CONTENTS

Dear Colleagues,

One of the significant events in 2013 was the Second National Congress on Physical Sciences (25-29 September 2013, Sofia) in which the Institute of Solid State Physics took part with 8 plenary lectures and 60 poster and oral presentations.

In 2013 the regular Internal Project Competition of the Institute took place. Five scientific projects were supported by modest levels of funding. Nevertheless, this internal funding promotes the scientific activity and attracts much attention among the scientists. Accounts of the scientific results of ISSP were reported 25 times in the media.

The total 2013 productivity of ISSP is 250 publications, 165 of them printed and 85 in press. 97 papers have been published in high impact factor or impact rank journals. The total number of citations in 2013 is over 1100. N. Sabotinov and N. Vuchkov are coauthors of the book "Strontium and calcium vapour lasers" Volume I, Prof. Marin Drinov Academic Publishing House. A Tribute to Marin D. Mitov, Advances in Planar Lipid Bilayers and Liposomes, Vol. 17 was published by Academic Press, A. Iglič and J. Genova (Eds). A. Paskaleva is coeditor of STI: "Advanced Oxides for Electronics", Elsevier. Nine invited chapters in prestigious books by foreign editors were published. ISSP currently holds 10 BG patents and 8 applications for patents are in procedure.

Professor Kiril Blagoev received the Marin Drinov Honorary Medal of BAS on a ribbon. Professor Elena Atanassova was awarded the Sign of Honor of the Bulgarian Academy of Sciences. Boyan Torosov received the Prof. Marin Drinov prize of BAS for young scientist. Silvia Bakalova received the prize of UNESCO and L'Oreal "For Women in Science". The team N. Vuchkov, K. Temelkov and N. Sabotinov was nominated for "Inventor of the Year 2013" by the Patent Office and the European Patent Office.

E. Vlakhov was awarded the Georgi Nadjakov Sign of Honor 1st degree and S. Stoichev received the Georgi Nadjakov Sign of Honor 2nd degree. Awards for the best scientific achievements of the year 2013 in ISSP were presented to the teams lead by Professor M. Petrov and Assoc. Professor T. Petrov. Medals and diplomas brought pride and satisfaction not only to their winners, but to the Institute as a whole.

Two forthcoming events will be organized by the Institute: the 18th International School of Condensed Matter Physics (1 - 6 September 2014, Varna) and the Fourth Balkan Symposium on Archaeometry (27 - 30 September 2014, Nessebar). They both will be devoted to the 145th anniversary of the Bulgarian Academy of Sciences.

Alexander G. Petrov

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Mission of the Institute: achievement of fundamental knowledge in the condensed matter physics, optics, spectroscopy and laser physics; application of this knowledge for the creation of new materials, devices and analytical methods for micro- and nano-technologies, as well as for new approaches in the interdisciplinary fields of the physics with biology, medicine, archaeology; transfer of the achieved results to the economy of Bulgaria.

Every second year since 1980, ISSP organizes at the Black Sea coast an International School-Simposium on contemporary problems in condensed matter physics (ISCMP).

EQUIPMENT, METHODS AND TECHNOLOGIES

ISSP has at his disposal rich variety of equipment, precise methods and technologies:

- Equipment and methods for electron microscopy and electron diffraction investigations, atomic, electric and magnetic force microscopy, X-ray diffraction with topographic, diffractometric and spectrometric facilities, ellipsometric measurements, spectroscopy from VUV to IR spectral regions, time-resolved spectroscopy, EPR spectroscopy;
- Equipment and know-how for single crystal growth from oxide materials for laser techniques and photorefractive effect applications, techniques and technology for thin layer deposition for microelectronic, optoelectronic and acoustoelectronic sensors and laser technology, cleanroom, complex equipment for molecular beam epitaxy, equipment for synthesis and investigation of high temperature superconducting materials;
- Equipment for polarization measurements in mesophases and polymer liquid crystals for display techniques, equipment for stroboscopic videomicroscopy and micromanipulation of lipid membranes;
- Various laser systems: gas discharge metal vapour and solid state (ns and fs) lasers, oscillating in UV, visible and IR spectral range, for plasma physics applications, laser analysis and material processing, for application in nanotechnology, medicine, archaeology, ecology, etc.;
- High-tech experimental setup for laser cooling of atoms (~ 0.0001K);
- Equipment (Physical Properties Measurement System produced by Quantum Design, USA) for studies of electrical, magnetic and thermal properties of materials, surfaces and structures;
- Scanning probe microscope (VEECO, Multimode, USA) for precise surface characterization at the nanoscale.

HISTORICAL REFERENCE: *ISSP at BAS is created by a Decree No 362 / October16, 1972, of the Ministry Council of Bulgaria. This Decree splits the existing Institute of Physics with Atomic Scientific Experimental Center (IP with ASEC) at BAS, founded by Academician G. Nadjakov in 1946, into ISSP and INRNE (Institute of Nuclear Research and Nuclear Energy), starting January 1, 1973. Since February 16, 1982 the Institute of Solid State Physics is named after Academician Georgi Nadjakov. The first Director (1973-1991) of the Institute of Solid State Physics was Academician Milko Borissov. The second Director (1991-1999) was Professor Nikolay Kirov.*

ORGANIZATION OF THE INSTITUTE OF SOLID STATE PHISICS

DIRECTORATE

Director:	Academician A.G. Petrov, D.Sc.
Deputy Directors:	Prof. K. Blagoev, D.Sc. Prof. I. Bivas, D.Sc.
Scientific Secretary:	Assoc. Prof. M. Primatarowa, Ph.D.

DIVISIONS

Theory	Head: Prof. H. Chamati, D.Sc.
Material Physics	Head: Prof. M. Gospodinov, D.Sc.
Nanophysics	Head: Prof. D. Nesheva, D.Sc.
Micro- and Acoustoelectronics	Head: Assoc. Prof. A. Paskaleva, Ph.D.
Low Temperature Physics	Head: Prof. N. Tonchev, D.Sc.
Physical Optics and Optical Methods	Head: Prof. S. Rashev, D.Sc.
Soft Mater Physics	Head: Acad. A. G. Petrov, D.Sc.
Laser, Atomic, Molecular and Plasma Physics	Head: Prof. K. Blagoev, D.Sc.
Innovation Department:	Head: Assoc. Prof. S. Andreev, Ph.D.
Education Department:	Head: Prof. I. Bivas, D.Sc.
Center for Investigation of the Physical Properties of Materials, Surfaces and Structures:	Head: Assoc. Prof. V. Lovchinov, Ph.D.

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Deputy Chairman: Prof. H. Chamati, D.Sc.
Secretary: Assoc. Prof. M. Grozeva, Ph.D.

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2. Acad. N. Sabotinov, D.Sc.
3. Prof. K. Blagoev, D.Sc.
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20. Assoc. Prof. D. Astadjov, Ph.D.
21. Assoc. Prof. K. Temelkov, Ph.D.
22. Prof. D. Dimitrov, Ph.D.

DIVISION THEORY

THEORETICAL DEPARTMENT

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TOTAL STAFF: **7**
RESEARCH SCIENTISTS: **6**

Prof. N.B. Ivanov, D.Sc.; Prof. P.C. Ivanov, D.Sc.; Assoc. Prof. E.R. Korutcheva, D.Sc.; Assoc. Prof. M.T. Primatarowa, Ph.D.; Assist. Prof. R. S. Kamburova; Assist. Prof. A. A. Donkov, K.G. Gaminchev, PhD student

RESEARCH ACTIVITIES:

We study the interaction of discrete (narrow) dark solitons with point defects in the integrable Ablowitz-Ladik lattice model. On-site and inter-site (bond) defects are considered. The stability of the analytical solutions for solitons bound to the defect is investigated. A comparison with the standard discrete nonlinear Schrödinger equation is made. Scattering of the dark solitons from point defects of different types is studied numerically. The model plays an important role in numerous physical systems, especially when the corresponding elementary excitations obey Pauli statistics.

We have considered the ferromagnetic spin chain with both first-and second-neighbor interactions. We obtained the condition for the appearance and stability of bright and dark solitons for arbitrary wave number and different anisotropies (on-site or inter-site). The complicated dependence of the dispersion and the nonlinear coefficients lead to regions in the Brillouin zone where strong second-neighbor interactions can turn the type of the soliton solution (from bright to dark or vice versa).

We have investigated non-equilibrium characteristics and critical behavior in brain dynamics during sleep. We found that contrary to traditional views that sleep is a homeostatic equilibrium process, sleep dynamics at short time scales of seconds to hours are far from equilibrium and demonstrate properties typical for physical systems exhibiting self-organized criticality (SOC) such as avalanches, earthquakes and sandpiles. Utilizing a probability matrix approach we showed that the entire class of sleep-stage transition pathways underlying the complexity of sleep dynamics throughout the night can be characterized by only two independent transition paths. These basic pathways remain stable under sleep disorders indicating an intriguing and a-priori unknown sleep micro-architecture of SOC type.

In a different line of research we have investigated the network of communications between key organ systems in the human body. Introducing a novel method based on the concept of time delay stability to identify and quantify coupling between nonlinear systems with transient output dynamics, we found that with transition from one physiological state to another the topology of the physiologic network dramatically changes, indicating a robust relation between network structure and physiologic function. We showed that processes of such transitions are associated with a hierarchical re-organization in global network connectivity and link strength characterized by specific stratification patters. Our investigations opened a new area of research, called Network Physiology. A Special Issue in the New Journal of Physics, where Prof. Ivanov is the Guest Editor, now focuses on this new field.

We presented an overview of the theory of phase transitions and critical phenomena in the framework of "idealized" classical magnetic models, such as the Ising ferromagnet. For these models Statistical Physics gives a detailed description of the behavior of various thermodynamic quantities in the vicinity of the transition temperature. The predictions of the named models were confirmed by the most precise experiments on magnets. Real systems, however, are more complex and additional features, such as anisotropy, defects, dilution etc. have to be taken into account. These features highly affect the transitional behavior of the ideal model or even suppress it. We have addressed these issues in terms of magnetic systems and discussed their application to biomembranes.

We study the growth of mounds representing stacks of monolayer islands in homoepitaxy assuming terrace-edge-kink mechanism of attachment of atoms to kink sites and allowing a permeability of the single steps. We show that the latter can result in slope selection of the growing mounds at comparatively small values of the Ehrlich-Schwoebel barrier to down-step diffusion. The value of the permeability coefficient at which a slope selection occurs is always very close to the upper limit for complete step permeability. The latter is in agreement with the row-by-row mechanism of step propagation at which the steps are kink-free for most of the time.

Evolutionary neuroscience has been mainly dominated by the principle of phylogenetic conservation. Specifically, by the search for similarities in brain organization. This principle states that closely related species tend to be similar because they have a common ancestor. However, explaining, for instance, behavioral differences between humans and chimpanzees, has been revealed to be notoriously difficult. In this paper, the hypothesis of a common information processing principle exploited by the brains evolved through natural evolution is explored. A model combining recent advances in cognitive psychology and evolutionary neuroscience is presented. The macroscopic effects associated with the intelligence-like structures postulated by the model are analyzed from a statistical mechanics point of view. As a result of this analysis, some plausible explanations are put forward concerning the disparities and similarities in cognitive capacities which are observed in nature across species. These theoretical results are shown to be consistent with the hypothesis of embodied animal intelligence.

PUBLICATIONS:

1. P.L. Parmeggiani, R.P. Bartsch and P.Ch. Ivanov, Physiologic Regulation in Sleep in: *Atlas of Clinical Sleep Medicine* ed. M. Kryger (Elsevier, 2013) pp. 36-40.
2. A. Chinea and E. Korutcheva, Intelligence and embodiment: A statistical mechanics approach, Neural Networks **40** (2013) 52-72
3. H. Chamati, Theory of Phase Transitions: From Magnets to Biomembranes, Advances in Planar Lipid Bilayers and Liposomes **17** (2013) 237-285
4. R.S. Kamburova and M.T. Primatarowa, Soliton dynamics in ferromagnetic chains with first- and second-neighbor interactions, Rom. Rep. Phys. **65** (2013) 1170–1177
5. M.T. Primatarowa and R.S. Kamburova, Interaction of narrow dark solitons with impurities in nonlinear lattices, Rom. Rep. Phys. **65** (2013) 374-382
6. C.-C. Lo, R.P. Bartsch and P.Ch. Ivanov, Asymmetry and basic pathways in sleep-stage transitions, EPL **102** (2013) 10008
7. E. Korutcheva, K. Koroutchev and I. Markov, Slope selection of mounds with permeable steps in homoepitaxy, Eur. Phys. J. B **86** (2013) 60
8. P.Ch. Ivanov and R.P. Barsch, Network Physiology: Mapping Interactions Between Networks of Physiologic Networks, in: *Networks of Networks: the last Frontier of Complexity*, Understanding Complex Systems (2014) 203-222

RESEARCH PROJECTS:

- Termomechanical and magnetic properties and nonlinear excitations in condensed media, funded by the budget subsidy of the Bulgarian Academy of Scences
- Formation of hydrogen negative ions via resonant charge transfer in atom-surface Collisions, Euratom 2013.
- Metric approach in the theory of phase transitions based on fidelity, with the Joint Institute for Nuclear Research, Dubna, Russia
- Research and Innovation Capacity Strengthening of ISSP-BAS in Multifunctional Nanostructures, INERA 316309, REGPOT-2012-2013-1, 7FP

DIVISION THEORY

RESEARCH GROUP

COLLECTIVE PHENOMENA
in Condensed Matter

HEAD: **Prof. Dimo I. Uzunov, Ph.D., D.Sc.**
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TOTAL STAFF: **2**
RESEARCH SCIENTISTS: **2**

Assoc. Prof. D.V. Shopova, Ph.D.

RESEARCH ACTIVITIES:

1. A second non-unitary phase in *p*-wave superconductors is shown to be stable in certain domains of the *P*-*T* phase diagram. Some errors in preceding papers related to this and other topics of the thermodynamics of unconventional superconductors are established [1].
2. The phase transition to ferromagnetic order in itinerant ferromagnetic superconductor UGe_2 as function of pressure shows change of phase transition order. At low temperature and high pressure the transition is of first order and at pressure of about 1.42 GPa the order changes to second. On the basis of Landau expansion of free energy up to the sixth order in magnetization we calculate the phase diagram taking into account the magneto-elastic interaction as the mechanism responsible for this change. We propose a simple Stoner-like dependence of the Curie temperature on the pressure and present the results for measurable thermodynamic quantities at the first order phase transition [2].

PUBLICATIONS:

1. D. I. Uzunov, Phys. Rev. B **87** (2013) 026501. "Comment on "Fluctuation-induced first-order transition *p*-wave superconductors."
2. D. V. Shopova, arXiv: 1312.7773 (2013). "Some remarks on the magnetic phase diagram of ferromagnetic superconductor UGe_2."

OTHER ACTIVITIES:

Expert activity: Dr. D. V. Shopova is an expert to REA at EC. In 2013 she has made 35 assessments of research project submitted to the EC. Other 12 European projects (EC ones and bilateral within EU countries) have also been assessed (D. I. Uzunov).
Teaching: Laboratory and seminar training of 1st year students (Department of Applied Physics at Technical University of Sofia) has been carried out (D. V. Shopova).

DIVISION MATERIAL PHYSICS

LABORATORY

ELECTRON-PHONON INTERACTIONS

HEAD: **Assoc. Prof. Ognyan Ivanov, Ph.D.**
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TOTAL STAFF: **6**
RESEARCH SCIENTISTS: **4**

Assoc. Prof. K. Christova, Ph.D.; Assist. Prof. L. Mihailov, Ph.D.; I. Boradjiev, Ph.D.; Y. Mutafchieva – physicist; Z. Stoyanov – physicist

RESEARCH ACTIVITIES:

Over the year was prepared the launch of a major European project in thematic area Security of the Cooperation program in the Seventh Framework Programme.
The possibility for use of the Surface Photo-Charge Effect Development of water sensors was examined. It has been shown that due to the strong sensitivity of the effect from the state of the interface: a solid - water, such sensors may be successfully developed.
Samples of cement supplied by the cement plant "Zlatna Panega" were studied. The initial results show that it is possible to analyze the fineness and quality of cement by the Surface Photo-Charge Effect.

The properties of the outer crust of cold non-accreting magnetars were studied using the latest experimental atomic mass data complemented with a microscopic atomic mass model based on the Hartree-Fock-Bogoliubov method. Nine different setups for the effective Skirm interactions were used. It was established how the different setups influence the Landau quantization of the electron motion in strong magnetic field as well as the composition and the equation of state of the matter in the crust.

The contribution of the movement and deformation of the nucleus to the ground state energy of the electron system of helium-like ions were analyzed. The studied ions were of all existing isotopes of elements with Z = 2-118. Calculations were made when taking into account the Staggering relation between the mass excess of the nucleus, which depends on the number of protons Z and neutrons N, and the parameters characterizing the electron system. There have been made initial steps to study the energy of the muon system of meso helium-like ions.

The phase composition of proton-exchanged optical waveguides in Lithium Tantalate is prolonged, but this year, it is proceed on the base of IR reflection spectra and mechanical stress measurements and analysis at different type of proton sources and technological regimes. New bands in the spectra, in the range of 850 - 1050 $см^{-1}$ have been observed. The results show that each phase has its own reflection spectrum, whose components have different contribution to the entire spectrum. On the basis of phase composition, the magnitude and type of the stress that arises in the protonated layer, are discussed. The recognition of the top sublayer's (being exposed to the strongest proton exchange) phase gives the opportunity for specifying the phases that build the rest of the entire proton exchanged layer.

We consider the interaction of a two-state quantum system with a class of pulses of finite temporal duration. The pulse shape function $f(t)$ of such a pulse is a nonanalytic function of time, with discontinuous derivatives at the turn-on and turn-off times. The

excitation line width - the excited-state population versus the detuning - is determined primarily by the magnitude of the jumps of the derivative $f^{(n)}(t)$ at the points of nonanalyticity, where n is the order of the first discontinuous derivative; this nonanalyticity shows up in the nth superadiabatic basis. The excitation line width for such pulses exhibits weak power broadening - it scales up as $\Omega_0^{1/(n+1)}$ where Ω_0 is the peak Rabi frequency of the transition: $\Omega(t) = \Omega_0 f(t)$. As a specific example, we consider the power-of-sine $f(t) = \sin^n(\pi t/T)$ $(0 \le t \le T)$ and a truncated Gaussian pulse, and we compare their excitation line widths with the well-known excitation profile of the rectangular pulse (the Rabi formula). We find that, because of the reduced power broadening, the $\sin^n$ and truncated Gaussian pulses may accelerate manipulation of qubits compared to rectangular pulses. The reason is that the lower power broadening allows one to use higher Rabi frequency, and hence shorter pulse duration, without affecting significantly other closely lying states.

PUBLICATIONS:

1. N. Chamel, R. L. Pavlov, L. M. Mihailov, Ch. J. Velchev, Zh. K. Stoyanov, Y. D. Mutafchieva, M. D. Ivanovich, A. F. Fantina, J. M. Pearson and S. Goriely. Unified description of dense matter in neutron stars and magnetars. *Proc. of the International Astronomical Union*, Volume 8, Issue S291 *"Neutron Stars and Pulsars: Challenges and Opportunities after 80 years"*, Ed. Joeri van Leeuwen, August 20-31, 2012 Beijing, China Nanjing, Cambridge University Press, 359-361 (2013). ISSN: 1743-9213.
2. O. Ivanov, A. Vaseashta, A method for fast and contactless control of raw materials, *Ceramics International*, 39, 2903-2907 (2013). ISSN: 0272-8842.
3. I. Boradjiev, N. V. Vitanov, Control of qubits by shaped pulses of finite duration, *Phys. Rev. A*, 88, 013402 (2013). ISSN 1050-2947.
4. O. Ivanov, Y. Mutafchieva and A. Vaseashta, Applications of an Effect Based on Electromagnetic Field-Matter Interactions for Investigations of Water. *Advanced Sensors for Safety and Security*, *NATO Science for Peace and Security Series B: Physics and Biophysics*, Eds. A. Vaseashta and S. Khudaverdyan, Springer Netherlands, 225-230 (2013). ISBN 978-94-007-7002-7.
5. M. Kuneva, K. Christova, S. Tonchev. Phase composition and stress in LiTaO3 proton-exchanged optical waveguides. *EPL*, 103, 67008 (2013). ISSN 0295-5075.
6. N. Chamel, R. L. Pavlov, L. M. Mihailov, Ch. J. Velchev, Zh. K. Stoyanov, Y. D. Mutafchieva, M. D. Ivanovich, A. F. Fantina, J. M. Pearson and S. Goriely. Equation of State of Magnetar Crusts from Hartree-Fock-Bogoliubov Atomic Mass Models. *Electromagnetic Radiation from Pulsars and Magnetars*, ASP Conference Series, 466, Eds. W. Lewandowski, J. Kijak, A. Slowikowska and O. Maron, 249-250 (2013). ISBN: 978-1-58381-814-5.

ONGOING RESEARCH PROJECTS:

1. “Electronic properties of solid state systems” - BAS
2. “Device for large scale fog decontamination” (COUNTERFOG) - 7th Framework Program, Thematic area Security, Collaborative project

TEACHING ACTIVITIES AT THE LABORATORY:

The Laboratory taken part in the project “Student Practices”, financed by the Operational Programme “Human Resources Development”, co-financed by the European Social Fund. Contracts have been signed with the Sofia University “St. Kl. Ohridski” and “University of National and World Economy”. Two students are selected to participate in the practice.

DIVISION MATERIAL PHYSICS

LABORATORY

CRYSTAL GROWTH AND STRUCTURAL METHODS

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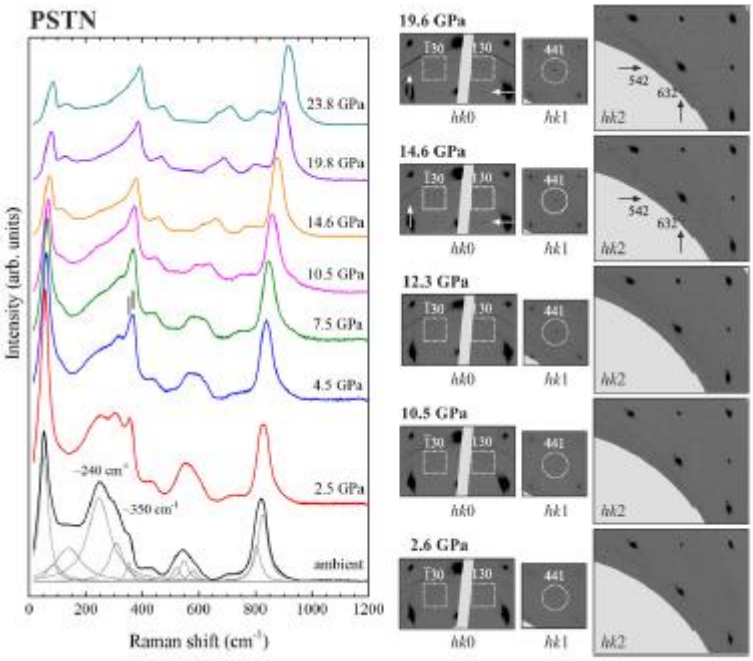
RESEARSCH SCIENTISTS: **7**

Prof. M.M. Gospodinov, DSc; Assoc. Prof. Z. I. Dimitrova, PhD; Assist. Prof. P. Terziyska, PhD; Assist. Prof. E. Vlaikova; Assist. Prof. L. K. Yankova; Assist. Prof. V.T. Tomov; S. Ts. Valkov, MS; S.T. Petrov, Bachelor; O.B. Mihailov, Technician

RESEARCH ACTIVITIES:

Crystals of perovskite-type relaxor-ferroelectric (ABO3) systems PbScTaO3 (PST) and PbScNbO3 (PSN) were investigated with a variety of experimental methods. We studied the effects of substitution of the A-ion with lanthanum, strontium and barium, by examination of the accoustic emission at applied external electric field. The temperature dependence of pressure-induced structural transitions in PST and PSN was clarified. Here an important role is played by the interaction between the polar and the antiferrodistorsive order near a transition temperatures in these compounds.



A series of pressure-induced phase transitions in PbSc0.5Ta0.5O3 and PbSc0.5Nb0.5O3 has been investigated *in situ* with synchrotron x-ray diffraction and Raman radiation at high A- and B-doping with equivalent and heterovalent cations at pressures up to 25 GPa. Critical pressures of the transitions and the dynamic compressibility of various phases were determined.

Phonon and two-magnon excitations in copper metaborate (CuB2O4) were investigated by polarized Raman spectroscopy. Most of the Raman-active zone-center phonons in CuB2O4 were identified, and the peak at 82 cm^{-1} is assigned to two-magnon scattring in the Cu (A) sublattice. From the Raman spectra an interaction process with energy of 33 cm^{-1} between neighboring atoms in the Cu (A) sublattice is established, which is also confirmed by other experiments.

The second-order phonon spectra of CuO single crystals were investigated by polarized Raman spectroscopy and theoretically from first principles. It was found that only the (zz) spectra have intense scattering bands. This effect is explained with involvement of resonant electronic transitions in this polarization geometry and with the fact that the excitation light is polarized along the copper-oxygen chains, which are a characteristic structural element of a broad class of high-temperature superconductors.

Crystals of La2CoMnO6 doped Pb were obtained by the high-temperature solution growth method and their magnetic properties as well as their electrical conductivity were determined. The examined crystals were found to have a predominantly ordered Co^{2+}/Mn^{4+} structure with statistically randomly distributed Mn^{3+} substituting ions Co^{2+} ions. A relaxor-type temperature dependence of the dielectric constant with a maximum at 180 - 210K was established. DC conductivity measurements indicate that the charge transfer in the range 180 - 350K is determined by small polaron hopping.

It has been established that in nanocomposites of the hydrogen-bonded liquid crystal 7OBA and carbon nanotubes new phases are induced with exotic properties not characteristic for pure 7OVA. The new phases were examined and confirmed by differential scanning calorimetry and Raman spectroscopy. In addition to differences in the spectra of the various phases, the latter can detect directly the presence of carbon nanotubes in the nanocomposite, as well as their interaction with the molecules of the liquid crystal.

We also studied the possibilities to obtain analytical solutions by the modified method of the simplest equation of a class non-linear differential equations – the extended equation of Korteweg-de Vries, the generalized equation of Camassa - Holm and statistical distributions associated with random fluctuations in systems of interacting populations.

PUBLICATIONS:

- Pekala, M.; Wolff-Fabris, F.; Fagnard, J-F.; et al., Magnetic properties and anisotropy of orthorhombic DyMnO3 single crystal, Journal of Magnetism and Magnetic Materials 335, 46-52 (2013). DOI: 10.1016/j.jmmm.2013.01.036
- Marquardt, H.; Waeselmann, N.; Wehber, M.; et al., High-pressure Brillouin scattering of the single-crystal PbSc1/2Ta1/2O3 relaxor ferroelectric, Physical Review B 87 (18), 184113 (2013). DOI: 10.1103/PhysRevB.87.184113
- Waeselmann, N.; Mihailova, B.; Gospodinov, M.; et al., In situ high-temperature high-pressure Raman spectroscopy on single-crystal relaxor ferroelectrics PbSc1/2Ta1/2O3 and PbSc1/2Nb1/2O3, Journal of Physics – Condensed Matter 25 (18), 155902 (2013). DOI: 10.1088/0953-8984/25/15/155902
- Mihailova, B.; Waeselmann, N.; Maier, B. J.; et al., Chemically induced renormalization phenomena in Pb-based relaxor ferroelectrics under high pressure, Journal of Physics – Condensed Matter 25 (11), 115403 (2013). DOI: 10.1088/0953-8984/25/11/115403
- Litvinchuk, A. P.; Moeller, A.; Debbichi, L.; et al., Second-order Raman scattering in CuO, Journal of Physics – Condensed Matter 25 (10), 105402 (2013). DOI: 10.1088/0953-8984/25/10/105402
- Dul'kin, E.; Mihailova, B.; Gospodinov, M.; et al., Effect of A-site La, Ba, and Sr doping on the threshold field and characteristic temperatures of PbSc0.5Nb0.5O3 relaxor studied by

acoustic emission, Journal of Applied Physics 113 (5), 054105 (2013). DOI: 10.1063/1.4790601
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- Е. М. Кожбахтеев, В. М. Скориков, Т. И. Миленов, П. М. Рафаилов, Г. В. Авдеев, Синтез и некоторье вопроси механизма образования углеродньих структур в гидротермальньих условиях, Russ. J. Inorg. Chem. 58 (2013) - in press, DOI: 10.7868/S0044457X13120155
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- Vitanov, Nikolay K.; Dimitrova, Zlatinka I.; Kantz, Holger, Application of the method of simplest equation for obtaining exact traveling-wave solutions for the extended Korteweg-de Vries equation and generalized Camassa-Holm equation, Applied Mathematics and Computation 219 (14), 7480-7492 (2013). DOI: 10.1016/j.amc.2013.01.035
- Dimitrova, Zlatinka I., Discussion on exp-function method and modified method of simplest equation, Comptes Rendus de l Academie Bulgare des Sciences 66 (7), 975-982 (2013).
- Z. I. Dimitrova and N. K. Vitanov, Integrability of differential equations with fluid mechanics applications: from Painleve property to the method of simplest equation, Journal of Theoretical and Applied Mechanics, 43(2), 31-42 (2013).

ONGOING RESEARCH PROJECTS:

Financed by the Bulgarian National Scientific Research Foundation at the Bulgarian Ministry of Education and Science:
DRNF 02/1: “Structural characterization of novel crystalline materials” – April 2013.

COLLABORATION:

Synthesis and study of multifunctional materials based on the complex oxides of bismuth and allotropic forms of carbon- Institute of Common and Inorganic Chemistry, Russian Academy of Sciences, Moscow, Russia

DIVISION MATERIAL PHYSICS

LABORATORY

BIOCOMPATIBLE MATERIALS

HEAD: **Assoc.Prof. Liliana Pramatarova, Ph.D.**
tel.: 979 5699; e-mail: lpramat@issp.bas.bg

TOTAL STAFF: **5**
RESEARCH SCIENTISTS: **4**

Assoc. Prof. E. Pecheva, Ph.D.
Assistant Todor Hikov, MSc; Chemist Ivaylo Tsvetanov, BSc
Physicist Dimitrinka Fingarova, PhD student

1. RESEARCH AREA OF THE LABORATORY

The research area of the laboratory is related to the development of innovative methods for the preparation and investigation of new nanodimentional materials with potential biomaterial applications. The tasks on which the laboratory works are part of important priority areas of the European framework programmes, as well as of the Bulgarian Academy of Sciences for 2009-2013, namely dealing with socially important human diseases. These scientific directions include *Improving the human potential and quality of life*, and *Improvement of strategies, oriented to increase the human life duration*. Other thematical priorities concern the *Preparation of materials by using innovative technologies, Modelling and design of multifunctional materials, Intelligent biomaterials for repair or correction of human bone tissue*. In this connection, the research aims of the laboratory lie within the priorities of the National Science Fund, as well as in the area of Nanotechnology.

2. MAIN SCIENTIFIC RESULTS IN 2013

- Composite layers of the type polymer/nanodiamond (PPHMDS/DND) were prepared on various substrates and they were investigated with AFM, SEM/EDX, FTIR and Raman spectroscopy based on our collaboration in the framework of the bilateral projects of the laboratory with the University of Ljubljana, Slovenia and National Institute for Laser, Plasma and Radiation Physics, Romania.
- The biological activity of the nanodiamonds and composite layers was tested with osteoblast cells and stem cells in collaboration with Institute of Biophysics and Biomedical Engineering.

3. NATIONAL AND INTERNATIONAL PROJECTS IN 2013

- "Role of substratum elasticity in osteoblast differentiation of mesenchymal stem cells", national project with the Bulgarian Science Fund (grant DFNI-B01-18/28.11.2012), leader for the ISSP Assoc. Prof. Dr. Lilyana Pramatarova, with the cooperation also of

the Institute of Biophysics and Biomedical Engineering-BAS and the University of Chemical technology and metallurgy, 2012-2014.

- "Investigation of hydroxyapatite - nanodiamond composite coating", international project with the Latvian Academy of Sciences, within the frame of the bilateral agreements of the BAS, leader Assoc. Prof. Dr. Emilia Pecheva.
- "Nanocomposites: Nanodiamond particles embedded in polymer layers, prepared by laser-liquid-solid-interaction (LLSI) method", international project with National Institute for Lasers, Plasma and Radiation Physics (INFLPR), Laser Department, Romania, the frame of the bilateral agreements of the BAS, leader Assoc. Prof. Dr. Lilyana Pramatarova
- "Novel Nanobiocomposites: model systems for bone tissue engineering", International project with University of Ljubljana, Slovenia, the frame of the bilateral agreements of the BAS, leader Assoc. Prof. Dr. Lilyana Pramatarova

4. PROJECTS IN 2014

- "Role of substratum elasticity in osteoblast differentiation of mesenchymal stem cells", national project with the Bulgarian Science Fund (grant DFNI-B01-18/28.11.2012), leader for the ISSP Assoc. Prof. Dr. Lilyana Pramatarova, with the cooperation also of the Institute of Biophysics and Biomedical Engineering-BAS and the University of Chemical technology and metallurgy, 2012-2014.
- "Investigation of hydroxyapatite - nanodiamond composite coating", international project with the Latvian Academy of Sciences, the frame of the bilateral agreements of the BAS, leader Assoc. Prof. Dr. Emilia Pecheva, 2012-2014
- "Nanocomposites: Nanodiamond particles embedded in polymer layers, prepared by laser-liquid-solid-interaction (LLSI) method", international project with National Institute for Lasers, Plasma and Radiation Physics (INFLPR), Laser Department, Romania, the frame of the bilateral agreements of the BAS, leader Assoc. Prof. Dr. Lilyana Pramatarova
- "Novel Nanobiocomposites: model systems for bone tissue engineering", International project with University of Ljubljana, the frame of the bilateral agreements of the BAS, leader Assoc. Prof. Dr. Lilyana Pramatarova

5. TEACHING ACTIVITIES AT THE LABORATORY

Correspondence PhD study– 1 student, free PhD study – 1 student, MSc diploma -1 student

6. PUBLICATIONS, PARTICIPATIONS AT INTERNATIONAL CONFERENCES AND CITATIONS IN 2013

- T. Hikov, L. Pramatarova, N. Krasteva, E. Radeva, P. Petrik, E. Agocs, E. Pecheva, R. Presker, O. Sabotinov, Study of nanocomposite layers based on polymer and nanodiamond particles: new materials for medical implants, Bulg. J. Phys. **39** (2013), 297-308
- Lilyana D. Pramatarova, Todor A. Hikov, Natalia A. Krasteva, Peter Petrik, Raina P. Dimitrova, Emilia V. Pecheva, Ekaterina I. Radeva, Elot Agocs, Ivaylo G. Tsvetanov and Radina P. Presker. Protein Adsorption on Detonation Nanodiamond/Polymer Composite Layers, MRS Proceedings, 1479, pp 51-56 (2013)

- Ivaylo Tsvetanov, Todor Hikov, Ekaterina Radeva, Natalya Krasteva, Radina Presker, Dimitar Mitev and Lilyana Pramatarova, Protein adsorption on composite layers of the type Ag-nanoparticles/polymer, 41 national conference on Physics education matters – 25-29 September 2013, Sofia, Bulgaria ((в печат)
- Todor Hikov, Ivaylo Tsvetanov, Ekaterina Radeva, Natalya Krasteva, Radina Presker, Dimitar Mitev and Lilyana Pramatarova. Protein adsorption on composite layers of the type DND/polymer, 41 national conference on Physics education matters – 25-29 September 2013, Sofia, Bulgaria (в печат)
- M. Keremidarska, A. Ganeva, D. Mitev, T. Hikov, R. Presker, L. Pramatarova, N. Krasteva. Cytotoxicity study of different detonation nanodiamond particles, International conference "Bioscience – development and new opportunities", 20-22 November, 2013, Sofia, Bulgaria, (в печат)

23 citations for 2013 of the papers published by the laboratory

DIVISION NANOPHYSICS

LABORATORY

PHOTOELECTRICAL AND OPTICAL PHENOMENA IN WIDE BAND GAP SEMICONDUCTORS

HEAD: **Prof. Diana Nesheva, D.Sc.**
tel: 979 5686; e-mail: nesheva@issp.bas.bg

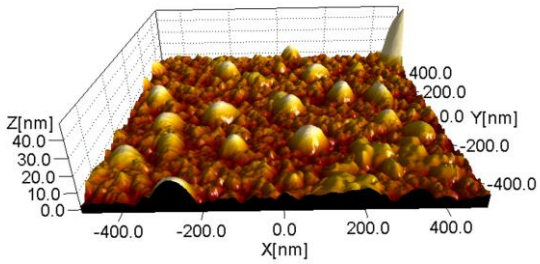
TOTAL STAFF: **10**
RESEARCH SCIENTISTS: **8**
HONORARY MEMBERS: **2**
ASSOC. MEMBERS: **1**

Assoc. Prof. D. Arsova, Ph.D.; Assoc. Prof. Z. Ivanova, Ph.D.; Assoc. Prof. V. Pamukchieva, Ph.D.; Assoc. Prof. Z. Aneva, Ph.D.; Assoc.Prof. Z. Levi, Ph.D.; Assoc.Prof. I. Bineva, Ph.D.; Assist. Prof. T. Vassileva, Ph.D.; E. Zaharincheva, technologist; V. Dzhurkov, Ph.D. student
Prof. E. Vateva, D.Sc., honorary member; Assoc. Prof. K. Kolentsov, honorary member; Assoc. Prof. S. Balabanov, Ph.D., Assoc. member

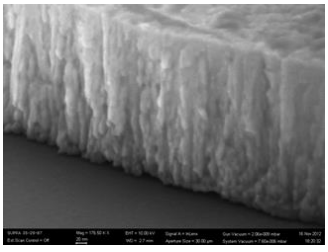
RESEARCH ACTIVITIES:

1. NANOSTRUCTURED THIN FILMS

Electrical and photoelectrical measurements are carried out on nanocrystalline $Zn_xCd_{1-x}Se$ thin films of various compositions in the temperature range (-196) – (+150) ºC. The films are annealed at 200 °C and 400 °C. A gradual increase of both dark conductivity and photoconductivity with decreasing Zn content is observed for the films annealed at 200 °C. However a deep minimum at x = 0.6 is observed in both compositional dependences of the films annealed at 400 °C. The obtained results are discussed considering the effect of the sublayer nominal thickness and the intergrain barriers on the electron transport in the films. It has been inferred that the annealing increases the density of Se vacancies and reduces the compositional disorder and the interface defect density.



Three-dimensional atomic force microscopy image of as-deposited $Zn_xCd_{1-x}Se$ thin film with x = 0.8.



Cross-section scanning electron microscopy image of $Zn_xCd_{1-x}Se$ thin film with x = 0.8. Column structure is observed.

Metal-Oxide-Silicon (MOS) structures (c-Si/thermal SiO_2/SiO_x/Al, x = 1.15 и 1.3) with ~100 nm thick SiO_x are prepared. A new two-step annealing procedure is applied to form three-region gate dielectrics containing Si nanocrystals (first in pure N_2 and then in

90% N_2 + 10% O_2 atmospheres). The first annealing step results in Si nanoparticle growth; the second annealing step is used to oxidize the already grown nanoparticles close to the top surface and to complete the growth process of the nanocrystals deep in the SiO_x bulk. IR measurements indicate phase separation and formation of Si nanocrystals in a SiO_2 matrix. High resolution TEM imaging results proved the formation of two regions: the first one, far from the top surface, exhibits Si nanocrystals (with diameter of ~ 3-4 nm), and a complete oxidation of the excess Si in the top region. Such structures, provided with semitransparent gold gate electrodes are studied for application as ultraviolet dosimeters. The structures can be charged negatively or positively by injecting or extracting electrons from the top electrode. Illumination with 395-400 nm UV light source causes discharge of previously charged structures. The discharge rate depends on the light intensity, sign of the trapped charge, as well on the preliminary created internal electric field in the gate dielectric.

2. CHALCOGENIDE GLASSES AND THIN FILMS

Thin films with various thicknesses (150 - 800 nm) from two Ge-Sb-Te compositions are investigated which are suitable for nonvolatile memory elements. The optical band gap energy and of refractive index are determined. It is established that the annealing at 90 °C and 120 °C in air changes slightly the optical parameters. The results from electrical measurements on these films carried out using planar geometry of electrodes show that the films are low-resistive and their electrical conductivity does not depend appreciably on the film compositionshe IR spectra obtained of some Ge-Sb-Te films demonstrate a high absorption coefficient *k* in far-IR, compatible with the *k* values in the visible-UV region which should be taken into account when discussing the results from optical and electrical measurements. In collaboration with colleagues from Ioffe FTI, St. Peterburg, Russia the switching effect in these films is investigated using a modified wlwctrical circuit with current generator. The application of the current generator yields results which better reflect the process of memory formation.

New chalcogenide alloys from the As_2Se_3-PbTe-Ag_4SSe and $GeSe_2$-GeTe-SnTe systems are synthesized, and the regions of glassformation within them are outlined. No glassy phases were obtained in the binary PbTe-Ag_4SSe and GeTe-SnTe systems. It is established, using AFM, visual and XRD analyses, that the region of glassformation within the As_2Se_3-PbTe-Ag_4SSe system lies partially on the As_2Se_3–Ag_4SSe (0 - 25 mol% Ag_4SSe) and As_2Se_3–PbTe (50 - 100 mol%As_2Se_3) sides, and this of the $GeSe_2$-GeTe-SnTe system – on the $GeSe_2$-GeTe (0 - 58 mol % GeTe) and $GeSe_2$-SnTe (25 - 45 mol % SnTe) sides. The main physicochemical properties of chosen glassy phases from the As_2Se_3-PbTe-Ag_4SSe system are investigated and the variation limits of the glass-transition, crystallization (strongly influenced by the PbTe content in the glasses), and melting temperatures, as well as the Vickers' microhardness are determined. The density determined by hydrostatic method, increases with the increase of both Ag_4SSe and PbTe content, and changes between 4.47 and 5.93 g/cm^3.

For the first time the glass formation in the Sb_2O_3-PbO-ZnO и Sb_2O_3-PbO-ZnS systems, as well as some important from a practical point of view physicochemical parameters (temperatures of glass transition and crystallization, coefficient of thermal expansion, density, microhardness, module of elasticity) are studied. All intra 4f-4f shell transitions of Er^{3+} ions in the range 600-1600 nm with decreasing temperature from 300 K down to 4 K are observed.

The optimal host composition of $(GeS_2)_{75}(Ga_2S_3)_{25}$ is determined from the low temperature photoluminescence (LTPL) of Ga_2S_3-GeS_2 glasses, doped with high Er_2S_3 concentrations (1.8-2.4 mol%), where all intra 4f-4f emission transitions are simultaneously observed. The relationship between emission and absorption spectra as function of Er-doping

is established. The influence of Er doping at 2.1 and 2.4 mol % Er_2S_3 and thermal annealing at 100 °C и 200 °C on the refractive index and optical energy gap is evaluated. PL investigations are expanded by addition of As into the Ge-S-Ga host when doping with Pr, Dy, Nd, Sm and Ho. LTPL of $Ge_{25}Ga_{1.7}As_{8.3}S_{65}$ is exhibited by a broad PL band, centred at ~1000 nm, whose intensity decreases at higher Er-doping. This PL quenching effect is explained by non-radiative energy transfer from defect states in the matrix towards Er^{3+} ions.

PUBLICATIONS:

1. B. Pejova, I. Bineva, "Sonochemically synthesized 3d assemblies of close-packed In_2S_3 quantum dots: structure, size dependent optical and electrical properties", Journal of Physical Chemistry C, **117** (2013) 7303–7314.
2. A. Amova, T. Hristova-Vasileva, L. Aljihmani, I. Bineva, V. Vassilev, "Region of glass formation and main physicochemical properties of glasses from the As_2Se_3-Ag_4SSe-PbTe system", Journal of Alloys and Compounds, **573** (2013) 32-36.
3. J. Zavadil, M. Kubliha, P. Kostka, M. Iovu, V. Labas, Z.G. Ivanova, "Investigation of electrical and optical properties of Ge-Ga-As-S glasses doped with rare-earth ions", Journal of Non-Crystalline Solids, **377** (2013) 85-89.
4. M. Nouadji, Z.G. Ivanova, M. Poulain, J. Zavadil, A. Attaf, "Glass formation, physicochemical characterization and photoluminescence properties of new Sb_2O_3-PbO-ZnO and Sb_2O_3-PbO-ZnS systems", Journal of Alloys and Compounds, **549** (2013) 158-162.
5. N. Koteeswara Reddy, M. Devika, M. Prashantha, K. Ramesh, Z.G. Ivanova, J. Zavadil "Tailoring the optical properties of amorphous heavily Er^{3+}-doped Ge-Ga-S thin films", J. Optoelectron. Adv. Mater., **15** (2013) 182-186.
6. D. Mateos, M. Curiel, N. Nedev, D. Nesheva, R. Machorro, E. Manolov, N. Abundiz, A. Arias, O. Contreras, B. Valdez, O. Raymond and J.M. Siqueiros, "TEM and Spectroscopic Ellipsometry Studies of Multilayer Gate Dielectrics Containing Crystalline or Amorphous Si Nanoclusters", Physica E: Low-dimensional Systems and Nanostructures, **51** (2013) 111-114.
7. L. Aljihmani, T. Hristova-Vasileva, K. Petkov, D. Nesheva, V. Vassilev, "Thermomechanical characteristics of chalcogenide glasses from the $GeSe_2$-GeTe-PbTe system", Materials Science: An Indian Journal (MSAIJ) **9** (2013) 234-238.
8. D. Mateos, N. Nedev, D. Nesheva, M. Curiel, E. Manolov, A. Arias, O. Contreras, B. Valdez, Z. Levi and J. Siqueiros, "Electrical Characterization of MOS Structures with Silicon Nanocrystals Suitable for X-ray Detection", Key Engineering Materials, **543** (2013) 150-153.
9. D. Nesheva, Z. Levi, Y. S. Raptis, C. Raptis, K. Petkov and V. Vassilev, "Electrical conductivity, photoconductivity and gas sensitivity of Ge-Se-Te thin films", J. Phys.:Conf.Series, **398** (2012) 012058.
10. M Fábián, E Sváb, V Pamukchieva, A Szekeres , K Todorova, S Vogel,"Reverse Monte Carlo modeling of the neutron and X-ray diffraction data for new chalcogenide Ge-Sb-S(Se)-Te glasses", J. Physics and Chemistry of Solids, **74** (2013) 1355-1362.
11. D. Mateos, A. Arias, N. Nedev, M. Curiel, V. Dzhurkov, E. Manolov, D. Nesheva, O. Contreras, B. Valdez, I. Bineva, O. Raymond, J.M. Siqueiros, "Metal-oxide-semiconductor structures with two and three-region gate dielectric containing silicon nanocrystals: Structural, infrared and electrical properties", Technical Proceedings of the 2013 NSTI Nanotechnology Conference and Expo, 1, pp. 396-399.
12. I. Bineva, A. Dinescu, D. Nesheva, M. Danila, Z. Aneva, Z. Levi, R. Muller, "Effects of the preparation conditions and furnace annealing on the structure and morphology of

$Zn_{0.8}Cd_{0.2}Se$ thin films" in CAS 2013 International Semiconductor Conference, Sinaia, Romania, October 14-17, 2013, CAS 2013 proceedings, Vol.1, pp. 129-132.

13. B. Katranchev, M. Petrov, I. Bineva, Z. Aneva, and D. Nesheva, "Orientation of dimeric liquid crystals through $Zn_xCd_{1-x}Se$ nanostructured surfaces", Nanoscience and Nanotechnology, **13** (2013) 98-100, Eds. E. Balabanova and I. Dragieva, Heron press.
14. L. Aljihmani, T. Hristova-Vasileva, S. Boycheva, E. Fidancevska, V. Vassilev, „Physicochemical properties of chalcogenide glasses from the $GeSe_2$-Sb_2Se_3-$PbSb_2Te_4$ system, International Scientific Conference "UNITECH 2013", Gabrovo, Bulgaria, 22-23.11.2013, Proceedings, Vol. 1 (2013) 346-349.
15. В.А. Рыжов, Д. Арсова, "Длинноволновые ИК спектры аморфных халькогенидных стекол системы Ge-Sb-Te", Труды международного междисциплинарного симпозиума „Физика поверхностных явлений межфазных границ и фазовые переходы", 2013, Русия, 184-188.
16. С.А. Фефелов, Л.П. Казакова, С.А. Козюхин, К.Д. Цендин, Д. Арсова, „Выбор измерительной цепи для исследования ефектов переключения и памяти в полупроводниковых системы Ge-Sb-Te", Труды международного междисциплинарного симпозиума „Физика поверхностных явлений межфазных границ и фазовые переходы", 2013, Русия, 222-225.
17. Л. Алжихмани, Т. Христова-Василева, Т. Ненов, В. Василев, „Физични свойства на оксихалкогенидни стъкла от системата $GeSe_2$-CdI_2-CdO", Международна научна конференция "UNITECH 2013", Габрово, България, 22-23.11.2013, Сборник с доклади, Том I (2013) 66-70.

ONGOING RESEARCH PROJECTS:

Financed by the Bulgarian Academy of Sciences:

1. Preparation, characterization and applications of new chalcogenide materials and thin films containing nanosized semiconductors.

Financed by the Bulgarian Ministry of Education and Science:

1. Characterization of new chalcogenide materials by atomic force microscopy, Contract DMU 03-91/12.2011.

COLLABORATION:

1. Investigation of the interaction of high energy electrons with SiO_x and nc(a)-Si-SiO_x thin films , Center for Solid State Physics and New Materials, Belgrade, Serbia.
2. Investigations of optical and structural properties of special glasses for photonic applications, Institute of Photonics and Electronics, Prague, Czech Republic.
3. Multicomponent chalcogenide semiconductors thin films suitable for phase change memory, Joffe Physico-Technical Institute, St. Petersburg, Russia.
4. Nanostructured and amorphous semiconductor films for sensors application, National Institute for Research and Development in Microtechnology – IMT Bucharest, Romania.

DIVISION NANOPHYSICS

LABORATORY

SEMICONDUCTOR HETEROSTRUCTURES

HEAD: **Assoc. Prof. Anna Szekeres, Ph.D.**
tel: 979 5788; e-mail: szekeres@issp.bas.bg

TOTAL STAFF: **6**
RESEARCH SCIENTISTS: **3**
ASSOC. MEMBERS: ***3***
Assoc. Prof. A. Szekeres, Ph.D.; Assoc.Prof. N. Peev, Ph.D.; Assist.Prof. S. Bakalova, Ph.D.;
Assoc. Prof. S. Simeonov, Ph.D.; Prof. S. Kaschieva, D.Sc.; Prof. S. Alexandrova, D.Sc.

RESEARCH ACTIVITIES:

During 2013 the main scientific research of the Laboratory continued studying the structure, optical, mechanical and electrical properties of Si-based semiconductor heterostructures with nano-sized dielectric layers and with nanostructured semiconductor films obtained by applying advanced technologies of plasma immersion implantation and laser ablation aiming their possible applications in nanoelectronics and optoelectronics. Work on interaction of high energetic electrons with Si-based structures and on the processes at phase boundaries was also continued.

1. NANOCRYSTALLINE AlN LAYERS SYNTHESIZED BY PULSED LASER ABLATION

The structure and properties of pulsed-laser deposited (PLD) AlN layers on silicon have been studied (Fig. 1). The layers were deposited at 400° C or 800° C in vacuum or in nitrogen at different pressures of 0.1 Pa to 10 Pa. By ellipsometric data modelling in a wide spectral range from 350 cm^{-1} to $5x10^4$ cm^{-1} the optical constants of the PLD AlN layers are determined. The band gap energy of the AlN layers deposited in vacuum is ~6.2 eV being in good agreement with crystalline AlN with hexagonal phase, whereas this energy reduces in the layers deposited in nitrogen ambient. By FTIR spectroscopy the vibrational modes of Al-N bonds in the layers have been identified. The hardness and elastic modulus of the nanocrystalline AlN layers

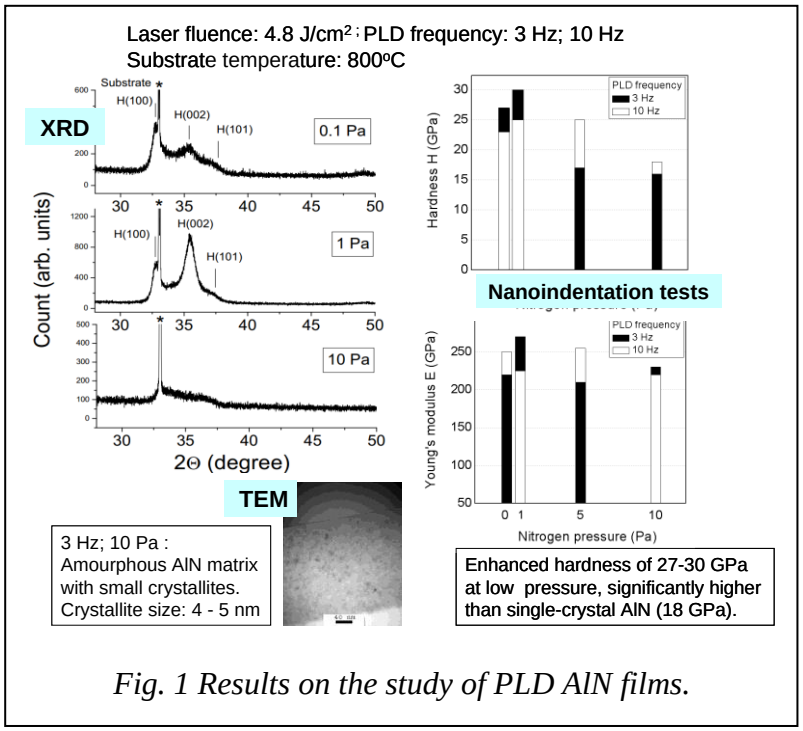


Fig. 1 Results on the study of PLD AlN films.

were estimated from Berkovich nanoindentation tests. The mechanical properties are well correlated with the observed films structure variations. Hardness values as high as 27-30 Pa were registered, as also very good resistance to plastic deformation and cracking of the AlN films was inferred, enhancing feasibility for hard protective coatings application.

2. NANOSIZED AND NANOSTRUCTURED SiO_2 AND SiO_xN_y LAYERS IN SILICON

During 2013 the study of thin layers of silicon oxide (Fig. 2) and oxynitride on silicon wafers, plasma immersion ion (PII) implanted with hydrogen through a dose of 10^13-10^{15} cm^{-2} and nitrogen at a dose of 10^{16} to 10^{18} cm^{-2}, respectively, was continued. The layers were grown by thermal annealing in dry oxygen at different temperatures ranging from 700°C to 1050°C.

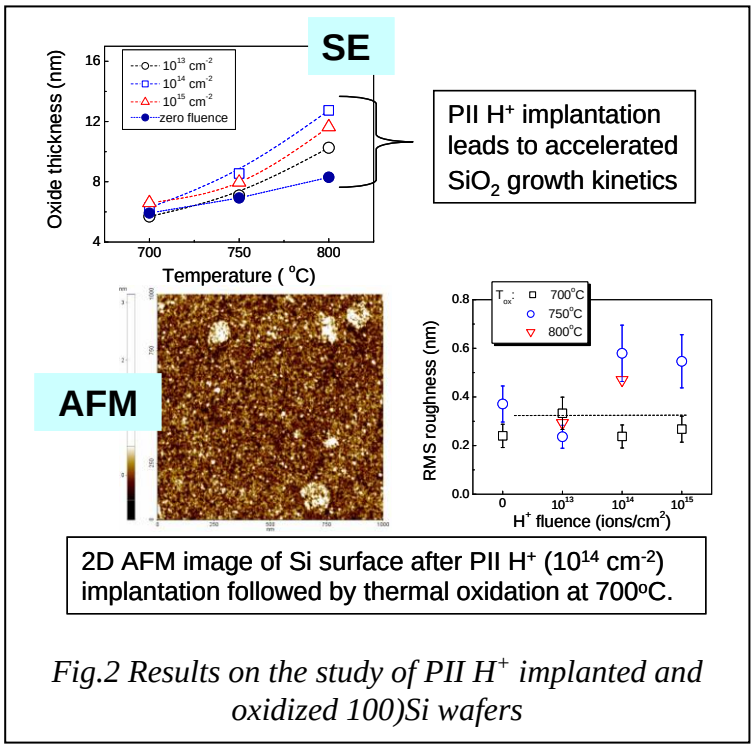


Fig.2 Results on the study of PII H^+ implanted and oxidized 100)Si wafers

Atomic force microscopy (AFM) has established a clear dependence of the surface amplitude parameters on the H^+ ion fluence (10^{13}-10^{15} cm^{-2}) and oxidation temperature (700°C, 750°C, 800°C) showing an increasing trend with increasing fluence and/or temperature. Thermal oxidation smoothes the implantation-induced roughness by reducing the number and size of pits on the surface but still the valley structure comprising the surface remains predominant. It is assumed that the observed surface morphology of H^+ implanted Si surface facilitates the diffusion of oxygen atoms into Si and, thus leads to an enhanced oxidation rate and lower level of structural stresses in the oxide, even at such low temperatures as 700°C.

FTIR and IRSE studies have established the formation of Si nanoparticles in thin SiO_xN_y layers synthesized by high temperature (1050°C) annealing of PII N^+ implanted silicon wafers. XPS spectra analysis confirms the presence of Si-Si bonds in the grown layer. It is assumed that free Si atoms form Si nanoparticles in the growing layer, which due to the high temperature may crystallize.

It has been established that under high-energy electrons irradiation accelerated diffusion of oxygen atoms through the SiO_2/Si structures occurs. Radiation defects generated in the oxide by MeV electrons facilitate the movement of oxygen atoms towards Si substrate leading to additional Si oxidation, As a consequence, the oxide thickness increases. Silicon atoms freed from Si-O bonds, broken by radiation, can be clustering resulting in appearance of Si nanoparticles in SiO_2 layers.

3. THEORETICAL STUDY OF THE PROCESSES AT PHASE BOUNDARIES

During 2013 the work continued on the theoretical study of processes in three-dimensional nanoparticles and nucleation of new phase. The probability of collision of atoms adsorbed on the crystal surface and the frequency of their collisions are established. The results are directly related to the processes associated with crystals and layers growth.

PUBLICATIONS:

1. A. Szekeres, S. Alexandrova, E. Halova, M. Gartner, M Anastasescu, M. Stoica, P. Osiceanu, A. Marin, Si nanoparticles formed in silicon oxynitride matrix by oxidation of plasma immersion n^+ implanted silicon surface layer, Nanoscience & Nanotechnology, eds. E. Balabanova, E. Mileva, Sofia, **13 (**2013) 41-44
2. A. Szekeres; L. Kolaklieva; G. Huhn; K. Havancsak; Zs. Fogarassy; G. Socol; C. Ristoscu; I N. Mihailescu, Pulsed laser synthesized aluminium nitride films with nanocrystalline structure: An enhanced mechanical hardness, Nanoscience & Nanotechnology Issue 13, 2013, 101-104.
3. A. Szekeres, S. Alexandrova, P. Petrik, B. Fodor, S. Bakalova, "Ellipsometric study of crystalline silicon hydrogenated by plasma immersion ion implantation", Appl. Surf. Sci. 281 (2013) 105–108.
4. M Fábián, E Sváb, V Pamukchieva, A Szekeres , K Todorova, S Vogel,"Reverse Monte Carlo modeling of the neutron and X-ray diffraction data for new chalcogenide Ge-Sb-S(Se)-Te glasses", J. Physics and Chemistry of Solids, 74 (2013) 1355-1362.
5. N. S. Peev, "Particle Collision Frequency and the Two-dimensional Particles Nucleation", "Comptes rendus de l'Académie Bulgare des Sciences" **66** (2013) 29-34.
6. N. S. Peev, "Processes in phase boundary region during liquid phase growth", Crystal Research and Technology 4**8** (2013) 116-126.
7. M. Anastasescu, M. Gartner, V. Pamukchieva, A. Szekeres, Surface topographic study of chalcogenide thin films of $Ge_xSb(As)_{40-x}S_{50}Te10$ glasses, Micron, in press
8. S Bakalova, A Szekeres, M Anastasescu, M Gartner, L Duta, G Socol, C Ristoscu and I.N Mihailescu, VIS/IR spectroscopy of AlN thin films grown by pulsed laser deposition at 400°C and 800°C and various N_2 pressures, Journal of Physics: Conference Series, in press

ONGOING RESEARCH PROJECTS:

"Characterization of nanosized and nanostructured dielectric and semiconductor films and heterostructures containing these films" *Financed by the Bulgarian Academy of Sciences*

INTERNATIONAL COLLABORATION:

1. "Ion beam modification of semiconductor surface layer for micro- and optoelectronics application purposes", ***with the Institute of Physical Chemistry, RA, Bucharest, Romania***
2. "Pulsed laser deposition of nanostructured AlN: Adjustable morphology and properties" ***with the National Institute for Lasers, Plasma and Radiation Physics, Bucharest, Romania***
3. "Interaction of MeV electrons Si/SiO_2 structures", ***with the Joint Institute for Nuclear Research, Dubna, Russia***

DIVISION MICRO- AND ACOUSTOELECTRONICS

LABORATORY

PHYSICAL PROBLEMS OF MICROELECTRONICS

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TOTAL STAFF: **12**
RESEARCH SCIENTISTS: **9**

Assoc.Prof. A. Paskaleva, Ph.D.; Assoc.Prof. S. Georgiev, Ph.D., Assoc.Prof. J. Koprinarova, Ph.D.; Assoc.Prof. N. Nedev, Ph.D.; Assoc. Prof. D. Spasov, Ph.D.; Res.Assist. Ts.Ivanov; Res.Assist. E. Manolov; E.Gajdarzhieva, physicist; S. Tsvetanov, technologist; M. Stoicheva, technologist, Ch. Petkanov, technologist

RESEARCH ACTIVITIES:

The scope of the research activities of the Laboratory is addressed the nanoelectronics as follows:

- investigation of thin and ultra-thin dielectric, semiconductor and metal layers important for the production of large-scale integrated microelectronic structures (nanoscale) and development of solid state sensors based on the silicon and the thin-film microelectronics (incl. high-k dielectrics for dynamic memories; gas- sensitive layers for sensor devices; mono- and polycrystal silicon, anisotropic and hard ferromagnetic layers).
- development and optimization of the technology for deposition of the layers investigated.
- development of new microelectronic structures and devices (incl. memory and sensor structures).

The time-dependent dielectric breakdown at constant voltage stress at different temperatures of thin (7-8 nm) Al and Hf-doped Ta_2O_5 layers (equivalent SiO_2 oxide thickness < 1 nm) for application in modern nanoelectronics has been investigated. It has been established, that the doping improves the reliability characteristics and modifies the electric breakdown mechanisms through the compensation by the dopant of the deep charge traps attributed to the oxygen vacancies in Ta_2O_5. The type and amount of the dopant in the layer have been optimized to achieve high breakdown voltages, time-to-breakdown and charge-to-breakdown, guaranteeing a lifetime above 10 years. In contrast to pure Ta_2O_5, for which the dielectric breakdown is dominated by the trapping of charge carriers at pre-existing traps, the breakdown of the doped Ta_2O_5 is defined by the stress-induced trap generation and the perculation model describes the dielectric degradation. At least three competitive factors constitute the Weibull distribution of dielectric breakdown in high-*k* systems: initial defects, stress-induced new traps and the degradation of the interface layer itself. Depending on the stress conditions, the nature of the pre-existing traps and the properties of the interfacial layer, the domination of one of these factors is observed.

The effect of Ag gate on the characteristics of Ta_2O_5-based MIS capacitors has been evaluated by comprehensive electrical investigations. It was found that that utilization of Ag as a gate electrode material ensures substantially lower leakage currents and higher breakdown voltages than traditionally used gate metals.

It is demonstrated that atomic layer deposition (ALD) is suitable deposition technique for preparation of dielectric films for resistive switching (RS) memories. TiO_2- and HfO_2-based MIM structures with TiN bottom and Pt top electrodes exhibit stable RS effect with high/low resistive state (HRS/LRS) ratio up to 100. HfO_2 films exhibit lower leakage current density and the thickness of the dielectric layer can be decreased to several nm. The RS effect in MIM structures with HfO_2 films can be scaled-down to thicknesses below 3 nm. Systematic study on the effect of Al_2O_3 barrier layer thickness on the resistive switching properties of $Pt/Al_2O_3/TiO_2/TiN$ structures has been performed. It was found that Al_2O_3 layer of certain thickness is essential to stabilize and enhance the resistive switching parameters. Endurance of 10^4 cycles was obtained for structures with 3 and 4 nm of Al_2O_3. Investigations at elevated temperatures allowed making a conclusion that the switching is filamentary and the mechanism responsible for RS is a drift of oxygen vacancies from TiO_2 to Al_2O_3 layer during the set process.

Mechanisms of useful trapping and charge storage in MHOS (metal/high-k dielectric/SiO_2/Si) structures have been investigated. The studies have been performed on different HfO_2-based high-k dielectrics deposited by PE-ALD (plasma enhanced atomic layer deposition). In part of the samples HfO_2 is doped with various amounts of Al_2O_3. The influence of high-k layer thickness, level of Al_2O_3 doping, annealing ambient and plasma oxidation time on electrical and dielectric properties as well as their charge storage ability has been investigated. The results show that by proper annealing steps and doping the process of charge trapping in HfO_2 could be substantially modified – it could be decreased as well as increased. HfO_2 layers doped with larger amount of Al_2O_3 reveal stronger trapping and larger memory window and from this point of view they are very suitable for future generations of non-volatile memories, (NVM).

Multilayer gate dielectrics containing crystalline and amorphous Si nanoclusters were characterized by Transmission Electron Microscopy (TEM) and Spectroscopic Ellipsometry (SE). Gate dielectrics were fabricated by thermal oxidation, followed by deposition of SiO_x films (x=1.15) using thermal evaporation of SiO in vacuum. In order to form two regions in the SiO_x film, silicon oxide with Si nanoclusters and silicon oxide on top, the samples were subjected to a two-step annealing process. Cross-sectional TEM proves the formation of two regions in the SiO_x film: a region free of nanoclusters close to the top surface and a second region with nanoclusters underneath the first one. The optical properties of the two-region films were studied by Spectroscopic Ellipsometry using Bruggeman Effective Medium Approximation. The dependencies of the refraction index (n) and extinction coefficient (k) on the wavelength of the films are in agreement with their structural properties. A correlation was found between the thicknesses of the regions determined by cross-sectional Transmission Electron Microscopy and Spectroscopic Ellipsometry.

The one-dimensional analytical model, describing the behavior of large scale photovoltaic cells under illumination, is further developed. The charge distribution across the depletion layer in the photovoltaic cell and respectively the distribution of the electric field have been determined. A self-consistent electric field, using as parameters the mobility and the lifetime of the charge carriers is found. This procedure allows simulation of the I-V characteristics and determination of parameters' influence on photovoltaic cells efficiency.

The possibility of investigation of thin dielectric layers by means of Surface Enhanced Raman Spectroscopy (SERS) through deposition of ultrathin silver layer with good adhesion to the dielectric surface have been studied.

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2. W. Weinreich, A. Paskaleva, A. Shariq, K. Seidel, J. Sundqvist, M. Lemberger, A. Bauer „Detailed leakage current analysis of MIM capacitors with ZrO_2, ZSZ and ZAZ as dielectric and TiN electrodes", J. Vac. Sci. Technol. B. 31(1) (2013) 01A109
3. I.Karmakov, A.Paskaleva "Interfacial layer of Hf-doped Ta_2O_5 stacks studied by Spectroscopic ellipsometry", Appl. Surf. Sci. 271 (2013) 12-18.
4. K. Fröhlich, P. Jančovič, B. Hudec, J. Dérer, A. Paskaleva, T. Bertaud, T. Schroeder, "Atomic layer deposition of thin oxide films for resistive switching", 224th Electrochemical Society Meeting, San Francisco (Oct. 27-Nov. 1, 2013) oral presentation, ECS Transactions 58(10) (2013) 163-170.
5. D. Mateos, M.A. Curiel, N. Nedev, D. Nesheva, R. Machorro, E. Manolov, N. Abundiz, A. Arias, O. Contreras, B. Valdez, O. Raymond and J.M. Sequeiros, "TEM and Spectroscopic Ellipsometry Studies of Multilayer Gate Dielectrics Containing Crystalline and Amorphous Si Nanoclusters", Physica E 51, pp. 111-114 (2013).
6. D. Mateos, N. Nedev, D. Nesheva, M. Curiel, E. Manolov, A. Arias, O. Contreras, B. Valdez, Z. Levy and J. Siqueiros, Electrical Characterization of MOS Structures with Silicon Nanocrystals Suitable for X-ray Detection, Key Eng. Mat., Vol. 543 pp. 150-153 (2013).
7. E. Atanassova, N. Novkovski, D. Spassov, A. Paskaleva, A. Skeparovski, "Time-dependent-dielectric-breakdown characteristics of Hf-doped Ta_2O_5/SiO_2 stack", in press Microelectron. Reliab.
8. B. Hudec, A. Paskaleva, P. Jančovič, J. Dérer, J. Dérer, A. Rosová, E. Dobročka, and K. Fröhlich, "Resistive switching in TiO_2-based MIM structures with Al_2O_3 barrier layer at the metal/dielectric interface", oral presentation at E-MRS 2013, Strasbourg, in press Thin Solid Films
9. A. Arias, N. Nedev, D. Nesheva, M. Curiel, E. Manolov, D. Mateos, V. Dzurkov, B. Valdez, O. Contreras, R. Herrera, I. Bineva, J.M. Siqueiros, MOS Structures Containing Si Nanocrystals for Applications in UV Dosimeters, in press Key Eng. Mat.
10. N. Nedev, A. Arias, M. Curiel, R. Nedev, D. Mateos, E. Manolov, D. Nesheva, B. Valdez, R. Herrera, A. Sanchez, Visible Light Sensor Based on Metal-Oxide-Semiconductor Structure, in press Key Eng. Mat.
11. A. Arias, N. Nedev M. Curiel, R. Nedev, D. Mateos, E. Manolov, D. Nesheva, B. Valdez, R. Herrera, A. Sanchez, Application of Metal-Oxide-Semiconductor structures for visible and near UV light sensing, in press Sens. Lett.
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Independent citations (2013): 140

COLLABORATION:

1. Fraunhofer Inst. of Integrated Systems and Device Technology, Erlangen, Germany
2. Inst. of Electronic Engineering, Slovak Academy of Sci., Bratislava, Slovakia
3. Institute of Semiconductor Physics, Kiev, Ukraine
4. Insitute of Physics, Universty of Skopie, Macedonia
5. University of Nish, Serbia

DIVISION MICRO- AND ACOUSTOELECTRONICS

LABORATORY

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RESEARCH ACTIVITIES:

In 2013 the scientific and applied research of Acoustoelectronics laboratory were focused on new materials, technologies and elements following the Academy's basic strategic goal - creation of a society based on knowledge that is an active partner in the European scientific area.

The research efforts in the laboratory were carried out in the following directions:

• Application of bulk acoustic waves (BAW) in resonant structures for preparation and investigation of sensor devices for detection of harmful gases in the environment.

• Synthesis and investigation of thin plasma polymer films and composites for applications in sensors and biocomposites.

• Resonant structures using surface transverse waves (STW), Rayleigh surface acoustic waves (RSAW) and BAW and their applications in communications and sensor technologies.

- MASS – SENSITIVE QUARTZ RESONATORS

The etching process of AT-cut quartz in $(NH4)_2F_2$ aqueous solution at low temperature from 70^0C to 90^0C was studied. The created resonators on so treated quartz plates retain their equivalent dynamic parameters. The AFM analysis on quartz roughness shows that the greatest quartz roughness is obtained at 70^0C. At etching temperatures from 75°C to 90°C the effective surface is reduced due to the reaction mechanism. It was shown that the difference in the average roughness of quartz plates etched at 70°C and 75°C of 0.63 nm, leads to sensitivity increase of QCM-MoO_3 system in 6, 9 and 7.5 times, for NH_3 concentrations of 100, 250 and 500 ppm respectively.

The increase of effective sorption surface, obtained by chemical etching, can be successfully used to realize high sensitive gas sensors.

The sorption ability of $Ge_{20}Se_{80}$ thin films applied as active layers of quartz crystal microbalance (QCM) for NO_2 gas sensing were investigated. To identify the chalcogenide system appropriate for gas sensing, we provided data for the packing fraction of a number of chalcogenide systems and discussed their suitability.

Raman spectroscopy, X-ray photoelectron spectroscopy and atom force microscopy measurements were performed on the thin films both before and after gas absorption, which showed that the introduced gas molecules interact electrostatically with the chalcogen atoms of the host material and initiate some degree of structural changes in it. The weight change due to NO_2 gas absorption was measured by the frequency change of the QCM. The

absorbed mass increased monotonically with the thickness of chalcogenide films and the NO_2 gas concentration. At the conditions of our experiment, up to 11.4 ng of the gas was absorbed into 200 nm thick $Ge_{20}Se_{80}$ film at 5000 ppm NO_2 concentration. The process of gas molecules absorption is found irreversible at the purging conditions. The studies show that the absorption of NO_2 in $Ge_{20}Se_{80}$ has irreversible character. The main reason for this is the strong electrostatic attachment of the NO_2 molecule to the chalcogenide atoms and the occurrence of a structural reorganization within the chalcogenide glass. Evidence of the influence of the gaseous molecules on the structure of the films has been collected through Raman spectroscopy. This revealed an increase of the number of edge-sharing tetrahedra in the structure. The AFM studies demonstrated an increase of the surface roughness after absorption of the gaseous molecules. The XPS studies showed a slight increase of the Ge–O bonds after absorption as well as an increased presence of nitrogen, which most likely interacted with chalcogen atoms after absorption. All these specifics of the process with the studied glass films make the NO_2 absorption process non-reversible. The comparison between the character and the sorption capacity of the films $Ge_{33}Se_{67}$ and $Ge_{20}Se_{80}$ shows that they are defined mainly by the x / y ratio and can be changed by amending it.

Temperature programmed thermal desorption is coupled to a SALDI mass spectrometer with rotating ball interface for the first time. The application of such approach for drug detection is demonstrated. Lidocaine, propranolol and diphenhydramine were studied as test analytes. It is shown that the presented technique provides a simple and rapid screening method for tablets and other pharmaceutical products with total analysis time as short as 40 sec or less. Tested analytes are detected as protonated molecules with no or very structure-specific fragmentation. The schemes of fragmentation are proposed. The detection limits of studied drugs were estimated to be 0.2÷0.5 ng/ml. It is also demonstrated that the presented technique is applicable to the quantitative analysis of liquid biological materials such as urine.

Modified surface properties such as composition, nano roughness, wettability have effect on the most important processes at biomaterial interface. The research of stem cells (MSCs) adhesive potential, morphology, phenotypical characteristics on oxide coated and plastic substrate with different surface parameters was made. The oxide coatings deposition on plastic substrates shifts the surface properties at the more hydrophilic region and results in next positive cell/ biomaterial response in vitro tests. The MSCs marker number increases on the oxide nano structural surface of plastic substrates.

- SYNTHESES AND STUDY OF PLASMA POLYMERS AND COMPOSITES

Searching for improved biomaterials and biosensors, the study on the interaction of Ag-based composite surfaces with fibronectin (FN) protein were carried out. Two types of composite layers, Ag-DND/PPHMDS and Ag-nano/PPHMDS were obtained by plasma polymerization of HMDSO and nanoparticles of Ag and Ag-DND. The composite layers are representative of the different incorporation of the Ag in the polymer net. The structures studied, consisting of composite layers with adsorbed FN, were optically characterized with Ellipsometry, Fourier Transform Infrared and Ultra Violet Spectroscopy as well as by stylus profiling (Talysurf). The kinetic study of the FN adsorption indicates that the process depends on the FN concentration and the exposure time as well as on the surface chemistry of the composites. Compared to the reference sample, all composite layers exhibit an indication of a stronger ability to initiate the intrinsic pathway of coagulation.

- RESONANT STRUCTURES USING RAYLEIGH SURFACE ACOUSTIC WAVES (RSAW), SURFACE TRANSVERCE WAVES (STW) AND BULK ACOUSTIC WAVES (BAW) AND THEIR APPLICATIONS IN COMMUNICATIONS AND SENSOR SYSTEMS

Systematic experimental studies on the temperature frequency characteristics (TFC) of AT-cut bulk acoustic wave (BAW) resonators coated with solid chemosensitive polymer films of

hexamethyldissiloxane (HMDSO) have been performed on series of devices to evaluate the effect of temperature on the sensor performance of quartz crystal microbalances (QCM) based on this principle. It has been shown that the polymer film causes a shift of the inflection temperature and affects the temperature coefficients of the cubic TFC. These phenomena, however, are unambiguously related to the thickness of the sensing polymer film and allow prediction of the TFC in the range of 100 to 550 nm HMDSO thickness. Thus the QCM sensor responses to different chemical agents can be precisely corrected for temperature induced frequency shifts during real-life measurements in environments of variable temperature.

A method for registration of changes in the hydrophobic condition of QCM coated with a thin layer of epoxy and carbon nanoparticles has been demonstrated. The nanoparticles convert the QCM surface into a super hydrophobic one with a large wetting angle (in the 151 to 155 degrees). By applying an electrical field between a liquid droplet on the QCM surface and the upper QCM electrode wetting of the QCM surface is enforced and this condition is registered by a frequency down shift of the QCM frequency. This method shows that the QCM can register changes in the liquid properties of the droplet causing changes in the super hydrophobicity of the QCM.

PUBLICATIONS:

1. Z. Raicheva, V. Georgieva, A. Grechnikov, V. Gadjanova, Ts. Angelov, L. Vergov, Yu. Lazarov, Improving Resonance Characteristics of Gas Sensors by Chemical Etching of Quartz Plates. Poster 3.7. Journal of Physics: Conference Series 398 (2012) 012046.

2. Ping Chen, Maria Mitkova, Dmitri A. Tenne, Kasandra Wolf, Velichka Georgieva, Lazar Vergov, Study of the sorption properties of Ge20Se80 thin films for NO2 gas sensing
Thin Solid Films 525 (2012) 141–147.

3. A.A. Grechnikov, A.S. Borodkov, V.B. Georgieva, S.M. Nikiforov, Ya.O. Simanovsky, S.S. Alimpiev, Rapid screening of pharmaceutical drugs using thermal desorption – SALDI mass spectrometry, Poster 2.8. Journal of Physics: Conference Series 398 (2012) 012033.

4. N. Donkov, V. Safonov, A .Zykova, J. Smolik, R. Rogovska, A. Goltsev, T. Dubrava, I. Rossokha, V. Georgieva, Nanoscale surface modification of plastic substrates for advanced tissue engineering applications , Poster 2.4. Journal of Physics: Conference Series 398 (2012) 012031

5. T. Hikov, L. Pramatarova, N. Krasteva, E. Radeva, P. Petrik, E. Agocs, E. Pecheva, R. Presker, O. Sabotinov, Study of nanocomposite layers based on polymer and nanodiamond particles: new materials for medical implants, Bulg. J. Phys. 39 (2012), pp 297-308

6. Lilyana D. Pramatarova, Todor A. Hikov, Natalia A. Krasteva, Peter Petrik, Raina, P. Dimitrova, Emilia V. Pecheva, Ekaterina I. Radeva, Elot Agocs, Ivaylo G. Tsvetanov and Radina P. Presker, Protein Adsorption on Detonation Nanodiamond/Polymer Composite Layers. MRS Proceedings, 1479, pp. 51-56 (2013)

7. I.D. Avramov and K. D. Esmeryan, "Thermal sensitivity of solid polymer coated surface transverse/Love wave based resonators on AT-cut quartz for sensor applications", Sensors & Transducers Journal, ISSN 1726-5479, Vol.147, No.12, Dec. 2012, pp. 15-26. (излязла от печат през 2013 г.)

8. K D Esmeryan, G McHale, C L Trabi, N R Geraldi and M I Newton, "Manipulated wettability of a superhydrophobic quartz crystal microbalance through electrowetting", Journal of Physics D: Applied Physics, ISSN 0022-3727, 46 (2013) 345307 (9pp), doi:10.1088/0022-3727/46/34/345307 IF (2012): 2,544

ONGOING RESEARCH PROJECTS:

1. Project financed by Bulgarian Academy of Sciences

1.1 Mass-, gas- and thermosensitivity of sensor systems and devices using different acoustic wave modes Bulk, Lamb, Rayleigh and Transverce surface acoustic waves.

2. Project financed by National Science Fund.

2.1 "Role of the elasticity of the substrate in the osteogenic differentiation of mesenchymal stem cells"

3. Projects in frames of Inter-academic and Inter-institute collaboration

3.1 Development of new sensitive layers (coatings) based on nano-sized semi-conductive structures for analytical application using mass-sensitive piezoresonance sensors.

3.2 Investigation of impurities in helium gases on the base of quartz crystal microbalance.

3.3 Development of a leaky surface acoustic wave (LSAW) sensor on lithium tantalate for liquid analysis.

COLLABORATION:

1. "Development of new sensitive layers (coatings) based on nano-sized semi-conductive structures for analytical application using mass-sensitive piezoresonance sensors"- Russian Academy of Science, Russia.

2. "Development of mass sensitive quartz resonators for operation at cryogenic temperatures". - Join Institute for Nuclear Research, Dubna, Russia.

3. "Development of a leaky surface acoustic wave (LSAW) sensor on lithium tantalate for liquid analysis" - Research Center Karlsruhe, Germany.

DIVISION LOW TEMPERATURE PHYSICS

LABORATORY

LOW TEMPERATURE PHYSICS

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RESEARCH ACTIVITIES:

The Low temperature physics laboratory deals with the theoretical and experimental study of new superconducting, magnetic and composite materials with a view to their application in various fields. This activity is related to the priority areas of the Bulgarian Academy of Sciences: New materials and new energy sources.

Science activity and main obtained results in 2013 are summarized below.

THEORETICAL STUDIES

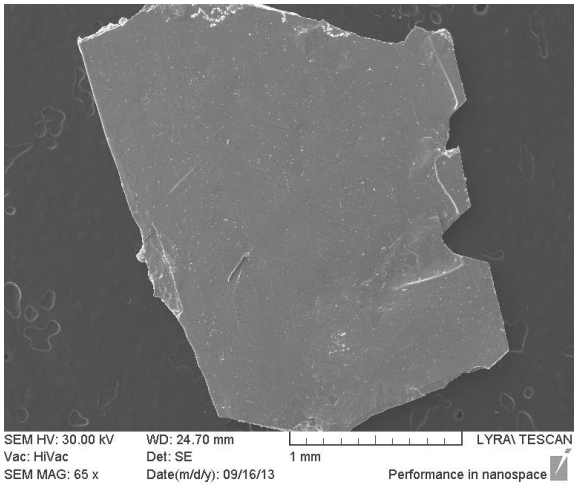
The actively developing approaches in the theory of nonequilibrium phase transitions are based on the Jarzynski equality. It relates the nonequilibrium average work done by an external force on a system, initially at equilibrium, to the ratio of the partition functions for the two (initial and final) equilibrium states. Thus the role of thermodynamic fluctuations far from equilibrium is taken into account and a number of experimental results obtained for "small systems" in the "meso" and "nano" scale level are interpreted. On the other hand in the theory of phase transitions much attention has been drawn to the role of fidelity, a concept emerging from quantum –information theory. It characterizes the geometric aspects of the state space. The estimates of the second derivative of this quantity (the so called "fidelity susceptibility") are obtained from the second derivative of the nonequilibrium average work carried out in the thermodynamic processes under consideration.

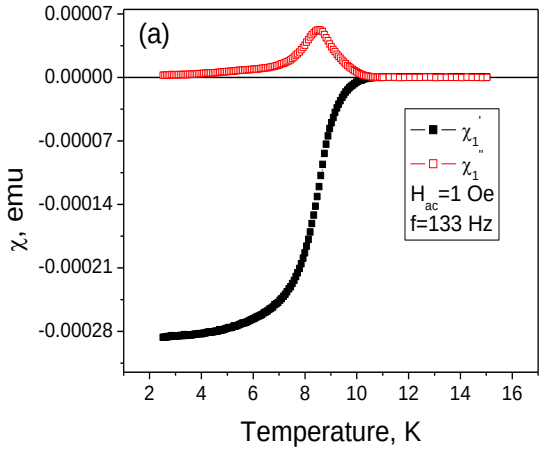
SUPERCONDUCTING AND COMPOSIT MATERIALS AND APPLICATIONS

Different high-temperature superconductors from the group of iron –based materials (FeSe, FeSeTe) and the group of cuprates ($HoBa_2Cu_3Oy$, $(Ho_{0.97}Sn_{0.03})Ba_2Cu_3Oy$, $Y_1Ba_3Cu_4O_z$, $Gd_1Ba_2Cu_3O_z$ and $Bi_{1.7}Pb_{0.3}Sr_2Ca_2Cu_3O_z$) have been obtained and investigated.

Iron-based superconductors

We synthesize for the first time polycrystalline samples FeSe+Ag with Tc~8-9 K and good intergrain connections. The irreversibility line is determined, which is essential for practical application. FeSe single crystals of considerable size and very good quality are also obtained by flux method. XRD analysis shows that crystals are mixture of tetragonal and hexagonal phase but the first one is more than 82 %. Crystals are superconducting with $T_c \approx$ 10 K.





Cuprate superconductors

Samples with nominal compositions $HoBa_2Cu_3O_y$ and $(Ho_{0.97}Sn_{0.03})$ $Ba_2Cu_3O_y$ were prepared by growing from the melt. It has been shown that the doping with tin increases irreversibility field and the second critical field in comparison with undoped specimen. In both specimen a phase transition glass-liquid in fluxoid system is observed. The obtained results are discussed.

The superconducting ceramics ($Y_1Ba_3Cu_4Oz$; $Gd_1Ba_2Cu_3Oz$ and $Bi_{1.7}Pb_{0.3}$ $Sr_2Ca_2Cu_3O_z$ (2223 , 2212 , 2201)) were synthesized and use as a supplement to the active mass of the electrode in Ni-Zn rechargeable batteries. The stability of the structure and properties of these ceramics in strongly alkaline medium was examined. The results show that the specimens retained the superconducting properties after storage in a highly alkaline medium. The positive effect of superconducting ceramics on the sustainability of recycling the zinc electrode of real Ni-Zn cell was confirmed. The usage of bismuth ceramics enable studies with greater amount of additive, and further improve the properties and characteristics of the negative electrode in alkaline Zn rechargeable systems.

Composite ceramic materials based on superconducting phase of Bi-Pb-Sr-Ca-Cu-O and of a ferromagnetic nano-powder $La_{0.6}$ Pb0.4MnO3 additive were synthesized. Systematic studies on the structure and phase formation were performed by XRD and SEM with EDX analysis. For suitable ratio of the two phases in the material different characteristics (superconductivity and ferromagnetism) are combined, making it versatile and interesting for practical use. Polycrystalline sample $La_{0.6}Pb_{0.4}MnO_3$, obtained by solid-phase method in oxygen environment, has a relatively high magneto- resistive effect (32.3%) measured at 4 K and magnetic field 10 kOe. The values of field saturation M_{sat} are: 75.8 emu / g at 4 K and 48emu / g at 300 K and that of the spontaneous magnetization M_s - 66.2 emu / g at 4 K and 26emu / g at 300 K) and are similar to those obtained for single crystals

We investigated the impact of the body on the chemical composition of surface on the three of the most frequently used orthodontic arches in Bulgaria. They are made of the following metal alloys: chromium -nickel stainless steel, nickel - titanium - copper - molybdenum and nickel - titanium. Orthodontic arches are part of the fixing technique used for the treatment of deformations. Each of these alloys has specific characteristics and allows to be selected at different stages of the treatment. The results of the X-rays and surface morphological studies have shown that the basic chemical composition of orthodontic arcs does not change during the treatment period, which is between 2, 6 and 10 weeks. The presence of chemical impurities and deposits associated with individual bacterial flora in the oral cavity of each patient.

PUBLICATIONS:

1. N.S.Tonchev and J.G. Brankov ,"Some inequalities in the fidelity approach to phase transitions," *J. Opt. and Adv. Mat*, Vol. 15, No.1 - 2, p. 73 - 76, (2013).

2. J.G.Brankov and N.S.Tonchev, "New Inequalities in Equilibrium Statistical Mechanics," *Bulg. J. Phys*., v. 40, No 1, pp. 40-55, (2013).

3. E. Nazarova, K. Buchkov, K. Nenkov, S. Terzieva "Doping dependence of magnetoresistivity in polycrystalline Y(Ca)BCO", *J. Opt. and Adv. Mat.*, Vol. 7, No. 1-2, (2013) 69; ISSN:1454-4164

4. N.Balchev, E.Nazarova, K.Buchkov, K.Nenkov, J.Pirov, B.Kunev, "Effect of Sn-doping on the superconducting properties of $HoBa_2Cu_3O_y$, obtained by the MTG method", *Journal of Superconductivity and Novel Magnetism*, DOI: 10.1007/s10948-013-2378-y (2013)

5. D. Mitkova, A. Stoyanova-Ivanova, S. Georgieva, P. Todorov, N. Kozarev, Y. Ermakov, V.Vitkova, Charged lipid bilayers in aqueous surroundings with low pH, in: A.Iglic, C. Kulkarni (Eds.), Advances in Planar Lipid Bilayers and Liposomes, Academic Press, Burlington, Volume 18, 2013, pp. 1–20, ISBN: 9780124115156

6. Angelina Stoyanova-Ivanova, Denitsa Mitkova, Stela Georgieva, and Victoria Vitkova, "Lipid bilayers as biocompatible model systems – does the acidity of the aqueous solution alter the membrane elasticity?", *Advances in Natural Science: Theory and Applications*, Volume1, 2012, 29-35

7. Stela Iv. Georgieva, Tsvetanka K. Nedeltcheva, Latinka K. Vladimirova, Angelina K.Stoyanova-Ivanova "Spectrophotometric method for rapid estimation of the oxygen stoichiometry in YBCO superconducting samples", *Central European Journal of Chemistry*, 11 (3) 2013, pp.381-387

8. Blagoy S. Blagoev, Stanimira D. Terzieva, Timerfayaz K. Nurgaliev, Boris L. Shivachev, Andrzej J. Zaleski, Valdek Mikli, Anna D. Staneva, Angelina K. Stoyanova-Ivanova", Magnetic and transport characteristics of oxygenated polycrystalline $La_{0.6}Pb_{0.4}MnO_3$ ", *Journal of Magnetism and Magnetic Materials*, 329 (2013) 34-38; ISSN: 0304-8853

9. V. G. Petrov*, S. D. Terzieva, Tz. I. Lazarova, V. Mikli , L. A. Andreeva, A. K. Stoyanova-Ivanova „Corrosive changes and chemical composition of the orthodontic archwires' surface during treatment", *Bulgarian Chemical Communications* (BCC) Vol. 45, 4 (2013) 455–460; ISSN: 0324-1130

TEACHING ACTIVITIES:

Ph.D. Student V. Petrov from Medical University-Sofia, supervisor Assoc. Prof. A. Stoyanova-Ivanova

Ph.D. Student G. Mitrova from Institute of Electrochemistry and Energy Systems-BAS, consultant Assoc. Prof. A. Stoyanova-Ivanova

Lectures and exercises in HTM University, Sofia, Assoc. Prof. A. Stoyanova-Ivanova, Assist. Prof. S. Terzieva

Graduate Student Eva Georgieva from Sofia University**,** supervisor Assoc. Prof. E. Nazarova

Student practices: Assoc. Prof. A. Stoyanova-Ivanova, Assist. Prof. S. Terzieva, Assist. Prof. A. Zahariev

K. Buchkov successfully defended his PhD thesis “Investigation of the overdoped state in superconducting Y(Ca)BCO system” under the supervision of Assoc. Prof. E. Nazarova in 2013.

ONGOING RESEARCH PROJECTS:

I. Projects financed by Bulgarian Academy of Sciences

1. New materials, structures and multifunctional magnetic systems

II. Projects financed by contracts with EU, NATO and other international sources

1. “Research and Innovation Capacity Strengthening of ISSP-BAS in Multifunctional Nanostructures” INERA 316309, REGPOT-2012-2013-1.
2. “Preparation and study of iron based superconducting materials” -EURATOM-FU07-CT-2007-00059

INTERNATIONAL COLLABORATION:

1. Institute of Low Temperature and Structure Research, Polish Academy of Sciences, Wroclaw, Poland.
2. Leibniz Institute for Solid State and Materials Research, Dresden, Germany.
3. International Laboratory for High Magnetic Fields and Low Temperatures – Wroclaw, Poland.
4. Physical Department of Salerno University, Salerno, Italy.
5. National Institute for Lasers, Plasma and Radiation Physics, Lasers Department; "Laser-Surface-Plasma Interactions" Laboratory, PO Box MG-54, RO-77125, Magurele, Ilfov Romania.

DIVISION LOW TEMPERATURE PHYSICS

LABORATORY

ENVIRONMENTAL PHYSICS

HEAD: **Assoc. Prof. Pavlina Simeonova, PhD**
Tel: 9746265; e-mail: poly-sim@issp.bas.bg

TOTAL STAF: **3**
RESEARCH SCIENTIST: **2**

Assoc. Prof. P. Simeonova, PhD; Mihaela Jerusalimova, Technical Assist.; Plamen Zashev, Technical Assist.; Petja Papazova, PhD student;
Associated members: Assoc. Prof. V. Lovchinov, Assoc. Prof. N. Shtarbov, Assoc. Prof. I. Shtarbova

RESEARCH ACTIVITIES:

Laboratory of Environmental Physics is dealing with classification, modeling and interpretation of complex multi-parametric systems of the environmental physics by the use of the methods of the multivariate statistics aiming prognosis, assessment, generalization and decision making in solving technological, ecological, economic and social problems.

RESULTS FROM THE SCIENTIFIC ACTIVITY

In 2013 The Laboratory cooperated with various scientific organizations from Bulgaria and abroad such as Faculty of chemistry and pharmacy - University of Sofia, University of Plovdiv, Institute of Oceanology – BAS, Sofia Medical University, Aristotle University of Thessaloniki, Greece, L'Universite de Liege, Belgium, International Laboratory of high magnetic fields and low temperatures, Wrozlaw, Poland, Physicochemical Technical Institute "A. Ioffe", St. Petersburg, RAS. The Laboratory works mainly in two scientific fields – environmetrics and magnetic properties of the matter.

1. The results obtained could be summarized as follows:

1. Three multivariate statstical methods (Cluster analysis and Principal components analysis as well as Principal components regression) were applied for model assessment of the water quality of Maritsa River on Bulgarian territory. The study used long-term monitoring data from 21 sampling sites characterized by 8 surface water quality indicators. It is shown that the water quality of Maritsa River catchment is determined mainly by "biological", "anthropogenic" and "eutrophication" factors.

2. A total of 26 sets of sized aerosol samples ($PM_{0.015}$-PM_{18}, 10 fractions) were collected together with colleagues from University of Thessaloniki, Greece using a Berner low pressure impactor from an urban site in the center of Thessaloniki, during the period of February-July 2007. Water soluble inorganic and organic components were analysed and mass concentrations for each fraction were determined. It was shown that dominating role in each fraction have the electrolites, followed by organic carbon. Additionally, it was proven by environmetric modeling that despite the size of the fraction several latent factors are responsible for the data structure – mineral (soil) dust, sea sprays, secondary emissions, combustion processes and industrial pollution.

3. The cadmium and zinc content in tissues of benthic organisms (*Mytilus galloprovincialis*) from Gulf of Varna were determined by atomic absorption spectrometry. The method was also applied for determination of toxic metals in tissues of snails. Correlation, regression and cluster analysis completed the data treatment procedure. It was shown that the benthic organisms could be used as biomonitors.
4. The present study deals with the interpretation of soil quality monitoring data using cluster and principal components analysis and self-organizing maps of Kohonen. All multivariate statistical methods contributed to the correct data classification and projection for the upper surface (0-20 cm) and subsurface (20-40 cm) soil layer for 36 sampling sites in the region of Burgas, Bulgaria. Using environmetrics it has been found that several sources definee the soil quality like agricultural activity, industrial impact, fertilizing etc.
5. Comparison between the catchments of the rivers Maritsa and Tundja by envionmetric modeling is performed and it is proven that for both rivers the ecological status of the upper stream differes significantly from that of the lower stream as the upper stream is much cleaner and non affected by pollution sources.
6. Clinical data from patients with prolactinoma, dioabetis mellitis type 2 and subject to variouys feeding options after surgery (enteral and parenteral nutrition) were treated by multivariate statistics. Specific patterns of patients are detected as well as specific grouping of parameters. It helps in optimizing the clinical testing and individual patients treatment.
7. Monocrystals of $DyMnO_3$ in magnetic fields up to 14T and in the tremperature interval 3 - 300 K were investigated. The Dy ordering temperature depending on the field is determined. The paramagnetic Curie – Weiss behaviour is mainly related to the Dy3 sublattice since the contribution of Mn sublattice is of secondary importance. The measurements of the DC magnetization indicate significant anisotropic features related to the anisotropic structure of the cubic system along the crystal diagonal with magnetic axis parallel to the crystalographic one.
8. Monocrystals of two types of tetraphosphates $LiNdP_4O_{12}$ and $LiErP_4O_{12}$ were studied in order to determine the influence of the magnetic moment of the doping ion (in this case Nd and Er) on the effectiveness of laser diodes produces of these materials.
9. Magnetic properties of three types of manganese oxalates crystalohydrates (γ-MnC_2O_4, α-MnC_2O_4 and γ-$MnC_2O_4.2H_2O$) were studies for the first tiem at different temperatures and magnetic fields. This study is in response to the significant theoretical interest for determination of the role of the crystal structure and the presence of two water molecules in the oxalates.

In 2013 the successful activity of the "Center for investigation of the physical properties of materials, surfaces and structures" – ISSP under the guidence of Dr. V. Lovchinov continued. Two sessions of measuring by the unique instrumentation PPMS were performed with the active participation of the PhD student Krastyu Buchkov from Low temperature physics, Assist. Prof. Dr. Irina Bineva from the Laboratory of photoelectric and optic phenomena in broadband semiconductors and the associated members of the Center Assoc. Prof. Dr. Nikolai Shtarbov and Assoc. Prof. Dr. Kirilka Shtarbova both for local and external users.

In 2013 the coworkers from the Laboratory took part in reviewing of 5 scientific manuscripts for various international journals (Advances in Biology Research, Journal of Environmental Science, Journal of Chemistry). Assoc. Prof. Dr. Pavlina Simeonova was member of scientific jury for delivering the academic position "associated professor" in Medical University, Sofia in Chair of Physics and Biophysics. Assoc. Prof. V. Lovchinov was member of scientific jury for delivering the educational and scientific level "Doctor" at Faculty of chemistry and pharmacy, University of Sofia. Assoc. Prof. Dr. P. Simeonova is member of the editorial board of the journal *Ecological Chemistry and Engineering S.*

The members of the Laboratory participated at the Second National Conference of Physics in September 2013 with posters.

Additional activities were registered:

1. Two scientific popular papers were written using the invitation of the editor-in-chief of the journal "Ecology" dealing with problems of the sustainable development: „Sustainable development, ecology, society" and „Sustainability indicators".
2. The coworker of the Laboratory Michaela Yerosalimova was sent for three months as ecologist in "Sitona" company, Razdgrad for practicing in observation and analysis of production of alternative energy sources (production of brickets) in order to collect data helping in improving the ecology of production. Thus, the scientific activity of the Laboratory was linked to practical applications.

2. The most significant scientific achievements

As the most significant scientific achievement of the Laboratory could be considered the study on statistical modeling of air pollution published in a journal with high impact factor.

R. Tsitouridou, P. Papazova, P.Simeonova, V. Simeonov. Chemical and statistical interpretation of sized aerosol particles collected at an urban site in Thessaloniki, Greece. *Journal of Environmental Science and Health, Part A*, Vol. 48, no. 14, (2013), 1815 – 1828.

A total of 26 sets of sized aerosol samples ($PM_{0.015}$-PM_{18}, 10 fractions) were collected using a Berner low pressure impactor from an urban site in the center of Thessaloniki, northern Greece, during the period of February-July 2007. The aerosol samples were chemically characterized for water soluble inorganic species (Cl^-, NO_3^-, SO_4^{2-}, NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+}.) and water soluble organic compounds (WSOC).

The determined compounds were then compared with mass concentrations of the PM fractions for nano (N: $0.015<D_p<0.06$), ultrafine (UFP: $0.015<D_p<0,125$), fine (FP: $0.015<D_p<2.0$) and coarse particles (CP: $2.0<D_p<8.0$), in order to perform mass closure of the water soluble content for the above fractions. Electrolytes were the dominant species in all fractions (24-27%), followed by TOC (16-23%). The water soluble inorganic and organic content accounts for 53% of the nano particle mass, 48% of the ultrafine, 45% of the fine and 44% of the coarse particle mass. Correlations between the analysed species were performed and the effect of local and long-range transported emissions has been examined by wind direction and backward air mass trajectories.

Additionally, multivariate statistical analysis (cluster analysis and principal components analysis) of the collected data was performed in order to reveal the specific data structure. Possible sources of air pollution were identified and an attempt is made to find patterns of similarity between the different sized aerosol and the seasons of monitoring. It was proven that several major latent factors are responsible for the data structure despite the size of the aerosols – mineral (soil) dust, sea sprays, secondary emissions, combustion sources and industrial impact. The seasonal separation proved to be not very specific.

PARTICIPATION OF THE LABORATORY IN EDUCATION

The Laboratory is responsible for the training of one PhD student (distant study) Petya Dimitrova Papazova under the scientific guidance of Assoc. Prof. Dr. P. Simeonova and Assoc. Prof. Dr. V. Lovchinov. In 2013 the last exam was taken as required by the training program. Thus, all obligatori requirements of the program were fulfilled. Parallel to this the research work of the PhD student was also finished. In 2013 two papers were published in journals with impact factor and other two were accepted for publication.With the last two studies P. Papazova participated at the Second National Conference of Physics with posters.

She collected the necessary number of credit points and will prepare her predefence and future defence of her doctoral thesis.

PUBLICATIONS:

1. M.Peekala, F. Wolf-Fabris, J.-F. Fagnard, P. Vanderbemden, J. Mucha, M. M. Gospodinov, V. Lovchinov, M. Ausloos. Magnetic properties and anisotropy of orthorhombic $DyMnO_3$ single crystal. *Journal of Magnetism & Magnetic Materials*, Vol. 335, (2013), 46-52.
2. D. Petrov, B. Angelov, V. Lovchinov. Magnetic and XPS studies of lithium lanthanide tetraphosphates $LiLnP_4O_{12}$ (Ln=Nd, Gd, Er). Journal of Rare Earths, Vol. 31, no.5, (2013), 485-489.
3. P. Papazova, P. Simeonova. Environmetric Data Interpretation to Assess the Water Quality of Maritsa River Catchment. *Journal of Environmental Science and Health, Part A,* Vol. 48, no. 8, (2013), 963-972.
4. R. Tsitouridou, P. Papazova, P.Simeonova, V. Simeonov. Chemical and statistical interpretation of sized aerosol particles collected at an urban site in Thessaloniki**,** Greece. *Journal of Environmental Science and Health, Part A,* Vol. 48, no. 14, (2013), 1815 – 1828.
5. P.Simeonova, D. Simeonov, L. Spassov, V. Simeonov. Determination and Statistical Interpretation of Toxic Metals Content in Mollusks and Snails from Black Sea. *Bulgarian Journal of Chemistry*, Vol. 2**,** no. 3, (2013), 105 – 114.
6. P. Papazova, T. Voyslavov, P. Simeonova, V. Simeonov. Chemomertic expertise and pollution risk assessment of soils. *Bulgarian Journal of Chemistry*, Vol. 2, no. 4, (2013), 1-8.
7. P. Simeonova, P. Papazova, V. Lovchinov. Application of Cluster Analysis in Interpretation of Toxic Metals Accumulation in Biomonitoring Marine Organisms. *Bulgarian Journal of Physics*, Vol. 40, (2013), 269-273.
8. P. Simeonova, P. Papazova, V. Lovchinov. Long-term statistical assessment of the water quality of the catchments of Tundja River and Maritsa River. *Bulgarian Journal of Physics*, (2013), (accepted for publication).

CITATIONS for 2013 – 50.

RUNNING SCIENTIFIC PROJECTS:

1. Project financed by BAS – "Environmental Physics"
2. EBR - "Electric and magnetic properties of perovskites magnetic materials", Liege, Belgium. L'Universite de Liege, Depart, Physigue, Group SUPRA.TECS.
3. EBR - „Structure and physical studies of nano-structured thin layer and bulk materials based on porous dielectric matices", Department of physics of dielectrics and semiconductors, Physicotechnical institute Ioffe, St. Petersburg, Russian Federation.

INTERNATIONAL COOPERATION:

Universite de Liege, Belgium - L'Universite de Liege, Depart, Physigue, Group SUPRA.TECS.
Department of physics of dielectrics and semiconductors, Physicotechnical institute Ioffe, St. Petersburg, Russian Federation, Russian Academy of Sciences.
International Laboratory for high magnetic fields and low temperatures, Wrozlaw, Poland..

DIVISION PHYSICAL OPTICS AND OPTICAL METHODS

LABORATORY

OPTICS AND SPECTROSCOPY

HEAD: **Prof. Svetoslav Rashev, D.Sc.**
tel: 979 5795; e-mail: rashev@issp.bas.bg

TOTAL STAFF: **19**
RESEARCH SCIENTISTS: **18**

Prof. K. Panayotov D.Sc.; Assoc. Prof. L. Tsonev, Ph.D.; Assoc. Prof. A. Andreev, Ph.D.; Assoc. Prof. S. Tonchev, Ph.D.; Assoc. Prof. A. Angelov, Ph.D.; Assoc. Prof. E. Keskinova, Ph.D.; Assoc. Prof. G. Hadjihristov, Ph.D.; Assoc. Prof. T. Tsvetkova, Ph.D.; Assoc. Prof. R. Peeva, Ph.D.; Assoc Prof. K. Antonova, Ph.D.; Assoc. Prof. B. Zafirova, Ph.D.; Assoc. Prof. M. Kaneva, Ph.D; Assoc. Prof. T. Tenev, Ph.D.; Assist. Prof. B. Katranchev, Ph.D.; Assist. Prof. B. Panchev; Assist. Prof. H. Naradikian; Assist. Prof. E. Karakoleva; I. Milushev, Ph.D.; Y.Velkova

RESEARCH ACTIVITIES:

Nanocomposites of liquid crystals and nanotubes: It has been demonstrated, that surface oriented monolayer carbon nanobubes (SWCNT), deposited o SiO_x/ITO/glass surface, serve to enhance the effect of surface memory in the liquid crystal 7OBA (heptyloxybenzoic acid), respectively the energy of „anchoring", which exceeds 4 times that of the SiO_x/ITO/glass surface.

We have observed for the first time in low-molecular liquid crystal systems, the theoretically predicted by *de Gennes*, chiral two-axial smectic phase (C_G) with triclinic (possibly lowest) symmetry - C_1, not typical for the „pure" achiral liquid crystal 7OBA.

Molecular dynamics, optics and electrooptics of mesomorhous media: A specific type of polymer-dispersed liquid crystal (PDLC) composites was produced and explored – planar single layers of large nematic microdroplets aligned by nano-structured Teflon nanolayers. The nematic director field in this composite material was efficiently modified by nano-rubbed Teflon on the glass plates of the PDLC cell. When these plates have rubbing directions orthogonal each other, the single layers of PDLCs exhibit a selective amplitude-frequency electro-optical (EO) modulation well controllable by AC voltage applied on the PDLC cell. The band-like EO modulation within a certain frequency range is attributed to the effect of screening of the external electric field driving the PDLC. The selective band-pass filtering by such surface-modified PDLC systems may be useful for applications based on various schemes by exploiting efficient EO modulation by PDLC in the infrasound frequency range which are of interest for military, geo-acoustic and bio-medical monitoring.

Investigation of new nanostructured optical materials (ion implanted polymers), using laser methods: Multiangle reflection ellipsometry is applied to characterize the refractive index change of the material in the subsurface layer produced by ion implantation of polymethylmethacrylate (PMMA) with low-energy (50 keV) silicon ions at implantation doses ranging from 10^{14} to 10^{17} cm^{-2}. By employing an effective medium approximation, the in-depth distribution of both real and imaginary parts of the complex refractive index of ion-modified material near the surface was modeled. The degree of in-depth modification of the target PMMA material upon ion implantation was established. A distinct dose level was found that produced a maximum efficiency of the ion-induced change of the optical

properties of the material. The knowledge of the refractive index of the formed ion-implanted PMMA material and the results for the depth profile of the complex refractive index of the ion-modified subsurface region of this plastic can be useful for the practical application of optically-transparent ion implanted polymers.

A kind of photo-induced anchoring at the surface of liquid crystal (LC), namely *trans-cis* photoizomerization-induced tilted anchoring, in a photoactive guest-host LC system was investigated. In particular, a LC mixture was studied consisting of a nematic LC MBBA as the host, and a photoactive LC azo dye as the guest (at 1 wt.% concentration). The surface anchoring found in this guest-host LC system confined in homeotropic thin films is due to *trans-cis* photoizomerization of the guest azo molecules upon a relatively low-intensity UV-light illumination (of the order of 10 mW/cm^2). Such light-induced (not thermally-induced) surface effect is closely related to the LCs applications and has to be taken into account, especially at high light intensity, when this effect can limit and even frustrate the LCs laser-driven applications based on photoactive guest-host LC systems (e.g., those operating by *trans-cis* photoizomerization).

Electrooptics of water coloid suspensions in chitin rodlike nanoparticles: The chitin rodlike nanoparticles were obtained from natural chitin after special protocol manipulation. Using ultrasonic manipulation, particles were obtained with stable dispersion of max 260 nm length and 23 nm diameter. There is growing interest in such solid or porous nanocomposite materials with anisotropic structure and respectively anisotropic mechanical, optical, etc. properties with applications for membranes, sensors, catalyzers, etc.

Semiconductor lasers with vertical radiation (VIXELs): We have discovered the phenomenon optical deterministic chaos in a laser diode – VIXEL with an active medium of quantum dots. We have studied both theoretically and experimentally VIXELs in combination with a cholesteric liquid crystal and have shown, that the system emits circularly polarized light.

Photonic crystals: Theoretical and experimental studies have been carried out on the eccett of the parameters of the optical crystal structure on the working mode of VIXELs with a photonic crystal.

Quantum optics: We have studied experimentally the properties of a quantum generator of arbitrary numbers and have proposed an improved method for manipuation, based on the time for arrival of the photon with substantially increased generation rate.

Solitons: We have studied theoretically the effect of the optical feedback on the behavior of solitons in VIXELs with broad aperture and obtained an analytical formula for the threshold and the velocity of spontaneous propagation. Experimental investigation of spacial solitons in VIXELs with 80 mkm aperture.

Waveguides with proton exchange: We have calculated the mechanical strain in proton-exchanged waveguides in $Li_{1-x}H_xTaO_3$ using an optical integral method. The obtained values for the mechanical strain and the change of refractive index enable us to calculate the coefficient of shrinking in PE waveguides of LT for a given phase composition and thickness of the layer.

We have published Volume I from the book „Physics in Bulgaria", containing the first publications on physics by bulgarian authors, as well as a number of books on the history of education in Sofia University.

Diffarction gratings: The phenomenon optical resonance was studied, with the involvement of a surface plasmon. We have experimentally demonstrated transmission with very low lossvof a metal layer, at excitation of „*long-range plasmon"*. These results demonstrate the possibility for practical employment of such gratings, working on plasmonic resonance, for optical sensors and security devices in the visible and UV range.

We have demonstrated experimentally a new method for production of holographis diffarcion gratings with an exact number of periods, by exposing an interferogram with waves of a cylindrical wavefront. Such gratings have applications for production of precise rotation indicators and for focusing X ray radiation. We have prepared a nickel copy of such a grating, that enables the production of polymer copies of cylindrical gratings.

Thin layer and multilayer optics: Technologically realized are layers Ag_2Te (Ag_5Te_3) using thermal evaporation in vacuum. Raman spectra of the obtained thin layers and microcrystals were studied. The effect of the three-layer structures ZnS/Ag/ZnS и MgF_2/Ag/MgF_2 was studied on the resonance at reflection and transmission as a result of the excitation of plasmons in the metal layer.

Physics and archaeology: Analyzed was the most ancient known today cult building in Bulgaria – the underground temple-well at the village of Garlo.An archaeo-astronomical hypothesis for its designation was proposed, that was corroborated by the preliminary measurements on the place. The regisration of the local relief around the temple, promotes the possibility for application of the modern method of luminescence dating.

Calculations on the vibrational structure of polyatomic molecules: We have optimezed the potential energy surface of formaldehyde H_2CO, by performing calculations at varying force constants values, presented in the form of quartic expansion in the vibrational cvoordinates.

Giroscopes and quantum effects: We have built an interferometric fiber-optical giroscope of Sagnac, designated for educational purposes.

We have considered theoretically the quantization of the electromagnetic field in nonstationary media (linear in E, with negative electroconductivity). The temporal evolution of the three independent statistical moments of second order has been derived.

Fifber optics: Using the localized function method based on the Galerkin method and applying a set of Sine functions to approximate the unknown electromagnetic fields the main characteristics of the photonic crystal fibres (PCFs) are calculated. We consider PCF, whose core of the host medium is surrounded of a ring of holes with a big diameter. The holes are fulfilled with air (n=1).

Such configurations make it possible to be evaluated the accuracy of the program code, because the field of the linear polarized mode (fundamental mode) is concentrated in the fiber core, what coincide with the domain of calculations.

A relative differences between two successive solutions differing by the number of the members in the expansion is: 3.9732×10^{-8} and by material domain dimension variations of 0.2mkm is: 7.7695×10^{-12}.

In the process of calculation it was established that the convergence has been improved by increasing the number of members in the expansions of the solutions, achieve the best one and change to the worse by further increasing of the members.

The main characteristics of the PCFs with two rings of holes with a big diameter and refractive index n_{holes} =1.0 are calculated. Due to the concentration of the field of the fundamental mode his effective refractive index stays unaffected by adding a second ring of holes. This is criterion that the developed program code is correct and gives true results.

A suggested theoretical method for reducing a number of holes to be calculated is realized in program code.

Ion implantation: The studies have been finalized on the formation of optical contrast in the layers of amorphous silicon carbide using focused ion beams as well as possibilities for applications of nano-dimensional optical storage of information for nano-dimensional information storage and production of lithographic masks. The effect was studied for formation of optical contrast in the materials of interest as a result of bombardment with low-energy (~50 keV) Galium ions at various temperatures of ion implantation, as well as the

effect of subsequent thermal annealing on the obtained optical contrast. The obtained nano optical images were studied using AFM and SNOM, as well as XPS.

PUBLISHED PAPERS:

1. Y.G. Marinov, G.B. Hadjichristov, A.G. Petrov, S. Marino, C. Versace, N. Scaramuzza: "Electro-optical response of PDLC single layers of large nematic droplets oriented by rubbed teflon nanolayers", J. Appl. Phys. **113**(6) (2013) 064301 (1-11).

2. Y. G. Marinov, G. B. Hadjichristov, A. G. Petrov, S. Marino, C. Versace, N. Scaramuzza: "Selective amplitude-frequency electro-optical modulation by polymer-dispersed liquid crystal films aligned by nanostructured teflon nanolayers", C. R. Acad. Bulg. Sci. **66**(6) (2013) 819 - 826.

3. Y.G. Marinov, G.B. Hadjichristov, A. G. Petrov, S. Sridevi, U.S. Hirenath, C.V. Yelamaggad, S.K. Prasad: "Trans-cis photoizomerization-induced tilted anchoring in photoactive guest-host liquid crystalline systems", J. Phys. Conf. Ser. 398 (2012) 012038 (1-6).

4. S.C. Russev, G.G. Tsutsumanova, I.L. Stefanov, G.B. Hadjichristov: "Ellipsometrical characterization of complex refractive index depth profile of 50 keV silicon ion implanted PMMA", Vacuum **94** (August) (2013) 19–25.

5. I.L. Stefanov, H.Y. Stoyanov, E. Petrova, S.C. Russev, G.G. Tsutsumanova, G.B. Hadjichristov: "Laser characterization of the depth profile of complex refractive index of PMMA implanted with 50 keV silicon ions", Proc. SPIE **8770** (2013) 87701N-6.

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10.**K. Panajotov**, M. Dems, C. Belmonte, H. Thienpont, Y. Xie, J. Beeckman, K. Neyts, "Vertical-cavity surface-emitting laser with cholesteric liquid crystal overlay", J. Lightwave Techn., in print, 2013.

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14. T. Czyszanowski, M. Dems, R. Sarzała, **K. Panajotov**, K. D. Choquette, "Photonic Crystal VCSELs: Detailed Comparison of Experimental and Theoretical Spectral Characteristics", IEEE J. Selected topics in Quant. Electr., **19**, 1701908, 2013.

15. M. Virte, **K. Panajotov**, M. Sciamanna, "Mode Competition Induced by Optical Feedback in Two-Color Quantum Dot Lasers," IEEE J. Quant. Electr., 49, 578, 2013.

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22. Evgeny Popov, Jerome Wenger, John Hoose, Svetlen Tonchev, « Strong three-dimensional field localization and enhancement on deep sinusoidal gratings with two-dimensional periodicity », Optics Letters, 10/21/2013; Doc.ID 195251**; IF 3.399**

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39. E. Stoianova, A. Angelow, "Squeezed States in Mach-Zehnder Interferometer" Scientific studies - Physics, Plovdiv University, **38,** no. 4, 152-156 (2013)

Monographs

1. Д. Христов, Е. Добрева, Ц. Бузова, М. Кънева, Н. Бъчварова, Ц. Чолова, А. Николова, Н. Кочев, М. Бъчваров, Б. Пейчев и др. **„**Физиката в България. Том I**",** Изд. Фараго, София, 2013, 125 стр., 4 ил. ISBN 978-954-2961-58-1

2. Д. Христов, М. Кънева, В. Тенева, Н. Стоилова, З. Добрева, Р. Горгоров, Д. Христов, **„**Началото на българската математическа наука I. Тетранионите на Емануил Иванов (Сборник)**",** Университетско издателство „Св. Кл. Охридски", София, 2013, 199 стр., 3 ил., ISBN 978-954-07-3579-5

3. В. Тенева, Д. Христов, Е. Бранкова, В. Тодоров, Р. Горгоров, З. Добрева, М. Кънева, Н. Стоилова, Ц. Физиева, „Началото на българската математическа наука II. Първите публикации на български математици, реферирани във Forschr. d. Math. (1903-1913) (Сборник)", Университетско издателство „Св. Кл. Охридски", София, 2013, 131 стр., ISBN 978-954-07-3580-1

4. Д. Христов, Н. Делчева, В. Тенева, З. Добрева, М. Кънева, Р. Горгоров, **„**Началото на българската математическа наука III. Физ.-мат. д-во в София и неговото Списание (Сборник)**",** Университетско издателство „Св. Кл. Охридски", София, 2013, 157 стр., 7 ил., ISBN 978-954-07-3581-8

5. Г. Цветков, Г. Гюлмезова, С. Кирилова, Д. Първанова, С. Даганова, Д. Христов, М. Кънева, Г. Петров, **„**Проф. дхн Елена Киркова – достоен продължител на делото на достойни предшественици**",** (ред. М. Кънева), Изд. „Фараго", София 2013, 189 стр., 21 ил., ISBN 978-954-2961-69-7

6. Ц. Узунова, Р. Доновска, М. Млечкова, Д. Христов, М. Кънева, **„**Алманах на Богословския факултет на Софийския университет „Св. Климент Охридски", 1923-1951"**,** Университетско издателство „Св. Климент Охридски", София 2013, 110 стр., 16 ил., ISBN 978-954-07-3636-5

COLLABORATION:

1. Free University of Brussels, Departmet of Photonics, Belgium

2. Forschungszentrum Rossendorf, Institut fuer Ionenstralphysik und Materialforschung, Germany.

3. Pluridisciplinary Laboratory Joliot Curie at the Ecole Normale Supérieure, Lyon (CNRS UMR 5161) France, The Institute Albert Bonniot, UJF & INSERM U309, and CEA, Grenoble, France.

4. Institute of Ion Beam Physics and Materials Research, AIM – Center, POB 510119 01314 Dresden Germany

5. Лабораторията по физика на комплексни системи в Университета „Жул Верн” в град Амиен, Франция

DIVISION SOFT MATTER PHYSICS

LABORATORY

LIQUID CRYSTALS

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TOTAL STAFF: **5**
RESEARCH SCIENTISTS: **4**

Assoc. Prof. V. Vitkova, Ph.D.; Assist. Prof. J. Genova, Ph.D.;
Assist. Prof. R. Marinov, Ph.D.; Eng. D. Mitkova
Honorary Member: Acad. Alexander Derzhanski, Ph.D., D.Sc.
Associated Members:
Assoc. Prof. H. Hinov, Ph.D., D.Sc.; Assoc. Prof. A. Zheliaskova, Ph.D.

RESEARCH ACTIVITIES:

The 17th volume of Advances in Planar Lipid Bilayers and Liposomes, Elsevier, dedicated to Assoc. Prof. Marin Mitov with guest editor Julia Genova was published during the reported year.

A model was introduced for newly observed parallel domains. It describes the appearance of twist walls in a planar nematic layer of mixture of phenyl benzoates under constant magnetic field applied perpendicular to the layer. The walls occurring with a threshold had been previously observed by L. K. Vistin' (Moscow, Russia) and collaborators. These walls are oriented to the initial orientation of the molecular director creating alternating domain structure with the period of 13 μm. It was established, that the period is independent on the cell thickness within the range 50-100 μm. Furthermore, the director jump between the areas having opposite tilt angles was attended by formation of a Becke-lines system, which faded away/disappeared through a three-dimensional twist-splay-bend deformation.

A whole set of software for data processing and analysis of shape fluctuations of quasi-spherical vesicles was implemented and applied for the measurement of the bending elasticity of various lipid bilayers. Strong quantitative criteria for the quality of every image of the image sequence of the studied vesicle and the quality of the vesicle as a whole were imposed. The white-noise contribution to the bending elasticity modulus was taken into account in the data processing, disregard of which yielded to a significantly lower (with more than 20 %) value of the bending constant. All the results, enlisted below were obtained via the so-developed software.

The bending rigidity of stearoyl-oleoyl-phosphatidylcholine (SOPC) bilayers with various contents of dioleoyl-phosphatidylserine (DOPS) was obtained using thermal shape fluctuation spectroscopy of quasi-spherical vesicles in acidic aqueous solutions with fixed ionic strength. The surface potential of SOPC-DOPS membranes was deduced from electrokinetic measurements and its dependence on pH and also on the DOPS molar content in bilayers was obtained. The values reported for the bending rigidity of SOPC-DOPS membranes are discussed in the frame of the existing theory for the electrostatic contribution to the bending modulus of charged lipid bilayers.

The experimental data about the mechanical and the electromechanical properties of lipid bilayers and native membranes were collected and an overview on the existing methodology for their measurements was performed. The emphasis was put on the investigations of the membrane bending elasticity with a particular attention to its alteration by the presence of biologically significant molecules such as cholesterol, carbohydrates, or amphiphilic peptides.

The study of the influence of cholesterol on the bending elasticity modulus of SOPC membrane in a wide interval of concentrations was finalized.

The influence of nanoparticles of different sizes and composition (cobalt ferrite, iron oxide with and without silicon coating, nanodiamond with different purification) with fixed concentration in the water phase on the bending elasticity of synthetic membrane was studied. Some of the nanoparticles reduced the bending elasticity modulus of the lipid membrane, for others we did not observe any change in the elastic properties in the frames of the experimental error.

PUBLICATIONS:

J. Genova, V. Vitkova, I. Bivas, Registration and analysis of the shape fluctuations of nearly spherical lipid vesicle, Phys. Rev. E 88 (2013) 022707, ISSN: 1539-3755.

M. Fosnarič, S. Penič, A. Iglič, and I. Bivas, Thermal fluctuations of phospholipid vesicles studied by Monte Carlo simulations, Advances in Planar Lipid Bilayers and Liposomes 17, Academic Press, London, (2013) 331–358, ISBN: 9780124115163

Vitkova, V. and A.G. Petrov, Lipid Bilayers and Membranes: Material Properties, in Advances in Planar Lipid Bilayers and Liposomes, A. Iglic, J. Genova (Eds), Academic Press: Burlington, vol.17, (2013), p. 89-138, ISBN: 9780124115163

J. Genova, Marin Mitov lectures: Measuring bending elasticity of lipid bilayers, Advances in Planar Lipid Bilayers and Liposomes 17, Academic Press, London, (2013) 1–27. ISBN: 9780124115163, ISSN: 1554-4516.

D. Mitkova, A. Stoyanova-Ivanova, S. Georgieva, P. Todorov, N. Kozarev, Y. Ermakov, V. Vitkova, Charged lipid bilayers in aqueous surroundings with low pH, in: A.Iglic, C. Kulkarni (Eds.), Advances in Planar Lipid Bilayers and Liposomes, Academic Press, Burlington, Volume 18, (2013), 1–20, ISBN: 9780124115156

H.P.Hinov, J.I.Pavlič, L.Todorova, Y.G.Marinov, S.Sridevi, M.G.Slaveykova, A.G.Petrov, P.M.Rafailov and U.Dettlaff-Weglikowska, Influence of Carbon Nanotubes and a Phospholipid Surface Layer on the Electrooptic Behavior of a Homeotropic Nematic E7, In: New Developments in Liquid Crystals and Applications, Chapter 6, P.K. Choudhury, Ed., Nova Science Pub., Inc., New York, USA, (2013), 151-198; ISBN: 9781626187405.

PARTICIPATION IN SCIENTIFIC FORUMS:

1. FEBS Workshop “Biological Surfaces and Interfaces”, 30 June-5 July 2013, Sant Feliu de Guixols, Barcelona, poster: "Bending rigidity of charged membranes studied experimentally in aqueous solutions with low pH", D Mitkova, Y. A. Ermakov and V. Vitkova.

2. 27th Conference of the European Colloid and Interface Society, 1–6 September 2013, Sofia, poster: "Bending elasticity of lipid bilayers at low pH values of the surrounding aqueous solutions", D. Mitkova, Y. A. Ermakov, and V. Vitkova
3. 27th Conference of the European Colloid and Interface Society, 1–6 September 2013, Sofia, poster: “Influence of iron oxide nanoparticles on bending elasticity and bilayer fluidity of phosphotidylcholine liposomal membranes”, P. B. Santhosh, S. I. Kiryakova, J. Genova, N. Poklar Ulrih

4. 27th Conference of the European Colloid and Interface Society, 1–6 September 2013, Sofia, poster: “Cholesterol Influence on the Bending Elasticity of Lipid Membranes”, J. Genova, I. Bivas and R. Marinov

5. X Anniversary poster session for young scientists, PhD students and students of Chemical Technology and Metallurgy, Sofia, 17 May 2013, Sofia, poster: “CHARGED LIPID MEMBRANES AT LOW pH”, D. Mitkova, Ch. Girginov, St. Georgieva, A. Stoyanova-Ivanova, N. Kozarev, and V. Vitkova

6. XVI Winter Workshop for PhD students and Young Scientists “Interdisciplinary Physics” Vitosha, 6-8 December 2011, София, oral presentation: “Elastic properties of two component lipid bilayers in aqueous solutions with controlled pH”, D. Mitkova and V. Vitkova

7. 27th Conference of the European Colloid and Interface Society, poster: "Lyso- and ω3-containing phosphatidylcholines affect the elastic properties of lipid membranes", V. Vitkova, D. Mitkova, R. Georgieva, and G. Staneva

8. II National Congress of Physical Sciences, 25–29 September 2013, Sofia, poster: "Investigations of charged lipid membranes in aqueous solutions with pH 5", D. Mitkova and V. Vitkova

9. II National Congress of Physical Sciences, 25–29 September 2013, Sofia, poster: "Viscoelastic properties of erythrocyte suspensions related to the cell dynamics in flow”, V. Vitkova, A. Farutin, B.Polack, C. Misbah, Th. Podgorski

10. II National Congress of Physical Sciences, 25–29 September 2013, Sofia, lecture: „Elastic properties of model and native membranes – theoretical and experimental investigations” V. Vitkova, J. Genova, I. Bivas

11. II National Congress of Physical Sciences, 25–29 September 2013, Sofia, poster: „REALIZATION OF MARİN MITOV IDEA FOR THE STROBOSCOPIC ILLUMINATION USED IN OPTICAL MICROSCOPY,” Julia Genova, Janez. I. Pavlič

12. II National Congress of Physical Sciences, 25–29 September 2013, Sofia, poster: „FIBRONECTIN-COATED COMPOSITES OF POLYMER AND NANODIAMOND PARTICLES” T. Hikov, I. Tsvetanov, E. Radeva, N. Krasteva, R. Presker, J. Genova and L. Pramatarova,

13. II National Congress of Physical Sciences, 25–29 September 2013, Sofia, poster: “Protein adsorption on composite layers of the type Ag-nanoparticles/polymer”, I. Tsvetanov, T. Hikov, E. Radeva, N. Krasteva, R. Presker, J. Genova and L. Pramatarova

14. II National Congress of Physical Sciences, 25–29 September 2013, Sofia, lecture: "Investigation of lipid – water system by means of nuclear magnetic resonance", R. Marinov and A. Derzhanski

15. II National Congress of Physical Sciences, 25–29 September 2013, Sofia, poster: "Evaluation of short-term and long-term stability of emulsions by centrifugation and NMR", S. Tcholakova, R. Marinov, N. Denkov, I. Ivanov

16. 15th International workshop on Nanoscience and Nanotechnology, NANO 2013, 21 - 23 November 2013, poster: "Bending elasticity of lipid membranes in presence of nanodiamond particles in the aqueous solution", D. Haustov, T. Hikov, D. Mitev, I. Tsvetanov, L. Pramatarova and J. Genova

ONGOING RESEARCH PROJECTS:

1. DMU03-80/2011 "The deformability as a key feature of biomembranes and the influence of biologically relevant substances on it – experimental studies on model systems" (National Science Fund, Bulgaria)

2. Bilateral Research Project /ISSP – BAS and ULB – Brussels/: „Thermal fluctuations of lipid membranes studied via digital holography" (Bulgarian Academy of Sciences and Wallonie-Bruxelles International, Belgium)

3. Bilateral Research Project /ISSP – BAS and the Frumkin Institute of Physical Chemistry and Electrochemistry – RAS/: „Mechanical and electrostatic properties of lipid membranes" (Bulgarian Academy of Sciences and Russian Academy of Sciences)

4. COST Action TD1104 "European network for development of electroporation-based technologies and treatments" (Acronym: EP4Bio2Med)

DIVISION SOFT MATTER PHYSICS

LABORATORY

BIOMOLECULAR LAYERS

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TOTAL STAFF: **4**
RESEARSCH SCIENTISTS: **3**

Acad. A. G. Petrov; Assist. Prof. L. Todorova; M. Dencheva-Zarkova, Chem. Engineer

RESEARCH ACTIVITIES:

In 2013, science activity of BML laboratory comprises investigations on dielectric flexoelectric and electro-optical properties of nematic liquid crystals (LC).

Electric field effect on second harmonic generation (SHG) in some nematic liquid crystals with an electric field controlled surface polarization was investigated using spatial scan of the LC sample. 5CB, MBBA and BMAOB nematic liquid crystals have been studied. The method of spatial distribution of SH intensity across the sample has demonstrated a correlation between SHG in the absence and in the presence of the electric field. The complex origin of the observed Electric Field Induced SH (EFISH) has been revealed.

We have observed for the first time the formation of transient magnetic field-induced walls matching the planar orientation of the director at the two boundaries with the orientation of the director at the bulk. The magnetic walls appear in thick cells (with a thickness of 50 μm and above) at very good planarity of the nematic layer and a slow increase of the field. They are transient and disappear in a few seconds (thick cells) or in a split second (thin cells). In thick cells and imperfect planar orientation of the director, we have observed stable walls containing sharp disclinations (probably of strength ± ½) in their structure. In the case of thinner nematic cells with thickness of either 10 μm or 20 μm, we have observed only the well-known Fréedericksz transition. A simple model is suggested incorporating reverse-twisted regions along Y direction and appearance of a system of Becke lines. We have observed the lines of Becke in the real focusing plane of the images. They relax to the initial one-dimensional Fréedericksz transition via three-dimensional twist-splay-bend deformations.

PUBLICATIONS

1. Y.G.Marinov, G.B.Hadjichristov, A.G.Petrov, S.Marino, C.Versace and N.Scaramuzza, Electro-optical response of polymer-dispersed liquid crystal single layers of large nematic droplets oriented by rubbed Teflon nanolayers, J. Appl. Phys. 113, 064301 (2013), ISSN: 0021-8979

2. Y.G.Marinov, G.B.Hadjichristov, A.G.Petrov, S.Marino, C.Versace, N.Scaramuzza, Selective Amplitude-Frequency Electro-Optical Modulation by Polymer-Dispersed Liquid Crystal Films Aligned by Teflon Nanolayers, C. R. Acad. bulg. Sci. 66, 819-826 (2013), ISSN: 1310-1331

3. H.P.Hinov, J.I.Pavlič, L.Todorova, Y.G.Marinov, S.Sridevi, M.G.Slaveykova, A.G.Petrov, P.M.Rafailov and U.Dettlaff-Weglikowska, Influence of Carbon Nanotubes and a

Phospholipid Surface Layer on the Electrooptic Behavior of a Homeotropic Nematic E7, In: New Developments in Liquid Crystals and Applications, Chapter 6, P.K. Choudhury, Ed., Nova Science Pub., Inc., New York, USA, (2013), 151-198, ISBN: 978-1-62618-740-5
4. M.Dencheva-Zarkova, S.Naydenova and AG.Petrov, Interaction of Cadmium and Mercury Ions with Bilayer Lipid Membranes Containing Channels, In: A Tribute to Marin D. Mitov, Vol 17, Adv. Planar Bilayers & Liposomes, Chapter 10, Ales Iglic and Julia Genova, Ed., UK: Academic Press, 2013, pp. 287-297. ISBN: 978-0-12-411516-3

CITATIONS FOR 2013 - 27

ONGOING RESEARCH PROJECTS

1. Bilateral scientific contract between the Russian Academy of Sciences and the Bulgarian Academy of Sciences:
"Preparation and investigation of organic nano-structure for optoelectronics" (2012-2014)
2. Projects, additionally financed by contracts with Ministry of Education and Science:
Indo-Bulgarian intergovernmental programme, contract DNTS/ India 1/04, NSF, "Investigations of Photostimulation Effects in Nano-Structured Liquid Crystals".

TEACHING ACTIVITIES

Academician Alexander G. Petrov - lecture courses on Bioelectronics for Faculty of Chemistry and Pharmacy, Sofia University "St. Kliment Ohridski".

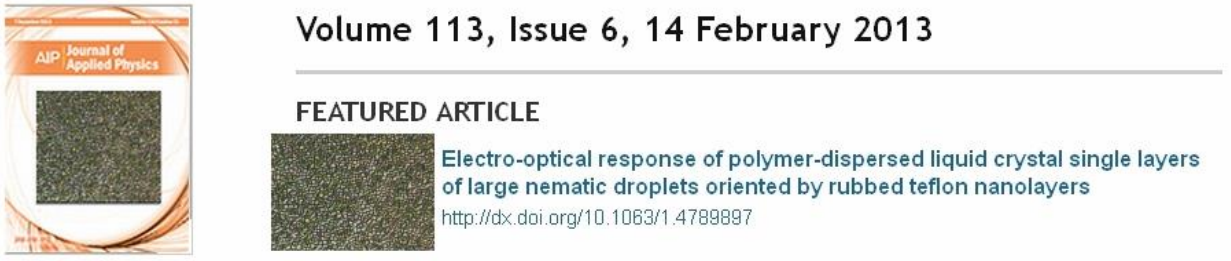

Fig.1 Cover page of J Appl Phys introducing our article: Electro-optical response of polymer-dispersed liquid crystal single layers of large nematic droplets oriented by rubbed Teflon nanolayers, Y.G. Marinov, G.B. Hadjichristov, A.G. Petrov, S. Marino, C. Versace and N. Scaramuzza, J. Appl. Phys. 113, 064301 (2013). ISSN: 0021-8979

DIVISION LASER, ATOMIC, MOLECULAR AND PLASMA PHYSICS

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TOTAL STAFF: **11**
RESEARCH SCIENTISTS**: 6**

Assoc. Prof. Dr. M. Stefanova, Assoc. Prof. Dr. V. Mihailov, Assoc. Prof. Dr. E. Dimova, Assoc. Prof. Dr. G. Malcheva, Assist. Prof. Dr. B. Torosov, Assist. Prof. Dr. V. Steflecova, Dr. T. Tenev, Physicist D. Yordanova, Physicist G. Dobrev, Physicist I. Temelkov, Physicist V. Tankova

RESEARCH ACTIVITIES:

Atomic structure and properties

Radiative lifetimes of 18 exited states of Tb I have been experimentally determined by time-resolved laser-induced fluorescence method (TRLIF). The radiative lifetime's data for 9 states have been measured for the first time. The data for the radiative lifetimes and transition probabilities of TbI have important application in astrophysics for investigation of Galaxy evolution as well as the Stars, containing rear-earth elements. The results are published in Physica Scripta.

Classical and Quantum optics

New type of broadband retarders and narrowband polarization filters have been described and experimentally tested. The new devices have been developed by application of the analogy of the theoretical model based on the composite pulses from nuclear and quantum physics to classical optics. The composite broadband polarization retarders and narrowband polarization filters are designed from a set of standard optical wave-plates with equal thickness and each of them twisted at estimated angles. The method has been applied for different types of wave-plates (achromatic, zero-order, multiple order and so on). A demonstration of the combination of two composite narrowband filters shows narrowing of the spectrum from 700nm to 10 nm width. Using the similar analogy an affective composite broadband optical isolator have been developed and experimentally tested. The results have been published in journal of Applied Optics.

A simple realization of a quantum simulator of Zeta function of Riemann is proposed by a Hamiltonian in which the interaction is of the "most - close neighbor". A theory of the composite stimulated Raman adiabatic passage, wherein the substantially improved accuracy of STIRAP using composite pulse pairs is developed. A theory of "shortcut" to adiabaticity based on non-Hermitian Hamiltonians is proposed. It is shown how to cancel noadiabatic losses and achieve arbitrarily fast transmission densities by adding imaginary member in the non-diagonal elements of Hamiltonian of a system with two levels. The stabilization theory of Kapitza in the complex plane is extended, i.e. in the case of the imaginary oscillating potentials. At high frequencies, the spectrum of quasienergies proved entirely real, but with an important difference in the case of real potential, which is related to the existence of the connected states. Potential applications can be found in the stabilization of optical resonators. The results of these studies are published in four articles in Phys. Rev. A.

Analytical spectroscopy

An experimental setting for investigation the influence of the magnetic field on the shape, parameters and illuminated spectrum in the Grimm lamp was built. For these experiments a modified Grimm lamp (Ferreira`s design) operating in flow mode has been used. Initial studies were carried out on the operating mode of the discharge with / without magnetic field. The influence of the intensity of the magnetic field on the shape of the discharge, and the change of the intensity of the emitted spectrum of helium in Grimm lamp have been investigated. There was a contraction of the plasma on the axis of the discharge and reducing the voltage drop on the lamp when turning on the magnetic field. At -110 Gauss value of magnetic field, double the intensity of the lines of the buffer gas of helium is recorded.

Studies on laser ablation in a hollow cathode discharge for the purpose of spectral analysis have been continued. The dependence of the emission signal of the laser -induced plasma on the presence and pressure of the surrounding atmosphere has been examined. The intensity of the analytical signals by laser ablation in the discharge in the hollow cathode as a function of the distance the sample – cathode has been tested. Spatial separation of the process of ablation and excitation ablated atoms is achieved. The optimal conditions in which amplification in the intensity of spectral analytical lines are established. Under construction is a new experimental setting for laser ablation in a hollow cathode, allowing operation in flowing buffer gas.

The next four experiments have been performed in close collaboration with colleagues from Laboratory for Metal Vapour Lasers. Elemental compositions are defined in 60 bronze artifacts from the Late Bronze Age (1600-1100 BC), found in the prehistoric settlement ballet by LIBS and ED-XRF techniques. Results are available for the quantification of the contents of Tin and Lead in them. The results will help to clarify the development of metallurgy in ancient times and prepared for publication in a special monograph devoted to the prehistoric settlement ballet.

Initial elemental analysis of pottery fragments, painted with white clay from the Late Bronze Age (II millennium BC), found in Ovchartsi – Municipality has been made. The purpose of the analysis is to identify the materials from which is made white substance used for inlay - whether used crushed minerals, clay or animal bones. Due to the complexity of the task, more thorough and different types of analyzes will be done.

Technological materials from the processing of the ore in Assarel Medet were investigated by LIBS analysis. The developed methods and apparatus may be used for remote and real-time control of the element composition in the synthesis of novel materials and other processes, as well as for control and diagnostic of environmental pollution, pollution in industrial areas abandoned and others, which will allow finding new areas of application.

Laboratory system for laser-fluorescence analysis was built on and was optimized. Prepared a wide range of new reference samples of dyes, pigments and binders with which are made preliminary experiments. Initial experiments for laser-fluorescence analysis with temporal resolution have been made.

Plasma physics

The investigations for creation of a miniature analytical detector for different gases admixture have been continued. The established method of Electron Collision Spectroscopy (ECS) stands the foundation of new direction of analyzing of gas impurities at high pressure. Registration and identification of atomic and molecular impurities of: 1 ‰ Ar, 6 ‰ Kr, 0.5 ‰ CO2 and 1 ‰ N2 in primary He gas at pressures from 50 to 220 Torr have been performed for the first time. An analysis of Pt and Ag atoms by registration of these metals in primary gas Ar has been carrying out. Results of studies carried reveal the potential of the

method ECS to work at high pressures and creation of innovative portable gas detector, which is used in environmental monitoring, controlled atmosphere in the production process, detection of hazardous and explosives safety systems.

PUBLICATIONS:

1. G Malcheva, L Engström, H Lundberg, H Nilsson, H Hartman and K Blagoev, 2013, Physica Scripta. Vol.88, №4, 045304 doi:10.1088/0031-8949/88/04/045304, Lifetime measurements of even and odd states in neutral terbium (Tb I).
2. K. Blagoev, M. Grozeva, G. Malcheva, and S. Neykova - **Spectrochimica Acta Part B: 79-80** (2013) 39-43, *Investigation by Laser Induced Breakdown Spectroscopy, X-Ray Fluorescence and X-Ray Powder Diffraction of the Chemical Composition of White Clay Ceramic Tiles from Veliki Preslav.*
3. E. St. Dimova, D. Comparat, A. A. Rangelov, G. St. Popkirov, and N. V. Vitanov, **Appl. Opt., v. 52, No. 34** (2013), *Efficient broadband composite optical isolator.*
4. Boyan T. Torosov, Giuseppe Della Valle, and Stefano Longhi, **Phys. Rev. A 87**, 032103 (2013) *Quantum simulation of the Riemann-Hurwitz ζ function*.
5. Boyan T. Torosov and Nikolay V. Vitanov, **Phys. Rev. A 87**, 043418 (2013) *Composite* stimulated Raman adiabatic passage.
6. Boyan T. Torosov, Giuseppe Della Valle, and Stefano Longhi, **Phys. Rev. A 87**, 052502 (2013) *Non-Hermitian shortcut to adiabaticity.*
7. Boyan T. Torosov, Giuseppe Della Valle, and Stefano Longhi, **Phys. Rev. A 88**, 052106 (2013) *Imaginary Kapitza pendulum*.

INTERNATIONAL COLLABORATION:

1. Institute of Physics Beograd, Serbia

EDUCATION:

One for master degree (supervisor Dr. G. Malcheva) prepared their diploma work in the Laboratory.

ONGOING PROJECTS:

1. Laser Diagnostics in archaeology DO 02-274/2008 with NSF
2. Physics of atoms, molecules and plasma – project in the framework of Bulgarian Academy of Sciences.
3. EURATOM – "Transport of W atoms and ions near the wall"
4. New techniques for quantum control and their application – NSF
5. N-BODY INTERACTIONS IN GAS COLD RYDBERG ATOMS - Drila 01/4 - NSF

DIVISION LASER, ATOMIC, MOLECULAR AND PLASMA PHYSICS

LABORATORY

METAL VAPOUR LASERS

HEAD: **Assoc. Prof. Margarita Grozeva, Ph.D.**
tel./fax: (+359 2) 979 5717; e-mail: margo@issp.bas.bg

TOTAL STAFF: **17**
RESEARCH SCIENTISTS: **10**

Prof. Nikolay **Vuchkov**, D.Sc.; Assoc. Prof. Dimo **Astadjov**, Ph.D.; Assoc. Prof. Todor **Petrov**, Ph.D.; Assoc. Prof. Krassimir **Temelkov**, Ph.D.; Assist. Prof. Krassimir **Dimitrov**; Assist. Prof. Vesselina **Gentcheva**, Ph.D.; Assist. Prof. Peter **Zahariev**, Ph.D.; Assist. Prof. Lubomir **Stoychev**, Ph.D.; Assist. Prof. Ognian **Sabotinov**, Ph.D.; Assist. Prof. Stefka **Slaveeva**, Ph.D.; Physicist Stefan **Karatodorov**, Ph.D. student; Physicist Georgy **Yankov**, Ph.D. student, Physicist Viktoria **Atanasova**, Ph.D. student; Physicist Blagovela **Blagoeva**; Nina **Koleva**, Ph.D. student; Physicist Kaloyan **Zlatanov**

RESEARCH ACTIVITIES:

RESEARCH AND DEVELOPMENT of new laser systems; optimization of the excitation, laser efficiency and beam quality; processes in the gas discharge plasma; laser-matter interaction.

LASER APPLICATIONS in materials processing (including biological tissues); in crystallography and physical chemistry; in nonlinear optics; in medicine; in restoration and conservation of cultural heritage monuments.

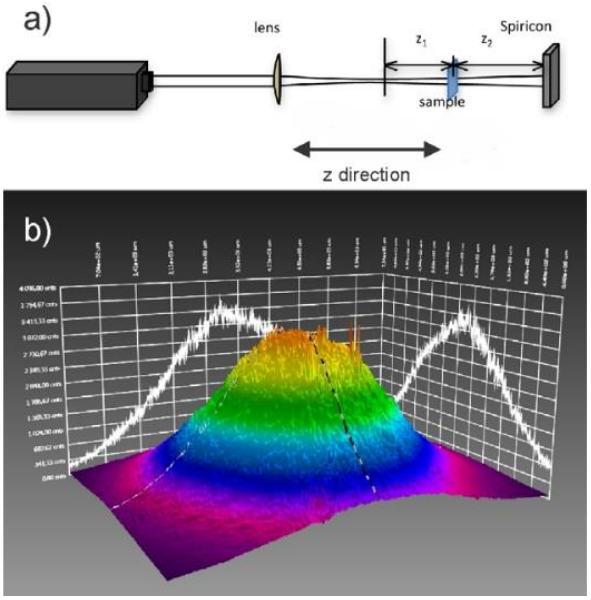
Comprehensive experimental study and theoretical analysis on the effect of spatial coherence on the focusability of annular laser beams is done. The spatial coherence fraction was computed from the interferograms recorded by a reversal shear interferometer. The resulting far-field patterns of focused annular beam were found to depend very critically on the spatial coherence of the incident beam. A theoretical analysis, based on Fourier transform of partially coherent incident light with coherent function taken as $J_1(r)/r$, is carried out. The far-field diffraction patterns are estimated numerically for the annular beams involving correlation interval and obstruction ratio. Experimental and theoretical results are in good agreement.

An active volume scaling in bore and length of a Sr atom laser excited in a nanosecond pulse longitudinal He-$SrBr_2$ discharge is carried out. Considering axial symmetry and uniform power input, 2-D model (r, z) is developed by numerical methods for determination of gas temperature in nanosecond pulsed longitudinal He-Ne-$SrBr_2$ discharge to find out the optimal temperature regime for achieving of a maximal multiline average output power.

Experimental determination of electron temperature and electron density in the discharge period of nanosecond pulsed longitudinal discharges, exciting high-power Cu^+ Ne-CuBr, He-Hg^+ and He-Sr^+ lasers, is carried out, using a simple method based on the time-resolved measurement of electrical discharge parameters, such as tube voltage and discharge current.

The optical properties of new multicomponent tellurite glassy matrixes possessing high nonlinear susceptibility were studied. The nonlinear refractive index n_2 and multiphoton

absorption β were measured using the subpicosecond *z*-scan method. The nonlinear refractive index of TBB glasses is almost one magnitude higher than the index of a standard material like fused silica. Second-harmonic generation was observed in thermo-electrically poled TBB glassy samples.



z-scan: (a) scheme of the setup and (b) typical image obtained with the beam profiler.

The combination technique of laser-induced plasma in hollow cathode discharge is investigated for which separation of the laser introduction and hollow cathode excitation is achieved by optimizing the background gas pressure and choosing the optimal sample-cathode gap length. At these conditions the discharge current is maximized to enhance the analytical lines intensity. The experimental results show that the optimal pressure for the system is 4-8 Torr. The increase of discharge current leads to enhancement of the analytical lines intensity.

The laboratory set-up for laser cleaning with nanosecond Nd:YAG laser is equipped with scanning optical guiding system which allows software control of the laser cleaning processes. Laser-induced fluorescence (LIF) laboratory set-up is expanded in order to allow laser excitation with both quasi-cw diode lasers and nanosecond pulsed Nd:YAG enabling registration of the spectrum and lifetime of LIF signal. A laboratory set-up for laser ablation and laser deposition in controlled ambient environment (type and pressure of the gas) is built.

LIBS analysis of two groups of Thracian gilded artefact, part of the museum collection of the NAIM-BAS: four horse-trappings appliqués of the Lukovit silver treasure, (4^{th} century BC) and seven horse harness appliqués of the Galiche silver treasure (2^{nd}-1^{st} century BC). The investigations are a part of an on-going study together with specialists from NAIM and IAS, aimed at reconstruction of technology of ancient gilding. The measurements are performed *in situ* at the museum exhibition room by a portable system LIBSCAN 25 for near-field measurements. The elemental composition analysis of the silver alloy and of the gilded layer at characteristic spots at the surface and in depth is done. The analysis of the recorded data has shown that the content of copper in the silver alloy is less than 0.5 % for both collections. Traces of lead and tin are also found. The in-depth profile of some gold lines shows that the gilded layer of the Lucovit treasure artifacts is much thicker than the gilded layer of the appliqués from Galiche, indicating of different gilding techniques.

The elemental composition of 60 Late Bronze Age artifacts from the prehistoric settlement of Balei is investigated by LIBS и ED-XRF analysis. Qualitative information of

lead and tin concentration in the bulk of the samples is obtained. The results of the analyses show variation of tin concentration between 7% and 17%. Investigation of the surface layer of the objects was also carried out. For most of the samples higher tin content at the surface compared to the main body of the objects is measured. The obtained results provide information of the manufacturing process of the artifacts. These investigations are performed together with colleagues of laboratory "Atomic spectroscopy" and NAIM.

INNOVATION:

One patent application is made in 2013 and 6 patents are held by laboratory members.

Nomination for "Inventor of the Year 2013" by the Patent Office and the European Patent Office for prof. N.Vuchkov, assoc.prof. K.Temelkov and prof. N.Sabotinov.

TEACHING ACTIVITIES:

In 2013 five PhD students were working in the Laboratory:

- S.Slaveeva – supervisor prof. N.Vuchkov, consultant assoc.prof. K.Temelkov;
- N.Koleva – supervisors prof. N.Vuchkov and assoc.prof. K.Temelkov;
- G.Yankov - supervisor assoc.prof. T.Petrov;
- S.Karatodorov and V.Atanasova - supervisor assoc.prof. M.Grozeva.

One student from Sofia University (K.Zlatanov) has done his MS thesis in the MVL laboratory.

A ten-day training course for three young scientists from Tomsk State University, Russia was organized by prof. N. Vuchkov and assoc. prof. K. Temelkov.

Giulio Fabbro from College Queen Mary, University of London attended two weeks intership in the Laboratory.

The traditional XVI Winter Seminar of PhD Students and Young Scientist was organized by Prof. K.Temelkov with the active participation of the young scientists of the Laboratory.

Several lectures and visits in the laboratories of were organized for groups of students from universities and schools.

PUBLICATIONS:

1. Dimo N. Astadjov, Om Prakash, 17th International School on Quantum Electronics: Laser Physics and Applications, **Proc. of SPIE Vol. 8770**, (2013) 87701O, *Experimental verification of focusability of coherent annular laser beams.*
2. Dimo N. Astadjov, Om Prakash, 17th International School on Quantum Electronics: Laser Physics and Applications, **Proc. of SPIE Vol. 8770**, (2013) 87701P, *Spatial coherence of low-cost 532nm green lasers.*
3. O. Prakash, D.N. Astadjov, P. Kumar, R. Mahakud, J. Kumar, S.V. Nakhe, S.K. Dixit, **Optics Communications 290,** (2013) 1–7; *Effect of spatial coherence on the focusability of annular laser beams;*
4. K. Blagoev, M. Grozeva, G. Malcheva, and S. Neykova - **Spectrochimica Acta Part B: 79-80** (2013) 39-43, *Investigation by Laser Induced Breakdown Spectroscopy, X-Ray Fluorescence and X-Ray Powder Diffraction of the Chemical Composition of White Clay Ceramic Tiles from Veliki Preslav.*
5. G Yankov, I Stefanov, Kr Dimitrov, I Piroeva, L T Dimowa, M P Tarassov, B L

Shivachev, H Yoneda and T Petrov, **Physica Scripta**, (2013), Phys. Scr.T157(2013) 014026 (5pp), *Measurement of nonlinear refractive index and multiphoton absorption by the subpicosecondz-scan method of tellurite multicomponent glassy matrixes having nonlinear susceptibility.*

6. Boris L. Shivachev, Krassimir Kossev, Louiz, T. Dimow, Georgi Yankov,Todor Petrov, Rositsa P. Nikolova, Nadia Petrova, **Journal of Crystal Growth 376** (2013) 41 –46, *Synthesis, growth, structural, thermal, optical properties of new metal-organic crystals: Methyltriphenylphosphonium iodide thiourea and methyltriphenyl-phosphonium iodide chloroform hemisolvate.*
7. Tatiana P. Chernogorova, Krassimir A. Temelkov, Nina K. Koleva, Nikolay K. Vuchkov, **IEEE Transactions on Plasma Science, 41**(10), pp. 3043-3047, 2013, *2D numerical modeling of gas temperature in large-volume Sr laser excited in nanosecond pulsed longitudinal He-SrBr2 discharge.*
8. K. A. Temelkov, S. I. Slaveeva, N. K. Vuchkov, **Proc. of SPIE, 8770**, art. 87701L (7 pages), *An experimental study on discharge parameters of high-power Ne-Cu+, He-Hg+ and He-Sr+ lasers excited in nanosecond pulsed longitudinal discharge*.

BOOK

1. *A. N. Soldatov, N. V. Sabotinov, E. L. Latush, G. D. Chebotarev, N. K. Vuchkov, N. A. Yudin, "*Strontium and calcium vapour lasers", Ist part, **2013** Professor Marin Drinov Academic Publishing House

PATENT

1. N.K.Vuchkov and K.A.Temelkov, appl. No. 111401 (2013), *Laser tube for strontium infrared laser with strontium halide vapours.*

ONGOING RESEARCH PROJECTS:

- Lasers, laser technologies and applications (funded by the budget subsidy of BAS).
- Laser induced fluorescence analysis for cultural heritage investigation and preservation (funded by NFS MDU 03/79 2012).
- Laser technologies and their applications (under the Academy's bilateral agreements with IFFM, Gdansk, PAN, Poland).
- Laboratory scanning system for laser cleaning (internal project funded by the ISSP).
- Lasers and Laser Assisted Anealing of nanostructures (WG 5) – part of "Research and Innovation Capacity Strengthening of ISSP-BAS in Multifunctional Nanostructures" (INERA/FP7-REGPOT-2012-2013-1).

APPLIED RESEARCH UNIT

MOLECULAR BEAM EPITAXY

HEAD: **Assoc.Prof. Gencho M. Minchev, Ph.D.**
Tel.: 9795775; e-mail:mbe@issp.bas.bg

TOTAL STAFF: **2**
RESEARCH SCIENTISTS: **2**

Assist. Prof. T. Mincheva, Ph.D.

APPLIED RESEARCH RESULTS:

A novel method for a broad range of technical or fundamental measuring tasks exploiting periodic processes or frequency sensors – i.e. for medical diagnostics, field bio-control, precise instrumentation, (nano)technological control, etc. The instrument (using the method) measures, with ultimate precision, the ratios of frequencies for a number of equal periodic processes. Its resolution is limited only by the unavoidable inherent natural phase noise of the used periodic processes or frequency sensors, so in this narrow sense no other measuring method could achieve better results. The advantages are clear: i) precision always close to the natural limits; ii) principal elimination of all internal souses of errors, imperfections and drifts; iii) an universal and "final" solution.

ONGOING RESEARCH PROJECTS:

Budget Project: "Identifying, registration and analysis of three-dimensional structure of bio-macro-molecules and cellular organelles based on bonding to sensors of a novel measuring equipment by conformal reaction".

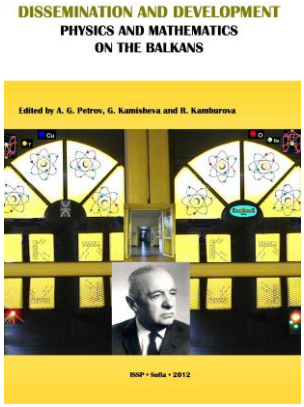
MUSEUM

HISTORY OF THE PHYSICS IN BULGARIA

CURATOR: **Assist. Prof. Ganka Kamisheva**
tel.: 979 5831, e-mail: gkamish@issp.bas.bg, skype: physmuseum

TOTAL STAFF **1**
RESEARCH SCIENTIST **1**

RESEARCH ACTIVITIES:



Reports in English and Bulgarian are published in the Proceedings of the international symposium "Dissemination and Development Physics and Mathematics on the Balkans" [1]. Two revised articles [2-3] are printed there.

From the historical point of view, discovering process has some stages. In my opinion, Elisabeth Kara-Michailova (1897 – 1968) has contribution in the one stage of process of discovery when she works in Vienna. She lays the foundation of university education and research on cosmic ray at the Sofia University (1940 – 1955) and experimental nuclear research at the Bulgarian Academy of Sciences (1955 – 1968). Biological aspects of radioactivity and low activities were her research choice. It lays radioactivity as a source of life [4].

Some Portugal scientific museums were visited during the 2013 annual meeting of the History of Physics Group at the European Physical Society [5]. Many scientific apparatuses are preserved at the Chemical Laboratory of the Lisbon National Museum of Natural History [6], in the Exhibition of Physics at the Lisbon Academy of Sciences [7], and in the Science Museum of the Coimbra University [8] from the Enlightenment.

Some articles are published [9-12] and a new one was given [13] in 2013.

PUBLICATIONS:

1. A. G. Petrov, G. Kamisheva, R. Kamburova (Eds.), Dissemination and Development Physics and Mathematics on the Balkans, ISSP, Sofia (2012) ISBN 97895491198-4-8.
2. G. Kamisheva, Origin of theoretical physics in Bulgaria, Dissemination and development physics and mathematics on the Balkans, ISSP, Sofia (2012) 34-43.
3. G. Kamisheva, A brief history of superconductivity in Bulgaria, Dissemination and Development of Physics and Mathematics on the Balkans, ISSP, Sofia (2012) 109-113.
4. G. Kamisheva, Professor Dr. Elisabeth Kara-Michailova (03.09.1897 – 22.04.1968), Proceedings of the third Joint European Symposium on the History of Physics, P. M. Schuster (Editor), Living Edition Science (2012) (In Print).
5. G. Kamisheva, Portugal Meeting, 2013 (12:26)
6. G. Kamisheva, Chemical Laboratory at the Lisbon National Museum of Natural History, 20 November 2013 (10:21) http://www.youtube.com/embed/XTl8h--jX1U?rel=0
7. G. Kamisheva, Exhibition of Physics at the Lisbon Academy of Sciences, 20 November 2013 (9:19) http://www.youtube.com/embed/VGQpnSXkqac?rel=0

8. G. Kamisheva, Science Museum of the Coimbra University, 10 November 2013 (18:42) http://www.youtube.com/embed/Nz6iLc0rx_A?rel=0
9. G. Kamisheva, The roots of theoretical physics in Bulgaria, Proceedings of the first joint European Symposium on the History of Physics, P. M. Schuster (Editor), Living Edition Science (2010) 291-306.
10. G. Kamisheva, History of science and technology in Bulgaria, Newsletter for the history of science in Southeastern Europe (2012) Nr 17, pp. 15-20.
11. Г. Камишева, Втора международна конференция "Корените на физиката в Европа, 100 години космични лъчи, Списание на БАН (6) 60-64 (2012).
12. Г. Камишева, А. Г. Петров, Сладкодумникът на българската физика, Н. Балабанов, Откровения, Унив. Изд. Паисий Хилендарски, Пловдив (2012) с. 204-210.
13. Г. Камишева, Типология на историческите извори за ретроспективно познание, Светът на физиката (2013) (In Print).