrical conductivity; Joule effect.

**Acknowledgments**: This study was supported by the European Union—Next GenerationEU within the Project No. BG-RRP-2.011-0001-C02.

# Synthesis and Characterization of Multifunctional Alumina-Based Composites with Various Additives

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The accelerated pace of life in the modern world and the large-scale development of industrial production is significantly increasing the need for the creation of new composite materials, which in extreme conditions, including a wide temperature range, multiple thermal cycling, chemically aggressive environment, in conditions of high radiation and mechanical loads, will maintain high physical-mechanical characteristics during the long-running operation. Due to its low cost, availability of raw materials and good combination of physical-chemical properties, corundum ceramics is the most used material for creating construction nodes and products for various purposes. Composites based on aluminum oxide with specified properties are used in various fields, including Aerospace, Automotive, Energy, Biomedical, Electronics, Catalysis and Armor. However, these materials are less plastic and as a result have lower toughness. In order to increase plasticity, ceramics are reinforced with various additives.

In the present paper we offer simplified technology for obtaining Alumina-Based Composite materials reinforced with carbon structures, metal oxides and basalt fibers using local raw materials, where modification of the final powder composite - α-alumina with a reinforcing component were implemented during its synthesis, which was ensure their homogeneous spatial distribution, which increase the crack-resistance and bending strength. In the implementation of this work, modern instrumental methods were applied: Electronic and optical microscopy, X-ray structural and granulometric analysis, IR spectroscopy. Determination of physical-mechanical characteristics were performed according to International Standards (ISO and ASTM).

**Keywords:** Ceramic materials, Characterization, Hot-pressing.

# Effect of Alpha Particle Irradiation on the Physical-Mechanical Properties of Monocrystalline Si$_{1-x}$Ge$_x$ ($x \le 0.02$) Alloys

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The development of high-efficiency devices based on semiconductor Si-Ge alloys for modern solid-state electronics significantly depends on determining the formation, thermal stability, and migration characteristics of radiation-induced defects in their structure. In this regard, the study of structurally sensitive physical properties of Si-Ge alloys under the influence of various types of radiation is of particular relevance.

Present work deals with the investigation of the electrophysical characteristics and changes in internal friction and shear modulus of Si$_{1-x}$Ge$_x$ ($x \le 0.02$) samples irradiated with $^{241}$Am alpha particles at a fluence of $10^{12}$–$10^{14}$ cm$^{-2}$ at a frequency of 1 Hz of torsional oscillations and in the range of $10^{-5}$ - $5\times10^{-3}$ of strain amplitude under room temperature conditions.

The experimental samples were grown by the Czochralski method along the [111] crystallographic direction. It was shown that irradiation with alpha particles at a fluence of $10^{12}$–$10^{14}$ cm$^{-2}$ has no essential effect on the character and density of dislocation distribution determined by metallographic methods. As a result of alpha irradiation, the specific electrical resistivity increases by 10–15%, the concentration of current carriers electrons decreases, and their mobility increases by 1.5 times. These changes become comparatively less pronounced with increasing germanium content in the Si$_{1-x}$Ge$_x$ ($x \le 0.02$) alloy samples.

Alpha particle irradiation leads to a notable increase in the critical strain amplitude during torsional oscillations, as well as in the shear modulus proportional to the square of the frequency. It is proposed that this radiation-induced strengthening results from the breaking away dislocations from point defects within a radiation-defects enriched atmosphere.

The observed radiation-induced changes in electrophysical and physical-mechanical properties of SiGe alloys provide valuable insights for the design and optimization of semiconductor devices operating in radiation-rich environments.

**Keywords:** Si-Ge alloys, alpha-irradiation, internal friction, shear modulus, strain amplitude.

# Optical Properties of GaN Synthesized by UV Stimulated Magnetron Sputtering Technology

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In this paper are presented optical properties of GaN polycrystalline samples received by reactive magnetron sputtering technology. The analysis of transmission spectra reveals correlation with growth temperature of GaN samples and band gap of the GaN material. By increasing temperature of samples for the formation of GaN, the edge of minimum of transmitted wavelength is shifted towards 361nm, which corresponds to the band gap 3.4 eV of the GaN material. The band gap of GaN material can be calculated from the edge of transmission spectra minimum. This work also shows that, with the increase of growth temperature of the samples for growing GaN, the optic properties of the GaN improve, which corresponds to increasing angle of the slope of the graph transmission spectra. Photoluminescence (PL) Spectroscopy measurement showed intense emission near a wavelength of 400 nm, which is close to the band-to-band transition corresponding to the band gap of gallium nitride.

**Keywords:** III nitrides; technology; growth; band gap;

# Fast-Charging Phosphorus Anodes Enabled by Fluorinated Weakly Solvated Electrolytes

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Phosphorus-based anodes hold promise for energy storage due to their high theoretical capacity and favorable lithiation potential. However, their practical application is hindered by sluggish reaction kinetics and irreversible capacity loss, primarily attributed to multiphase lithiation/delithiation reactions and the dissolution of lithium polyphosphide intermediates. Herein, a weakly solvated electrolyte incorporating a fluorinated cosolvent is designed to effectively suppress dissolutions of lithium polyphosphides, enhance interfacial stability, and accelerate reaction kinetics. With this electrolyte, a phosphorus-based anode achieves a remarkable capacity of 2615.2 mAh $g^{-1}$ at 1C, maintaining 91.7% capacity retention over 1000 cycles. Even at a high rate of 4C, it delivers 2210.7 mAh $g^{-1}$ with an exceptional retention of 96.7% after 1500 cycles. Furthermore, at 0 $^{o}$C, the anode sustains a capacity of 2016.7 mAh $g^{-1}$, with 97% retention after 300 cycles at 1C. This study provides a novel electrolyte design strategy to regulate the solvation sheath, paving the way for high-rate, long-cycle phosphorus-based anodes suitable for fast-charging applications.

**Keywords:** Weakly solvated electrolyte; interfacial stability; phosphorus-based anode; fast charging.

# Photophysics of Chitosan-Iron Oxide Nanoparticle Composites

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In this study, we aim to elucidate the photophysical behavior of chitosan-iron oxide (Ch:$Fe_3O_4$) composite nanoparticles using steady-state fluorescence and phosphorescence investigations. The XRD analysis of Ch:$Fe_3O_4$ composite revealed (220), (311), (400), (511) and (440) difraction planes that agree well with JCPDS file, PDF No. 65-3107. The position and relative intensity of all the diffraction peaks of the Ch:$Fe_3O_4$ were consistent with the crystalline pattern of the $Fe_3O_4$ phase. The involvement of chitosan did not result in a phase change but only broadened difraction peaks. Fluorescence spectra of Ch:$Fe_3O_4$ ($\lambda_{exc.}$ = 375 nm) exhibits maxima at 427 nm, 449 nm, 508 nm, and 569 nm. The band positioned at 427 nm correspond to a slightly shifted $\pi$–$\pi$* transition like that of pure chitosan, suggesting electronic interactions between the nanoparticles and the functional groups of chitosan, while the emission band at 449 nm accord with modified n–$\pi$* transitions induced by enhanced spin–orbit coupling introduced by $Fe_3O_4$. The glycosidic bonds of chitosan influenced by the presence of $Fe_3O_4$ nanoparticles exhibit a band situated at 505 nm. The band situated at 566 nm implies a charge-transfer transition between $Fe_3O_4$ and chitosan, in which electrons are transferred from the chitosan to the $Fe_3O_4$ core, leading to lower-energy ligand-to-metal charge transfer transitions. The time-correlated single photon counting (TCSPC) measurements was used to estimate the excited state lifetime of the Ch:$Fe_3O_4$ composite. The fluorescence decay lifetime curve fit bi-exponential function with two lifetimes and is characterized by values of 1.18 ns and 4.44 ns. An enhanced of value of quantum yield of 0.24% was reached for Ch:$Fe_3O_4$, compared with a lower quantum yield of 0.07% for chitosan. Phosphorescence analysis of pure chitosan and the Ch:$Fe_3O_4$ composite show similar spectral profiles, except that the Ch:$Fe_3O_4$ maxima are shifted to shorter wavelengths. The deconvolution of the phosphorescence spectra for pure chitosan discloses emission maxima at 402, 425, 508, 547, and 607 nm, while for Ch:$Fe_3O_4$, the 607 nm peak shifts to 638 nm, going into the red spectral region.The red shift from 425 nm to 442 nm and the presence of the 638 nm band suggest that $Fe_3O_4$ nanoparticles stabilize the triplet states, introducing additional low-energy states that facilitate phosphorescent emission. Phosphorescence lifetime measurements of the Ch:$Fe_3O_4$ composite show triplet lifetimes of 1.09 μs and 8.83 μs, while pure $Fe_3O_4$ displays lifetimes of 1.10 μs and 8.46 μs. These enhancement in the photophysical parameters of Ch:$Fe_3O_4$, such as singlet and triplet lifetimes, along with the values of fluorescence and phosphorescence quantum yields are expected to support significant advancements in medical and bioscience applications.

**Keywords:** Chitosan, $Fe_3O_4$, Ch:$Fe_3O_4$ Composite; Fluorescence spectroscopy;

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# Molecular Beam Epitaxy of III-Nitrides for Power, Microwave and Optoelectronics

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Wide-band-gap compounds based on III-nitrides (AlN, GaN, InN) and their solid solutions are increasingly used in industry. Starting with the "LED revolution" in lighting, for which Japanese scientists received the Nobel Prize in Physics in 2014, implementation continues in microwave solid-state electronics (5G, 6G, microwave telecommunications including space-based, AESA, DAA, electronic warfare, etc.). UV optoelectronics and photonics based on III-nitrides are developing by leaps and bounds. The "second semiconductor revolution" is taking place in power electronics, marking the transition from silicon transistors to GaN-based transistors, which allows for a significant increase in efficiency, a reduction in the weight and size of power supplies and electric motor controllers, and thereby a reduction in their cost.

In 2024-2025, we developed technologies for creating AlN seed layers (40 nm) on SiC with a low dislocation concentration and a surface roughness of less than 0.2 nm using molecular beam epitaxy (MBE) methods. Optimization of the ammonia MBE technology of the GaN channel layer and the barrier layers of AlN and AlGaN heterostructures made it possible to obtain a two-dimensional electron gas mobility of > 2000 $cm^2V^{-1}s^{-1}$ at concentrations of up to $1.25 \cdot 10^{13}$ $cm^{-2}$ on buffer-free heterostructures with a GaN channel thickness of 300-400 nm, which corresponds to the best standard heterostructures with 1.5-3.5 µm. It should be noted that thin buffer-free heterostructures have low thermal resistance, memory effect and current collapse, long lifetime, power density and efficiency. On such heterostructures, JSC "INTEGRAL" and JSC "Minsk Research Institute of Radio Materials" created Power and microwave HEMT.

For high specific currents and, accordingly, frequencies and speeds of transistor operation, it is necessary to further increase the density of the two-dimensional gas and reduce its sheet resistance. Using InAlN as a barrier, on buffer-free heterostructures, we managed to obtain a mobility of up to 1100 $cm^2V^{-1}s^{-1}$ at concentrations of up to $2.5 \cdot 10^{13}$ $cm^{-2}$, which corresponds to a sheet resistance of ~250 Ohm/sq. Further modification of the heterostructure design allowed us to obtain a mobility of 1600 $cm^2V^{-1}s^{-1}$ on a two-barrier heterostructure at a concentration of up to $2.4 \cdot 10^{13}$ $cm^{-2}$ with a sheet resistance of 165 Ohm/sq., which is a record. The use of such heterostructures will allow us to obtain record-breaking transistor characteristics.

Using previously developed technologies of MBE layers of $n^{++}$GaN and $p^{+}$GaN with record characteristics of electron concentration and hole mobility, as well as MBE layers of AlGaN with a laser threshold of 300 $kW/cm^2$, we managed to develop a design and grow heterostructures of UV PIN photodiodes with a sensitivity of 105 mA/W at wavelength 295 nm, which is close to the best world results.

**Keywords:** Molecular beam epitaxy; III-nitrides; HEMTs; UV PIN PDs.

# Singlet-Triplet Splitting and Mollow Triplet Dynamics in Impurity-doped Core/shell Quantum Dots

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This work presents a comprehensive theoretical investigation of the electronic and optical properties of a two-electron system confined in a CdSe/CdS core/shell quantum dot (QD) structure modeled with a Woods–Saxon potential. The study focuses on the influence of monovalent and divalent impurity states, particularly examining the effects of off-center impurity positioning and external electric fields on singlet and triplet state dynamics. The system is analyzed within the effective mass approximation and perturbation theory framework, allowing for accurate evaluation of energy level shifts and transition behaviors under varying structural and external parameters.

Our results demonstrate that the energy levels of the singlet and triplet states are highly sensitive to the QD geometry. Increasing shell thickness significantly reduces the singlet–triplet energy splitting, eventually leading to a saturation regime where further size variation yields minimal effects. The introduction of off-center impurities further modulates the symmetry and splitting of these states, offering a route to tailor energy landscapes through impurity engineering.In the presence of an external electric field, the system exhibits well-defined Rabi oscillations in the occupation probabilities of the singlet and triplet states. These oscillations show strong dependence on the field strength, with both amplitude and frequency tunable by the applied field. While idealized models predict persistent oscillations, practical considerations imply damping due to environmental interactions, pointing toward realistic system behavior. Additionally, the optical emission spectrum is studied through the evolution of the Mollow triplet. We observe a transition from a single-peak emission profile to a clearly resolved three-peak structure with increasing Rabi frequency. The Mollow splitting is found to scale linearly with the Rabi frequency, with symmetrical divergence of the satellite peaks from the central component, illustrating the coherent light–matter interaction in this confined system.

These findings provide valuable insights into impurity-controlled state manipulation and field-induced dynamics in core/shell QDs, with implications for quantum information processing and optoelectronic applications.

**Keywords**: quantum dot; CdSe/CdS; Woods–Saxon potential; singlet-triplet splitting; Rabi oscillations.

# Ecologically Friendly New Composite Materials

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Ecologically friendly new composite materials with high-technical characteristics are made on the basis of wood sawdust and organic/inorganic binders. These composite materials are obtained on the basis of a new binders phenylethoxysiloxane (PhES-80), liquid glass, polyethylene and colophony (at different pressures and temperatures). The binder used simultaneously acts as both a binder and a reinforcement agent. The surface structure of the new composite materials was studied by means of optical microscopy, Scanning Electron Microscopy and Energy Dispersive X-ray Micro-analysis. For composites tensile strength at bending, impact viscosity, thermogravimetric stability and water absorption coefficient have been examined. Optimal conditions for obtaining new, ecologically friendly composites have been established. The obtained composites are characterized by high mechanical properties, thermal resistance, ecological purity and low water absorption capacity, which is one order of magnitude smaller than the water absorption of existing particle board. . Here is presented a new composite material on the basis of wood sawdust and such binders as liquid glass, phenylethoxysisilane of two types PhES50 and PhES80 (first molecular mass is less than for second one) in directions of obtaining and investigation of composite structure and such physical properties, as mechanical strengthening (at bending and impact viscosity), thermal stable properties and water absorption. The structural investigations were provided with use of optical and scanning electron microscope (SEM) for define of the morphology of the composites and a character of distribution of the ingredients in the composite body with use of the picture of optical and scanning electron microscopes. From mechanical properties there were studied the strengthening at bending and the impact viscosity. The methods of Vica and thermal gravimetry were used for investtigation of thermal stability of the composites.

**Keywords**: Ecologicalle, new, materials, composite, binder, glass.

# The Impact of Transformative Materials on Energy, Environment, Health and Sustainable Development

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Today and globally, we experience considerable, urgent and critical challenges in all domains of sustainable development, which is a comprehensive and complex system of systems requiring multidisciplinary and interdisciplinary science and technology inputs with economic, environmental, and social objectives, and considerable scientific and technological innovation. In broad terms, sustainable development is achieved when the present needs and challenges are met without critical depletion of natural and manufactured resources and without placing in jeopardy the ability of future generations to meet their own needs and challenges. The trade space is very wide, and the multitude of trade-offs generate considerable challenges and make it often very difficult to achieve an effective balance, which is most beneficial to all concerned. During the last sixty years the planet's population has grown exponentially, from 2 to almost 8 billion people, and the technological progress achieved has been tremendous, especially in the industrialized countries. These trends are expected to continue, even at faster rates. However, all these associated technological activities in the pursuit of better living standards have created a considerable depletion of resources and pollution of land, water, air, and natural resources, for the global population. Considerable achievements have been obtained in the development and deployment of transformative materials such as light weight metallic alloys, metal matrix composites, intermetallic and carbon fiber composites, and hybrid materials. Nano, nano-structured and nano-hybrid carbon-based materials systems and nanotechnologies are now being deployed with considerable impact on energy, environment, health, and sustainable development. This presentation presents perspectives of the global impact of innovation and transformative materials with a focus on nanomaterials and nanotechnologies with examples from several domains of sustainable development.

**Keywords**: Innovation, transformative materials, advanced materials, advanced technologies, nanomaterials, nano-hybrid materials carbon base nano materials systems, nanotechnologies, sustainable development, energy, environment.

# In Vivo Diagnostics Modeling: - Determination of Dye Concentration Using a Spectroscopic - Statistical Method

Z. Melikishvili, G. Kachlishvili, A. Gurchumelia, R. Kokhreidze,
V. Marchilashvili, **M. Kurkhashvili**

It is known that, by means of a specialized spectroscopic device and using an in vivo method, it is possible to obtain information about the concentrations of various substances dissolved in the blood through the skin — a process referred to as in vivo diagnostics.

Two fundamental problems exist:

During in vivo diagnostics, the system is subject to continuous changes, which causes the measurements to be aperiodic in repeatability and non-trivially masked, thereby hindering the reproducibility of the diagnostic outcome.

Although each substance and its concentration is characterized by a unique spectral fingerprint, these fingerprints are distributed across different spectral regions, and their identification requires a high-resolution spectrometer.

Our goal is to develop a simplified modeled system for in vivo diagnostics (see **Fig. 1**), which, on the one hand, includes a special device that approximates a blood vessel under certain assumptions, and on the other hand, a mathematical model capable of identifying a dye and determining its concentration in solution.

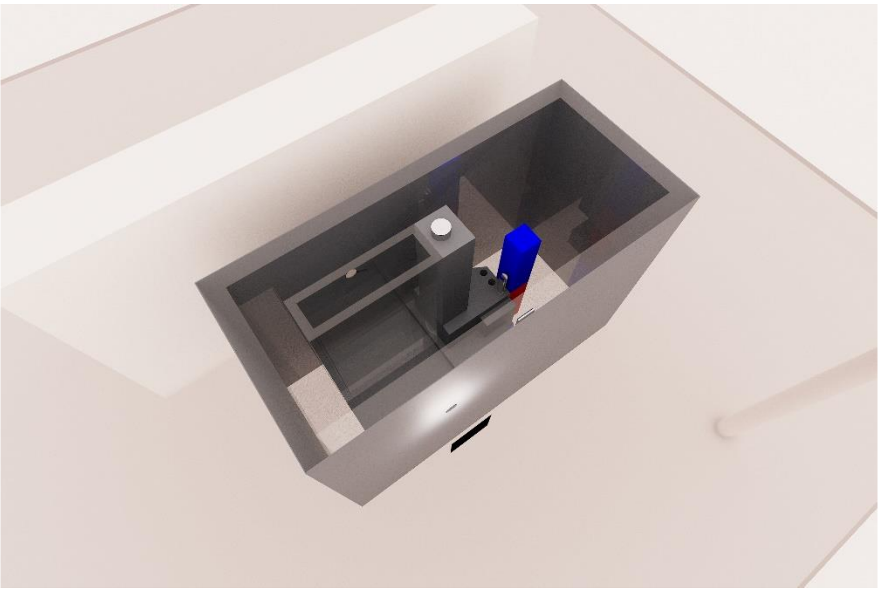

*Fig.1. the figure shows a device in which the movement of the cuvette causes a 5–10% increase or decrease in the volume of the solution contained within it, which, under certain conditions, corresponds to the expansion and contraction of a blood vessel.*

# Development of Optical Spectroscopic Methods for Biomedical Diagnostics

Z. Melikishvili, G. Kachlishvili, **V. Marchilashvili**, M. Kurkhashvili , R.Kohreidze

We have developed a device utilizing multispectral photoplethysmography (MPPG) and a methodology that enables assessment of deviations in human blood circulation dynamics in vivo. Clinical studies have demonstrated that specific spectral ranges reflect changes in blood volume, while other ranges capture aggregation phenomena caused by erythrocytes. All in all, the clinical results show that this method and device can be effectively used for monitoring blood circulation dynamics (see Figure). Furthermore, the methodology enables investigation of the origin of acquired photoplethysmography signals across different wavelengths, which is essential for physiological monitoring of blood circulation.

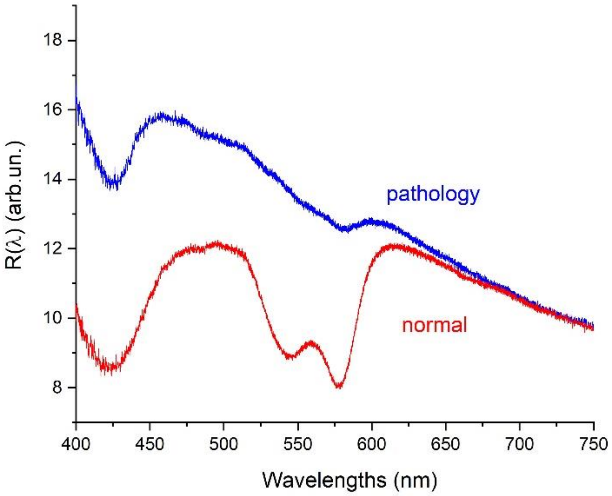

**Figure.** Spectral comparison of MPPG signals between normal and pathological blood circulation states. The graph shows reflectance R(λ) measurements across wavelengths from 400-750 nm. The red curve represents normal blood circulation patterns, while the blue curve indicates pathological conditions. Notable differences are observed in the spectral ranges of 450-500 nm and 580-620 nm, where pathological conditions show elevated reflectance values compared to normal states. These spectral variations correspond to changes in blood volume and erythrocyte aggregation phenomena, demonstrating the diagnostic potential of MPPG analysis for detecting blood circulation abnormalities.

# Semiconductor Detectors for Neutron- and γ-Radiation

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The objective of the present investigation is to develop and to demonstrate portable semiconductor detectors for neutron- and terrestrial γ-radiation. The latter also involves placing the device on unmanned aerial vehicles (UAVs). An essential part of the investigation is the study of various semiconductor materials being suitable to form active components of detectors. These include GaAs p-i-n diodes, HEMT based on AlGaAs/GaAs heterostructures, as well as n-Si and SiGe p-n diodes. In case of silicon devices, by introducing 10B ions, a p-layer is formed, which simultaneously acts as a converter for neutrons. The design and technology of the detection devices are described, as well as the results of measuring the electrophysical characteristics of the active components before and during irradiation with two types of sources: 60Co (γ-radiation) and252Cf (fast neutrons). The effect of irradiation on the samples was recorded by the change in current. The research results allow for creating first portable neutron (180mm x 50mm x 30mm) and terrestrial γ-radiation (200mm x 30mm x 20mm) detectors in Georgia.

**Keywords:** Neutron and γ-radiation, p-i-n and p-n diodes, HEMT transistor.

# Influence of Oxygen Pressure on Phase Formation of Tl-based Polycrystalline and Coated Superconductors

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The formation of the non-substituted Tl-1223 phase at ambient pressure is a difficult task compared to other members of the Tl-based superconductors. Many works on the thallination of $Ba_2Ca_2Cu_3$ precursors used 1 atm oxygen pressure, primarily when the synthesis process is conducted through a two-zone furnace. The existing 1 atm oxygen ambient pressure in the thallination process is guaranteed pressure for the synthesis of the Tl-1223 pure phase. Because the pressure created by $Tl_2O_3$ in a sealed quartz tube is not sufficient for the formation of the Tl-1223 phase, in the case of the oxygen pressure, we can neglect the sample-filling factor of the quartz tube (the ratio between the sample and capsule volume); additional oxygen pressure provides the required pressure in the closed quartz tube.

The presented work is devoted to the effect of oxygen pressure on the formation of thallium-based high-temperature superconductors. Our experimental results showed that a 1 atm pressure formed a non-pure Tl-1223 phase containing a precursor $BaCuO_2$ phase, with an onset transition temperature ($T_c$) of 115 K and a transport critical current density of 25 A/cm². Unlike this, at 2 atm, the Tl-1223 phase formed near the single-phase region consists of a small number of impurity phases with critical temperatures and current densities of 118 K and 129 A/cm², respectively. Enhancement of oxygen gas partial pressure to 3 atm leads to the formation of Tl-2223 phases, with $T_c \approx 125$ K and $J_c \approx 82$ A/cm². In contrast, cases 4–8 atm formed only the Tl-2212 phases. In summary, we can state that the Tl-1223, Tl-2223, and Tl-2212 single phases are formed at oxygen pressures of 2, 3, and 4 atm, respectively.

**Keywords:** Tl-based superconductors; Oxygen pressure; Critical temperature; AC susceptibility;

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# Studying of the Shape Memory and Superelastic Effects into the Nickel free Titanium Alloys for using in a Wide Temperature Range

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The inelastic behavior of a number of alloys which are manifested by the shape memory effect, superelasticity and damping properties, has been the subject of numerous observations since the second half of the 20th century. In terms of practical application of these effects, titanium and copper-based alloys have been in the Center of attention. The main interest is directed to the shape memory effect, and the main object has been titanium nickelide.

It is now well known that the shape memory effect and superelasticity are based on a special type of martensitic transformation - thermoductile martensitic transformation. The temperature hysteresis of such a transformation is very narrow - on the order of tens of degrees. The reversibility of thermoductile martensitic transformation in alloys is due to the high degree of coherence of the crystal lattices of the initial $\beta$ and $\alpha$ martensitic phases and the smallness of their volumetric mismatch. The last is one order smaller than in the case of conventional martensitic transformation. For a long time, it was believed that the complete reversibility of the martensitic transformation was maximally satisfied by orderliness of the crystal lattices of the phases, for example, in the case of titanium nickelide.

In the paper experimentally is established and studied the possibility of revealing of two (divided by temperature) effects of shape memory. In binary and multicomponent titanium alloys, a thermo-elastic martensitic transformation of $\alpha$“ martensite into $\beta$ austenite is realized. For example: in Ti-Ta, Ti-Nb binary alloys and in alloys of the Ti-Ta-Zr system. The temperature intervals of the onset ($A_s$) and completion ($A_f$) of the first and second martensitic transformations are equal to 300-450° and 500-580°, respectively. However, during certain thermomechanical processing and additional alloying by hydrogen, a change in the temperature interval may occur.

The realization of the second effect of shape memory can be induced both by isothermal delay at a certain temperature under load, and by multiple thermal cycling of the first shape memory effect in the $A_s - A_f$ temperature interval and subsequent heating above the $A_f$ temperature.

An original method of thermomechanical processing of alloys has been developed, which allows the first and second shape memory effects to be revealed, both separately

and together. The second high-temperature effect of shape memory is associated with both the inverse shape memory effect and the diffusional distribution of components in the alloy at high temperatures, as between phases as each phase, which is clearly manifested during deformation of samples under prolonged loading.

**Keywords:** Ti-Ta; alloys; martensite; shape memory effect; superelasticity.

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# Optical Investigation of ZnPc and CuPc in Formic Acid

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Phthalocyanines are highly conjugated macrocyclic compounds known for their chemical stability and unique optical properties. With strong absorption in the visible region and fluorescence emission, they are widely studied for applications in optoelectronics, sensors, and photovoltaics. Among them, zinc phthalocyanine (ZnPc) and copper phthalocyanine (CuPc) are two of the most studied derivatives. This study presents a comparative analysis of the optical properties of ZnPc and CuPc dissolved in formic acid (FA), focusing on their UV-VIS absorption and fluorescence behavior in thin films. UV-VIS spectra revealed distinct Q and B absorption bands for each compound. ZnPc showed characteristic peaks at 627 nm, 657 nm, 690 nm, and 720 nm, while CuPc displayed maxima at 649 nm and 691 nm. Both compounds exhibited Soret bands around 295, 337, and 394 nm. Thin films prepared by two different methods, showed spectral changes, including bathochromic shifts and broadening due to molecular aggregation. Fluorescence measurements confirmed the UV-VIS behavior, with ZnPc displaying higher emission intensity than CuPc under identical conditions. Fluorescence spectra for both compounds were recorded at a concentration of 29 µM in (FA) using two excitation wavelengths (335 nm and 650 nm). ZnPc emitted strongly at 729 nm under both excitation conditions, while CuPc peaked at 695 nm and 726 nm, with lower intensity. At 335 nm excitation, ZnPc showed a red-shifted shoulder at 829

nm, while CuPc had a secondary peak at 726 nm. These results highlight the superior properties of ZnPc, suggesting its potential for fluorescence-based optoelectronic applications.

**Keywords:** ZnPc; CuPc; UV-VIS; Absorption, Fluorescence.

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## Effect of Zn:Sn stoichiometry on the morphological and electrical properties of Aerosol Deposited ZnSnO Films

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Zinc tin oxide (ZnSnO) is a ternary oxide semiconductor that has gained increasing attention due to its wide band gap, typically around 3.5 to 4.0 eV, depending on the specific stoichiometry of the material, good transparency in the visible range, and potential for n-type conductivity. These characteristics make ZnSnO a promising candidate for applications including thin-film transistors, solar cells, and sensors [1]. ZnSnO combines the properties of its binary components, ZnO and $SnO_2$, offering enhanced control over electrical and optical behavior through stoichiometric tuning. Among the various deposition techniques, aerosol spray pyrolysis stands out as a cost-effective and scalable method for producing uniform thin films. In this study, we investigated the influence of Zn:Sn stoichiometric ratios (1:2 and 2:1) on the morphological and electrical properties of ZnSnO thin films deposited by aerosol spray onto p-type silicon substrates. Scanning electron microscopy (SEM) images revealed that the obtained samples exhibit uniform surface coverage, though the crystallite morphology significantly depends on the Zn:Sn ratio. For Zn:Sn = 2:1, well-defined crystallites with sizes ranging from 100–150 nm were observed. In contrast, the sample with Zn:Sn = 1:2 presented irregular, disordered structures. The current-voltage characteristics of the ZnSnO films was analyzed under both dark and illuminated conditions (100 mW/cm²). For the sample with Zn:Sn = 2:1, the semilogarithmic I–V plot demonstrated a saturation current $I_s$ = 8.8 mA and an ideality factor n = 2.6, suggesting a charge transport mechanism dominated by recombination in the depletion region, along with additional parasitic effects such as trap-assisted tunneling. Concerning Zn:Sn = 1:2, the extracted parameters were $I_s$ = 1.6 µA and n = 1.4, indicating a diffusion-dominated transport mechanism with contributions from junction recombination. Besides this, a higher saturation current (e.g., 8.8 mA) could be more efficient for applications where rapid photoresponse and high conductivity are more prioritized than detecting extremely low concentrations (e.g.,1.6 μA). These findings demonstrate that varying the Zn:Sn stoichiometry significantly influences both the morphology and electrical performance of ZnSnO films, enabling targeted optimization for specific device applications.

**Keywords:** ZnSnO; SEM; I-V Characteristics; Charge Carrier Transport;

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# Decommissioning Small Facilities (Preparation of Dismantling of the Installation Containing Radioactive Sources)

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Georgia being a small country, does not possess nuclear enterprises. It only ever had a single nuclear refresh reactor IRT-M, belonging to the Institute of Physics (IoP). The reactor was shut down in 1989 and practically decommissioned. The fuel (both fresh, and spent) was transferred out of the borders of Georgia. Only entombed reactor core remained.

The last nuclear installation was a subcritical assembly (also belonged to IoP) containing PuBe source and 1883g. of 36% enriched Uranium. The decommissioning of the installation was conducted under the supervision of International Atomic Energy Agency (IAEA) with the support of USA. Uranium was repatriated to Russia. Radioactive source was transferred to the Centralized Storage Facility (CSF).

Currently Georgia plans to decommission the installation K-60000, which contains 80 sources of $^{60}$Co with a total initial activity 60000Ci. The installation belongs to the Institute of Electrochemistry.

IAEA defines recommendations for decommissioning small facilities through its guidance SSG-49. Meanwhile, the list and the content of the decommissioning related documents are defined by IAEA SRS-45. The graded approach should be implemented also to these documents (considering small size of the facility) as defined by Requirement 2 of IAEA GSR part 6. The first stage considers collection of all the

necessary information, which covers investigations of all documents and conducting radiological assessment. The installation contains 20 rods with four sources at each rod. All theoretical data for the radioactive sources were collected. Radiological measurements show absence of hot spots in the operation room. Smear tests were taken from the channels with rods to assess the possible contamination. (Special video monitoring device was constructed to conduct the activity remotely). The sizes of rods were measured and source activity was calculated by computer software MicroShield based on experimental data. Preliminary decommissioning plan was developed.

**Keywords:** Decommissioning, Radiation protection, Safety, Contamination, Dismantling.

# Development of Neutron Instruments at the WWR-K Research Reactor

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The WWR-K reactor is a pool-type water-cooled reactor, which was commissioned in 1967. The nominal power is 6 MW. The reactor has 10 horizontal channels for neutron research in the field of condensed matter and nuclear physics.

This report will provide an overview of the current state of the spectrometer complex on extracted neutron beams at the WWR-K reactor, which currently includes 4 installations: ARMAN - a neutron reflectometry installation with vertical sample geometry, TITAN - a neutron radiography and tomography installation for studying the internal structure of a sample, AGAVA - a neutron radiography installation for radioactive materials, NAA - a neutron activation analysis installation. Currently, work is underway to create a new neutron powder diffraction installation. The most important methodological results of the spectrometer complex development in recent years and plans for further modernization of the installations will also be considered.

**Keywords:** neutron beam; experimental instruments; research reactor.

# Development of large current, high magnetic field High Temperature Superconductors for fusion magnets

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The fast growth in interest and efforts of the private and public sector in developing nuclear fusion reactors for electric power generation is primarily stimulated by the discovery and development of High Temperature Superconductors (HTS) on an industrial scale. The high magnetic fields required to realize the conditions needed for fusion of light elements in tokamaks and stellarators for the production of energy, can only be generated efficiently by the use of superconducting magnets. The REBCO tape HTS superconductors can operate at much higher magnetic fields than the more classical materials like NbTi and Nb3Sn, which are being used in reactors like ITER, now being built in France. The high field performance opens the path to compacter reactors and therefor economically more viable machines.

High magnetic fields of up to 20 T in tokamak-type fusion devices require the use of HTS and 50-100 kA class, full-size REBCO cabled conductors. A typical way to build multi tape cabled conductors is to stack bundles of tapes in parallel (Stacked Tape Conductors) or helically wind the tapes around a round core (Conductor On Round Core (CORC®/HFRC cables). Prototypes of these conductors are presently under development and, among others, proposed for the superconducting coils of multiple commercial startups and the European DEMO and the Chinese BEST fusion reactors.

The large Lorentz forces, occurring under these extreme operating conditions may locally generate high mechanical stresses in the brittle REBCO tapes, which can lead to irreversibly degradation of the superconducting transport properties. At the University of Twente conductor optimization studies are ongoing with focus on the mechanical performance under the extreme forces. The program includes performance studies on the basic REBCO tapes up to full-size configurations in collaboration with industrial and public partners. A selection of experimental and modeling methods and results is presented.

## Acknowledgment

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# Electrical Transport Properties of Single-crystal $Bi_{1-x}Sb_x$ Micro- and Nanowires in Semimetal and Semiconductor States

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We report an investigation of the electrical transport properties, thermoelectric properties, the Shubnikov de Haas (SdH) oscillations of single crystal $Bi_{1-x}Sb_x$, micro and nanowires in semimetal and semiconductor states.

It is shown that the quantum size effect (QSE) occurs in the Bi-2at%Sb wires with diameter 4-5 times larger, than in pure Bi wires:

- semimetal - semiconductor transition in $Bi_{1-x}Sb_x$ nanowires manifested in the “semiconductor” temperature dependences of resistance $R(T)$ at diameter $\leq 400$ nm;
- the change in sign of thermopower at temperature less, than in pure Bi;
- the occurrence of the negative magnetoresistance in a transverse magnetic field ($H \,//\, C_2$ and $H \,//\, C_3$) takes place at $d < 400$ nm.

From SdH oscillations we find the carrier mobility from light L-electrons $\mu_e=(80-100)*10^3$ cm$^2$/Vs in Bi-2at%Sb wires at 4,2 K, that testifies to high structural perfection of investigated nanowires.

In Bi-3at%Sb foils SdH oscillations were observed only in directions $H$ □ $I$.

Semiconductor $Bi_{1-x}Sb_x$ nanowires show the temperature activated dependence $R(T)$ and the growth of the energy gap with decreasing wire diameter due the quantum size effect. The sharp deviation from the exponential dependence $R(T)$ and SdH oscillations at low temperatures observed in thinner semiconductor $Bi_{1-x}Sb_x$ nanowires are interpreted in terms of the surface state in topological insulators, through a spin-orbital Rashba interaction in the surface TI.

Power factor dependence on the wires diameter, temperature, magnitude and magnetic field direction were calculated.

**Keywords:** Shubnikov de Haas (SdH) oscillations; topological insulator (TI); nanowires; quantum size effect (QSE).

# Static Atomic Charges in Boron Planar Clusters $B_n$ ($n = 1 – 20$)

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Borophenes and other 2D boron-based materials are promising for various advanced multifunctional applications. The kinetics of their formation can be affected by the static charges of atoms constituting the small quasi-planar boron clusters [1,2], which serve as building blocks of such materials. Taking into account the coordination of atomic sites in the structure, static atomic charges for small (containing up to 20 atoms) planar boron clusters in the electrically neutral and positively and negatively singly charged states have been estimated. Their values are in the ranges: –0.75e ($B_7^0$) – +0.53e ($B_{20}^0$), –0.50e ($B_7^+$, $B_8^+$, and $B_9^+$) – +0.56e ($B_{17}^+$), and –1.00e ($B_7^-$) – +0.51e ($B_{20}^-$), respectively.

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[2] T. Odishvili, L. Chkhartishvili. All-boron planar clusters with electric dipole moment. Solid State Sci., 2025, 160, 107833 (1-4).

**Keywords:** Cluster; Static Atomic Charge; Boron; Borophene.

# Sintering Science: From Historical Foundations to Emerging Manufacturing Frontiers

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This work provides a comprehensive exploration of the past, present, and future of sintering science, tracing its evolution from early experimental observations to its current role as a cornerstone of advanced materials engineering. The discussion emphasizes how sintering underpins the design and fabrication of materials used in critical fields such as energy storage and conversion, microelectronics, biomedical implants, and systems operating in extreme environments. By focusing on both thermodynamic and kinetic mechanisms, the presentation highlights the interplay of solid-state and liquid-phase sintering, paying particular attention to grain boundary interactions and the dynamics of microstructural evolution within crystalline systems.

A key contribution addressed is the continuum theory of sintering, developed by the author, which has provided a unifying framework for modeling densification and structural transformation. This theory has not only advanced the fundamental understanding of sintering processes but has also enabled the development of multi-scale approaches and field-assisted sintering models that bridge atomic, mesoscopic, and continuum regimes. Such models are crucial for linking process variables - like temperature gradients, applied pressure, and electrical fields - to predictable outcomes in density, porosity, and grain refinement.

Beyond the theoretical dimension, the presentation underscores how these models find practical application in emerging technologies. Spark Plasma Sintering (SPS) is a primary example, where the framework supports predictive simulation of densification and microstructure evolution, offering a rational basis for optimizing process parameters. The work also introduces transformative processing methods such as Additive Manufacturing–integrated SPS, Pressureless Ultra-Fast Sintering (PLUFS), and Electro-Nano-Pulsing (ENP). These approaches promise to overcome conventional trade-offs between speed, scalability, and precision, granting researchers and engineers an unprecedented level of control over material architecture.

Taken together, these historical insights, theoretical frameworks, and novel paradigms chart a roadmap toward the next generation of sintering-based manufacturing. The vision is one of accelerated, energy-efficient, and digitally integrated material processing strategies that not only enhance performance but also support sustainability and adaptability. This synthesis demonstrates that the science of sintering is entering a phase of profound innovation that is likely to redefine how engineered materials are conceived, designed, and produced.

**Keywords:** Sintering; Field-Assisted; Additive Manufacturing.

# A Method for Obtaining Polymer Nitrogen Fertilizers of Prolonged Action Containing a Functional Group

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The widespread use of fertilizers, including nitrogen fertilizers, is a prerequisite for increasing crop yields and obtaining high-quality products. But the use of nitrogen fertilizers at the same time creates major environmental problems. In particular, they are easily soluble in water, and most of the applied fertilizers are washed out and end up in drinking water, accumulating in products and causing severe infestations. A certain part of fertilizers fades, penetrates into the upper atmosphere and leads to the destruction of the ozone layer.

The solution to this problem is extremely urgent and requires the development of new technologies that will significantly reduce the application rates of nitrogen fertilizers and the conversion of nitrogen fertilizers into a difficult-to-dissolve state.

We have developed completely different nitrogen fertilizers and their preparation technology, which eliminates their leaching and peeling, and environmental pollution. The most important thing is that the gradual, slow transition of these fertilizers to a soluble state under the action of microorganisms in the soil provides the plant with nitrogen throughout the growing season, resulting in an increased nitrogen absorption coefficient, quantitative and qualitative yield indicators.

The method of obtaining polymer nitrogen fertilizers of prolonged action provides for the production of nitrogen fertilizers containing functional groups by the interaction of the initial components. This method differs in that additional heating is carried out at a temperature of 950 C. In addition, the carbamide-melamine oligomer, the active chemical compound sodium alkali (NaOH) and the condensing component formaldehyde (CH2O) in the molar ratio: 1.00 : 0.05 : 1.00 are used as the initial components.

Biodegradable polymer nitrogen fertilizers with prolonged action, containing a functional group, provide dosed top dressing of grain crops (wheat, barley, rye, triticale) during the growing season. The application rate is reduced to 27-50%, fertilizer savings of up to 27-50% are achieved, yields increase to 15-30%, and products become environmentally friendly. Longacting fertilizer is used to protect the environment from pollution by nitrogen fertilizers.

**Keywords:** Nitrogen fertilizer; Biodegradable; Formaldehyde; Oligomer; Prolonged action.

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# Electrically Tunable Doubled-Wavelength Laser Emission in Dye-Doped Photonic Cholesteric Liquid Crystal

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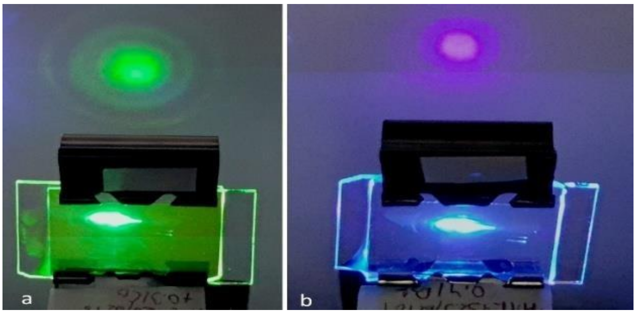
Lasers based on dye-doped cholesteric liquid crystals (DD-CLC) exhibit remarkable properties. They are compact and easy to construct, can emit light at various wavelengths when pumped by a single beam, and allow simple tuning of the emitted laser line through external or internal stimuli[1]. This work presents a simultaneous double-wavelength lasing from a DD-CLC mixture. Specifically, we achieved simultaneous lasing in the visible and near-infrared (NIR) ranges using a single pumping beam. The primary emitted laser line was detected in the visible range, while a secondary emission peak was observed in the NIR range. Using a suitably designed stacked cell composed of two DD-CLC mixtures, we obtained a variable number of simultaneously emitted laser lines across both the visible and NIR wavelengths. Upon application of an electric field, a blue shift of the laser lines in both spectral regions was observed. We achieved a broad tunable lasing range of approximately 15 nm in the visible spectrum, with the tunable range extending to 30 nm in the NIR range. This tunable range opens up exciting possibilities for new applications in sectors such as medical imaging, optical coherence tomography, biological analysis, flow cytometry, and telecommunications.



Doubled laser emission from DD-CLC in the visible (a) and NIR (b) ranges of the optical spectrum.

**Keywords:** Laser emission, Photonic, CLC, Doubled-wavelength

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# Lasing from Liquid Crystal Layer with Nonuniform Thickness

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Laser emission from a dye doped cholesteric liquid crystal (DD CLC) layer with nonuniform thickness is studied. A typical liquid crystal laser is a thin layer of DD CLC sandwiched between two solid alignment surfaces. With pulsed optical pumping, the layer generates laser emission in the direction perpendicular to the plane of the layer. Usually, the layer thickness of 5...40 µm is used. The wavelength of the lasing depends on the period (pitch) of the CLC helix, which can be compressed and stretched under the influence of the orienting surfaces. Since the glass plates used for this aim typically are not perfectly flat, the question arises: how does the non-uniformity of the DD CLC layer thickness affect the laser emission wavelength?

We investigated a DD CLC laser layer with an average thickness of about 12 µm and designed for laser emission in the range of 625 nm. It was shown that with a structure period (helix pitch) of 0.42 µm, changes of 0.1 µm in the layer thickness inevitably cause the formation of a multi-domain structure of the layer. And within a single domain, the thickness variations of ±0.1 µm lead to a change in the structure period by ±3.66 nm. Taking into account the refractive indices of DD CLC, this is expressed in a change in the laser emission wavelength of ±5.5 nm in the spectral region around 625 nm. The most important result of the work is the fact that a further increase in the layer thickness fluctuations (over ±0.1 µm) does not lead to an increase in the change of the helix period and, consequently, the laser emission wavelength, since it causes the appearance of a multi-domain structure, where in neighboring domains the helix periods are practically the same, only the number of the helix half-turns changes.

The theoretical calculations have been performed and then confirmed by experimental measurements. The spread of the laser emission wavelengths exactly coincided with the above-mentioned ±5.5 nm.

**Keywords:** Cholesteric Liquid Crystals; Laser Emission; Multi-domain Structures
This work was supported by the Shota Rustaveli National Foundation of Georgia **(project No. FR-22-3061).**

# Critical Current Density of GdBCO Coated Conductors Oxygenation under High Pressure - High Temperature Conditions

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Coated conductors (CCs) are advanced materials with one of the highest levels of superconducting characteristics at 77 K compared to other high-temperature superconductors and are very promising for the creation of powerful magnets, electric motors, generators, energy storage devices and current limiters for use in the aerospace, fusion industries, medicine, wind power generation and other fields. In the present study, we repeatedly treated Fuijkura Ltd GdBCO_CC samples cut from the stripe with model numbers FYSC-S12, from whose surfaces copper was removed by chemical etching, i.e. the surface of the superconducting layer was covered with a 2 μm thick silver layer, under oxygen pressure of 100-160 bar at 600-800 °C for 3-12 h. We studied transition temperatures and critical current density, $J_C$, dependences vs magnetic field (up to 5 T at 77 and 5 K) by SQUID magnetometer of each sample before and after treatment. Lattice parameters of Gd123 layer of GdBCO_CC samples were estimated using Rietveld refinement from X-ray data obtained in CuKα radiation ($\lambda$ = 1.54184 Å). Besides, the charge carrier density was estimated from the Hall effect at 100 K using transport measurements with PPMS for the starting sample and the treated samples after chemical etching of the Ag layers from their surfaces. Thus, we estimated the oxygen doping level of Gd123 structures. After treatment at 160 bar $O_2$ at 800 °C for 3 h $J_C$(77K,0T) of GdBCO_CC was increased for 21.5 % from 2.12 to 2.70 MA/cm$^2$ and its $J_C$(5K,0T)=30.22 MA/cm$^2$, while heating for 6 h leaded to $J_C$(77K,0T) increase for 18 %, but during 12 h resulted in its decrease from 1.79 to 1.11 MA/cm$^2$. Treatment of samples at 600 °C under 100 bar $O_2$ for 3, 6, and 12 h resulted in $J_C$(77K,0T) increase for 8, 14 and 13 %, respectively.

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# Room-Temperature Phosphorescence ZnPc(COOH)₄/Ch/MgO System

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In this study, we conjugated $ZnPc(COOH)_4$ with MgO nanoparticles (NPs) coated with chitosan through the free –OH and $–NH_2$ groups to enhance the photosensitizing properties. MgO NPs were synthesized by the co-precipitation method using sodium dodecyl sulfate (SDS), a well-known surfactant that improves the surface properties of nanoparticles, and aloe vera extract (AVE), which acts as an eco-friendly reducing agent and a non-hazardous gelling agent for stabilizing the nanostructures. On the other hand, the peripheral carboxy ($–COO^–$) substituted ZnPc soluble in aqueous media can forms homogeneous solutions. The UV-Vis absorption spectrum of $ZnPc(COOH)_4$/Ch/MgO in water exhibits an intense "shoulder" peak (extinction coefficient > 200,000) at approximately 380 nm (the Soret band), followed by a Q-band extending from 600 nm to 760 nm, with two maxima of subbands located around 647–649 nm and 705–709 nm, respectively. The fluorescence spectrum occurs at longer wavelengths than the absorption spectrum. The $ZnPc(COOH)_4$/Ch/MgO solutions, when excited at 360 nm show an emission band at 479 nm, and an additional, weaker band appears at 708 nm. When excited at 640 nm, the $ZnPc(COOH)_4$/Ch/MgO solutions exhibit the same emission bands but of a higher intensity at 708 nm and 782 nm. The fluorescence intensity of $ZnPc(COOH)_4$/Ch/MgO increases significantly due to intramolecular proton transfer between the $ZnPc(COO^–)_4$ and the $NH_3^+$ groups of the MgO/chitosan nanoparticles. The absolute quantum yield of fluorescence of $ZnPc(COOH)_4$/Ch/MgO system equals approximately 4%. Also, $ZnPc(COOH)_4$/MgO/chitosan system exhibits phosphorescence at room temperature. The triplet excited state lifetime of the system under 355 nm excitation, displays a bi-exponential decay. The corresponding lifetime values are reached values of 1.16 µs and 8.89 µs. The phosphorescence quantum yield of this system reaches 10.63%.

To summarize, the present study facilitates the development of new sustainable room-temperature phosphorescent materials. This result indicates that the interaction between $ZnPc(COOH)_4$ and MgO/Ch NPs was strong, which was beneficial for restricting the molecular vibrations of MgO/Ch and promoting room-temperature phosphorescence emission. The extended lifetime of the triplet excited state facilitates the development of relatively inexpensive detection systems based on decay time measurements.

**Keywords:** MgO NPs; $ZnPc(COOH)_4$/MgO/chitosan system; UV-VIS Spectroscopy; Fluorescence; Phosphorescence.

**Acknowledgements:** This paper was supported financially by the Ministry of Education and Research of the Republic of Moldova, MSU, subprogram #011209, a project PN-IV-P8-8.3-ROMD-2023-0048 (DSUPRAMED), within PNCDI IV.

# Assessment of DDTs Decontamination in Polluted Soil by Magnetite and Zerovalent Iron Nanoparticles

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The ratio between the concentration of dichlorodiphenyltrichloroethane (DDT) and its metabolites, dichlorodiphenyldichloroethylene **(DDE)** and dichlorodiphenyldichloroethane **(DDD)** provides an approximate indication of the timing of both the introduction and degradation of pesticide residues in contaminated soils. Analyses of soil samples collected from an orchard site located in the Calarasi district of the Republic of Moldova revealed the presence of obsolete organochlorine pesticides contamination, with concentrations exceeding the **maximum residue levels (MRLs)** by several tens of times. The detected pollutants included **DDTs** (DDT isomers and related compounds) and **HCHs** (hexachlorocyclohexane isomers). Experimental soil remediation trials were conducted ***ex situ*,** under both **aerobic conditions** and **cyclic anaerobic/aerobic conditions**. For the cyclic anaerobic/aerobic treatments, different amendments, such as **$Fe_3O_4$ nanoparticles (NPs)**, **zero-valent iron ($Fe^0$) NPs, in a form of** a colloidal aqueous solution, and **soybean extract** was introduced into the soil. The experimental results demonstrated that the initial **DDT / (DDE + DDD)** ratio was **11.58**, indicating a relatively **recent input of DDT**. Anaerobic degradation appeared to predominate, as evidenced by the **DDD / DDE** ratio of **2.43**, signifying a greater accumulation of DDD relative to DDE. The analysis of the **DDT / (DDE + DDD)** ratio in experimental variants indicates a **significant reduction of the parent DDT compound**, while the **DDD / DDE** ratio demonstrates that **aerobic degradation remained dominant**, though a relative increase in anaerobic transformation products was observed. The **DDT / DDD** ratio further corroborates the **notable accumulation of DDD**, underscoring an **enhanced contribution of anaerobic pathways** in the DDT degradation mechanism.

**Keywords: $Fe_3O_4$ Nanoparticles**; **Zero-valent Iron Nanoparticles**; DDTs; Nanobioremediation

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# Inverter Technology in Green Tea Production

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Green tea is one of the main types, accounting for 18-20% of world tea production. Green tea is made from tender leaves of Camelia sinensis (L) O. Kuntze using special technological processes. Thermal processes play an extremely important role in the formation of quality indicators of green tea. The main technological process is fixation, the purpose of which is to inactivate the oxidizing enzymes of the tea leaf and to fix the chemical compounds contained in it in their original state. The fixation process can be carried out by various methods (roasting, steaming, moist hot air, electrophysical methods). Making tea is an energy intensive process. Cost reduction is an important task and is actually possible by reducing energy costs, using alternative energy sources and innovative technological processes. The goal of the research is to significantly reduce the energy costs of green tea production using new technological processes and to develop energy-saving technology, The research results of experimental devices and the technological process are discussed in the paper. Based on the obtained results, an energy-saving innovative technological device and process of tea leaf fixation has been developed (Georgian patent 7427 B. 2022). Thermal energy generated by the induction method is used as an energy source, which significantly increases the speed of energy conversion and the efficiency of using thermal energy: in the process of fixing tea leaves, the body of the technological device directly participates in the generation of electromagnetic induction, the working surface of which is heated by electromagnetic induction. Inverter technology the energy consumption per unit of finished tea in the process of fixing is 0.35 - 0,38 kWh / kg, which is several times less than the same figure for existing equipment. The results of the development and testing of a new energy-saving technology in real conditions confirm the possibility of a significant reduction in the cost of green tea. Along with this, the new technological device is characterized by less metal capacity and overall dimensions. An experimental implementation of innovative green tea technology was carried out on one of the farms of the Ozurgeti municipality.

**Key Words**: green tea, inverter technology, fixation machine, energy saving.

# UV Photodiode Integrated on Power-Oriented AlGaN/GaN HEMT Structure

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We report on the fabrication and characterization of ultraviolet (UV) Schottky photodiodes fabricated on $Al_xGa_{1-x}N$/GaN high-electron-mobility transistor (HEMT) structures grown on both silicon and sapphire substrates via MOCVD. The integration of photodetectors with highfrequency transistors on a common heterostructure offers a promising route toward compact, visible-blind UV receiver systems with improved signal quality and reduced noise. The photodiodes feature semi-transparent Schottky contacts (Ni/Au 3/3 nm) and utilize two contact pad configurations: internal and external. Devices were fabricated using standard DUV lithography, ion-etching, and electron-beam metal evaporation techniques. Ohmic contacts (Ti/Al/Ni/Au – 20/150/72/40 nm) were annealed at 850 °C, while substrate cleaning with HCl significantly reduced leakage currents down to 80 -120pA under dark conditions. Photodiodes fabricated on Si substrates demonstrated lower leakage currents and improved rectifying behavior compared to those on sapphire, likely due to a lower defect density in the Si-based heterostructure. These observations align with previous reports linking Schottky interface quality and defect concentration to performance metrics in GaN photodetectors. Responsivity measurements using a polychromator setup revealed a sharp UV selectivity with peak performance near 310 nm, consistent with the wide bandgap characteristics of GaN. The photodiode demonstrated a responsivity of 0.03 A/W at 310 nm under a reverse bias of –2 V. This level of responsivity is noteworthy, given that the underlying AlGaN/GaN heterostructure was originally designed for high-power transistor applications. The integration strategy presented here allows simultaneous fabrication of photodiodes and HEMTs in a single processing cycle, simplifies production and supports future implementation in UV sensing systems, where compactness, sensitivity, and noise suppression are critical.

**Keywords:** AlGaN/GaN HEMT heterostructure, Schottky photodiode, UV photodetector, responsivity, integrated optoelectronics.

# Comparative Characterization of Graphene Oxides Obtained from Flake Graphite and Graphite Foil

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Graphene oxide (GO) was obtained by oxidation of flake graphite (Graphite) and graphite foil (Graflex) powders at a relatively high (30–50°C) temperatures using $KMnO_4$–$H_2SO_4$ system. Samples are studied using spectroscopic methods (UV–Vis, FTIR, Raman spectra). Both samples' UV–Vis spectra are similar but the GO(glaflex) sample showed a higher absorption intensity. The characteristic peak in the absorption spectrum of both samples was observed at approximately 265 nm. The Raman spectra of the samples show GO (graflex) peaks position and FWHM (Full Width at Half Maximum) and intensity are D: 1324.48 and 147.74 cm$^{-1}$ and 333.73 and G: 1595.17 and 65.01 cm$^{-1}$ and 312.09, respectively, at intensity ratio of $I_D/I_G = 1.07$. Similar data for GO(graphite) are D:1325.83 and 178.37 cm$^{-1}$ and 228.06 and G:1597.58 and 67.74 cm$^{-1}$ and 225.19, respectively, at $I_D/I_G = 1.01$. The FTIR spectra of both samples are also quite similar, although there may be slight differences depending on the oxygen content. These spectra show absorption bands of OH,C=O,C–O,COH,and C=C functional groups. Broad peaks at ~3389 cm$^{-1}$ due to the stretching vibration of OH groups indicate the presence of adsorbed water molecules and OH functional groups. The peak at 1620 cm$^{-1}$indicates the aromatic ring (C=C stretching). Peaks at 1220 cm$^{-1}$ and 1721 cm$^{-1}$ correspond to stretching vibration of C–O–C and C=O groups. The hydrodynamic diameter and ζ-potential of both sample suspensions were also determined. The average particles size of GO(Graflex) is 321.5 nm, while the particles size of GO(Graphite) reaches 252 nm. The measured ζ-potential values for GO(Graflex) and GO(Graphite) are –31.58 and–50.04 mV, respectively. It has been established that characteristic XRD diffraction maximum of flake Graphite and Graflex at $2\theta$=26.45–26.50° completely disappears during the oxidation process due to complete oxidation of precursors into GO. XRD analysis also confirmed that obtained GO phases characterized by the peaks located at $2\theta$= and 10.41°–10.67°. The EDS analysis results indicate that the samples exhibit slight differences in carbon and oxygen contents. For the GO obtained from flake graphite, the atomic ratio of carbon to oxygen C:O is 58.65:46.53. In contrast, the C:O ratio for GO(Graflex) is 60.49:39.51. We can conclude that graphite foil and its wastes are new carbon precursors for synthesizing graphene oxides.

**Keywords:** flake graphite, graphite foil, graphene oxides, UV–Vis, FTIR, Raman spectra.

# Automation and AI for Advanced Electron Microscopy

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Integrating artificial intelligence (AI) into electron microscopy (EM) workflows can significantly enhance efficiency, accuracy, and capabilities of microscopy analysis. Carl Zeiss Microscopy GmbH is presenting a new AI feature in the ZEN core software for the integration of AI into ZEISS field-emission scanning electron microscopes (FE-SEM) and focused ion beam scanning electron microscopes (FIB-SEM) workflows. This software platform streamlines image acquisition, preprocessing, analysis, and classification by utilizing AI-supported denoising to enhance images before segmenting parts and training models to classify structures efficiently.

ZEN core also provides essential tools for improving the FIB-SEM workflow for sample preparation. The new TEM Prep Automation workflow for the ZEISS Crossbeam FIB-SEM automates steps from chunking to lift-out to thinning, or, if applicable, allows for manual processing. This feature enables the investigation of diverse materials in a single run and facilitates the seamless preparation of multiple samples and various materials. TEM Prep Automation improves the preparation of TEM lamellae, enhancing efficiency, consistency, and quality. It leverages the benefits of the ZEISS Crossbeam FIB-SEM, including high stability and precise control over the milling process, allowing users to achieve optimal thickness and uniformity for TEM lamellae. Additionally, the simultaneous live SEM high-resolution imaging enables accurate monitoring of the thinning process.

Automation and integration of AI into electron microscopy workflows enhance the capabilities of microscopy by automating complex tasks, improving accuracy, and increasing efficiency, ultimately leading to more insightful and reliable analysis.

**Keywords:** electron microscopy, focus-ion beam microscope, TEM lamella, artificial intelligence, nanomaterials research

# An Additional Diagnostic Sensor System for Hemodialysis Machines

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Despite decades of use and development, hemodialysis machines have not evolved significantly in recent years compared to the potential advances in biomedical engineering, sensor technology, and artificial intelligence. Many machines still rely on predefined parameters and do not fully utilize real-time physiological monitoring and intelligent feedback systems.

Although hemodialysis machines are a central part of renal replacement therapy, several critical subsystems of the device are still outdated or insufficiently reliable by current biomedical engineering standards. Among the most notable areas are temperature sensors, air bubble detectors, and electric motors, which are vital for patient safety and treatment efficiency.

Dialysate temperature is a key parameter for maintaining patient stability during hemodialysis sessions. However, current temperature sensors often lack precise resolution and are slow to respond to rapid fluctuations. Overheating or undercooling of the dialysate, even by small margins, can lead to hypotension, thermal stress, or patient discomfort. In addition, most systems do not incorporate adaptive thermal control based on patient-specific feedback, such as core body temperature or hemodynamic response. Modern noninvasive temperature sensing methods or predictive thermal algorithms are available in other biomedical fields but are not currently used in dialysis systems due to design limitations.

Electric motor failure may go unnoticed until the patient experiences symptoms. The lack of redundant safety interlocks or self-calibrating motor controllers in some models poses a significant risk.

Air embolism is one of the most dangerous potential complications of hemodialysis, but air bubble detection systems remain relatively primitive.

Nowadays, patient weight loss monitoring is available, but it is not sufficiently sophisticated to prevent unfortunate incidents. Although temperature sensors, air detectors, and electric motors in hemodialysis machines are vital components, they often fail to meet modern expectations in terms of accuracy, adaptability, and safety. Upgrading these subsystems with modern sensor technology, artificial intelligence-driven feedback control, and multi-layered security architecture is not only possible, but urgently needed to improve the outcomes and reliability of dialysis treatment.

**Keywords:** hemodialysis machine, temperature sensor, air embolism, electric motors.

# Influence of Monocrystalline Germanium on the Physical-Mechanical Properties of Indentation-Induced Phase Transitions in Silicon

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The effect of maximum loads applied to the Vickers indenter, on the elastic modulus and average contact pressure characteristics for the phase transitions in the double- side polished (111) oriented plates of the monocrysatlline Si+2at.%Ge alloy has been studied using ultramicroindentation method on a Shimadzu DUH-211S dynamic ultramicrotester system.

Using a well-known method developed on the basis of the elastic recovery mechanics at the contact of the indenter, a special program was created to perform sequential operations of numerical calculations and the values of average contact pressure have been determied, as a function of displacement in a complete loading-unloading cycle of the indenter. Critical values of average contact pressure associated with indentation-induced phase transformations during unloading, as well as the duration of metastable phase formation, were evaluated.

In the range of maximum loads from 10 to 100 mN, the unloading curves of indentation of the monocrystalline Si + 2 at.% Ge alloy substrates revealed tilted plateaus and gradual slope of the curve corresponding to intermediate crystalline SiGe-IV and SiGe-XII, and amorphous SiGe phases.

In p-Si + 2 at.% Ge alloy, processes of elastoplastic deformation induced by high indenter loads were revealed. On the ascending segments of load–displacement and average contact pressure–displacement curves “pop-in” effects of SiGe-I → SiGe-II phase transition and dislocation-origin plastic deformation were observed.

The viscous fracture characteristics of n- and p-type Si and Si + 2 at.% Ge alloy substrates in their the initial and high-energy electrons irradiated states were studied. Numerical values for the critical stress intensity factor (fracture toughness) and fracture energy were determined.

**Keywords:** Si-Ge alloy, Vickers indenter, phase transition, contact pressure, elastic modulus.

# Ultrafast Synthesis and Sintering of functional oxide materials by Light Irradiation

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Advanced functional oxide materials are most commonly synthesized using the solid-state reaction method, which involves prolonged heating—often for tens to hundreds of hours—of a mixture of precursor oxides at high temperatures. This is a highly time and energy consuming process. Moreover, extended heating can lead to the evaporation of certain components, resulting in changes in stoichiometry and a decline in material quality. Therefore, there is a need to develop new technologies to significantly reduce the synthesis and sintering time.

We have developed a novel synthesis method that replaces conventional furnace-based thermal treatment with intense light irradiation. This technique, which we refer to as photostimulated solid-state reaction (PSSR), involves exposing a mixture of starting oxides to combined infrared, visible and ultraviolet light of high intensity. Our results show that the reaction rate achieved using PSSR exceeds that of traditional thermal solid-state reactions by two to three orders of magnitude.

We will demonstrate the application of PSSR for the rapid synthesis and sintering of superconducting, magnetic, and other functional oxide materials, in both bulk and thin-film forms. The role of non-thermal effects during light irradiation will be highlighted, and possible mechanisms underlying the PSSR process will be discussed.

## Acknowledgments

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# Development of Semiconductor Detectors of Thermal Neutrons and other Ionizing Radiation at SIPT

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The report presents a brief history of the development of thermal neutron and other ionizing radiation detectors at SIPT. Research activities on this class of detectors conducted at SIPT are discussed. An innovative semiconductor p-n junction detector, fabricated by ion implantation for thermal neutron detection, is described, where the inverted p-layer simultaneously functions as a neutron converter. The radiation parameters of thermal neutron detectors produced in recent years by ion implantation of the $^{10}$B isotope are also examined. The feasibility of fabricating a semiconductor p-n junction sensor/detector using the rapid thermal diffusion method is addressed. A complete cycle of experimental work was carried out, and the electrophysical characteristics of prototype sensors obtained by this method were analyzed.

The schematic of the laboratory setup for sensor fabrication using this method is presented. A simulation-based interpretation of the rapid thermal diffusion process and the spatial distribution of temperature are provided. The determination of optimal converter and detector parameters was performed using Geant4, SRIM-2013, and C++ codes. The characteristic radiation parameters of the decay products of the $^{10}$B(n,α) nuclear reaction, $^{4}$He and $^{7}$Li, in interaction with matrix atoms (Si, SiGe), were investigated. These include total and projected ranges, nuclear and electronic energy losses, energy dissipation into lattice ionization, phonon generation, vacancy formation, displacement of matrix atoms, spatial distribution of vacancies and displaced atoms, as well as other radiation parameters. Visualization of p-n structures and compositional analysis were carried out using scanning electron microscopy (SEM).

# Zinc Phthalocyanine Functionalized With Au-Chitosan Nanoparticles

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Zinc phthalocyanine (ZnPc) is a new-generation photosensitizer successfully used in photodynamic therapy (PDT), a modern and minimally invasive method for treating certain forms of cancer and microbial infections. This molecule exhibits strong absorption in the near-infrared (NIR) region, allowing activation deep within tissues, where other treatments often struggle to reach. Upon light activation, ZnPc generates reactive oxygen species (ROS) that selectively destroy tumor cells without damaging healthy tissue. Its chemical stability and preferential accumulation in malignant cells make it an ideal candidate for clinical applications. Recent studies highlight the potential of ZnPc to be combined with various nanoparticles, such as Ag, Au, or different polymers, to enhance biodistribution and photodynamic activity [1]. In this study, ZnPc was functionalized with Au–chitosan nanoparticles and characterized using UV-Vis absorption spectroscopy, X-ray diffraction (XRD), zeta potential measurements, and dynamic light scattering (DLS). The results demonstrated that the reaction temperature plays a crucial role in controlling the size, shape, and crystalline structure of the gold nanoparticles (GNPs). Moreover, it was shown that chitosan can act as a scaffold for the assembly of GNPs, which were successfully used for ZnPc functionalization. The first optical indication of GNP formation was a visible color change over time, from violet to light pink. This visible color arises from the interaction of light with GNPs via surface plasmon rezonance. Since the optical spectrum of GNPs strongly depends on their size, shape, local environment, and electronic coupling, their formation was monitored not only visually but more accurately through UV-Vis spectroscopy, showing a characteristic absorption maximum at 520 nm. The zeta potential was approximately –32.25 mV, and DLS analysis revealed a mean GNP diameter of approximately 272.2 nm. All diffraction peaks are attributed to the (111), (200), (220), (311), and (222) planes of a face-centered cubic (fcc) gold crystal. The UV-Vis spectra of $ZnPc(COOH)_4$ and $ZnPc(COOH)_4$:Au showed a well-defined B-band maximum at around 364 nm and only a slight attenuation of the Q-band for $ZnPc(COOH)_4$:Au compared to the pure phthalocyanine. Additionally, a minor red shift was observed in the Q-band-from 700 nm, characteristic for $ZnPc(COOH)_4$, to 708 nm for $ZnPc(COOH)_4$:Au.

**Keywords:** ZnPc; Au-Chitosan; UV-VIS Spectroscopy; DLS Spectroscopy; Zeta Potential;

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# The In-Situ Polymerisation Method to Advanced Tl-1223 Phase HTS Materials

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Thallium-based superconductors, such as Tl-Ba-Ca-Cu-O, are intriguing systems featuring distinct Tl-O and Cu-O layers, varying compositions, and different transition temperatures. Among the members of the Tl-based series, Tl-1223 is one of the interesting phases for both fundamental and applied research due to its high Tc and Jc. The transition temperature of the Tl-1223 phase synthesised by the conventional method is Tc≈118 K when prepared in a nitrogen flow, displaying a very high Tc of up to Tc≈130 K and Tc≈133.5 K under high pressures (3.5 GPa).

The sol-gel process has an advantage over other methods in achieving homogeneous mixing of component cations on the atomic scale and forming bulk superconducting materials from gels. The idea of In-situ polymerisation is a method of producing polymers where monomers are polymerised directly at the desired location, such as within a matrix or on a surface. This approach offers several advantages, including the ability to integrate with other processes and cost-effectiveness.

In this connection, we present our approach to synthesising the precursors using the sol-gel method. We utilised an in situ polymerisation process to create high-purity and highly reactive precursors. It is important to note that this method for synthesising Tl-based superconductors has not been reported previously.

X-ray diffraction (XRD) results revealed the crystalline structure of the patterns, while phonon vibration was investigated using an infrared (FT-IR) spectrum. The surface morphology of the samples was examined by scanning electron microscopy (SEM). The critical temperature ($T_c$) and transport critical current density ($J_c$) were determined using the method of high harmonics.

In summary, the XRD result indicates that Tl-1223 is present as a significant phase, accompanied by a small number of impurities, including Tl-1212 and precursor phases, as well as $BaCuO_2$. Nonlinear susceptibility measurements revealed a critical temperature of approximately 118.4 K and critical current densities of 160 A/cm$^2$.

**Keywords:** Tl-based; In-situ polymerisation; Chemical properties; Superconducting properties.

## ACKNOWLEDGMENTS

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# Structural Study of Biocomposites Developed on the Basis of Secondary Polypropylene and Waste of Nut-bearing Plants, using Modern Instrumental Methods

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Bio composites modified with organic silicon based on plant-based raw materials (walnut shells) and a commercially unsuitable polymer have been developed using simple technology. It has been shown that both modifiers significantly increase the strength of bio composites and reduce water absorption. $T^{o}$ study the physical and mechanical characteristics of the developed samples, standard pressure forms of water absorption were used; Heat resistance, dependence of softening on $T^{0}$ were determined according to "Vika"; The ultimate strength in bending and longitudinal bending, as well as impact toughness were studied. The physical and chemical characteristics of the developed composite were studied using modern instrumental methods: trinocular microscopy, optical scanning electron microscopy, polarimetry, TGA, infrared (FTIR).

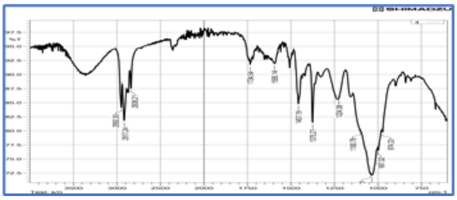


Fig.1. Sample-FTIR spectrum of PP+60 wt.% modified with TEOS 5 wt.% walnut shell

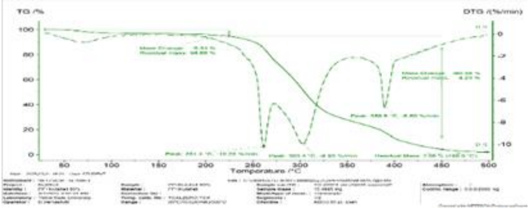
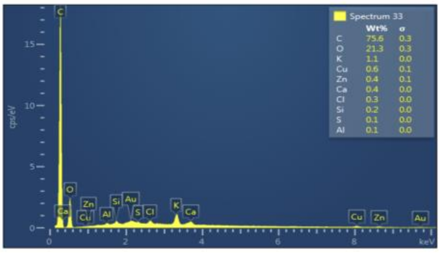


Fig.2. Sample-Modified PP+80wt. % walnut shell-1DTG



| | Wt% | σ |
|---|---|---|
| C | 75.6 | 0.3 |
| O | 21.3 | 0.3 |
| K | 1.1 | 0.0 |
| Cu | 0.6 | 0.1 |
| Zn | 0.4 | 0.1 |
| Ca | 0.4 | 0.0 |
| Cl | 0.3 | 0.0 |
| Si | 0.2 | 0.0 |
| S | 0.1 | 0.0 |
| Al | 0.1 | 0.0 |

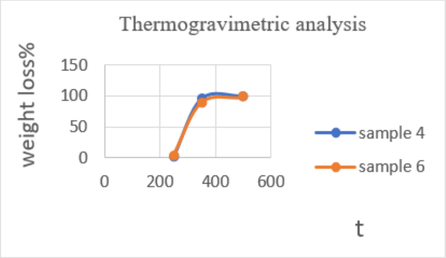


Fig.3.Sample- Elemental analysis with scanning microscope PP+60 wt. % modified with TEOS 5 wt.% walnut shell

Sch.1. Samples PP+40,80 wt.% of modified with TEOS 5 wt.% walnut shell graphical analysis

**Keywords:** Silicon-containing carbohydrates; Bio composites; Secondary polymers; Modification.

# Formation of BCCO Precursors via Organometallic Routes Using Ba, Ca, and Cu 2-Ethylhexanoate for the Synthesis of Tl-based Coated Superconductors

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The principle of metal-organic chemical vapour deposition (MOCVD) is to achieve contact between the volatile compound material deposited and a substrate heated under a vacuum or nitrogen (N2) gas flow containing partial oxygen. The metal-organic deposition is an attractive process for the high-rate deposition of films on continuous lengths of biaxially textured metallic templates for second-generation (2G) high-temperature superconductor (HTS) wires. The $Ba_2Ca_2Cu_3O_x$ precursor is one of the compounds with suitable physical properties and high reactivity, which are essential for the fabrication of Tl-based superconducting materials. The BCCO precursor thin film also serves as a material from which superconducting cables, processors, and other components can be manufactured.

The present work focuses on the preparation of the BCCO precursor via organometallic synthesis. The process contains three main stages. In the first stage, we synthesised the salts of 2-ethylhexanoic acid for Barium, Copper, and Calcium using different methods. In the second stage, we mixed all these solutions, stirred them, and evaporated them until they were homogeneous and had formed a suspension. In the third stage, this suspension was coated on the thin films of Lanthanum aluminate ($LaAlO_3$) using a spin coating machine. Finally, the coated precursor was annealed in flowing oxygen at different temperatures.

The resulting samples were characterised by X-ray powder diffraction patterns, obtained on a Dron-3 + PC diffractometer with CuKα radiation. The Fourier-transformed IR spectra of the samples were recorded in the region of 400−4000 cm−1 on a Cary 600 series FTIR spectrometer. The morphology and structure were analysed using a ZEISS Sigma 300 VP scanning electron microscope (SEM).

**Keywords:** Organometallic; Synthesis; Precursor; Coated; Tl-based.

**ACKNOWLEDGMENTS:** This research, FR-24-11856, has been supported by the Shota Rustaveli National Science Foundation of Georgia (SRNSFG).

# On the Mechanism of Photoresponse Occurrence in the Wavelength Range of 1.6-2.2 μm in Silicon Photodetectors

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The development of IR photodetectors (PDs) on silicon, intended for fire monitoring, is still relevant due to the low cost of the material, well-developed technology and the use of Si signal processing devices.

The main problem is that silicon is transparent at wavelengths longer than about 1.1 μm. Therefore, it is necessary to find ways to extend the sensitivity towards longer wavelengths.

For this project to prepare IR PD fabrication, n- and p-silicon with different resistivity obtained by the Czochralski or zone melting methods was used. P-n and n-p junctions were obtained by boron/phosphorus diffusion, depending on the type of silicon conductivity. Diode structures of circular configuration were formed on the front side of the wafer, and ohmic contacts - on the back side.

In the PD photosensitivity spectra, regardless of the type of silicon conductivity, the same photoresponse was observed in the wavelength range of 1.6-2.2 μm with peaks at wavelengths of 1.8-1.83 μm and 1.91 μm (radiation characteristic of hydrocarbon combustion).

The study of the influence of such factors as resistivity, conductivity type of the source material, depth of the p-n/n-p junction, and the introduction of nickel as a getter on the photoresponse allowed for increasing this value.

The observed photoresponse is probably due to the deep-level defects.

**Keywords:** Silicon IR photodiode, Photoresponse, Deep-level defects.

# Superconductivity in ZrTe2- and ZrTe3- Based Compounds

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The transition metal dichalcogenides and trichalcogenides display remarkable electronic properties, including topological behavior, charge density waves (cdw), and superconductivity. Single crystals of intercalated ZrTe2- and ZrTe3- based compounds can be grown by means of an isothermal chemical vapor transport technique. While pristine ZrTe2 is not superconducting and ZrTe3 displays only filamentary superconductivity at ambient pressure, both compounds exhibit robust superconducting properties upon intercalation with small amounts of transition metals or lanthanides. Both compounds are regarded as van der Waals materials, and as a result the single crystals can exfoliate easily.

ZrTe2 is a topological semimetal in which intercalation with Fe, Ni, Cu, Ru, and Pt all result in bulk superconductivity. The behavior of the upper critical magnetic field Hc2 is consistent a two-band superconductivity model. ZrTe3 is regarded as a uniaxial material well known for its line chain nature and for displaying cdw and filamentary superconductivity. The superconducting behavior becomes robust upon the intercalation by e.g. Cu. Ag, Ni, Tb and Er. Similarly to intercalated ZrTe2, the superconductivity in intercalated ZrTe3 is consistent with a two-band model. Here will discuss the behavior of these materials by means of measurements of electrical resistivity, Hall effect, magnetization, heat capacity, and Seebeck coefficient.

# Investigation of the Structure of Anionic Nanoporous Materials by IR Spectroscopy

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Phosphates are special compounds that are part of living organisms and play a major role in plant and animal life, so they are central to all forms of life. The interest in this type of material is great and the range of applications is vast, from agriculture to medicine. Despite their great practical importance, such materials are poorly understood scientifically. The method of infrared spectroscopy allows their comprehensive study. Isomorphous substitution of phosphorus in the aluminosilicate framework of zeolite allows changing the total charge of the zeolite framework from negative to positive.
Based on natural zeolite from Georgia - clinoptilolite - mono-, di- and tri-substituted sodium phosphates were introduced into the zeolite structure at the nanolevel by melting. The obtained phosphate zeolite nanoporous materials were studied by *Fourier transform infrared spectroscopy (FTIR*) on an Agilent Cary 630 FTIR spectrometer in the range of 350-5000 cm$^{-1\,(}$USA).
The materials retained the zeolite structure and the presence of the corresponding anion in the zeolite structure was determined. The IR spectra of the obtained materials differ sharply from each other. This can be explained by the fact that the anions occupy different positions in the zeolite structure. Phosphate ions almost completely occupy the inner structural space of zeolite.
The obtained anionic nanoporous materials have a wide range of applications, including agriculture, medicine, and ecology, as well as the purification of water contaminated with non-polar and radioactive elements.

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**Keywords:** I.R. spectroscopy, Natural zeolites, Aanionic nanoporous materials, Phosphates.

# Porous Structure of Modified Natural Zeolites

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Natural and synthetic zeolites, hydrated microporous crystalline aluminosilicates of the general formula $M_x[Al_xSi_yO_{2(x+y)}]\cdot mH_2O$ ($M^+ = Na^+$, $K^+$, … $½Ca^{2+}$, $½Mg^{2+}$, ...), have a wide application due to unique set of molecular-sieve, sorption, ion exchange and catalytic properties. In general, synthetic zeolites are more suitable for use as adsorbents and ion exchangers due to the high uniformity of pore size distribution and the presence of a single compensation cation, while natural zeolites, despite the presence of mineral impurities and heterogeneous cationic composition, are very attractive from an economic and environmental point of view. However, there are chemical and thermal methods for "improving" the properties of natural zeolites. In addition, along with a framework with nanosized pores, natural zeolites, as a rule, have a developed system of mesopores with sizes from several nanometers to micrometers, and the presence of mesopores is an important factor in the practical applicability of zeolites.

We studied the effect of acid and thermal treatment on the structure and properties of natural zeolites of the HEU group with different aluminum content – heulandite (Si/Al=3.6) and clinoptilolite (Si/Al=5.2), which have mesopores with a diameter of up to 120 nm and a maximum in the size distribution at 10-12 nm. Heating of samples was shown to cause stepwise dehydration proceeding up to ≈800 °C, amorphization starting at ≈250 °C, and structural changes at high temperatures, but changes in micro- and mesoporous systems during heating in the temperature range of maintaining the crystal structure of the HEU type are insignificant.

An acidic environment leads to significant dealumination (the molar ratio Si/Al increases to ≈9.5 for both samples), decationization is also characteristic of heulandite (the total charge of metal ions per Al atom decreases from 1 to 0.68), in the case of clinoptilolite the charge is retained, but the cationic composition changes since calcium is washed out along with the leaching of aluminum; hydrochloric acid solutions do not lead to amorphization of the microporous crystalline structure of zeolites, but gradually dissolve it. As a result of acid treatment, the volume of micropores accessible to large molecules sharply increases (from ≈7 to 80-90 $mm^3/g$) and the surface area (from ≈13 to 120-175 $m^2/g$) in heulandite; in clinoptilolite, these changes are not so strong – from ≈94 to 100-130 $mm^3/g$ and from ≈18 to 21-37 $m^2/g$, respectively. In both zeolites, acid-induced changes in the mesoporous system are observed, leading to a predominance of pores with a diameter of up to 4 nm.

**Keywords:** Zeolites; Adsorption; Ion exchange; Mesopores.

# Applied Research on Using Ozone Generator in Viticulture instead of Pesticides

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Applied Research experimental methods of treating the SME vineyards using dissolved ozone in water as an alternative to chemicals and pesticides is described in the presented article. As a result, we obtained a cheap and effective, environmentally friendly way of vineyard cultivation, and we preserved a wide range of microelements, in wine, vine leafs and soil. The content of resveratrol and quercetin in vine leaves was maintained. For a fundamental evaluation of this method according to various parameters, additional research is needed.

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# Synthesis of Organic-Inorganic Materials

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Synthesis in the mode organic self-propagating high-temperature synthesis (OSHS) enables the production of materials from mixtures of solid-phase dispersed powders. A distinctive feature of the technology for obtaining materials from mixtures containing organic compounds is their formation at relatively low temperatures at the synthesis wave front, within the range of 100 - 300 °C

In this study, ammonium nitrate was employed as an oxidizer, while organic compounds of the CxHyOz and CxHyNz series served as reducing agents. The synthesis was conducted in an inert gas atmosphere using a specially designed metal-cased reactor. Condensation of gaseous products occurred on the reactor walls. The innovative reactor design facilitated the differentiation of the final products, resulting in the formation of three distinct substances during synthesis: water vapor, a condensed brown-yellow oily liquid, and a highly porous, amorphous black material.

The composition of the initial reactants, heating rate, and synthesis temperature thresholds were established, and it was determined that the formation of the target product depends on the internal volume of the reaction zone. The OSHS process was found to proceed via the carbonization of organo-inorganic materials in a gaseous medium, with synthesis occurring through substitution and addition reactions involving oxygen- and nitrogen-containing groups.

**Keywords:** Synthesis, Oxidizer, Reducing agent, Structure

# Innovative Devices for Obtaining Materials and Products by the SHS Metallurgy Method

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The control of phase separation and dispersion processes within the reaction mass, along with the formation of phase and chemical compositions and microstructure, has enabled the development of a new scientific field—**Self-propagating High-temperature Synthesis (SHS) Metallurgy**. SHS metallurgy offers the possibility of producing advanced materials and products by harnessing and controlling the explosion-like nature of high-temperature combustion reactions. A key feature of the SHS process is its minimal gas emission and complete formation of condensed products. The presence of both a fuel and an oxidizing agent in the initial mixture allows the reaction to proceed in a combustion mode, primarily driven by redox reactions that generate the necessary thermal energy. The SHS process typically unfolds in two stages: the first involves the rapid, localized initiation of the reaction within seconds, while the second stage encompasses secondary physical and chemical transformations that define the final product's composition and structure. At the same time, for realization at the second stage of the process, the change of technological parameters (dispersity, ratio of components, external influences, etc.) allows to control the synthesis process and creates stability at given values of combustion rate. The process of obtaining materials is diverse, the laws of heat release and heat transfer, the aggregate state of reagents and products, the kinetics of phase and structural transformations and other macroscopic characteristics of the process occurring in exothermic mixtures are important. Carrying out the process of SHS - metallurgical technology is possible both in atmospheric conditions and under the influence of external forces (gas pressure, centrifugal force). Notably, applying centrifugal force can increase product yield and recovery efficiency by 10–20%. Under such conditions, three types of phase separation can be observed: complete ($\eta = 1$), where alloy and slag are distinctly separated; partial ($0 < \eta < 1$), where they remain partially bonded; and none ($\eta = 0$), where no phase separation occurs. The technological possibilities of obtaining materials by SHS-metallurgy with the use of innovative devices developed by us are disclosed. Advantages of these technological devices for obtaining SHS-materials in relation to traditional industrial methods of their obtaining are discussed, along with a review of the range of materials produced and potential sample configurations. Finally, the technical and economic performance indicators of the developed SHS systems are presented.

**Keywords:** SHS -metallurgy, synthesis, phase separation, centrifugal force.