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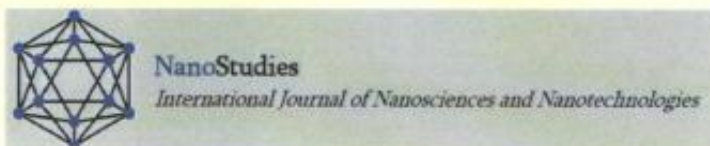
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3rd International Conference “Nanotechnologies”

October 20 – 24, 2014, Tbilisi, Georgia

Nano – 2014

A b s t r a c t s

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FOREWORD

In Georgia, the tradition to conduct scientific forums devoted to the developments in nanotechnologies starts with the 1st International Conference “Nanochemistry – Nanotechnologies” (Nano – 2010). The 2nd International Conference “Nanotechnologies” (Nano – 2012) was held as a section of the multidisciplinary conference devoted to the 90th anniversary of the Georgian Technical University. This year our university holds the 3rd International Conference “Nanotechnologies” (Nano – 2014).

The conference aims to summarize recent progress achieved in synthesizing of nanomaterials, studying their physical, chemical, and technological properties and predict new possibilities of applications of nanotechnologies in techniques. The Nano – 2014 will be an international forum of nanoresearchers, which will intensify cooperation between scientists of different countries working in the field of nanotechnology.

Present Abstracts book contains more than 120 abstracts submitted to the Nano – 2014 by professors and researchers of many leading universities and other scientific institutions from the 21 countries (Armenia, Azerbaijan, Belarus, Bulgaria, Canada, Georgia, Germany, Hungary, India, Iran, Iraq, Japan, Kazakhstan, Lithuania, Mexico, Poland, Russia, Slovenia, Turkey, Ukraine, and United States of America). Most of these specialists attend the conference. Topics of presentations also are too diverse – they contain the actual directions of nanosciences and nanotechnologies, such as:

- Nanostructured materials: metallic alloys and composites, ceramics, polymers, hybrid materials, liquid crystals, nanodispersed powders, ion-implanted and irradiated with high-energy particles materials, nanomaterials of less-common morphology, carbon nanocomposites, etc.
- Processing of nanomaterials: deposition, coating, self-propagating high-temperature synthesis, consolidation, etc.
- Nanophysical effects: quantum dots, nanowires, thin films, high-temperature superconductivity, electron hopping transport, nanosize effects in catalysis, surface effects, etc.
- Nanoelectronics: detectors and sensors, bionanosensors, “smart” nanotechnology systems, solar cells, etc.
- Nano biomedical applications: bio- and microbial nanotechnologies, nanopharmacology, drug delivery, etc.

Georgian Technical University, as the conference organizer and co-sponsor, deeply appreciates the Conference Grant support from the Shota Rustaveli National Science Foundation. We are also thankful to the Institute of Nanotechnology – ‘Connecting Global Innovation’ (Glasgow, Scotland, United Kingdom) for international promotion of our conference through networks, and journals ‘Nano Studies’ and ‘European Chemical Bulletin’, which intend to publish selected presentations in the form of full-text papers.

Archil Prangishvili

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of the 3rd International Conference “Nanotechnologies”
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PREPARATION AND STUDYING OF STRUCTURAL, ELECTROCHEMICAL AND CONDUCTIVITY PROPERTIES OF Al–Ni–Cr ALLOY

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Al–Ni–Cr alloys containing different ratios of Ni and Cr were prepared by mixing Al, Ni, and Cr at 800 °C under the argon atmosphere. The prepared alloys were heated for 1300 h to 560 °C, and then cooled rapidly by water to the ambient temperature.

Surface morphology for alloys was studied by scanning electron microscope (SEM). The resultant homogeneous surface is a result of heat treatment. The X-ray diffraction patterns showed (111), (200), and (220) diffraction lines from Al cubic crystalline structure, and suggested that the intensity of peak of (111) orientation is predominant. It was observed three binary phases grown in alloys: Al₃Ni (orthorhombic; $a = 6.598$, $b = 7.352$ and $c = 4.802$ Å), Cr₉Al₁₇ (rhombohedral, $a = 12.910$ and $c = 15.677$ Å), and Ni₂Cr₃ (tetragonal; $a = 8.820$ and $c = 4.580$ Å). The average crystallite sizes of the prepared samples were found to be from 3000 to 3094 nm by SEM, which is much smaller than that estimated from XRD data.

Corrosion resistance increases with increasing Ni–Cr content in Al alloys. The electrical volume resistivity decreased with increasing Ni–Cr content at low frequency. This behavior can be seen generally at 50 Hz, where the electrical volume resistivity reached the value of $3.98 \cdot 10^{-8} \Omega \cdot \text{cm}$ for the ratio Al – 1.80 at. % Ni – 0.18 at. % Cr.

PHASE TRANSITIONS AND MULTI-LAYERED NATURE OF MARTENSITE STRUCTURES IN SHAPE MEMORY ALLOYS

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Shape memory alloys take place in a class of functional materials by exhibiting a peculiar property called shape memory effect. This property is characterized by the recoverability of desired shape on the material at different conditions. Shape memory effect is based on martensitic transformation, and comprises a reversible transition from product martensite to parent austenitic phase. The main applications of these systems include couplings for electrical connectors, sensors and actuators. The industrial application of these materials has recently shifted from the bulk sizes to the micro- and nano-scales, like micro-valves and micro-actuators with technological advances.

Copper based shape memory alloys serve as an economical alternative to other alloys, and they are widely used as a shape memory element in devices. These alloys are metastable at β -phase field and undergo two ordered transitions on cooling, and bcc structures turn into B₂(CsCl) or DO₃(Fe₃Al)-type ordered

structures. These ordered structures undergo the non-conventional structures via martensitic transformation on further cooling from high temperatures. The product phases have unusual complex structures called long period layered structures such as 3R, 9R or 18R depending on the stacking sequences on the close-packed planes of the ordered lattice.

Martensitic transformations occur by two or more lattice invariant shears on a {110}-type plane of austenite matrix which is basal plane or stacking plane for martensite, as a first step, and the transformed region consists of parallel bands containing alternately two different variants. All of these martensite phases are long-period stacking ordered structures that is the underlying lattice is formed by stacks of close-packed planes.

Lattice invariant shears occur with cooperative movement of atoms less than interatomic distances on {110}-type close packed plans of austenite matrix. The lattice invariant shears occurs, in two opposite directions, $\langle 110 \rangle$ -type directions on the {110}-type basal planes and this kind of shear can be called as {110}-type mode and has 24 variants in self-accommodating manner. These lattice invariant shears give rise to the formation of unusual complex layered structures called long period layered structures such as 3R, 9R or 18R depending on the stacking sequences on the close-packed planes of the ordered lattice. The periodicity and therefore the unit cell are completed through 18 layers in direction z in 18R case.

In the present contribution, X-ray diffraction and transmission electron microscopy (TEM) studies were carried out on two CuZnAl and CuAlMn alloys.

OBTAINING OF FERRIC-CONTAINING CATALYST ON THE BASE OF ZEOLITIC MATRIX

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The dependence of chemical activity on size of reacting particules due to the fact that the properties of the individual atoms of the elements, and the clusters and nanoparticles formed from these atoms are different from that of the compact, volumetric substance. In the first approximation for understanding and analyzing the chemical size-dependent properties, it can be compared reactivity of compact substances, nanoparticles, and atomic and molecular clusters [1].

The boundaries between these dimensional modes are changed for each element and must be studied specifically. Most catalytic systems are nanosystems [2]. In heterogeneous catalysis, the active substance deposits on the carrier as nanoparticles increase their surface area. For example, it is established that increasing of specific activity of nanocrystals of platinum in regard to oxidation of carbon monoxide at increasing d from 10 to 60 nm depend on that small nanocrystals on surface of catalyst that are more than “costal” structural elements which form transition sites between faces (100) and (111). The CO molecules on transition sites are in linear form, nonmobile and have the deficit of electron density if compared with molecules on faces [3, 4].

In this paper, we tried to put iron as oxide in cationic form on the surface of the pre decationized natural clinoptilolite (CL) by the method of multiple impregnation with salts of iron(III) and hydroxide gel $\text{Fe}(\text{OH})_3$.

The structure and crystallinity of the CL, before and after decationation and the treatment with freshly made ferric hydroxide were verified by XRD and the EPR analysis was used to identify the presence of Fe^{3+} ions in FeHCL system. The XRD patterns were obtained on a Dron-2 diffractometer using a monochromatic $\text{Cu K}\alpha$ radiation. The X-ray diffraction patterns of calcined ferrizeolite have shown that the symmetry of the calcined Fe zeolite is orthorhombic. In the calcined crystals with a monoclinic symmetry, the splitting of reflections in the XRD pattern is usually observed at $2\theta = 24.4$ and 29.3° . Therefore, the persistence of the orthorhombic symmetry even in the calcined state provides supplementary evidence for the lattice positions of iron in the ferrizeolites.

The major Fe sites in structure have no bonds to framework oxygen. In FeHCL , 45 % of Fe is found in the center of the ten-membered *A* channel forming a disordered square planar Fe 2*p*-tetraammine complex with two additional H_2O molecules complex. In the eight-membered *B* channel 43 % of the total Fe forms an approximately square planar H_2O complex.

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THE OXIDATIVE DEHYDROGENATION OF LOWER ALCOHOLS ON COPPER ZEOLITES AND HTSC

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Earlier it was shown that the activity of initial synthetic and natural zeolites in ethanol and methanol oxidation is caused by present of active molecular oxygen near the alcohol, adsorbed on alkali cations, but the introduction of transition metals' ions changes the character of catalytic action.

Recently comparison of activity of copper-contained catalysts on various carriers – the synthetic zeolites X, Y, mordenite, ZSM-5, natural zeolite clinoptilolite and high-temperature superconductors (HTSC) in conversion of C_1 - C_2 of alcohols is carried out.

In particular, as a matrix the synthetic zeolites X, Y, mordenite, ZSM-5 and natural zeolite clinoptilolite (CL) were applied, while as the oxidic form HTSC $\text{Y}_1\text{Ba}_2\text{Cu}_3\text{O}_x$ and $\text{Bi}_2\text{Sr}_2\text{CaCu}_3\text{O}_x$ were used.

Zeolite catalysts were prepared by an ion exchange method from solutions of copper–ammonia complexes (pH = 10) and copper nitrate (pH = 5); HTSC-samples were synthesized by the traditional ceramic technique from the corresponding metal oxides. The catalytic experiments were carried out by the microflow method with varying of temperature, the size of catalyst grain and gas flow rate. The composition of the initial mixture and yields were analyzed chromatographically. On copper zeolites the main products of alcohols conversion are CO₂ and H₂O.

The reactions as complete and partial oxidation, so intermolecular dehydration of alcohols up to dimethyl ether and C₂H₄ accordingly occurred on Cu-clinoptilolite under 493 K. The dehydration of ethanol prevails up to 553 K, and the conversion of ethanol occur under two parallel – consecutive paths: CH₃CH₂OH → C₂H₄ → CO₂ (I) and CH₃CH₂OH → CO₂ (II). Scheme II prevails.

Main products on HTSC were aldehydes, CO₂ and CO. The catalytic activity of Bi₂Sr₂CaCu₃O_x at partial and deep oxidation was much lower than that of Y₁Ba₂Cu₃O_x, and differences in activity and mechanism of conversion can be caused by their structural differences: difference in the number of CuO – CuO₂ layers per unit cell or active centers, as well as different coordination environments of these centers, and their different accessibilities to reagent molecules.

The influence of conditions of ion exchange (pH = 5 and 10) on a state and location of copper cations is proved with our catalytic and EPR data.

So, catalytic activity of zeolites and HTSC in oxidative dehydrogenation of C₁–C₂ alcohols is determined by presence of identical active sites – the associates of copper-ions with oxygen; in zeolites they are migrate into big cavities – copper-ions with extra coordination by oxygen, and for superconductive cuprates they are the fixed O–Cu–O chains or CuO₂ planes, which are capable to change their coordination at loss of oxygen.

IN-SITU STUDIES OF POLYMER PROCESSING FOR OPTIMIZED STRUCTURE AND PROPERTIES

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The transformation from a molten polymer to a crystalline solid product is a complex process. We show how special X-ray / rheology tools can be used to follow the development of structure during flow and the subsequent crystallization process and to identify the critical steps in this transformation. We have found that time-resolving X-ray scattering studies are a valuable approach, especially when coupled with other in-situ techniques such as neutron scattering and ex-situ methods such as electron microscopy.

We illustrate the use of these tools with a study of the crystallization of polyethylene blends after being subject to shear flow in the melt. The resultant crystal textures and hence properties are strongly dependent on the shear strain imposed in the melt. High shear strain in the melt leads to a high density of row nuclei which serve to template the subsequent crystal growth. The microscopy on the final samples provides a complementary technique which offers valuable information on the spatial distribution of the morphology.

ENHANCEMENT OF THERMAL AND MECHANICAL PROPERTIES FOR REINFORCED IRAQI CLAY

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In this study, we have investigated the possibility of using Iraqi bentonite clay to improve the thermal and mechanical properties of the polyvinyl chloride (PVC). The grain sizes of clay that adopted are 25 and 45 μm , and calcination temperatures are 300, 700, and 900 $^{\circ}\text{C}$ for 2 h.

The result shows that the composite prepared by modified Iraqi bentonite powder, that is calcined at 900 $^{\circ}\text{C}$, has an advantage in heating insulator properties by 40 % from that found for PVC as it is, and the value of stress strength exceed by 3-times as that for original value.

NOVEL IN COMPACTNESS WITH RESPECT TO GEM SET

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In this paper, we study the impact space relationships with ideal topology. Specially, we use the idea of GEM set to define a new of special spun of compactness. We call that the perfected compact spun such that a non-empty subset A of a spun X is called Perfect Compact if and only if for each of n families there exist a finite elements $X_i, i = 1, \dots, X_n$, such that $X = \cup_{i=1}^n X_i$. So, space X is called Perfected Compact space if and only if for each of a non-empty subsets X is prefer of compact.

SYNTHESIS, PHYSICAL AND MECHANICAL PROPERTIES STUDY OF EPOXY PHENOL NOVOLAC COBALT ACRYLATE CARBON NANOTUBE NANOCOMPOSITE

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The study of optimal manufacturing process of composites reinforced with carbon nanotubes has become a critical stage in the early phases of discovery of outstanding physical properties of carbon

nanotubes [1 – 3]. The increasing interest has been brought by rapid advancements in nanotechnology and composites manufacturing techniques.

This paper combines a study of two processes for manufacturing of multiwall nanotubes reinforced epoxy phenol novolac (EPN) with nano cobalt acrylate and characterization of physical properties of this nano composite.

Shear mixing method and solution process are the techniques used to manufacture plates and thin films of composites containing different weight fractions of unpurified and purified multiwall nanotubes. The first method consists in processing the pure mixture of EPN and nanotubes in a reactor, and the second method uses ultrasound to improve dispersion of nanotubes in the matrix, through solvent medium.

Solution process shows a better dispersion of the reinforcement in the matrix, but physical properties do not show significant improvements. Mechanical properties, such as tensile strength, Young's modulus, fracture toughness, and hardness do not show relevant improvements. The reason for this behavior is the poor adhesion at the interface carbon nanotube– matrix caused by tendency of multi-walled nanotubes to agglomerate in bundles, which create discontinuities in the final composite [1].

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THERMOSTABLE COMPOSITE NANOMATERIALS BASED ON SOLID PHOSPHATE BINDERS

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Due to outstanding thermal and electric conductivity, chemical stability and unique mechanical properties carbon nanotubes (CNT) are promising candidate for designing CNT-based multifunctional thermostable composite materials. Previously it was found that embedding of 2 wt. % of multiwall carbon

nanotubes (MCNT) into thermostable phosphate matrix leads to raise the conductivity up to 13 orders of magnitude in comparison with initial phosphates [1]. The composition of conductive thermostable phosphate materials was patented [2]. In investigations liquid aluminum phosphate binder was applied.

Procedure of producing of the materials based on liquid phosphate binder contains several difficulties [3]. Usually these binders are unstable while keeping, after some time crystallization of liquid phosphate occurs. Crystallization process is usually accompanied with precipitation, and the atomic ratio of phosphate to metal (P / Me) in liquid phase is changed. Therefore the ratio of binder to filler should be also changed for correct composites preparation.

In order to improve the preparation method of composite material based on phosphate binders the possibility of using of solid magnesium phosphate $Mg(H_2PO_4)_2 \cdot 4H_2O$ as a binder was studied. Application of solid phosphate binders allows using more advanced preparation technology for dry building mixtures.

In present communication we report on studying of thermal stability and conductivity of initial phosphate materials and phosphate / MWCNT composites. Thermal behavior of phosphate matrix demonstrates its good performance for designing of thermostable composite materials. Oxidation process of MWCNT in phosphate matrix starts at temperatures 200 – 250 °C higher than that in pure multiwall carbon nanotubes. Conductivity of the composites based on magnesium phosphate binder is in 1.5 – 2 orders higher than conductivity of the composites with aluminum phosphate binder. Using of solid phosphate binder makes possible producing composites with higher MWCNT amount. Thus, improved procedure for composite materials producing allows more effective designing of multifunctional nanocomposites.

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InAsSbP-BASED QUANTUM DOTS PHOTODETECTORS FOR SEVERAL MID-INFRARED APPLICATIONS

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Semiconductor quantum dots (QDs) confine electrons and holes in all three dimensions, which lead to a δ -like electronic density of states where the energy levels are totally quantized. This property is

making them attractive for optoelectronic devices not only for improved laser diodes, but also for single photon sources, quantum computing systems and new generation QD-photodetectors [1, 2]. This also leads to an increase in infrared photodetectors response and operating temperature, as well as photovoltaic (PV) solar cells and thermo-PV (TPV) cells efficiency [2 – 4]. Photoconductive cells (PCC) can provide a very economic and technically superior solution for many applications where the presence or absence of light is just detected or where the intensity of light should be measured [5]. The state-of-the-art performance of these devices makes it possible to sense several types of gaseous plumes and emissions enabling chemical warfare agent detection / discrimination. Among quantum size objects' fabrication techniques, the self-organized Stranski–Krastanow method is an important one by which dislocation-free nanostructures can be produced. Depending on the growth conditions, the elastic strain can be relaxed by the formation of QDs, quantum rings or even unique island-pit pairs. InAsSbP solid solution is a promising material because it can cover the 3 – 5 μm mid-infrared regions adjusting its alloy composition with three V elements only [6 – 8].

Here the fabrication and investigation of low bias and room temperature InAsSbP QD PCCs made of n-InAs(100) crystals for several mid-infrared applications are reported. The modified liquid phase epitaxy is applied for QDs nucleation. Statistical evaluation of AFM measurements shows that the areal density of QDs ranges from 6 to $8 \cdot 10^9 \text{ cm}^{-2}$, with heights from 0.5 to 25 nm and widths dimensions from 10 to 40 nm.

On the photoresponse (PR) spectra of PCC with QDs are revealed not only enlargement toward the long wavelengths up to $\lambda = 3.7 \mu\text{m}$, but also additional peaks at $\lambda = 2.65, 2.85, 3.56$ and $3.65 \mu\text{m}$, which were not been detected on PR spectrum of InAs-based PCC without QDs. The main peak for the band-to-band transitions in InAs bulk crystals corresponds to $\lambda = 3.48 \mu\text{m}$ at room temperature. Additional peaks revealed also on $T = 78 \text{ K}$ photoluminescence spectra of prepared QD-based photodetectors. We assume that the QDs are responsible for those additional peaks due to occurred band-to-QDs subband transitions.

Our investigations shown that even at very low applied voltages ($\pm 2 \text{ mV}$) a sufficient increasing of the PR signal on additional peaks is occurred. In particularly, at $U = \pm 1.5 \text{ mV}$ the value of PR signal at $\lambda = 3.65 \mu\text{m}$ becomes practically equal to the signal's value of the main maximum at $\lambda = 3.48 \mu\text{m}$. These properties make them very attractive, in particularly for the fabrication of multicolor mid-infrared photodetectors. Other very important features of those devices are that they can work at room temperature and that as power source can be used consumer accumulators or even batteries. Because the most important industrial gases have a strong absorption in mid-infrared region, in particularly, methane at $\lambda = 3.3 \mu\text{m}$, CO_2 at $2.65 \mu\text{m}$, as well as water vapor at $2.85 \mu\text{m}$, therefore, proposed and fabricated QD PCCs can be used also in optical gas sensors and systems. Other important application is determination of the glucose concentration in human blood, etc.

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ON POSSIBLE NATURE OF METALLIC CONDUCTANCE OF BORON-NITROGEN COMPOUNDS

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It is well proved (e.g., see our calculations [1 – 4]) that, all the boron nitrides BN – diatomic molecule, crystalline modifications, nanotubular and fullerene-like structures – possess wide band or HOMO – LUMO gaps, what limits their applications. Recently, hypothetical tetragonal phase has been found [5] to be metallic, but metastable as compared to the known BN crystals. Usually, the metallicity of boron nitrides with the stoichiometric ratios of B : N \approx 1 : 1 are related to structural defects and / or impurities (e.g., see [6]). There are number of evidences that boron nitride structures prefer the stoichiometry with B-excess. In particular, the phase equilibrium studies in the B / BN system by both *in situ* experiments and thermodynamic calculations have revealed the existence of solid boron subnitrides BN_x, $x < 1$ [7]. All these phases can be imagined as mixtures of boron crystalline modifications doped with N. Because icosahedron B₁₂ is known to be their main structural motif, the presumable local geometries of environments of N atoms in boron-rich B / N systems can be constructed on the basis of crystal structure data on B₁₂-networks [8]. We reported [9] a mass-spectrometric study of boron clusters containing B₁₂, which produced by laser vaporization from boron-rich targets and demonstrated [10] that, created boron clusters can be self-assembled into nanostructures. These studies together with results available in literature on behavior of N in boron crystals [11] lead to the conclusion that, N atoms have to occupy the nano-sized crystallographic voids characteristic for boron-rich structures.

It was demonstrated both experimentally [12] and by us theoretically [13] that, in semiconducting boron crystals heavily doped with donor-impurities the covalent–metallic conversion can occur. Similarly, BN_x compounds are expected to be metallic. Boron is less electronegative than nitrogen. However, in boron nitrides with boron excess, B atoms enable to form icosahedra and other clusters enhancing the electronegativity of the B-component. Thus, N atoms should act as electron-donors.

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ELECTRICAL AND OPTICAL PROPERTIES OF TITANIUM DIOXIDE DIELECTRIC FILMS FORMED BY MAGNETRON SPUTTERING

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Progress in microelectronics and nanoelectronics has stimulated the design of fundamentally new methods for producing oxide films, as well as the further development of conventional methods. High-temperature treatment leads to the spread of diffusion regions, the diffusion of unwanted impurities, the generation of defects (dislocations, voids, cracks), the violation of the ratio between the components in binary semiconductor compounds, and so on. All these factors have a detrimental effect on the parameters of integrated circuits and the yield of devices. Taking into account the factors above, we have reason to believe that low-temperature methods are very promising. A large number of methods may be used to form thin TiO₂ layers; these include evaporation [1] or sputtering [2, 3] of TiO₂, metalorganic chemical vapor deposition (MOCVD) [4], chemical vapor deposition (CVD) [5, 6], rapid thermal oxidation (RTO) [7] and so on. All of them have in some cases advantages and in some cases disadvantages. In this report we suggest reactive magnetron sputtering method for receiving thin dielectric TiO₂ layers with high dielectric constant.

Titanium oxide thin films were deposited onto silicon substrates by using DC magnetron sputtering system. Pure titanium (99.999 %) of 100 mm diameter and 6 mm thickness has been used as sputtering target. High purity argon and oxygen were used as the sputtering and reactive gases respectively. Rotary and turbo pump combination was used to get the desired vacuum. The base pressure of the system is less than 10⁻⁵ mbar. After attaining the base pressure the oxygen partial pressure was set using a needle valve. Before each run the target was pre sputtered in Ar atmosphere for 5 – 10 min in order to remove the surface oxide layer of the target. All the depositions were carried out at a total pressure of 1.3 · 10⁻³ mbar. The distance between the target and substrates was kept at 45 mm. The thickness of the film is determined from step height measurements by a-step stylus profilometer. The crystallinity was examined by using materials research diffractometer (MRD) and X-ray diffractometer. Optical properties of the TiO₂ film was studied by spectroscopic ellipsometry (V-VASE) and infrared spectrometry. The SE equipment was of the polarizer-sample-rotating-analyzer type. Electrical properties were studied by semiconductor parameter analyzer and semiconductor probe station (SPA).

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DNA AND NANOTECHNOLOGY

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The aim of the present work is spectroscopic and thermodynamic study of DNA catalytic properties in the following processes: a) redox; b) formation of inter-strand cross-links; c) performing of photodynamic effects; d) nanoscale resonance radiationless electron excitation energy transfer. The most attention is paid to the latter, as truly nanoscale method in its origin.

The nanoscale method of laser induced fluorescence resonance energy transfer (FRET) to donor (acridine orange) – acceptor (ethidium bromide) intercalator pair for quantitative and qualitative study of stability quality DNA double helix in solution in real time is offered. FRET method allows to estimate the concentration of double helix areas with high quality stability applicable for intercalation in DNA after it was subjected to stress effect. It gives the opportunity to compare various types of DNAs with 1) different origin; 2) various damage degrees; 3) being in various functional states.

Alternative model and mechanisms of photodynamic effect on DNA in solutions are proposed. They are based on photoenergy degradation in solutions. The energy activates electrolytic dissociation of water molecules on H_3O^+ and OH^- and acts as a catalyst for hydrolysis reactions of phosphodiester and glycoside linkages.

METAL IONS SORPTION BY DNA DOUBLE HELIX AS A MULTISTEP NANOMOLECULAR ADSORPTION PROCESS

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Soft ions, in particular Cu^+ , Ag^+ , Pt^{2+} , and Hg^{2+} ions, are able to form the so-called inter-strand crosslinks in DNA. Let's consider the process in case of Ag^+ . First, silver ions are adsorbed on DNA major groove (N_7G or chelate complex N_7G and O_6G). At small silver ion concentration on DNA does not cause

ejection of AO and EB. On the other hand, silver ions at interaction with DNA induce double proton transfer in GC pair [1]. Chelate complex with silver ions makes it easy to unfold DNA double helix with wrong Watson–Crick GC pair. The work presents electron configuration of GC atom pairs taking part in H-bonds before and after DPT. In the last process Guanine's atom O₆ is in enol form, nitrogen atom N₁G is in pyridine state and N₃C in pyrrole state. After unfolding of double helix in neutral water solution N₃C atom cannot keep enol state in a long time and it should transfer into its usual pyridine state. At the same time silver ions can with definite possibility attack nitrogen atoms N₁G still existing in pyridine state. During the following folding of double helix inter-cross link formation between N₁G* and N₃C takes place. In this way the process of inter-cross link formation can be considered as such simple processes as: 1. Silver ion adsorption on DNA (N₇G) and double proton transfer of GC pair with the life-time τ_1 , 2. Unfolding of double helix, formation of N₁G* – Ag⁺ binding, HN₃C transfer to N₃C and formation of link between N₁G* – Ag⁺ – N₃C. Total time of the process is τ_2 , 3. DNA folding with formation of stereoscopically distorted double helix with inter-cross links (τ_3). So, in the case of DNA compound absorption process of inter-cross link formation can be reduced to a multi-stage adsorption process consisting of several simple adsorption processes named above with the total time of $\tau_1 + \tau_2 + \tau_3$.

* Rare tautomeric form of bases.

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NANOSCALE NONRADIATE ENERGY TRANSFER BETWEEN INTERCALATOR MOLECULES IN DNA DUPLEX

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The goal of the present research is development and application of laser induced fluorescence excitation energy transfer method to donor–acceptor intercalator pair for quantitative and qualitative study of stability quality DNA double helix in solution, in real time. The approach is based on the example of acridine orange molecule (donor) and ethidium bromide (acceptor) intercalated in DNA.

Fluorescence resonance energy transfer (FRET) radii were experimentally estimated in background electrolyte solution (0.01 M NaNO₃) and proved to be 3.9 ± 0.3 nm and the data are in satisfactory agreement with the theoretically calculated value $R_0 = 3.5 \pm 0.3$ nm.

Concentration of DNA sites, exposed to Cu(II), Cu(I), Ag(I) ions, AgNPs and temperature, which are applicable for intercalation, were estimated in relative units.

FRET method allows estimating the concentration of double helix areas with high quality stability applicable for intercalation in DNA after it was subjected to stress effect. It gives the opportunity to compare DNAs of 1) different origin; 2) with various damage degrees; 3) being in various functional states.

MICROWAVE IN ENVIRONMENTAL TECHNOLOGIES AND SYNTHESIS OF NANO MATERIALS: PROCESSING OF ORGANIC AND INORGANIC COMPOUNDS

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The signing and ratification of the Association Agreement between the European Union and Georgia marked the beginning of a new stage in the history of Georgia. It signaled the political and historical return of Georgia to the Community of European Countries, known as the European Union (EU). This seminal event will come to no avail if Georgia does not overcome the huge gap in economic and social development between Georgia and EU countries. Georgia must take her place in the EU at the same level of science and education standards, environmental protection, and standard of living as the rest of the EU countries [1, 2].

The global problem of rapidly increasing quantity of industrial and domestic waste is particularly acute in Georgia where a disproportionately large amount of toxic waste is concentrated in a relatively small area [3]. Recent discoveries by Georgian scientists and scientific institutions in the field of microwave enhanced processing of hazardous mining and metallurgical [4, 5], polymeric [4], agricultural, municipal, medical, radioactive waste and microwave assisted synthesis of nano-particles and nano-materials [6], brought to the possibility of semi-industrial and industrial processing.

The lab-scale implementation of the developed and optimized equipment for producing highly demanded marketable products, like liquid and gaseous fuel, manganese oxide concentrate, manganese alloys and multi-composite compounds, metallic, semiconducting and polymeric nano-materials is reported. The advances of microwave enhances processing can form a scientific and technological basis for Georgia to move toward increased economic and social development, environmental safety and security establish a "Green Economics" and a Knowledge Based Society and achieve sustainable development. Innovative approaches and experimental microwave installation uses for waste processing and nano-particle synthesis place Georgia in the forefront of using microwave technology.

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NANOCOMPOSITES BASED ON BIOPOLYMER CHITOSAN AND AMINO-CONTAINING SILICAS FOR REMOVAL AND CONCENTRATION OF HEAVY METAL IONS

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Properties of inorganic sorbents could be upgraded by valuable characteristics of organic polymer. In particular, chitosan has good biocompatibility, high adhesion to the surface, a wide range of pH stability, expressed chelating properties. Silica is characterized by advanced surface stability in acidic medium, acceptable kinetics, thermal stability, and resistance to microbial attack. All these facts confirm that nanocomposites mineral-chitosan can be used as effective adsorbents, enterosorbents, etc.

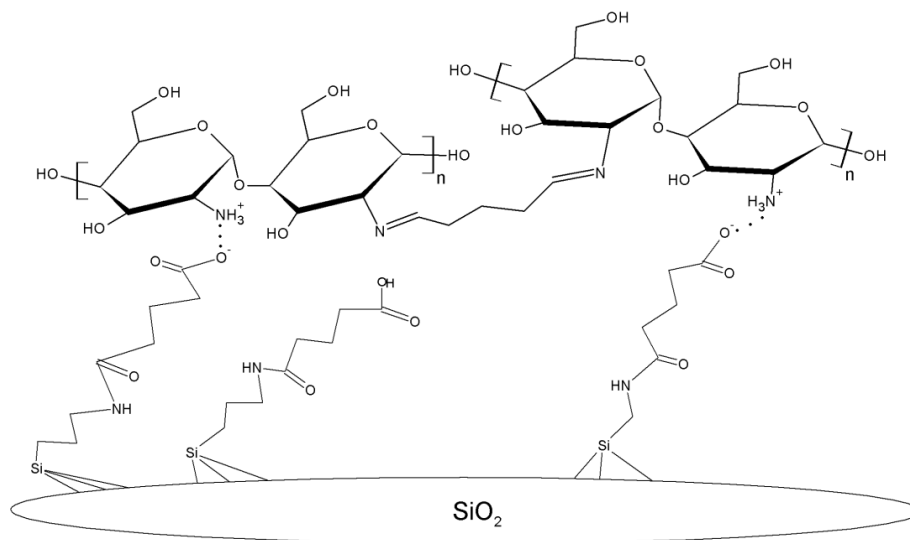


Fig. 1. The structure of synthesized nanocomposite based on chitosan and aminosilica.

Nanocomposites aminosilica-chitosan (Fig. 1) has been obtained by treatment of mineral carrier with glutaric anhydride followed by adsorption modification with chitosan solution and partial crosslinking of amino groups of the polymer layer with glutaraldehyde. Anchorage of chitosan on the minerals surface was confirmed by IR spectroscopy. Concentration of immobilized chitosan was estimated using thermogravimetric analysis.

The synthesized nanocomposite based on chitosan and mesoporous aminosilica was found to show better adsorption activity with respect to milligram amounts of toxic metal ions than synthesized nanocomposite based on chitosan and macroporous aminosilica. In particular, at the pH 2.5 the nanocomposite mesoporous aminosilica–chitosan removes Mo(VI) and Cr(VI) oxoanions from a solution composed of acetate ions with maximum adsorption capacity (A_{\max}) 0.80 and 0.15 mmol / g, whereas the macroporous aminosilica–chitosan composite extracts 0.25 and 0.03 mmol / g, respectively. At pH 7.0 the nanocomposite based on chitosan and mesoporous aminosilica extracts Fe(III) ions with the A_{\max} of 0.17 mmol / g, and at the same conditions the nanocomposite mesoporous aminosilica–chitosan removes 0.14 mmol / g. The synthesized nanocomposite based on chitosan and mesoporous aminosilica extracts Cu(II) and Zn(II) ions with maximum adsorption capacity 0.14 and 0.13 mmol / g, respectively (pH 8.0, ammonium-acetate buffer). The synthesized nanocomposite based on chitosan and macroporous aminosilica was found to show lower adsorption capacity with respect to these ions: 0.09 mmol / g for Cu(II) and 0.05 mmol / g for Zn(II). It was shown that the maximum adsorption capacity of silica with immobilized chitosan with respect to all studied ions is achieved within a day.

SOME TYPES OF NANOSENSORS DETECTING THE PATHOGENS

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It is a part of project studying the problems concerning nanosensors application for detecting the pathogenic microorganisms / viruses. Rapid, selective, and sensitive detection of viruses is central to implementing an effective response to viral infection through medication or quarantine. Well known fact is, that the smallest forms of life, bacteria, cells, and the active biological components of living cells, have sizes in the nanometer range. Nanosensors physical, biological, chemical, or surgical sensory points are used to convey information about nanoparticles to the macroscopic world. Nanosensors can be broadly classified into two groups, namely, those that have nanoscale dimensions and those that perform nanoscale measurements but do not necessarily have nanoscale dimensions. Types of nanosensors used in nanomedicine applications are: carbon nanotube-based nanosensors, nanoscaled thin film sensors, microcantilever and nanocantilever-enabled nanosensors, nanoshells, nanofibers, nanobelts, nanoprobles, and quantum dots. There are applied nanowire pH sensors of proteins and DNA, field-effect and cantilever sensors measuring surface stresses, magnetic nanosensors detecting DNA, optical nanosensors, etc.

The target of interest of our work is biosensors. Biological recognition elements or bioreceptors of a biosensor mostly are of biological origin such as enzyme, an antigen, an antibody, a tissue, a cell, DNA (deoxyribonucleic acid). The artificially produced elements (such as polymers) may be accepted and included as components of biosensors. Nanosensors deliver real-time information about the antibodies to antigens, cell receptors to their glands, and DNA and RNA to nucleic acid with a complimentary sequence. Dr. V. K. Khanna's manual book states, that the recognition element is the component used to fasten the target molecule, and must therefore be highly specific, stable under storage conditions, and immobilized. The physicochemical transducer acts as interface, measuring the physical change that occurs with the

reaction at the bioreceptor, and then transforming that energy into quantifiable electrical output. Finally, signals from the transducer are fed to a microprocessor where they are amplified and analyzed; the digitally dissected data is converted to concentration units and transferred to a display or / and data storage device.

Accuracy of measurements strongly depends on properties of well-preselected nanomaterials. One of the simplest medical nanomaterials is a surface perforated with holes, or nanopores. These pores must be large enough to allow small molecules such as oxygen, glucose, and insulin to pass but must be small enough to impede the passage of much larger immune system molecules such as immunoglobulins and graft-borne virus particles. The flow of materials through nanopores can also be externally regulated. Nanosensors sensitivity can be increased due to better conduction properties, the limits of detection can be lower, very small quantities of samples can be analyzed, direct detection is possible without using labels, and some reagents can be eliminated. Lieber's group has reported direct, real-time electrical detection of single virus particles with high selectivity using nanowire field-effect transistors to measure discrete conductance changes characteristic of binding and unbinding on nanowire arrays modified with viral antibodies. Using nanowire arrays, it was found that the detectors could differentiate among the 3 viruses and as commented "the possibility of large-scale integration of these nanowire devices suggests potential for simultaneous detection of a large number of distinct viral threats at the single virus level".

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ADIABATIC DESCRIPTION OF THE ELECTRONIC AND LINEAR-OPTICAL PROPERTIES OF CONICAL QUANTUM DOT

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Within the framework of the stationary adiabatic approximation, it is examined the problem of electronic states in a conical quantum dot, with small angle of a solution and defined the criteria applicability of the adiabatic approximations. For the regime of strong size quantization analytical expressions for the particle energy spectrum, wave functions, absorption coefficient and dependencies of effective threshold frequencies of absorption on the geometrical sizes of quantum dot are obtained. The selection rules corresponding to different transitions between quantum levels are found.

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FABRICATION AND PROPERTIES OF THE CARBON FIBER ELASTIC BI-STABLE HINGE WITH DOUBLE-WELL POTENTIAL

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The carbon composite materials are widely used as construction materials in the different industries such as aerospace, military or in the civil engineering. Sheets of the epoxy resin composite matrix, reinforced with the carbon fibers generally have excellent tensile properties, low densities, high thermal and chemical stabilities in the absence of oxidizing agents, good thermal and electrical conductivities, and is a recyclable ecologically friendly material. Carbon fiber consists of at least 92 wt. % carbon, and is elaborated from polyacrylonitrile as a precursor. The ribbon shaped monatomic layer in the carbon fiber has an average width of 6 nm and length in the order of several hundred nm. A carbon fiber strand with diameter being around 5 μm may be used for forming flexible composite sheets with the high strength to weight ratio, in comparison with the traditional steel springs. These strands are twisted together like yarn (called a tow) and woven into carbon fiber fabric which typically comes in 1k, 3k, 6k and 12k weights. A 1k fabric has 1 000 strands of carbon in each tow while a heavier weight 12k fabric has 12 000 strands per tow.

For experimental purposes carbon fiber / epoxy composite cylindrical plates with discretely changed curvature of a surface were fabricated in the Department of Engineering Physics at the Georgian Technical University. We used carbon fibers 1k plain ultralight weave, with 90 g / m² plane density, provided by the FiberGlast Developments Corporation, UK. For the plates' forming we used epoxy resin System # 2000, provided from the same supplier. Curved carbon composite sheets were formed on the surface of a mold with the cylindrical surface, made from brass tubes of different diameter. The molds surface preliminary has been prepared by cleaning and covering with a very fine layer of a mineral oil. Then the molds covered by the epoxy resin / fiber combination. After this the mold is covering with vacuum bagging thin elastic films with the next layer of a strong film (lavsan) with a mounted vacuum hose. External films were carefully taped to the mold's flange. Vacuum bagged is used to remove air bubbles and voids and cure the final composite under high temperature and pressure (we used curing oven allowing to maintain up to 120 °C).

At the alternate assembling in a package the curved composite plates with the longitudinal and cross steady states, is formed the bi-stable hinge, characterized with double-well potential. Such packages can find application in a space based unfolding designs. Experimentally were prove possibility of application of such kinematic pair, in which there is no rubbing surfaces, during the kinematic pairs' parts relative movement, and accordingly, the friction among the rings of the kinematic pair absents at all.

MODERN THEORIES OF HOMEOPATHIC NANOPHARMACOLOGY

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The most efficient medications used in medicine affect the tissue receptors. Supposedly, there are special receptors in an organism, so called homeoreceptors, supporting the action of the homeopathic preparations. I. S. Chekman, the Corresponding Member of the Academy of Sciences of Ukraine, states that their interaction causes the whole cascade of not only biochemical and physical-chemical, but also quantum-mechanical reactions resulting in the therapeutic effect [1, 2].

At present, the view of the homeopathy stimulating the immunobiological forces of a body is widely recognized. P. V. Simonov detected that, subminimal doses of substances cause retention evidenced by the clearly seen protective properties. The author called this action preventive. As for the high dilutions theoretically not containing even one molecule of the active substance, the view of it among the homeopaths varies widely. On the other hand, the studies of some scientists evidence that the highly diluted solutions can lead to the biological effects.

Hahnemann was the first to pay particular attention to the regular dilutions and put forward the idea of drug potentiation. It should be noted that it is the homeopathic preparation prepared by using dynamization being a carrier of certain specific information. Some authors give a hypothesis of water becoming coherent as a result of interaction between the water dipole and irradiation of a diluted molecule and acquiring the property to transfer the specific information to the cell receptor, like the laser does. The surface of the cell membrane is the mediator between the electromagnetic waves and biological activity of a cell. The receptor molecules are forced to move between the bilipid layers and resonate with specific frequencies to cause a signal transfer.

Presumably, high dilutions of substances change the electromagnetic forces thus causing the resonance of the signal proteins of a cell surface, which transfer the biological activity through the cell receptors and ionic channels and initiate the signal transferring processes. In recent years, they tried to explain the effects of homeopathic drugs by using a famous Arndt–Schultz law. However, this law is not universal. If considering the literary data, the issue as to whether the given law is effective with high dilutions is unclear as such dilutions contain no molecules of the initial substance. Despite this, certain regularities between the effects of the maximally high and minimally small doses can be identified.

There is a theory linking the mechanism of action of homeopathic drugs to the effect of contamination. Free radicals are formed in a contaminated solution resulting in the pharmacological effect. In 1971, G. Baeyer designed the first cybernetic model with the high dilution being the information carrier. Many researchers have offered the mechanisms to explain the memory of the alcohol and water mixtures. These mechanisms are described in the works of an American researcher D. Vahina, Director of the Department of Non-Traditional Medicine at the National Health Institute. The information transferring action of the material particles of a substance is provided by changing the properties of the solvent. One of

the models suggests that during the dynamization, the water molecules form the structures like a grape bunch corresponding to the configuration of the molecules of the substance [1].

Didier Grandgeorge was one of the first to try to explain the mechanisms of action of a homeopathic drug by means of neurophysiology. In his opinion, the central nervous system functions with the scales of homeopathy. A nerve impulse causes the changes in the state of a cell membrane and liberation of the homeopathic doses of neurotransmitters (mediators) in the synaptic gap.

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HOMEOPATHIC NANOPHARMACOLOGY ACCORDING TO THE INFORMATION-ENERGY HOLOGRAPHIC THEORY

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The use of super-low doses of medications in homeopathy not gained by means of potentiation will yield no result. Therefore, the specific technology to prepare homeopathic drugs must be strictly observed. Otherwise, the super-low doses of the medications gained through one-moment dilution will not have any biological activity. Based on the results of the studies carried out at a Ukrainian laboratory, I. S. Chekman found that potentiation (agitation) changes the physical-chemical and quantum-mechanical properties of a substance [1]. In 1989, K. Simeonov proposed a new theory of homeopathy. We can assume that there originates an information field of a certain strength in the environment [2], which gets stronger with every next dilution. As the therapeutic substance degrades, the energy and information used by the nature to create the substance from the beginning may be liberated.

If considering the force and information components of the active source of the homeopathic drug, it may be defined as an information-energy field able to move from one carrier to another without losing therapeutic properties and having biological activity even in the absence of the therapeutic substance. As the volume is no more significant for the ready homeopathic drug and any part of the drug has the same therapeutic properties, we can assume that the new form of the therapeutic substance behaves in the same way as a *hologram* [3]. The method of holography was offered by Denis Gabor in 1947. The idea of a hologram is to fix the image with the ability to reproduce it in the future, like a recorded voice with the difference that in the latter case, the subject of reproduction is voice. Photography means taking a picture, which will be subject to the action of the lenses of the objective, while holography is the technology to create a certain system, a hologram, which is not a picture and allows reproducing the fixed image [4].

By considering the idea of the homeopathic drugs having a relatively more active source, there is a view suggesting that there is a “contact” point for them in a human body. It seems that such a “contact”

point is a similar information-energy field and can be defined as a human's *biohologram*. In this case, there is a resonance between the drug and the human body, the physiological systems producing the mechanisms of adaptation with a wide spectrum of further therapeutic effect activate and take place as a chain reaction. From the beginning, the nervous, endocrine and immune systems get engaged in these reactions. Thus, the positive effect of homeopathy is the result of the *adaptive* action of the body. If no resonance develops in case of incorrect selection of the drug (code), no action will occur. By using this fact, N. K. Semionova developed the information-energy holographic theory of homeopathy, which is based on the idea of the homeopathic drug and human body, as hologram and resonance between them. The information-energy holographic theory of homeopathy proposed by N. K. Semionova substantially changes the trends of the further scientific studies. In particular, instead of trying to find the remains of the therapeutic substance in a homeopathic drug, it is necessary to identify the information-energy field of the drug.

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THEORETICAL PREMISES AND PREDICTIONS FOR NANO-SENSOR APPLICATIONS

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In recent years the tendencies to minimizing of sensor /detecting devices are clearly revealed. These tendencies result in appearing of micro- and even nano-sensors and their different applications. Nano-sensors are used in different branches of humans' everyday activities: measuring techniques, medicine, machine building, aircrafts, etc.

In present paper, the theoretical premises of creation of nano-sensors are reviewed and the predictions of their further development and investigations to be carried out are made. Sensors detect information transforming mechanical displacement into electric signals. And there are used different materials: piezoelectric and others, possessing high electric and magnetic properties. However, most of them greatly lose their properties at minimizing to nano-scale and nowadays mostly only capacitive and piezo-resistance sensors are in practical use. Besides, it appears methods of direct transformation of displacements into electric signals by means of photo-detectors inserted into integrated optical-electric-mechanical systems. The definite information arises as well, concerning tunnel sensor elements, using the effect of tunneling of electrons.

In capacitive sensors, the voltage applied to its plates transforms the mechanical displacement into varying capacitance and, thus, the charge, that causes appearance of the current $i = dq/dt$, and its change

Δi together with the change in the distance between electrodes Δd at the displacing voltage $v = V_m \sin \omega t$ will be given as $\Delta i(\Delta d) = \omega V_m C(\Delta d)$.

Piezo-resistance sensors work due to the change in the volumetric electric conductivity arising at the mechanical stress. These sensors should be much less than the elastic element, thus consider them as the thin layer of piezoelectric material coating the area of mechanical stress. Semiconducting materials are usually the basic material for them. But note that they meet some difficulties when approaching the nano-scale range due to highly clarified temperature dependence.

Application of fiber-optical sensor systems with laser light sources is considered now as the most perspective way of reception of “smart” materials and devices, providing the integration of reception, storing and transfer of any information concerning the conditions of the selected object. Simplest methods are based on the control of any change in the intensity of a light passing through the fiber-optic inserted into the investigated material due to its deformation or rupture.

Nowadays one may observe as well the fast development of detecting methods based upon the effects of interference and spectroscopy for white (visible), close ultra-violet and far infra-red light within the fiber-optics inserted into the investigated material / substance.

Obviously, it is rather incomplete list of latest achievements in the given branch of techniques.

SYNTHESES OF BULK NANOSTRUCTURED MATERIALS IN DYNAMIC CONDITIONS

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This paper consists of an experimental investigation and manufacture of multifunctional bulk nanostructured composite materials based on titanium, nickel, aluminum and boron. The crystalline Ti, Ni, Al, B, elementary pure (at list 99 %) powders were used as precursors. The blends with different percentage content of powders were prepared. The high energetic “Fritsch” Planetary premium line ball mill is used for blend processing, mechanical alloying, amorphization and nanopowder production. The time of the processing were varied in range: 1, 2, 5, 15, 30, and 36 h. Phase composition and particle sizes of the blend components were controlled by X-ray diffraction system. The optimal technological regimes for nanopowder preparation are determined experimentally. Ball milled nano blend compacted by explosive consolidation technology and nanostructured bulk composite materials are fabricated. For shock wave generation the industrial explosives and new explosives obtained from decommissioned weapons are used in the experiments. The technological parameters of the explosive consolidation and the structure-properties relationship are also presented and discussed in the paper.

SEWING PHOTOCHEMICAL UV IRRADIATION OF UNSATURATED POLYMER(ESTER AMIDE)S

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The α -amino acid (AAB) based poly(ester amide)s (PEAs) are relatively new class of biodegradable biomaterials [1, 2]. Besides the diversity in material properties, they have shown good biocompatibility [3, 4] that makes PEAs highly attractive for biomedical applications. One of the most convenient and universal ways to render biodegradable polymer functional is the incorporation of unsaturated double bonds in the polymeric backbones [5].

The unsaturated PEAs obtained in this study were also undergone thermal (100 °C, 1.0 % of benzoyl peroxide) and photochemical (UV-irradiation, 5 % of Darocur-1173 photoinitiator) curing (confirmed by loss of the solubility of the polymers in organic solvents, including TFA) that can allow to further regulate their biodegradation rates and mechanical characteristics of the polymers.

We defined polymer samples (0.10 – 0.13 mm film) mechanical properties. Films were drying in a vacuum at 50 – 70 °C. The film thickness was 0.3 – 0.5 mm. Mechanical properties of the films studied using “Multitest 1” and preparing the so-called “doggy bone” shaped samples (Fig. 1).

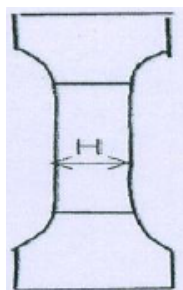


Fig. 1. Sample used to study the mechanical properties of polymer films form (“doggy bone”).

We measured Young’s modulus E (GPa-a), the maximum force F_{\max} (MPa-in), rupture strength σ (MPa), rupture elongation ε (%) before irradiation and after 5 min of irradiation.

Based on preliminary data, we can assume that the polymers are subjected to photo-chemical transformation and could be considered as promising candidates for constructing photo-curable surgical devices, e.g., resorbable vascular stents, etc.

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HOW TO ESTIMATE CHARGE TRANSFER BETWEEN CONSTITUENT ATOMS IN SOLIDS: BN CASE STUDY

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Usually, association of atoms in a solid structure causes redistribution of the electronic charge. Effective static charges of constituent atoms are the important characteristics affecting electronic structure and through it – all the physical properties of the material.

However, dependences of the measurable parameters on the effective charges are so complex that, they are virtually undetectable experimentally. As for the theoretical values, they are characterized by a significant scatter making them almost unreliable. The reason for this lies in the impossibility of unambiguous division of the electron density between constituent atoms.

Such a situation pushes the search for a semi-empirical solution. In this work, we derived the relation allowing calculation of effective atomic charges in a binary compound based on empirical structural, dielectric and elastic parameters of the material.

The values of effective charges obtained for boron nitrides are physically reasonable. They can be used in the refinement of available theoretical results on electronic structure and ground-state parameters of materials. Similar estimates of charge transfer can be carried out for other binary compounds as well.

COMPLEX FORMATION STUDY BETWEEN BACTERIOPHAGES AND SYNTHETIC CATIONIC POLYMER

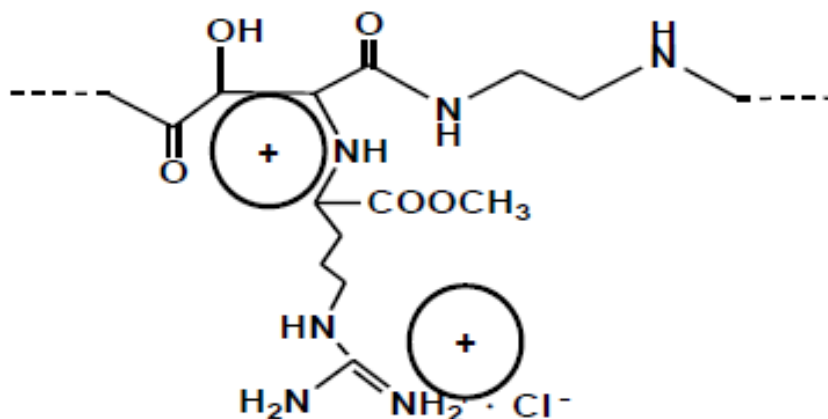
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The emergence of pathogenic bacteria resistant to most currently available antimicrobial agents initiated the search of new, alternative antimicrobial agents. Among various approaches developed the attention has been paid to bacteriophages and cationic polymers. Generally, bacteriophages are viruses that invade bacterial genetic system and cause their lysis (kill bacteria). Cationic polymers interact with bacteria *via* multifunctional mechanism that involves destabilizing the bacterial membrane and binding onto the bacteria's DNA, which in both cases results in the death of the bacteria [1]. The goal of the present study is

to combine these two antibacterial agents having different nature and mechanisms bactericidal activity. At the first stage of the research we studied the interaction (complex) of bacteriophages as negatively charged nanoparticles (size 140 – 300 nm, zeta-potential $-(11 - 31)$ mV) [2] with a synthetic cationic polymer. To monitor this process we used dynamic light scattering (DLS) method (Nano-Zetasizer ZEN-3600, Malvern Instruments, UK).

Serial staphylophages “Phagestaphi” of Biochimpharm, LLC (Tbilisi, Georgia) having an average size 178 nm and zeta-potential -15 mV were selected for complex study. As a cationic polymer we used the new arginine containing polymer depicted in Scheme below. The polymer ($M_w \approx 20$ KDa), containing two positively charged sites per elemental unit was originally developed in our lab [3].



Typically, to 2 mL of serial phage solution 2 mL of distilled water or saline solution containing different amounts (from 0.02 to 5 mg per mL) of the cationic polymer was added, mixed, incubated at room temperature for 10 – 15 min and placed in nanosized cuvette for the measurement. An intensive complex formation between the phages and the cationic polymer was observed. After adding water solutions of the polymer nanoparticles size (initial 178 nm) changed (increased) rather drastically – from *ca.* 300 up to 800 nm when varying the polymer’s quantity from 0.02 to 0.2 mg per mL; in parallel, the particles zeta-potential (initial -15 mV) changed (decreased) from -5.5 to -0.4 mV that might be the main reason of the phage aggregation.

By further increasing cationic polymer’s content in the solution (up to 2 and 5 mg per mL) the particles size reduced to *ca.* 300 nm; in parallel, the particles zeta-potential increased up to 13.4 and 22.5 mV that presumably resulted in the dissociation of the phages clusters and size reduction. A similar process was observed when saline solutions of the polymer were used.

Based on the obtained results, we can conclude that bacteriophages and synthetic cationic polymer are able to form complexes after simple incubation in water solution, and at a certain polymer concentration the zeta potential of phages changes from negative to positive value. The further study of these complexes including both bactericidal activity and selectivity are in progress now.

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POSSIBILITY OF CREATION OF HIGHLY SENSITIVE FIBER- OPTICAL SENSORS WITH SUBPICOMETER RESOLUTION

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Sensors of various physical quantities (pressure, temperature, distances, speed of rotation, speed of linear movement, acceleration, weight, deformations, coefficient of refraction, electric field, electric current, a magnetic field, concentration of gas, a dose of radiation, etc.) can be created on the basis of fiber-optical technology. For creation of some of these sensors we offer completely optical relaxation generator of light impulses, constructed on a contour of the closed optical delay in which light interruption by light is made. Frequency of generated light impulses in this generator is defined by the optical length of a delay contour and speed of light distribution in a contour. The optical length of a contour changes under external influence. Consequently, the generator light impulses' frequency changes. By our assessment resolution of measurement of this change it makes of 0.3 picometer.

PHOTOSWITCHABLE SPIROPYRAN'S MICELLE NANOCONTAINER FOR DRUG DELIVERY

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The modern state of development of the science allows creating the potent medications to fight severe diseases. Such preparations are able to destroy the diseased cells, but unfortunately, in a living organism they also destroy health cells before reaching the ill target cells. Only minor percent of the preparation amount reaches the target cell, while the rest of it is distributed in the body and causes adverse

side effects. Nanotechnology offers a number of ways to solve this problem. One of such solutions is packing the drug in a nanocontainer, which protects a body against the toxicity of the medical preparation on the one hand and protects the drug against the influence of the body ferments on the other hand.

The principal element of the nanocontainer carrying the drug is a stable particle micelle formed from the amphiphilic molecules as a result of lyophobic (hydrophobic) interaction forces in a polar solvent. The micelle is proportionate to the principal biological structures, such as the cell, DNA and proteins. A lyophobic part of a micelle is inside the micelle, while its lyophilic part is on its surface and is in contact with the liquid. A micelle carries any substance in the liquid with poor solubility to its lyophobic heart.

The authors have found that the photochromic spiropyrans with a long radical at a nitrogen atom doped in the cholesterol liquid crystal composition are nanostructured as micelles. The process of micellization is evidenced by the solubility increased by one range and photosensitivity increased by 50 % compared to the short-radical analogues.

The unique ability of a spiropyran to sharply change its physical-chemical properties under the impact of photoinduction is seen in the possibility to change the size of a micelle by the action of light. The lyophobic forces in the liquid crystal composition doped with a spiropyran with a long alkyl radical at a nitrogen atom lead to the formation of the loose micelles of spiropyran molecules. The merocyanine amphiphilic molecules with a zwitterion head and non-polar tail formed as a result of the UV light photoisomerization contract the micelle with lyophilic forces.

The substance with poor solubility in the polar solvent is taken to the micelle heart by the loose micelles of the spiropyran by the action of lyophilic forces. Under the UV radiation, the micelle contracts and is emptied off its content. This means that in addition to the physical-chemical properties of spiropyrans, it is possible to reversibly control the micelle sizes and emptying it with light. Based on this unique feature of a spiropyran, besides the target transportation of a hydrophobic drug in a living body, it is possible to accomplish the processes of dosing and distributing the drug in time and space. Emptying a nanocontainer with the drug having reached the diseased area in the body is possible to empty by a remote command.

The high section of two-photon absorption of a spiropyran allows using a two-photon infrared laser technology and avoiding the damage to some body organs (e.g. eyes, ears) by the light irradiation.

In some cases, the deep penetration of a nanocontainer loaded with a medication in a tissue needs the nanoparticles with their size much less than that of the spiropyran loose micelles. This problem can be solved by using a new type of nanocontainers proposed with their principal element being long-radical 6–8-dinitro-derivative spiropyrans synthesized and studied by us. The constant of the thermodynamic balance of this compound is more in polar solvents than in the photo-chemical one ($K_T > K_{PH}$) (in ethanol, $K_T = 2.30$ and $K_{PH} = 0.12$). Therefore, in a cholesterol liquid crystal matrix, dinitro-derivative spiropyran is in the balanced state in its merocyanine form. The relevant micelles are contracted without the UV radiation, and the nanocontainers designed on their basis have high penetration ability. The reduced loading capacity of a drug caused by the reduced volume of nanocontainers will be compensated by the higher micellization ability of the substance. Instead of one large nanocontainer, several relevant nanocontainers with better penetration ability will transport the same amount of drug.

Unloading of a container after it penetrates a target cell can be done with visible light, which is harmless for a living body, by transition of form B into a loose micelle of form A.

The nanocontainers designed based on spiropyran micelles meet the basic requirements for their application in medicine: they are proportionate to the principal biological structures: the cell, DNA and proteins; they are not toxic and have the ability to change their parameters in a reversible manner depending on the command received, i.e. the nanocontainers can be influenced in time and space in a remote manner.

NANOSTRUCTURED PHOTOCROMIC LIQUID CRYSTAL POLYMER FILMS

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The combination of supramolecular liquid crystal (LC) structure with a photochromism gives systems to operate and regulate their optical parameters by light. Retaining properties of LC and photochromic molecules in one system, interaction between them gives special properties and enables the creation of new multifunctional nanomaterials. This “smart” materials are present unique for photonics, optoelectronics, record and information storage. The work describes a new method of creating polymer nanomaterials based on composition consisting of nemato-chiral (NCh) LC, doped with photochromic spiropyrans (SP) synthesized by us. Merocianine (MC) form photoinduced by UV light from SP with long alkyl chain, is amphiphilic molecule with zwitterionic lyophilic head and lyophobic tail. Such molecules are selforganized as nanostructures-micelles in the NChLC. The formation of micelles disturbs the thermodynamic equilibrium. The new formed MC molecules are added to already existed phoroexposed molecules for restoring the equilibrium. It increases absorbing centers and ultimately increases effective photosensitivity compared with the system containing SP with a short chain (Fig. 1).

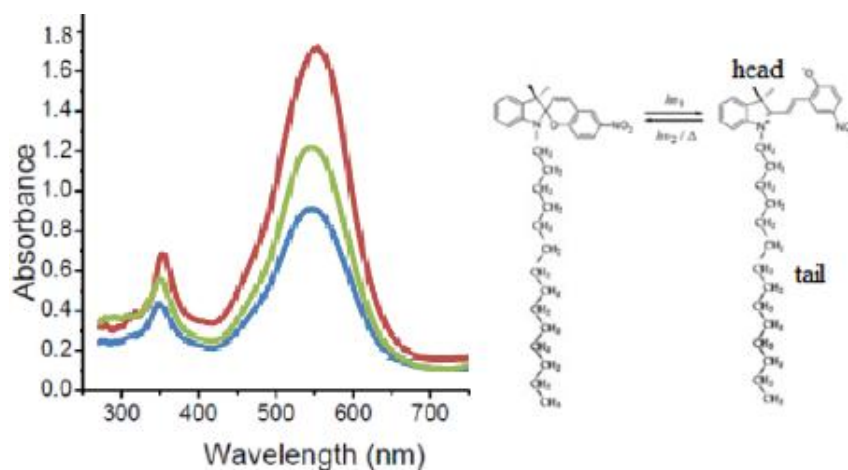


Fig. 1. Absorption spectra of the compositions doped with SPs: blue – doped with Compound I, green – doped with Compound II, red – doped with Compound III. R = CH₃ (I), C₈H₁₇ (II), C₁₄H₂₉ (III).

The spiropyran-doped compositions were introduced into the polymer matrix by the improved method of microcapsulation developed by us. The optical investigation of the films showed that in the films the same correlation is observed as in the compositions. This pointed to the fact that, in the result of microcapsulation of the polymer matrix, the composition retained its initial properties. The increase of photosensitivity, along with the radical length, is well demonstrated upon information recording in the polymer films (Fig. 2). The violet and white colors correspond respectively to irradiated and nonirradiated parts of the films. The contrast strengthening between irradiated and nonirradiated areas of the film (b), shows the increase of photosensitivity.

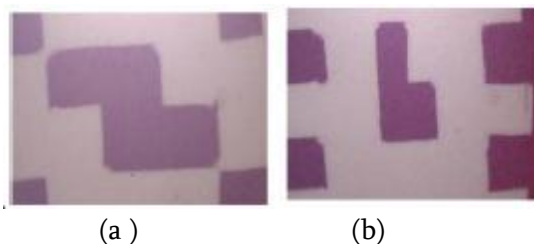


Fig. 2. Photo-imprinted images on the polymer films using the mask doped with (a) Compound I and (b) Compound III.

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CREATION OF BACTERICIDAL NANO-ZEOLITE SORBENT

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Creation of antibacterial and antiviral nano-zeolite materials by the use of natural silica alumina systems is the urgent scientific problem. This problem is important and it pursues obtaining of fine dispersion highly pure zeolite crystals of focused properties.

The object of the study was development of a new method for obtaining antimicrobial and antiviral Ag-containing zeolite material, by chemical treatment of rock of Georgia containing natural mineral phillipsite. Creation of such zeolite sorbent aimed fusion of sorption-detoxication properties of zeolite and antibacterial-antitoxic properties of silver.

Specific crystalline structure of phillipsite conditions open nature of intra-crystalline space for gradual exchange of metal cations. Phillipsite is characterized by well-developed micro porous structure and exchange capacity (3.31 m equiv. / g) and by adsorption capacity to water vapor (7.25 mmol / g) and high selectivity to Ag cations [1] exceeds greatly natural clinoptilolite used currently in surgery [2] and stomatology [3].

By the use of methodology developed by us and on the basis of ion-exchange method Ag-containing fine dispersion phillipsite-NaAgP was obtained. Experiment provided interaction of zeolite solid phase and 0.2 N silver nitrate water solution at the ratio 1 : 6, over water bath. Qualitative assessment of washed and 105 °C-dried sample was made by chemical analysis and water vapor adsorption measurements at $P/P_s=0.40$ and 25 °C. Results of chemical analyses prove logical increase of Ag cations exchange rate into intra-crystalline structure of phillipsite, together with increase of ion-exchange number. High degree (92 %) of inculcation of Ag cations into zeolite structure was achieved. Characterization of obtained sample of porous structure by the method of desiccator proved decrease of adsorption volume at the accumulation of Ag cations. Correlation of cation composition, adsorption capacity and crystallinity was proved by X-ray diffraction analysis. As a result of study by the same method the obtained zeolite material was identified as phillipsite type Ag-containing fine dispersion zeolite of prolonged effect, of high phase purity, which can be used in surgery, dentistry and other branches of medicine as antiseptic material.

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ELECTRIC CURRENT-ASSISTED CONSOLIDATION AND SYNTHESIS OF NANOSTRUCTURED MATERIALS: ACHIEVEMENTS AND PROSPECTS

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The first practical uses of electric current for heating and sintering of metals date back to the end of the 19th – beginning of the 20th century. Thanks to significant progress in the understanding of the electric current effects on inter-particle sintering and successful development of many materials with attractive properties in the past two decades, electric current-assisted consolidation of powders has become a well-defined research direction [1 – 4]. At present, several consolidation techniques are used differing in the current application modes. These include AC current, high-voltage pulses formed by a capacitor discharge and low-voltage DC pulses passing through a specimen as well as induction heating with or without suspects. This presentation focuses on a low-voltage high-current sintering technique widely known as Spark Plasma Sintering (SPS) [1, 3, 4]. SPS is based on the use of pulsed DC to sinter powder materials placed in a die normally made of graphite. Possibilities of shortening densification time, lowering sintering temperature, controlling grain growth and producing dense or porous nanostructured materials have made SPS very popular in many laboratories worldwide. The SPS facilities are also suitable for conducting solid-state reactions, among which are those between two or more mixed reactants as well as reactions of decomposition and reduction in conditions of dynamic vacuum in the SPS-chambers [4].

In our research on the mechanisms of the SPS and its potential for the development of nanostructured materials, we work with ceramic, metal-ceramic and metal-carbon composite materials. We showed that dense nanostructured interpenetrating phase TiB₂-Cu composites with TiB₂ grains 100 nm in size can be formed by SPS [5]. The SPS technique was used to in situ synthesize dense and fracture tough B₄C – TiB₂ composites with submicron- and micron-sized grains from mixtures of titanium, boron and amorphous carbon [6]. It was shown that the difference in the sinterability of the phases in the presence of agglomerates is critical for the microstructure development of the composites during the SPS. The technique was shown to be efficient for sintering of copper-carbon and Ti₃SiC₂ – Cu nanocomposites, in which densification at low temperatures helped avoiding phase re-distribution typical of liquid phase sintering and

undesirable interfacial reactions [7], respectively. Our current interests lie in the field of making porous materials by the SPS. We have shown that SPS of immiscible metals allows forming a nanograined network from each metal in the sintered compact. These networks can serve as a basis for the fabrication of nanoporous materials. By selectively dissolving iron from the SPS-ed Ag–Fe nanocomposites, we obtained porous silver with pores and ligaments 100 – 200 nm in size [8]. The phase of a composite that will further be used to form a porous skeleton upon selective dissolution can be synthesized in situ during the SPS process. Using this approach, we have obtained self-supporting porous graphite by conducting graphitization in the nickel–amorphous carbon mixtures and dissolving nickel from the SPS-ed compacts. Porous graphite was formed by platelets with diameters ranging from 0.3 to 2 μm and a thickness of 0.2 μm and had a specific surface area of 12 m^2 / g .

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PURIFICATION METHOD OF THE QUARRY GROUNDWATER OF GEORGIA'S ORE POLYMETALIC DEPOSIT FROM THE HEAVY METAL SULPHATES AND THEIR SUBSEQUENT SELECTIVE REMOVAL

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The proposed method makes possible the complete neutralizing sulfates, sets of heavy metals in sediment.

Sediment filtering and purification results the water, which is discharged into the river or is used as a technical-water.

NANO TO MICRO PARTICLE SIZE DISTRIBUTION MEASUREMENT IN LIQUID BY INTERACTIVE FORCE APPARATUS FOR FINE PARTICLE PROCESSING

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The direct measurement of fine particles size distribution of dispersions or coagulations in liquid is important for water purification, fine particles separation for recycling and mineral processing, as well as the new material production. The nano to micro particle size is usually measured by light scattering method; however, it is difficult to measure at high concentration of suspension. Here, a novel dynamical method by using the interactive force measurement (IMF) between particles in liquid under electric field is used for measuring distribution of fine particle. Three types of nano to submicron particles, that is well-dispersed nano particles, coagulated nano particles and settled submicron particles, have been measured by interactive force measurement method. The particle size distributions are compared with the size distributions of dried particles measured by TEM or SEM. The well-dispersed nano particle size distribution by IMF is influenced by the nano size surfactant micelles. The size distribution of coagulated nano particles in water is larger than the result by TEM. On the other hand, the submicron nickel particle size distribution is similar with the one analyzed by SEM.

On the other hand, particle size distribution of nano to submicron liquid particles has been measured. Emulsion of water / oil (w / o) type is prepared with oil and water mixture. The nano to micro emulsion particle size is usually measured by light scattering method. The particle size distribution of emulsion of light oil measured by the interactive force apparatus agreed well with the one by the light scattering method. The mean water diameter (50 %) in light oil is approximately 7 nm. The water size distribution in emulsions of gasoline is difficult for the small reflection index and C-heavy oil is difficult for the black color by the light scattering method. The interactive force apparatus can measure both emulsions. The mean water diameter (50 %) in gasoline of w / o emulsion is 3.5 nm. The interactive force apparatus is useful to measure not only nm to micro size solid particles but also emulsions.

Also the air bubble size distribution can be measured by IMF.

NANODISPERSED JELLIES AND THEIR POWDERS FOR AGRICULTURE, MEDICINE AND CONSTRUCTION

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The expediency of application of nanotechnology for considerable reduction of sintering and melting temperatures of silicate, biomedical and other high-melting special materials (superconductors,

semiconductors, dielectrics, refractory materials, monocrystals, artificial bones, dental cements, fiber-optic hairs, cables, etc.) is indicated in the work [1]. In earlier works of famous scientists there is a mention of existence of silica in the form of molecular solution and jelly-like sols of nanometric dispersity, thereby their properties are thoroughly studied.

Results of formation of jelly-like sols of silicates, silica and elements contained in the Georgian waters, which can be used in agriculture, medicine and construction are given in the presented work.

Micro- and macroelements are entered into soils for increase of soil fertility and improvement in quality of agricultural production, as well as for cultivation of unique plants for medicinal preparations.

For the same purposes we have received jelly-like sols of waters of Kvirila (contains microelement Mn) and Kazretula (contains microelements Cu, Fe, Zn and macroelement S) Rivers. Jellies, containing macroelements Mg, Ca and S are received from Black Sea waters.

Potassium and phosphor are entered into soils from natural resources of Georgia, which require appropriate processing technology. Jells of famous mineral and medicinal waters of Georgia, as well as of red and white wines, vodka, lemonades and other liquids of any required composition are received for treatment of balneological illnesses, dermal, bone diseases and arthropathies, as well as for development of perfumery and cosmetology.

Development of construction of hydrotechnical and sea coast-protection structures, harbors and human settlements on the Black Sea shore (at Kobuleti – Poti – Anaklia Cities, etc.) requires application of special sulfate-resistant, low-heat, waterproof, swamp-resistant cements and concretes and active silica-containing ultradisperse additives to them. Such additives can be also received from jellies of swamp waters with simultaneous removal of bogs located near human settlements of Western Georgia that is of great importance on its own.

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SIZE INDUCED PHASE TRANSFORMATION OF METALLIC MATERIALS

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Transition metals and their alloys frequently crystallized at ambient temperatures in the form of metastable modifications which gradually transform into the stable α -phase. The phase transition process is commonly attributed to the effect of the external parameters such as temperature, pressure and chemical composition of the system.

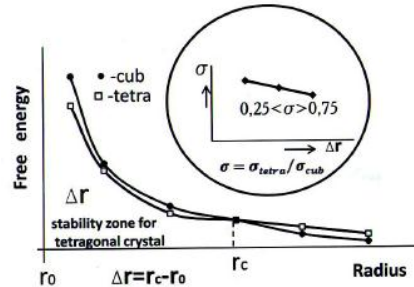
In the present paper, the size dependent phase transformation of the crystal clusters (with the radius r) is analyzed on the basis of general thermodynamic properties of crystals of a simple crystallographic shape. It follows from Gibbs–Thompson relationship that both free energy (ΔG) and vapor pressure over the metastable phase depend on the r . In case of coexistence of unstable tetragonal and stable cubic phases,

free energy of the metastable cluster is higher and the surface energy (σ) is lower than the corresponding values of a stable cluster: $\Delta G_{tetra\infty} > \Delta G_{cubic\infty}$, $\sigma_{tetra\infty} > \sigma_{cubic\infty}$, and $P_{tetra\infty} > P_{cubic\infty}$. On the other hand the sublimation pressure (P) decreases with an increase in surface energy of a crystal. For the stable and unstable phases, respectively, the following equations are valid:

$$RT \ln(P_{tetra r} / P_{tetra\infty}) = \Delta G_{tetra r} - \Delta G_{tetra\infty} = 2M\sigma_{tetra} / r\rho_{tetra},$$

$$RT \ln(P_{cubic r} / P_{cubic\infty}) = \Delta G_{cubic r} - \Delta G_{cubic\infty} = 2M\sigma_{cubic} / r\rho_{cubic},$$

where M is a molecular mass and ρ is a density of the corresponding phase. Owing to considerably higher σ , the metastable phase possesses lower free energy of formation at low values of r , while crystal phase becomes more stable at higher cluster dimensions.



Variation of phase structure of the electrodeposited manganese with r and σ is in good agreement with the theoretically predicted trends.

INFLUENCE OF PRODUCING CONDITIONS ON STRUCTURAL STATE OF BORON CRYSTALS

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Nanoscale structure provides a unique opportunity to obtain materials with improved characteristics. In this respect, boron attracts an increasing attention. Taking into account the low specific weight and possibility to form nanoscale structure, boron-containing materials and coatings can be successfully used in the electronic, nuclear and aerospace engineering. They also can be utilized in medicine and for protection of the service personnel working with neutron sources. Basic data on the preparation of nanocrystalline (previously they were called as “ultra-dispersive”) boron powders and the results of their characterization have been summarized, e.g., in [1, 2]. This work deals with the nanocrystalline particles of boron and boron-based materials in dependence on the producing conditions: mechanical and high-voltage electric discharge grindings; chemical and electrical arc synthesis; heat treatment of amorphous boron.

Mechanical grinding and further fractionation of fine (<1 μ m) boron powders in a liquid medium allows to obtain so-called ultra-dispersive fraction of boron powders. For example, when boron is finely powdered by shock-abrade influence on air, boron nanocrystalline particles of size of ~250nm are formed.

Fractions of such powders after washing in distilled water and removal of the so-called “amorphous” parts formed in the process of grinding can be used for various purposes.

The electric arc and electric discharge are frequently for producing nanostructures, preliminary treatment of powders (with the purpose of their activation), and sintering of powders. Studying of the process of grinding of β -rhombohedral boron crystalline powders by high-voltage electric discharge showed this method to be promising for dispersing nanocrystalline particles of boron and boron carbide.

During electrical arc synthesis at appropriate choice of starting materials, electrodes and modes of synthesis it is possible to obtain boron, boron carbide, carbon and mixtures thereof in nanocrystalline form. Due to the simplicity and capabilities of technological improvement, such a method may be the most productive and used for production of boron and boron-containing materials for various applications.

Using the required precursors (boron oxide or boric acid) in combination with the carbonaceous substances (e.g., sucrose) and spraying their aqueous solutions on a preheated up to 400°C quartz substrate one can obtain a precipitate, in which after appropriate heat treatment (900–1400°C) it can be detected nanocrystalline particles of boron, boron carbide and mixtures thereof. Changing the conditions of deposition and thermal treatment it is possible to obtain a powder with the required ratio of components.

Analysis of published data shows the theoretical and practical possibility of obtaining nanostructured boron and appropriate heat treatment of amorphous boron powders. It has been established that by choosing medium temperature, duration of annealing of amorphous powders may be prepared nanocrystals of α - and β -rhombohedral modifications of boron. The prospect of using unique properties of boron in modern technology should encourage the design of novel boron-based nanocrystalline materials.

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ADHESIVE CONTACT OF ELASTIC BODIES WITH STOCHASTIC SURFACE ROUGHNESS

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Models of adhesive contact between elastic bodies with stochastic surface roughness are under consideration. Roughness is simulated by nonlinear Winkler–Fuss layer which can resist to compressive and tensile (in the case of adhesion) contact stresses [1]. Mechanical properties of the layer are determined by statistical theories of adhesive contact between nominally flat rough surfaces [2 – 4]. The sliding contact of solids is described in Cartesian frame of axes $Ox_1x_2x_3$ by nonlinear boundary integral equations with non-monotonic operators [5]:

$$\begin{aligned} u(\mathbf{x}) + \lambda \int_{\Omega} K(\mathbf{x}, \mathbf{y}) p(u(\mathbf{y})) d\mathbf{y} + \mu\beta\lambda \int_{\Omega} L(\mathbf{x}, \mathbf{y}) \tilde{p}(u(\mathbf{y})) d\mathbf{y} &= \delta - f(\mathbf{x}); \\ \int_{\Omega} p(u(\mathbf{x})) d\mathbf{x} = P; \quad \mu \int_{\Omega} \tilde{p}(u(\mathbf{x})) d\mathbf{x} = T; \quad \mathbf{x} = (x_1, x_2), \quad \mathbf{y} = (y_1, y_2) \in \Omega, \end{aligned} \quad (1)$$

with unknown both function $u(\mathbf{x})$, $\mathbf{x} \in \Omega$, and bodies approach δ . P and T are the normal and tangential forces applied to bodies along the lines x_3 and x_1 , respectively; $K(\mathbf{x}, \mathbf{y}) = |\mathbf{x} - \mathbf{y}|^{-1}$ and $L(\mathbf{x}, \mathbf{y}) = K^2(\mathbf{x}, \mathbf{y})(x_1 - y_1)$; f is the nominal gap between the solid and conventional boundary $x_3 = 0$ of

adhesion interaction before deformation; $\lambda = (\pi E)^{-1}$; E is the reduced modulus of contact pair [6]; β is the Dundurs' parameter [6]; Ω is an arbitrary region of plane $x_3 = 0$, that contains nominal contact region S . The functions $p(\cdot)$ and $\tilde{p}(\cdot)$ depend on micro-geometrical parameters of roughness, distribution of the roughness heights, elastic properties of solids and specific work of adhesion w . The value $\tau = \mu\tilde{p} \equiv \mu(p+z)$ is the interfacial shear stress, μ is the friction coefficient, p is the nominal contact pressure and z is specific force of molecular attraction between the solids (is the overload due to adhesion), that depends on p . It is assumed that $p > 0$ corresponds to compression, and $p < 0$ – to tension. If $\mu\beta = 0$, then contact is normal.

The equations (1) are similar to those of classic unilateral contact problems for elastic bodies with Winkler–Fuss coatings. The solution $u(\mathbf{x})$, $\mathbf{x} \in \Omega$, determines nominal contact stresses (normal $p(u(\mathbf{x}))$ and shear $\mu\tilde{p}(u(\mathbf{x}))$), nominal contact region $S = \{\mathbf{x} : u(\mathbf{x}) \geq 0\}$, friction force T and its nonlinear dependence on the normal force P for all range of values of Tabor's adhesion parameter. Adhesive contribution to the total friction force T is estimated. For the solving of nonlinear boundary integral equations (1) the method of successive approximations is used.

The proposed model of adhesion of rough elastic solids allows studying the contact of solids with an arbitrary nominal geometry providing the control and design of adhesion. It may be adapted to estimation of adhesive and elastic properties of rough elastic bodies by depth-sensing indentation [7].

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SHAPE TRANSITION OF STRAIN-INDUCED InAsSbP ISLANDS GROWN ON InAs (100) SUBSTRATE: FROM MICRO-PYRAMID TO NANO-PYRAMID

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The liquid phase epitaxy technique is used for self-assembled InAsSbP-based strain-induced islands formation on InAs (100) substrate. Here is shown that such islands, as they decrease in size, are undergoing an interesting shape transition. As the island's volume decreases, the following succession of shape transition has been experimentally detected: truncated pyramid, {111} faceted pyramid, {111} and partially {105} faceted pyramid, completely unfaceted “pre-pyramid” which gradually evolves to sub-micrometric semiglobe, with further transition to the lens-shape quantum dot (QD). SEM and TEM measurements have shown that at further decreasing of the QDs volume, the QDs shape transition is undergoing again from lens-shape to the nano-pyramid. Experimentally measured value of the critical size of shape transformation from “pre-pyramid” to semiglobe is within 450 – 550 [1] and from lens-shape QD to nano-pyramid ~ 3 nm.

In order to explain and quantitatively calculate the critical size of the island shape transformation from pyramid to semiglobe and from lens-shape QD to nano-pyramid, the theoretical approach described in [2] is applied. Here we derive an explicit approximation for the energy, which provides good explanation of island shape transition.

The island's energy equilibrium condition can be written as

$$E_S^{pyramid} + E_R^{pyramid} = E_S^{semiglobe} + E_R^{semiglobe}, \quad (1)$$

where $E_S^{pyramid}$, $E_R^{pyramid}$, $E_S^{semiglobe}$, and $E_R^{semiglobe}$ are the extra surface and interface energies and the energy change due to the elastic relaxation of the pyramid and semiglobe, respectively. In the case when lens-shape QD's surface evolves to the nano-pyramid, the energy equilibrium condition can be written as

$$E_S^{lens-shape} + E_R^{lens-shape} = E_S^{nano-pyramid} + E_R^{nano-pyramid}. \quad (2)$$

According to [1], the final expressions for the equations (1) and (2) can be written as

$$-\frac{c}{2}(b_1 - b_2)^2(b_1 + b_2)\tan^2 \theta_p \left(\ln \frac{b_1 + b_2}{b_1 - b_2} + \frac{3}{2} \right) + (b_1^2 - b_2^2) \left(\frac{1}{\cos \theta_p} \gamma_e - \gamma_s \right) = -cD_{Cr}^3 \left(\frac{3}{2} - \ln \frac{\cot \theta_G}{2} \right) + \frac{\sigma \pi D_{Cr}^2}{2}, \quad (3)$$

$$\frac{\pi \sigma d^2}{2} \frac{1 - \cos \theta}{\sin^2 \theta} - \frac{cd^3}{4} \ln \frac{4}{\phi} = \frac{2}{\sqrt{3}} b^2 (\gamma_e \cos \theta - \gamma_s \cot \theta) - 2c \frac{b^3}{3} \ln \frac{\sqrt{3}}{2\phi}, \quad (4)$$

where b_1 and b_2 are the pyramid's base edges lengths, γ_s and γ_e are the surface energy of the substrate and the island edge facets, respectively. D_{Cr} and b are the critical sizes of corresponding shape transformations. Thus, solving the equation (3) at $b_1 = 670 \text{ nm}$, $b_2 = 150 \text{ nm}$, $\gamma_e = 5 \cdot 10^{-5} \text{ J/cm}^2$ [3], $\gamma_s = 3.42 \cdot 10^{-6} \text{ J/cm}^2$, $c = 0.784 \text{ J/cm}^3$, $\theta_G = 25^\circ$, and $\theta_p = 40^\circ$ [1], the critical size of $D_{Cr} \approx 550 \text{ nm}$ for InAsSbP islands shape transformation from "pre-pyramid" to semiglobe is determined. From equation (4) the critical size $b \approx 3 \text{ nm}$ for the lens-shape QD's shape transformation to nano-pyramid is calculated, at $\gamma_e = 5 \cdot 10^{-5} \text{ J/cm}^2$, $\gamma_s = 3.2 \cdot 10^{-5} \text{ J/cm}^2$, $\sigma = 1.45 \cdot 10^{-6} \text{ J/cm}^2$, $d = 2 \cdot 10^{-6} \text{ cm}$, $\theta = 60^\circ$, and $\phi = e^{-3/2} \cot \theta$. Theoretically evaluated values for both shape transformation's critical sizes with high accuracy coincide with experimental results.

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DETERMINATION OF PARAMETERS OF THE INDUCTION MELTING METHOD FOR SYNTHESIS OF NANOCRYSTALLINE PARTICLES

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This presentation deals with the possibility of application of one of the versions of induction heating to obtaining of crystal nanoparticles [1]. The induction heating has the following advantages: rapidness of heating, high concentration and precise localization of energy at heating, high quality, the possibility of accurate automated control of the process, elimination of complex maintenance procedures, no smoke or other harmful emissions at heating, etc. [2]. The main drawback of induction heating is that it is impossible

to heat up dielectrics by this method. According to the principle of induction heating, the induction device can be presented as a freely connected transformer in which the turns of primary winding are connected magnetically to the turn of secondary winding formed by melting. Thus, we can assume that the ratio between the current induced in the melt and the current in the winding is approximately equal to the number of turns in the winding [3, 4]. The maximum current density is induced around the perimeter of the melt, decreasing exponentially in the melt depth towards the center. The depth of current penetration is

$$h = 503(\rho / f)^{1/2}, \quad (1)$$

where ρ is the resistivity of melted metal; f is the current frequency in the winding.

The most of amount of current flows in the distant layers of the melt, within the thickness, equals to the penetration depth. The power generated in these layers can be estimated by the formula

$$N \approx I^2 R, \quad (2)$$

where I is the current in the melt; $R = 2\pi\rho / rh$ is the resistance of the melt.

The evaporation rate v is determined by the vapor pressure p , evaporation temperature T , K and molecular mass M :

$$v = 58.34 \left(\frac{M}{T} \right)^{1/2} p. \quad (3)$$

The temperature dependence of vapor pressure in the general form is described by the formula

$$\lg p = A/T + B, \quad (4)$$

where A and B are the constants characteristic of the given substance.

Varying the evaporation rate, the substrate temperature, and the pressure and composition of the gas, it is possible to obtain crystal nanoparticles over the range of 3 – 100 nm.

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DISTRIBUTION OF THE CURRENT CARRIERS IN THE INVERSION CHANNEL OF NANOWIRE BASED FETs

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The current carrier distribution in the inversion layer of the nanowire based field-effect transistor is analyzed using classical and quantum-mechanical evaluation of carrier distribution. It is shown, that in the

inversion channel of the nanosize FET based bio-chemical sensors are significant difference between charge carrier distributions forms in classical and quantum-mechanical approaches.

This difference can have strong influence on the carrier transport. In classical approach the charge carrier distribution has maximum at the front oxide-nanowire interface, whereas in the quantum-mechanical approach the maximum displaces away from the interface. The value of the electron concentration increases with increasing of the gate voltage as well as its maximum relocates closer to the front oxide-nanowire interface. Majority of the electrons concentrates near the front oxide surface and occupies the region from 1 to 2 nm. This fact should be taken into account for designing submicron devices and sensors.

Those results can be useful for deep insight and for accurate qualitative and quantitative description of the physical processes taking place in the electrolyte-gated nanowire FETs based sensors. Classical and quantum-mechanical models of electron charge distribution can be applied to find appropriate description of physical phenomena, which takes place.

A NEW MECHANISM OF DIFFUSION IN NANOMATERIALS

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It is known, coefficient of diffusion in polycrystalline materials and nanomaterials is considerably higher than in bulk of same substances. In nanomaterials, coefficient of diffusion increases with reducing in size of nano-particles. There are many attempts to explain this phenomenon, but all they have failed because all they are based on traditional molecular-kinetic theory, which is suitable only for high temperature region ($T > 0.7T_m$).

We have suggested novel mechanism of diffusion of atoms in condensed matter suitable for low as well as for high temperature [1 – 4], which has explained all diffusion phenomena in solids within whole temperature region [4, 5]. This mechanism is based on a new concept of the atomic motion in condensed matter, according to the molecular-potential theory [6] proven experimentally. According to this new concept, the probability of atomic motion in condensed matter determine state of their chemical bonds with neighboring atoms, which may vary under different external influences (heating, pressure, illumination, etc.). As is known, in molecules, as well as in solids, electrons contributing in chemical bonds can occupy two different kinds of quantum states, where they are strengthen or weaken the inter-atomic binding. In first case, they occupy bonding levels (bands), while in second case – anti-bonding ones. Electron created on the anti-bonding level (band) by the transition from bonding ones and corresponding unoccupied state (hole) on the bonding level (band) are anti-bonding quasi-particles (ABQPs). Regardless of the way of increasing in their number (heating, illumination, pressure, etc.), ABQPs weaken chemical bonds between neighboring atoms. In condensed matter, there is certain probability (for given concentration of ABQPs) that several ABQPs due to their chaotic motion will fall in an atom vicinity, which can distinctly weaken its

chemical bonds simplifying its displacement in lattice. In case of nano-particles, the electron placed on the anti-bonding level and corresponding hole on the bonding level will freely move if energy-difference between these levels is $\sim kT$, what takes a place even at room temperature.

The atomic displacements' probability has been expressed by the formula: $W_A = A(n_{ABQP} / N_a)^\beta W_{ph}$, where n_{ABQP} is the concentration of ABQPs, N_a is the concentration of atoms in substance, W_{ph} is the probability of the excitation of phonon of certain energy near the given atom, A is an almost-temperature-independent coefficient, and β is the number of ABQPs sufficient for causing an atomic displacement. One can see from stated relation that such probability mainly is determined by the concentration ABQPs and not by the temperature, unlike the diffused opinions from molecular-kinetic theory that, it should be an exponential function of temperature. Reducing the size of nano-particles also increases the number of ABQPs, because in small nano-particles ABQPs achieving its surface border are mainly reflected. This is a reason why they cannot leave nano-particle, unlike to equal volume in the bulk material. Consequently, ABQPs in nanoparticle have more neighboring atoms than in bulk solid, which intensifies their weakening effect on bonds. Such effect can be described introducing effective concentration, ratio of which with its real value equals to the ratio of frequencies of ABQPs appearance near the given atom in nano-particle and bulk during an atomic vibrations cycle. Thus, when the nano-particles size reduces coefficient of diffusion in nanomaterial increases.

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MECHANISM OF THE HALL–PETCH LAW “ANOMALY”

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As is known, when the size of the nanoparticles reduces, before the critical size specific for given material the hardness of nanomaterials grows and then falls. The last effect is considered as anomalous part of the Hall–Petch law.

In this paper, we present a mechanism according to which the mentioned “anomaly” is imagined as a quite natural phenomenon. This mechanism is based on a new concept of the atoms motion in condensed matter, according to the molecular-potential theory [1, 2] as it was proven experimentally. According to this new concept, the probability of atoms motion in condensed matter is determined by the state of their chemical bonds with neighboring atoms, which may vary under different external influences, such as temperature, pressure, illumination, etc.

It is known that, in molecules, as well as in solids, electrons contributing in chemical bonds can occupy quantum states of two different kinds, where they are strengthening or weakening the inter-atomic binding. In first case, they occupy bonding levels (bands), while in second case – anti-bonding ones. Electrons occupying anti-bonding levels (bands), due to their transition from bonding ones, and corresponding unoccupied states (holes) on bonding levels (bands) are anti-bonding quasi-particles (ABQPs).

Regardless of the way of increasing in their number (heating, illumination, pressure, etc.), ABQPs weaken chemical bonds between neighboring atoms. In small nanoparticles, ABQPs reaching their surface are mainly reflected (Fig. 1). This is a reason why they cannot leave nanoparticle unlike to equal volume in the bulk solid material. Consequently, ABQPs in a nanoparticle have more neighboring atoms than in bulk. It intensifies their weakening effect on bonds.

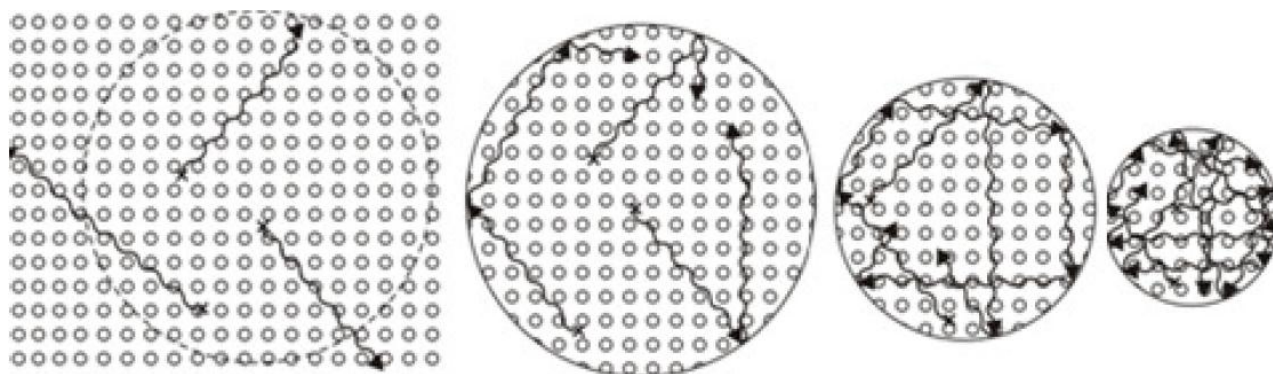


Fig. 1. Schematic illustration of growth in ABQPs' concentration with reducing in nanoparticles size at given temperature.

Such effect can be described introducing effective concentration, the ratio of which with real value equals to the ratio of frequencies of ABQPs' appearance near the given atom in nanoparticle and bulk of same material during an atomic vibrations cycle. Thus, the reducing in the size of nanoparticles enhances their softening effect. Therefore, one can observe the reducing in hardness of nanomaterials.

In the same way, it can be explained the decreasing of melting temperature with reducing the size of nanoparticles [3].

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PHYSICAL FUNDAMENTALS OF A NEW MECHANISM OF SUPERPLASTICITY

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Superplasticity in nanomaterials exceeds that in common materials. And it occurs at lower temperatures. As is known, plasticity in materials increases with temperature or pressure and decreases with particles sizes in nanomaterials. It has been proposed some models to explain these experimental data. They indicate the absence of any comprehensive mechanism of superplasticity [1, 2]. It is clear that the superplasticity like all the other types of deformation related to the easiness of atomic motion which is described by the molecular-kinetic theory. But, the mentioned size-dependency is unaccountable in frames of traditional molecular-kinetic theory. Here we suggest novel concepts. As argued experimentally those are possible to give explanation of any fact obtained in nanomaterials.

According to these concepts, all properties of substance are determined by the states of chemical bonds between constituent atoms in given conditions. The modification of these states changes nanomaterials properties as well. Such a modification can be done by different influences (heating, illumination, pressure, injection of current carries, etc.) [3].

It is known that in solids, as well as in molecules – nanoparticles are located between them – electrons contributing in chemical bonds can occupy two different kinds of quantum states, where they strengthen or weaken the inter-atomic binding. In first case, they occupy bonding orbitals (levels), while in second case – anti-bonding ones [4]. Electron created in the anti-bonding level as a result of the transition from bonding one by any influence and corresponding unoccupied state (hole) in the bonding-level are anti-bonding quasi-particles (ABQPs). Regardless of the way of changing in their number, ABQPs weaken chemical bonds between neighboring atoms [5].

Superplasticity is a too-increased plasticity at given temperature and under the fixed pressure. This new approach can be argued by the fact that, at given pressure generated excess in ABQPs concentration more likely facilitates the atomic motion. The growth of concentration occurred due to pressure impact in the condensed matter changes the energy spectrum of electrons involved in chemical bonding, which is reflected in convergence of the bonding and anti-bonding levels and concentration of ABQPs at the given temperature increases together to probability of atomic motion [6]. In matter (e.g., nitrides, oxides), in which these bonding and anti-bonding levels are separated from each other significantly, superplasticity takes place at high temperatures – at sufficient number of ABQPs.

The metals Ni, Al in nanocrystalline structure and fragile nanomaterials TiN, SiC, Si, (Fe, Ni)B_x superplasticity reduces the grain size. This new approach can be proved by the fact that reducing in the size of nanoparticles increases number of ABQPs, what has a bond weakening action and becomes higher because ABQPs will be more frequently with atoms contained in nanoparticles. This occurs mainly due to the reflecting of ABQPs from boundaries between nanoparticles.

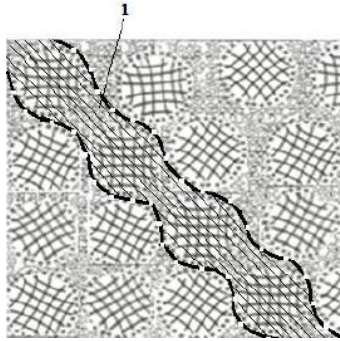


Fig. 1. Disposition of nanoparticles with different crystallographic orientations in the nanomaterial. 1 – micro sliding plane.

Some of authors believe that the plastic deformation in nanomaterials always starts as micro sliding of athermal grain boundaries. By the new approach, micro sliding can be explained as follows. Formation of nanomaterials by pressing means turning of nanoparticles with initially chaotic crystallographic orientations. Turning triggers reduction in energy distance between bonding and anti-bonding levels. Then the concentrations ABQPs in some parallel planes will be higher than in others, and micro sliding will take place easily. At this process, nanoparticles can be melted despite the fact that sliding surfaces of nanoparticles are at much lower temperature if compared with the melting point characteristic of bulk material.

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ABOUT EDUCATION OF NANOTECHNOLOGY PROFESSIONALS OF THE FUTURE

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Growth of the welfare of humanity is determined by the actual creation of novel technologies. To the date, it has been achieved impressive results. But, it should be noted that, unfortunately, all the technologies are full of waste spending of materials and energy processed in techno-sphere, so that the largest part of the human effort is spent on the creation of waste and environmental pollution. The first alarm bell assemble Club of Rome, which published its report in early 70s that if the current pace of technological approaches and the development of industry is retained, the world resource crisis will be inevitable.

This crisis was accelerated by the new industrial giants – China and India’s – emergence in the global industrial arena. Especially, we should take into account that the Western (Europe and US) companies have introduced “already yesterday’s technology” in these countries. It has been estimated that when one of these two giants achieves the level of energy consumption per capita in the US in 1960 the possible collapse will be inevitable! It is also noteworthy that techno-sphere development, which has become the driving force of our civilization, held under the slogan: “It can be more fully conquest of the Nature and we snatched it!”

From the above, it is clear that for the civilization survival it is necessary to change paradigms of science and technology. It is necessary to move from the idea of conquering with Nature to new paradigms providing harmony with it. In order to achieve harmony in the creation of new technologies to ensure that techno-sphere, which resembles natural processes, will maximize the efficiency, but not hurt the environment. The nanotechnology and other technologies need to create techno-spheres such as: information technology, bio technology, cognitive studies – science about mechanism of thinking (N. Bohr said, “In order to adequately evaluate any phenomenon, we need to recognize the mechanism used for thinking”), etc. Thus, the fantastic achievements of science and technology may lead to the destruction of Humanity. What is way to avoid this fatal outcome? Only one – the spiritual ascension of the Humanity! For survival of modern civilization, it is not sufficient the development of novel technologies. In our opinion, it is necessary the raising the Humanity’s spirituality to get rid of mutual hatred and use the achievements only for own well-being.

Therefore, it is necessary to inclusion in the educational programs of universities of a special course of the spirituality education. In our opinion, for the training of a nanotechnology specialist of the future, it is necessary to develop a new program that will teach these subjects from the first year of the education to form a basis for solving of newly emerging problems. Certainly, due to the depth of these disciplines the time of the learning process cannot be divided between separate departments. These specialists will have more general knowledge that will be useful to solve of the emerging problems. In our opinion, this is justified by the fact that when young professionals work in practice, they are involved in the implementation of the task and they have everything for deeper study.

ION-IMPLANTED NANOSIZE STRUCTURAL METALS WITH IMPROVED SURFACE MECHANICAL PARAMETERS

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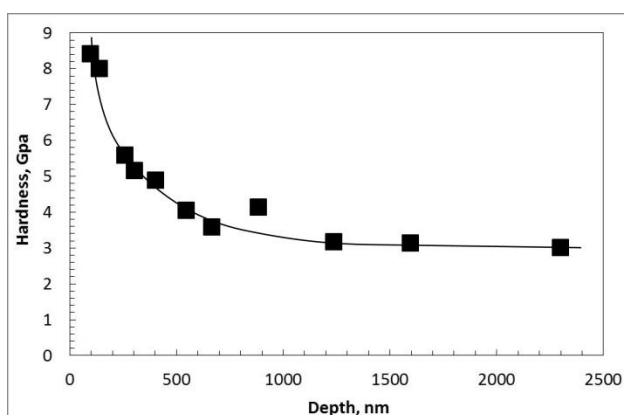
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Various processes of developing new construction materials with improved mechanical properties are widely used for the production of various purpose devices with increased operation parameters. Innovation radiation technologies, based on ion bombardment are among successfully used alternative methods. The basic ones of them are: direct ion implantation (II), ion beam mixing, ion beam-assisted deposition, plasma source ion implantation. Radiation technologies are free from the limitations of equilibrium thermodynamics (exceeding impurity solubility limits and concentration of formed radiation point defects; low process temperatures, new phases nucleation and growth, etc.).

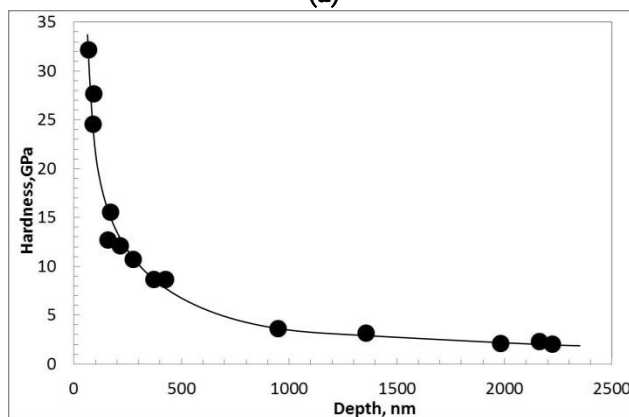
Therefore, using these methods, differing substantially from conditions of equilibrium thermodynamics we can form modified, nanosize surface composite layers of metals and alloys in equilibrium, non-equilibrium, metastable and nano-crystalline states.

To improve strength and wear resistance parameters of surface layers of molybdenum, niobium and refractory steel AISI – 310 method II is used. To select modes II computer calculation of implanted atoms distribution was made, as well as of formed displacements of atoms (vacancies) using SRIM 2012 programs. Processed plane-parallel initial specimens with surface roughness of 4 – 10 nm were bombarded with nitrogen and carbon ions with energies 120 keV, flows 10^{15} ion / $\text{cm}^2 \cdot \text{s}$ and irradiation fluencies $10^{16} - 10^{18}$ ion / cm^2 . Microindentation was used to study microhardness by pressing indenter under various loads and permanent deformation rate; the tests were conducted in SHIMADZU Dynamic Ultra Micro Hardness Tester, DUN – 213S.

Wear resistance is determined by the method of abrasive wearing of the material, and measuring changes in the indenter imprint. As an example see below results of microindentation of initial (a) and irradiated with nitrogen ions (fluence $1 \cdot 10^{18}$ ion / cm^2) (b) niobium specimens.



(a)



(b)

Analysis of microhardness study test results showed more than 2 – 3-fold raise of strength at the depths of ion penetration in all the materials, independent of the type of bombarding ions. With the material strength growth substantial proportional wear resistance rise by an order of magnitude is observed. Method II is used at the final stage of construction material manufacturing, preserving untouched other features, design and methods of items fabrication from the above materials. The developed technology and materials can be used for commercial production of various-purpose parts, devices with improved operation parameters, applied in machinery engineering, processing industries, medicine, and other fields of science and industry.

RECENT ADVANCE IN ELECTROPHORETIC DEPOSITION FOR NANOTECHNOLOGICAL APPLICATION

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Nanotechnology is a multidisciplinary area of applied science and engineering that deals with the utilization of unique physical, chemical, and biological properties of nanoscale substances in fundamentally new and useful ways. Although the researches on nanoscale is back to the centuries, the study of biological systems and the engineering of many materials such as colloidal dispersion, metallic quantum dots, and catalyst can be given as a common previous areas performed in nanometer regime, the application of nanotechnology for design and production industries is relatively new. Recent advance on the image, engineer and manipulate system in the nanometer scale leads to production and uses of nanoparticles or nanosurfaces. Hence it is becoming more and more important topic in the whole world. Several techniques can be concerning the manufacture of nanosized materials however, in recent years, the electrophoretic deposition (EPD) has been recognized as a most growing and promising technique for the manufacturing of nanotechnology based coating materials due to the high versatility of its use with different materials and the cost-effectiveness of the process.

In this paper, fundamental aspects of electrophoretic deposition, mechanism, affecting factors and applications in various areas including coatings, nanoscale assembly, micro patterned thin films, advance and fiber reinforced ceramics, glasses, laminated, graded or hybrid materials, etc. is overviewed. A special attention has also given to performed researches aimed to utilization of boron and boron compounds in EPD processes to increase the final product properties. Boron is a material, which can show high corrosion resistance, high hardness, high refractory properties and strong bonding properties with different substrates. Furthermore, the high ionization energies means that stability at low voltages make it a potential material for electrophoretic deposition.

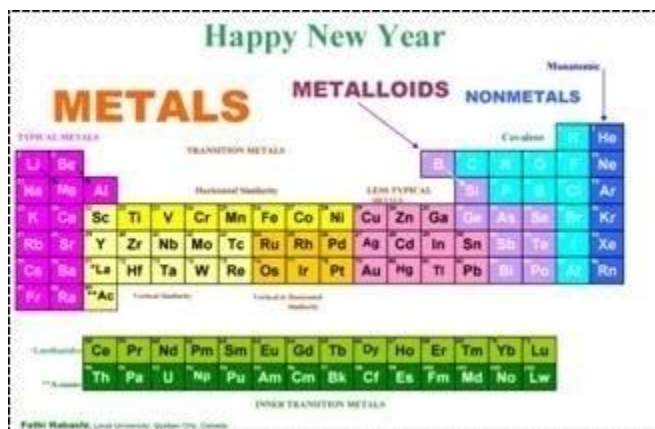
A NEW LOOK AT THE PERIODIC TABLE

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As science advances, its laws become fewer but of greater scope. In this respect the Periodic Law, which is the basis of the Periodic Table, represents a major step in the progress of chemistry — it affords the natural classification of the elements. The Periodic Table was developed by chemists more than one

hundred years ago as a correlation for the properties of the elements. With the discovery of the internal structure of the atom, it became recognized by physicists as a natural law.



When the crystalline structure of solids was studied, the nature of the chemical bonds was understood, and the theory of metals was put forward, it became an essential tool not only for chemists and physicists, but for metallurgists as well. Of the 87 naturally occurring elements, 63, i.e., about three fourth are described as metals, 16 as nonmetals, and 9 as metalloids. A new look at the Periodic Table is given.

INVESTIGATION OF COATINGS NbN AND Nb–Si–N DEPOSITED BY MAGNETRON SPUTTERING

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NbN and Nb–Si–N films were deposited by magnetron sputtering the Nb and Si targets on silicon wafers at various powers supplied to the Nb target, P_{Nb} . The films were investigated by an atomic force microscope (AFM), X-ray diffraction (XRD), X-ray photoelectron spectroscopy (XPS), nanoindentation and microindentation. The deposited films were annealed to establish their thermal stability.

It was shown that the surface roughness of the films increased with P_{Nb} , and decreased with an introduction of silicon. The NbN films were nanostructured, and the Nb–Si–N films had a nanocomposite structure, and represented an aggregation of δ -NbN_x nanocrystallites embedded into the amorphous Si₃N₄ tissue (nc – δ -NbN_x / a-Si₃N₄). The Nb–Si–N films exhibit the higher hardness than NbN films mainly due to the formation of the nanocomposite structure.

TECHNOLOGY OF THULIUM MONOSULFIDE NANOFILMS

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Monosulfides of rare-earth elements have interesting magnetic, optical, thermal and other properties [1 – 3], but not all compounds of this class are studied rather fully. The TmS belongs to such low-studied materials. The purpose of the present work was development technology of preparation of thulium monosulfide nanofilms. The TmS films of 0.9 – 1.2 μm thickness with length of 5 mm and width of 4 mm were prepared by vacuum-thermal discrete evaporation of the previously synthesized bulk material. At the preparation of films, the vacuum in the working camera was 10^{-5} Pa, temperature of the evaporator equaled to ~ 2750 K, temperature of substrate varied in the range of 720 – 1200 K. Distance from the evaporator to a substrate was equaled to 70 mm. For substrates were used plates of a form of a rectangular parallelepiped made from single-crystalline silicon, polycrystalline glass and leuco-sapphire. At substrate temperatures below 720 K and higher 1200 K, the two-phase films are formed. Optimal temperatures are 935 – 1120 K.

According to the high resolution electron scanning microscope studies, the increase of substrate temperature increases the size of characterizing particles from 18 to 48 nm. So that, at substrate temperatures of 930, 980. And 1115 K the size of the characterizing particles equals to 18, 32, and 48 nm, respectively. Thus, it is possible to conclude that the received films are nanofilms.

It was observed that, the lattice parameter of prepared films depends on the sizes of characterizing particles: with increase characterizing particles lattice parameter increases from 5.19 to 5.35 Å, that is less than the parameter of corresponding bulk crystal 5.417 Å [4]. Such distinction is characteristic for some metals (e.g. Cd and Yb [5]).

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IMMOBILIZATION OF ZERO-VALENT IRON NANOPARTICLES IN BIOMATERIALS

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Zero-valent iron nanoparticles (ZVI) are widely used to remediation of groundwater and streamwater from heavy metals and stable organic pollutants (Reactive Barriers). Especially noteworthy is the fact that Fe⁰ reduces different halide compounds of hydrocarbons, chlorine-containing pesticides, organic dyes, nitrozo compounds and explosives. The restoring ability is used to reduce ions CrO₄²⁻, Cr₂O₇²⁻, ClO₄⁻, NO₃⁻ and remediation of water from Hg⁺², Ni⁺², Cd⁺², Pb⁺² and also a number of radionuclides. ZVI had wide application in the USA and Canada while this method was appeared in Europe later [1 – 4]. The cost of these methods to remediation of water depends on many factors (type of pollution, cost of reagents, the purpose of remediation and quality, remediation methods and other). That's why Fe⁺² and Fe⁺³ reduce till Fe⁰ with new recover reagents and methods is an actual problem. The aim of the present work is immobilization of ZVI in bioorganic materials and obtaining hybrid organic-inorganic reactive barriers. Biopolymers contain of many functional groups, including of hydroxyl, carboxyl, carbonyl and ether groups. These groups have the ability to stabilize the nanosize particles and prevent the formation of large-size particles. Biosorbents have a high sorption capacity towards ion of heavy metals, which are several times larger than a similar capacity of inorganic sorbents [5]. In the complex sorbents that we have made, on the one hand matrix (biomaterial) is sorbent of heavy metals and on the other hand particles of immobilized iron are reactive barriers towards toxic metal ions and stable organic pollutants. Activation method (processing of wood waste, sawdust, shavings, chips, cereal crop residues) has been developed for biomaterials, which includes their hydrothermal treatment at 200 °C and 2.0 – 2.5 MPa (1 h) and then rapid decline of pressure, which leads to decomposition of the wood structure and increase in the surface. In the activated wood for immobilize purpose zero-valent iron powder it treated with concentrated solutions of iron salts at 50 – 80 °C. After drying of wood (dampness 10 – 12 % mass.), iron ions recover by sodium borohydride in organic solvents. There have been studied the possibility to obtain ZVI of by organic recover substance, including plants extracts. By similar method it was realized immobilization of ZVI in porous inorganic compounds. Microstructure of immobilized the powders was studied by optical and electronic scanning microscopes (Nikon ECLIPSE LV 150, NMM-800TRF, Nanolab-7). Phase analysis of sorbents was conducted on the X-ray diffractometer DRON-3M (Cu-K_α, Ni filter, 2° / min).

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SMART NANOTECHNOLOGY SYSTEMS, AS A SPACE OF HUMAN, TECHNOLOGY AND ENVIRONMENT INDEPENDENT FACTORS

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More scientific research is an important direction for the development of nanotechnology. It substantively changed as smart systems, which are the basis of human, technical, and environmental factors in the space of mutual dependence.

Information technology, including the Criminal Investigation, focuses on bio-information “messaging” look, the essence of effective coding and machine processing research. At the same time, even the smart systems emerge as a secret tool for detection and measurement, as well as experimental device, which will generate different semantic structures and make available the adequacy of control.

Nano scientific and technical advances have made it possible with the help of a new and deeper understanding of the complex phenomena underlying the security system of the human factors research. The human factor, the psychophysical properties of complex technical systems to adapt to conditions, as well as emotional, psychological and behavioral characteristics to determine the class of the current study, are in extreme situations. In addition, it is worthwhile reliable management and extreme conditions were determined by the perception and the ability to respond [1].

Energy information structure and function of the human body is built as a dynamic volume hologram, which makes it possible to obtain complete information from parts of the body surface. Organism itself reveals pathologically changed parts of the body and the “surface takes” it in the reaction zone, where the deviation between the pathological zone and the background is maximal. Hardware of medical and special-purpose for any (even from sub-cell) hierarchical level allows the visual information. It is determined by the “messages” that carries information. Semantic connection between the sources of information is discussed.

Computer analysis method of “no clear information” definition is based on the emotional state – verbal and non-verbal information on the perception of the baseline established on the basis of a range of technical – software systems. The resistance of the organism depends on many factors. It can be mathematically described and translated into machine language.

Experimental analysis of the transport (Trace Evidence Examination) is defined by a combination of factors: human absent-minding and response factors. Fatigue, mood and emotion factor have been developed on the basis of the findings and recommendations. Studies have confirmed that the active form of tired people will feel less fatigue. In case of a situation of extreme danger and immediate response to that it has to take the technical security systems. Practical recommendations were proposed.

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RESEARCH OF PROCESSES OF PHOTO STIMULATED CRYSTALLIZATION OF NANO DIMENSIONAL LAYERS OF SILICON ON SAPPHIRE FILMS

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Pulse photon annealing of semiconductor layers is widely used in practice. However, despite extensive investigation into these processes, no commonly accepted mechanism of the observed phenomena has been developed so far.

In this paper, experiments were carried out on 10 – 100 nm epitaxial structures of Si by grown on a sapphire substrate using the electron-beam method. For improvement of structural perfection of the received layers, we performed the following annealing: thermal annealing to $T = 1200$ °C in an inert atmosphere, annealing with a pulse laser ($\lambda = 0.69$ μm) under milliseconds or nanoseconds conditions, and lamp annealing. The last annealing was carried out on a unique device intended for pulsed photon annealing using halogen incandescent lamps. The annealing pulse duration was varied in the range $\tau = 0.1 - 10$ s, and the power density reached $W = 190$ W / cm^2 . Photon irradiation was conducted from the sides of both Si and sapphire. The optical transparent sapphire substrate made it possible to directly affect the transition sapphire–silicon imperfect region.

We study the electro-physical parameters of silicon layers and its optical parameter, namely, the transmission spectra ($\lambda = 0.2 - 10$ μm). The measurements were performed at room temperature. When studying optical spectra near the fundamental absorption edge, one can estimate the value and nature of the internal mechanical stresses induced by defects in semiconductors. X-ray diffraction analysis of structures was carried out on a DRON – 3M diffractometer before and after annealing.

Estimation of nature and size of the internal mechanical pressure was based on investigation the fundamental optical absorption spectra in thin layers. It is shown that, internal mechanical pressure has the character of compression.

The influences of pulse-photon annealing on processes of crystallization of polycrystalline or amorphous Si films, and also of internal mechanical pressure relaxation, are studied. It is shown, that, depending on irradiation regimes the relaxation can reach high values.

The “electronic mechanism” of annealing of structural defects based on the change in the quantum state of the electronic subsystem of a crystal under pulse photon irradiation is proposed.

A STUDY OF SHELL FORMATION IN InP BASED COMPOSITE NANOWIRES

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The composite nanowires comprising crystalline semiconductor cores surrounded with amorphous shells are considered as promising materials for the fabrication of nanowire based transistors, photovoltaics, gas sensors, catalysts for direct water splitting by sunlight etc. Recently we have developed the new pyrolytic technology and produced some core-shell 1D nanomaterials using the sublimation of products, formed after thermal annealing of InP + Zn source in the N₂H₄ + 3 mol. % H₂O vapor [1 – 3]. The nanowires were synthesized from the gaseous phase on the Si substrate that was located in the “cold zone” just above the source. Fig. 1 represents the transmission and scanning electron microscope images of the grown core-shell nanostructure. The purpose of this work was to study the mechanism of the formation of shells in these composite nanowires. The nanowires were grown in the temperature range of 400 – 650 °C.

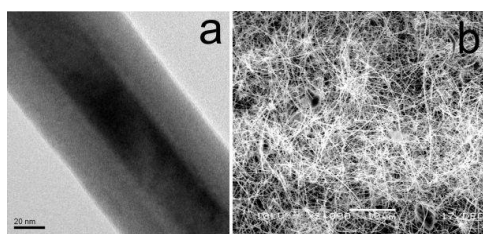


Fig. 1. TEM image of InP – Zn₃(PO₄)₂ core-shell nanostructure (a); SEM image of core-shell nanowire network (b).

TEM analyses and XRD patterns revealed that the cores of nanowires grown at 400 °C on the Si substrate consisted of crystalline InP with average diameters of 21 nm. All spots on the selected area electron diffraction patterns were also assigned to the InP with the zinc-blende structure. In contrast to this, the shells, that had the thicknesses in the range of 8 – 25 nm, were synthesized as the amorphous layers. The energy dispersive X-ray analysis was used to determine the composition of grown nanostructures. It was proved, that the shell consisted of the amorphous zinc phosphate Zn₃(PO₄)₂. Zn, with the melting point of 420 °C, readily sublimates at source temperatures above 500 °C. In the presence of hydrazine and water decomposition products (NH₃, NH₂, H₂, O₂) InP also decomposes at this source temperatures, producing volatile In suboxides (In₂O) and phosphorous vapor. Considering the thermodynamic parameters of gaseous species (In₂O, P and Zn vapor) it was found, that the shell was formed due to the segregation of phases during the synthesis of nanowires. The driving force for the phase segregation and formation of core-shell nanostructures was the extremely high value of the Gibbs free energy of the synthesis reaction: $3\text{Zn} + 8\text{In}_2\text{O}(\text{g}) + 18\text{P}(\text{g}) = \text{Zn}_3(\text{PO}_4)_2 + 16\text{InP}$ ($\Delta G = -6690$ kJ / mole at 400 °C). The growth proceeded through a vapor-solid mechanism. The substrate temperature was sufficient to form the single crystal InP core, while it was quite low to crystallize zinc phosphate. As a result an amorphous Zn₃(PO₄)₂ shell was formed around the InP core.

At higher growth temperatures (up to 650 °C) the continuous Zn₃(PO₄)₂ shell was shrank. The shell was transformed into nanospheres that were surrounding InP core and forming bead-like nanostructures. This was explained by the viscous flow of zinc phosphate at high temperatures and surface tension governed shape formation.

Zn₃(PO₄)₂ is widely used in medicine as a dental cement and its safety has been well established. This fact together with luminescent properties of InP nanowires raised interest for the future application of zinc phosphate encapsulated InP nanostructures as biological markers in medicine.

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ON BORON NITRIDE COATING OF METALS

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BN coatings are obtained with the method of radio frequency (RF) magnetron sputtering technique on different substrates. For RF technique a physical vapor deposition (PVD) system from target to substrate is used. BN coating formation are investigated on varies substrates such as AISI D2 Steel, 316 L steel, optical glasses, Ti implants, aluminum, copper, and germanium. Compositional, structural and mechanical measurements and analysis are performed for the characterization of coatings are investigated by using XRD, SEM, CaloTest®, Filmetrics F20 Thin-Film Analyzer Device®, Step Profilometer, Scratch Tester, Tribometer Tester, Nanoindentation Tester, FTIR, AFM and Profilometer. From our investigations, it is found that BN films thickness is from nanometer range to several microns. Also, it is observed that BN coatings obtained in different phases (polymorphs) such as a-BN, e-BN, r-BN, w-BN, t-BN and h-BN structures besides c-BN structures. The effects of chemical and microstructural constitution on the tribological properties were investigated. Generally, it is found that there is good adhesion and lower friction because of more than one structure. According to deposition parameter, in some cases hardness is found to increase or decrease.

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POSSIBILITIES OF PHYSICAL METHODS IN DEVELOPMENT OF MICROBIAL NANOTECHNOLOGY

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Some results of investigations in the field of microbial nanotechnology performed by the research collaboration are presented to demonstrate the possibilities of physical methods for characterizing noble metal nanoparticles produced by microbes. Several groups of new microorganisms isolated in Georgia for the first times were studied as models for developing methods of nanoparticle biosynthesis. The terrestrial actinomycetes belonging to *Arthrobacter* (*Arthrobacter globiformis* 151B and *Arthrobacter oxydans* 61B) and *Streptomyces* (*Streptomyces glaucus* 71MD and *Streptomyces sp.* 211A) genera, the new strain extremophile bacteria *Streptosporangium spp.* 94A and two novel strains of thermophilic actinomycetes (*Thermoactinomyces spp.* 44Th and *Thermomonospora spp.* 67Th) were used to study biotechnology of microbial synthesis of gold and silver nanoparticles. The blue-green alga *Spirulina platensis* (strain IPPAS B-256) was also used for obtaining gold and silver nanoparticles for medical and pharmaceutical application.

A variety of spectral and analytical methods was used to characterize the synthesized gold and silver nanoparticles. The ultraviolet–visible (UV–vis) spectrometry was used for observing surface plasmon resonances absorption spectra in gold and silver nanoparticles with peaks at 530 nm for gold and 425 nm for silver. Transmission electron microscopy (TEM) and scanning electron microscopy (SEM) were carried out for visualization and approximate assessment of sizes of the formed nanoparticles. The data of X-ray diffraction (XRD) method for gold and silver nanoparticles demonstrated presence of number of Bragg reflections corresponding to the fcc crystal structure. The Scherer equation was used to determine sizes of nanoparticles using one of the interference peaks on the diffractograms.

The particle sizes estimated for the studied samples were in the range of 5 to 80 nm that is in good agreement with estimations by other methods. The analytical methods of neutron activation analysis (NAA) and atomic absorption spectrometry (AAS) were applied for determination of total Au and Ag content in the biomass of studied bacteria. In both cases the analogical dynamic of total metal accumulation were observed: the concentration of metal increases rapidly in the first few hours and then slowly decreases. In the first 'rapid' phase, the metal ions were mainly adsorbed onto the surface of bacterial cells extracellularly. In the second phase, the metal ions were transported into the cells and accumulated intracellularly. The results of the study of the biosorption process during nanoparticle production obtained either the use of the method of equilibrium dialysis and AAS, which were analyzed within the Freundlich model, show that it strongly depends on the surface properties of microbial cells. The sonication of bacterial biomass at synthesis of Au and Ag nanoparticles increases the total surface and reduces sizes of its fragments. For example it was shown that the value of the surface plasmon peak in the case of sonication of *Spirulina platensis* biomass was about 4 times more intense than that without sonication. Energy-dispersive analysis of X-rays (EDAX) and NAA were also used to study multi-elemental content of the samples taking into account the possible medical application of the synthesized Au and Ag nanoparticles. The NAA results show that the concentrations of some toxic elements in the obtained biomass do not exceed the permissible levels and microbially synthesized Au and Ag nanoparticles may be used for industrial, medical and pharmaceutical purposes.

MAGNETO-OPTICAL AND OPTICAL PROPERTIES OF ION IMPLANTED $(\text{YBiCaSm})_3(\text{FeGeSi})_5\text{O}_{12}$ GARNET FILMS

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We have investigated the optical and magneto-optical properties of the ion-implanted $(\text{YBiCaSm})_3(\text{FeGeSi})_5\text{O}_{12}$ garnet films. It has shown that ion implantation influences significantly the magneto-optical properties of the garnet films and practically does not change its optical characteristics. In the proceeding, we have researched the magneto-optical properties of ion-implanted $(\text{YBiCaSm})_3(\text{FeGeSi})_5\text{O}_{12}$ garnet films after it was annealed at 270 °C.

This kind of the experiment is particularly interesting in the matter of annealing process as it reduces the implantation defects and restores crystalline structure of ferrite-garnet [1].

We have also determined the spectral dependences of the component of the tensor of dielectric permittivity for the surface of the ferrite-garnet films before and after implantation process.

These calculations let us evaluate the influence of implantation on an electronic energy structure of the surface layer for the sample [2].

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NEW METHOD OF PREPARATION OF SUPERPARAMAGNETIC NANOPARTICLES

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Magnetic nanoparticles have shown great potential in many biological and biomedical applications such as targeted drug delivery, magnetic fluid hyperthermia, magnetic resonance imaging, and tissue engineering [1]. All these applications require magnetic nanoparticles to be water soluble and biocompatible. For biological and biomedical applications, magnetic iron oxide nanoparticles are the primary choice because of their biocompatibility and chemical stability. Many synthesis methods have been explored for magnetic iron oxide nanoparticles. These include organic solvent heating method, polyol method, and co-precipitation method. The co-precipitation method is the most effective technique for preparing aqueous dispersions of iron oxide nanoparticles because the synthesis is conducted in water. For this report, we studied several biological molecules as surface coatings to achieve biocompatibility such as ascorbic acid, polyvinyl alcohol (PVA), poly(ethylene glycol) (PEG) and dextran. These molecules were used to control the particle size, to prevent the nanoparticles from aggregation, and to achieve biocompatibility.

The most conventional method for obtaining Fe₃O₄ is by co-precipitation [2]. The size and shape of the iron oxide NPs depends on the type of salt used (such as chlorides, sulfates, nitrates, perchlorates, etc.), the ferric and ferrous ions ratio, the reaction temperature, the pH value, ionic strength of the media, and the other reaction parameters (e.g. stirring rate, dropping speed of basic solution) [4].

But this method needs to be improved in order to raise monodispersity that is necessary in the case of biomedical applications [1]. To do this, we for the first time turn on the electrohydraulic effect (Yutkin effect) [3] in a well-known scheme for the treatment of nanoparticles in order to significantly reduce scatter radius of particles. To do this, we have a device created by us that is stationary pilot equipment. As a result, size radius of particles become almost same and the particle solubility in water is increased.

We carried out preparation of the magnetic colloid by an adapted co-precipitation method in the presence of electrohydraulic effect, with further magnetite stabilization. The samples are analyzed by VSM at room temperature to find the saturation magnetization of ascorbic acid coated iron oxide NPs.

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STUDY OF BIOLOGICAL NANOOBJECTS SENSORY BY NONLINEAR OPTICAL SPECTROSCOPY

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The new approach of study and detection of biological nano objects using their oscillation optical spectrum is the very interesting step for development of novel methods of different diseases treatment in the modern health care. Optical spectroscopy's advantage of providing detailed and vast amounts of information on the viruses and other microorganisms under investigation can also be its disadvantage. For future developments in viruses and microorganisms identification, new instrumental designs need to utilize recent advancements while exclusively focusing on specific clinical needs. Furthermore, by building up extensive and reliable databases with probabilistic identification algorithms, optical spectroscopy has real potential as a noninvasive, easy-to-use, fast and reliable characterization technique of viruses, ultimately giving identification at the single-cell level.

Unique characteristics of separate types the microorganisms, received by means of methods IR Fourier and Raman spectroscopy, found the application in case of pathogenic biological agents identification. Advantages of spectroscopy methods before traditional methods of laboratory diagnostics are connected to the minimum expenditure of a researched material, speed of output of the response, absence the long stages of sample preparation, need uses of labeled reagents and chromogenic substrates, possibility of detection hardly cultivated and not cultivated forms of viruses. All this specifies perspective of use of new nonlinear optical methods of spectroscopy for indication of pathogenic biological agents such are viruses and other pathogenic microorganisms provoking illnesses. For investigation of most suitable optical (vibrational) parameters of pathogenic microorganisms, including viruses, spread by an air flux by means of droplet of moisture and air-dust is necessary along with creation of advanced optical spectroscopy methods elaboration of optical nanoinstruments (sensors) which is the basis and challenge for development of novel measuring systems of XXI century health care.

In general there are two fundamental approaches for the new nano materials and devices realization: In a top down approach structures are miniaturized mainly by means of well-established metal powders or semiconductor structures and instruments fabrication technologies. In a bottom up approach, materials as well as functional systems are made by assembling of nanosized components like carbon nanotubes or DNA. There are several brilliant phenomena associated with micro – nano size materials and devices. At the same time it is necessary to take into account and find the limit of the miniaturization of micro- and nanostructures. It is very important to identify the classes of condensed matter substances and systems that are better suited to micro – nano world, where they will operate most effectively.

Nowadays, due to issues of proliferation of dangerous viruses such as Ebola, different flu viruses (H1N1, H1N2, H2N1, H3N1, H3N2, H2N3), and others it is the very necessary to elaborate the novel procedures of biological security which will be based on advanced science and technology methods such as nonlinear optical spectroscopy which should be the tool not only for detection of nano size pathogenic microorganisms but very effective method of their treatment as well.

SEMICONDUCTOR MAGIC NANO-CRYSTALS AND QUANTUM DOTS – STILL CHALLENGING?

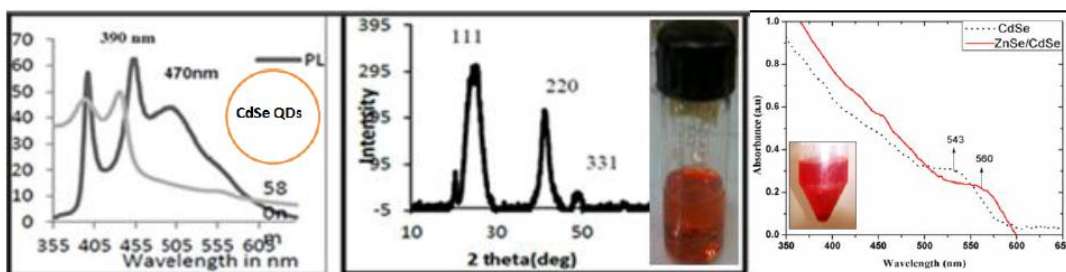
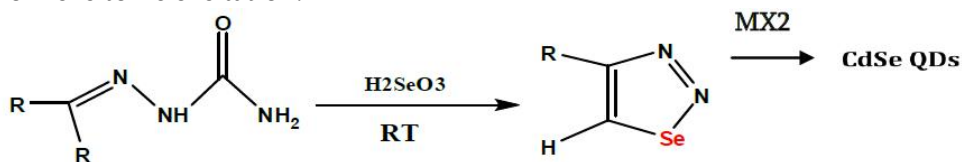
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Nanophotonics, light emitting diodes (LEDs), biology and solar cells have welcomed addition and studies on colloidal semiconductor quantum dots (QDs). The control of size and size distribution for the various applications is a challenging part of such materials, with reasonable design and understanding of growth and nucleation mechanism for these high tech tiny nano-crystals. Applications of 1,2,3-selenadiazoles in material chemistry are mainly due to their ability to release free active Se during thermolysis or photolysis. This presentation describes chemistry of various CdSe magic-size and ZnSe / CdSe core-shell QDs from new Se-precursor via semicarbazones and their conversion to respective 1,2,3-selenadiazoles that are prepared by solution or solventless methods and are characterized by NMR, IR and UV-Visible spectroscopy.

The new selenadiazoles are found to be excellent precursors for preparation of quantum dots of CdSe and other metal selenides which can alter the face of nanotechnology. Core-shell nano-particles are high end research target in nanotechnology. Core-shell metal nano-particles differ from their semiconductor counterpart. We have employed organo-selenium based synthesis for core-shell quantum dots and studied their optical properties. It is found that reaction of selenadiazole leads to slow release of free selenium which first generate the core semiconductor, i.e. CdSe, by reacting with cadmium acetate and continuous release of selenium from the same source reacts with zinc acetate in subsequent steps thus generating a unique method for synthesis of core-shell CdSe / ZnSe quantum dots in which CdSe core is coated with ZnSe shell or layer but core / shell may be altered if desired by the same method.

The optical behavior of such particles is dependent on ratio of selenium and metals, e.g. with increase in shell particles the band-gap shifts to red region. However, with increase of CdSe shell, the absorption wavelength moves to lower energy. Photoluminescence spectroscopy revealed multi centered peaks originated from excitonic excitation.



CdSe magic-size and ZnSe / CdSe core-shell QDs from new Se-precursor.

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LESS-COMMON, ULTRASMALL, AND RADIOACTIVE NANOPARTICLES

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When the nanotechnology are a began to develop intensively as an independent field in the frontiers of physics, chemistry, materials chemistry and physics, medicine, biology, and other disciplines two decades ago, such terms as “nanoparticle”, “nanopowder”, “nanotube”, “nanoplate”, and other related shape-like terms had rapidly become very common. For instance, a simple search using SciFinder results hundreds thousands of articles with keywords “nanoparticle” or “nanotube”. At the same time, during the last years, efforts of researchers have led to reports of enormous number of the nanostructure types above and the discovery of more rare species, such as “nanodumbbells”, “nanoflowers”, “nanorices”, “nanolines”, “nanotowers”, “nanoshuttles”, “nanobowlings”, “nanowheels”, “nanofans”, “nanopencils”, “nanotrees”, “nanoarrows”, “nanonails”, “nanobottles”, or “nanovolcanoes”, among many others. The problem how to name a discovered rare nanoform is commonly resolved according to imagination of researchers. Since any novel nanoform / nanostructure could theoretically get useful, unexpected and unpredictable applications (as, for example famous graphene, discovered not long ago [1]), each new achievement, reproducible or not, is welcome due to an extreme importance of nanotechnology at this moment and in future. Without a good understanding of the reasons for shape formation, approaches to the synthesis of nanostructures can be hard to carry out. According to the available literature, no any universal generalization of rare and common nanostructures is observed. Several existing classifications are related with dimensionality of the nanostructure itself and their components [2, 3] (for instance, 0D clusters and particles, 1D nanotubes and nanowires, 2D nanoplates and layers, 3D core / shell nanoparticles or self-assembled massives, intermediate dimensional nanostructures as fractals or dendrimers) or the classification based on the triad symmetry group-shell composition-structural formula of the shell (here nanostructures are divided in branches, classes, and subclasses determined by the symmetry group of a shell and the sets of the quantum numbers of a structure) [4].

In our presentation, we offer for discussion by the nanotechnological community a non-formal classification, which is not directly related with dimensionality and chemical composition of nanostructure-forming compound or composite and it is based mainly on the less-common nanostructures. The discussion is focused to the examination of less-common nanostructures (i.e., published mainly in the range of 1 – 100 reports) corresponding to the shapes above. Such structures possess unusual shapes and high surface area, which make them very useful for catalytic, medical, electronic and many other applications [5].

A special attention will also be paid to the nanoparticles having size range of 1 – 10 nm (ultrasmall particles [6]) and nanoparticles, containing radioactive elements [7]. These nanoparticles possess a series of useful applications (in particular, in nanomedicine and bionanotechnology) and are currently under extensive development.

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NANO LUMBER, INNOVATIVE CONSTRUCTION MATERIAL OF THE 21ST CENTURY

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Human used lumber to create working tools, battle equipment, living houses, fortification buildings, etc. since the ancient ages. Lumber was, is and always will be the most wanted ecologically clean material in world construction industry. Despite all the good features which lumber has – like: lightness, high strength of density, texture, easiness to obtain, nice color gamma and etc. – lumber and constructions made from it have some negative features: they are burnable, have low bio endurance, inclination to rotting, etc. These negative features are lowering the carrying capacity of the lumber. Mostly these are the reasons why the human uses other materials than lumber to construct their buildings.

Lumber of the coniferous trees is more used in constructions then the lumber of deciduous trees, because of their low technical indicators. By norms only 3rd and 4th quality lumber should be used in construction, which is the most among the woods which were cut down. 1st and 2nd quality lumber is very rear in the world construction market. In the researches to remake low quality lumber into high quality there are used the nanotechnologies.

In this report, there are reviewed nanotechnologies, which gives a chance with the deep treatment of the lumber to receive the new construction materials which gives the lumber unique features.

Using nano timber resolves many problems which have engineers while using lumber. These technologies will have great opportunity in the seismically active countries like Georgia and it will help to develop tree constructions.

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SENSITIVITY AND LOW-FREQUENCY NOISES OF GAS SENSORS MADE ON NANOSCALE COMPOSITE MATERIAL

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Thin film gas sensors made of nanocomposite $\text{In}_2\text{O}_3 \cdot \text{Ga}_2\text{O}_3 \cdot \text{SnO}_2$ (70 : 20 : 10) material have been manufactured by high-frequency magnetron sputtering method. The technological cycle of sensors manufacturing processes is described. Sensitivity of the prepared sensors at the temperature of working body 250 °C and low-frequency noises within the 1 – 300 Hz range are investigated. The response of sensors to vapors of ethanol and acetone was investigated using resistive and noise methods.

It is shown that the value of the sensitivity measured by the noise method exceeds the value of sensitivity measured by the resistive method. Sensors show appreciable sensitivity to the ethanol vapors already at working body temperature 150 °C. Sensors can be used for the detection of low concentrations of ethanol vapors.

The monotonous increase in the sensitivity of these sensors with increase in the ethanol and acetone vapors content allows applying nanoscale sensor also for a fast determination of gases concentration in air.

CARBON NANOCOMPOSITES PRODUCED BY HIGH PRESSURES AND HIGH TEMPERATURES

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On the turn of the last century, the newly coined word “nanotechnology” has become one of the most popular and widely used terms. Carbon nanostructures have been considering as the main initial materials suitable for the nanotechnology since fullerene discovery. New composites produced from carbon nanostructures at high pressures and high temperatures (HPHT) are attractive materials for many applications: in electronics, technics and in biology and medicine [1]. This presentation is addressed to our recent results related to the phase transitions in carbon nanostructures and properties of carbon nanocomposites.

To produce HPHT synthesis we used a high pressure chamber consisting of two truncated hemispheres of $\sim 2 \text{ cm}^3$ in volume or “toroid” type with $\sim 0.1 \text{ cm}^3$ in volume using press machine with the axial force of 1000 ton force. The synthesis time varied from 30 to 90 seconds and the temperature was up to $1650 \text{ }^\circ\text{C}$ [2], as initial materials we used fullerenes, detonation nanodiamonds and natural micron sized diamonds.

1. We revealed an unusual effect of fullerenes addition to the phase transformation of graphite to diamond at HPHT synthesis. It was shown that the graphite–diamond conversion efficiency increases in 1.4 times at $P = 5.5 \text{ GPa}$ and $T = 1200 \text{ }^\circ\text{C}$ if 0.015 to 0.3 % fullerene (of the graphite mass) is added to a mixture of a catalytic metal and graphite. The size distribution of the output diamonds produced with fullerenes is practically the same compared with that produced from control blend without additives. It has been shown that modification of graphite used in the synthesis of diamond in the presence of a metal catalyst Ni–Mn by low concentrations of a fullerenes extract of C_{60} – C_{70} at a pressure 5 GPa in the temperature range 1600–1800 K, reduces the activation energy of phase transition from the graphite–diamond from 160 ± 40 to $100 \pm 40 \text{ kJ/mol}$ [3].

2. We found a way to produce a diamond-copper composite with high thermal conductivity by capillary infiltration of copper into a bed of diamond particles of 180–400 μm size. The measured value of thermal conductivity of the composite ranged from 480 to 910 $\text{W} \cdot \text{m}^{-1} \cdot \text{K}^{-1}$ [4, 5].

3. The mechanism of detonation nanodiamonds sintering at HPHT has been studied. It was found the X-ray coherent scattering region increased from 4.5 to 12 nm at increasing temperature from 1200 to $1900 \text{ }^\circ\text{C}$ at 6 GPa. Possible mechanism of the sintering process was suggested. The thermal conductivity of detonation nanodiamonds samples sintered at the same temperature range is rising from ~ 5 to $\sim 40 \text{ W/m} \cdot \text{K}$. When sintering temperature is higher than $1900 \text{ }^\circ\text{C}$ nanodiamonds rapidly transform to graphite with increasing samples volume and increasing samples thermal conductivity up to $100 \text{ W/m} \cdot \text{K}$. The synchronous rise of thermal conductivity and X-ray coherent scattering region of nanodiamonds allows determining the nanodiamonds boundary thermal conductance. The value of nanodiamonds boundary conductance is about 3–4 $\text{GW/m}^2 \cdot \text{K}$. Thus Kapiza length for detonation nanodiamonds can be estimated at 670 nm [6, 7].

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GaN NANOWIRES ON Si (111) SUBSTRATES FOR GAS SENSOR APPLICATIONS

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Nanowires (NWs) made of GaN and related group III – N alloys, having a huge potential for new devices, attract much attention recently. The GaN-based materials are very thermally and chemically stable. This makes them very suitable for operation in chemically harsh environments. Therefore, wide band-gap group III nitride compound semiconductors are alternative options to supplement silicon, in particular in chemical sensor applications [1].

The aim of this paper is to report on our developments in applications of GaN NWs grown by plasma-assisted MBE on Si (111) substrates for simple gas sensing devices. Two types of growth procedures were used to prepare GaN NWs structures. The first one resulted in a dense ensemble of GaN NWs being $\sim 400 - 500$ nm long with diameter of 20 – 30 nm. They were homogeneously distributed and well oriented with the *c*-axis being perpendicular to the substrate. Density of nanowires was quite large ($\sim 250 \mu\text{m}^{-2}$). Therefore, even a small tilt of them, estimated from XRD to be below $\pm 2^\circ$, led to a partial coalescence in upper parts of NWs. In the second procedure, after growth of $\sim 1 \mu\text{m}$ long NWs, the conditions were changed to Ga-rich by increasing the Ga flux and reducing growth temperature. As the result the NWs were overgrown with a planar GaN layer.

Two types of GaN NWs based gas sensors were fabricated. For the planar device (Fig. 1) samples with ensemble of GaN NWs grown on semi-insulating Si (111) substrates were used. Then, Ti / Al / Au electrical contacts were defined on the surface by standard photolithography and lift-off processes and annealed to form low resistance source and drain electrodes. Since NWs were closely packed thin bridges connecting them were created in the active area of the device between the electrodes. In the vertical sensor devices (Fig. 2) electrical resistivity *along* the NWs, *not across* the NWs as in a planar geometry, is measured. In such a case, we used conductive Si substrate and the NWs overgrown with a compact GaN layer. Then, the mesa-type sensors were made by dry etching and metal deposition techniques. Finally, both types of structures were electrically tested in NO₂, NH₃ and hydrogen atmospheres at temperatures up to 80 °C to check and compare their gas sensing properties.

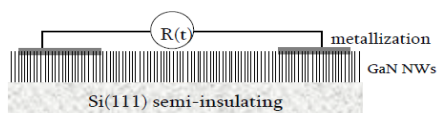


Fig. 1. Planar gas sensing device.

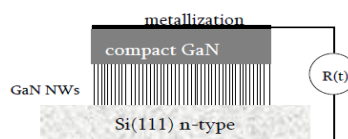


Fig. 2. Vertical gas sensing device.

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TEMPERATURE-FREQUENCY DEPENDENCES OF ELECTRICAL PROPERTIES OF METAL-DIELECTRIC $(\text{FeCoZr})_x(\text{CaF}_2)_{100-x}$ NANOCOMPOSITES

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In this paper temperature and frequency dependencies of electrical properties of metal-dielectric nanocomposites films, prepared by ion-beam sputtering of complicated target in the argon and oxygen atmosphere, are presented. For measurements of $(\text{FeCoZr})_x(\text{CaF}_2)_{100-x}$ nanocomposites, prepared by ion-beam sputtering in the atmosphere of argon and low content of oxygen (argon pressure $P_{\text{Ar}} = 8.1 \cdot 10^{-2}$ Pa and oxygen pressure $P_{\text{O}_2} = 9.0 \cdot 10^{-3}$ Pa) and in the atmosphere of argon and high content of oxygen (argon pressure $P_{\text{Ar}} = 8.5 \cdot 10^{-2}$ Pa and oxygen pressure $P_{\text{O}_2} = 4.3 \cdot 10^{-2}$ Pa), were chosen.

A computer stand for testing of electrical properties of nanocomposites in the range of temperature from 80 to 373 K with 5 K step, available in Department of Electrical Devices and High Voltage Technologies at the Lublin University of Technology, were used. All measurements on the alternating current in the range of frequency from 50 Hz to 5 MHz were performed.

The aim of this paper was to determine the effect of the oxygen beam, used in the process of $(\text{CoFeZr})_x(\text{CaF}_2)_{100-x}$ nanocomposites production, on their electrical properties. Measurements of conductivity, phase angle and capacity were made and their dependences of temperature and frequency were determined.

The work and investigations were carried out as a research project No IP2012 026572 within the Iuventus Plus program of Polish Ministry of Science and Higher Education in the years of 2013–2015.

AC ELECTRIC PROPERTIES OF NANOCOMPOSITES PREPARED IN VACUUM CHAMBER BY ION SPUTTERING

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In this paper there are shown results of measurements of electric properties of nanocomposites $\text{Cu}_x(\text{SiO}_2)_{100-x}$, $(\text{FeCoZr})_x(\text{Al}_2\text{O}_3)_{100-x}$, $(\text{FeCoZr})_x(\text{CaF}_2)_{100-x}$, and $(\text{FeCoZr})_x(\text{PZT})_{100-x}$ prepared in vacuum chamber by ion sputtering.

Measurements were carried out within the frequency range 50 Hz – 5 MHz for measurement temperatures from 77 to 373 K.

Comparison of results obtained for nanocomposites prepared by pure argon ion sputtering and by mixed beam of argon and oxygen ions was presented. It was established that when the mixed beam of argon and oxygen ions was used the phase angle becomes positive, which is connected with creation of coat consisting of oxides of metallic phase atoms on nanogranules surface. In nanocomposite $(\text{FeCoZr})_x(\text{CaF}_2)_{100-x}$ coat consists of oxides and fluorides of metallic phase atoms, which broadens the range of phase angle changes to the area over $+90^\circ$.

The work and investigations were carried out as a research project No IP2012 026572 within the Iuventus Plus program of Polish Ministry of Science and Higher Education in the years of 2013–2015.

EuMgB₅O₁₀ AND EuP₃O₉ NANOSTRUCTURES WITH ONE-DIMENSIONAL ENERGY TRANSPORT

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Processes of energy migration in EuMgB₅O₁₀ and EuP₃O₉ were investigated in our work. As was shown in the range of papers [1, 2] such structures possess strong anisotropy and are quasi-one-dimensional. Mechanisms of excitation energy delocalization in EuMgB₅O₁₀ and EuP₃O₉ matrices have been investigated by means of spectroscopic techniques.

Luminescence spectrum of EuMgB₅O₁₀ shows the most intensive luminescence at 610 nm corresponding to ⁵D₀ → ⁷F₂ luminescence band. Decay curves for EuMgB₅O₁₀ were taken at 610 nm for 10, 77 and 300 K. These curves are shown in the Fig. 1. The 300 K decay curve exhibits more pronounced deviation from monoexponential decay law than curves taken at 10 and 77 K.

In the case of one-dimensional (or quasi-one-dimensional) energy transport the long-time part of decay curve must follow the law: $I = I_0 \exp(-t/\tau_0 - Bt^{1/3})$ [3]. Approximation of decay curves by this law confirms one-dimensional type of energy migration in EuMgB₅O₁₀ and allows to determine energy migration rate B that increases from 1.5 to 3.4 ms^{-1/3} at temperature increase from 77 to 300 K.

Contrary to this decay curve for EuP₃O₉ at 300 K is monoexponential with $\tau \approx 4$ ms, while at 10 K the curve shows a sufficient deviation from monoexponential decay law (Fig. 2). For 10 and 77 K the curves are coincident. Analysis of decay curves has shown that the mechanisms of energy migration in these materials are sufficiently different from the ones taking place in EuMgB₅O₁₀. While for EuMgB₅O₁₀ the most effective energy transport takes place at 300 K via ⁵D₀ → ⁷F₁ transitions of Eu³⁺ ion, for EuP₃O₉ energy transfer is more effective at 10 K and mediated by Eu³⁺ – O²⁻ CT states.

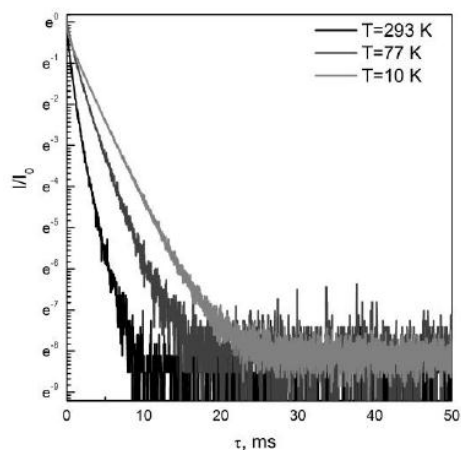


Fig. 1. Decay curves of ⁵D₀ → ⁷F₂ for EuMgB₅O₁₀ at different temperatures.

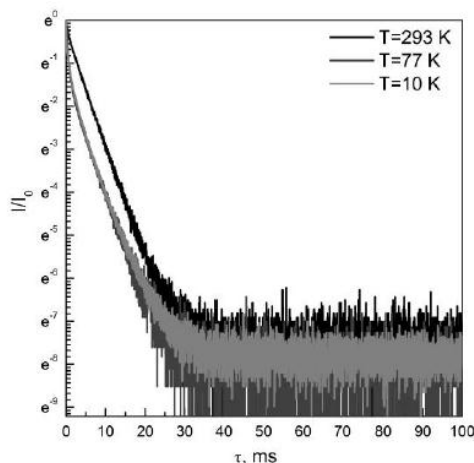


Fig. 2. Decay curves of ⁵D₀ → ⁷F₂ for EuP₃O₉ at different temperatures

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TO THE KINETICS OF QUANTUM DISSIPATIVE SYSTEM: QUANTUM BROWNIAN PARTICLE MOTION

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New exact generalized quantum evolutionary (kinetic) equations for the equilibrium double-time correlation functions of a quantum dynamic system interacting with a thermostat were derived in the case of linear as to the Bose-amplitudes it's interacting with the phonon (boson) field. The random phase approximation (RPA), factorizing initial condition, has not been used to derive those equations. In the initial moment of time for the correlation functions a thermal initial conditions were used. The generalized Bogolubov's lemma for a dynamical system interacting with the Boson field is proved and used for excluding the dynamical variables of a thermostat (boson amplitudes) from the derived kinetic equations. The collision integrals of these equations include explicitly both the dissipative terms describing the systems' dynamics and the terms responsible for the time evolution of the initial correlations.

The derived equations are used to analyze the kinetic and linear transport phenomena in exactly solvable model of the quantum dissipative system: A quantum Brownian particle, dynamics of which is described by the Caldeira–Legget Hamiltonian. The specific kinetic equations and formula are obtained and the influence of the initial correlations is discussed.

The splitting time of the correlation functions (the relaxation time) and the mobility of the Brownian particle were calculated.

EPOXY / CARBON NANOTUBES COMPOSITES: EFFECT OF FUNCTIONALIZATION ON ELECTROMAGNETIC PROPERTIES

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Epoxy resins constitute the basis of one of the most important thermoset polymers. They are widely used for the manufacturing of advanced composites in applications ranging from microelectronics to aerospace. The use of carbon nanotubes (CNT) as a filler in epoxy resin has attracted great attention due to the possibility to improve the properties of the resin. The unique structure of carbon nanotube, their low density, high surface area, and high aspect ratio provide a wide range of extraordinary characteristics, for example, superior mechanical properties, excellent electrical and thermal conductivities, great thermal

stability and reluctance toward chemical agents. Chemical functionalization of CNTs is reported as way to improve poor dispersion and compatibility of CNTs in epoxy resin [1].

Although many progresses have been achieved in investigations of polymer nanocomposites with carbon nanotubes, in recent years they have gained a big momentum due to its potential applications as novel electromagnetic (EM) materials. The CNT has two kinds of structures including the symmetry and chirality, where the chiral structures enhance the EM wave absorption performance of CNTs. The analysis of electromagnetic interference (EMI) shielding efficiency (SE) of composites based on different polymers matrix and CNTs becomes a very popular topic in material sciences [2].

In the present study we stress on the effects of surface functionalization of multi-walled CNTs (MWCNTs) with aromatic amines through mixing on the rheological characteristics of the dispersions in epoxy resin, as varying nanotube contents from 0.03 to 0.3 wt. %. It is proved experimentally that amine functionalization may have different effect on dispersion state, rheological, DC conductivity, radio frequency and microwave response properties. We observed the lower rheological and electrical percolation threshold for the composites filled with non-functionalized MWCNT, and at the same time higher absolute values of dc conductivity in the case of using non-functionalized fillers.

In contrast to that, in radio frequency range, 1 – 20 kHz, significant effect of functionalization on the values of ac conductivity has been observed for small MWCNTs concentrations, 0.08 wt. %. At 1 kHz we find that MWCNT functionalization leads to ac conductivity rise on almost 3 orders of magnitude vs. the conductivity of epoxy filled with the same concentration of non-functionalized MWCNTs.

Finally, we do not find any difference between EM behavior of functionalized and non-functionalized MWCNT within epoxy resin in microwave frequency range for all concentrations. The absolute values of MW attenuation do not depend on the type of MWCNT used, just on its concentration and the thickness of epoxy coating. The EMI SE up to 17 dB has been observed for 10 mm thick resin loaded with 0.3 wt. % of MWCNTs, which is compared with results collected for polymer composites filled with nanotubes, carbon black and carbon onions in much higher concentrations (2 – 5 wt. %) [2].

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REMAGNETIZATION AND MAGNETORESISTANCE EFFECT IN MAGNETIC NANOSTRUCTURES UNDER FEMTOSECOND PULSED LASER IRRADIATION

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Physical limits of the minimal remagnetization time and minimal sizes of a remagnetization media represent one of fundamental problems of the physics of magnetism, which has a crucial significance for realization of ultra-fast and ultra-dense recording and readout of information [1]. Growing attention to this problem is related to modern achievements of nanotechnologies, possibility to produce of new magnetic nanostructures with given physical properties and the novel development of ultra-fast laser sources. Today, prospects of the solution this problem associates with the use of the impact of femtosecond laser impulses on

the ferrimagnetic multilayered nanostructures, specifically, tunnel magnetic junctions, that can lead to magnetic state variations and the remagnetization effect.

The laser-induced remagnetization of a ferrimagnetic nanolayer under femtosecond pulsed laser radiation is characterized by its initial laser-induced swift heating, thermal demagnetization with different speeds of ferrimagnetic sublattices with subsequent a magnetic bias that can be caused both laser-induced electron excitations (the inverse magneto-optical Faraday effect) and nonequilibrium transitional ferromagnetic-like magnetic states combined with exchange interaction relaxation [2].

We have investigated features of the laser-induced remagnetization and magnetoresistance effects, under the femtosecond pulsed laser radiation, in magnetic tunnel junctions on the basis of the RE-TM amorphous compounds, TbCoFe with strong enough perpendicular magnetic anisotropy and the magnetic compensation temperature T_M and the Curie temperature T_C , which can be tuned in wide temperature range by varying its composition. The tunnel barrier nanolayer consisted of PrO compound representing a wide-gap semiconductor. By the all-optic pump-probe technique we investigated the laser-induced remagnetization of the TbCoFe-based magnetic junctions under femtosecond pulsed laser radiation. It was established the role of the laser-induced effective internal magnetic fields related to the magneto-optical inverse Faraday effect and the laser-injection spin nonequilibrium redistribution in the magnetization reverse of the investigated magnetic junctions. The influence of a transient ferromagnetic-like state on the magnetization switching in the ferrimagnetic junctions was studied. One together with an exchange interaction relaxation [3] can lead to the pure laser-induced thermal remagnetization.

The ferrimagnetic TbCoFe compounds in contrast to well-known [1, 2] ferrimagnetic compounds, GdFeCo, which were wide used as the physical model for the investigation of mechanisms of ultra-fast laser-induced remagnetization, possess strong enough perpendicular magnetic anisotropy that determine their practical applications for high-speed and high-dense recording of information.

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INFLUENCE OF SOME METAL IONS ON LOW TEMPERATURE TRANSFORMATION OF ALUMINA METASTABLE OXIDES IN α -Al₂O₃

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Ceramic obtained on the base of aluminum oxide has wide application range, because it has unique properties, for example, wear-resistance, dielectric characteristics, and exploitation-ability at high temperatures and in corrosive atmosphere. During the transformation of the phases of aluminum hydrates, different forms of Al₂O₃ (α , χ , η , δ , θ , γ , ρ) are obtained. It is established, that generation of thermodynamically stable phase (α -Al₂O₃) takes place above 1200 °C, on account of which size of the initial

crystallites increase by 3 – 10 times. Many scientific-researching centers work on this problem and lots of chemical methods are used for low-temperature $\gamma > \alpha$ or $\theta > \alpha$ phase transitions: During low-temperature phase transformation formation of agglomerates decreases. Present work deals with possibilities of low-temperature transformation of the oxyhydroxides obtained by transition of alumina isopropoxide via sol-gel method in α - Al_2O_3 during existence of small amount of rare-earth elements' compounds. Low-temperature synthesis of α - Al_2O_3 is energy-economical process and it is perspective for developing technologies of corundum ceramics fabrication.

Mixture ($\text{Al}_2\text{O}_3 \cdot n\text{H}_2\text{O}$) is obtained in a result of hydrolyze of alumina isopropoxide and its peptization is carried out by adding of nitric acid. Cerium, holmium, thorium, gadolinium, dysprosium and lanthanum nitrates are added to the sol specimens in amount of 0.1 – 0.2 mas. % calculated on metals. Drying of dopant-added sols is conducted at 120 °C. It is established, from IR spectroscopy, that gel consists nonhydrolyzed Al – O – C bonds too. Annealing of obtained gels is carried out at 500, 800, 1000, 1100, 1200 °C for 2 h. It is established, from the X-ray-phase analysis that, during presence of holmium generation of α - Al_2O_3 begins below 1000 °C. The same specimen at 1100 °C transforms in α - Al_2O_3 . At this temperature in case of presence of lanthanum, dysprosium, cerium and gadolinium transformation takes place by 70 – 85 %. In case of presence of thorium stabilization of γ - and θ -phases takes place. It is established, that thorium causes inhibition of α -phase generation at 1100 °C at the time when in all other doped specimens the α -phase is generated at lower temperatures (1000 – 1050 °C). According to the DSC data in the interval of 200 – 600 °C all specimen are characterized by dehydration of alumina oxyhydroxides and generation of alumina unstable compounds. They mainly consists of from γ - and θ -phases.

Microstructure of the powders and the produced corundum product was studied by optical and electronic scanning microscopes (Nikon ECLIPSE LV 150, NMM-800TRF, Nanolab-7). Grain size and fraction distribution of the synthesized powder was established by Analysette 12 Dyna sizer. Phase analysis of the specimens was conducted on the X-ray diffractometer DRON-3M (Cu- $\text{K}\alpha$, Ni filter, 2° / min).

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NANOSENSOR FOR THERMOELECTRIC SINGLE-PHOTON DETECTOR

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The thermoelectric single-photon detector (TSPD) is one of the real competitors to superconducting detectors for single photon detection in a wide range of the electromagnetic spectrum [1]. Single-photon detectors are required in research in different areas of modern science, particularly in space astronomy, high energy physics, quantum-computing and quantum cryptography. They can also serve as a basis for development of a new generation of measuring systems for applications in medicine, homeland security, elemental microanalysis, analysis of defects in microchips, etc. [2].

The TSPD operation principle is based on photon absorption by absorber as a result of which a temperature gradient is generated on the edges of the sensor. Photon detection becomes possible by measuring the potential, emerging between the two absorbers. The scheme of the TSPD sensitive element has been given. Materials which can be used to prepare the absorber and the sensor and the achievable count rates and energy resolution are given in publications [1, 3]. A conclusion is done according which the thermoelectric detector may possess an energy resolution of 0.1 eV and a gigahertz level count rate. The conception of TSPD using a nanoscale sensor is proposed in [4].

In the present work the results of modeling of kinetic processes in the thermoelectric detector sensor after photon absorption are presented. Different geometries of the TSPD with sensor size decreases from microns to nanometers are considered. The time dependence of the electric potential appearing on the sensor is calculated. Examples of such dependencies for tungsten absorbers and a cerium hexaboride sensor for 100 eV photons absorption operating at 9 K have been given. We have determined the optimal dimensions of the TSPD sensor and of the absorber to achieve high count rates for different energies of photons.

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NANOTECHNOLOGY AND SEMICONDUCTOR DEVICES

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Nanotechnology is defined as the manipulation of matter with at least one dimension sized from 1 to 100 nanometers. Although modern semiconductors manufactured are measured in nanometers, production of semiconductors is not traditionally classed as nanotechnology. Nanotechnology is likely to manifest itself in the semiconductor industry as semiconductor devices. The examples of modern semiconductor technology are quantum dots, quantum wires or nanotubes and quantum wells. The physical properties and various methods of fabrication III – V semiconductor QD's are described in [1]. Because of its dimensions nanostructured materials are useful to interact with light, and it is thought that twenty-one century will be the era of photons. Although one use of III – V semiconductor QD's is high effective light emitted devices, as well as and wavelength conversion changing emitted light to the desired spectrum, the resent works show that two main field of application QD are: a new class of fluorescent materials for biosensor, and energetic materials for new generation solar cells [2].

The method of electrochemical deposition of metals (In, Ga, Al, Sb, Bi, Cu, Ni, Ag, Pt, Pd, Fe) on semiconductor surface was used for fabrication of various semiconductor devices [2 – 5]. By deposition of the III group metals (In, Ga) on III – V semiconductor GaP, followed with heat treatment in hydrogen, it was obtained the nanostructured layer $\text{In}_x\text{Ga}_{1-x}\text{P}$ on GaP surface, and the possibility of application of obtained structures for quantum dot solar cell was theoretically investigated [2].

The current research is an attempt of obtaining spintronic material by original method of electrochemical deposition of ferromagnetic metals on the GaAs surface [4] and investigation of their electrical and photoelectric properties. The process steps are improved and novel process techniques are developed for manufacturing of GaAs-based devices.

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MAGNETIC NANOCOMPOSITE FeFe₂O₄&Au⁰ FOR BIOMEDICAL APPLICATIONS

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Over the last several years, magnetic nanoparticles have attracted considerable attention because of their immense qualities for functioning at the cellular and molecular level of biological interactions [1, 2]. These require manufacturing approach, which enable distinctive controllable properties of nanostructures such as size, shape, magnetism, active surface etc. Thereupon, nanocomposites with magnetic core material and precious-metal coating seem to be one of the most promising.

Ferrimagnetic FeFe₂O₄ & Au⁰ composite was formed by means of the rotation-corrosion dispergation procedure [3]. Its physicochemical parameters were assessed using transmission electron microscopy (TEM), X-ray diffraction (XRD), and fluorescence spectroscopy techniques (Fig. 1).

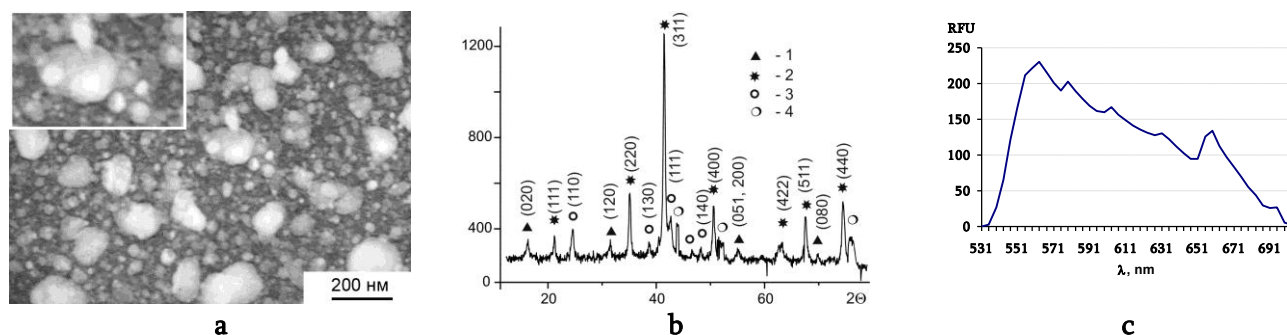


Fig. 1. Nanosized FeFe₂O₄ & Au⁰ composites: a – TEM-image; b – XRD-pattern, legend numerals correspond to 1 – γ-FeOOH, 2 – FeFe₂O₄, 3 – α-FeOOH, 4 – Au⁰; c – fluorescence spectra.

According to the TEM images, the majority of obtained nanocomposite structures had 40 nm mean diameter, with spheroidal magnetite core, while sometimes the associations of two or even three core structures coated with common gold shell were formed. The XRD-pattern of the nanocomposite had shown ferrous to ferric oxidation upon an atmospheric oxygen exposure. These conform the porous shell structure, which is fully expected for the gold to iron weight ratio in the nanosized FeFe_2O_4 & Au^0 estimated as 0.7 : 93.3. During the nanocomposite excitation by broadband light source 500 – 650 nm the fluorescence spectra were recorded (Fig. 1c) that attributed to surface plasmon resonance [4]. The occurrence of plasmonic peaks shift to far red frequency range, probably due to core associations, is the most remarkable finding, as it fits with so called ‘transparency window’ for body tissues.

Thus, core–shell nanocomposite FeFe_2O_4 & Au^0 formation exploiting the proposed methodology may have good prospects for biomedical applications, especially as a platform for molecular therapeutics.

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ANTIMICROBIAL PROPERTIES OF FeFe_2O_4 & Ag^0 NANOCOMPOSITES

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Nanocomposite structures comprising a magnetic core and a silver cover were proved as a promising candidate to fight against Hospital-acquired infections with high resistance to antimicrobial agents, which occur in patients of Resuscitation and Critical Care Units [1].

Our previous studies had showed apparent anti-inflammatory properties of FeFe_2O_4 & Ag^0 nanoparticles together with positive impact upon phagocytic component of immune system in experimental zymozan peritonitis [2]. Hence, the objective of the work presented was to test presumed antimicrobial activity of this nanocomposite in experiments on gram-positive and gram-negative bacterial cultures.

Core–shell type nanoparticles FeFe_2O_4 & Ag^0 were formed on the steel surface contacting with AgNO_3 water solution, which contained 15 mg Ag^- per liter in open-air system [3]. Before the experiment the source sole of nanoparticles was evaporated up to one fifth of the initial volume and further treated keeping sterile conditions. Bacterial suspensions of *S. Aureus* and *E. Coli* containing $4 \cdot 10^5$ CFU were diluted with equal volume of 2- and 5-fold concentrated soles of the nanocomposite, respectively. After 1 h incubation 20 μl of each suspension were seeded at plain agar in 35 mm Petri dishes and harvested for 24 h at 37 °C. The samples diluted with 0.85 % saline instead of the nanocomposite were used as reference.

The results of CFU counting have showed high efficacy of FeFe_2O_4 & Ag^0 nanopcomposite against both gram-positive and gram-negative pathogens (Fig. 1).

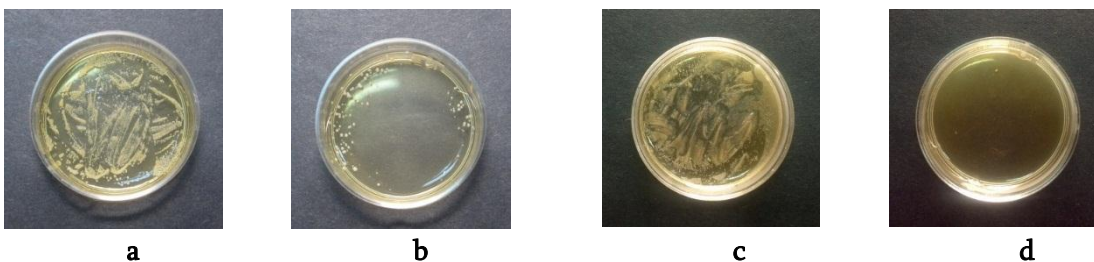


Fig. 1. The activity of FeFe_2O_4 & Au^0 nanoparticles upon the bacterial cultures growth: a, b – *S. Aureus* and c, d – *E. Coli* (reference vs. nanocomposite treated plates).

Multiple fading of the CFU counts in the nanocomposite-treated plates is indicative of its high antimicrobial activity. Additionally, superparamagnetic properties due to magnetite core of the nanocomposite enable its targeted deposition using external magnetic field.

Thus, FeFe_2O_4 & Ag^0 nanocomposites have good prospects for the development of the novel anti-infectious agents suitable to overcome Hospital-acquired antibiotic resistance.

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ON ELECTRICAL PROPERTIES OF SELF-ORGANIZED GRAPHENE / GRAPHITE STRUCTURES

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Recently, the agenda of extensive search of simple and low-cost nanomaterials includes also the opportunities offered by pencil drawn line i.e. rubbed graphite layers of nanoscale thickness [1, 2]. More recently, electronic components made of pencil drawn line have been investigated [3]. The main tendency in research is aimed at working out sensors or other elements of primary signal registration. On the other hand, first in-depth investigation of such layers exhibit promising properties to be functionalized in more complicated electronic components [4].

We investigated electrical properties of graphite layers obtained by rubbing directly on insulating substrates. It was found that the layers rubbed on different insulating materials behave similarly.

First, one can obtain resistance of such layers in a wide range, from 10 s of $\text{M}\Omega$ to $\text{k}\Omega$. Temperature dependence of electrical resistance shows that these layers behave like a semiconducting material and shallow energy levels reflecting the sliced package of the structure contribute in carrier transport. Namely, the rubbed layers with low conductance exhibit strong T -dependence and the less is the resistance the weaker is the dependence. No metallic conductance was observed.

For optical observation of the topography of rubbed off layers we used water soluble NaCl crystalline substrate to separate obtained graphite structure. Flat structures up to 1 cm² in size as well as sustained 3D hollow cylinders and hemispheres of ~ 1 mm diameter built of rubbed graphite walls were separated. Optical observation of separated layers shows that some part of layers remains transparent during manifold rubbing, which indicates on nanoscale thickness of such areas. Estimation the thickness revealed that the layers contain areas of several monolayer thicknesses. Comparative analysis of optical images obtained by transmission and reflection microscopy revealed that a transparent lamina of few-layer graphene is formed in rubbed off layers. Mapping of layer thickness over a wider area shows that 2 to 6 layer graphene are in comparative majority within transparent regions. We obtained $I-V$ characteristics of a separated transparent area which exhibited symmetrical non-linear behavior with larger slope near zero bias which is specific to graphene structures.

Optical observations allowed us to sketch out the strata of the rubbed layers. We distinguished three levels of the structure: 1) the bottom layer comes from deep trenches or pores in the substrate filled with graphite flakes; 2) a layer of transparent lamina above the substrate; 3) ridge-like structures at the top, formed along rubbing direction. Correspondingly, high surface conductance is due to microscale thick graphite ridges, and the semiconducting properties come from few-monolayer-thick lamina.

Our findings acknowledged the unique behavior of graphite drawn layers as a solid state material. The distinctiveness of layer formation, temperature behavior of its electrical conductivity as well as its electrical characterization testified to the existence of modified electron gas in obtained structures. We explain this as a consequence of self-organization process and formation of dissipative lamina at interface of friction. Accordingly, the shaped lamina with the thickness of a few basic carbon planes alters the physical behavior of the whole rubbed off graphite drawn structure.

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LUMINESCENCE CENTERS IN STOICHIOMETRIC AND NON-STOICHIOMETRIC CeO₂ NANOCRYSTALS

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Cerium dioxide (CeO₂) is widely used in many technical application such as catalysis, gas sensors, electrochromic and UV coatings, etc. At last time, many researches focused on nanocrystalline CeO₂ due to

possible applications in the field of electroluminescent devices, integrated optics and in biomedicine [1]. Antioxidant properties of CeO₂ nanocrystals allow using this material in the wide range of biomedical applications [2, 3]. The CeO₂ has fluorite-type structure with face-centered cubic lattice. Non-stoichiometric oxides (CeO_{2-x}) are characterized by disordered arrangement of oxygen vacancies. Oxygen non-stoichiometry defines basic biomedical properties of cerium oxide – the ability to participate in redox processes taking place in the organism [4]. Literature data on the structure and properties of nanosized CeO_{2-x} often contradict each other. Moreover, most of the properties of nanocrystalline CeO_{2-x}, remain almost unexplored.

The CeO₂ nanocrystals with different degrees of oxygen stoichiometry have been investigated by means of luminescence spectroscopy techniques. It was shown that luminescence of CeO₂ is determined by two optical centers of different nature: the first one Ce⁴⁺ – O²⁻ complex and the second one Ce³⁺ ions. The ratio of Ce⁴⁺ / Ce³⁺ centers depends on the amount of oxygen vacancies. Therefore, the variation of ceria stoichiometry allows changing the concentration of Ce⁴⁺ – O²⁻ and Ce³⁺ luminescence centers (Fig. 1). Luminescent characteristics of optical centers in non-stoichiometric CeO_{2-x} nanocrystals have been investigated. Investigation of splitting of Ce³⁺ 4*f*–5*d* luminescence excitation band has shown that reduction of Ce⁴⁺ occurred mainly by the mechanism of oxygen vacancy formation on the nearest-neighbor position to the cerium ion. Thermo luminescent analysis showed the presence of shallow electron traps associated with oxygen vacancies.

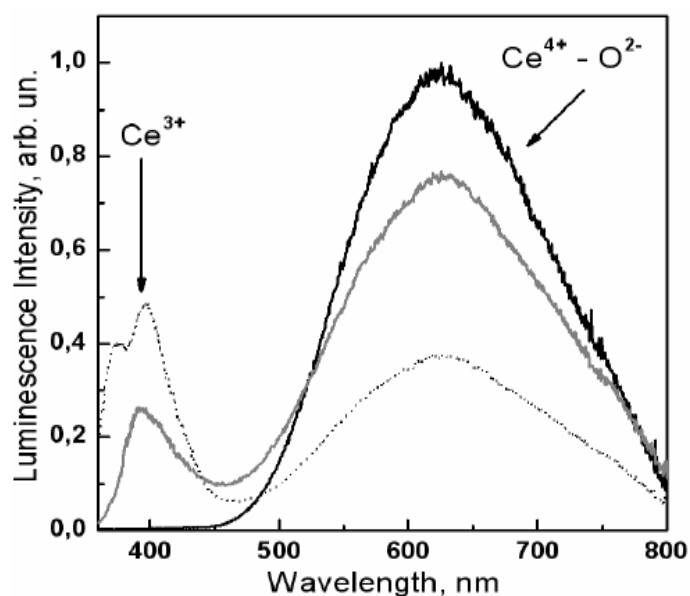


Fig. 1. Luminescence spectra of CeO₂ nanocrystals with different oxygen stoichiometry.

Variation of the Ce³⁺ / Ce⁴⁺ ratio in CeO₂ allows controlling the oxygen non-stoichiometry by luminescence properties of this material. Size dependence of oxygen non-stoichiometry for CeO₂ nanocrystals was shown.

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CHALLENGES AND PERSPECTIVES OF NANOSCALE ELECTROMAGNETICS

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A great progress has been achieved during last two decade in the synthesis and fabrication of different nanostructured artificial materials with fascinating mechanical, electronic and optical properties irreducible to properties of bulk media. Accompanied by the impressive parallel development of the characterization techniques and measurement instrumentation, this process necessitates the revision of traditional concepts of physics and chemistry of condensed matter, adapting them to peculiarities of the nanoworld and significantly extending our knowledge of the nature of solids and our capabilities to control their properties.

Following this general trend, a research discipline – *nanoelectromagnetics* – is introduced as a synthesis of macroscopic electrodynamics and microscopic theory of electronic properties of different nanostructures. The approach is exemplified by carbon nanotubes (CNTs) and briefly touches upon other nanocarbon forms. The method of effective boundary conditions is shown to be a universal tool for the study of electrodynamic problems of nanotubes. Electromagnetic scattering theory is applied to calculate polarizabilities of finite-length single- and multi-walled carbon nanotubes (SW- and MWCNTs) in terahertz and IR ranges. Antenna properties of CNTs and CNT bundles are described. The influence of the length and diameter of a MWCNT and electron relaxation time on the regime of the CNT interaction with an electromagnetic field is analyzed. We demonstrate theoretically the dominant role of finite size effect in the non-Drude conductivity of CNT films due to the strong slowing down of surface polariton in CNT [1, 2]. Significant screening effect is demonstrated to be inherent to electromagnetic response of MWCNTs films at gigahertz frequencies while it practically disappears in the THz range. The main features of the gigahertz and terahertz spectra of effective permittivity and electromagnetic interference shielding efficiencies of a MWCNT-based composite observed previously in experiments are systematized and described.

The experimental evidence of the CNT length-dependence of the THz spectra of SWCNT films [3] is also presented and discussed. The experiments have been carried out with films comprising calibrated in length CNTs [4]. We show blue shift of the THz peak in conductivity spectra of SWCNT thin film with decreasing SWCNT length. Thus, experimental results demonstrate the phenomena of localized plasmon resonance in SWCNTs and prove theoretically predicted antenna effect in SWCNTs in terahertz and far-infrared ranges.

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THE MULTIWALLED CARBON NANOTUBE–MALEIC ANHYDRIDE–OCTENE1 NANOCOMPOSITE AS THE MATRIX FOR CdS NANOPARTICLE SYNTHESIS

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Semiconductor CdS nanocrystals – a member of the II – VI group of materials finds application in production of phosphor [1], solar cells [2], sensors [3], light emitting diodes [4], photocatalyst materials [5] and lasers [6]. If the polymer grafted multi-walled carbon nanotubes (MWCNTs) will be used as the matrix for the synthesis of the CdS nanocrystals, the advanced products with invaluable features for application at above mentioned fields will be obtained [7].

In this work, “grafting from” approach was used to graft Maleic anhydride-Octene1 copolymer macromolecule to oxidized MWCNTs. Then the process was continued by the synthesis of the CdS nanocrystals in this matrix under ultrasonic cavitation. The obtained polymer nanocomposite was characterized by several instrumental investigation techniques like FTIR, XRD, TEM, SEM, UV–Vis, Raman spectroscopy, thermogravimetric analysis and etc. These techniques prove the completion of the synthesis process and reveal the accuracy and significance of the method. The TEM images show clear appearance of uniform CdS nanocrystals in the nanocomposite matrix.

The adhesion effect and tendency to form entangled stacks generally make MWCNTs unusable for manufacturing advanced plastic materials. However, grafting MWCNTs with maleic anhydride-Octene1 copolymer via the “grafting from” approach gives us the opportunity to overcome this problem and to develop a new matrix for nanofabrications. Moreover, synthesis of the CdS nanocrystals within this matrix gives us the advanced nanocomposites promising new opportunities. Therefore, the obtained material can be a precursor for the manufacturing the advanced plastic-composite materials or an additive to construction materials for strengthening purposes and it can improve the semiconductor technology.

The novelty of this work is the first time use of MWCNT–MA–Octene1 matrix obtained via grafting from approach for synthesis of the CdS nanocrystals under ultrasonic cavitation to obtain the polymer nanocomposite with advanced properties for future applications.

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DEVELOPMENT NOVEL NANOSTRUCTURED Cu – W COMPOSITES AND INVESTIGATION THEIR STRUCTURE / PROPERTY RELATIONSHIP

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Copper–20 wt. % tungsten (Cu–20W) powder mixtures were consolidated into cylindrical rods using both hot shock wave consolidation (HSWC) and hot vacuum compaction (HVC) processes. Two types of Cu–W precursor compositions, one type with a nanometer-scale W and another with coarser grain sizes of $> 1 \mu\text{m}$ W were consolidated to near theoretical density at 800 and 1000 °C. The shock wave loading intensity was about 10 GPa; the loading intensity during static compression was 33.9 MPa (346 kg / cm²).

The investigations showed that the combination of high temperatures (above 800 °C) and the use of a two-stage shock wave processing method were found to be beneficial to the consolidation of the Cu–20 % W composites, resulting in high densities, good integrity, and good electrical properties. The structure and property of the samples depended on the distribution and size of the precursor W particles. It was established that for the Cu–W composites, the use of the nanoscale W precursor gave better results than that with the $> 1 \mu\text{m}$ grain size. Specifically, the coefficient of relaxation is lower, equaling to 4.3 – 8.6 *versus* 8.0 – 10 for the Cu–W composition made with the larger, micrometer W grain size. It was further established that the electrical properties of the consolidated composites with nanoscale W are characterized with higher resistance and lower dependence of the susceptibility with the applied external magnetic field.

It was demonstrated that HEC undoubtedly has advantages compared to other technologies (e.g., HVC) allowing the fabrication of novel Cu–W composites with improved electrical properties, sometimes even better than those of pure Cu.

NANO AND NANOSTRUCTURED HYBRID MATERIALS SYSTEMS FOR MULTIFUNCTIONAL APPLICATIONS

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Carbon nanotubes and graphene are almost perfect molecule with truly amazing combinations of thermal electrical and structural properties. In order to achieve their full potential they need to be fully

integrated hybrid materials in all sorts of matrices. Full integration requires their development beyond conventional composites so that the level of the non-nano material is designed to integrate fully with the amount of nanotubes and graphene. Here the nano materials are part of the matrix rather than a differing component, as in the case of conventional composites. In order to advance the development of multifunctional materials integrating nanotubes and graphene, this research is focused on the simultaneous control of nanoarchitecture, structural properties, thermal and electrical conductivity of fully integrated hybrid materials. These are hybrid materials systems designed to surpass the limits of rule of mixtures engineering and composite design. The goals are to implement multifunctional designs to fully mimic the properties of carbon nanotubes and graphene on larger scales for enhanced thermal and electrical management in addition to the control of other properties such as strength, toughness energy and power. These new approaches involve exfoliation, functionalization, dispersion, stabilization, alignment, polymerization, reaction bonding and coating in order to achieve full integration. Typical examples of structural applications of polymeric and ceramic matrices and applications in energy systems such as capacitors and batteries as well as other material systems are presented and discussed.

DNA AND PAMAM DENDRIMERS AS CATALYSTS IN REDUCTION REACTIONS AND NANOTECHNOLOGY

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Absorption spectra of AgNPs and of the following complexes DNA – AgNO₃ – AgNPs, DNA – AgNO₃ – AgNPs – AA are presented. It can be seen that AA reduced silver ions in ternary complex DNA – AgNO₃ – AgNPs. Thus, AgNPs activate the process of quick reduction of Ag⁺ ions to silver atoms. Analyzing absorption spectra we can draw the following conclusions:

- 1) Ag⁺ ions interfere in H₃O⁺ ion mobility and prevent oxidation of AgNPs, and
- 2) AgNPs in their turn activate the process of Ag⁺ ions reduction in the presence of AA. AgNPs absorption spectra shift to red side (6 – 7 nm) and significant increase of absorption spectra intensity undoubtedly point out the increase of AgNPs size in the complex with DNA.

It should be underlined that without DNA nothing happens to AgNPs in water solution.

Besides, silver-encapsulated PAMAM dendrimers which are stable nano-size complexes easily soluted in water and lipids, were created and investigated by spectroscopic and thermodynamic methods. They have strong absorption in active spectral areas used in phototherapy and bionanophotonics.

THE EFFECT OF ELECTROHYDRAULIC DISCHARGE FOR HIGH DISPERSIVE MAGNETIC NANOFLUID SYNTHESIS

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Fluids containing magnetic nanoparticles represent the colloidal dispersion of magnetic materials (ferromagnets: magnetite, ferrite) with particle size of 5 to several tens of nm, which are stabilized into polar (water or alcohol) or nonpolar (hydrocarbons and silicones) environment through surfactants or polymers (surface active substances). Principle of stability in colloidal systems is provided by interaction between particles together with Brownian motion, which compensates gravitation (the Brownian motion must overcome co-precipitation velocity), according to this the nanoparticles (which volume fraction is no more than 25 % in liquid) are at the equilibrium state.

According to this, for synthesis of magnetic liquid it is necessary to solve some problems: First of all it is necessary to gain magnetic particles with size no more than 8 – 15 nm and to cover the particles of dispersive phase by the stabilizer molecules, which must prevent the agglomeration of particles and at the same time provide formation of steady colloid system of one-domain magnetic particles, dispersed in a liquid-carrier. Chemical deposition, by general point of view, don't gives finely divided (< 10 nm) homogenous dispersion [1, 2], because in the liquid medium there are some micro and > 10 nm sized nanoparticles, some chemical radicals and conjugates represented.

We proposed usage of electrohydraulic effect [3] for during and after synthesis of magnetic nanofluid for better disperse synthesized nanofluid by breaking up μm and tens of nm sized particles into smallest pieces (< 15 nm).

The essence of this method consists in discharging by special pulse electrical current into covered or open vessel constituting magnetic fluid into two discharging rods resulting high hydraulic pressure around discharging zone accomplished by useful mechanical work, for our case – mechanical breaking. Adding several kV voltage on the discharging rods the impulse amplitude riches tens of thousands ampere resulting instant and significant increasing the pressure in liquid provoking formation of the ultrasonic striking wave. The moving velocity of the fluid volume riches hundreds of m / s. Resonant processes and strong infra and ultra-oscillations additionally dispergate and dismiss large materials, breaks through the sorption and chemical conjugates in the fluid [3]. Electromagnetic field of discharge also influences on ionic characterization of the medium and thus stabilization of dissolution.

Low concentration magnetite nanofluid processed by electrohydraulic discharge and ultrasonic waves. After precipitation the supernatant area of the fluid measured for absorbance on spectrophotometer which show increment in concentration of small particles < 15 nm. Fluid homogeneity and superparamagnetic behavior revealed also from magnetic measurement data.

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STRUCTURAL SPECIFIC FEATURES OF COORDINATION COMPOUNDS OF SOME METALS WITH SULFANILAMIDE PREPARATIONS

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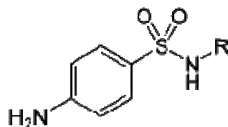
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*Dedicated to the Memory of Prof. Arsene Shvelashvili,
Associated Member of the National Georgian Academy of Sciences*

The mechanisms of action and transformations in the organisms of many known medicinal substances have not been thoroughly studied and clarified so far. To reveal possible changes at the molecular level, we must know not only the elemental composition of chemical compounds, but also their structure, i.e. the spatial arrangement of atoms in the molecules (ions) that the crystals of medicinal preparations are constructed of without this knowledge, it is impossible to reveal the mechanism of transformations of the preparations. The knowledge of the exact spatial structure of medicinal substances is important for, first of all, understanding of the mechanism of interaction of medicinal substances with the macromolecules of enzymes, protein hormones, receptors, etc. This, in its turn, can be the basis for creation of new-generation medicinal preparations, the molecules (ions) of which more intensively and specifically will have an effect on the functions of particular enzymes and receptors.

Sulfanilamides are similar just as in their composition and properties, so in the values of geometric parameters of the structure. They always contain a sulfamide (sulfonamide) group—SO₂—NHR, while the R-radical is of a heterocyclic character (R = pyrimidine, pyridazine and heterocycles). At the same time, from the stereochemical stand point, sulfanilamide anions having the N, O and S donor atoms can play the part of both bridge and bidentate-cyclic ligands.



This paper deals with the comparative characterization of the structures of studied sulfanilamide-containing compounds, and revealing of the differences in the composition of their structural elements and of significant changes in the geometric parameters characterizing the structure.

In the crystalline compounds we studied, sulfanilamides in the deprotonized state (the proton breaks from N—H, and the corresponding anion is formed) are external-sphericacido-anions and very rarely participate in the formation of coordination bonds.

The explanation of the obtained results by a steric effect prompts that, if these compounds participate in complex formation, only trans-forms of polyhedrons are formed.

In the described crystalline coordination compounds (M(II) = Mg, Mn, Co, Cu, Zn), sulfanilamides are external-sphericacido-anions, while in the compounds [M(Aet)(OH₂)₅](Aet)·kH₂O (where M(II) = Sr and Ba, Aet – the etazol anion, k = 3 and 2) – one of two anions is coordinated to the metal, playing the part of bridge bidentate – cyclic ligand. According to the obtained data, the bath angle Θ varied within the range of 55 – 100 °, and the (CSNC) torsion angle Φ – within the range of 55 – 70 °. The exception was the compound [Ni(R)₂(OH₂)₂] (where R is the sulfapyridazine anion), for which $\Phi = 7.2$ °.

NANOELECTRONICS SENSORS BASED ON SILICON-ON-INSULATOR TECHNOLOGY.

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From the first designed silicon integrated circuits (IC) and up to now the aim of IC design was to minimize the active elements (transistors) dimensions. Now topologic norms for IC diminished from about 100 μm to nanoscale. So microelectronics developed into nanoelectronics and thus allowed to design ultrafast operating and ultra large ICs. Such transformation required to develop some new technological processes. Among them so-called “silicon-on-insulator” technology (SOI) was of fundamental importance as a base of creation three-dimensional, two-dimensional, one-dimensional nanostructures and devices.

Using of SOI technologies provided essential improvement of electrical characteristics of silicon sensors and their stability to external extreme influence of irradiation and temperature. It is important that constructions of SOI transistors with nanothickness channels automatically ensure transformation of traditional resistive type passive sensors (Hall elements, thermistors, piezoresistors, photoresistors, etc.) into active converters of external influences on the base of field transistors with control system of metal-dielectric-silicon-dielectric-metal (MDSDM) type. This construction provides the possibility of various methods of signals inducted by external influence processing. In particular channel current modulation by gate potentials can be used to increase signal-noise ratio. Also it is possible to use heterodynous schemes for measuring alternative external actions and to apply the feedbacks between sensors signals and control gates. Above mentioned is illustrated by the example of SOI MDSDM Hall probe, temperature and pressure sensors which parameters are drastically better as compared with conventional Si analogue.

It will be also demonstrated that creation of SOI sensors with nanoscale channel makes possible to design chemical and biological sensors with unique sensitivity and selectivity. In turn one-dimensional Si thread formed from Si layer of SOI structure can be used for development of new sensors with very high sensitivity including sensors on the base of photonic crystals.

APPLICATION OF STRUCTURAL NANOMATERIALS IN PETROLEUM INDUSTRY

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Nanotechnology is a rapidly growing technology with considerable potential applications and benefits, to effect revolutionary changes in several aspects of the oil and gas industry. While tangible benefits realized in oil and gas industry, the area of construction to the oil industry has been slow to embrace the new technology. The construction sector might accommodate broad applications of nanotechnology and nanomaterials in several areas of the oil and gas industry, such as exploration, drilling, production and enhanced oil recovery. For example, lighter, stronger and more long lasting structure; low maintenance coating; better properties of cementitious material and steel alloys; construction related smart

sensors for monitoring of the structural integrity. In short, there are numerous areas in which nanotechnology can contribute to more efficient, less expensive and more environmentally sound technologies. In this paper, a broad overview of potential application of various nanotechnology developments in the construction of oil and gas fields is discussed. The potential opportunities and challenges that face future trends of nanotechnology application in this field are also discuss.

FEATURES OF CHANGES IN ELECTRON CONCENTRATION IN n-Si CRYSTALS IRRADIATED WITH HIGH-ENERGY PROTONS

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There are studied the zone-melting n-Si single crystals with electron concentration of $5 \cdot 10^{13} \text{ cm}^{-3}$. These samples were irradiated with 25 MeV protons within the dose range $(1.8 - 9.0) \cdot 10^{11} \text{ cm}^{-2}$ at room temperature (300 K). The studies were conducted using the Hall measurement method in the temperature range of (77 – 300) K. It was found that increasing in the electron concentration values within the above specified range with dose of irradiation and reaches values of about 10^{14} cm^{-3} . In our opinion, the increase in electron concentration with increasing in radiation dose is associated with radiation annealing of nanoscale growth defects of vacancy-type and releasing the phosphorus dopant atoms blocked inside these defects. Radiation annealing, i.e. destruction, of growth defects of vacancy-type takes place due to their interaction with interstitial silicon atoms, which together with other point defects are generated during the irradiation.

PHYSICAL PROPERTIES OF THE TRANSPARENT AT VISIBLE REGION OF LIGHT, CONDUCTING DIAMOND LIKE CARBON NANOSTRUCTURE FILMS

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One of the many forms of carbon, so called diamond like carbon (DLC) or tetrahedral amorphous carbon consists mainly of sp^3 and sp^2 bonded carbon atoms. The structure of DLC film is changed depending on relation of sp^3 / sp^2 phases and accordingly changed their main physical properties: electrical, optical and structural parameters.

DLC shows different electrical properties ranging from insulating diamond to metal graphite. It can behave as a semiconductor and is able to accept dopant. The electrical resistivity of insulating DLC can be reduced by doping, using various elements. The layers of n-type DLC conductivity is received by doping nitrogen [1], and p-type - by doping boron [2].

In this paper the technology of creation of DLC films with electrical conductivity, transparent in the visible region of light, and the results of their electrical, optical and structure investigations are presented. Structural investigations were carried out by atomic force microscope (AFM) and scanning electron microscope (SEM). The DLC films with electrical conductivity were created by plasma evaporation of mixed vapors of toluol, argon, and nitrogen on the silicon surface (n-Si and p-Si) and on the glass.

The electro-physical investigations were carried out by measuring of Si-DLC-Cu structure impedance, i.e. $C-V$ and $G-V$ characteristics on homemade low resistance bridge device at frequencies of electrical field from 30 kHz to 1 MHz and amplitude of 50 mV. Also $I-V$ measurements of Si-DLC-Cu were carried out, and the conductivity type, charge carriers concentration and mobility were measured by the Hall method.

DLC films with n-type conductivity of $10^{-3} \Omega \cdot \text{cm}$, mobility of $3500 \text{ cm}^2 / \text{V} \cdot \text{s}$ and thickness of 200 nm were received by doping of nitrogen on n-Si. Structures on p-Si show specific for p-n junction sharp increase of electrical current at the voltage -3 V . The dielectric permittivity ϵ' of the n-Si-DLC-Cu structure significantly increased ($\epsilon' = 16$ at 30 kHz, $V = 0$) in comparison with non-doped samples ($\epsilon' = 3.5$) [3] and showed strong frequency dependence: ϵ' increased from 7.4 to 17 with decrease of electrical field frequency. Tangent of angle of dielectric losses $\tan(\epsilon''/\epsilon')$ also showed strong frequency dependence from 0.55 to 3.10 with decrease of electrical field frequency.

It was revealed that the transparency of DLC films is 80 % at visible region of spectrum and structural measurements showed that these films consist of nanosized conducting clusters with distances where the mechanism of hopping conductivity is realized.

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NANOSIZE EFFECTS IN CATALYSIS

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In contrast to chemical kinetics, thermodynamics is so far not very actively used for describing the state and behavior of operating heterogeneous catalysts. The reason is indeed the non-equilibrium state of operating catalysts that does not allow common equilibrium thermodynamics to be used. In the last decade, however, there was a progress in understanding how the approaches of non-equilibrium thermodynamics could be applied to operating catalysts.

The presentation gives two examples of such applications related to nanosize properties of the active phase of many catalysts. First of all, this is an explanation of superlow temperature of melting nanoparticles of metal catalysts active in the carbon nanofiber production. Another example is semiquantitative description of the size effect on activity of at least metal catalysts.

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PREPARATION AND PERSPECTIVES OF MAGNETIC AND NANOSIZED METAL CONTAINING AMORPHOUS CARBON COMPOSITE CHEMOSORBENTS AND CATALYSTS

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Amorphous carbon and its composites are widely used materials in various field of chemistry, for example as adsorbents, chemosorbents, catalysts, and support materials. The properties of these carbonaceous materials are strongly depends on the nature and size of the materials distributed within or on the surface of the carbon network.

A simple method has been developed to prepare nanosized (10-100 nm) metal, metal-oxide, metal-sulphide (or nitride and carbide) containing amorphous carbon nanocomposites with ball-like shape, high hardness, low hydrodynamic resistance, and some other advantageous physical and chemical properties which can widely be used in various fields of industry and environmental protection.

The metal forms of various sulphonate or iminodiacetate functionalized styrene-divinylbenzene copolymer ion-exchangers, loaded partially or completely with various valence state of metal ion salts such as Cu, Ni, Mn, Zn, or Fe with different counter ions such as chloride, nitrate, or sulphate, are carbonized at 500 – 1000 °C for 2 – 10 h with dry or water saturated hot N₂ stream. Selecting appropriate synthesis conditions, the products are amorphous carbon composites containing nanosized metal, metal oxide or metal sulphide. The nanosized metal or metal-compound containing carbons prepared in this way are promising new materials and could effectively be used as chemosorbents or catalyst precursors, for example

- Metal-sulphide (MnS, FeS, NiS, ZnS) containing chemosorbents for mercury removal;
- Metal-oxide type or metal sulphide (ZnO or ZnS) carbon composites for photocatalytic reaction for COD removal from wastewaters; or
- Metallic nanosized copper containing carbons as chemosorbents for mercury, radioactive iodine, or as catalysts for preparation of triazoles;
- Iron oxide containing carbons can be tested as sorbents for phosphate or arsenic removal from drinking water and as catalyst for waste free synthesis of paracetamol;
- Nanosized iron containing carbons can be used as magnetizable carbon supports for noble metals (Pd, Au, Pt, Rh, Ir, Ru, Ag) or Cu catalysts.

Besides the type of functional groups of ion exchanger and the type and valence of the used metals, the reaction temperature, reaction time, and cross-linking of starting polymer matrix have strong influence on the size, nature, and properties of the formed metal (metal oxide or sulphide) species located in the amorphous carbon.

Nanosized metal sulphide type chemisorbents has been prepared in the concurrent reduction of metal centers and sulphonate groups of metal forms of sulphonated ion exchangers. In the case of electronegative metals, the reduction of sulphonate groups leads to formation of lower valence metal sulphides such as MnS, FeS, ZnS or NiS, while in the case of copper, only metallic copper and sulphur dioxide are formed. Similar conditions in the case of carboxylate type ion exchangers led to metallic Cu but to ZnO, MnO, or NiO. In case of iron(II) and iron(III) forms of ion-exchangers, depending on the reaction temperature, valence state of iron salt used and the reaction time, amorphous carbons formed containing different nanosized magnetic phases (FeO, Fe₂O₃, Fe₃O₄, and Fe) (Fig. 1).

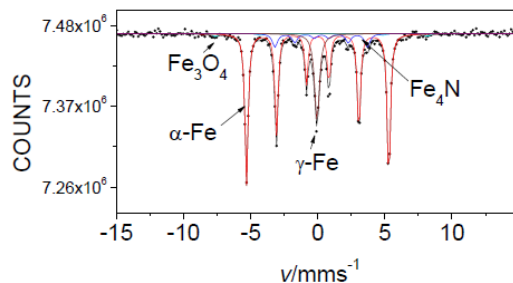


Fig. 1. Mössbauer spectra of a carbonized sample prepared from FeCl₃ and iminodiacetate functionalized styrene-6 %-co-divinylbenzene ion exchanger sample at 600 °C for 4 h.

Using iminodiacetate type (divalent metal ion selective) ion exchangers, the role of counter-ion of used metals salts becomes one of the key factors, especially in the case of three-valent metal salts, when not only the protonated nitrogen atom of iminodiacetate group but the third valence of the used metal (e.g. Fe(III)) are compensated with the negative charge of the original counter ion of the used metal salt. For example, in case of iron(III)-loaded resins, the iron(III) chloride loaded resin gives metallic iron and mainly magnetic iron oxide type carbons, but the [-CH₂-NH⁽⁺⁾(COO)₂⁽²⁻⁾(Fe⁽²⁺⁾)]SO₄⁽²⁻⁾ type iron(III) sulphate loaded resin gives FeS_{0.95} (pyrrhotite) containing carbon phase.

It is a special interest, that iron(III) nitrate loaded iminodiacetate-type resins gave mechanically strong, ball-like (due to high crosslinking with 6 % of divinylbenzene) metallic iron or magnetic iron-oxide containing carbons, which proved to be magnetic. Due to its mechanical strength this product is a promising carbon carrier with magnetic properties, which has superior importance in removing the carried valuable catalyst materials like noble metals. Although the low surface area of a balls do not allow fixing large amount of catalytically active species, controlling the carbonisation process of iron(III) nitrate loaded iminodiacetate type resins (900 °C, 2 h), a mass of carbon nanotubes covered balls are formed (Fig. 2).

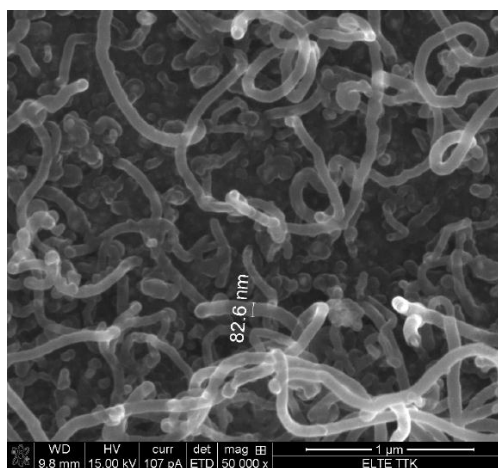


Fig. 2. Scanning electron microscopic picture of carbon-nanotube covered magnetic carbon balls (iminodiacetate type resin, iron(III) nitrate loading, 900 °C, 2 h).

These nanotube covered balls have higher carbon surface as the simple carbon balls, so deposition of noble metals (Pd, Pt, Ru, Rh, Ir, Au), Cu, Ag, or other metals or compounds results in a magnetically separable carbon carried catalyst with good mechanical properties, in the form of free-flowing 100 – 200 micron balls. There is an interesting and simple way for the metallization of these magnetic carbon carriers using cementation, if the deposited metal is more electropositive than the iron itself. It means that immersing the iron-containing carbon balls into the solution of noble metals, noble metals are deposited onto the surface of nanotubes and iron(II) ions go into solution. In this way, a room temperature controlled metallization can be performed. Using this method a platinum covered magnetic carbon, which can be used in hydrogenations, aminations, and some other organic reactions, and removable with a simple electromagnet from the reaction medium, has been prepared and its SEM picture is shown on Fig. 3.

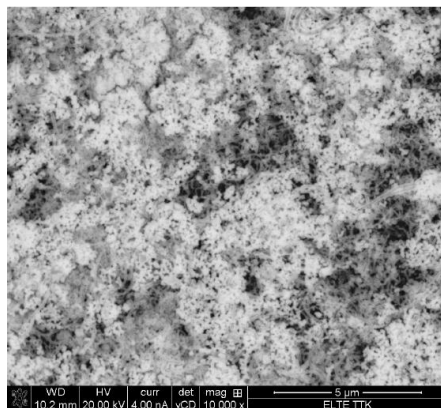


Fig. 3. SEM picture of a 100 nm size over-loaded Pt particle containing magnetic carbon ball catalyst.

The perspectives of using this kind of magnetically separable and movable (within the stainless steel or glass reactors) catalyst carriers and catalysts are enormous. Further perspective is removing carbon or iron from the covered balls. For example, removing carbon (C–H₂O reaction catalyzed by iron) from the balls covered with iron on the surface gave an empty iron network in ball form, which is a perspective material to catalyze gas–gas reactions like ammonia synthesis or Fischer–Tropsch (gasoline) synthesis, because the resistance of empty ball like iron clathrate cage contains holes for gas stream and the surface area is extremely high (Fig. 4).

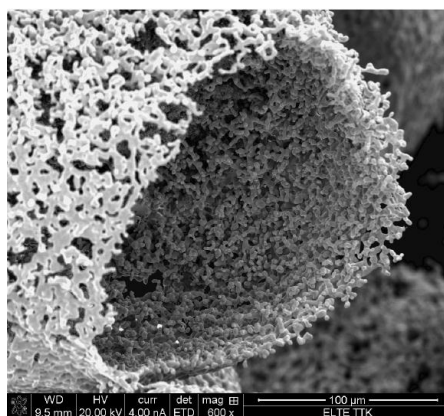


Fig. 4. Cage-like ball-shape metallic iron network prepared from iron covered carbon balls.

Removal of iron (with acidic leaching) and carbon from noble metal covered clusters to prepare similar cage-like empty and hole-containing noble metal networks are in progress.

PREPARATION OF SILVER NANOPARTICLES IN SILVERNITRATE SOLUTION BY USING TANNIN

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Recently the interest in the research and preparation of nanosized particles of silver has significantly increased. This interest was boosted by the fact that there opened new vistas for application of nanomaterials in many fields of science and industry, in particular, for production of new efficient catalysts, for designing of new elements of optical systems, for synthesis of new materials etc. Their capability of effective interaction with light quanta is of particular interest. This capability is due to the plasmon resonance, which is collective oscillation of conduction electrons of the metal. Therefore, silver nanoparticles are promising construction blocks for photon and plasmon devices. Besides, the silver nanoparticles are widely used in biology, medicine and agriculture. The methods of synthesis of silver nanoparticles can be divided into physical, chemical and biological ones. From the chemical methods, the reduction of silver particles from water solutions of silver salts in the presence of various stabilizers is the most common. As is known, the kinetics of formation of metal particles and their dispersion depend on the origin and concentration of the reductant, the temperature of the solution and the type of a stabilizer [1].

In work [2], the process of preparation of silver nanoparticles from silver nitrate with glucose as a reductant under microwave treatment and the optimal synthesis conditions were reported. The authors of work [3] studied silver hydrosols with the electrostatic stability factor by using the methods of macroelectrophoresis, spectrophotometry and electron microscopy.

In this work, the reduction of silver nanoparticles from its nitrate by using tannin was studied. Sodium carbonate was used as a reductant. Silver nitrate was placed in a reaction test tube, the 1 % tannin solution was added drop by drop. After thorough continuous stirring, a few drops of 1 % sodium carbonate were added to the mixture. The resultant mixture was thoroughly stirred, and the hydrosol gained a light brown color, which pointed to the emergence of nanoparticles. The samples made were of the following concentration of AgNO_3 : $5 \cdot 10^{-2}$, $5 \cdot 10^{-3}$ and $5 \cdot 10^{-4}$ M.

The optical spectra of the obtained solutions were investigated by using UV-visible Spectrometer Sintra 10e. All solutions showed the absorption peak at 420 nm. The electronmicroscopic examination by using transmission microscope JEM-100 SX showed that the solutions under study contained mainly the silver nanoparticles 60 – 140 nm in size. After being subjected to the microwave field, the nanoparticles underwent subsequent dispersion and their size decreased to 10 – 20 nm. The experiments showed that it was possible to prepare silver nanoparticles from silver nitrate at room temperature.

Relatively simple technology, low-cost chemical reagents and good reproducibility of the process make this method quite promising for preparation of silver nanoparticles.

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HOT EXPLOSIVE CONSOLIDATION OF NANOSTRUCTURED TUNGSTEN–SILVER PRECURSORS

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Different precursors of refractory nanostructural W–Ag composites were consolidated into cylindrical billets by hot explosive consolidation (HEC) method. Different types of compositions with a nanoscale W phase (100 nm) and coarse matrix phase of Ag were consolidated to near theoretical density under and above of melting point of Silver (940 &– 1050 °C). The intensity of loading in all experiments was around 10 GPa. The combination of high temperatures and two stage explosive densification processes was found to be beneficial to the consolidation of the nanostructural W based composites, resulting in high densities, good integrity, and good electronic properties. The structure and property of the samples depends on the value of consolidation temperature and dimension of consolidated particle sizes. It was established that for the W–Ag based composites application of high temperature and consolidation of precursors near melting point of silver 940 °C gives good result and samples without cracking, high value of density and uniform distribution of consisting phases were obtained. The above mentioned and other features of structure / property relationship in depending on phase content and consolidation conditions, as well as the HEC technique will be presented and discussed.

PLASMON ENHANCED FLUORESCENCE OF THIACYANINE DYE IN L–b–L POLYMER FILM

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In recent time nanophysics has been developed rapidly. One of the perspective branches of nanophysics is the creation of hybrid systems consisting of organic and inorganic components, for example, such systems as organic fluorescent dye molecules and nanoparticles of noble metals. Nanoparticles of noble metals have a unique collective property of plasmon resonance. This effect is widely used for creation of chemical and biological sensors. Interaction of surface plasmons with bio-objects (DNA, viruses, antibodies) allows to increase the intensity of fluorescence of bio-objects up to one order of magnitude. So the surface plasmon resonance (SPR) effect sufficiently increases the possibility of detection, identification and diagnostics of biological objects.

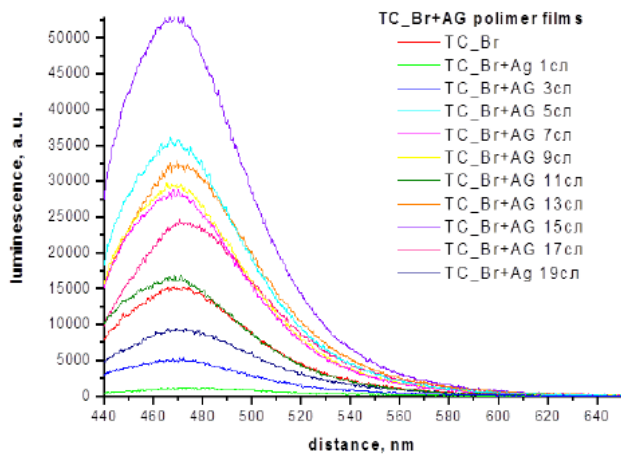


Fig. 1. Luminescence spectra of “TC Br dye monomers + Ag nanoparticles” with different distances between monomers and Ag nanoparticles.

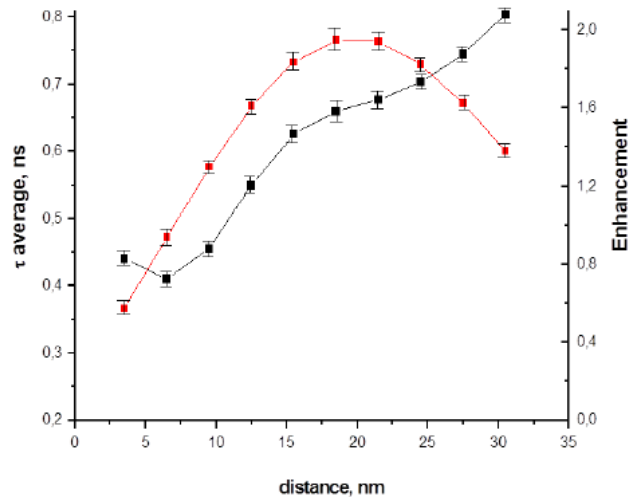


Fig. 2. Dependence of decay time and luminescence enhancement on the distance between monomers and Ag nanoparticles.

In this paper, we discuss a system consisting of inorganic Ag nanoparticles and organic TC Br luminescent dye (that can be used as fluorescent probe). Control by the luminescent properties of the monomer band of the hybrid complex was carried out by variation of the interaction between the metal particles and the monomers. Value of exciton–plasmon interaction was controlled by deposition of different numbers of polymeric layers between nanoparticles and TC Br monomers. During the experiments, the possibility of both increase and quenching of TC Br luminescence band was shown (Fig. 1). Using the luminescence spectra and luminescence decay curves we have constructed a diagram (Fig. 2). The maximum increase of luminescence intensity in 3.5 times in comparison with the original value at deposition of 15 polymer layers (24.5 nm) was found.

THERMO-ELECTRICAL, STRUCTURAL AND STABILITY PROPERTIES OF (Bi₂O₃)_{1-x-y}(Eu₂O₃)_x(Er₂O₃)_y NANOPARTICLES FOR SOLID OXIDE FUEL CELLS

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In recent years, many experimental researches have mostly focused on improving of the Bi-based electrolytes which have high oxide ionic conductivity at low temperatures and better performance as alternatives to traditional stabilized zirconia has taken place. Generally, these systems are much better solid electrolytes than well-known stabilized zirconia, because some of the bismuth trioxide phases exhibit higher ion conductivity than other oxide ionic conductors [1]. Doped-Bi₂O₃ materials of solid electrolyte systems are good oxygen anions O²⁻ conductors which have collected much attention as potential solid

ceramic electrolytes for solid oxide fuel cells (SOFCs) because of their relatively high oxygen ionic conductivity at lower temperatures [2 – 4]. (Bi₂O₃)-based electrolytes have also wide other technological applications in devices with high economical interest such as oxygen sensors, ceramic membranes for oxygen separation, oxygen pumps, catalyzing of some heterogeneous reactions, partial oxidation of the hydrocarbons and additive material in paints [5 – 6].

In this study, europium(III) oxide and erbium(III) oxide doped bismuth trioxide solid solutions, the (Bi₂O₃)_{1-x-y}(Eu₂O₃)_x(Er₂O₃)_y ternary system were obtained with $x = 10.15$ mol. % and $y = 5.20$ mol. % dopant concentrations have been synthesized in air atmosphere and electrical conductivity properties of the samples have been investigated by 4-point probe technique. The crystal structure of the (Bi₂O₃)_{1-x-y}(Eu₂O₃)_x(Er₂O₃)_y has been determined by X-ray powder diffractions (XRD) measurements before and after electrical conductivity measurements of the samples. Thermal behavior and thermal stability of the phases were investigated by differential thermal analysis (DTA). The samples which synthesized in this study can be used in diverse industrial applications such as electrolytes of the solid oxide fuel cells (SOFC).

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NANOSIZED SILICA WITH HIGH CONTENT OF METHYL GROUPS IN SURFACE LAYER

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Polydimethylsiloxanes have been applied for preparation hydrophobic nanomaterials, particularly fumed silicas, with high contents of grafted organic groups in the surface modifying layer. These products are widely used as active fillers for polymeric systems, effective thickeners of dispersive media and nanosized powders in modern materials science. However, chemisorption of polydimethylsiloxane chains on the silica surface require significant energy expenditure and modification processes are usually carried out at the relatively high temperatures (about 400 °C). Decreasing in temperature of chemical treatment of the silica surface and using of the cheaper modifiers with high molecular weights are main tasks in the realization of modification processes with PDMS application. Herein we are developed an approach to synthesis of hydrophobic disperse silica materials modified with PDMS.

Fumed silica with a specific surface area of 300 m²/g (Kalush, Ukraine) has been taken for modification. PDMS–5, PDMS–20, PDMS–50 and PDMS–100 (Kremnepolimer, Ukraine, the number is a kinematic viscosity of polydimethylsiloxane oligomer in Centistokes) were used as modifying agents. Modification of silica surface was performed in the reactor with a mixer at 200 °C for 2 h with or without dimethyl carbonate (DMC) or diethyl carbonate (DEC) (Sigma–Aldrich).

Thermal properties, structure and functionality of the grafted surface layer were studied by thermogravimetric method, IR-spectroscopy. Number of organic groups in the grafted layer of modified silica has been estimated from the data of elemental analysis. The results are shown in Table 1.

Table 1. Basic parameters of samples thermal decomposition (T_{initial} , T_{max} ($T_{\text{max}2,3}$), T_{final} , $T_{50\%}$).

Sample (weight ratio)	Temperature, °C				Total weight loss, %
	T_{initial}	T_{max} ($T_{\text{max}2,3}$)	T_{final}	$T_{50\%}$	
SiO ₂ +PMS-5 (5:2)	115	270 (410)	465	280	22.2
SiO ₂ +PMS-20 (5:2)	165	310 (420)	440	323	16.3
SiO ₂ +PMS-20+DMC (5:2:2)	165	330 (377)	465	347	18.6
SiO ₂ +PMS-20+DEC (5:2:2)	165	335 (438)	495	366	13.4
SiO ₂ +PMS-50 (5:2)	257	383	489	390	12.6
SiO ₂ +PMS-50+DMC (5:2:2)	200	399	492	398	13.0
SiO ₂ +PMS-50+DEC (5:2:2)	255	399	495	399	15.2
SiO ₂ +PMS-100 (5:2)	255	380	514	378	9.8
SiO ₂ +PMS-100+DMC (5:2:2)	230	358 (375)	508	376	16.4
SiO ₂ +PMS-100+DEC (5:2:2)	270	373	498	376	7.3
SiO ₂ + DMC (5:2)	35	85	160	240	3.9
SiO ₂ + DEC (5:2)	35	80 (187, 275)	500	260	5.0

T_{initial} is the start temperature of the process

$T_{50\%}$ is the temperature, at which the 50 % of mass are losing

T_{max} is the temperature, at which maximum weight lost

T_{final} is end process temperature

In conclusion: i) the higher the molecular weight of PDMS is, the higher is thermal stability; ii) initiators decrease the organic layer decomposition rate.

HYDROXYAPATITE FORMATION ON TITANIUM-CONTAINING ALLOY SURFACE

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The unique properties of biological materials produced by living organisms have always attracted the attention of researchers from the point of view of the possibilities of their practical use. In modern medicine, is widely used and investigated biotechnical products and systems in which the various elements and parts interact with biological fluids, soft and hard tissues of the body. Transplantation of foreign material is inevitably accompanied by suppressive therapy, which severely limits the recovery of damaged tissue. The process of the heterogeneous nucleation of calcium phosphate occurs in simulated body fluid (SBF), which is consist of supersaturated calcium and phosphate solution. The aim of this work is comparative studies of the influence composition of the SBF on the process of biomimetic synthesis of hydroxyapatite on the surface of the titanium.

For formation of a layer of Hydroxyapatite, titanium plates containing various functional groups, was immersed in a simulated body fluid for the process of mineralization. It took several weeks. Infrared spectroscopy for these samples showed at Fig. 1.

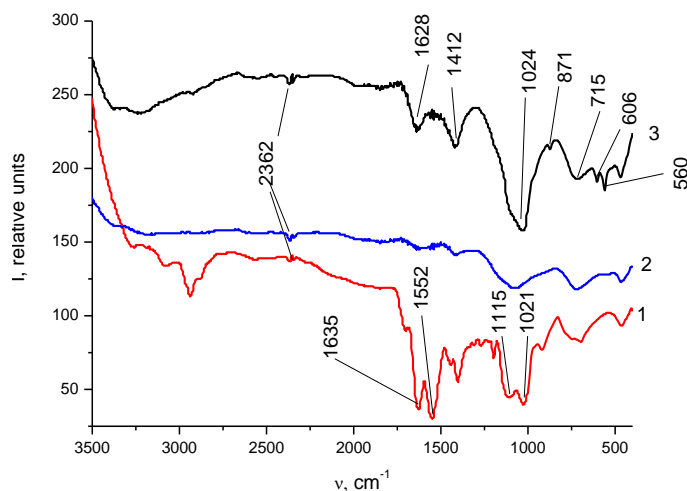


Fig. 1. FTIR spectrum of samples: 1 – Ti (initial sample), 2 – three-day layer, 3 – layer after three weeks exposure in SBF.

Performed comparison of media influence on hydroxyapatite formation. All samples investigated with IR-spectrometry and X-ray photoelectron spectroscopy.

NEW PROPERTIES OF PS–BaSO₄·5H₂O COMPOSITES

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Composites consisting of polystyrene as matrix and BaSO₄·5H₂O as filler have been investigated with different percentages of BaSO₄·5H₂O: 0, 3, 5, 7, and 10 wt. %. The dielectric properties were measured in the frequency range from 1 – 10 MHz at room temperature. The results show that the dielectric constant, dielectric loss and electrical conductivity are increasing with the increase of the concentration of the BaSO₄·5H₂O. Also these dielectric properties were changed with the increase of the frequency.

SELF-PROPAGATING HIGH-TEMPERATURE SYNTHESIS OF COMPOSITES BASED TiB₂–Al₂O₃

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Among reactions-based synthesis in the mode, the self-propagating high-temperature synthesis (SHS) is particularly attractive, on account of its advantages of low energy requirement; short processing

time, simplicity of facilities, and formation of high-purity products. The SHS technique has been extensively applied to produce a great number of advanced materials such as borides, carbides, nitrides, silicides, and intermetallics [1 – 3]. When incorporated with thermite reactions based on Al as the reducing agents, the SHS approach represents an in situ procedure for preparing ceramic, intermetallic, and metal matrix composites reinforced by Al₂O₃, because such thermite reactions are highly exothermic and produce a stable oxide Al₂O₃ [3, 4].

Preparation of TiB₂–Al₂O₃ and CrB₂–Al₂O₃ composites with a broad range of phase composition was conducted by SHS involving reaction of different types. SHS was carried out in the constant-pressure chamber in argon atmosphere at 1 atm. Aluminum (99.1 % purity), TiO₂ (98.0 % purity, anatase, B₂O₃ (96.0 % purity) were used as initial components. To definition of processes occurring in combustion wave in TiO₂–B₂O₃–Al system the «hardening» method was used [4]. XRD analysis for all mixes shows that the final products SHS consist of TiB₂ and Al₂O₃. The structure of the melt after SHS is a porous, strong material that has in some zones dendrite constituent and grainy inclusions, crystallized into six membered lamellar formation of titanium diboride in aluminum oxide matrix. Typical SEM micrographs in shows reveal the grains TiB₂ with a small and rather uniform particle size. It is possible that the fibrous crystals can be formed by two mechanisms – either “vapor–solid” or “vapor–liquid–crystal”. Aluminum can serve as concentrate for fibrous crystals growth, which is made by the mechanism of “vapor–liquid–crystal” [3, 4].

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**ENGLISH–GERMAN–RUSSIAN–GEORGIAN ELECTRONIC DICTIONARY
(GLOSSARY) IN NANOCHEMISTRY, NANOPHYSICS AND NANOTECHNOLOGY**

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Nanoscience and nanotechnology are interdisciplinary branches that mandatorily require a creation of united term base. This is communication language for specialists of various branches (physicists, chemists, biologists, technicians, material scientists and others) who create nanoscience and nanotechnology besides, notions and terms corresponding to international standards will cause their uniform understanding and allow us to get rid of false, ambiguous interpretations. This language is created in advanced countries [1 – 4] and we have to make it understandable for Georgians using adequate terms in our native language.

There is no special Georgian-language dictionary (neither in printed nor in electronic form) in nanoscience and nanotechnologies – new and very prospective branches of science and technology, except of parts of English–German–Russian–Georgian “Short Dictionary (Glossary) in nanochemistry and nanotechnologies” [5 – 7], which was published in 2011–2013 in journal “Nano Studies” (Georgia), and which is the first attempt to create Georgian glossary in nanoscience and nanotechnology; it is a predecessor of electronic dictionary which creates by us together with Georgian physicists, specialists in nano- and information technology and lexicographers from the A. Chiqobava Institute of Linguistics (Tbilisi).

Creation of Georgian electronic dictionary in nanochemistry, nanophysics and nanotechnology is timely, if not belated, since these branches develop successfully and rapidly in USA, advanced European countries (especially in Germany), China, Korea and Japan beginning with 80’s of past century. Nanoscience is being developed of a high rate, and the electronic format of dictionary provides possibility of its fast update.

Electronic dictionary will have one subject and different linguistic directions, particularly in special, nanoscience (nanochemistry, nanophysics) and nanotechnology directions; multilingual, translational: English–German–Russian–Georgian, illustrated and with explanations in Georgian; its volume, determined by words, word combinations and terms will count 5340 unit per each language, total of up to 21360 units. Based on significance of nanoscience and nanotechnology is extremely topical a creation of electronic dictionary in this branch, which will be mass consumer product. It will have a lexicographical, reference and especially educational value.

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AN ALTERNATIVE METHOD OF OBTAINING OF CARBON NANOTUBES, FIBERS AND MAGNETIC CLUSTERS

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Magnetic nanomaterials are considered to be very useful for recording and number of other technical purposes. But, applications are limited by their oxidation. A way to keep good magnetic properties for a long time is to encapsulate magnetic nanoclusters inside inert materials such as carbon.

In this work, carbon nanotubes, nanofibers, and magnetic clusters doped with ferromagnetic metals are obtained by the thermal dissociation of organic hydrocarbons at low-oxygen partial pressure condition. Depending on amount or density of hydrocarbons, velocity of the pyrolysis product within a reactor and substrate surface conditions, carbon nanomaterials of various geometric forms and sizes can be obtained (e.g., it is possible the vertical growth of nanofibers with diameter from 20 – 30 μm and length from 20 μm up to several cm).

Besides, the mentioned method includes the obtaining of pure metals in nanocrystalline form from minerals of ferromagnetic elements, and pure hydrogen from hydrocarbons, as well purification of the gaseous hydrogen.

The cheap precursors, simply controllable technological process, as well as simple apparatus used make it possible to obtain diversity of low-cost carbon-based nanomaterials.

SHS OF CAST NiCrCoFeMnAlX NANO-STRUCTURED POLYMETALLIC HIGH ENTROPY ALLOYS AND COATINGS OF THEM

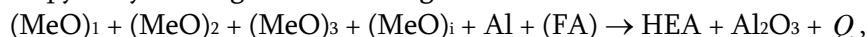
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High entropy alloys (HEAs) or multi-component alloys are a new effort in materials science and engineering. The standard definition of an HEA is an alloy that contains at least five major metallic elements ($n \geq 5$), each with concentration 5 – 35 at. % [1]. The configuration entropies of HEAs ($S_{conf} = R \ln n$, where R is the universal gas constant, assuming the alloys in a fully (close to fully) random state (random solid solution), are much higher than those of conventional alloys with one or at most two principal elements, and here comes the definition of HEAs. Depending on the alloy compositions, HEAs can possess many interesting mechanical and physical properties, and particularly they have great potentials to be used as high temperature materials, or coating materials requiring high hardness and high wear resistance.

Nevertheless preparation of the multicomponent materials is not easy science and technological task. We should promote high homogeneity (fine distribution of all elements into volume of alloy). Besides if the alloy content high chemical active component (Ti, Al, Zr, Hf, etc.) it require use expensive mold materials and complicated techniques.

In this work, we investigated a cost-effective SHS process for fabricating cast NiCrCoFeMnAlX high-entropy alloys through the following aluminothermic reaction:



where (MeO) are: NiO, Cr₂O₃, Fe₂O₃, Co₃O₄, etc.; Al is metal reducer, FA is an additive facilitating phase segregation, and Q the reaction heat. The process flowsheet is: after initiation with an igniting coil, SHS reaction frontally propagates downward. Because the attained temperatures (up to 3000 °C) are well above the m.p. of reaction products, the melt represents a mixture of multicomponent mutually insoluble metals (HEAs) and oxide (Al₂O₃) phases. Due to strongly different specific weights, these phases undergo gravity-assisted phase separation. As the result, the cast multicomponent HEAs are formed. Combustion was

performed at centrifugal acceleration $a = 10-400 g$. In this way we expected to (a) improve the yield of target product, (b) remove gaseous byproducts, (c) diminish the grain size in the product, and (d) make product composition more uniform. As follows from the SEM micrograph the cast HEAs exhibit a clearly pronounced nanostructure. Increasing of Al content into HEA was found to markedly change the microstructure and phase composition of HEAs. The Vickers hardness of synthesized HEAs was found to vary between 400 and 800 Hv.

On the second stage we carried out a search for the reactive systems and process parameters that would be favorable for deposition of protective coatings of HEAs directly onto commercially available Fe alloys. The cast protective coatings are formed due to strongly heat exchange between high temperature alloys and substrate. The phase composition and microstructure of protective coatings were investigated. This work can be regarded as the first positive experience to produce cast polymetallic high-entropy alloys by centrifugal SHS.

The work was supported by the RFBR (Project No. 14-08-00694).

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HYDROGEN AND PROPERTIES OF BORON NITRIDE PRODUCED UNDER EFFECT OF CONCENTRATED LIGHT HEATING

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Due to versatility, rapid heating and cooling rates, ability to adjust temperature profile along each axes, maximum operating temperatures and environmental adaptability the heating under effect of concentrated light radiation in an optical furnace has number advantages. This technique can be suitable for both conducting and non-conducting materials. Moreover, the light heating is one of the cleanest alternative energy methods available.

The studies on boron nitride (BN) have been of great interest due to the discovery of new carbon-related nanostructures, such as nanotubes, nanofibers, graphene, etc. Just recently, we focus on the properties of nanostructured BN, in order to obtain further insight into the relationship between the structures and properties of carbon-related materials. The BN compounds are known to possess a similar layer-structure and almost identical cell dimensions to that of graphite [1]. Based on such similarities, many research efforts have been theoretically and experimentally directed to B-N nanostructures [1].

Previous investigation have demonstrated that structure and properties produced in an optical furnace can be very different in depend on synthesis conditions [2]. Direct synthesis of powders from nanosized amorphous boron (Fig. 1a) in flow of nitrogen with impurity of H₂O results in formation of nanosized powders (Fig. 1b). This powders mainly compose of 76 % sassolite H₃BO₃ (boric acid) and 33 % BN (Fig. 1c).

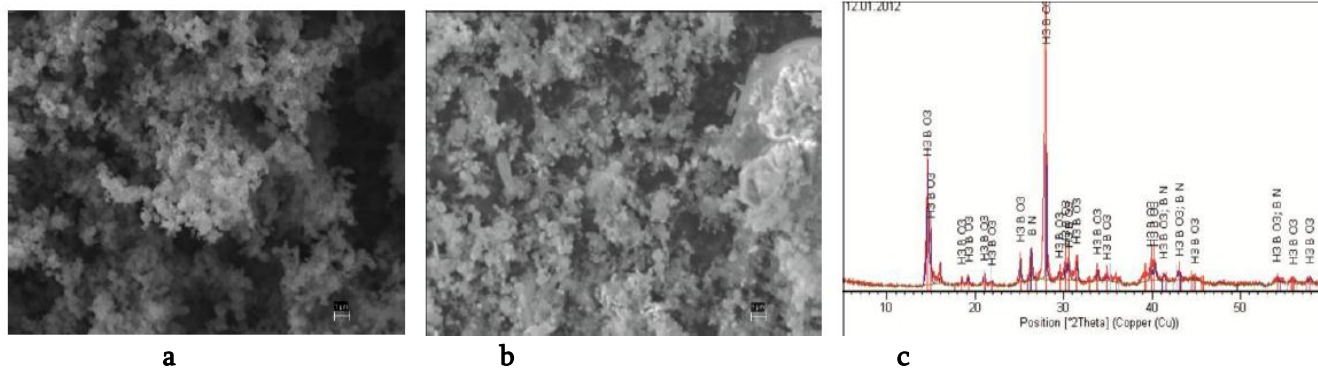


Fig. 1. SEM image of initial amorphous boron (a), synthesized powder material (b) and its phase composition (c).

Infrared Fourier spectra have demonstrated absence of hydrogen in initial amorphous boron (Fig. 2a). There are difference of IR Fourier spectra for powders produced at a distance from the center of the reaction zone of 30 and 20 mm (Fig. 2b). Produced powders have a very strong peak of hydrogen with wave number of 3197 cm^{-1} that indicate that the specific defects and defective structures formed during rapid heating and cooling rates provide the suitable trapping sites for hydrogen storage and consequently affect the hydriding properties of nanostructured powders.

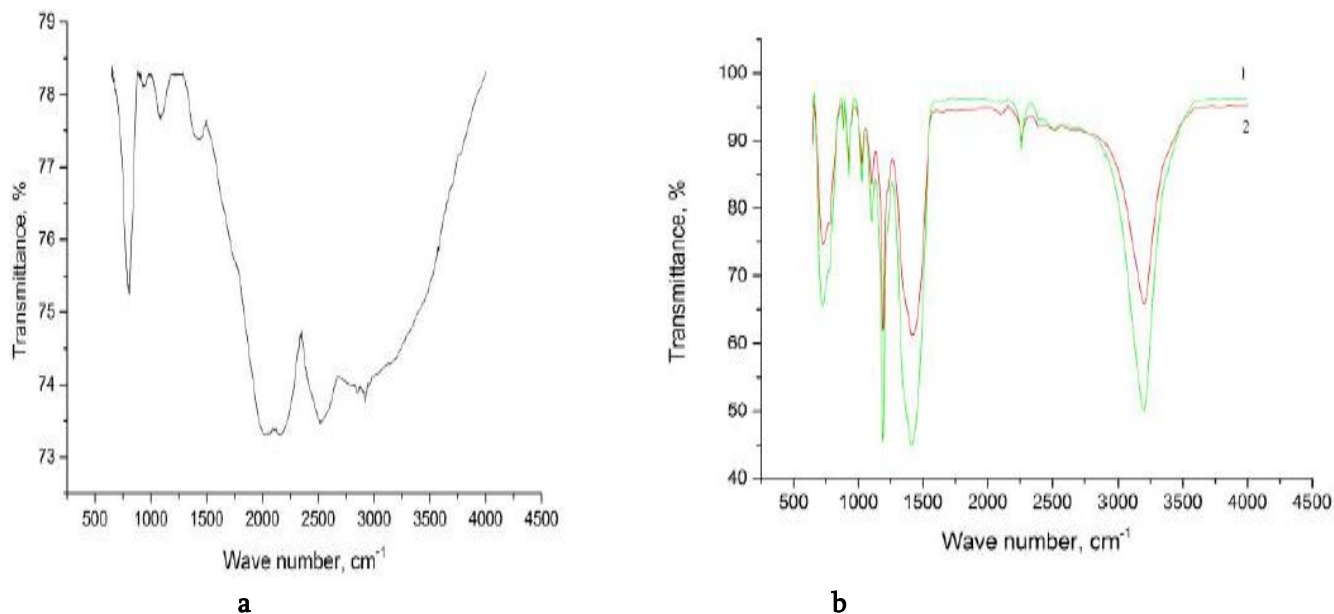


Fig. 2. IR Fourier spectra of initial amorphous boron (a) and powders produced at the distance from the center of the reaction zone of 30 mm (1) and 20 mm (2).

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NANOPOROUS CHIRAL SORBENTS FOR CHROMATOGRAPHIC SEPARATION OF OPTICAL ISOMERS OF ALCOHOLS

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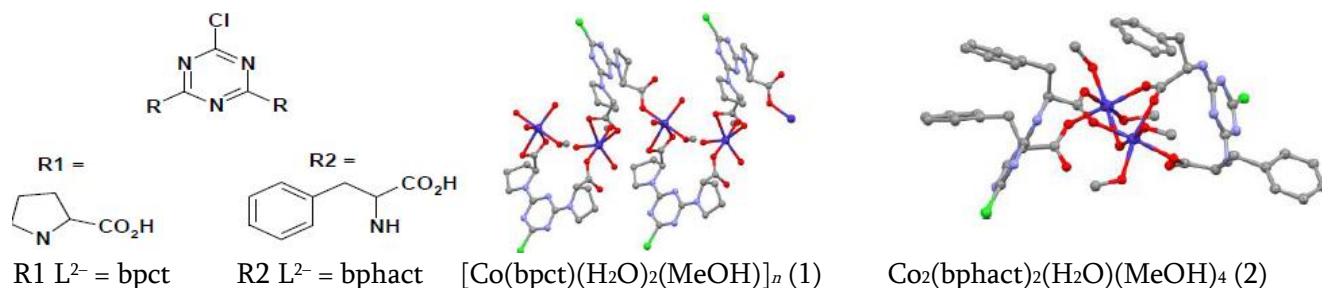
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Analysis and preparative separation of optical isomers of organic compounds is important task of biochemistry, pharmacy, etc. Chromatography is one of the most promising methods for such processes. The aim of this work was to study the efficiency of new chiral coordination polymers as stationary phase for chromatographic separation of optical isomers.

1D coordination polymer $[\text{Co}(\text{bpct})(\text{H}_2\text{O})_2(\text{MeOH})]_n$ (1) and dimer $\text{Co}_2(\text{bphact})_2(\text{H}_2\text{O})(\text{MeOH})_4$ (2) were synthesized using ligands, prepared from S-isomers of aminoacids (ligands are shown on the figure, fragments of aminoacids are N-substituted).



Compounds 1, 2 and desolvated form of sample 1 $[\text{Co}(\text{bpct})]_n$ (3) were studied as solid phases in chromatographic separation of racemic alcohols. The composition of the mixtures after separation was analyzed using standard chiral analytical column. It was shown that studied sorbents allowed to achieve 3.3 % enantiomeric excess of one of the isomers in conditions of the experiment (Table). Among studied alcohols, separation of isomers 2-butanol was the most efficient, and desolvation of the coordination polymer did not improve its efficiency.

Table. Values of enantiomeric excess of alcohols after chromatographic separation of racemates on columns, filled by chiral coordination polymers (± 0.05 %).

Coordination polymer	<i>ee</i> (2-butanol), %	<i>ee</i> (2-hexanol), %	<i>ee</i> (3-hexanol), %
$[\text{Co}(\text{bpct})(\text{H}_2\text{O})_2(\text{MeOH})]_n$ (1)	3.32 (R) ¹	0.19	2.79
$\text{Co}_2(\text{bphact})_2(\text{H}_2\text{O})(\text{MeOH})_4$ (2)	1.02 (R) ¹	–	–
$[\text{Co}(\text{bpct})]_n$ (3)	2.22 (R) ¹	–	–

¹ The letter in brackets indicates the isomer, which is better retained on a column.

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ADSORPTION PROPERTIES OF MAGNETO-SENSITIVE NANOCOMPOSITES $\text{Fe}_3\text{O}_4 / \text{TiO}_2$ WITH DEVELOPED OUTER SURFACE

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A perspective area of materials science and nanochemistry is a creation of nanostructured, multilayer magnetic materials. Mesoporous materials have a developed surface and they're perspective materials for catalysis, separation, adsorption and transport of molecules. An association of mobility properties with magnetically sensitive nanoparticles and mesoporous materials makes it possible to create a new generation of nanosystems with a wide range of properties. The objects of this research are nanocomposites like $\text{Fe}_3\text{O}_4/\text{SiO}_2$. It's obtained by using a template synthesis with sol-gel conditions.

Block copolymer (poly (ethylene glycol)-block-poly (propylene glycol)-block-poly (ethylene glycol)) Pluronic-123 (PL), sodium dodecyl sulfate (SDS), hexadecylpyridinium chloride (GDPH) were used as templating agents. The proposed procedure for the preparation of magnetic sorbent is based on the reaction of n-butylortotitanate on the surface of magnetite with TiO_2 as a shaper of surface. Adsorption capacity of the nanocomposites has been tested on DNA molecules, IG, albumin. Quantity of adsorbed biomolecules were determined spectrophotometrically (Lambda-35 Perkin-Elmer USA, $\lambda = 260$ and 28 nm).

Adsorption isotherms of DNA have saturation (Fig. 1a, b) and described by the Langmuir equation, characteristic of monomolecular adsorption on adsorbents with energetically active adsorption centers. The value of the adsorption of DNA is $2.7 \text{ mg per } 1 \text{ g}$ of adsorbent, IG – 4.9 mg / g .

A desorption of DNA was performed in TE buffer $\text{pH} = 8$ to 30 min in the dynamic mode at room temperature. A desorption IG was performed at the model environment from 30 min to 1 h in the dynamic mode at room temperature. It was established complete desorption of DNA and IG from the surface of nanocomposites.

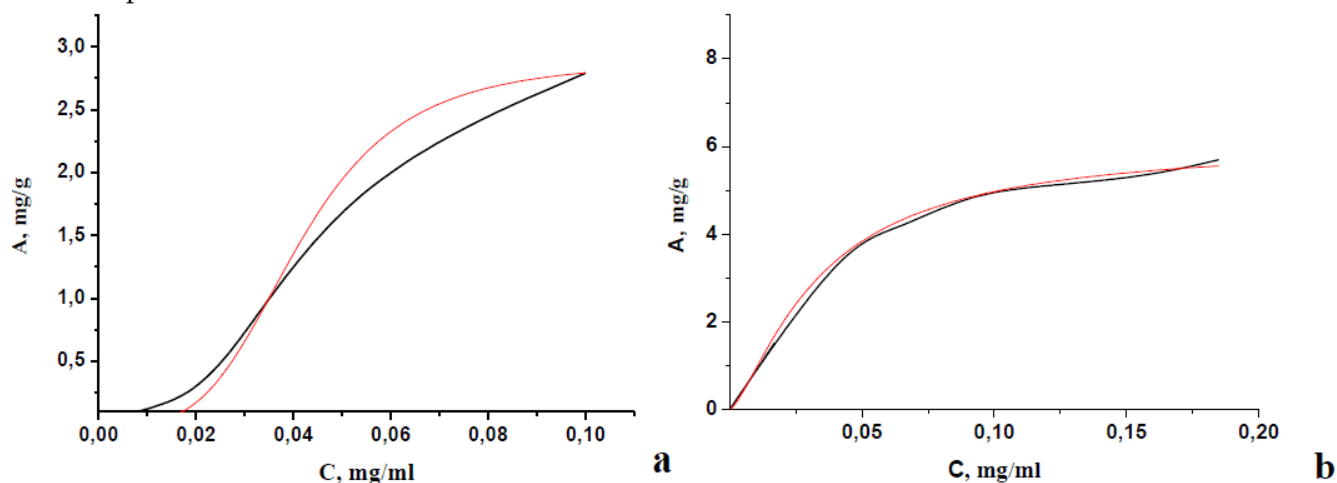


Fig. 1. Adsorption isotherms of DNA (a) and IG (b) for samples of nanocomposites $\text{Fe}_3\text{O}_4/\text{TiO}_2$.

Thus, the obtained magnetic nanocomposites can be used as adsorbents for the extraction of antibodies and DNA from solution. Nanocomposites can be used as model systems for the removal of viruses and other biological objects.

NITRIDE–NITRIDE NANOLAYERED COMPOSITES WITH SUPERIOR HARDNESS

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The hardness of binary nitrides naturally increases with decreasing grain size to a certain limit, which is determined empirically for each individual nanostructured coating. Therefore, the control of dispersion of a grained structure is one of the essential factors of controlling the hardness of a coating. Physical limit of grinding of a grained-structure of the vacuum arc coatings is due to the specific mechanism of their synthesis. For example, coatings from titanium mononitride, being ultrafine in the direction perpendicular to that of growth, have a fibrous structure in the direction of coating growth. The fibrous structure of titanium nitride coatings formed by conventional substrate temperatures (300 – 500 °C), when applying DC bias potential to the substrate is less than 500 V. In the direction of the coating growth, the titanium nitride grains borders conditionally separating the nanostructure and microcrystalline state are too extended – more than 100 nm. The situation is similar to the case of formation of a dispersed structure from chromium mononitride coatings. In all the samples had obtained a columnar-structure with multiple defects. The average diameter of the elements of the coating structure reaches 100 nm.

An effective way to control crystallite size in both direction and plane of growth of the coating was the method for producing of multilayer biphasic nanostructures. Multilayer structures of the coatings are prepared by periodic deposition of individual thin layers of two different nitride phases of predetermined thicknesses. Superhard nanostructured composite coatings (hardness over 40GPa) can be classified according to the sizes of the structural elements. If the structural unit comprises alternating layers of two different materials with thicknesses in the nanoscale range, the coating composition is called as nanolayered.

Usually, nanolayered coatings are biphasic nanocomposites consisting of alternating nanolayers of two different materials with layer thicknesses h_A and h_B , which ranges up to tens of nanometers. The total thickness of the two layers, termed as periodically repeating bilayer ($\Lambda = h_A + h_B$ is the thickness of a bilayer), can reach up to 40 nm. This bilayer is also called the period of the superstructure or modulation period. Two other sizes of a nanolayer – length and width – are not limited and usually substantially exceed the thickness. Several hundreds of these alternating nanolayers of different materials form the nanolayered composite coating. Hardness of the nanocomposite considerably increases when Λ has an optimum value for each pair of materials forming the coating.

Nanolayered composite coatings are divided into several groups. In this paper, we consider only nitride–nitride composite nanolayered coatings of type: TiN–CrN, TiN–ZrN, TiN–MoN_x, ZrN–CrN, ZrN–MoN_x and CrN–MoN_x with hardness over 40 GPa.

Nanolayered nitride–nitride composite coatings were synthesized on the modernized installation “Bulat–6”. For such coatings it was also equipped with a special substrate holder of swing type. For substrates served the polished stainless steel (X18H9T) discs with diameter of 19mm and thickness of 3mm. This installation was also equipped with a DC voltage source, whose value can be changed within 20 – 1000 V, as well as a pulse generator with adjustable amplitude voltage pulses in the range 0.5 – 2 kV and a repetition rate of 0.5 – 7 kHz.

PLASMA TECHNOLOGIES FOR MULTIFUNCTIONAL COMPOSITE MATERIALS DISPERSION-HARDENED BY NANO-STRUCTURED PARTICLES

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Possibility of synthesis of necessary disperse phases during high voltage electric discharges (ED) in disperse system “hydrocarbon liquid – powder” is used for dispersion, activation and synthesis of bimodal micro- (from 10^{-6} to 10^{-7} m) and nanosized (from 10^{-7} to 10^{-9} m) composite powders. ED in disperse system “hydrocarbon liquid – powder” leads to synthesis of nanocarbon, dispersion of metal powders and synthesis of their carbides due to the impact of plasma channel, electromagnetic fields, mechanical impact of shock waves, hydro flows and volume microcavitation, which allows to ensure their homogenization during processing. Spark-plasma sintering (SPS) allows purposeful control of grain growth rate and thus the formation of nanostructured microheterogeneous structure of composite materials with high physical-mechanical and performance properties.

New approach in developing plasma technologies consist in that dispersion-hardening dopants (namely TiC, TiB₂) are not mechanically added to powder mixture as additional component during powders mixing, like it is done in conventional methods, but instead is synthesized during powders ED treatment as a result of reactionary synthesis under impact of microplasma discharges. Distinction of new approach for dispersion-hardening dopants relatively to conventional methods consists in realization of cyclic pulsed (few microseconds) practically nonoxidizing ED in disperse system “hydrocarbon liquid – powder”. The nanocarbon of different allotropic modifications (depending on liquid composition) is synthesized as a result of hydrocarbon liquids pyrolysis by plasma discharge channel. Intensive heat (plasma) and mechanical (shock waves) influence on initial powders leads to increase of number of crystal structure defects, which contributes to activation and dispersion of particles. Melting or evaporation of particles may also occur as a result of low-temperature plasma impact, which leads to changes in their properties during quick cooling in liquid. Prospects of using ED technology are associated with the possibility of obtainment of uniformly distributed bimodal micro- and nanosized particles with increased levels of free energy, and thus with increased ability of intensive interaction with nanocarbon particles for creation of hardening phases, in powder blend composition. ED treatment ensures not only the high level of dispersion, but also the higher strength of dispersion-hardening particles adhesive bond with matrix material due to activation of surface.

Preservation of high dispersity of grains of products material is ensured by using SPS. During SPS that consists in passing pulsed current (superposition of direct and alternating currents) through powder with simultaneous mechanical compression, the formation of plasma is agitated in gaseous phase that fills gaps between particles. This promotes quick heating and (under the impact of external pressure) compaction to almost non-porous state, which allows to ensure preservation of ultrafine structure in great degree and opens possibilities of obtainment of highly dense powder composites with increased physical-mechanical properties.

Processes of ED synthesis of micro- and nanosized powders of new compositions from elementary powders of metals and their mixtures and subsequent application of high-speed SPS of obtained powders create conditions for increase of strength (from 10 to 20 %), hardness and wear-resistance (from 30 to 60 %) of obtained materials.

THE INNOVATIVE CONCRETE NANOTECHNOLOGY IN GEORGIA

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Earlier it has already been reported about the possibility of enlarging cement obtaining with active mineral additives. It was shown that joint thermal treatment of active mineral additive increases strength of the cement. It is known, that the properties of the concrete, besides other factors, depend on the activity of the mineral additives that are inserted into the cement.

In the presented work, cements were obtained inserting zeolite tuff. Before inserting into the cement-mixture the additive subjected to thermal treatment at the temperature 100 – 700 °C. Data, testifying active mineral additives thermal treatment positive influence on the strength of the cement and concrete. X-rays of the active mineral additives, thermal treated at 100 – 700 °C, and also saturated by sulfur dioxides at 700 °C were studied and periods of mixtures seted. Quite interesting results were obtained when physical-mechanical properties of cement were studied on the basis of Portland cement and thermal treated mineral additives. Inserting of thermal treated mineral additive – zeolite tuff $Al_2O_3 \cdot SiO_2$ in the cement mixture, when in the hardening system between each other at the nano level react additives and clinker minerals, their product increases activity, compressive and flexural strength of concrete.

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EFFICIENT NUCLEATION AND PROPERTIES OF GaN NANOWIRES GROWN ON AMORPHOUS Al_2O_3 BY PLASMA-ASSISTED MOLECULAR BEAM EPITAXY

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Recent in-situ studies of growth of GaN nanowires (NWs) by plasma-assisted molecular beam epitaxy (PAMBE) on Si (111) by Hestroffer et al. [1] show that the self-induced nucleation of GaN NWs starts only after partial amorphization of the silicon nitride film that inevitably forms on the silicon substrate under nitrogen flux. This indicates the existence of a barrier for GaN nucleation on monocrystalline substrate, so creation of nucleation sites (e.g. by partial amorphization of the substrate) is needed to enhance nucleation rate.

To explore this effect in more detail we have compared efficiency of self-induced nucleation of GaN NWs on three different substrates, namely on bare *c*-oriented sapphire, on Si (111) with a native silicon nitride buffer layer and on Si (111) with a thin amorphous Al₂O₃ buffer layer deposited at low temperature by atomic layer deposition. On all substrates catalyst-free growth of NWs proceeded under the same, highly nitrogen-rich conditions at ~ 750 °C [2, 3].

Our studies show that no growth of NWs occurs on *c*-oriented sapphire. This agrees with the observations by Geelhaar et al. [4] who have reported that, without a catalyst, NWs do not form on crystalline sapphire. Analysis of nucleation kinetics shows that, under the same conditions, NWs nucleate much faster on amorphous Al₂O₃ than on a partially amorphous silicon nitride buffer layer. Post growth analysis by scanning and transmission electron microscopy show separated NWs on a bare silicon whereas high density of GaN nuclei are found between NWs grown on Al₂O₃ buffer (Fig. 1). We propose to explain this by a higher density of surface defects, being effective GaN nucleation sites, on amorphous Al₂O₃ than on partially amorphous silicon nitride. The different surface reactivity due to different chemical compositions of the buffer layers might play the role, too.

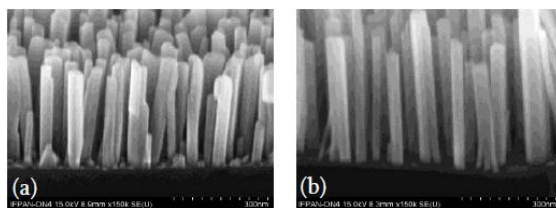


Fig. 1. Cross-section SEM views of GaN NWs (a) on Si (111) substrates with 2 nm thick amorphous Al₂O₃ buffer and (b) on bare Si (111).

Finally, arrangement on the substrate as well as structural and optical properties of GaN NWs are studied and correlated with microstructure of substrates on which they are grown.

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HYBRID POLY(3-HEXYLTHIOPHENE) / GaN NANOWIRE STRUCTURES ON SILICON FOR SOLAR CELL APPLICATIONS

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Hybrid organic-inorganic structures attract great interest due to promise of cost-effective technological solutions for photovoltaics, light emitters and sensors. A combination of p-type conjugated polymer with n-type inorganic semiconductor is being studied as a base for bulk heterojunction

photovoltaic cell where charge separation occurs on polymer / inorganic semiconductor interface. Such hybrid semiconductors use high electron mobility of embedded inorganic semiconductors to enhance poor charge transport capabilities of organic material. Poly(3-hexylthiophene) (P3HT) was chosen as organic material in our experiment because it has been intensively studied as both an electronic and optoelectronic material. It exhibits p-type like conductivity with bandgap around 1.8 eV [1].

For this study we fabricated a structure which consists of unintentionally doped self-induced GaN nanowires covered with a layer of poly(3-hexylthiophene). GaN nanowires were grown on n-type Si substrate using plasma-assisted molecular beam epitaxy (PAMBE) technique [2]. PAMBE yields arrays of high-quality defect-free nanowires with excellent electron transporting abilities. Vertical nanowires penetrate through P3HT layer providing uninterrupted path for electrons to be harvested on cell contacts. This is an advantage of nanowire-based structure over bulk heterojunction solar cells using inorganic semiconductor nanoparticle blends with P3HT [3]. Electrical characteristics of structure were measured through top contact applied to P3HT and bottom contact applied to Si.

Spectral response measurements show that all components of structure (Si, GaN NWs, P3HT) exhibit light sensitivity. In the case of n-GaN / n-Si heterojunction, there is a 2 eV energy difference between GaN and Si valence bands. So holes can diffuse only from GaN to Si. Due to this GaN / Si junction gives photocurrent of polarity reversed in relation to P3HT / GaN junction. External quantum efficiency (EQE) curve shows maximal value around GaN bandgap energies. Also a structure containing n-i-p junction nanowires is discussed, introducing additional exciton separation area inside nanowire exploring possibility to utilize reported enhanced light absorption of nanowires.

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TECHNOLOGIES FOR HIGH EFFICIENT SOLAR CELLS

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There are two different types of high efficient solar cells and modules:

- Concentrator modules with III-V-multijunction cells, with efficiencies more than 40 %;
- Crystalline silicon modules, efficiency more than 20 %.

Up to the year 2010 the cost of crystalline silicon modules was the major part of PV-power stations that led to better expectations to thin film modules.

Now the low price of crystalline Si-modules (less than 0.70 € / W_p) at efficiencies more than 20 % and their higher reliability gives a clear advantage over thin film-modules, requiring two times more space and installation cost, which becomes the deciding part of the overall cost of solar power stations.

The thin film modules will find a bright market in architectural designs, like facades. The standard monocrystalline Si-solar cells have efficiencies no more than 17 – 18 %.

There are three possibilities to get more than 20 % with Si-Solar cells:

- Bifacial solar cells (requiring quite a distance behind the modules);
- Selective emitter solar cells;
- n-type solar cells with heterojunctions.

It will be given a comparison of all these types of high efficient solar cells and modules. Some examples of installations at the Technology Park Berlin-Adlershof will be demonstrated.

CO-PRECIPIATION METHOD IN NANOSCALE STABILIZED ZIRCONIA POWDERS TECHNOLOGY FOR CERAMIC FUEL CELLS

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Stabilized zirconia is used in a SOFC as the solid electrolyte and the anode. To this end powders with different disperse and phase compositions are needed. Therefore technology for producing zirconia powders must be predictable and controlled.

Co-precipitation is the method that allows the actively control the process of oxides solid phase formation. But systematic physicochemical and technological studies of this process are not sufficiently described in scientific literature. One of the main disadvantages of the method is extremely high activity of intermediate zirconium compounds which leads to aggregation and agglomeration of precipitation products and finished powders. In other words, this method, in its classical variant, does not allow the manufacture of non-agglomerated and mono-disperse nanopowders. In order to prepare high quality stabilized zirconia nanopowders it is important to carefully study physicochemical processes and phenomena that accompany the formation of zirconia solid phase throughout the entire formation sequence: “solution → zirconium hydroxide precipitation → amorphous zirconium hydroxide → crystalline zirconium dioxide”.

This paper deals with physicochemical processes of the formation of nanostructure in stabilized zirconia powders while obtaining it from aqueous solutions of zirconium salts and a stabilizer by co-precipitation method.

On the basis of analysis of the processes occurring in heterogeneous system “solution of zirconium salts(IV) + Me(III) → intermediate product → solid zirconia” the main physicochemical stages of transformations in solutions of zirconium salts(IV) throughout the entire formation process of zirconia were established. The basic physicochemical processes are: crystallization, precipitation and co-precipitation, thermal decomposition, chemical or mechanical disintegration of aggregates.

Interaction between primary complexes is effected by chemical processes of olation and oxolation, resulting in formation of secondary particles. The size of the secondary particles depends on the conditions of preparation and storage of solutions and varies between 0.5 and 2.5 nm. These particles are primary structural elements in forming of zirconium hydroxide and dioxide solid phase. Thus, it can be said that in forming of the solid phase of stabilized zirconia powders the main structural unit during the entire transformation process: “aqueous solution of zirconium salts and a stabilizing element → hydroxopolymer → xerogel → amorphous oxide → crystalline oxide” is tetrameric hydroxocoplplex of zirconium.

There are relatively many ways to control the processes of solid phase formation both on a micro- and on a macro levels while preparing stabilized zirconia powders from aqueous solutions. Yet systematic studies are scarce.

To develop a process for preparation of high quality stabilized zirconia powders by co-precipitation method, a study was carried out to examine effects of the source solution concentration, medium, temperature and pH on building up and formation of micro- and macrostructure of stabilized ZrO₂ powders. It was established that concentration of source solutions and precipitation pH level have the most effect on precipitate structure and crystallite sizes of finished stabilized zirconia powders. Zirconia crystallites with minimal size are formed when pH = 6. Increasing of zirconium oxychloride concentration produces fine-grained powders, but at concentrations greater than 1.5 mole / L formation of gel-like precipitates was observed which are hard to filtrate.

NEW APPROACHES TO STUDY OF COMBUSTION MULTILAYER POLYMER MATERIAL

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In the World in one year there are several millions of fires, destroyed countless valuables, dies more than 150 thousand people and more people are injured.

In general, residential and public buildings and premises are killed about 90 % of the total number of people killed by fires. In this case, the main causes of death in the fire – the action of the combustion products (up to 76 % of total deaths) and high temperature (up to 19 % of total deaths), which is a consequence of the use of fire-polymer laminates, well supporting the process of combustion and flame spread. These materials are easily ignited and melted, emit toxic substances during combustion.

Toxic products of combustion are the main factor that leads to the greatest number of casualties. The composition of the combustion products depend on the composition of the burning material and the conditions for its combustion. In case of incomplete combustion of organic substances in low temperature conditions and lack of air, carbon monoxide, alcohols, ketones, aldehydes, acids formed. These products form a caustic and toxic smoke. Furthermore, products of incomplete combustion and burning are capable of forming explosive mixtures with air [1].

One of the main ways of increasing the fire safety of buildings and structures is to use the most effective flame retardants (passive protection) for building structures, to reduce the flammability of polymer laminates and the spread of fire on them. For this it is necessary to simulate the behavior of the material in case of fire in the laboratory, therefore, a need exists studies polymer laminates for flammability, flammability, smoke generation capacity, the rate of flame propagation, as well as other toxic and dangerous fire hazards.

In order to stop the combustion process laminate prompted us layer of a material which will function as a barrier. This layer will not offer the possibility of further flame spread deep into the material, stopping automatically when the combustion process to burn through it. There will be a process of gradual

decay, which would prevent or minimize human involvement in the process of liquidation and localization of the source of fire extinguishing means.

Using the installation provides performance on her research on the integrated study of the combustion processes of multilayer polymeric materials with the possibility of direct determination of each parameter separately. At installation it is possible to create a variety of composite materials with predetermined properties on the basis of mathematical models prepared according to the statistics obtained from tests of various materials in the plant.

To find the experimentally determined characteristics of the process it is necessary a framework for the study. After analyzing all the range of facilities, equipment and booths for work related to the study of combustion processes of polymer laminates, we can say that for a full analysis of the complex combustion processes is needed setting that combines the ability to identify all the required parameters at the same time, in which the research is not to separate the material and the parameter, and it is possible to determine the various parameters of most polymer multilayer materials [2].

Material parameters that must be determined: a group of combustibility, ignition temperature and the temperature of corruption spontaneous ignition temperature, flame spread, smoke production rate. It is necessary not only to determine the entire range of parameters occurring during a fire to further ensure the safety of the works (minimizing access to the working area), and also provide the possibility of additional research setting.

Existing facilities do not allow a comprehensive assessment of fire of building materials. In addition, they are very cumbersome and unsafe for operation [3]. When construct a building, you should take into account its ergonomics and safety of the constituent elements.

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WEAR PROCESSES IN METALLIC COMPOSITES MODIFIED WITH BORON NITRIDE

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There is investigated influence of the anisodesmic compound – hexagonal boron nitride (h-BN) – on wear processes in brass and iron. The studies are performed on samples of brass- and iron-based composite materials, in which nano-crystalline h-BN is used for antiwear modifier.

Fixation of h-BN particles in matrix-material achieved by two methods: (1) insertion the copper-plated boron nitride nanopowder in the melt or (2) pressing the mixture of powdered components

(~ 300 nm matrix-material and ~ 100 nm boron nitride) followed by high-temperature sintering. Structural studies show that boron nitride particles are almost uniformly distributed in the matrix of obtained composites.

Wear processes have been studied determining weight losses and moments of friction at normal and catastrophic loadings. It is shown that nanocrystalline h-BN (with Young's modulus much lower than that of matrix) insertions changing wear mechanism can reduce intensity of wear by 1.5 – 2 times. There are also investigated the friction processes using polyethyleneglycol + (h-BN) as a third body. Significant reduction in the friction coefficient has been observed for loads of 2 – 5 MPa.

POLARIZATIONS – SPACE METHOD TO STUDY THE PHASE STATE IN CLOUDS

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Recently, the development of methods of polarization in radar received a considerable attention. The advantage of this polarization analysis is the possibility of obtaining additional information about the properties of the reflecting object by defining the polarization of the radar signal. One important application of this method is the obtaining information about the shape of the particles and their phase state [1].

Particles property to depolarize the incident radiation can be used to study phase transitions in atmospheric water. In practice, for this purpose it can be used two antennas: one of which emits and receives the energy polarized only in a certain plane, while the other may receive energy only polarized in the plane perpendicular to the plane of polarization of the first antenna [2 – 4]. Assuming amplification and then comparing the signals detected by these antennas, it can be calculated so-called depolarization and, respectively, the horizontal and vertical signal reflections at maximal load capacity. Depolarization of echo-signals from small spherical (Raleigh) particles absents and as they increase the depolarization factor increases. It was established that, the wave depolarization is very significant on the icy particles. Depolarization factor in this case may to be $-(5 - 10)$ dB, and for the very small droplet clouds: $-(15 - 20)$ dB. Areas with $\Delta P > -9$ and $\Delta P < 20$ likely can be attributed as mixed. From the above it follows that the polarization-diversity is a method, which clearly captures the phase transitions of water in the atmosphere.

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EXPERIMENTAL FACILITY FOR STUDY OF NANO-MATERIALS INCLUDING THE INFLUENCE OF IRRADIATION

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The physics of 20th century developed a new technological direction – microelectronics and promoted for its wide applications. The beginning of 21st century physics was signified by discovery of nanoelectronics and creation of new technologies up to monoatomic level. Since the semiconductor, in particular, silicon technology was well-developed nowadays many nanostructured materials are based on semiconductors. Hence, it is necessary to give special attention on the semiconductor substrates which have most application in this new technology. On the other hand, the silicon itself and insulator–silicon structures due to high stability of operating conditions (temperature, pressure, and content of medium) being a basis of various designs of most modern microelectronic devices have very wide applications in different branches of national economy: engineering, power industry, aircraft, astronautics, radiation environment etc.

One of important applications is space environment and the use of nanostructures is promising for this purpose. However, adequate understanding of the specificity of the behavior of these devices in space can be achieved, if corresponding developments will be accompanied by the study of the behavior of devices in special facility simulating the diverse effect of space. Significantly more information can be obtained using tests based on facility combining exposure to corpuscular radiation (as a factor undoubtedly affecting all cosmic objects) with other factors in space.

A facility was developed and fabricated at Yerevan Physical Institute (YerPhI) which creates the following physical conditions: vacuum 10^{-6} Torr. ($1.33 \cdot 10^{-4}$ Pa), electron beam with energy up to 8 MeV, different temperatures from -150 to $+150$ °C, ultraviolet radiation. These four parameters may act separately or together depending on user requirements. In fact their complex influence simulates some environmental factors of near Earth space [1]. On this setup, preliminary studies of the properties of silicon single crystals were performed, which showed promising application of modeling tests to study the behavior of materials and microelectronics devices with the purpose of estimating prospects of their application in different area of extreme physical conditions: different temperature, pressure, radiation, chemical and other environments.

Measurements of silicon conductivity (the main property in the space usage) were carried out directly under the electron irradiation process (in-situ). It was shown that the specific conductivity of silicon samples, measured at the irradiation process and after irradiation, has different values; the first is much higher. The higher value of specific conductivity under the irradiation process is due to ionization mechanisms (Auger or other irradiation induced process) which results in the formation of non-equilibrium carriers (hole–electron pairs). These carriers are accelerated in reverse directions which gives additional contribution to the specific conductivity [2].

We consider mentioned facility for study the properties of nanostructure materials as well as for their investigation at extreme conditions listed above, and an attempt for creation of nanostructures via irradiation. There are some publications on radiation influence on the properties of nanostructures [3, 4] however our facility gives possibility to study the subject property in-situ under external influences.

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THE JOURNEY FROM MACRO TO NANO ON COATING APPLICATIONS

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This study covers some information about our previous and ongoing investigations on the production of advanced materials by combination of SHS, sintering and RF magnetron sputtering PVD processes [1].

Advanced ceramic powders such as B₄C, TiB₂, ZrB₂, W₃B₇ were synthesized via self-propagating high-temperature synthesis (SHS) method using a mixture containing B₂O₃ and reducing Mg powders with TiO₂, ZrO₂, CaWO₄ and / or C powders followed by acid leaching. Micron and sub-micron sized boron compounds without requiring any industrial milling processes were produced [2 – 7].

Obtained advanced ceramic powders were consolidated by using spark plasma sintering (SPS) technique which is mainly used for obtaining compacts within very short times compared to other sintering techniques. In SPS technique, powders which are in micro or nanoscale form sintered bodies without causing grain growth which will lead to high mechanical and physical properties. By that processes, high purity, high density target materials (such as TiB₂, B₄C) were produced for PVD systems [8 – 10].

In RF magnetron sputtering PVD system, sputtered atoms from target material tend to move within plasma and condense on a substrate which will lead thin film coatings. Thin film coatings would give certain properties to substrate materials such as tribological, optical and electronic. To obtain these properties, B₄C and TiB₂ PVD thin film coatings were successfully applied on silicon, glass and steel substrates [11].

In this study, the results of conducted researches will be presented.

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STRENGTH DEPENDENCE OF CRYSTAL FROM THE “FIRST PRINCIPLES”

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About higher strength of polycrystalline materials compared to monocrystalline shows the empirical Hall–Petch (H–P) relationship. However, for nanocrystals, when the grain size becomes smaller than a certain critical value (10 – 15 nm) has been established experimentally that the strength decreases with decreasing size of the crystallites. Mechanism of deviations is currently poorly understood. Understanding reverse H–P law can give computer experiment based on ab initio calculations at the atomic level. Structure of nanoparticles with a diamond-like structure will be described in the hexagonal axis by the axis z of the spatial diagonal of a cube [111]. The structure of the particles in this case will be described by alternating three layers of close-packed planes of atomic. We determine the energy of the interaction between the structural units, with a free surface, using a method developed in [1, 2]. As a result of computer simulation we obtain the average value of strength $\bar{\sigma}_i = \sigma_0 (1 - K_i \cdot d^{-1})$, nanoplates with a thickness d , infinite nano timber with a base $S = d^2$ and nanoparticles as a cube with an edge d . Here σ_0 is the theoretical strength of volumetric diamond crystal in [111] direction, and the H–P coefficients K_i for all three cases (nanoplates, nanobrus, nanoparticles) are determined by the following formulas: $K_p = 2c/3$, $K_s = 7.896a$, and $K_\Omega \approx 2c/3 + 7.896a$ (a and c are the lattice parameters). Computational experiment conducted for BN_{cub} is presented on Fig. 1 showing the dependence of the strength of the characteristic size of the crystal. Lattice constant of BN_{cub} in hexagonal axes $a = 4.8423$ and $c = 12.14 \text{ \AA}$. The theoretical strength of BN_{cub}

under uniaxial compression along the [111] is $\sigma_0 = 102.84$ GPa [1]. For the defect-free nanoparticle, when size decreases then the strength also decreases. Direct H–P law is valid only for real nanomaterials with presence of defects and with characteristic linear dimension.

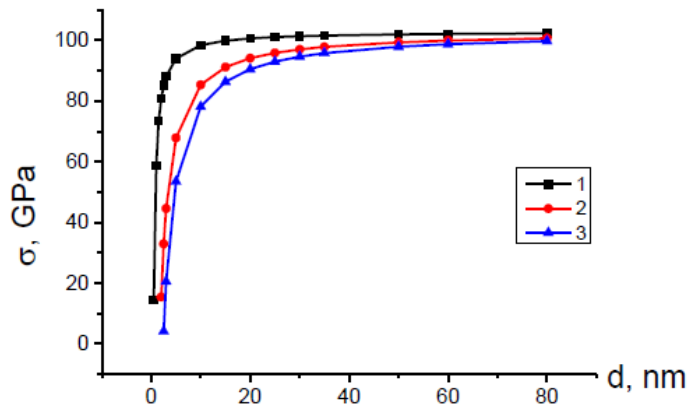


Fig. 1. Dependences the strength of BN_{cub} for: 1) nanoplates, 2) nanotimber (whisker), and 3) nanoparticles from their size.

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MODEL OF ELECTRON HOPPING TRANSPORT IN NANOCOMPOSITES PRODUCED BY ION-BEAM SPUTTERING AND ITS VERIFICATION

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Model of hopping charges transport in metal-dielectric nanocomposites, produced by ion-beam sputtering was developed. In the model the structure of nanocomposites and electric properties of both metallic phase nanoparticles and dielectric matrix were taken into account. From the model it results that in low-frequencies area, depending on values of conductivity and permittivity, resistive or capacitive type of conductivity could occur. In middle-frequencies area voltage resonance is possible to be observed. Further increase of frequency, in number of cases, may lead to inductive type of conductivity.

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FORMATION OF WATER NANODROPS IN CELLULOSE IMPREGNATED WITH INSULATING OIL

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The paper presents results of measured the DC conductivity dependence on moist pressboard impregnated with insulating oil for various levels of moisture and samples temperature. The paper verified that the conductivity was due to an electron hopping (tunneling) between nearest potential wells created by water nanodrops situated in a cellulose structure. Results and analysis in this paper discovered and determined water nanodrops, which were created in the pressboard impregnated with insulating oil structure with approximate number of 220 water molecules and average dimension of nanodrops was around 1.5 nm.

SPONTANEOUS NUCLEATION AND CATALYST-FREE GROWTH OF GaN NANOWIRES BY PLASMA ASSISTED MOLECULAR BEAM EPITAXY

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It is well established that GaN nanowires (NWs) are promising building-blocks of new electronic and optoelectronic devices. Due to an easy accommodation of lattice mismatch NWs offer a large degree of freedom in designing of heteroepitaxy of highly lattice mismatched materials, which is crucial for monolithic integration of GaN devices with Si technology. This is why GaN NWs on silicon structures attract so much attention recently and are of both fundamental and technological interest.

In this talk we report on catalyst-free growth of GaN NWs by plasma-assisted molecular beam epitaxy (PAMBE) on Si substrates. Mechanisms of self-induced nucleation and of growth of the NWs will be

reviewed. We will show that that presence of the SiN interlayer, which unavoidably forms on the substrate as soon as the nitrogen source is switched on, affects basic properties of GaN NWs. First, they are aligned perpendicularly to the surface of the substrate independently on its crystallographic orientation in agreement with the model developed by Consonni et al. [1]. Since the GaN / Si lattice mismatch induced stress is negligible the NWs exhibit much lower strain and density of extended defects than those grown in a direct contact with the substrate. Moreover, the SiN interlayer is nitrogen-terminated which imposes N-polarity of the nanowires obtained. Then we show that by tuning microstructure of the SiN interlayer the in-plane alignment of NWs can be changed from epitaxially linked to the Si lattice to completely random in-plane arrangement [2]. Finally, we show that under specific conditions GaN NWs can be grown without any interlayer, i.e. with a direct contact with silicon substrate. Due to a specific nucleation mechanism these NWs grow epitaxially on the Si (001) substrate, first in the form of zinc blende islands and then as double wurtzite GaN nanorods with Ga-polarity. On account of the lattice mismatch between GaN island and Si the edge dislocations are created at the GaN / Si interface. XRD measurements show that orientation of these nanowires is epitaxially linked to the symmetry of the substrate so that [0001] axis of w-GaN nanowire is directed along the [111] Si axis. We use these findings to explain mixed polarity of GaN NWs on Si (111) substrates reported in the literature.

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