Russian Nanotechnologies and European Framework Programmes

2006

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Sixth Framework Programme of EU

International Association for Promotion of Co-operation with Scientists

Russian Contact Point NANOTECH
Shubnikov Institute of Crystallography of Russian Academy of Sciences

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PREFACE

The term “**nanotechnologies**” has become a catchword of sorts. As any catchword, it shows that public interest in the matter is growing. In actual fact, nanotechnologies involve manipulation of atoms that give rise to completely new qualitative phenomena and make it possible to create completely new materials. The development of nanotechnologies depends not only on the ability to manipulate individual atoms but also on changes in the basic principles of the organization of science. Only a truly interdisciplinary team with specialists in all the required areas that communicate effectively among themselves could get serious and reliable results. It’s clear that the solution of new tasks demands an international collaboration between research institutes, groups and individual researchers in Europe. Recent “European Parliament resolution on nanosciences and nanotechnologies: an action plan for Europe 2005–2009 (2006/2004(INI))” stresses the importance of international cooperation in this field and “calls on the European Commission to intensify further the already excellent relations with Russian scientists.”

The 6th European Framework Programme for Research and Technological Development (FP6, 2002–2006) contained a strong emphasis on international cooperation in initiatives funded under the thematic priority “Nanotechnology, knowledge-based Materials and new industrial Processes” (FP6-NMP). One of the aims of the present Booklet is to show the results of the Russian organizations participation in FP6-NMP calls.
Part I (pages 3-17) is describing EU-funded FP6-NMP projects in which Russian organizations are involved as partners of corresponding Consortiums.

The 7th European Framework Programme (FP7, 2007–2013) has been launched. The first FP7-NMP calls for proposals were published on 22 December 2006. The first deadlines will be in late Spring 2007. **Part II** (pages 18-64) of the Booklet is giving **29** proposals of Russian organizations with description of their potential scientific activities. It will help to identify the problems of mutual interest in the framework of FP7-NMP priority. The overall project portfolio is wide in scope, encompassing different topics in the area of nanotechnologies. We should point out a new stage in the development of the study of materials: the transition from the study of semiconductors to that of bioorganic materials and the unification of organic and inorganic studies. As a matter of the fact, any serious discussion of nanotechnologies becomes a call to the inner self-reorganization of the entire scientific community. The information mentioned above may be of interest for a wide audience, in particular, for partner search and building of Consortiums for proper FP7-NMP projects.

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PART I

EU-FUNDED PROJECTS WITH RUSSIAN PARTICIPATION WITHIN THE THEMATIC PRIORITY «NANOTECHNOLOGES AND NANOSCIENCES, KNOWLEDGE-BASED MULTIFUNCTIONAL MATERIALS AND NEW PRODUCTION PROCESSES AND DEVICES» OF THE 6-TH FRAMEWORK PROGRAMME (FP6-NMP)

http://cordis.europa.eu/fp6/projects.htm
http://cordis.europa.eu/search/index.cfm

European Commission launched **16** calls within the FP6-NMP thematic priority. Following the FP6 rules, the calls were open to researchers from virtually all Countries in the world. Organizations from Russia were the most active among the "third countries". For instance, **127** Russian organizations submitted proposals in the first FP6-NMP calls issued in December 2002.

The FP6 targeted third countries top-up call (FP6 -2006-TTC-TU) was significant for Russian organizations interested in collaboration with European partners. The Russian Federal Agency for Science and Innovations (FASI) supported Russian scientists and scientific teams successfully participating in this call by approximately EUR 450,000. The funding limit for any one proposal under this call was about EUR 44,500.
5 of 17 successful projects within FP6-2006-TTC-NMP call were submitted by Russian organizations. **26** of 315 FP6-NMP projects already funded by European Commission have included partners from Russia:

- **5 Integrated Projects** (***IP***);
- **4 Networks of Excellence** (***NoE***);
- **17 Special Targeted Research Projects** (***STREP***).

The brief description of these projects is presented below.

NOVEL AND IMPROVED NANOMATERIALS, CHEMISTRIES AND APPARATUS FOR NANOBIOTECHNOLOGY (NACBO)

IP; Duration: 2004-12-01- 2008-11-30; Coordinator: **University of Kent, UK**; Russian participant: S**hemyakin -Ovchinnikov Institute of Bioorganic Chemistry of RAS, Moscow**; Description: *http://www.nacbo.net/*

This IP proposes the research, development and commercialization of discrete but overlapping areas of material science, materials chemistry and supporting/applying hardware systems. It will deliver novel and improved solutions to emerging and current needs in biology, health, chemistry, process engineering and the environment. Most particularly its outputs intend to address molecular diagnostics. The project will also address training of individuals, at all levels, in areas of relevance to its work and promotion of public awareness and female participation in science, engineering and technology with respect to nanotechnology and biotechnology. Finally it intends to deliver an effective web based resource for reference purposes with respect to bio/environmental compatibility of materials and chemistries involved in nanotechnology.

SELF-ORGANIZED COMPLEX-SPIN MAGNETIC NANOSTRUCTURES (NANOSPIN)

STREP; Duration: 2005-01-27- 2008-01-26; Coordinator: **University of Leicester, UK**; Russian participant: **NT-MDT Co, Zelenograd, Moscow**;
Description: http:*//www.nanospin.le.ac.uk/*

NANOSPIN accumulated all advanced researches, technologies and devices manufactured by world leading nanotechnology equipment producers. The overall scientific objective of NANOSPIN is to design and prepare complex magnetic nanoparticles composed of a metallic core and one or more shells of ferromagnetic or antiferromagnetic metals and to understand their behavior in order to control their magnetic properties (blocking temperature, anisotropy, exchange bias, spin quantum barrier height, etc.). The overall technological objectives are to activate the nanoclusters to enable them to be produced as ordered arrays on surfaces and to demonstrate proof of principle in classical and quantum single-particle data storage. The multiple-shell clusters will be produced by metal condensation in superfluid liquid He droplets. Large helium droplets, formed by expansion of liquid helium into vacuum via a pinhole nozzle, are skimmed to form a collimated beam and pass through pickup cells where they acquire evaporated metal atoms. The atoms move through the droplet, coagulate to form clusters, and cool to an ultra-low temperature on a sub microsecond timescale. In contrast, the journey time between each pickup cell is milliseconds and so shell formation in one cell is complete before the droplet reaches the next cell. This will allow discrete shell structures to form sequentially.

SELF-ASSEMBLED SEMICONDUCTOR NANOSTRUCTURES FOR NEW DEVICES IN PHOTONICS AND ELECTRONICS (SANDIE)

NoE; Duration: 2004-07-01- 2008-06-30; Coordinator: **University of Leipzig, Germany**; Russian participant: **A. F. Ioffe Physico -Technical Institute of RAS, St. Petersburg**; Description: *http://www.sandie.org/*

This NoE is dedicated to the formation of an integrated and cohesive approach to research and knowledge in the field of Self-Assembled semiconductor Nanostructures (SAN). These nanostructures can then be cemented in position by the deposition of further layers of the substrate material. By varying the semiconductor materials-involved, the growth conditions, and by vertically stacking layers of nanostructures, a rich variety of novel materials can be produced for the study of the fundamental properties of strongly confined systems, and for the development of advanced electronic and optoelectronic devices. The resources and the approach of the Network reach from the study of fundamental phenomena to their exploitation for the design of novel materials and structures for use in advanced electronic, photonic and optoelectronic devices. A measurable integration of the human resources, equipment and methods in the European research area will be achieved by the Network with a program of joint activities.

EMERGING NANOPATTERNING METHODS (NAPA)

IP; Duration: 2004-03-01- 2008-02-29; Coordinator: **VTT Technical Research Centre, Finland**; Russian participant: **Institute of Microelectronics Technology of RAS, Chernogolovka, Moscow District**; Description: *http://www.phantomsnet.net/NAPA/*

The NaPa consortium integrates the new patterning methods into one project, both anticipating and responding to the increasing need for technologies, standards and metrology required to harness the new application-relevant properties of engineered structures with nm-scale features. The NaPa consortium complements the deep UV technology by providing low-cost scalable processes and tools to cover the needs of nanopatterning from CMOS back-end processes through photonics to biotechnology. To achieve this, research in three technology strands is proposed: nanoimprint lithography, soft lithography & self-assembly and MEMS-based nanopatterning. Research in three overarching themes required by all strands: Materials, Tools and Simulation will be undertaken. NaPa brings together 35 leading academic and industrial European institutions with a vast amount of recent know-how on nanofabrication, partly developed within FP5. Complementing R&D, the consortium will design exciting nanoscience and nanoengineering courses to advance the training of the next generation of scientists and engineers and to create a positive attitude towards science among young people.

METAMATERIALS ORGANIZED FOR RADIO, MILLIMETER WAVE, AND PHOTONIC SUPERLATTICE ENGINEERING (METAMORPHOSE)

NoE; Duration: 2004-06-01- 2008-05-31; Coordinator: **Helsinki University of Technology, Finland**; Russian participant: **St. Petersburg Electrotechnical University "LETI"**; Description: *http://www.metamorphose-eu.org/*

The main scientific objective of this Network is to develop new types of artificial materials, called metamaterials, with electromagnetic properties that cannot be found among natural materials. The results of this development should lead to a conceptually new range of radio, microwave, and optical technologies, based on revolutionary new materials made by large-scale assembly of some basic elements (microscopic and baroscopic) in unprecedented combinations. These artificial electromagnetic functional materials are engineered to satisfy the prescribed requirements. Joint research activities of this Network will include composite materials with extreme electromagnetic properties (such as "left-handed" media and materials with null-valued effective parameters), electrically controllable materials, stop band materials, met geometries like fractals and quasi-periodical structures, artificial surfaces and sheets. The strategic objective to develop new metamaterials means opening a new branch of research in the multidisciplinary field of material physics, electromagnetic, optics, radio engineering, and electronics. The Metamorphose initiative integrates 13 different countries around Europe.

INTERMETALLIC MATERIALS PROCESSING IN RELATION TO EARTH AND SPACE SOLIDIFICATION (IMPRESS)

IP; Duration: 2004-11-01 - 2009-10-31; Coordinator: **European Space Agency**; Russian participants: **State Aviation Technical University, Ufa; Institute of Structural Macrokinetics and Materials Science of RAS, Chernogolovka; Institute of Chemical Problems for Microelectronics of RAS, Moscow**;
Description: *http://www.spaceflight.esa.int/impress/*

The scientific objective of the IMPRESS IP is to understand the critical link between materials processing, structure and final properties of novel, higher-performance intermetallic alloys. These multifunctional materials possess remarkable mechanical, physical and chemical properties, which make them very attractive for certain industrial applications. The new knowledge, derived from ground research and space experiments onboard the International Space Station, will lead to macroscale prototypes with tailor-made properties. The selected applications include the development of intermetallic materials and processes for large 40cm prototype turbine blades and advanced catalytic devices, such as hydrogenfuel cell electrodes, based on <20-micron powders. The long-term objective will be to develop cost-effective and sustainable ways of producing new high-quality components for extreme applications, thereby addressing energy and pollution issues. In turn, this will improve the competitiveness of European industry and the quality of EU citizen's lives. A unique team of 200 scientists from 15 countries has been assembled, with expertise in metallurgy, physical chemistry, metrology, computer modelling, fluid dynamics, product design and engineering.

MULTIFUNCTIONAL PERCOLATED NANOSTRUCTURED CERAMICS FABRICATED FROM HYDROXYLAPATITE (PERCERAMICS)

STREP; Duration: 2004-02-01- 2007-01-31; Coordinator**: Riga Technical University, Latvia**; Russian participants: **Autonomous Non-Commercial Organization Center for Orthopedic and Medical Material Sciences, Tomsk; Institute of Mathematical Problems of Biology, RAS, Pushchino, Moscow District**;
Description: *http://www.perceramics.vip.lv/*

The project will develop a percolated nanostructured electrically polarized ceramics (CER) fabricated from hydroxylapatite (HAP) to improve quality of bone eligible bioimplants, work out new material for immobilization of microorganisms frothier further use to product of various biologically active compounds (BAC) and purify the environment. A surface of CER will provide a relevant biological - non-biological interface to adhere cells/microorganisms. A surface morphology of CER will be supplied at an engineered scale eligible for a cell receptor “tail” size and will be “packed” from HAP nanoparticles. The CER surface will be charged and supplied with a web of the canals. Engineering support-employing knowledge acquired from computational physics research on charging and adhesion/cohesion by HAP nanoparticles will be provided. The results are planned to implement in industry, medicine, environment and biotechnologies.

SUPERHIGH ENERGY MILLING IN THE PRODUCTION OF HARD ALLOYS, CERAMIC AND COMPOSITE MATERIALS (ACTIVATION)

STREP; Duration: 2004-07-01- 2007-06-30; Coordinator: **Technical University of Crete, Greece**; Russian participants: **St. Petersburg State University; Techniques and Technology of Disintegration LTD., St. Petersburg**; Description: *http://pi.ijs.si/pibrain.exe?Cm=Project&Project=ACTIVATION&Reference=505885*

The aim of STREP ACTIVATION is the development of new materials and technologies based on particle size reduction and mechanical activation of particles. Improved performance of new materials will be achieved by means of finding an optimal balance between the size effects and effects of mechanical activation of particles. The specific feature of the project is the use of the planetary mills characterized by dramatically higher energy density than conventional milling equipment. The main groups of materials studied in this project would be hard alloys, intermetallics and composites, salons and multi component ceramic oxides. The aims of the project include development of technologies providing high-volume production of nanoscale materials at low cost and technologies of recycling of solid materials in a fast, efficient and environmentally friendly process. Technological developments will exploit novel industrial planetary mills of continuous mode. Applications of the approach in various fields of industry including manufacturing of cutting tools, production of special refractories, production of advanced ceramics, development of hard thin coatings, development of improved thermal spray coatings, will be investigated.

BALLISTIC MAGNETORESISTANCE IN THIN FILM NANOCONTACTS (BMR)

STREP; Duration: 2004-03-01 - 2007-02-28; Coordinator: **University of Plymouth, UK**; Russian participant: **Kazan State University**; Description: *http://www.ist-world.org/ProjectDetails.aspx?ProjectId=97693e56e7b04b4aaa5a40bdca6e502e*

The project explores a superior property in nanoscale magnetic thin film devices - the spin dependent ballistic electronic transport, which is a size-dependent phenomenon that may only occur in nanoscale materials and devices due to quantum mechanics effect. The project represents a new approach to materials science and engineering, as well as for design of new devices and processes for future data storage, spintronic devices and computers.

The aim of project is to employ the state-of-the-artnanofabrication technology for the fabrication of thin film vasoconstrictions with diameter of 50 ~ 5 nm, and to carry out a concerted experimental and theoretical study of the spin transport properties in relation to physical sizes, micromagnetic structures, interfacial and ferromagnetic/ semiconductor electrode materials, and polarization in the vicinity of the nanocontacts, aiming to explore high ballisticmagnetoresistance (BMR), to study the magneto elastic deformations of the contacts that can contribute to the transport process.

PHYSICS AND TECHNOLOGY OF ELEMENTAL, ALLOY AND COMPOUND SEMICONDUCTOR NANOCRYSTALS: MATERIALS AND DEVICES (SEMINANO)

STREP; Duration: 2004-09-01- 2007-08-31; Coordinator: **Middle East Technical University, Turkey**; Russian participant: **NTVP "POVERKHNOST" OOO, Moscow**; Description: *http://pi.ijs.si/pibrain.exe?Cm=Project&Project=SEMINANO&Reference=505285*

The primary objective of this project is to develop fundamental knowledge on the production techniques, characterization and methods of applications of semiconductor nanocrystals to light emitting devices and floating gate memories. Three main research directions can be identified in the project: physics and chemistry of a number of elemental, alloy and compound semiconductor nanocrystal formation and mechanisms of charge transport and light emission will be studied in a systematic way to acquire fundamental knowledge; methods and technology of obtaining new materials with well-characterized nanocrystals suitable for use in device work will be developed; devices such as Metal Oxide Semiconductor (MOS) for use in flash memories and light-emitting devices (Leeds) will be designed, fabricated and tested as prototypes of devices incorporating the unique features of nanocrystals. Full cycle starting from material processing to the demonstration of devices will be covered.

MULTICOMPONENT NANOSTRUCTURED MATERIALS FOR SEPARATION MEMBRANES (COMPOSE)

STREP; Duration: 2004-03-01 - 2007-02-28
Coordinator: GKSS FORSCHUNGSZENTRUM, Institute of Chemistry, Geesthacht, Germany; Russian participant: **A.V. Topchiev Institute of Petrochemical Synthesis, RAS, Moscow**; Description: *http://compose.gkss.de/about.htm*

It is the objective of COMPOSE to develop new materials with predefined physical and chemical characteristics: nanostructured organic/inorganic hybrid materials and functional self-organized supramolecular copolymers. Organic/inorganic hybrid materials will be developed and manufactured into membranes for the selective separation of gases and liquids. Among the materials to be developed are high free volume polymers filled with in-site generated inorganic phases and mixed matrix membranes consisting of polymer and dispersed carbon molecular sieve flakes. Organic/inorganic hybrid membranes will also be developed for nanofiltration in organic solvents. The membranes envisaged can have enormous economic benefit for the chemical and pharmaceutical industry. The second route to totally new membrane materials is the self-organization of block copolymers. This part of COMPOSE dealing with creating membranes by molecular self-assembly promises new paradigm in membrane technology and knowledge.

TAILORED NANOSIZED METAL CATALYSTS FOR IMPROVING ACTIVITY AND SELECTIVITY VIA ENGINEERING OF THEIR STRUCTURE AND LOCAL ENVIRONMENT (NANOCAT)

STREP; Duration: 2005-02-01- 2008-01-31; Coordinator: **ABO Akademi University, Finland**; Russian participant: **Tver State Technical University, Tver**

The project is aimed to study the influence of metal nanoparticle size and its environment on catalytic behaviour in some representative reactions of industrial importance and, finally, to establish the fundamental knowledge on atomic/molecular level relating the nanocatalyst synthesis and behavior. The model reactions represent selective oxidation, chemo- and enantioselective hydrogenations as well as catalytic isomerization reactions, where the use of conventional supported catalysts yields to too low selectivity's of the desired products.

By changing the size, shape and local environment of the nanostructures, their functionality may be controlled. To achieve the main goal, following tasks will be performed:

i) Development and physicochemical characterization of Ru, Pt, Pt-Au and Pd nanoparticles of 1-10nm diameter incorporated in inorganic and organic fictionalised and non-fictionalised micromesoporous matrices, polymer or carbon nanofibers.

ii) Catalyst testing in hydrogenation and oxidation , yielding the intermediates used for production of biologically active compounds, healthy food ingredients and perfumes.

iii) Development of reaction mechanisms by combination of diffusion and kinetic modelling together with time dependent Monte Carlo - quantum chemical calculations.

COMPUTER AIDED MOLECULAR DESIGN OF MULTIFUNCTIONAL MATERIALS WITH CONTROLLED PERMEABILITY PROPERTIES (MULTIMATDESIGN)

STREP; Duration: 2005-03-01- 2008-02-29; Coordinator: **Institute of Polymer Research GKSS, Germany**; Russian participant: **A.V. Topchiev Institute of Petrochemical Synthesis, Moscow**; Description: *http://multimatdesign.gkss.de/*

Many technical processes involve permeation of molecules of various sizes through nanostructured materials. The characteristics of such permeation phenomena are governed by the structure and dynamics at the nanoscale level of the relevant materials. Typical applications are separation of fluid and gaseous mixtures, packaging and drug release. These materials are multifunctional, because they must combine the required permeability characteristics with suitable other properties such as mechanical stability or biocompatibility. The main objective of MULTIMATDESIGN is to make decisive contributions to a breakthrough towards the knowledge-based design of the above materials. This objective will be accomplished by the extensive application of computer aided molecular design (CAMD) tools leading to the acquisition of new knowledge. CAMD is a very attractive approach allowing the detailed investigation of structure and dynamics on the length and time scales most important for the transport processes of interest.

NANOSILICON-BASED PHOTOSYNTHESIS FOR CHEMICAL AND BIOMEDICAL APPLICATIONS (PSY-NANO-SI)

STREP; Duration: 2005-03-01 - 2008-02-29; Coordinator: **Technical University of Valencia, Spain**; Russian participant: **M.V. Lomonosov Moscow State University, Faculty of Physics**; Description: *http://cordis.europa.eu/fetch?ACTION=D&SESSION=&DOC=1&TBL=EN_PROJ&RCN=29776&CALLER=FP6_PROJ*

The project joins together the most common and well-studied elements on the Earth - silicon and oxygen. The project claims to explore a new type of interaction among these elements, though in their artificially created forms (silicon converted into nano Si - with small Si clusters connected into highly porous network, and oxygen excited into highly reactive singlet state). Project will address fundamental issues of physics (optics of nanostructured semiconductors, energy transfer between molecules), chemistry (photochemical reactions mediated by singlet oxygen with molecules, electrochemistry of porous semiconductors, surface reactions), biology (photooxidation of biomolecules) and medicine (photostimulated apoptosis of living cells). Therefore, it will contribute to the advancement in these fields of science and will ensure continuous breakthrough innovations in important issues of human well-being. Technological frontiers to explore are application of highly reactive singlet form of oxygen molecule generated by nano Si in a variety of fields vital for the improvement of human life: curing of severe diseases, fine organic synthesis and protection of environment. Project explores two fundamental discoveries made by consortium members: generation of singlet oxygen by nano Si and its biodegradability.

LONG-PERIOD OBSERVATION OF SINGLE (BIO)-MOLECULAR MOTORS BY MINIMAL-INVASIVE FLUORESCENCE LIFETIME IMAGING NANOSCOPY (SINGLEMOTOR-FLIN)

STREP; Duration: 2005-06-01 - 2008-05-31; Coordinator: **Europhoton GMBH, Germany**; Russian participant**: Nuclear Physics Institute, RAS, Gatchina, St. Petersburg**; Description: *http://www.euro-flin.de/*

The recently invented fluorescence lifetime imaging nanoscopy (FLIN) provides a groundbreaking tool for the study of single molecules (SM) and single molecular motors (SMM) as well as a broad array of phenomena in the nanoworld. Previous limitations for SMM studies, resolution, short observation times, and photodynamic reactions, are now overcome by minimal-invasive picosecond FLIN. FLIN is the extension of the extremely successful fluorescence lifetime imaging microscopy (FLIM) into the nanodomain, with 10 to 100nm space resolution. FLIN results from the combination of 4pi-microscopy with novel ultra sensitive, nonscanning imaging detectors, based on time- and space-correlated single photon counting (TSCSPC) that allows ultra-low excitation levels. This results in long-period (1 hour), minimal-invasive observation of living cells and SM/SMM, without any cell damage or irreversible bleaching. Minimal-invasive FLIN (MI-FLIN) with global point spread function modelling allows observation of SMM movement at 1-nm accuracy and 10-nm resolution. Enhanced basic understanding of biological and artificial machines and motors will lead to improved model systems and proceed one day to the design of artificial systems, improving the interface of biological and non-biological worlds.

Biological SMM are involved in many disease states and project is aimed to improve understanding of how these motors operate and how they break down in disease.

SAFETY ASSESSMENT AND LIFETIME MANAGEMENT OF INDUSTRIAL PIPING SYSTEMS (SAFE PIPES)

STREP; Duration: 2005-09-01 - 2008-08-31; Coordinator: **Vienna Consulting Engineers (VCE HOLDING), Austria**; Russian participant: **CKTI-VIBROSEISM CO. LTD., St. Petersburg**; Description: *http://www.vce.at/frames/research/frame_research_current.htm*

The overall objective of STREP is to develop a complete integrated monitoring system that allows to rate industrial piping systems over their whole service life and to increase the general safety. The goal is to reduce investment cost for maintenance, inspection and loss of production as well as to limit accidents, hazardous to mankind and environment. This proposal addresses important industrial lifecycle issues of the nuclear industry and the sector of chemical plants. Current methodologies shall be replaced by online sensor and decision support systems. No limit for the assessment throughout the lifecycle shall remain. The conceptual objective is to demonstrate the opportunities for the advanced technology to deliver a radical new approach to the lifecycle control and maintenance of structures. This will be achieved by showcasing the optimization of piping systems in industrial installations that is enabled through a new rating paradigm for risk assessment, management, maintenance and retrofit. A complete integrated monitoring system will allow to rate industrial piping systems over the whole service life and to increase the general safety.

NETWORK OF EXCELLENCE: TO OVERCOME THE FRAGMENTATION OF EUROPEAN RESEARCH IN MULTIFUNCTIONAL THIN FILMS (EXCELL)

NoE; Duration: 2005-04-01- 2010-03-31; Coordinator: **COCKERILL SAMBRE ARCELOR, Belgium**; Russian participants: **Moscow State Institute of Steel and Alloys, Moscow; Institute of Spectroscopy of RAS, Troitsk**

EXCELL is designed to become a key instrument to overcome the fragmentation of the European research in the field of studies of surface properties of nanocomposites and in thin multifunctional films with wide applications in numerous European industrial sectors. EXCELL aims at a deep restructuring of European research in this particular area via establishing a durable integration in order to stimulate innovative research and development, standardization and the promotion of the industrial uptake of the breakthrough technologies. Although EXCELL is built by a minimal number of participants (it combines 14 European institutions), it represents the European excellence in nanofilms research and applications. EXCELL is a focused project as all the partners are fully committed to the durable and long lasting integration and restructuring of their research capacities without which the whole research area will become flagging regardless the efforts spent by each particular institution.

RADICAL INNOVATION MASKLESS NANOLITHOGRAPHY (RIMANA)

STREP; Duration: 2005-10-01 - 2008-09-30; Coordinator: **IMS NANOFABRICATION GMBH, Austria**; Russian participant: **Institute of Microelectronics Technology, RAS, Chernogolovka**; Description: *http://www.rimana.org/*

The STREP RIMANA aims to research and develop a key maskless nanopatterning technology for low to medium volume production, essential for the semiconductor industry and emerging nanotechnology industry.

RIMANA is driven by two global industrial needs:

- An ML2 tool for short run and low to medium volume leading edge device manufacturers (Logic, ASIC, Silicon Foundries)

- A fast Mask Writer for the leading edge high volume device manufacturers (MPU, DRAM, Logic)

Both global industrial needs are addressed by the proposed RIMANA project with the following overall S&T objectives and work plans:

- Concept and realization of a new, highly innovative compact APS (Programmable Aperture Plate System), including high-speed electronics with the ability to generate a massive parallelisation of electron beams for the 32nm technology node and beyond

- Concept and realization of Data Path improvements to achieve higher data rates

- Design and generation of test benches to demonstrate sub-32nm node ML2 high throughput capabilities in resist

- Brainstorm of results with perspectives for potential industrial realization

CHARGED PARTICLE NANOTECH (CHARPAN)

IP; Duration: 2005-04-01-2009-03-31; Coordinator: **IMS -Nanofabrication AG, Austria**; Russian participant: I**nstitute of Microelectronics Technology, RAS, Chernogolovka**); Description: *http://www.charpan.com/*

The IP CHARPAN focuses on the research and development of a new production technology for nanotechnology devices. In particular, CHARPAN will enable low cost engineering of complex 3D surface structures with nanometer precision. A 18 member strong and diversified team from industry, academia and acclaimed European research institutes are drawn together in a single integrated project to achieve the ambitious goals:

-Development of projection-focused multi beam equipment for charged particle beam patterning, providing a massively parallel beam, structured by a programmable aperture plate.

-Producing a prototype of the CHARPAN nanostructuring tool to establish a proof-of-concept (POC) of the CHARPAN concept and applications.

-Research and development of charged particle beam process applications for new industrial manufacturing processes and new materials.

-At the end of the project a CHARPAN ion beam demonstration tool will be produced.

ECO EFFICIENT ACTIVATION FOR HYPER FUNCTIONAL SURFACES (ACTECO)

IP; Duration: 2005-05-01-2009-04-30
Coordinator: **EUROPLASMA NV, Belgium**; Russian participant: **Troitsk Institute for Innovation and Fusion Research**; **State Research Centre**;
Description: *http://www.acteco.org/Acteco/public/projectobjectives.htm*

The objective of this IP is to support the less RTD intensive sectors of textile, biomedical and food industries in the development of more sustainable and safer processes through eco-innovation (new products and production systems). This project involves new plasma processes that are able to bring innovative properties with a lifetime close to the final products' one. This breakthrough will be achieved by developing existing knowledge in plasma processes and functional materials in combination with new plasma systems for nanotechnology. The ACTECO project will contribute to the modernization of the industry and to the adaptation to the new economy; substantially improve overall quality within the value chain; minimize waste, use of hazardous substances and resource consumption. The first phase of the Work programme is related to Research at laboratory scale on the development and optimization of the surface modification processes in constant interaction with an Equipment development activity. The second phase is focused on Applied Research by optimizing existing prototypes at pilot scale. The new processes will be then developed through pre-industrial applications comparing the several facilities involved in the project (real devices and real environment).

ANTIMONIDE QUANTUM DOTS FOR MID-INFRARED NANO-PHOTONIC DEVICES (DOMINO)

STREP; Duration: 2005-06-01- 2008-05-31; Coordinator: **University Montpellier II, France**; Russian participant: **A.F.Ioffe Physico-Technical Institute of RAS, St. Petersburg**

The main objective of this project is to demonstrate the feasibility of antimonides-based quantum dots (QDs) nanophotonic quantum dots laser diodes (QDLDs) operating continuous wave at room temperature (RT) in the 3-5µm wavelength range. Sb-based heterostructures, grown on GaSb or InAs substrates, exhibit a number of unique possibilities among III-V compounds in terms of band structure engineering. In particular, it is the only III-V technology exhibiting interband transitions in the mid-IR. However till now no quantum well laser diode is able to operate at wavelengths between 3 and 5µm. QDs heterostructures are expected to extend the emitted wavelength and to strongly improve the performances of semiconductor LDs (reduced threshold, high operating temperature) as demonstrated with the GaAs and InP technologies. The successful demonstration of Sb-based QDLDs could thus pave the way to the development of high performance mid-IR optoelectronic devices and photonic sensors. Another goal of project is to retrieve a clear picture of Sb-based nanostructures physical properties which is a prerequisite to obtaining reliable, emitting devices, to define their field of applications, and to assess the interest of developing other nanophotonic devices. DOMINO will open the route to further long-term research on semiconductor nanostructures and nanophotonic devices.

NANOSTRUCTURED FERROLECTRIC FILMS FOR TUNEABLE ACOUSTIC RESONATORS AND DEVICES (NANOSTAR)

STREP; Duration: 2005-05-15 - 2008-05-14; Coordinator: **Chalmers University of Technology, Sweden**; Russian participant: **St. Petersburg Electrotechnical University "LETI"**; Description: *http://www.nanostar-eu.com/*

The main focus of project will be concentrated on the development of the theory, fabrication processes and device demonstrators for functional validation of nanostructured multifunctional ferroelectrics films and components. Tuneable Thin Film Bulk Acoustic Resonators (TFBAR), varactors, and delay lines are typical components to be developed. The capabilities of the nanostructured ferroelectrics will be demonstrated by functional validation in integrated nanoelectronic microwave demonstrators. Tuneable TFBARs are the new devices with new functionality, which has no analogues in electronics industry.
Main milestones:
i) Development of industry relevant fabrication processes for nanostructured ferroelectric films with radically new properties
ii) Validation via device demonstrators and circuit applications of the demonstrators
iii) Generation of new knowledge in the physics, fabrication technologies.

SINGLE-PHOTON NANOSTRUCTURED DETECTORS FOR ADVANCED OPTICAL APPLICATIONS (SINPHONIA)

STREP; Duration: 2006-01-01- 2008-12-31; Coordinator: **Ecole Polytechnique Federale de Lausanne, Switzerland**; Russian participant: **Moscow State Pedagogical University, Department of Physics/Radio-Physics**; Description: *http://www.sinphonia.org/*

This project targets the development of near-infrared single photon optical detectors based on nanostructured superconductors. These detectors will achieve ultimate sensitivity and temporal resolution for application in long-distance optical communications, quantum cryptography, diagnostics and testing, and remote sensing.

We will pursue the following objectives:

- Fabricate single photon optical detectors with unprecedented performance at telecom wavelengths (four orders of magnitude more sensitive and three orders of magnitude faster than commercially-available avalanche photodiodes and photomultipliers)

- Demonstrate their implementation in several IST applications by industrial partners.

In order to achieve these goals, the following approach will be taken:

- Material development, nanofabrication and optical characterization will be pursued by academic and public research institutions. Applications will be demonstrated by SMEs and major industrial players with a leading position in optical communications, professional electronics and advanced optical technologies.

NANOPHOTONICS TO REALIZE MOLECULAR-SCALE TECHNOLOGIES (PHOREMOST)

NoE; Duration: 2004-09-28 – 2008-09-30; Coordinator: **University College Cork, National University of Ireland, Cork**; Russian participant: **Institute of Solid State Physics of RAS, Chernogolovka; A.F. Ioffe Physico-Technical Institute of RAS, St. Petersburg**; Description: *www.phoremost.org*

NoE PHOREMOST builds on the critical mass existing in Europe in this emerging area, rapidly developing as a result of the concomitant progress in nanostructured materials, nanofabrication technologies, nanoscale characterization techniques, novel concepts linking electromagnetic radiation in electronic and optical systems, recent concepts involving optical properties of nonperiodic, fractal and quasicrystal structures, as well as a better understanding of nonlinear properties of molecules. The main driving force behind nanophotonics is the expectation to access the molecular scale dispensing with electrical contacts. PHOREMOST will integrate the activities in the nanophotonics area of 34 pioneering and world leading partners from universities, research centres and industry to: (a) overcome fragmentation, (b) ensure efficient use of resources, (c) identify future RandD opportunities, (d) guarantee the supply of suitably trained personnel, (e) anticipate future research needs, (f) ensure the excellence in research translates into applications in the life sciences, environment, infotainment and security, (g) benefit from the untapped expertise in accession and third countries and, (h) contribute to the public understanding of science. To achieve its objectives the Network organizes its long-lasting impact work with integrating and spreading excellence activities. The management activities are designed to ensure a smooth and efficient running of the network.

PREDICTING FIRE BEHAVIOUR OF NANOCOMPOSITES FROM INTRINSIC EXTENSION (PREDFIRE-NANO)

***STREP*;** Duration: 2005-02-01 – 2008-01-31; Coordinator: **University of Ulster, UK**; Russian participant: **Institute of Radio Engineering and Electronics of RAS, Fryazino, Moscow District**; Description: http://www.engj.ulst.ac.uk/predfire

STREP PREDFIRE–TTC complements the current PREDFIRE project. It will address two critical issues for PREDFIRE by pursuing the following objectives i.e. a) on-line measurements of the monodispersivity of nanoparticles in the polymers (related to PREDFIRE using only off-line measurements) and b) surface temperature measurements of a burning polymer through its flames (related to PREDFIRE using inadequate thermocouple techniques). The first objective will ensure the monodispersivity of the polymer nanocomposite during production avoiding early in the process unintended specimens, whereas the second objective will assist in the validation of the predictive models in PREDFIRE. Both areas will use MM (millimetre) and microwave spectroscopy to measure a) the dielectric properties of the nanocomposite polymer which are known to be related to the monodispersivity of the nanoparticles and b) the reflection and radiation from the burning polymer since flame are transparent to MM wavelengths.

CONTROLLING MESOSCOPIC PHASE SEPARATION (CoMePhS)

STREP; Duration: 2005-06-01 – 2008-05-31; Coordinator: **National Technical University of Athens, Greece**; Russian participant: **Institute for Theoretical and Applied Electrodynamics of RAS, Moscow**; Description: *http://www.comephs.com/*

Conventionally, electronic device functions are generated by combining various materials, in which each material has one particular functionality. With the atomic limit as the ultimate achievable goal in sight, we try to explore methods that do not need extensive use of top-down nanotechnology, but use device structures that are spontaneously created by nature in the general framework of electronic phase separation. Here one material can adopt more than one electronic state, and by judicious organization of these electronic states device functions can be generated with built-in atomic precision. In a number of materials like manganites, a spectacularly diverse range of exotic magnetic, electronic, and crystal structures can coexist at different locations on the same crystal. CoMePhS (FP6 project, contract № NMP4-CT-2005-517039) is the first European project that aims to concentrate all necessary resources in order to achieve functionality of mesoscopic textured states setting up a basis for a new set of electronic technology. The extended partnership of ITAE-Mos-RU has the objective to perform additional theoretical tasks concerned with the mesoscopic phase separation and inhomogeneous states (droplet structures, stripes, etc.) in the strongly correlated electron systems (magnetic oxides, low-dimensional compounds, and superconductors).

The project “DELILA” funded by European Commission within the Thematic priority “Information Society Technologies” (FP6-IST) covers the important topic in the area of nanotechnologies.

DEVELOPMENT OF LITHOGRAPHY TECHNOLOGY FOR NANOSCALE STRUCTURING OF MATERIALS USING LASER BEAM INTERFERENCE (DELILA)

STREP; Duration: 2006-01-01 -2008-12-31; Coordinator: **Cardiff University, UK**; Russian participant: **Institute of Applied Physics of the RAS, Nizhnii Novgorod**; Description: *http://www.delila.cf.ac.uk/*

STREP DELILA focuses on researching and developing a new production technology for fabrication of 2D and 3D nanostructures and devices. In particular, DELILA will enable low cost and large volume production of surface structures and patterns with nanometric resolution. Industrial end-users are currently discouraged from expanding their nanotechnology-related business activities by either unacceptably high costs or the impossibility to control production processes on a nanometric scale. DELILA will play a key role in realising the full potential of interference nanolithography by combining optical technology, ICT and micro/nano-technology, as current nanofabrication tools are limited to archaic, slow processing rates, or do not achieve a competitive cost-effective strategy. It is well known that during interference of several coherent beams of laser radiation, conditions for localization of laser energy into a large set of areas with sizes up to a quarter of the wavelength and periods up to one-half of the wavelength of used radiation are easily realized. Thus, when the UV radiation of excimer lasers or solid-state lasers generated at the fourth or fifth harmonic is employed, the laser energy can be localized into a set of areas with sizes 40–80nm.

The method developed by Russian scientists with the use of high-power pulsed radiation makes it possible to realize the nonlinear mechanisms of nanoscale modification and obtain structures with sizes less than 40nm.

During experimental studies in pulsed interference lithography, a XeCl laser with a pulse energy of up to 100mJ, a duration of up to 10ns, and a coherence length of ~30cm with diffraction quality is used. The method can be used for the creation of resonant and antireflection structures for optics, well-positioned sub-100nm crystals for semiconductor electronics, two-dimensional relief for biomedicine (DNA sorting, attachment of reagents to a definite point in space, photo- and biocatalysis, etc.), and other applications.

PART II

PROPOSALS OF RUSSIAN ORGANIZATIONS FOR POTENTIAL SCIENTIFIC ACTIVITIES

AMORPHOUS - NANOCRYSTALLINE MATERIALS

Institute of Solid State Physics RAS

PRESENT STATUS of RESEARCH

Brief Descriptions of Research

Nanocrystalline structure prepared by controlled crystallization of amorphous phase and the dependence of structure parameters on nanocrystallization conditions have been studied for a lot of systems based on **Al, Zr, Ni, Fe, Cu**, **Mg**. Nanocrystalline structure was shown to consist of the nanocrystals located in amorphous matrix; the nanocrystals size ranges from 5 to 50 nm depending on alloy composition. The materials obtained exhibit exceptional physical properties, for example, soft magnetic properties ($Fe_{73.5}Si_{13.5}B_9Nb_3Cu_1$ alloy). Microhardness of light high-strength nanocrystalline Al-Ni-Yb alloy is as great as 4.2 GPa whereas the density is only 3.4 g/sm^3 (the microstructure of nanocrystalline $Al_{86}Ni_{11}Yb_3$ alloy is shown in Figure).

Regularities of structure formation has been investigated and nanocrystalline structure has been firstly formed at heating in bulk Zr- and Fe-based metallic glasses. The structure specific features and composition of individual nanocrystals were determined; magnetic and mechanical properties were measured. Some mechanical properties were measured at elevated temperatures: plasticity of Zr-based alloys was found to be more than 400% at 550°C. Structure/property correlation was determined.

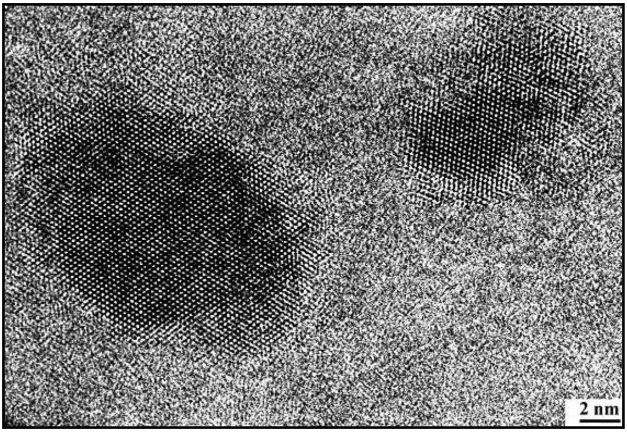
Nanocrystalline structure was also produced by a severe plastic deformation of amorphous Fe-Si-B alloys. These alloys contain no Cu and Nb, this makes possible to improve magnetic properties of the alloys.

Special Facilities in Use and Their Specifications

The equipment used: X-ray Siemens D-500 diffractometers, electron microscopes (high resolution electron microscope JEM-4000EX, transmission electron microscope JEM-100CX, scanning electron microscope ZEISS SUPRA 50VP), equipment for amorphous alloy production.

Selected Papers

1. G.Abrosimova, A.Aronin, H.Alves, U.Köster et al. - J. Mater. Sci . 34 (1999) 1611.
2. G.Abrosimova, A.Aronin, T.F.Gloriant, A.L.Greer, - NanoStruct. Materials, 12 (1999) 617.
3. G.Abrosimova, A.S.Aronin, Yu.V.Kir'janov, et al. - J. Mater.Sci., 36 (2001) N 16, 3933.
4. A.Aronin, G.E.Abrosimova, Yu.V.Kir'janov, Physics for Solid State, 43 (2001) 2003.
5. G.Abrosimova, A.Aronin, et al.- J. Metast.and Nanocryst. Materials 24-25 (2005) 69.



DIRECTIONS of FUTURE RESEARCH

Possibility of Application

Creation of the materials with desirable properties for later application as magnetic sensors, transformer elements, high-strength materials etc.

Suggestion on Cooperation with Foreign Partners

Torino University, Italy, Cambridge University, Great Britain, Madrid University and Bask University, Spain, National Polytechnic Institute of Grenoble, France, Leibnitz Institute of Solid State Physics and Materials Science, Dresden, Germany.

CONTACT INFORMATION

Institute of Solid State Physics, Russian Academy of Sciences,
Prof. A.Aronin, Dr. G.Abrosimova, Dr. A.Mazilkin, Dr. D.Matveev, Dr. O.Rybchenko, Dr. I.Zverkova, E.Ignatieva,
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NANOBIOTECHNOLOGY IN PROTEOMICS AND MEDICINE

Institute of Biomedical Chemistry RAMS

PRESENT STATUS of RESEARCH

Brief Descriptions of Research

Goal – creation of nanodevices for medical diagnostics and treatment. To realize the goal set, the Institute of Biomedical Chemistry RAMS develops the following 3 research directions. *Research 1*: Creation of nanobioarrays based on multi-channel atomic force microscopes for use in medical proteomics. *Research 2*: Fabrication of nanodevices for medical diagnostics:*Research 3:* Creation of nanosystems for treatment.

Special Facilities in Use and their Specifications

Research 1. Nanobioarrays based on multichannel atomic force microscopes with high concentration sensitivity (at the concentration level of 10^{-18} M) and parallel analysis of molecules in 16 channels are being developed for use in medical proteomics.

Research 2.

2.1. Fabrication of highly sensitive nanobiochips to the AFM for the diagnostics of infectious infections and cancer at a single-molecular level.

2.2. Fabrication of nanobiochips on the CD basis for the diagnostics with the aid of CD-ROM to a personal computer; these devices are designed as compact disks with sensitive biomolecular zones deposited onto them – such as antibodies, antigens, aptamers, oligonucleotide probes. Such diagnostic devices will enable to conduct simultaneous diagnostics of a disease spectrum within 10 min and may find an application in clinico-diagnostic laboratories not equipped with special technical devices; moreover, some tests may be adapted for conducting at-home analyses by the user himself.

2.3. Fabrication of high fast-acting nanobiochips to an optical biosensor for real-time diagnostics; such nanobiochips are, in fact, standard cuvettes modified with biomolecular layers (i.e. with antigens, antibodies, aptamers, oligonucleotide probes). On depositing the biological fluid with partner biomolecules onto the biochip, specific biomolecular complexes are formed; this leads to the increase in refractive index registered in real time.

2.4. Creation of electrochemical nanobioarrays based on the nanoparticles of metals (such as gold and silver) for identification of various forms of cytochromes P450 participating in the metabolism of a wide spectrum of drugs, for control over the metabolic rate of various drugs in patient serum.

2.5. Creation of highly-sensitive nanowire detectors for the diagnostics at a single viral and microbial particles' level. Such devices register changes in conductance of semiconductor nanowires (modified by biomolecules) upon formation of receptor-ligand complexes on the nanowire surface. Registration of marker molecules is carried out in real time.

2.6. Creation of fast-acting and very cheap nanodevices on the basis of nanopores for direct registration of single DNA molecules and for genome sequencing. Passing of single DNA through the nanopore of the counting DNA-device result in changes of electrical conductance of a nanopore and appropriate registration of this single DNA.

Research 3. Creation of drug delivery systems based on phospholipid nanoparticles applied for intravenous injections of medicinal drugs in treatment of cancer and infectious diseases, including AIDS and hepatitis C.

Selected Papers

1. Ivanov Yu.D et al., **Detection of hepatitis B virus surface antigen with the use of an optical Biosensor**, Zh. Microbiol. (Moscow) 2003, 2, 58-62.
2. Kuznetsov V. et al., **Atomic force microscopy revelation of molecular complexes in the multiprotein cytochrome P450 2B4-containing system**, Proteomics. 2004 Aug;4(8):2390-6.
3. Archakov A.I. et al., **AFM Fishing Nanotechnology is the Way to the Reverse Avogadro Number in Proteomics**, Proteomica, 2006 in press.
4. Ivanov Yu.D. et al., **Nanotechnology in Proteomics**, Proteomica, 2006, 5, 1399.

FOREIGN COLLABORATORS

Saarland University in Germany, Institute of Technical Biochemistry of Stuttgart University, Cologne University in Germany, Institute of Analytical Biochemistry of Potsdam University, INSERM, France, Glasgow University. Partners from Saarland University in Germany (the person in charge, Rita Bernhardt) and INSERM (the person in charge, Dr. Gaston Hui Bon Hoa) were the participants of INSERM –U-310 INRA-station 806, joint projects INCO Copernicus PL965070, Russian-Germany Project 0311721, etc.

DIRECTIONS of FUTURE RESEARCH

Possibility of Application

1. Creation of nanobioarrays on the basis of multi-channel atomic force microscopes is necessary for a fast-acting and highly sensitive proteomic analysis of the protein profile of biological fluid.

2. Nanodevices for medical diagnostics will make possible (1) obtaining of new diagnostic systems with a sensitivity by several orders higher than that of existing test-systems – up to a sensitivity at a single-molecular level; (2) obtaining of fast-acting systems operating in real time.

3. Creation of transport nanosystems for treatment of infectious diseases and cancer on the basis of phospholipid nanoparticles.

CONTACT INFORMATION

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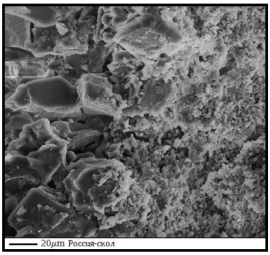
THE DEVELOPMENT OF NANOFILTRATION CERAMIC MEMBRANES AND FILTERS TECHNOLOGIES, ON THE BASIS OF DEEP LIQUIDS AND SUSPENSIONS SEPARATION

Joint-stock company "Scientific and Technical Centre BAKOR"

PRESENT STATUS of RESEARCH

Brief Descriptions of Research

Because of the excavation and working out of native nonferrous metals, nowadays it is necessary to involve to the processing the ores with a compound mineralogical structure, as well as delicate/thin ingrained and oxidized ore. This inevitably results in increasing of thin milling of source materials before the floatation and raises the moisture of thin-milled concentrates (the size of particles become less then 200nms). It also reduces the selectivity of separation process. Filtrating elements were tested at the enterprises "Karelskiy Okatysh", Kovsorskiy GOK, ZAO MHK "Eurohim", OAO "Oskol Electrometallurgcal Industrial Complex", and at Achinskiy Alumina Industrial Complex of OAO "Russkiy Alyuminiy" – to dehydrate the hydroxide aluminum. Those tests showed the necessity of creation of filtrating elements with the membranes which size is less then 200 nms and detected the need to develop membranes production technology.



Microstructure of the filtration ceramic element with membrane for ultrafiltration processes

The Centre has available equipment for making new ceramic materials and goods.

Selected Papers

1. Krasny B.L., Tarasovsky V.P., Valdberg A.Y., Kaznacheeva T.O, **The research of filter properties of ceramic materials**, Chemical and Oil-gas engineering. No1, 2005, p. 40-42.

2. Krasny B.L., Anciferov V.N., Tarasovsky V.P., **The application of porous permeable materials at different ferrous and nonferrous metals production revisions**, International Conference "Present-day technologies, equipment and raw materials for fireproofs". 14-15 April, 2006, Moscow.

3. Patent No 2255792, 2006, Krasny B.L., Tarasovsky V.P., Marinina T.C. - **For The Method of production of goods from silica**.

DIRECTIONS of FUTURE RESEARCH

The Centre BAKOR invites foreign companies working in the field of ceramic membranes to cooperate in making of goods and instruments for nanofiltration. Centre BAKOR has available productive capacity to organize the production of goods developed within the Project.

CONTACT INFORMATION

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INVESTIGATION OF THE INITIAL STAGES OF GAS-TO-PARTICLE CONVERSION IN THE ATMOSPHERE

Institute of Chemical Kinetics and Combustion SB RAS
Institute of Atmospheric Optics SB RAS

PRESENT STATUS of RESEARCH

Brief Descriptions of Research

We have developed a novel method for fast measurement of mass concentration and diffusion coefficient of low-volatile admixtures in the atmosphere. The principle is based on rapid cooling of the air by liquid nitrogen vapors. At these conditions, the atmospheric water gets spontaneously condensed. The formed water fog absorbs low-volatile substances from the air. After the fog droplets evaporated we obtain detectable size aerosol particles. Automated diffusion battery is used as classifier of the particle formed. Thus we increase the natural condensation growth by10000 times approximately. Specifications of the method: vapor pressure of the substances captured – $<10^{-8}$Hg.mm., detection limit 1 ng/m^3 single measurement time – 4 min. Our technique also makes sufficiently easier the filter sampling of low volatile substances for chemical characterization.

The method has successfully passed all laboratory calibration procedures and already being applied in environmental research in Eastern Siberia and Baikal lake region for the last five years.

Selected Papers

1. Ankilov A.N. et.al. **Determination of low volatile molecules and molecular clusters concentration formed in the atmosphere during chemical transformations**, J. Aerosol Sci., vol. 31, Suppl. 1, 2000, pp.696-697
2. Ankilov A.N. et.al. **Determining concentration of the aerosol forming substances in the atmosphere**, Atmos. and Oceanic Optics, vol. 13, 2000, No.06-07, pp.597-601.

DIRECTIONS of FUTURE RESEARCH

Possibility of Application

Fast detection and easy sampling of low volatile substances under indoor and environmental conditions.

Suggestion on Cooperation with Foreign Partners

The participants are interested in geographical expansion of measurement and development of the equipment up to the technological level.

CONTACT INFORMATION

Institute of Chemical Kinetics and Combustion SB RAS;
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ELECTRODEPOSITED MULTILAYERS

Institute of Solid State Chemistry and Mechanochemistry SB RAS

PRESENT STATUS of RESEARCH

Brief Descriptions of Research

Multilayers (ML) which exhibit the giant magnetoresistance effect (GMR) are of potential technological **application** ranging from magnetic field sensors to data recording devices. The aim of this work is to study the effects of changing the electrochemical deposition conditions on the composition and thicknesses of both magnetic and non-magnetic thin layers [1], which play a critical role in determining the magnetotransport properties of electrodeposited ML.

The group was the first to show the importance of electromigration and mixing by co-evolved hydrogen in the enrichment of magnetic layer by a nonmagnetic component. Such phenomenon observed during recent studies of Cu/ Ni–Cu structures deposited from acetate and sulphamate electrolytes [2], when hydrogen and nickel ions discharge accelerate mass transfer of copper [3], and the excess of a partial current of copper above a limiting diffusion current with growth of cathode polarization is increased and achieves 3–5 times in acetate electrolytes and 5–6 times – in sulphamate. It leads to a deviation of element composition of the magnetic layer from expected, and a deterioration in the magnetotransport properties of electrodeposited ML [4].

The group has also made wide use of the electrochemical quartz crystal microbalance (EQCM) to explore the chemical stability of thin Ni and Co layers and contribution from side processes [5].

The team has particular experience in interpreting the voltammetric behaviour of electrodeposited films, especially with the help of mechanically renewed electrodes [6].

In addition, the team's expertise includes the magnetoresistance effect investigations and the development of in-situ diffraction techniques using synchrotron X-rays. Our **facilities** include ex-situ SEM, XRD, GMR, x-ray-fluorescence analysis and atomic absorption spectrometry, but focussing on the in-situ electrochemical methods in combination with quartz microgravimetry.

The team closely **collaborated** with W. Schwarzacher, prof. of H.H.Wills Physics Laboratory, University of Bristol, United Kingdom.

Scientific papers:

1. S.N. Ovchinnikova, A.I. Maslii. Elektrokhimiya, 2006, vol. 42, №11, p. 1376.
2. A.I. Maslii, S.N. Ovchinnikova, A.A. Weiss, W. Schwarzacher and V.V. Boldyrev. Dokl. Akad. Nauk, 1999, v.369, № 2, p.214.
3. O.I. Kasyitich, W. Schwarzacher, V.M. Fedosyuk, P.A. Laskarzhevsky, A.I. Maslii. J. Electrochem. Soc., 2000, v.147, p.2964.
4. S.N. Ovchinnikova, A.I. Maslii. Elektrokhimiya, 2006, vol. 42, № 8, p. 980. 5. S.N. Ovchinnikova, N.P Poddubnyi, A.I. Maslii, V.V. Boldyrev and W.Schwarzacher. Elektrokhimiya, 2002, vol. 38, p. 1339.
6. S.N. Ovchinnikova, N.P. Poddubnyi, and A.I. Maslii. Elektrokhimiya, 2003, vol. 39, p. 752.

CONTACT INFORMATION

Novosibirsk, ISSCMC SB RAS, Acad. V.V. Boldyrev, Dr. A.I. Masliy, S.N. Ovchinnikova, A.Zh. Medvedev;
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PLASTIC FORMING OF NANOPROFILED ELEMENTS: SUPERSMOOTH SUBSTRATES, QUANTUM WELLS, QUANTUM WIRES, QUANTUM DOTS

Institute of Solid State Physics RAS

PRESENT STATUS of RESEARCH

Brief Descriptions of Research

Our experience in mass production of laser optics by means of plastic forming provides us with promising facilities for manufacturing of nanosmooth substrates, quantum wells, quantum wires, quantum dots and other elements for nanooptics and nanoelectronics which have a set of advantages in comparison with usually applied chemical–abrasive treatment, X-Ray and electron lithography, etc. In all the methods applied before, removal of extra material by various means is used in order to arrange necessary profiles. In our method of plastic forming instead of removal governed displacements of surface atoms in necessary directions are used. This process is arranged by application of external pressure via a die from hard material having necessary profile of the surface. The technological process is close to stamping, so it is much more economic in comparison with lithography methods. The level of chemical purity is very high, because no foreign chemical substances like etchants or others are used and the dies are made from chemically resistant materials (sapphire, tungsten carbide, etc.), so no traces of them are left after the forming. The profiles of the dies can be manufactured by electron or X-Ray lithography. For shaping of nanometer profiles of the dies self-organization of surface geometry under ion-beam irradiation or plastic deformation can be used (see the figure, where AFM image of plastically formed surface of aluminum oxide is presented). The division of the vertical scale corresponds to 1 nm, of the horizontal scale – to 10 nm. By this way, templates for economic production of systems of quantum wells, wires and dots can be prepared.

Special facilities in use

We have high precision equipment for nanoprocessing and nanodiagnostics of surfaces.

Selected papers:

1. Klassen N.V. et. al. Proc. of the 5-th Intern. Conf. **Inorganic scintillators and their applications**, ed.V. Mikhailin, Moscow State University 2000, pp.668-673

2. Klassen N.V. et.al. **Material Research Transactions**, No2, 1997, pp.57-65, Moscow.

DIRECTIONS of FUTURE RESEARCH

We plan to apply plastic forming for preparation of nanosmooth substrates for light emitting diodes and other quantum well structures, magnetic memory disks, series of quantum wires and dots from metals and semiconductors, preparation of complicated Fourier optics for fine X-Ray and light focusing, etc.

CONTACT INFORMATION

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ENZYME HYDROGENASE IS A BIOCHEMICAL MOLECULAR MACHINE FOR ENERGY TRANSFORMATION AND METAL NANO-PARTICLES PRODUCTION

Institute of Basic Biological Problems RAS

PRESENT STATUS of RESEARCH

Brief Descriptions of Research

The reversible interconversion of hydrogen to protons and electrons catalysed by hydrogenases is a central metabolic feature of some microorganisms [1, 2]. The enzyme hydrogenase as electrocatalyst is able to improve the characteristics of hydrogen fuel cells [3]. The hydrogen fuel electrode based on hydrogenase from *Thiocapsa roseopersicina* immobilized directly on carbon filament material has been made. The enzyme electrode has operated according to electron tunneling between the enzyme active site and the electrode support [4]. The efficiencies in energy conversion of the enzyme electrode and the noble metal based commercial fuel electrode are similar. The thermostable hydrogenase from *T. roseopersicina* is an appropriate catalyst for development of systems based on molecular hydrogen.

The ability of hydrogenases isolated from *T. roseopersicina* and *Lamprobacter modestohalophilus* to reduce metal ions and oxidize metals has been studied [5]. Hydrogenases from both phototrophic bacteria oxidized metallic Fe, Cd, Zn and Ni into their ionic forms with simultaneous evolution of molecular hydrogen. The presence of methyl viologen in the reaction system accelerated this process. *T. roseopersicina* and *L. modestohalophilus* cells and their hydrogenases reduced Ni^{2+}, Pt^{4+}, Pd^{2+} or Ru^{3+} to their metallic forms under H_2 atmosphere producing nano-particles with sizes about 5–10 nm. These results suggest that metals or metal ions can serve as electron donors or acceptors for the hydrogenases from phototrophic bacteria.

This investigation was made in **cooperation** with Moscow State University and foreign scientists from Japan and France.

Selected papers:

1. Gogotov I.N., Zorin N.A., Serebriakova L.T., Kondratieva E.N. **The properties of hydrogenase from Thiocapsa roseopersicina.** Biochim Biophys. Acta, 1978. V. 523. P. 335.
2.Sherman M.B., Orlova E.V., Hovmoller S., Zorin N.A. **Three-dimensional structure of the nickel containing hydrogenase from Thiocapsa roseopersicina**. J. Bacteriol., 1991. V. 173. P. 2576.
3.Noda K., Zorin N.A., Nakamura C., Miyake M., Gogotov I.N., Asada Y., Akutsu H., Miyake J. **Langmuir-Blodgett film of hydrogenase for electrochemical hydrogen evolution.** Thin Solid Films, 1998. P. 327, P. 639.
4.Morozov S.V., Voronin O.G., Karyakina E.E., Zorin A.N., Cosnier S., Karyakin A.A. **Tolerance to oxygen of hydrogen enzyme electrodes.** Electrochem. Comm., 2006. V. 8. P. 851.
5. Zadvorny O.A., Zorin N.A., Gogotov I.N. **Transformation of metals and metal ions by hydrogenases from phototrophic bacteria.** Arch. Microbiol., 2006. V. 184. P. 279.

CONTACT INFORMATOIN

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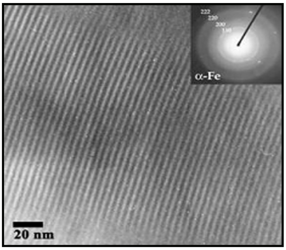
CONTROLLABLE GROWTH OF ORDERED MAGNETIC NANOSTRUCTURE ARRAYS IN SOLID STATE NANOREACTORS

Moscow State University, St-Petersburg State University, St-Petersburg Nuclear Physics Institute, Gatchina, RF; INNOVENT e.V., Jena, GKSS Research Center, Geesthacht, Germany

PRESENT STATUS of RESEARCH

Brief Descriptions of Research

One of important challenges in materials science today is the preparation of nanostructures with accurately controlled properties and dimensions. Our approach is based on chemical reactions in geometry-confined mesoporous systems which result in the formation of nanomaterials with the predefined shape and size of building elements. Several types of solid state matrixes (including zeolites, single-wall carbon nanotubes, mesoporous silica or mesoporous aluminosilicates, porous alumina, layered hydroxides and clays) are considered as one- and two-dimensional solid state nanoreactors. The study represents formation of magnetic nanocomposites based on the metallic (Fe, Ni, Pt, Fe-Co, Fe-Pt alloys, etc) and metal oxide (α-Fe_2O_3, γ-Fe_2O_3, Fe_3O_4, etc) nanostructures in solid state matrices. Usual characterization techniques involve HRTEM, ED, SAXS, SANS, SANPS, BET and magnetic measurements. Particles were found uniform and well ordered in the matrices. The use of these nanoreactors gave us an opportunity to determine the influence of anisotropy parameters of nanocrystals on the physical properties of magnetic nanostructures in a wide range of length/diameter ratios (the diameters from 2 to 100 nm).



TEM micrograph of iron nanowires inside mesoporous silica channels

Special Facilities in Use and Their Specifications

The study necessitates the use of small-angle polarized neutron scattering facilities (St-Petersburg Nuclear Physics Institute and GKSS Center) for investigation of magnetic reversal at nanolevel.

Selected papers

1. K.S. Napolsky, A.A. Eliseev, A.V. Knotko, A.V. Lukahsin, A.A. Vertegel, Yu.D. Tretyakov. Materials Science and Engeneering C, 2003, v. 23, N1-2, p. 151-154.
2. Yu.D. Tretyakov, A.V. Lukashin, A.A. Eliseev, Russian Chemical Reviews, 2004, 73, 9, 974.
3. A.A. Eliseev, I.V. Kolesnik, A.V. Lukashin, Yu.D. Tretyakov. Adv. Eng. Mat. 2005, v. 7, 4, 213.

Areas of application

Ultra-high density recording media for magnetic data storage.

CONTACT INFORMATION

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Tel. +74959395248, Fax. +74959390998; E-mail: eliseev@inorg.chem.msu.ru.

MULTI-LAYER METALLIC NANO-LAMINATES: TECHNOLOGY, STRUCTURE, PROPERTIES

Institute of Solid State Physics RAS

PRESENT STATUS of RESEARCH

Brief Descriptions of Research

Greater number of researchers make attempts to produce novel nano-crystalline materials with specific mechanical, magnetic, or electrical properties. We demonstrate a possibility of producing a metal nano-laminate metallic ribbons by simple metallurgical method based on by hot rolling in vacuum. This method in many cases can be more efficient and cheap, compared to sputtering or electro-chemical coating. As an example, we have produces a Cu-Nb nano-layered composite demonstrating interesting electric and mechanical properties.

The nano-laminate was produced by the following procedure, constituting a technological cycle, repeated three times: integration of a packet of 32 layers (16 both for Cu and Nb in the first cycle), hot rolling of the packet in vacuum, cold rolling in air down to the thickness equal to that of the initial layer. In the second and third cycle, the packets were made up of the layers rolled in the previous cycle.

Structure of the nano-laminate Cu-Fe after cold rolling in the 3-rd cycle

As one can see in Fig.1, after the third cycle of rolling, a mean layers thickness is of about 11 nm varying from 24 to 7 nm. Even at rather small mean thickness the layers have clear boundaries and not intermixed.

A dependence of the composite mechanical hardness as a function of true (logarithmic) deformation at rolling first demonstrate near-square root behavior and the hardness increases from 80 to 180 HB. When the layers thickness becomes smaller than 300-600 nm, the dependence becomes nearly linear and the hardness comes up to 350 HB late in the cycle, which is characteristic of heat treated medium-carbon steel.

The critical superconductive current density was measured in this nano-laminate at 4.2 K after rolling and annealing at 400, 600 and 1000 ºC. The critical current was measured in an external magnetic field in the range from 0.25 to 0.98 T at a two field orientations: normal to the nano-laminate plane and parallel to it. In the first case, the Abrikosov vortices were normal to the niobium layers, and the pinning centers were dislocations, grain boundaries, and disperse particles of copper in niobium, while in the second case in addition to the mentioned pinning centers there appeared interphase boundaries between the layers of copper and niobium. The efficiency of the interlayer interphase boundaries as pinning centers was found to be very high: when the mean layers thickness is 11 nm these interphase boundaries allow one to increase the current density by 411 times in the field of 0.5 T.

Selected Papers

1. Karpov M.I., Vnukov V.I., Medved N.V., Volkov K.G., Khodoss I.I., **Nanolaminate-bulk multylayered Nb-Cu composite: Technology, Structure, Properties**, 15-th Intern. Plansee Seminar' 2001, Proceedings, v.4, p. 97.

2. M.I. Karpov, B.A. Gnessin, V.I. Vnukov, N.V. Medved, V.P. Korjov, G.E.Abrosimova, I.M. Khodoss, **The formation of the structure and mechanical properties of multy-layered metallic composites with nanometrical layers thickness**, Proceedings of 16-th International Plansee-Seminar 2005 Reutte, Tirol, Austria, v.1, p.785.

Areas of application

There are two main directions for application of this data. The first one is the design of new metallic materials with improved mechanical properties on the base of this technology. The second one is the same for new technical superconductors.

We are open to collaborate with scientific and industry organizations in both these directions.

CONTACT INFORMATION

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DEVELOPMENT IN TECHNOLOGY OF CREATING NANO-COMPOSITE MATERIALS WITH REQUIRED SPECTRAL PROPERTIES

State Institute of Rare Metals (GIREDMET),
State Research Institute of Chemistry and Technology of Organoelement Compounds,
Lomonosov State Academy of Fine Chemical Technology (MITKHT)

PRESENT STATUS of RESEARCH

The unique properties of nanosized objects are determined mainly by the effect of the surface on atomic and electronic processes at a quantum level. The bulk part of nanocrystals is formed by the initial crystal lattice whose average size is of several tens of nanometers. Optical and electronic properties of nanocrystals where the motion of charge carriers is limited in two (quantum lines) or three (quantum dots) directions are different than those of their bulk analogs. Among the objects with altered optical properties, the nanocrystalline silicon and silicon-based composites are the most attractive substances due to its ability to shift the edge of major absorption to visible and ultraviolet regions.

At present, there are two main classes of complex emulsion media, which are used for the absorption of ultraviolet radiation: chemical compounds with chromophore groups absorbing radiation in the UV region; compounds, in which strong scattering of photons from the ultradispersed particles of some metal oxides incorporated into the matrix is employed. However, practical application of these media can lead to negative consequences. For example, their application as sun-blocking materials gives rise to the emergence of melanoma due to the UV degradation of proteins and the formation of active radicals. Besides that, emulsion media may be used as sun-blocking materials just in case of low intensity UV-radiation. The results of our research will give an opportunity to create new materials with required optical properties, the using of which allows us to control the spectral structure of transmitted radiation. Thus as against from available composites in present work one uses physical principle of radiation absorption, which is based on quantum confinement effect in nanoparticles. Variation of size and directed modification of surface states allow controlling their optical properties. This in tern gives us the reason to develop new technologies of providing of such composites. New UV absorbing composites, which are under investigation now, will be applied in medical purposes and also for protection of different surfaces from UV-radiation of high intensity.

CONTACT INFORMATION

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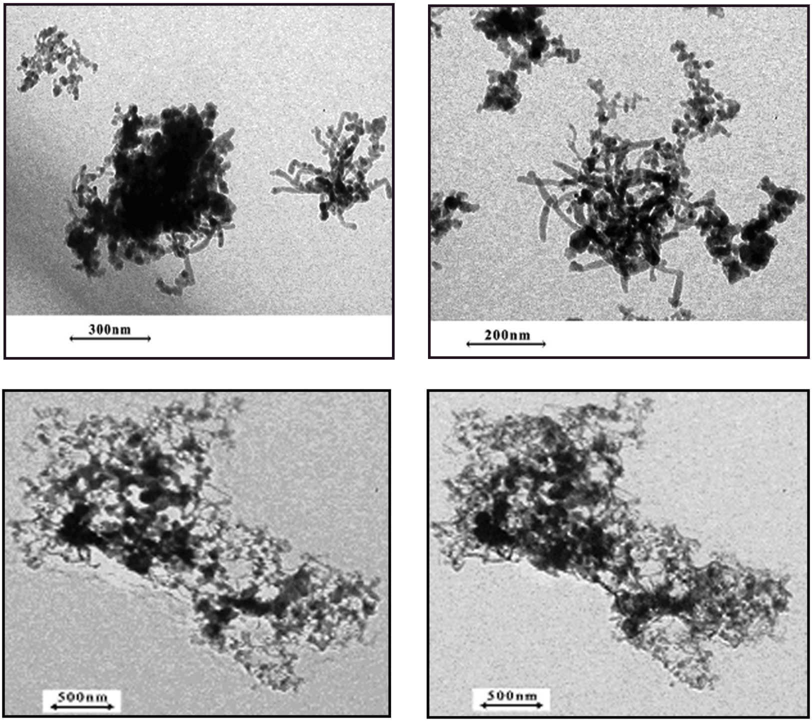
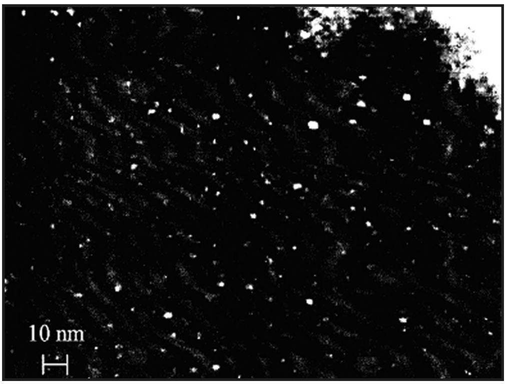


Electron photomicrographs of samples of nanocrystalline silicon; (in the bottom figure on the left) the image taken at the initial observation moment and (in the bottom figure on the right) the same sample subjected to the action of electron beam during 7 min



TEM image of silicon carbide nanocrystals

RESEARCH AND DEVELOPMENT OF MODIFIED OXIDE CERAMIC MATERIALS

State Scientific Center of Russian Federation “Leipunsky Physical Energy Institute”

PRESENT STATUS of RESEARCH

Brief Descriptions of Research

The experimental investigations have allowed to achieve improved thermal conductivity, thermostability and plasticity of oxide ceramic materials: UO_2, $(U,Th)O_2$, PuO_2+MgO, $BaPuO_3$, PuO_2+Fe+MgO, $MgAl_2O_4$, MgO, Gd_2O_3, etc. The specified properties have resulted from generating the nanoparticles in precipitates in the process of powder preparation. Technology consists of component co-precipitation after thermal treatment, pelletization and pellet sintering.

Thermal conductivity for all investigate modified ceramic oxide materials has the similar kind of temperature dependences: thermal conductivity is reducing up to 600–800°C, and thereafter increasing again. Thus the analogy to temperature dependence of thermal conductivity of single-crystal materials takes place. Sintered articles contain metal atoms differing in valence, have a “fused” structure, a minimum amount of polyhedral pores and almost invisible grain boundaries. It results in the increase of the phonon and photon components of thermal conductivity.

The phenomenon of the increased thermal conductivity of modified ceramics has been confirmed by in-reactor testing of the PuO_2+MgO Fuel. Examinations of Fuel Elements after irradiation (total burnup = 20,5% h.a.) have shown: fuel pellets have preserved their shape and microstructure and had almost no cracks. It is quite unusual for any oxide ceramic fuel.

Special Facilities in Use and Their Specifications

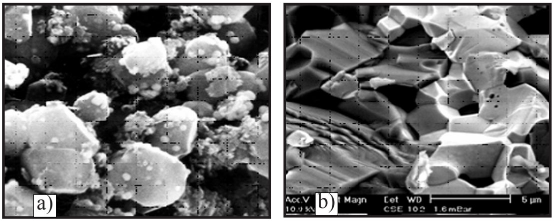
Facilities for dissolving, precipitation and filtration; high-temperature furnaces; presses; facilities for studies of thermal conductivity of materials, their microstructure, phase constitution, and others; welding machines etc.

Selected Papers

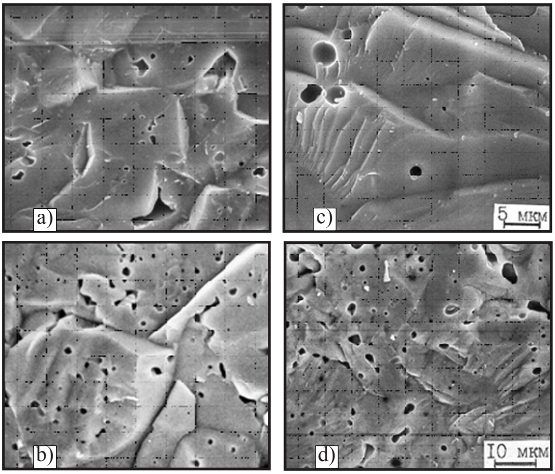
1. Kurina I.S., Troyanov V.M., **Studies into the Problems of Using Inert Matrix Fuel to Reduce the Plutonium Stock**. - New Nuclear Engineering Materials. Moscow, MEPI, 2003, p. 18.
2. Kurina I.S., Gudkov L.S., Rumyantsev V.N., **Investigation of ThO_2 and $(U,Th)O_2$.** - Atomic energy, v. 92, No. 6, 2002, p. 461.
3. Kurina I.S., Popov V.V., Moseyev L.I., Dvoryashin A.M., **Characterization of Modified Inert Matrix Fuels.** - Working material of a IAEA Technical Meeting in Obninsk, Nov. 21-23, 2005. IAEA, NPTDS/NE, Vienna, 2006, p. 583.
4. **The results of the work have covered by patents (RU)**: №2098870 (1997), №2135429 (1999), №2176115 (2001). Claim for a discovery No. 2006109211 (2006).

FOREIGN COLLABORATORS:

1996 - 1997 – PNC (Japan). ISTC Project #220 “Research and Development of the PuO_2+MgO Fuel”;



Microstructure of Powder (a) containing the particles 1-2 μm and 2-10 nm and Pellets (b) of Fuel (40 wt.% PuO_2+60 wt.% MgO)



Microstructure of sintered ceramic materials: Spinel $MgAl_2O_4$ modified (a) and made using standard technology (b); UO_2 modified (c) and made using standard technology (d)

1999 - 2002 – JAERI (Japan). ISTC Project #1321 "Research and Development ROX-Fuel";
1999 – CAE (France). Project "Manufacturing of Fuel Elements with PuO_2+MgO Fuel".

DIRECTIONS of FUTURE RESEARCH

Possibility of Application

Atomic engineering, solid-fuel elements, electronics engineering, ceramic manufacturing.

Suggestion on Cooperation with Foreign Partnersы

- Development of Modified Inert Matrix Fuel for plutonium utilization.
- Development of Modified Electrolyte for Solid-Fuel Elements with increased requirement.

CONTACT INFORMATION

SSC RF "Leipunsky Physical Energy Institute", pl. Bondarenko 1, Obninsk, 249020 Kaluga Region; Kurina I.S., Popov V.V., Rumyantsev V.N.; E-mail: http://@www.ippe.obninsk.ru.

NANOSIZE METAL PARTICLES PRODUCTION BY THERMAL DECOMPOSITION OF BISMUTH CARBOXYLATES

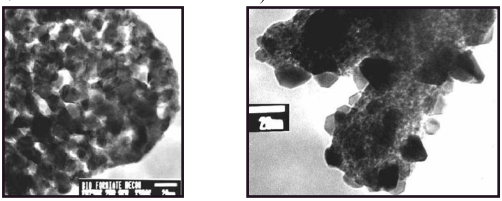
Institute of Solid State Chemistry and Mechanochemistry SB RAS

PRESENT STATUS of RESEARCH

Brief Descriptions of Research

Bismuth monocarboxylates have been synthesized within the series: formates–caprylates–stearates. It has been show that depending on atmosphere and nature of organic solvent, their thermal decomposition results in the formation of nanosized (1–10 nm) particles of metal bismuth or its oxide [1,2].

a) b)

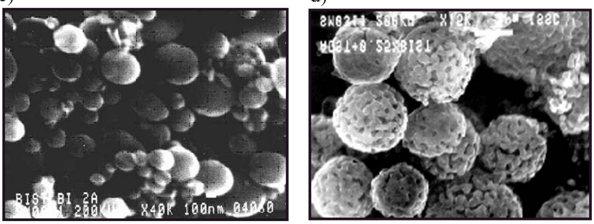


TEM-images of nanosized bismuth particles formed by thermal decomposition of bismuth formate (a) and caprylate (b)

Reduction of bismuth oxohydroxostearate by benzyl alcohol results in the formation of metal bismuth particles of spherical shape the average size of which was estimated to be 0,1–0,5 μm. Reduction of silver and bismuth stearates mixture by benzyl alcohol results in the formation of spherical aggregates of ~1 μm size, consisting of the silver and bismuth particles of 0,1 μm size.

Researches confirmed an opportunity for production of mixed nanosize powders of bismuth- silver-, copper-, antimony-, lead-, nickel-contained composites to create bismuth-contained materials of wide use for technique.

c) d)



SEM-image of nanosize bismuth particles formed by thermal decomposition of bismuth stearate (c) and its mixture with silver stearate in benzyl alcohol (d)

The nanoscale bismuth system is attractive as a potential thermoelectric material. Metal nanoparticles have been widely exploited to use in heterogeneous catalysis, magnetic recording media, microelectronics, and lubrication.

Selected Papers

1. Yukhin Y., Bokhonov B., Evseenko V, Tukhtaev R., et al. **Synthesis of nanosized bismuth particles and its compounds.** X APAM Topical Seminar and III Conference “Materials of Siberia” “Nanoscience and Technology”. Novosibirsk, 2003. P. 151.
2. RF Patent No. 2225282. **The method of preparation of powder bismuth**. Yu.M. Yukhin, B.B. Bokhonov, R.K. Tukhtaev, T.A. Udalova. Bull. No.7. Publ. 10.03.2004.

CONTACT INFORMATION

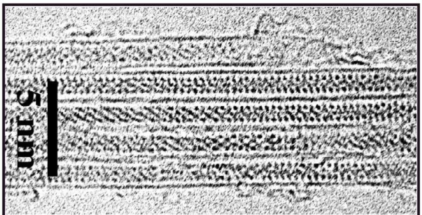
ISSCMC SB RAS, Novosibirsk,
Prof. Yu.M. Yukhin, Dr. B.B. Bokhonov, Dr. R.K. Tukhtaev, E-mail: yukhin@solid.nsc.ru.

SYNTHESIS AND INVESTIGATION OF NANOCRYSTALS IN CHANNELS OF SINGLE-WALLED CARBON NANOTUBES

Moscow State University (Department of Materials Science, Department of Chemistry), Moscow, RF; Institute of Crystallography, Moscow, RF; Institute of Problems of Chemical Physics, Chernogolovka, Moscow Region, RF; University of Oxford (Department of Materials), UK

PRESENT STATUS of RESEARCH

Brief Descriptions of Research



HRTEM imaging of the composite CuI@SWNT

The study is focused on the controllable growth of 1D nanocrystals (KI, CuCl, CuI, AgI, Fe, Co, Bi, BiMn, S, Se, Te, I_2, SnF_2, $SnCl_2$, $SbCl_3$, $FeCl_3$, $AlCl_3$, CdI_2, ZnO, CdS) in channels of single-walled carbon nanotubes (SWNTs) (inner diameter 1–1.4 nm), and on the investigation of electronic properties of the nanocomposites. The synthetic strategy is based on the impregnation of pre-opened SWNTs by molten salts or salt solutions in vacuum of 0.01 mbar with subsequent slow cooling to room temperature. The structure of 1D crystals formed in SWNTs is characterized by HRTEM imaging and EDX analysis, proving the successful filling of SWNTs channels with fine nanocrystals of chosen materials (up to ~73 wt.%). Incorporated compounds (acceptors or donors) affect the electronic structure of SWNT resulting in the shift of RBM- and G-lines in Raman spectra, corresponding to the shift of the Fermi level of nanocomposites.

Special Facilities in Use and Their Specifications

The study necessitates high-quality HRTEM with spherical aberration (CS) correction and high acceleration voltage (such as FEI TITAN or JIM JEOL 4000 microscope series).

Selected Papers

1. N.A. Kiselev, A.V. Krestinin, A.V. Raevskii, O.M. Zhigalina, G.I. Zvereva, M.B. Kislov, V.V.Artemov, Yu.V. Grigoriev and J.L. **Hutchison, Extreme-length carbon nanofilaments with single-walled nanotube cores grown by pyrolysis of methane or acetylene.** Carbon, 2006, 44, №1, pp.2289.
2. M.V. Chernysheva, A.A. Eliseev, A.V. Lukashin, Yu.D. Tretyakov, S.V. Savilov, N.A. Kiselev, O.M. Zhigalina, A.S. Kumskov, A.V. Krestinin, J.L. Hutchison. **Filling of single-walled carbon nanotubes by CuI nanocrystals via capillary technique**. Physica E, 2006, in press.

Possible Applications

Active elements of electronic devices and circuits, field emitters, increase of strength and sliding strength of materials, reinforcing of polymers.

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QUANTITATIVE-STRUCTURE-ACTIVITY-RELATIONSHIPS IN NANOMATERIAL SCIENCE OF FULLERENES AND CARBONEOUS NANOTUBES

Peoples' Friendship University of the Russian Federation,
Emanuel Institute of Boichemical Physics RAS,
Ioffe Phisico-Technical Institute RAS

PRESENT STATUS of RESEARCH

Brief Descriptions of Research

How hazardous are nanomaterials and how reliable are (if any) precautions which are or should be undertaken meeting their entering the living world (see Prof. R.Clift, *Nanotechinsight,* 1, Sept.2006)? The conclusive and convincing testing will not appear in the near future due to enormously high price of *in vivo* and *in vitro* tests, both in time and cost. On this ground, *in silico* testing via computer modeling seems more feasible and promising. Suggested Quantitative-Structure-Activity-Relationship (QSAR) approach may accumulate size, shape and surface conditions that classify nanomaterials and show the way of the prediction of their behavior. There is a time for the QSAR approach to start since a great number of data in the field of computational nanatechnology obtained by now makes possible to generalize them towards establishing relationships.

The project is based on first results on the way concerning a peculiar aspect of nanomaterial science caused by *odd electrons*. The term stands from the difference between the number of atom valence electrons and that one of the neighboring atoms coupled to the considered one. The situation is so frequently met for nanomaterials that odd electrons should be added to the main characteristics of nanomaterials. Actually, chemical susceptibility of fullerenes and carbon nanotubes, peculiar characteristics of covalent nanocrystallite surfaces, and nanomagnetism seem absolutely different at first glance while being of the same origin.

Fullerenes and nanotubes form a common class of odd-electron carboneous systems. They have been studied by now quite exhaustively that makes the formulation of the project concept most transparent. Peculiarities of nano-size systems behavior directly depend on the odd electron coupling. Thus, in the case of benzene molecules, those are strongly coupled and fully covalently bonded, so that the species does not show any peculiar (radical) properties. Oppositely, in fullerenes [1] and carbon nanotubes [2], the coupling is weak so that they behave completely different. The bare silicon surfaces are magnetic [3] while the same carbon surfaces are not. Difference in the magnetic properties of the bulk traditional magnetic solids and their surfaces as well as nanoparticles, different magnetic behavior of solids composed of molecular nanocomplexes of the same structure but differed by transition metals atoms (say, Ni and Co) etc. follow from the difference in coupling of the available odd electrons as well.

Special Facilities in Use and Their Specifications

The quantum theory of the electron bonding is suggested as the computational basis for the events. One-determinant Hartree-Fock approach has been shown [4] to provide a correct quantitative determination of both *chemical* and *magnetic* susceptibilities of odd electrons that lays the foundation of a generalized odd-electron QSAR.

Selected Papers

1. E.F.Sheka, **Odd Electrons and Covalent Bonding in Fullerenes**. Int. Journ. Quant. Chem. 100 (2004) 375.
2. E.F.Sheka, L.A.Chernozatonski. J. Phys. Chem. A (submitted).
3. Elena F. Sheka, Ekaterina A.Nikitina, and Valentin A.Zayatz, **Highspin molecular magnetism of silicon surfaces**, Surf. Sci., Vol. 532-535 (2003) 754-756.
4. E.F.Sheka, V.A.Zayets, **Radical properties of fullerenes and origin of its chemical activity**, Rus. Journ. Phys. Chem. 79 (12) (2005) 2009-2014.
5. E.F.Sheka, **Violation of covalent bonding in fullerenes**, Lecture Notes in Computer Science, Computational Science – ICCS2003, Eds. P.M.A.Sloot, D.Abramson, A.V.Bogdanov, J.Dongarra, A.Y.Zomaya, Y.E.Gorbachev, Springer : Berlin, 2003, Part II, 386-398.
6. E.F.Sheka, **Fullerenes as polyradicals**, Centr. Eur. Journ. Phys. 2(1) (2004) 160-182.
7. E.F.Sheka, V.A.Zayets, I.Ya.Ginzburg, **Nanostructural magnetism of polymerized C60 crystals**, JETP 103 (2006) 728-739.
8. E.F.Sheka, **"Chemical portrait" of fullerene molecules**, Rus. Zhurn. Strukt. Khimii 47 (2006) 613-619.
9. E.F.Sheka, B.S.Razbirin, A.N.Starukhin, D.K.Nelson, **Electron structure and spectra of N-methylfulleropyrrolidine**, Optics Spectr. 102 (2007) 245-255.

DIRECTIONS of FUTURE RESEARCH

Possibility of Application

Nanoscience of fullerenes and nanotubes.

Suggestion on Cooperation with Foreign Partners

1. Quantitative analysis of chemical activity of fullerenes and nanotubes.
2. Computational synthesis of fullerene derivatives in accordance with relevant chemical reaction and/or technology.
3. Computational description of adsorption processes on nanotubes.
4. Quantitative description of fullerene- and NT-based addition reactions complicated by donor-acceptor intermolecular interaction.
5. Electric field controlled donor-acceptor reactions involving fullerenes and nanotubes.
6. Quantitative description of odd-electron features of grapheme sheets.
7. Optical spectra of matrix-isolated molecules of fullerene derivatives.

CONTACT INFORMATION

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B.S.Razbirin, Ioffe Phisico-Technical Institute of RAS.

FORMATION AND STRUCTURE OF Ag AND Se NANOPARTICLES OBTAINED FROM SOLUTIONS AND STABILIZED BY POLYMERS

Shubnikov Institute of Crystallography RAS; Institute of Macromolecular Compounds RAS, Russia; Centre Interdisciplinaire de Microscopie Electronique - Ecole Polytechnique Fédérale de Lausanne (CIME-EPFL), Switzerland

PRESENT STATUS of RESEARCH

Brief Description of Research

Nano- and thin-film technologies based on novel composite systems such as polymer matrices associating metallic and non-metallic nanoparticles open a broad range of new applications. For instance, in biomedical fields, used nanoparticles have specific bactericide properties while the polymer properties are crucial for stabilization of particle dispersions, a controlled solubility for efficient particle release, and appropriate mechanical strength of the final product. Nanocomposites can be used as drugs with a wide range of pharmacological activity, bioactive additives, transport matrices for drugs, adsorption matrices for immune diagnosis.

Institute of Macromolecular Compounds of RAS and Shubnikov Institute of Crystallography of RAS proposed the research directed to establish the mechanisms of the formation of silver and selenium nanoparticles in polymer solutions on nano-size level, to study the adsorption phenomena in functional macromolecular systems, the structural and morphologic features of the nanocomposites. Our interest is in the determination of influence of different polymers on the state, structure, sizes and shape of nanoparticles. Stability of the composite systems is also of great importance for all possible applications particularly in biomedical field. In the figures 1 and 2 are presented the Ag and Se nanoparticles synthesized during the oxy-reduction process in aqueous solutions in the presence of various polymers.

The nanocomposites are examined by transmission electron microscopy, electron diffraction, X-ray energy dispersive spectroscopy, and X-ray small-angle scattering methods. This characterization is performed in cooperation with Centre Interdisciplinaire de Microscopie Electronique - Ecole Polytechnique Fédérale de Lausanne. We are also open to any joint investigation for the comprehensive study of physicochemical, medical, and biological properties of materials.

Selected papers

1. Suvorova E.I., Klechkovskaya V.V., Kopeikin V.V., Buffat P.A. **Stability of Ag nanoparticles dispersed in amphiphilic organic matrix**. J. Crystal Growth, 275 (2005) 2351.

2. Kopeikin V.V.; Valueva S.V., Kipper A.I., Borovikova L.N., Nazarkina Y.I., Khlebosolova E.N., Filippov A.I. **Adsorption of hydroxyethyl cellulose selenium nanoparticles during their formation in water.** Russian Journal of Applied Chemistry, 76 (2003) 600.

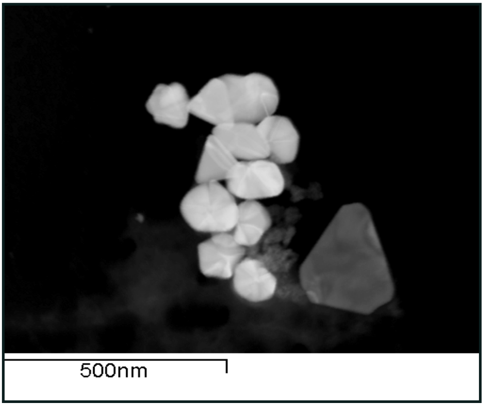

Figure 1.
Ag nanoparticles in polyvinylpyrrolidone

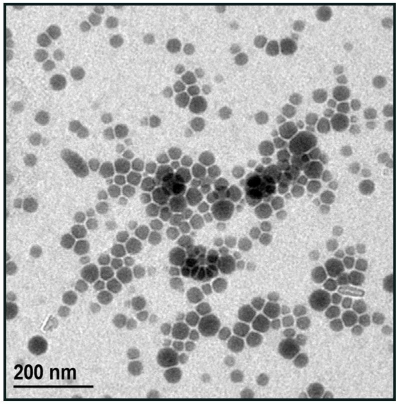

Figure 2.
Se nanoparticles in copolymer vinilpyrrolidone with N,N,N,N-triethylmethacryloyloxyethyl ammonium iodide + sodium dodecyl sulfate, molar ratio anion/cation =1/4

3. Kopeikin V.V., Valueva S.V., Kipper A.I., Borovikova L.N., Filippov A.P. **Synthesis of Selenium Nanoparticles in Aqueous Solutions of Poly(vinylpyrrolidone) and Morphological Characteristics of the Related Nanocomposites**. Polymer Science, series A, 45 (2003) №4, 374.

CONTACT INFORMATION

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Vera V. Klechkovskaya, Elena I. Suvorova, Vladimir V.Volkov (IC RAS);
Svetlana V. Valueva, Ludmila N. Borovikova (IMC RAS); Philippe A. Buffat (CIME-EPFL).

DEVELOPMENT OF NANOSTRUCTURED MATERIALS WITH HIGH OXYGEN MOBILITY

Institute of Solid State Chemistry and Mechanochemistry SB RAS

PRESENT STATUS of RESEARCH

Brief Descriptions of Research

The oxygen-transport membranes (OTM) selectively separate oxygen from an air supply, or other source, at elevated temperature (800-1000^{o}C) under an oxygen chemical potential gradient. Besides oxygen production, the OTM materials are of interest for use in catalytic membrane reactors for the selective oxidation of hydrocarbons. The key to success is that the membrane material exhibits high ionic and electronic conductivity while maintaining structural, chemical, and mechanical stability at the severe operating conditions.

In the course of preliminary work, it was found that anomalously high values for oxygen transport in perovskite related oxides may occur already at moderate temperatures, which is related to a specific nanostructure. The nonstoichiometric perovskites can be considered as solid solutions with a miscibility gap; at high temperatures (>1000^{o}C) they form solid solutions with a random distribution of crystal lattice defects (oxygen vacancies, dopant ions, etc.). In the course of cooling, the solid solution becomes oversaturated and unmixed, inducing the formation of coherently stacked domains of 5-50 nm in size. Oxygen vacancies are localized inside the nanodomain as structural elements, whereas overstoichiometric mobile oxygen ionic defects are ejected to the vicinity of the domain boundaries. Thus, unmixing of the doped nonstoichiometric oxides results in the formation of a high density of conductive channels with low activation barriers for oxygen transport (Fig. 1).

Selected papers

1. A. Nemudry, E.L. Goldberg, M. Aguirre and M.Á. Alario-Franco, **Electrochemical topotactic oxidation of nonstoichiometric perovskites at ambient temperature,** Solid State Sciences, 4 (2002) 677.
2. I.L. Zhogin, A.P. Nemudry, P.V. Glyanenko, Yu.M. Kamenetsky, H.J.M. Bouwmeester, Z.R. Ismagilov. **Oxygen diffusion in nanostructured perovskites**, Cat. Today. 2006, Vol 118/1-2, p. 151-157.
3. A. Nemudry and N. Uvarov, **Nanostructuring in composites and grossly nonstoichiometric or heavily doped oxides**, Solid State Ionics, 177 (2006) 2491.

FOREIGN COLLABORATORS

Dr. Henny J.M. Bouwmeester, Inorganic Membranes, University of Twente, Enschede, The Netherlands; Prof. R. Schomaecker, Institute of Inorganic Chemistry, Technical University, Berlin, Prof. A. Magerl, Kristallographie und Strukturphysik Universität Erlangen-Nürnberg, Erlangen, Germany; Prof. M.A. Alario-Franco, Lab. de Química del Estado Sólido, Universidad Complutense, Madrid, Spain.

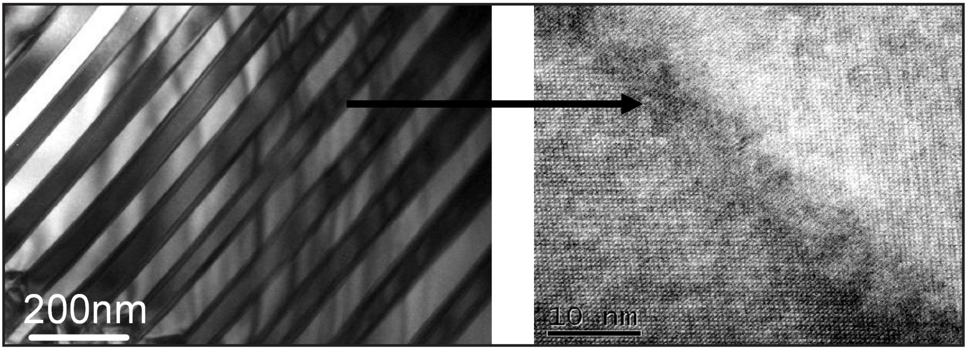

Figure 1. $SrCo_{0.8}Fe_{0.2}O_{3-z}$, formation of nanodomain texture with highly defective domain boundaries served as conductive channels with low activation barriers for oxygen transport

DIRECTIONS of FUTURE RESEARCH

Possibility of Application

The use of nanodomain-textured perovskites having high concentrations of conductive channels with lower values of the activation energy for oxygen diffusion allows one to lower the operating temperatures of OTM membranes, which is beneficial to minimize chemical and mechanical degradation and to extend the operational life time of the membranes.

Suggestion on Cooperation with Foreign Partners

1. Study of the mechanism of oxygen transport in nanostructured oxides.
2. Formation of nanoparticles of oxygen conducting oxides and gas tight thin films.
3. Studies of nanostructuring in perovskite related oxides by X-ray (including SI). and neutron diffraction, positron annihilation, HREM etc.
4. Development of pilot set up for natural gas conversion and partial oxidation of hydrocarbons.

CONTACT INFORMATION

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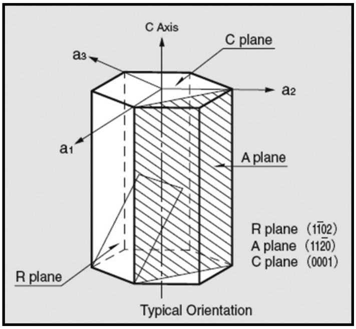
SAPPHIRE SHAPED CRYSTALS FOR GaN, AlN AND InN LIGHT-EMITTING (LED) NANOSTRUCTURES

Institute of Solid State Physics RAS;
A.F.Ioffe Physical-Technical Institute RAS

PRESENT STATUS of RESEARCH

Brief Descriptions of Research

In recent years the III-V nitrides have attracted much attention because of the potential to produce high-temperature and high-power electronic devices, as well as bright light-emitting diodes (LEDs), lasers. Sapphire is optimal substrate material due to its low cost, chemical stability at high temperatures, good adjustments to lattice parameters of III-V nitrides and high thermal conductivity.



The most commonly used orientation of sapphire for GaN, AlN and InN growth is the (0001) oriented basal plane (c-plane). But the last experiments showed that r- and a-planes provide higher effectiveness of light emission. Layers of nitrides in these orientations do not have internal electric fields which decrease light emission in the case of c-plane. The shaped growth techniques based on Stepanov method provide the production sapphire crystals of predetermined cross-section and promise good cost saving.

Special facilities in use and their specifications:

Installations for sapphire shaped crystals and equipment for nanodiagnostics of surfaces (local electron microprobe X-Ray spectral analyzer, X-Ray diffractometer, electron, tunnel and atomic force microscopes, etc.).

Selected papers

1. P.I.Antonov, V.N.Kurlov **A review of developments in shaped crystal growth of sapphire by the Stepanov and related techniques.** - Progress in Crystal Growth and Characterization of Materials, v. 44, 2002, p. 63.
2. V.N.Kurlov, S.N.Rossolenko **Growth of large-sized sapphire plates for optical applications** - Bull. Rus. Acad. Sci., Physics, v. 63, No 9, 1999, pp. 1339-1344.
3. V.N. Kurlov, S.N.Rossolenko **Growth of shaped sapphire crystals using automated weight control.** -J. Cryst. Growth, v. 173 (1997) pp. 417-426.

DIRECTIONS of FUTURE RESEARCH

The improvement of quality and economics of III-V nitride nanostructures on sapphire ribbons (with a low defect concentration for GaN epilayers) of various orientations (c-, r-, and a-planes) is the goal. Slightly misoriented sapphire substrates are interesting is well due to possibility of direct deposition of semi-conducting nanowires with promising light-emitting parameters. The mutual use of the complementary experience of teams in sapphire shaped growth, III-V nitrides deposition and investigation of crystal defects is needed.

CONTACT INFORMATION

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BIOCOMPATIBLE HIGH-STRENGTH HYDROGELS AS ARTIFICIAL CARTILAGERS FOR USING IN SURGERY

Institute of Macromolecular Compounds RAS

PRESENT STATUS of RESEARCH

At present, the high necessity for an implantation material exists in prosthetic plastic operations performed with replacement of damaged or lossed cartilages. Arthritis is known to be one most widely-spread disease. The cartilages are degradated and destroyed in joints affected by arthritis. Traumata of joints including sport ones also lead to the injury of the cartilaginous tissue. In many cases the complete replacement of the affected joint with artificial one is performed. The application of the biocompatibl hydrogel materials capable to functionate in an organism as artificial substitutes for natural cartilaginous tissues can allow to solve of the recovery of joints by the less invasive and simple method.

As compared with the analogs the new kinds of the hydrogel materials based on the natural and synthetic polymers have in several times higher strength (till 12-23 MPa; in the analogs – not more 2-3 MPa). An improvement of the mechanical characteristics is achieved by the formation in the process of synthesis the structures approaching on the level of the organization to the natural cartilaginous tissue, that is the novelty of the present project.

DIRECTIONS of FUTURE RESEARCH

The market use of the materials suggests their application as the artificial cartilages for the joint surgery and also for the reconstruction of intervertebral disks, aorta, trachea and bronchi, the nasal septum, the external ear and for also the solution of problems of the facial aesthetic surgery.

CONTACT INFORMATION

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NANOTECHNOLOGY OF HIGH-ENERGY GAP SEMICONDUCTORS $A^{II}B^{VI}$

Institute of Solid State Physics RAS

PRESENT STATUS of RESEARCH

Interest in AIIBV compounds is encouraged by variable possible applications of these semi-conductors and promising possibilities to replace expensive single crystals by far less expen-sive nanocrystal-based materials and articles in some applications.

In 2003–2005, the equipment and techniques were developed to obtain different nanocrystals such as CdTe, CdSe and $Cd_{0,9}Zn_{0.1}Te$. The nanopowder-based technique was developed to fabricate bulk materials (BMs) from CdTe and $Cd_{1-x}Zn_xTe$ (CZT). Some optical properties of these nanopowders and bulk materials have been studied (Figures 1 and 2).

In 2006, the effects of temperature, stress and strain on kinetics of the phase transition in the BMs made of CdTe and CZT nanopowders with 5–15 nm particles were studied, microstructure and texture of the BMs were investigated, basic properties of these materials such as microhardness, light transmittance in the IR region, and specific resistivity were tested. Preliminary measurements of energy spectra of the BMs responded to different sources of alpha and gamma radiation were performed in collaboration with Russian Federal Nuclear Center VNIIEF. Some properties of the BMs and single crystals are listed in the table.

	Single crystal		**BM**	
Characteristic	CdTe	$Cd_{0,9}Zn_{0.1}Te$	CdTe	$Cd_{0,9}Zn_{0.1}Te$
Density, g/cm³	5,80	5,83	5,41	5,65
Microhardness, MPa	430	450	1460	1510
Light transmittance (λ=10 μм), %/cm	66	—	60	—
Specific resistivity, Ohm·cm	up to $5 \cdot 10^8$	up to 10^{10}	up to 10^{10}	up to 10^{10}

As a result of the experimental studies, 5 patents were issued. The performed studies have shown a promising effectiveness of BMs made of II-VI compound nanocrystals, especial-ly as regards variband attenuators and scattering filters operating in near-IR and mid-IR ranges. These BMs are also perspective for semiconductor ionizing-radiation detectors operating at room temperature without cooling.

CONTACT INFORMATION

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http://www.sttic.com.ru/lpcbc/lpcbc.html; http://www.issp.ac.ru/lpcbc/; E-mail: nkolesn@issp.ac.ru.

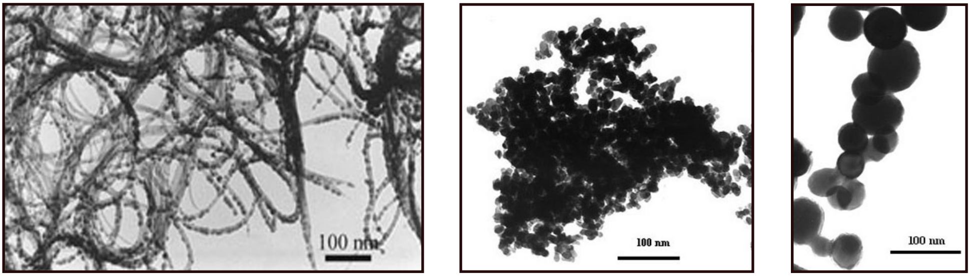

Fig. 1. CdTe nanotubes (on the left) and $Cd_{0,9}Zn_{0,1}Te$ nanoparticles (TEM)

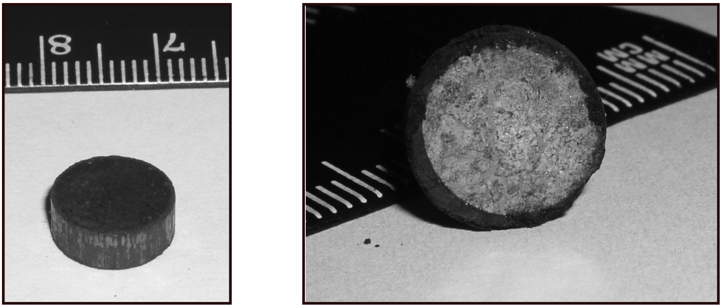

Fig. 2. BM of CdTe (on the left) and of $Cd_{0,9}Zn_{0,1}Te$

NANOBIOMATERIAL BASED ON THE DNA(RNA) MOLECULES AND THE CD DEVICE FOR ITS USE

Engelhardt Institute of Molecular Biology RAS
Institute of Spectroscopy RAS
Shubnikov Institute of Crystallography RAS

PRESENT STATUS of RESEARCH

Brief Description of Research

Nanotechnology based on double-stranded nucleic acids (ds NA) is currently in the focus of research [1]. Our strategy [2] of creating the nanoconstructions (NaC) containing ds NA or their complexes with various polycations ***differs in principle*** from the variants of the step-by-step strategy. We use not isotropic ds NA molecules (**A**), but these molecules fixed at distance "**d**" of 2.5–4.5 nm (**C**) in the spatial structure of the particles of their cholesteric dispersions (CD, **B**), resulted at the phase exclusion of NA molecules (**A**) from water-salt-polymer-containing solutions (a so called "entropy condensation") (Fig.1).

Each particle of CD has a mean size ~ 500 nm and contains ~ 10^4 NA molecules with a "liquid" mode (C) of their spatial ordering. The phase exclusion of the ds DNA molecules from water-salt polymer-containing solution is accompanied not only by the formation of the DNA CD (see a particle of CD in the middle, B), but by the appearance of an abnormal optical activity (D). For the alternative approach called "enthalpy condensation" of ds NA molecules, the biocompatible and biodegradable poly(aminosaccharide)-chitosan capable of neutralizing about 90% of the negatively charged NA phosphate groups (necessary for a spontaneous condensation of the NA-chitosan complexes) was used.

The elaborated by us, directed formation of flat nanobridges, consisting of alternating antibiotics molecules and metal ions (– antibiotic-metal ion-antibi-otic –…) between the NA or chitosan molecules results in the formation of new NaCs with unique properties [3-4]:

i) These NaCs have rigid three-dimensional structure that permits one to handle easily with NaCs and to visualize rigid NaCs and estimate their size by AFM (Fig.2) for the first time.

ii) The NaC exhibits an abnormal optical activity; for this NaC, two abnormal bands in the CD spectrum located both in the NA and antibiotic absorption regions are specific.

iii) the stability of NaC depends now not on the osmotic pressure of the solvent, but on the number and energy of nanobridges between ordered neighboring NA (or chitosan) molecules.

Thus, a new NA-based nanobiomaterial with tailored properties of biological and technical importance was created. NaCs were immobilized in the content of polymeric hydrogel. This was accompanied by strong stabilization of abnormal optical properties of NaCs.

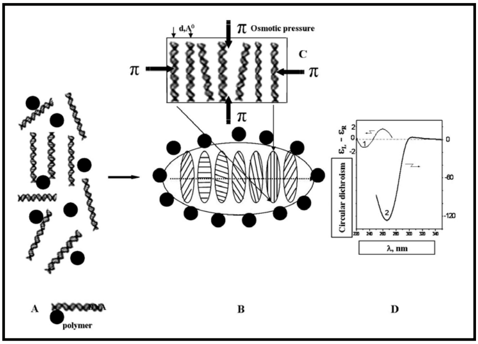

Figure 1. General scheme of the formation and the properties of the DNA CLCD

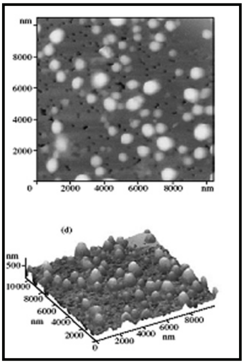

Figure 2. The images (2-D (A) and 3-D (B), respectively of the DNA NaCs fixed onto the surface of the nuclear membrane filter (PETP). The mean size of NaCs correspond to 500 nm. The small dark spots correspond to the pores in the filter (D ~ 0.2µm)

Selected Papers

1. Seeman N.C., (2003), **DNA in a material world**, Nature, 43, p. 427.
2. Yevdokimov Yu.M., Salyanov V.I., Spener F., Palumbo M., (1996), **Adjustable crosslinking of neighboring DNA molecules in liquid-crystalline dispersions through (daunomycin-copper) polymeric chelate complexes,** Int. J. Biol. Macromol., 19, p. 247.
3. Yevdokimov Yu.M., Salyanov V.I., Zakharov M.A., (2001), **A novel type of microscopic size chip based on double stranded nucleic acids,** Lab on a chip, 1, p. 35.
4. Yu.M. Yevdokimov, M.A. Zakharov, V.I. Salyanov, (2006), **Liquid crystalline dispersions of double-stranded nucleic acids and their complexes as a basis for nanodesign: review**, Kristallografiya, 51, p. 1082.

APPLICATION and FUTURE PROSPECTS

The created nanobiomaterial can be used: **in biotechnology, medicine, pharmacology, ecology,** etc. – as a microscopic-size multifunctional biosensing unit capable of detecting biologically relevant compounds; **in molecular biology and medicine** – as carrier for the genetic material; **in technical sciences** – as multifunctional optical filters.

CONTACT INFORMATION

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ATOMIC FORCE MICROSCOPY OF SURFACES OF CRYSTALS AND NANOMATERIALS

Shubnikov Institute of Crystallography RAS

PRESENT STATUS of RESEARCH

Brief Descriptions of Research

The investigations are dedicated to the study of surface relief and local electrical properties of ferroelectric crystals and films, Langmuir-Blodgett films of different organic components and nanocomposites. In the research, the complex of methods is used (various modes of atomic force microscopy including electrostatic force microscopy, Kelvin probe microscopy, piezoelectric force microscopy, capacitance scanning microscopy) what allows to divide the contribution of different contrast mechanisms and to increase the reliability of the results interpretation. The special attempt is made to ensure the metrological base of the AFM measurements and to achieve the repeatable results.

Special Facilities in Use and their Specifications

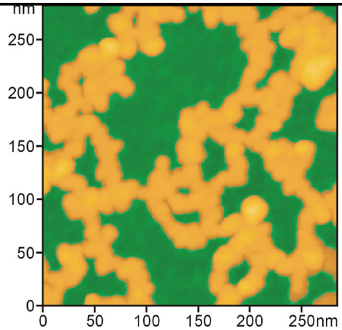
Scanning probe microscopes produced by NT-MDT (Russia): Solver P47 (maximum scanning area (XYZ) – 50×50×2.5 μm), Solver P47H (maximum scanning area – 100×100×12 μm), Ntegra prima (maximum scanning area – 100×100×12 μm and maximum scanning area – 5×5×2 μm); Clean room for atomic force microscopy "TRACKPORE ROOM" (class 8 ISO 14644-1) with controlled temperature (in the range 18 – 30 °C with error ±0.2 °C) and humidity (in the range 30 – 70 % with error ±3 %).

Selected Papers

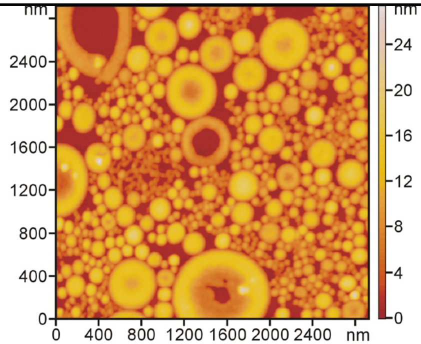
1. Tolstikhina A.L., Belugina N.V., Shikin S.A.
AFM Characterization of domain structure of ferroelectric TGS crystals on a nanoscale, Ultramicroscopy. 2000. V. 82, P. 149.
2. Belugina N.V., Tolstikhina A.L., Gainutdinov R.V.
About the nature of two-dimensional formations at the polar surface of cleaved triglycine sulfate crystals, Ferroelectrics. 2001.V. 249, P. 237.
3. Gaynutdinov R.V., Vainshtein D.I., Hak S.J., Tolstikhina A.L., Den Hartog H.W.
AFM of metallic nano-particles and nano-structures in heavily irradiated NaCl, Rad. Ef. Def. In Solids. (2003) V. 158, P. 77.
4. Demianets L.N., Pouchko S.V., Gaynutdinov R.V.
Fe_2O_3 single crystals: hydrothermal growth, crystal chemistry and growth morphology, Crystal Growth. 2003. V. 259, P. 165.
5. Sorokina K.L., Tolstikhina A.L.
Atomic Force Microscopy Modified for Studying Electric Properties of Thin Films and Crystals. Review, Crystallography Reports. 2004. V. 49, P. 476.

FOREIGN COLLABORATORS

H.W. den Hartog. Material Science Center, University of Groningen, The Netherlands; P.A. R. Thölén. The division of Microscopy and Microanalysis at the Physics Department, Chalmers University of Technology, Göteborg, Sweden.



Topographic AFM-image of planar nanostructure of palladium particles deposited onto mica surface by Langmuir-Blodgett method



Topographic AFM-image of “pure” fullerene Langmuir-Blodgett film

CONTACT INFORMATION

IC RAS, Atomic-Force Division group, A.L.Tolstikhina, E-mail: alla@ns.crys.ras.ru.

ZnO DISORDERED NANOOBJECTS: SYNTHESIS AND UV LASING AT ROOM TEMPERATURE

Shubnikov Institute of Crystallography RAS

PRESENT STATUS of RESEARCH

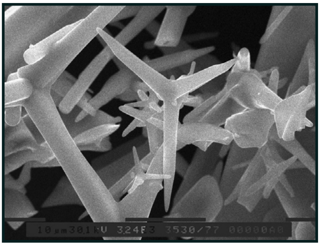
Brief Descriptions of Research

Zinc oxide is a material which is maximally adopted for obtaining the stimulated emission in UV region on its base. The highest value of exciton binding energy among binary semiconductors (($\cong$60 meV) provides the existence of UV band up to 500K in ZnO luminescence spectrum.

Disordered ZnO objects with high optical quality were synthesized by two methods (pyrolysis and hydrothermal synthesis). The low threshold UV lasing was obtained at room temperature on the ZnO-objects synthesized by both methods (excitation by frequency-triple YAG:Nd^{3+}laser (λ=355 nm, τ ~ 4 ns)) [1].

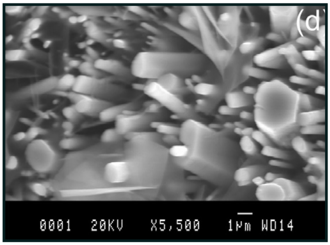
Growth, morphology and UV-lasing ZnO disordered nanoobjects

High temperature pyrolysis

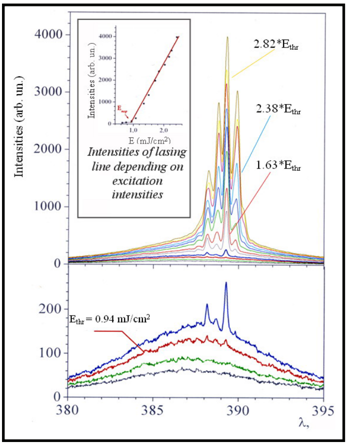


powder (A)

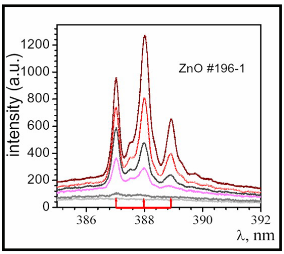
Hydrothermal method



polycrystalline film (B)



RT lasing spectra of ZnO powders synthesized by high temperature pyrolysis [1]



RT lasing spectra of ZnO polycrystalline film synthesized by hydrothermal method on Zn plate [3]

lasing characteristics	
threshold energy, mJ/cm²	*0.55 (A); 1.1 (B)*
lasing mode linewidth, nm	*0.2 (A, B)*
intermode space, nm	*0.55 (A), 0.97(B)*

Selected papers

1. L.E.Li, L.N.Dem'yanets, S.V.Nikitin, A.S.Lavrikov. Quantum Electronics, 2006, 36(3), 233.
2. L.N.Dem'yanets, L.E. Li, T.G. Uvarova. J.Cryst.Growth, 2006, 287(1), 23.
3. L.N. Dem'yanets, L.E. Li, T.G. Uvarova. J. MATER. SCI. 2006, 41(5), 1439.

DIRECTIONS of FUTURE RESEARCH

Possibility of Application

UV-Microlaser devices, LEDs.

Suggestion On Cooperation With Foreign Partners

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THE TRACK MEMBRANES NEW GENERATION – TRACK NANOMEMBRANES CHARACTERIZED WITH INCREASED PRODUCTIVITY AND DECREASED ADSORBTION LOSSES

Shubnikov Institute of Crystallography RAS

PRESENT STATUS of RESEARCH

The traditional track membrane pore structure represents body of the cylindrical pores with narrow pore diameter dispersion. These track membranes are characterized with small productivity compared to the other type membranes one due to the small porosity resulted from pore cylindrical shape. The hydraulic resistance of the cylindrical pore with diameter of 10–100 nm and length of 10000 nm is very large. The track membrane pore shape has to be non-cylindrical. The pore part of small diameter provided the membrane selectivity must be of small length and remaining pore part provided the membrane productivity must be of large diameter i.e. the pore shape must be asymmetrical (asymmetrical track membranes). Department of membrane technology IC RAS has developed the method of asymmetrical track membrane production. The one side of polymer film irradiated with high energy ions is treated with ultraviolet radiation heightened the chemical resistance of thin surface polymer layer. This stage is followed by track chemical etching under addition of the surfactant to the etchant. As result, the asymmetrical track nanomembrane is produced with pore shape of "asymmetrical cigar". The productivity of this membrane is by 3–5 more compared with the traditional track membrane one under the same selectivity.

One more any membrane important characteristic is the adsorption losses of components separated. The fulfilled investigations have improved the membrane adsorption properties dependence from electrostatic interaction between membrane surface and particles in the separated blend. To minimize adsorption losses, membrane surface must be neutral or the one and particles have to be charged with opposite charges. The satisfaction of these requirements is real with physical-chemical modification of membrane surface only since the separated particles nature variety. The developed chemical modification method consists of consequence treatment of poly ethylene terephtalate track nanomembrane with polyethyleneimine and polyvinylpyrrolidone. This modification method enabled the track membrane adsorption losses of model proteins and dies to decrease by the factor 10–30.

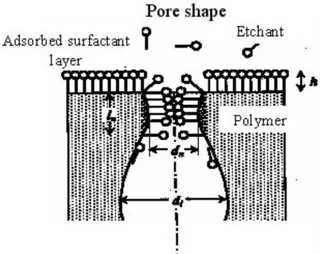
FOREIGN COLLABORATORS

Department of membrane technology collaborates with foreign partners:
European Institute of Membrane, Montpellier, France;
Institute of Nuclear Chemistry and Technology, Warsaw, Poland;
Loughborough University, Loughborough, U.K.;
University of the Western Cape, Bellville, South African Republic.

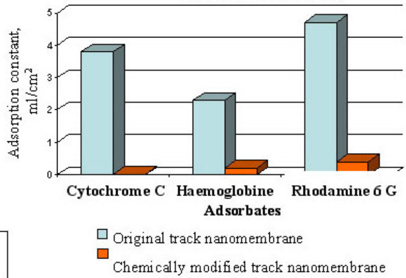
Setting for crystal growth including track nanomembrane cassette

Asymmetrical and chemically modified track nanomembranes to nanotechnology

Pore shape



Adsorption losses of original and chemically modified track nanomembranes



d_w, nm	Pore shape	Water productivity, ml/cm²*min*bar
30	cylinder	0,03
30	asymmetrical	0,21
50	cylinder	0,08
50	asymmetrical	0,40
100	cylinder	1,4
100	asymmetrical	4,3

CONTACT INFORMATION

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MULTI-PHASE POLYMER SYSTEMS WITH IMBEDDED NANOPARTICLES: STRUCTURE INVESTIGATION AND MODELING

Shubnikov Institute of Crystallography RAS

PRESENT STATUS of RESEARCH

The **main objectives** are determination of structure parameters of polymeric matrices with imbedded nanoparticles of different kind by small-angle X-ray scattering, electron diffraction and atomic-force microscopy methods.

The investigations include:

1. Determination of the ordered superstructure of polymer systems with imbedded metallic and metaloxide nanoparticles having the desired catalytic and magnetic properties.

2. Investigation of metallic nanoparticle formation in multilayered nanoporous polymer filtration membranes.

3. Determination of structure of bio-cellulose with imbedded nanoparticles. These materials are of great interest in medicine applications as antibacterial dressings and filtration materials.

4. Synthesis and investigation of structure of self-assembled and Langmuir-Blodgett planar polymer multilayer films and nanofilm systems with imbedded nanoparticles of different kinds.

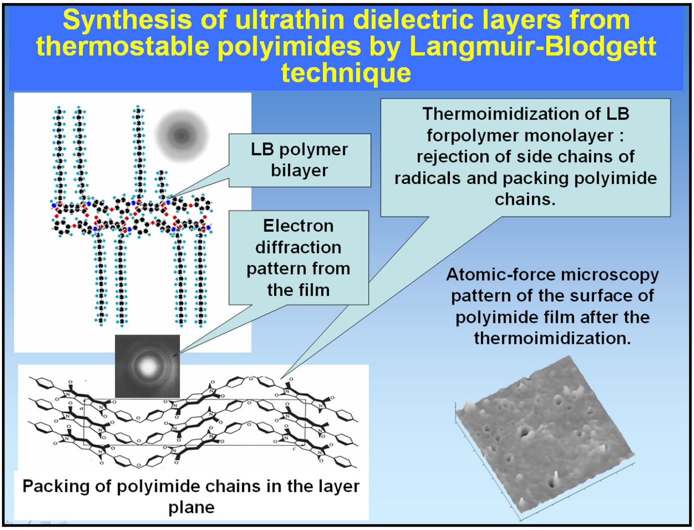
5. Development of (i) theoretical concepts and models for the understanding of polymer network interactions (ii) methods for the interpretation and modeling of X-ray and neutron scattering data from these systems.

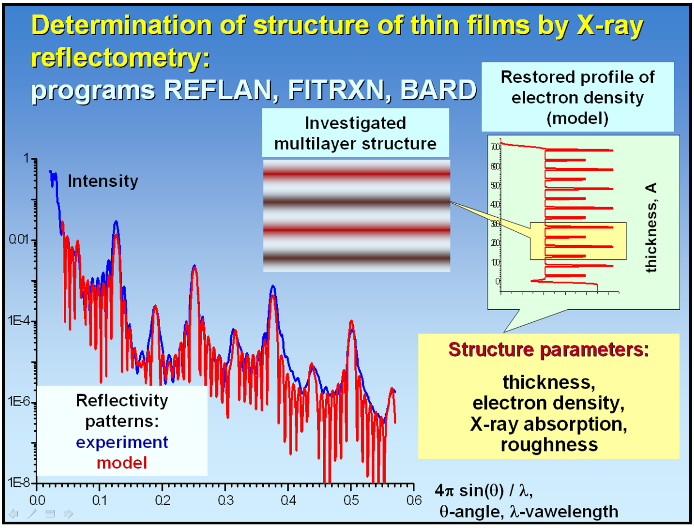
6. Determination of shape, electrical and magnetic properties of imbedded nanoparticles by advanced atomic-force microscopy methods.

The **capabilities of the investigations** are extraction, representation and interpretation of nanoscaled domain structure information from the small-angle scattering patterns. The data can be obtained directly from solutions, gels, powders, thin films etc. in a non-destructive way and under the natural conditions. Polymer systems are studied during temperature treatment using modern laboratory equipment and also synchrotron radiation facilities.

The studies are performed in close collaboration with:

1. A.N.Nesmeyanov Institute of Organoelement Compounds of RAS,
2. Moscow State University,
3. Institute of Macromolecular Compounds of RAS, St. Petersburg,
4. European Molecular Biology Laboratory (EMBL), Hamburg outstation,
5. Neutron facilities in Dubna, Russia.





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HIGH-RESOLUTION X-RAY DIFFRACTION DIAGNOSTIC OF MULTILAYER HETEROSRUCTURES AND NANOPOROUS LAYERS

Shubnikov Institute of Crystallography RAS

PRESENT STATUS of RESEARCH

High-resolution X-ray methods for characterization of subsurface and transitional layers of multilayer mirrors, multilayer heterosystems, nano- and mesoporous layers on monocrystal substrates are developed. The various registration schemes and analysis methods for the diffraction data are offered.

On the basis of double-axes X-ray diffractometry and reflectometry methods, studies of pseudomorphic HEMT structures are performed. There are the functional areas which form quantum well in such heterostructures by its building between thick layers or in a system of several layers differing in chemical composition. The electron energy levels, their positions and therefore the physical characteristics of instruments and devices managed on the basis of such heterostructures depend on chemical composition, structural perfection and degree of quantum wells boundaries degradation.

Figure 1 demonstrates the possibilities of the High-resolution X-ray double-axes diffractometry in the analysis of GaAs $In_xGa_{1-x}As$/GaAs (001) heterostructure with pseudomorphic quantum well separated by the 1 nm thickness AlAs barrier layer (left insert). The existence of thin layers with relatively sharp boundaries predetermines a large number of oscillations on diffraction curves (dots – experiment, solid line – theoretical treatment, 004 reflection, copper radiation).

The use of the adequate mathematical apparatus allows one to determine with high precision not only main heterostructure parameters (thickness, deformation, static Debye-Waller factor), but also to characterize the interfaces between these layers. Large volume of information included in such curves provides a unique possibility to control structural parameters within several nanometers for the layers located far from the surface.

Modeling a large number of the diffractions curves from various crystallographic planes allows one not only to determine reliably the distribution of structure parameters around the quantum well but also to estimate the anisotropy of displacements distribution of chaotic atoms in the layers plane, and in the perpendicular direction. Our study showed that the characterization of multilayer heterosystem with thin (several nanometers) deeply located layers requires the use of the high-resolution X-ray reflectometry methods, along with X-ray double-axes diffractometry, that is especially important for the determination of the thickness and composition of the layers with lattice parameters slightly different from the lattice parameters of substrate (Fig.1, left insert).

The theoretical treatment of experimental data allows us to determine the thickness and the composition of the layer with resolution ranging within 0.1 – 0.2 nm the thickness. The right insert of Fig. 1 shows the density distribution $\rho(z)$ of the central barrier AlAs layer.

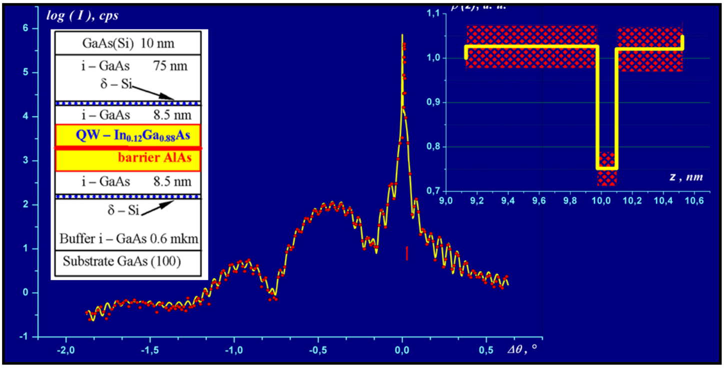

Figure 1

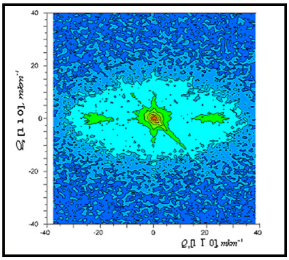

Figure 2a

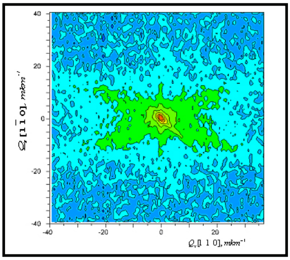

Figure 2b

The triple crystal X-ray diffractometry (TCD) represents a much effective instrument for studies of porous layers on semiconducting substrates. The series of TCD curves at two sample azimuth positions allows one to build the model of porous layers construction and to obtain average geometrical parameters and pores crystallographic orientation in the bulk. The TCD method easily reveals the influence of technological regimes of porous layers preparation on the structural parameters and orientation of pores relatively to the substrate. The fine structure of peculiarities of the porous layers construction is obtained from numerical modeling of diffuse scattering in the vicinity of reciprocal lattice center. Figure 2 (a, b) shows the maps of diffuse scattering from inclined pores in InP layers (004).

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LOW-DIMENSIONAL NANOSTRUCTURES ON VICINAL SURFACES: INVESTIGATIONS OF ATOMIC, ELECTRONIC STRUCTURES AND TRANSPORT PROPERTIES

Institute of Solid State Physics RAS

PRESENT STATUS of RESEARCH

Brief Descriptions of Research

The atomic and electronic structures of clean and decorated ordered vicinal surfaces of metals, semiconductors and insulators (W, Cu, Si, Al_2O_3) were studied by LEED, SPM (STM, AFM, MFM), and by electron spectroscopy techniques for future application of self-assembled structures on stepped surfaces in micro- and nanoelectronic devices [1-4].

The STM images with atomic and subatomic resolution of Cu{410}-O, Cu(100)-O surfaces were taken at different tunneling tip states by nonmagnetic (W) and antiferromagnetic (NiMn) probes to obtain information on oxygen and copper atom arrangement. The change of the apex electronic state due to appearance of adsorbed atom(s) and/or the tip geometry modification lead to chemical selectivity of the W probes [2] and subatomic resolution in STM images of Cu{410}-O surface (Fig. 1a). LEED and STM data demonstrate a possibility to fabricate atomically accurate terraced structures based on Si(hhm) with different periodicities (5.7 and 11.4 nm) depending on surface type and thermal treatment procedure [4]. STM images of Si(557) demonstrate triple steps with different facet orientations for surfaces with different terrace widths (Fig. 1c).

Vicinal surfaces of Al_2O_3 (R-, a-, c-planes) were studied by AFM. The technology of high perfection stepped sapphire substrates fabrication for micro- and nanoelectronics is developed (Fig.2a). Possibility of nanostructure fabrication based on organic and metaloorganic species (porphyrines and metalloporphyrines) are investigated. The self-organization effects in such objects are in progress (Fig.2b).

Special Facilities in Use and Their Specifications

The main Laboratory equipment: ultra high vacuum (UHV, $p \leq 1\times10^{-10}$Torr) electron spectrometers ESCALAB 5, MICROLAB MK-II (UPS, AES, LEED, XPS and EELS techniques, sample temperatures 7K - 300K); LAS-3000 (RIBER) (LEED, AES, RT STM GPI-300 atomic resolution on metals and semiconductors. SPM Solver ProM, Solver HV (NT-MDT).

Selected Papers

1. S.I.Bozhko, et.al.**, Mono- and multilayered opalline superlattices: application to nanotechnology of 2D ordered array of nanoobjects and 3D metalattices**,
Applied Surface Science, v.234 (2004) 93–101.

2. A.N.Chaika, S.I.Bozhko, **Atomic structure of the Cu(410)-O surface: STM vizualization of oxygen and copper atoms**, JETP Letters 82 (2005) 416-420 (in Russian journal
Pis'ma v Zh. Exp. i Teor. Fiziki 82 (2005) 467–472).

3. S.I. Bozhko, A.N. Chaika, A.M. Ionov, S.L. Molodtsov, D.V. Vyalikh, V.D.P. Servedio. **Photoemission experiments and density functional calculations forthe W(112) stepped surface with submonolayer Au coverages**. Surface Science 600 (2006) 249–256.

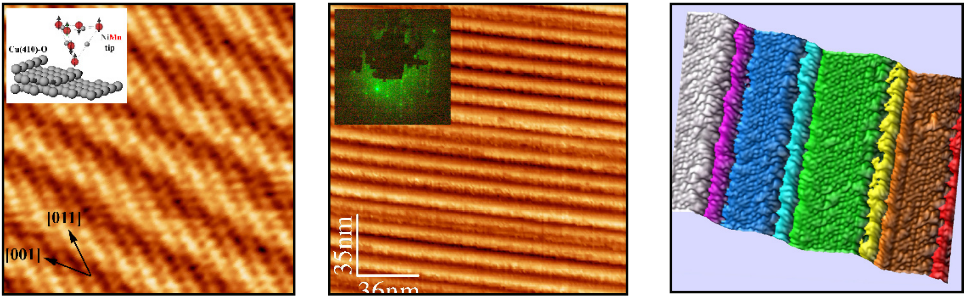

Fig.1. STM images of vicinal surface resolved by RT STM GPI-300. (a) STM image of Cu(410)-O surface with subatomic resolution obtained by NiMn tip, $4\times4nm^2$. (b) STM image of regular Si(557) stepped surface, $178\times178nm^2$, inset: corresponding LEED pattern. (c) Atomically resolved 3D-image of Si(557) surface

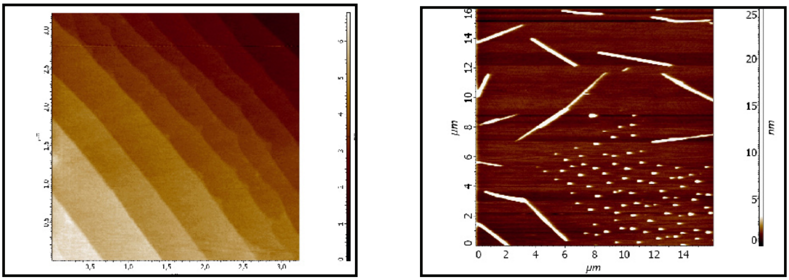

Fig.2. AFM images of Al_2O_3 and porphyrine microassembles. (a) High perfection stepped surface of Al_2O_3 R-plane. (b) Self assembled porphyrine structures on Si surface

4. A.N.Chaika, S.I.Bozhko, A.M.Ionov, A.N.Myagkov, N.V.Abrosimov, **STM and LEED studies of the atomically ordered terraced Si(557) surfaces**, Fizika i Technika poluprovodnikov, in press.

FOREIGN COLLABORATORS

Prof. D.Roditchev, Institut des Nano-Sciences de Paris, CNRS Universités Paris 6 et Paris 7; Prof. I.Shvets, Trinity College Dublin, Dublin 2, Ireland.

DIRECTIONS of FUTURE RESEARCH

Performed investigations showed that vicinal (stepped) surfaces of Si and Al_2O_3 are perspective candidates for future micro- and nanoelectronic device fabrication. It is planned to use them as templates and matrixes for future low-dimensional nanostructure fabrication.

CONTACT INFORMATION

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NANOSTRUCTURED CRYSTALS OF THE $M_{1-X}R_XF_{2+X}$ FLUORITE PHASES

Shubnikov Institute of Crystallography RAS

PRESENT STATUS of RESEARCH

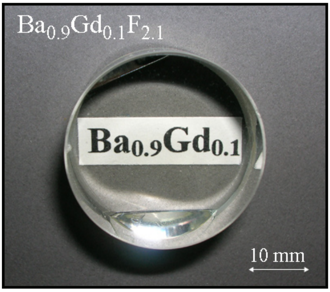
Brief Descriptions of Research

Nanostructured crystals (NSC) of the $M_{1-x}R_xF_{2+x}$ fluorite phases are promising optical materials in the UV and IR ranges, their superionic conductivity is used in chemical sensors for fluorine detection and fluorine generators. These crystals are also used as the basis for the production of fast high-absorbing and radiation stable scintillators, photorefractive materials, substrates with a controlled lattice period, as well as in low-threshold lasers. The basics on the formation of $M_{1-x}R_xF_{2+x}$ NSC, specific features of their structure and properties studied at the INCRYS are reported in [1].

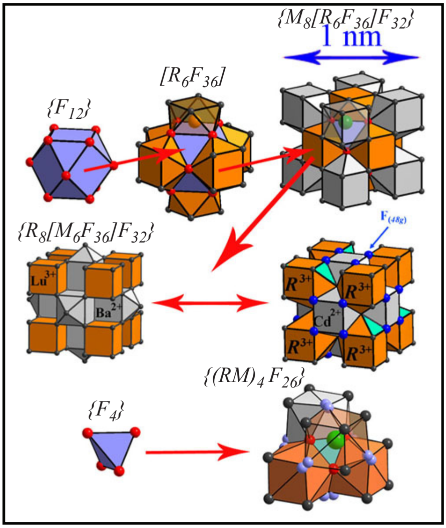
NSC of the $M_{1-x}R_xF_{2+x}$ phases (M = Ca, Sr, Ba, Cd, Pb; R are 16 rare-earth elements, REE) are transparent and they do not scatter light (photo). NSC are formed in 80 MF_2 – RF_3 systems, whose diagrams were studied at the INCRYS [2]. X-ray structural techniques were used to confirm the formation of clusters within the crystals which accumulate all types of structural defects (M^{2+} and R^{3+} with non-cubic coordination, interstitial F^{1-}, F vacancies). Heterovalent isomorphic replacements effectively impact properties of nonstoichiometric crystals of $M_{1-x}R_xF_{2+x}$, whose structure is characterized by three inhomogeneity levels (in terms of size scale).

Level 1 - *nanometers* – have $\{M_8[R_6F_{68-69}]\}$, $\{R_8[M_6F_{68}]\}$ and $[(R,M)_4F_{26}]$ clusters which make them nanostructured materials (NSM) [3]. Clusters self-assembly from anionic cuboctahedral $\{F_{12}\}$ or tetrahedral $\{F_4\}$ (nuclei) and high-charged R^{3+} cations (Fig. a, b) occurs in diluted melts. The clusters are enriched with REE and fluorine with respect to MF_2. Their type and composition is accounted for by matrix (MF_2) type, REE type and content, crystal sample preparation conditions. In most $M_{1-x}R_xF_{2+x}$ phases cluster formation is manifested by a maximum on the melting curves. Variations in the coordinates of maximum (composition, temperature) over the REE series is a feature showing that the phases belong to compounds with a variable composition (berthollides).

Level 2 – cluster associates with linear sizes ranging from few to hundreds *nm*, which do not scatter light (photo). This level is studied using electron diffraction and high-resolution electron microscopy techniques. In crystal samples with RF_3 content of dozens mole %, volumes of non-distorted or weakly perturbed matrix were detected (NMR data, EPR, Raman scattering etc.). This means that nanoparticles enriched with REE are quite large in size. Crystals of non-stoichiometric $M_{1-x}R_xF_{2+x}$ phases are nanocomposites formed by microdomains with different compositions and structure. Microdomain phases $M_{1-x}R_xF_{2+x}$ were detected within their homogeneity areas from X-ray diffraction patterns, electron diffraction patterns and moire effect on atomic resolution electron microscopy patterns.



$M_{1-x}R_xF_{2+x}$
M = Ca, Sr, Ba, Cd, Pb;
R = Sc, Y, La, Ce, Pr, Nd, Sm, Eu, Gd,
Td, Dy, Ho, Er, Tm, Yb, Lu



Level 3 of inhomogeneity is measured in *mm*. It is related with kinetic phenomena – the formation of cellular substructure upon crystallization of multicomponent melts with incongruous melting (in general). This level is associated with the formation of various defect structure in crystallites from neighbouring parts of the crystal rod (two types of clusters - $\{M_8[R_6F_{68-69}]\}$ and $\{R_8[M_6F_{68}]\}$ in the $Ba_{0.8}Yb_{0.2}F_{2.2}$ crystal etc.).

Selected Papers

1. Sobolev B.P., **The Rare Earth Trifluorides. Part 2. Introduction to Materials Science of Multicomponent Fluoride Crystals**, Barcelona: Institut d'Estudis Catalans, 2001, 460 p.
2. Sobolev B.P., **The Rare Earth Trifluorides. Part 1. The High Temperature Chemistry of the Rare Earth Trifluorides.** Barcelona: Institut d'Estudis Catalans, 2000, 520 p.
3. Sobolev B.P., Golubev A.M., Herrero P., **Fluorite Phases $M_{1-x}R_xF_{2+x}$ (M = Ca, Sr, Ba; R – Rare Earth Elements) as Nanostructured Materials**, Crystallography Reports, 2003, 48, № 1, 141-161.

DIRECTIONS of FUTURE RESEARCH

The studies of the evolution of the defect structure at the all above mentioned inhomogeneity levels for $M_{1-x}R_xF_{2+x}$ nanostructured crystals are in progress in collaboration with the Institute for Materials Science, Madrid, Spain; University of Barcelona, Spain; University of Freedom, Brussels, Belgium and Institutes of the Russian Academy of Sciences.

CONTACT INFORMATION

IC RAS, Laboratory of Fluoride Materials, Leninsky prospect 59, Moscow 119333;
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SPIN-LABELED MEMBRANE-PEPTIDE SYSTEMS

Institute of Chemical Kinetics and Combustion SB RAS

PRESENT STATUS of RESEARCH

Brief Descriptions of Research

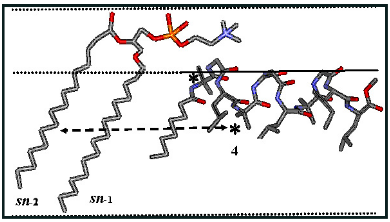
Investigation of the mechanism of drug delivery inside a cell by studying the supramolecular structure and dynamics of water channels created in the hydrophobic core of the membrane by membrane-penetrating peptides. Selectively spin-labeled synthetic analogues of peptides and lipids are used. The location, aggregation, and dynamics of molecules in the membrane are studied by employing advanced electron paramagnetic resonance (EPR) spectroscopy.

Special Facilities in Use and Their Specifications

Pulsed EPR spectrometers: Elexsys E-680X/E-580E FT EPR (Bruker) and ESP-380 FT EPR (Bruker). Spectrometers are equipped with a dielectric cavity (Bruker ER 4118 X-MD-5) inside Oxford Instruments CF 935 liquid helium flow cryostat. Pulsed ELDOR and ENDOR measurements are possible. Also, a home-made high-field high-frequency EPR facility is available (2 mm band).

Selected Papers

1. D.A. Erilov, R. Bartucci,, R. Guzzi, A.a. Shubin, A.G. Maryasov, D. Marsh, S.A. Dzuba, L. Sportelli, **Water concentration profiles in membranes measured by ESEEM of spin-labeled lipids**, J. Phys. Chem. B, 109, 120003-12013 (2005).
2. A.D. Milov, Yu.D.Tsvetkov, F. Formaggio, M. Crisma, C. Toniolo, J. Raap, **Secondary structure of a membrane-modifying peptide in a supramolecular assembly studied by PELDOR and CW-ESR spectroscopies**, J. Am. Chem. Soc. 123, 3784 (2001).
3. A.D. Milov, R.I. Samoilova, Yu.D. Tsvetkov, F. Formaggio, M. Crisma, C. Toniolo, J. Raap, **Spatial distribution of spin labeled trichogin GA IV in the Gram-positive bacterial cell membrane determined from PELDOR data**, Appl. Magn. Res. 23, 81-95 (2002).
4. E.S. Salnikov, D.A. Erilov, Yu.D. Tsvetkov, C. Peggion, F. Formaggio, C.Toniolo, **Location and aggregation of the spin-labeled peptide trichogin GA IV in a phospholipid membrane as revealed by pulsed EPR**, Biophys. J. 91, 1532-1540 (2006).



Supramolecular structure of the peptide-lipid system elucidated with pulsed EPR. Stars indicate the positions where labels were selectively attached to the peptide backbone

FOREIGN COLLABORATORS

Rosa Bartucci, Rita Guzzi, Luigi Sportelli, Dipartimento di Fisica and Unita INFM, Universita della Calabria, Italy; Derek Marsh, Max-Planck-Institut for Biophysikalische Chemie, Goettingen, Germany; C. Peggion, F. Formaggio, C. Toniolo, Department of Chemistry, University of Padova, Padova, Italy;
Jan Raap, Gorleus Laboratory, Leiden , The Neterlands.

DIRECTIONS of FUTURE RESEARCH

Our ultimate research problem is to obtain fundamental information for the rational design of *de novo* methods to deliver drugs to mammalian cells.

CONTACT INFORMATION

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Prof. S.A. Dzuba – Director of the Institute.

ENGINEERING OF LASER MEDIUM ON THE BASE OF NANOSTRUCTURED LIQUIDCRYSTALLINE AND POLYMER MATERIALS

Shubnikov Institute of Crystallography RAS

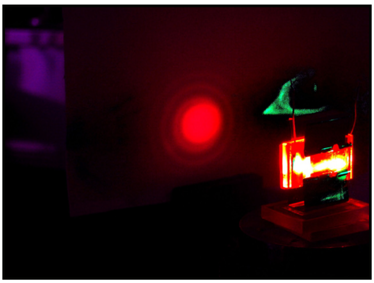
PRESENT STATUS of RESEARCH

For spectral diapason 340 – 1000 nm, liquidcrystalline materials (LCM) are developed with controlled (by the material composition) spectral position of forbidden photon zone. The mode composition of laser generation and leakage channels were determined.

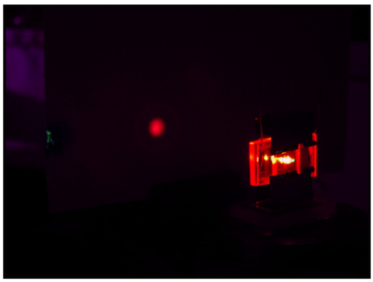
Hybrid liquidcrystalline structures (in fact, nanostructured) of the cholesteric–nematic type are developed where the effective control of laser generation is obtained.

Spatially-periodic liquidcrystalline structures can be induced by applied electric fields. Computer modeling shows, that flexoelectric grids, in fact, are chiral objects induced by an electric field, and they demonstrate examples of field-induced photon crystals in which a laser generation is observed.

On the base of LCM, doped with dyes, laboratory samples of laser elements are created, demonstrating laser generation on the borders of a forbidden photon zone. New promising possibilities are found for the control of laser elements on the base LCM by electric field.



It was shown that the circles-structure of beam cross-section is not a consequence of diffraction divergence, but it is a result simultaneous execution of conditions of laser generation for different directions



Laser generation in three-layers cellcholesteric – nematic – cholesteric

CONTACT IFORMATION

IC RAS, Moscow, RF; Laboratory of Liquid Crystals (S.P. Palto – Head of Lab. E-mail: lbf@ns.crys.ras.ru); Moscow State University, Laboratory of Polymers (V.P. Shibaev – Head of Lab.)

SELECTIVE REMOVAL OF ATOMS AS A NEW METHOD FOR PRODUCTION OF NANOSCALE MULTILAYER PATTERNED MEDIA FOR VARIOUS APPLICATIONS

Russian Research Centre «Kurchatov Institute», Moscow

PRESENT STATUS of RESEARCH

Brief Descriptions of Research

The method of Selective Removal of Atoms (SRA) was discovered and developed in RRC «Kurchatov Institute». Its idea consists in controllable modification of the thin films chemical composition under the influence of ion beams of certain energy. As a result the physical properties of material change dramatically – it's possible to modify insulating materials into metals or semiconductors, nonmagnetic materials into magnetic ones, to change the optical properties.

Special Facilities in Use and their Specifications

The SRA method has several intrinsic advantages allowing one to consider it as a promising basis for principally new technology aimed at production of nanoscale elements for various applications. The method is parallel in its nature and permits a simultaneous preparation of the elements over the whole area. It also allows to provide a presise matching of the elements in various layers of the structure with accuracy up to one nanometer. As an example of its facilities the patterned magnetic media with areal density of nanoscale elements of 60 GB/sq.inch was produced.

Selected Papers

1. B.Gurovich, D.Dolgy, E.Kuleshova, E.Velikhov, E.Ol'shansky, A.Domantovsky, B.Aronzon, E.Meilikhov, **Ion beam control of electrical, magnetic, and optical material properties**, Physics-Uspekhi, 44(1), 95-114 (2001).

2. B.Gurovich, D. Dolgy, K. Prikhodko, A. Domantovsky, K. Maslakov, E.Meilikhov, A.Yakubovsky, **Selective Removal of Atoms as Basis for Ultra-High Density Nanopatterned Magnetic and Other Media Production**, B. Aktas et al. (eds.) , "Magnetic Nanostructures". Springer Publishers.,2007, VIII, 208 p. 47-64.

3. USA Patents #6,218,278 and 6,004,726; priority 05/22/98.

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Prof. Boris Gurovich, E-mail: evgenia-orm@yandex.ru.

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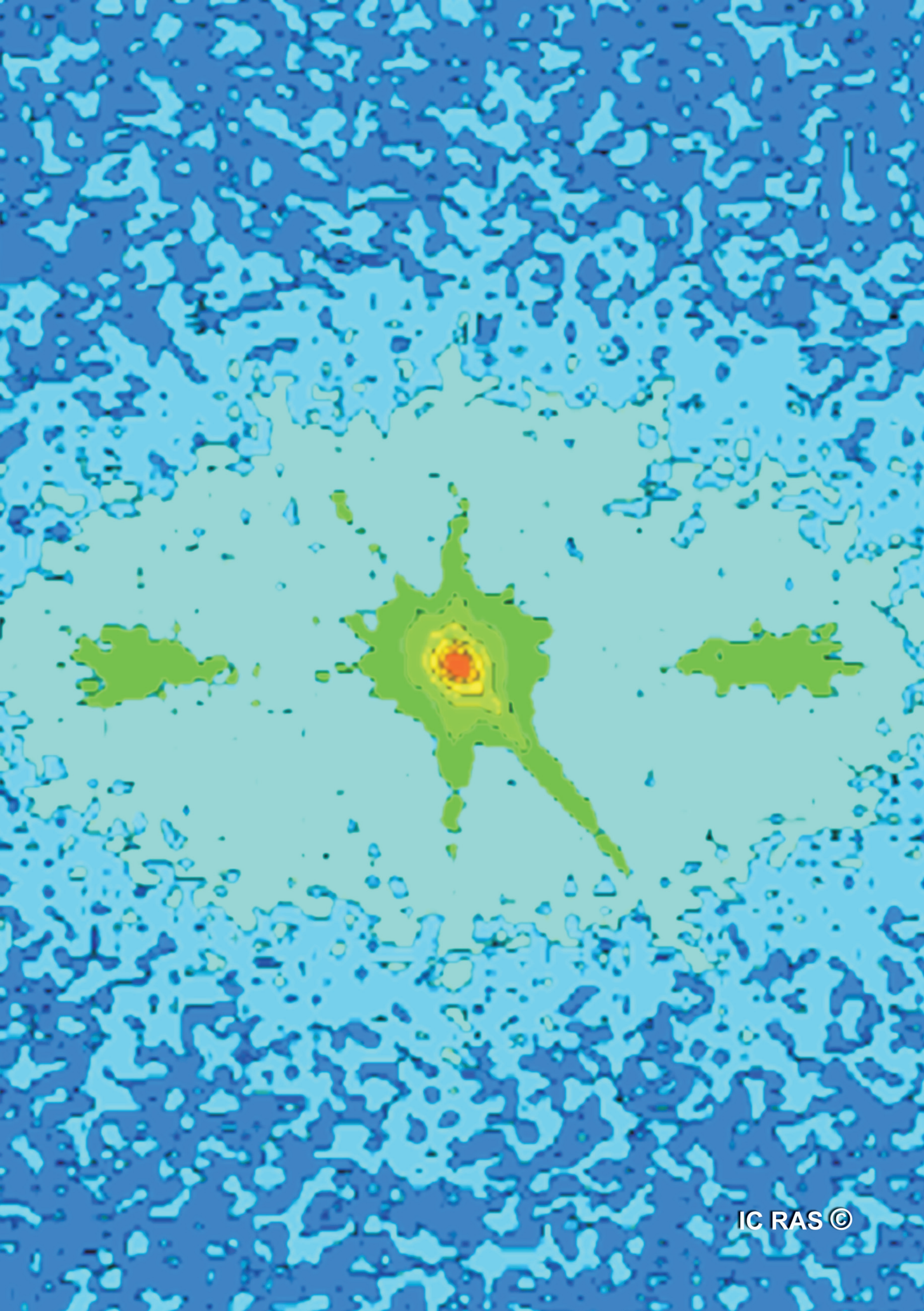
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