Bulgarian Academy of Sciences

GEORGI NADJAKOV INSTITUTE
OF SOLID STATE PHYSICS

ANNUAL RESEARCH REPORT
2015

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Dear Colleagues,

On 15th of October 2015 the Institute of Solid State Physics hosted a meeting of the Advisory Board of Science, Technology and Innovation of the Municipality of Sofia. In the frames of this initiative a "Nanotechnology Centre" was established at the Institute with funds received from the European Union for the realization of the project REGPOT-INERA within the 7th Framework Programme and the project "Upgrading technological equipment for innovative applied research on multilayer optical structures" Operational Programme "Competitiveness of Bulgarian Economy" 2007-20013. The centre was inaugurated by the Mayor of Sofia Mrs. Y. Fandakova, who visited the facility and got acquainted with the novel cutting edge equipment available at the Institute and the numerous potential applications it offers – synthesis of novel materials in the field of nanomedicine, acousto- and microelectronics, solar energy, nanophotonics, etc., as well as innovative products for industry with socially relevant applications.

During the second year of the INERA project eight new experimental systems were purchased, installed and put into operation at ISSP, namely: Atomic layer Deposition System (Beneq TFS 200); Automatic spectroscopic ellipsometer (M2000D, Woollam) Microfluidic Platform (CellASIC® ONIX, Millipore Merck); Automated Handheld Cytometer (Scepter 2.0); Compact Electrochemical Workstation (SP-200, Bio-Logic); Membrane filtration system (MaxiMem, Prozesstechnik GmbH); Experimental setup for Chemical vapour deposition (Oxford Nanofab Plasmalab 100); Femtosecond Laser System (Mai Tai SP). Several training seminars were organized, aimed at improvement of the qualification of the institute's staff and giving detailed information on the specifications and possibilities of the newly purchased equipment.

Two scientific events were organized by the Institute in the frames of the INERA project: Light in Nanoscience and Nanotechnology (19th - 23rd October 2015, Hissar) and Laser and Plasma Matter Interaction (18th - 20th November 2015, Plovdiv). They were both dedicated to the "International year of light – 2015".

The total number of publications of ISSP during 2015 is 111, 84 among them printed and 27 in press. 71 papers have been published in high impact factor or impact rank journals. The total number of citations in 2015 exceeds 1231. The monograph "Physics of Living Matter" (in Bulgarian), authored by acad. Alexander Petrov, was published by Marin Drinov Publishing House of BAS. ISSP currently holds 10 BG patents, 11 applications for patents are in procedure, 2 of which are submitted in 2015.

Plamen Ivanov received an award of the W. M. Keck Foundation (1 million Dollars) for his research on Network Physiology. Vesselin Kovachev received the Marin Drinov Honorary Medal of the Bulgarian Academy of Sciences. Doriana Malinovka was awarded with the Georgi Nadjakov prize.

The scientific teams, led by assoc. prof. Diana Nesheva and assoc. prof. Elena Nazarova were awarded for their best scientific achievements for the year 2015 in ISSP.

Two International Conferences are planned for the next year. INERA Conference "Vapour Phase Technologies for Metal Oxide and Carbon Nanostructures" will be held from 5th to 9th of July, 2016 in Velingrad, Bulgaria and the 19th International School on Condensed Matter Physics "Advances in Nanostructured Condensed Matter: Research and Innovations" will be held from August 29th to September 2nd, 2016 in Varna, Bulgaria.

Hassan Chamati

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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. The third Director (1999-2015) of the Institute of Solid State Physics was Academician Alexander G. Petrov.*

ORGANIZATION OF THE INSTITUTE OF SOLID STATE PHISICS

DIRECTORATE

Director:	Prof. H. Chamati, D.Sc.
Deputy Directors:	Prof. K. Blagoev, D.Sc. Assoc. Prof. A. Paskaleva, D.Sc.
Scientific Secretary:	Assoc. Prof. J. Genova, Ph.D.

DIVISIONS

Theory	Head: Prof. H. Chamati, D.Sc.
Material Physics	Head: Assoc. Prof. P. Rafailov, Ph.D.
Nanophysics	Head: Prof. D. Nesheva, D.Sc.
Micro- and Acoustoelectronics	Head: Assoc. Prof. A. Paskaleva, D.Sc.
Low Temperature Physics	Head: Prof. N. Tonchev, D.Sc.
Physical Optics and Optical Methods	Head: Prof. S. Rashev, D.Sc.
Soft Matter Physics	Head: Assoc. Prof. V. Vitkova, Ph.D.
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.

SCIENTIFIC COUNCIL

Chairman: Prof. D. Nesheva, D.Sc.
Deputy Chairman: Prof. I. Bivas, D.Sc.
Secretary: Assoc. Prof. E. Dimova, Ph.D.

1. Acad. A. G. Petrov, D.Sc.
2. Prof. K. Blagoev, D.Sc.
3. Prof. H. Chamati, D.Sc.
4. Assoc. Prof. A. Paskaleva, D.Sc.
5. Assoc. Prof. V. Vitkova, Ph.D.
6. Assoc. Prof. J. Genova, Ph.D.
7. Assoc. Prof. M. Grozeva, Ph.D.
8. Assoc. Prof. P. Zahariev, Ph.D.
9. Assoc. Prof. O. Ivanov, Ph.D.
10. Assoc. Prof. V. Mihailov, Ph.D.
11. Assoc. Prof. E. Nazarova, Ph.D.
12. Assoc. Prof. G. Popkirov, Ph.D.
13. Assoc. Prof. M. Primatarowa, Ph.D.
14. Assoc. Prof. P. Rafailov, Ph.D.
15. Assoc. Prof. T. Tenev, Ph.D.

DIVISION THEORY

THEORETICAL DEPARTMENT

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RESEARCH ACTIVITIES:

We addressed the critical behavior of a few classical lattice-spin O(n) models, associated with one- and two-dimensional lattices, and interacting via a pair potential restricted to nearest-neighbors and being isotropic in spin space. When the potential involves a continuous function of the scalar product, the Mermin-Wagner theorem and its generalizations exclude orientational order at all finite temperatures in the thermodynamic limit, and exclude phase transitions at finite temperatures for one-dimensional systems. We have considered here some comparatively simple functions of the scalar product which are bounded from below, diverge to $+\infty$ for certain mutual orientations, and are continuous almost everywhere with integrable singularities. Exact solutions are presented for the one--dimensional case, showing absence of phase transitions and absence of orientational order at all finite temperatures in the thermodynamic limit; for the two-dimensional case and in the absence of more stringent mathematical results, extensive simulations carried out on some of them point to the absence of orientational order at all finite temperatures, and suggest the existence of a Berezinskii-Kosterlitz-Thouless transition.

We used the fundamental in quantum optics Jaynes-Cummings model to study the response of spin ½ chain to a single mode of a laser light falling on one of the spins, a focused interaction model between the light and the spin chain. For the spin-spin interaction along the chain we use the XY model. We report here the exact analytical results, obtained with the help of a computer algebra system, for the energy spectrum in this model for chains of up to 4 spins with nearest neighbors interactions, either for open or cyclic chain configurations. Varying the sign and magnitude of the spin exchange coupling relative to the light-spin interaction we have investigated both cases of ferromagnetic or antiferromagnetic spin chains.

We constructed the Lax pairs for systems of mKdV type equations related to the Kac-Moody algebras $A_r^{(1)}$, $D_4^{(1)}$. Using these Lax operators we derived the explicit form of systems of evolutionary nonlinear partial differential equations. It is shown that these systems of equations have Hamiltonian formulation and the corresponding Hamiltonians are found. It is shown that the Lax operators for mKdV equations can be found using general operators with the help of Mikhailov reduction group. The FAS for the corresponding algebras are derived. The solution to inverse scattering problem is represented as RHP. This gives a possibility to obtain the solutions in explicit form using the dressing method. It is shown that all of the derived equations are members of hierarchy and they are related by the recursion operators. The same operators also relate the hierarchy of the corresponding Hamiltonian structures.

Neural plasticity transcends a range of spatio-temporal scales and serves as the basis of various brain activities and physiologic functions. At the microscopic level, it enables the emergence of brain waves with complex temporal dynamics. At the macroscopic level, presence and dominance of specific brain waves is associated with important brain functions. The role of neural plasticity at different levels in generating distinct brain rhythms and how brain rhythms communicate with each other across brain areas to generate physiologic states and functions remains not understood. Here we perform an empirical exploration of neural plasticity at the level of brain wave network interactions representing dynamical communications within and between different brain areas in the frequency domain. We introduce the concept of time delay stability (TDS) to quantify coordinated bursts in the activity of brain waves, and we employ a system-wide Network Physiology integrative approach to probe the network of coordinated brain wave activations and its evolution across physiologic states. We find an association between network structure and physiologic states. We uncover a hierarchical reorganization in the brain wave networks in response to changes in physiologic state, indicating new aspects of neural plasticity at the integrated level. Globally, we find that the entire brain network undergoes a pronounced transition from low connectivity in Deep Sleep and REM to high connectivity in Light Sleep and Wake. In contrast, we find that locally, different brain areas exhibit different network dynamics of brain wave interactions to achieve differentiation in function during different sleep stages. Moreover, our analyses indicate that plasticity also emerges in frequency-specific networks, which represent interactions across brain locations mediated through a specific frequency band. Comparing frequency-specific networks within the same physiologic state we find very different degree of network connectivity and link strength, while at the same time each frequency-specific network is characterized by a different signature pattern of sleep-stage stratification, reflecting a remarkable flexibility in response to change in physiologic state. These new aspects of neural plasticity demonstrate that in addition to dominant brain waves, the network of brain wave interactions is a previously unrecognized hallmark of physiologic state and function.

We systematically study how diverse physiologic systems in the human organism dynamically interact and collectively behave to produce distinct physiologic states and functions. This is a fundamental question in the new interdisciplinary field of Network Physiology, and has not been previously explored. Introducing the novel concept of Time Delay Stability (TDS), we develop a computational approach to identify and quantify networks of physiologic interactions from long-term continuous, multi-channel physiological recordings. We also develop a physiologically-motivated visualization framework to map networks of dynamical organ interactions to graphical objects encoded with information about the coupling strength of network links quantified using the TDS measure. Applying a system-wide integrative approach, we identify distinct patterns in the network structure of organ interactions, as well as the frequency bands through which these interactions are mediated. We establish first maps representing physiologic organ network interactions and discover basic rules underlying the complex hierarchical reorganization in physiologic networks with transitions across physiologic states. Our findings demonstrate a direct association between network topology and physiologic function, and provide new insights into understanding how health and distinct physiologic states emerge from networked interactions among nonlinear multi-component complex systems. The presented here investigations are initial steps in building a first atlas of dynamic interactions among organ systems.

We have employed the software package GROMACS 4.x molecular dynamics package in conjunction with the MARTINI coarse grain force field to perform our simulations. To achieve our goal, we designed a script to construct in advance general initial configurations with different shapes. We have shown that the preformed DPPC and DSPC vesicles remain thermodynamically stable throughout the simulation time, although the time step needed to

solve the equation of motion for DSPC vesicles is several orders of magnitudes smaller than that of DPPC. The success of the proposed approach enables us to “build” an initial simulation set of vesicles and to shorten the simulation time significantly.

We study a diluted Blume-Capel model of 3-state sites as an attempt to understand how some social processes as cooperation or organization happen. For this aim we study the effect of the complex network topology on the equilibrium properties of the model, by focusing on three different substrates: random graph, Watts-Strogatz and Newman substrates.

The promotion of collinear classical spin configurations as well as the enhanced tendency towards nearest-neighbor clustering of the quantum spins are typical features of the frustrating isotropic three-body exchange interactions in Heisenberg spin systems. Based on numerical density-matrix renormalization group calculations, we demonstrated that these extra interactions in the Heisenberg chain constructed from alternating S=3/2 and sigma=1/2 site spins can generate numerous specific quantum spin states, including some partially-polarized ferrimagnetic states as well as a doubly-degenerate non-magnetic gapped phase. In the non-magnetic region of the phase diagram, the model describes a crossover between the spin-1 and spin-2 Haldane-type states.

We studied the interaction of propagating solitons with impurities in two Ablowitz-Ladik chains with a complicated coupling between them numerically. The system is a discrete analog of coupled nonlinear Schrödinger equations. The interchain coupling which couples opposite sites of the Ablowitz-Ladik chains includes linear and nonlinear interactions. The soliton dynamics depends on the soliton parameters (width, velocity), interchain coupling constant and defect strength. It is obtained that solitons which are exited in one of the two chains can be perfectly switched and at the same time transmitted, trapped or reflected by the attractive impurities. The point defects do not influence the period of energy transfer and it is close to the period for the homogeneous case.

PUBLICATIONS:

1. H. Chamati and S. Romano, Classical lattice spin models involving singular interactions isotropic in spin space. Physical Review E **92** (2015) 012135; 13 pages.
2. H. Tonchev, A. A. Donkov and H. Chamati, Interaction of a single mode field cavity with the 1D XY model: Energy spectrum *J. Phys.: Conf. Ser.* **682** (2016) 012032.
3. V. S. Gerdjikov, D. M. Mladenov, A. A. Stefanov, S. K. Varbev, Integrable equations and recursion operators related to the affine Lie algebras $A_r^{(1)}$, J. Math. Phys. 56 (2015) 052702.
4. V. S. Gerdjikov, D. M. Mladenov, A. A. Stefanov, S. K. Varbev, Soliton equations related to the affine Kac-Moody algebra $D_4^{(1)}$, Eur. Phys. J. Plus 130 (2015) 106.
5. K. K. L. Liu, R. P. Bartsch, A. Lin, R. N. Mantegna and P. Ch. Ivanov, Plasticity of brain wave network interactions and evolution across physiologic states, Front. Neural Circuits **9** (2015) 62.
6. R. P. Bartsch, K. K. L. Liu, A. Bashan, P. Ch. Ivanov, Network Physiology: How Organ Systems Dynamically Interact, PLoS ONE **10** (2015) e0142143.
7. M. A. Fernandez, E. Korutcheva and J. de la Rubia, A 3-states magnetic model of binary decisions in sociophysics, arXiv eprints arXiv:1507.05111 [physics.soc-ph] (2015).
8. H. Chamati, R. Trobec and J. I. Pavlič, Peculiarities in the Study of Preformed DSPC Lipid Vesicles by Coarse Grain Molecular Dynamics, Advances in Biomembranes and Lipid Self-Assembly, in press (2016).

9. N. B. Ivanov, S. I. Petrova and J. Schnack, Alternating-spin S=3/2 and sigma=1/2 Heisenberg chain with three-body exchange interactions, arXiv eprints, arXiv:1601.05319 [cond-mat.str-el] (2016).

ONGOING RESEARCH PROJECTS:

1. "Quantum effects in nanostructured magnetic materials", project funded by the budget subsidy of BAS
2. "Field theoretical approach and numerical studies of macromolecular chains in confined geometries", Academy's bilateral agreement with Poland
3. "Low-dimensional Heisenberg spin system with three body interaction", Grant DNTS/ Germany/01/02, 3.09.2014

DIVISION THEORY

RESEARCH GROUP

THEORY OF COMPLEX CONDENSED MATTER

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

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

RESEARCH ACTIVITIES:

Fluctuation effects on the thermodynamics of metastable phases in vicinity of equilibrium points of first order phase transitions have been investigated [1, 2]. The overall order parameter, the internal energy, the Helmholtz free energy as well as the variations of these three quantities have been calculated by two methods: perturbation theory and numerical calculations. In general, the results obtained in these independent methods turn out in conformity each other. The results can be applied to interpretation of results for a great variety of symmetry-conserving phase transitions in Nature.

The effect of the anisotropy on the shape of the phase diagrams of the ferromagnetic superconductores UGe2, URhGe и UCoGe has been investigated within the framework of the phenomenological approach by Ginzburg and Landau [3]. Both crystal and Cooper-pair anisotropies have a little effect on the phase diagram shapes, while the uniaxial anisotropy of the magnetization has an essential effect. Some model limitations in the description of the phase diagrams have been pointed and discussed [3].

PUBLICATIONS:

1. D. I. Uzunov and A. Umantsev, Physica A (submitted in Dec. 2015); in press; see also, arXiv: 1512.07380; “Equilibrium fluctuations in a metastable state of a Ginzburg-Landau system”.
2. D. I. Uzunov, arXiv: 15.12.04819; “Fluctuation effects in metastable states near first order phase transitions”.
3. Diana V.Shopova and Michail D.Todorov, Phys. Lett. A, 379 (2015) 1371; “Phenomenological description of anisotropy effects in some ferromagnetic superconductors”.

INTERNATIONAL ACTIVITY:

Assessments of research projects submitted to the EC have been performed. Several referee reports for papers submitted to Phys. Rev. Lett., Phys. Rev. B, Phys. Rev. E, Phys. Lett. A, and Physica A have been carried out.

DIVISION MATERIAL PHYSICS

LABORATORY

ELECTRON-PHONON INTERACTIONS

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RESEARCH ACTIVITIES:

Over the year was worked on the European project in thematic area Security "COUNTERFOG". In the scientific collection *В. И. Пустовойт-Избранные труды* of the publishing house *Наука,* Москва were published 6 chapters. In them are described various aspects of surface photo-charge effect. In 2015 studies were carried out on the interaction of solid-surface two-phase fluid. Based on the obtained results have been developed sensors for the parameters of two-phase fluids.

The electron density and the pressure oscillations at the neutron drip point for different magnetic fields in a cold nonacreating magnetar were studied.

The influence of the relativistic corrections on the electron – nuclear and muon – nuclear isoelectronic/isomuonic systems ground state energy was analyzed.

We consider the decay of a Higgs boson to $Z\gamma$. Applying the *Cutkosky's* rules we found an analytical formula for the imaginary part of the Feynman amplitude. We recover the Feynman amplitude from its imaginary part by means of (unsubtracted) dispersion relation.

A formula for the potential measured on a laser-irradiated metal surface is derived.

The effect of 23 MeV electron irradiation on p-Si-SiO_2 structures has been studied. The oxide film is deposited by magnetron sputtering method, with film thickness of 10, 20 and 100 nm. The mechanical stress changes as a function of the irradiation dose and the oxide film thickness. SEM is applied for surface morphology to be imaged of the samples. The electron irradiation affects significantly Si-SiO_2 systems with oxide films of 10 nm and 20 nm thickness in what concerns the stress behavior, while for the thickest oxide (100 nm) it is stress insensitive. MeV electron irradiation, however, promotes drastic changes of the surface morphology of 100 nm thick films that possess a maximal surface roughness. A nano-sized grain-like microstructure is found. The mean grain size of the as-deposited and the electron beam irradiated films depends on both the film thickness and the MeV electron irradiation dose. The conclusion could be drawn that electron irradiation acts as an annealing procedure for p-Si-SiO_2 structures in the range of doses applied. With respect to the stress, annealing is especially manifested for small film thicknesses.

PUBLICATIONS:

1. Chamel, N., Fantina, A. F., **Mihailov, L. M.**, Stoyanov, Zh. K., Mutafchieva, Y. D., Peña Arteaga, D., Pavlov, R. L., Velchev, Ch. J.. Electron Captures and Neutron Emissions in Magnetic White Dwarfs and Magnetars. Nuclear Theory, 34, Heron Press, (accepted for publishing): 2015, ISSN:1313-2822, 83 - 92

2. Chamel, N., Mutafchieva, Y. D., Stoyanov, Zh. K., **Mihailov, L. M.**, Pavlov, R. L.. Landau quantization and neutron emissions by nuclei in the crust of a magnetar. Journal of Physics: Conference Series, Institute of Physics Publishing, (accepted for publishing): 2015, ISSN:1742-6588, DOI:doi:10.1088/issn.1742-6596, SJR:0.217

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5. Stoyanov, Zh. K., Pavlov, R. L., **Mihailov, L. M.**, Velchev, Ch. J., Mutafchieva, Y. D., Tonev, D., Chamel, N.. Nuclear induced effects and mass correlations in low and multiply charged helium-like ions. Journal of Physics: Conference Series, Institute of Physics Publishing, (accepted for publishing): 2015, ISSN:1742-6588, DOI:doi:10.1088/issn.1742-6596, SJR:0.217

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7. Chamel, N., Stoyanov, Zh. K., **Mihailov, L. M.**, Mutafchieva, Y. D., Pavlov, R. L., Velchev, Ch. J.. Role of Landau quantization on the neutron-drip transition in magnetar crusts. Physical Review C, 91, 6, American Physical Society, 2015, ISSN:0556-2813, DOI:http://dx.doi.org/10.1103/PhysRevC.91.065801, SJR:2.14, ISI IF:3.733

8. Davydov I., **Ivanov O.**, Svircov D., Odrinsky A., Pustovoit V.. Contactless Spectroscopy of deep levels in semiconducting materials: GaAs. “V. I. Pustovoit - Selected works”, Nauka, Moscow, 2015, ISBN:978-5-02-036939-9, 711 - 715

9. **Ivanov O.**, **Mihailov V.**, Pustovoit V. I., Abbate A., Das P.. Surface photo-charge effect in solids. “V. I. Pustovoit - Selected works”, Nauka, Moscow, 2015, ISBN:978-5-02-036939-9, 733 - 736

10. **Ivanov O.**, Svircov D., Michailova Ts., Nikolov P., Pustovoit V.. Automatized system for measuring the surface density of current carriers and electrical permittivity of conducting materials. “V. I. Pustovoit - Selected works”, Nauka, Moscow, 2015,

ISBN:978-5-02-036939-9, 737 - 741

11. Pustovoit V. I., Borissov M., **Ivanov O.**. Photon charge effect in conductors. “V. I. Pustovoit - Selected works”, Nauka, Moscow, 2015, ISBN:978-5-02-036939-9, 669 - 671

12. Pustovoit V. I., Borissov M., **Ivanov O.**. Surface photo-charge effect in conductors. “V. I. Pustovoit - Selected works”, Nauka, Moscow, 2015, ISBN:978-5-02-036939-9, 672 - 681

13. Pustovoit V. I., **Ivanov O.**. Surface charge redistribution effect in a conductor subjected to electromagnetic radiation. “V. I. Pustovoit - Selected works”, Nauka, Moscow, 2015, ISBN:978-5-02-036939-9, 681 - 685

14. Chamel, N., Fantina, A. F., **Mihailov, L. M.**, Stoyanov, Zh. K., Mutafchieva, Y. D., Peña Arteaga, D., Pavlov, R. L., Velchev, Ch. J.. Electron Captures and Neutron Emissions in Magnetic White Dwarfs and Magnetars. Nuclear Theory, 34, Heron Press, (accepted for publishing): 2015, ISSN:1313-2822, 83 - 92

15. Chamel, N., Mutafchieva, Y. D., Stoyanov, Zh. K., **Mihailov, L. M.**, Pavlov, R. L.. Landau quantization and neutron emissions by nuclei in the crust of a magnetar. Journal of Physics: Conference Series, Institute of Physics Publishing, (accepted for publishing): 2015, ISSN:1742-6588, DOI:doi:10.1088/issn.1742-6596, SJR:0.217

16. Fantina, A. F., Chamel, N., Mutafchieva, Y. D., Stoyanov, Zh. K., **Mihailov, L. M.**, Pearson, J. M., Pavlov, R. L.. Role of the symmetry energy on the neutron-drip transition in accreting and nonaccreting neutron stars. Physical Review C, American Physical Society, (accepted for publishing): 2015, ISSN:0556-2813, SJR:2.14, ISI IF:3.733

17. Kaschieva S., **Christova K.**, Starbov N., Starbova K., Dmitriev S.N.. Mechanical Properties of Si-SiO2 Structures with Magnetron Sputtered Oxide Irradiated by MeV Electrons. Nuclear Instruments and Methods in Physics Research, B, (accepted for publishing): 2015

18. Stoyanov, Zh. K., Pavlov, R. L., **Mihailov, L. M.**, Velchev, Ch. J., Mutafchieva, Y. D., Tonev, D., Chamel, N.. Nuclear induced effects and mass correlations in low and multiply charged helium-like ions. Journal of Physics: Conference Series, Institute of Physics Publishing, (accepted for publishing): 2015, ISSN:1742-6588, DOI:doi:10.1088/issn.1742-6596, SJR:0.217

DIVISION MATERIAL PHYSICS

LABORATORY

CRYSTAL GROWTH AND STRUCTURAL METHODS

HEAD: **Assoc. Prof. Peter Rafailov, Ph.D.**
tel.: 979 5718; e-mail: rafailov@issp.bas.bg

TOTAL STAFF: **8**
RESEARSCH SCIENTISTS: **6**

Prof. M.M. Gospodinov, DSc; Assoc. Prof. Z. I. Dimitrova, PhD; Assist. Prof. E. Vlaikova; Assist. Prof. L. K. Yankova; Assist. Prof. V.T. Tomov; S.T. Petrov, B.Sc.; O.B. Mihailov, Technician

RESEARCH ACTIVITIES:

During the reporting period we proceeded with investigations on the magnetocaloric effect in single crystals of hexagonal $HoMnO_3$. The maximum entropy change upon rotation from the ab-plane to the c-axis reaches 8 J/kg.K in a 7T magnetic field with associated adiabatic temperature change of 5 K.

A new composite material of $BiFeO_3$ crystallites inside a nonmagnetic glass-like matrix has been synthesized. The employed glass ceramic synthesis enables one to obtain a crystal phase with magnetic properties similar to those of single-crystalline multiferroic $BiFeO_3$ nanoparticles.

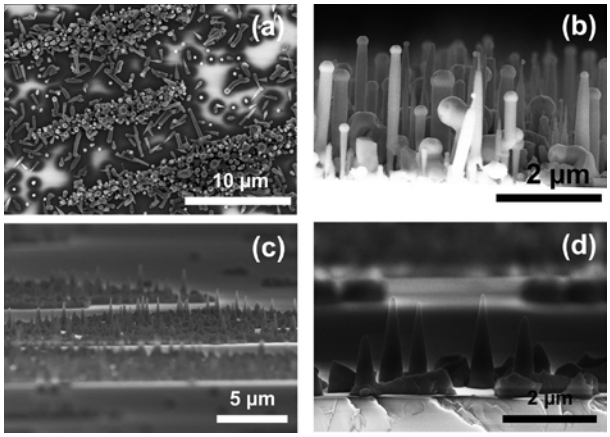


Fig. 1. SEM micrographs of the as grown InN nanorods.

Vertically aligned InN nanorods were grown on sapphire substrates. With x-ray diffraction and Raman spectroscopy it was established that they consist of hexagonal phase and are preferentially oriented along the (0001) crystal axis.

Films of a single-layer and double-layer graphene were produced by chemical vapor deposition on Cu substrates and characterized by Raman spectroscopy as grown and after transferring the graphene film on Si /SiO_2. The measured electrical properties of the single-layered graphene are promising for application as transparent electrode.

With the modified method of the simplest equation are derived solutions of the type "traveling wave" were obtained for a class of differential equations with polynomial nonlinearity. The method is exemplified by the derivation of solutions of the generalized

equation of Korteweg - de Vries or higher-order equations describing waves in shallow water. Numerical model has been studied to describe the wall motion of large arteries in pulsating blood flow.

PUBLICATIONS:

1. Balli, M, Roberge, B, Vermette, J, Jandl, S, Fournier, P, **Gospodinov, M M**. MagnetocaloricpropertiesofthehexagonalHoMnO3 single crystal. Physica B, 478, 2015, 77 - 83. SJR:0.527, ISI IF:1.319
2. **Dimitrova Z.I.**, Ausloos M.. Primacy analysis in the system of Bulgarian cities. Open Physics, 13, 1, 2015, ISSN:2391-5471, 218 - 225. ISI IF:1.085
3. **Dimitrova Z.I.**. Numerical investigation of nonlinear waves connected to blood flow in an elastic tube with wariable radius. Journal of Theoretical and Applied Mechanics, 45, 4, 2015, ISSN:0861-6663, 79 - 92
4. Egorysheva, A. V., Milenov, T. I., Ellert, O. G., Avdeev, G. V., **Rafailov, P. M.**, Efimov, N. N., Novotortsev, V. M.. Magnetic glass-ceramics containing multiferroic BiFeO3 crystals. SOLID STATE SCIENCES, 40, 2015, ISSN:1293-2558, DOI:10.1016/j.solidstatesciences.2014.12.011, 31 - 35. ISI IF:1.839
5. **Terziyska, P. T.**, Butcher K. A., **Rafailov P.**, Alexandrov D.. Growth of vertically oriented InN nanorods from In-rich conditions on unintentionally patterned sapphire substrates. Applied Surface Science, 353, Elsevier, 2015, ISSN:0169-4332, 103 - 105. ISI IF:2.711
6. Vitanov N.K, **Dimitrova Z.I.**, Vitanov K.N.. Modified method of simplest equation for obtaining exact analytical solutions of nonlinear partial differential equations: further development of the methodology with applications. Applied Mathematics and Computation, 269, 2015, ISSN:0096-3003, 363 - 378. ISI IF:1.551
7. Vitanov N.K, **Dimitrova Z.I.**. Risk analysis. Technological, political and other risks. Volume 1; Qualitative analysis of risk. , Publishing House “Vanio Nedkov”, 2015, ISBN:978 - 619 - 194 - 00, 103
8. Vitanov N.K, **Dimitrova Z.I.**. TURBULENCE. MINIMUM KNOWLEDGE FOR PH. D. STUDENTS. vol. 1. , Publishing House “Vanio Nedkov”, 2015, ISBN:978-619-194-015-8, 162

ONGOING RESEARCH PROJECTS:

Financed by the Bulgarian National Scientific Research Foundation at the Bulgarian Ministry of Education and Science:
DNFI T02/26: “Novel hybrid structures based on photorefractive crystal-liquid crystal and graphene” – December 2014.

COLLABORATION:

Funded under Academy’s bilateral agreement – joint project with the Institute of Optical Materials and Technologies – BAS and the National Chiao Tung University – Taiwan.

DIVISION MATERIAL PHYSICS

LABORATORY

BIOCOMPATIBLE MATERIALS

HEAD: **Assoc.Prof. Emilia Pecheva, Ph.D.**
tel.: 979 5699; e-mail: emily@issp.bas.bg

TOTAL STAFF: **3**
RESEARCH SCIENTISTS: **3**

Physicist Todor Hikov; Ivaylo Tsvetanov, BSc

RESEARCH AREA OF THE LABORATORY

- The research area of BCM laboratory is related to the development of methods for obtaining and characterization of new materials with biomedical and dental applications. Our themes are directly related to some of the main scientific directions of the EC as well as of the strategic tendencies and priorities accepted in the BAS, Bulgarian National Science Fund and the Bulgarian National Innovation Fund. These include "Fighting with socially important diseases", "Improving the human potential and quality of life", "Improvement of strategies, oriented to the increase the human life duration". Other theme priorities are related to "Obtaining new materials by innovative technologies", "Modeling and designing multifunctional materials", "Intelligent biomaterials for modifying or restoring of human bone".
- **Keywords:** biocompatible materials, composite layers, organosyloxane polymer-nanodiamond, laser interaction with biocompatible and biological materials.

RESEARCH RESULTS

- Te biological activity and cytotoxicity of polymer composites and nanodiamond particles with osteoblast and stem cells have been studied and was observed that the materials are not toxic and there is a good cell adhesion and spreading on the composites and in the presence of nanodiamonds. In collaboration with IBBE-BAS and SAS-Slovenia.
- The interaction of nanodiamond particles with cancer cell was studied for their use as drug carriers or local influence on cancer cells. In collaboration with SAS-Slovenia.
- The possibility to use the cavitation effect, originating around dental ultrasonic instruments to clean dental plaque or calculus was studied and it was found that the cavitation helps cleaning up dental plaque and calculus without a mechanical contact with the teeth. In collaboration with University of Birmingham, UK.

INTERNATIONAL AND NATIONAL COLLABORATION IN 2015

- Nanocomposites: Nanodiamond particles embedded in polymer layers, prepared by laser-liquid-solid-interaction (LLSI) method, National Institute for Lasers, Plasma and Radiation Physics (INFLPR), Elementary Processes in Plasma and Applications laboratory, Romania, 2013/15, Assoc. Prof. L. Pramatarova
- Novel nanobiocomposites: model systems for bone tissue engineering, University of Ljubljana, Faculty of Electrical Engineering, 2013/15, Assoc. Prof. L. Pramatarova
- The effect of the substrate's elasticity over the osteoblast differentiation of mesenchym stem cells, Assoc. Prof. N.Krasteva, IBBE-BAS, 120 000 lv for 2 years, 2013/14 (NSF)

- Biomaterials and surfaces: solid surface modification using nanodiamonds as a model for growing coatings for implants, Assoc. Prof. L. Pramatarova (project with BAS)

TRAINING IN LAB BCM:

There are 2 PhD students in the laboratory and 1 bachelor of Sciences.

INNOVATIVE ACTIVITY IN LAB BCM DURING 2015

Taking into account the interesting applications of nanodiamonds in medicine (look below), during 2015 the laboratory has begun preliminary experiments of the interaction of nanodiamonds with cancer cells. This is fairly new theme worldwide, as well as in our laboratory. A new project was submitted with SAS, Slovenia (2016/18), whose goal is to develop the work started in 2015 on this new subject.

Application of nanodiamonds in medicine: therapeutical agents for diagnostic probes, gene therapy, source for delivery, antiviral and antibacterial treatments, tissue base, and new medical devices such as nanorobots, carriers of substances like small molecules like lysosomes, vaccines and medicine. Future use for bioanalytical purposes, such as protein cleaning or fluorescent biomarkering. The use of nanodiamond as anticancer agent in health products is already giving promising results for future experiments.

PERSPECTIVES

- New project subsidized by BAS, related to laser interaction with biological tissues (teeth and bones).
- Partner in 18-month project of University of Strasbourg: "4D nanoscopy without markers"
- New project with RAS, Romania: “Precise ablation of the tooth mineral with ultrashot impulse laser. Preliminary study of optimal laser parameters”.
- New project with SAS, Slovenia: “Functionalization of nanodiamond particles for biomedical applications”.

PUBLICATIONS

1. E. Pecheva, R.L. Sammons, A.D. Walmsley, The performance characteristics of a piezoelectric ultrasonic dental scaler, Medical Engineering and Physics, 2015 http://dx.doi.org/10.1016/j.medengphy.2015.10.008, IF:1.825
2. M. Keremidarska, K. Hristova, T. Hikov, E. Radeva, D. Mitev, I. Tsvetanov, R. Presker, D. Drobne, B. Drašler, S. Novak, V. Kononenko, K. Eleršič, L. Pramatarova, N. Krasteva, Development of Polymer/Nanodiamond Composite Coatings to Control Cell Adhesion, Growth, and Functions, Advances in Planar Lipid Bilayers and Liposomes, A. Iglič, Ch.V. Kulkarni, M. Rappolt (editors), Elsevier, 2015, ch. 1, vol. 21, 2015, pp. 1-26
3. E. Radeva, T. Hikov, D. Mitev, H.Stroescu, P. Petrik, R. Presker, L. Pramatarova, Optical Characterization of Composite Layers Prepared by Plasma Polymerization, Journal of Physics: Conference Series (2016)
4. P. Montgomery, Audrey Leong-Hoi, F. Anstotz, D. Mitev, L. Pramatarova, O. Haeble, From superesolution to nano-detection: overview of far field optical nanoscopy techniques for nanostructure, Journal of Physics: Conference Series (2016)

Citations during 2015

There are 13 citations of our publications in 2015

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: **8**
RESEARCH SCIENTISTS: **6**
HONORARY MEMBERS: **2**
ASSOC. MEMBERS: **1**

Assoc. Prof. D. Arsova, Ph.D.; Assoc. Prof. Z. Ivanova, Ph.D.; Assoc. Prof. Z. Levi, Ph.D.; Assoc. Prof. I. Bineva, Ph.D.; Assist. Prof. T. Vassileva, Ph.D.; Assist. R. Dzhurkova; 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

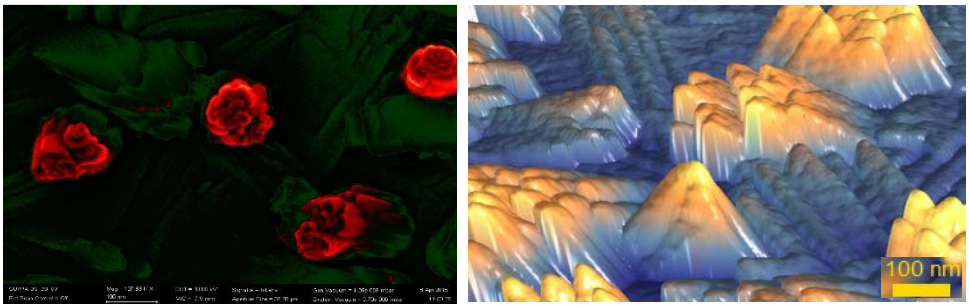
RESEARCH ACTIVITIES:

Nanostructured thin films

The influence of the film thickness on the surface morphology of tellurium thin films prepared by thermal evaporation in vacuum at low deposition rates is investigated. Formation of nanorods is observed on the surface of films with thicknesses 30 nm and 90 nm. The thickness increase to 300 nm leads to consolidation of the objects and formation of stacked nanosheets structure, resembling the bulk structure. The development of the new technology for thin films deposition, assisted by frequency modulation of the substrate during thermal evaporation in vacuum, continued with Te deposition at frequencies 0, 50, 150, 300 and 4000 Hz. Scanning electron microscopy (SEM) and atomic force microscopy (AFM) investigations reveal that, similar to the case of Se, the frequencies in the range 0-300 Hz leads to rough film surfaces, with maximum roughness at 50 Hz, while the films produced at 4 kHz are extremely smooth. Electrical and sensing properties of frequency modified structures Si/Te/aquadag with different thicknesses of the active Te layer are investigated. The observed dark current variations with varying the applied frequency are not systematic. Tentative investigations of the sensing ability of the Te films with different thicknesses towards water, ethanol, acetone, and ammonia vapours show an appreciable response only to ammonia vapours; the best sensitivity is for thinnest films (30 nm thickness) deposited at 50 and 150Hz. The investigated structures are promising for resistive sensors for ammonia.

Long term changes in the structure and morphology of $Zn_xCd_{1-x}Se$ (x = 0.4, 0.6, и 0.8) thin films produced by thermal evaporation are followed by AFM and XRD. The XRD investigations show typical solid solution patterns without any decomposition. A relaxation of the lattice is observed through the years, showing tendency towards thermodynamic equilibrium.

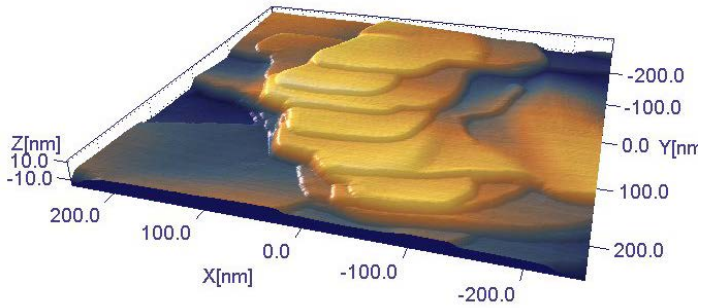
A non-uniform strain is observed for x= 0.4 and 0.8 which, as proven by AFM measurements, is due to structural defects. 2D fast Fourier transform patterns are derived from the AFM images and grain structure evolution as well as various morphological changes occurring in the films



(a) (b)

Thermally evaporated tellurium films: a) Typical nanosized layered formations of film with thickness of 300 nm - SEM image; б) 3D AFM image of clusters of nanowires, obtained at substrate vibration with frequency of 50 Hz. The colour scale maximum is 150 nm (yellow) and coincides with the thickness of the film.

with the time are observed and discussed. A progressive recrystallization with formation of layered structures is observed for x=0.8 and 0.4 composition, while for x=0.6 the process is much slower. The x = 0.6 composition is announced as the most promising for long-term applications because of its highest structural stability with time.



3D-AFM image of a $Zn_{0.8}Cd_{0.2}Se$ thin film, stored at standard room condition for 5 years. A typical example of layered structure with screw dislocation is presented.

Surface morphology of chemically deposited ZnSe and CdSe thin films is investigated. The nanocrystalline character of the films is confirmed and surface roughness, nanocrystals`mean size and size distribution are estimated. The mechanism of charge carrier transport through 3D assemblies of ZnSe and CdSe quantum dots (QDs) with zincblende structure in weak size-quantization regime is investigated. In the case of ZnSe QD assemblies, it is found that the predominant mechanism governing the charge transport in the temperature range from 380 to 650 K is thermionic emission, with the trap levels taking part in the formation of intergrain barrier being located at 0.37 eV above the middle of the band gap. The conductivity of the CdSe QDs is governed by thermally activated band-to-band electronic transitions with thermal band gap energy of 1.85 eV in the range 480 - 540 K and by thermionic emission in the lower-temperature region, down to 300 K. This study is performed together with a colleague from Macedonia.

Homogeneous SiO_x layers (x = 1.3) and composite samples Si-SiO_y (y = 1.8) containing amorphous silicon nanoparticles were irradiated on Microtron MT-25 in Dubna with 20 MeV high-energy electrons at doses 7.2×10^{14} el / cm^2 and 1.44×10^{15} el / cm^2. AFM, Raman scattering and electrical measurements were carried out on non-irradiated and irradiated layers. It is found that the electronic irradiation leads to substantial reduction in the

surface roughness of the homogeneous samples, due to the effect of annealing, and causes formation of amorphous silicon nanophase. The irradiation of composite layers improves the quality of the interface between the amorphous silicon nanoparticles and the oxide matrix and causes an appearance of new electrically active defects in the oxide matrix. This type of research is important since exposure to high energy electrons is used in medicine for both treatment of patients and disinfection.

Chalcogenide glasses and thin films

The effect of direct structure formation by photo-induced mass transport in amorphous $As_{40}S_{60-x}Se_x$ ($0 \leq x \leq 60$) thin films is studied using atomic force microscopy. The surface relief gratings are created at various wavelengths (λ = 473 - 650 nm) and the influence of λ on the diffraction efficiency (η) and the grating period (Λ) is evaluated, depending on the ratio of [S/Se] in the films composition. Maximal values of η are obtained for $As_{40}S_{30}Se_{30}$ и $As_{40}S_{20}Se_{40}$ compositions (63 and 66 %, respectively) and Λ=3.59 μm.

Optical properties of Er-doped Ge-S-In glasses are investigated by transmission and low-temperature photoluminescence (LTPL) under exposure with 628.2 nm. It is established that addition of cesium halides CsX (X = Cl, Br, I) leads to an enhanced effect of simultaneous presence of host luminescence and of 4f-4f radiative transitions of Er^{3+} ions, which is more pronounced with decreasing temperature down to 4 K. The comparison with the results for Ge-S-Ga system shows that this peculiarity is most expressed at chalcohalide GaS-CsBr glasses by maximal splitting of the main LTPL band. This effect is explained on the basis of energy transfer between the host matrix and the doping ion. The microstructural features of fluorophospate $(MnF_2)_x(NaPO_3)_{80-x}(ZnF_2)_{20}$ ($0 \leq x \leq 50$ mol%) glasses are determined by such structure-sensitive parameters as the glass transition temperature and the microhardness. The average volume of microvoids, their formation energy and the module of elasticity are calculated. The observed changes in the local ordering with increasing MnF_2 content in the glass composition are discussed.

AWARD

The group of listed below scientific works NNo1-3 was chosen by the Scientific Council of the Institute of Solid State Physics at the Bulgarian Academy of Sciences as the best research and development achievement of the Institute for the year 2015.

PUBLICATIONS:

1. Nesheva D., Nedev N., Curiel M., Dzhurkov V., Arias A., Manolov E., Mateos D., Valdez B., Bineva I., Herrera R., Application of metal-oxide-semiconductor structures containing silicon nanocrystals in radiation dosimetry, Open Physics, **13**, 63 – 71, 2015.
2. Herrera R., Curiel M., Arias A., Nesheva D., Nedev N., Manolov E., Dzhurkov V., Perez O., Valdez B., Mateos D., Bineva I., de la Cruz W., Contreras O, Structural, compositional and electrical characterization of Si-rich SiOx layers suitable for application in light sensors. Materials Science in Semiconductor Processing, **37**, 229 - 234, 2015.
3. Arias A., Nedev N., Curiel M., Nedev R., Mateos D., Manolov E., Nesheva D., Valdez B., Herrera R., Sanchez A, Application of metal-oxide-semiconductor structures for visible and near UV light sensing, Sensor Letters, **13**, 556-560, 2015.
4. Arias A., Nedev N., Nesheva D., Curiel M., Manolov E., Mateos D., Dzurkov V., Valdez B., Contreras O., Herrera R., Bineva I., Siqueiros J. M, UV Dosimeters based on metal-oxide-semiconductor structures containing Si nanocrystals, Sensor Letters, **13**, 561-564, 2015.

5. Avanesyan V.T., Dzhamgozova E.R., Arsova D, Electrical properties of chalcogenide glass of composition $Ge_8As_{32}S_{60}$, Glass Physics and Chemistry, **41**, 4, 2015.
6. Bineva I., Hristova-Vasileva T., Pejova B., Nesheva D., Levi Z., Aneva Z., Long term ageing changes in structure and morphology of nanocrystalline $Zn_xCd_{1-x}Se$ thin films, Proceedings of the International Semiconductor Conference CAS 2015, 71–74, 2015.
7. Iovu M., Lupan E., Zavadil J., Kostka P., Ivanova Z.G., Seddon A.B., Furniss D., Photoinduced surface relief grating formation in $As_{40}S_{60-x}Se_x$ thin films, Proc. SPIE, **9258,** 9258051-6, 2015.
8. Kostka P., Zavadil J., Iovu M., Ivanova Z.G., Furniss D., Seddon A.B., Low-temperature photoluminescence in chalcogenide glasses doped with rare-earth ions, J. Alloys Compounds, **648**, 237 – 243, 2015.
9. Pejova B., Bineva I., Charge carrier transport through 3D assemblies of zincblende CdSe and ZnSe quantum dots in weak size-quantization regime, Journal of Materials Science: Materials in Electronics, **26**, 4944 – 4955, 2015.

ONGOING RESEARCH PROJECTS:

Financed by the Bulgarian Academy of Sciences:

1. Preparation and properties of nanostructured and amorphous chalcogenide, oxide and nitride semiconductors and structures for applications in optoelectronics and sensorics.

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.

Financed by the contracts and programs of other international organizations:

1. Investigation of surface morphology of thin nanostructured films using scanning probe microscopy, Agreement between Bulgarian Academy of Sciences and Macedonian Academy of Sciences and Arts.

INTERNATIONAL 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. Nanostructured and amorphous semiconductor films for sensors application, National Institute for Research and Development in Microtechnology, IMT Bucharest, Romania.
3. Investigations of optical and structural properties of special glasses for photonic applications, Institute of Photonics and Electronics, Prague, Czech Republic.
4. Light-induced phenomena in chalcogenide glasses for optoelectronic applications, Riga, Latvia.
5. Studies of different transparent conductive oxide (TCO) thin films for solar energy and optoelectronics applications, Institute of Physical Chemistry, Bucharest, Romania.

DIVISION NANOPHYSICS

LABORATORY

SEMICONDUCTOR HETEROSTRUCTURES

TOTAL STAFF: **2**
RESEARCH SCIENTISTS: **2**
ASSOC. MEMBERS: ***4***
Assoc.Prof. N. Peev, Ph.D.; Assist.Prof. S. Bakalova, Ph.D.;
Assoc. Prof. A. Szekeres, Ph.D.; Assoc. Prof. S. Simeonov, Ph.D.; Prof. S. Kaschieva, D.Sc.; Prof. S. Alexandrova, D.Sc.

RESEARCH ACTIVITIES:

The main scientific research is on structure, optical and electrical properties of pulsed laser deposited (PLD) nanostructured AlN films, ZnO and TiO_2 films, deposited by chemical methods for possible applications in optoelectronic devices. The studies on Si-based heterostructures, formed on Si by low energy H^+ plasma immersion ion implantation and subsequent annealing in oxidizing ambient for possible application in innovative nanoelectronic devices have been continued. Theoretical studies of the processes at phase boundaries have also been performed.

Characterization of nanustructured AlN films synthesized by pulsed laser deposition

The first stage of the multi-stage pulsed laser deposition of AlN films was carried out at 800°C, while the second stage deposition was conducted at room temperature, 350°C or 450°C in N_2 ambient at 0.1 Pa. The analysis of the AFM images established a strong dependence of surface morphology and amplitude parameters on the substrate temperature. In the UV-VIS spectral region the refractive index values of AlN films are higher than that of amorphous AlN, suggesting formation of nanocrystals in the AlN multilayers. This is consistent with the observations from GIXRD and TEM which showed that the polycrystalline structure of the AlN layers deposited at 800°C is remarkably transferred to the ones synthesized at lower temperatures and exhibited a randomly oriented wurtzite (hexagonal) structure with nanosized crystallites. The IR ellipsometric and FTIR spectrophotometric results showed vibration bands with maximum position which is characteristic of phonon modes in crystalline hexagonal AlN.

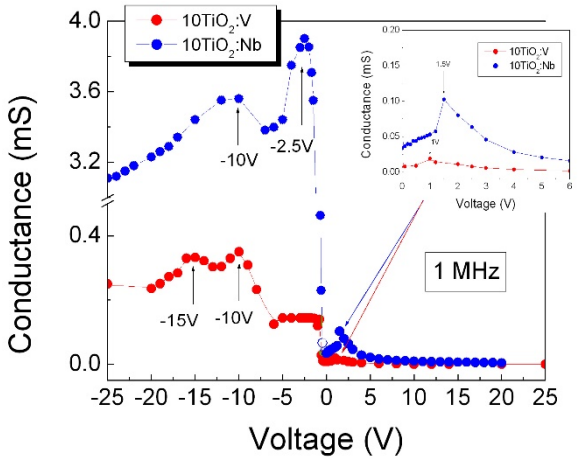
The electrical properties of PLD AlN films doped with Si, deposited at 800°C in N_2 ambient at low pressures, were also studied. It was found that the current through the layers is space charge limited, as the charge carriers were trapped in deep acceptor levels located at the adjacent crystal grains boundaries. The Si donor density in the AlN:Si film, estimated from the 1 MHz C-V characteristics of MIS structures with AlN:Si film, is of the order of 10^{18} cm^{-3}. The frequency dependence of the films resistivity revealed that the charge transport mechanism in AlN:Si film is dominated by either thermally-activated hopping or electron tunneling from occupied to nearest unoccupied deep levels.

Characterization of doped ZnO and TiO_2 films grown by chemical methods

The structure and properties of ZnO films, co-doped with donor and acceptor pair In-N has been studied. The films were grown on glass, alumina, n- and p-type Si substrates by chemical route procedures involving a sol-gel deposition, followed by hydrothermal treatment at 500°C for 1 hour. SEM imaging showed interconnected, randomly oriented nanorods with a length of a few hundred nanometers. The films crystallized in wurtzite structure with no preferred orientation, as indicated by XRD. The I-V and C-V measurements on MIS structures with In-

N co-doped ZnO films, revealed donor type defects related to charge carrier traps in the investigated films.

By sol-gel method, TiO_2 multilayers with anatase crystalline structure and doped with 1.2 at. % Nb or V were deposited layer-by layer on glass and Si substrates. The transmittance values were independent on the type of dopants and were around 80 % in the 400-1000 nm spectral range. The I-V and C-V characteristics of MIS structures with TiO_2:Nb(V) multilayers have pointed out that the doping level in the films should be equal or greater than 10^{16} cm^{-3}. The character of the I-V dependences and decrease of the specific resistivity ($\rho \sim 10^4$-10^5 Ohm.cm) by increasing the electrical field have evidenced for bulk character of the electrical conduction in the TiO_2:Nb(V) films and revealed that the current through the films is space charge limited current via deep levels with energy distribution in the energy gap of TiO_2.



Conductance-voltage characteristics of MIS structure with 10 layers of TiO_2:Nb(V). The observed maxima at different voltages testify to the presence of traps with a concentration of $N_t \sim 10^{16}$ cm^{-3} and with different energy levels in the TiO_2 band gap.

PUBLICATIONS:

1. S. Alexandrova, A. Szekeres and E. Valcheva, “Silicon Surface Modified by H+ Ion Plasma Immersion Implantation and Thermal Oxidation”, Bulg. Chem. Commun., **47**(Special Issue) B 63–70, 2015.
2. S. Simeonov, S. Bakalova, A. Szekeres, I. P. Minkov, G. Socol, C. Ristoscu, I. N. Mihailescu, Electrical Characterization of Si Doped AlN Films Synthesized By Pulsed Laser Deposition, Eur. Phys. J. Appl. Phys. **70**, 10102, 2015.

ONGOING RESEARCH PROJECTS:

1. *Financed by the Bulgarian Academy of Sciences*: Preparation and properties of nanostructured and amorphous chalcogenide, oxide and nitride semiconductors and structures for applications in optoelectronics and sensorics.
2. *Financed by the National Agency for Nuclear Energy*: Investigation of the interaction of high energy MeV electrons with nanosized silicon in silicon dioxide, Joint Institute for Nuclear Research, Dubna, Russia.

INTERNATIONAL COLLABORATION:

1. Studies of different transparent conductive oxide (TCO) thin films for solar energy and optoelectronics applications, Institute of Physical Chemistry, Bucharest, Romania.
2. Pulsed laser deposited AlN nanostructures: tunable morphologies and properties, Institute of Atomic Physics, RAN, Romania.

DIVISION MICRO- AND ACOUSTOELECTRONICS

LABORATORY

PHYSICAL PROBLEMS OF MICROELECTRONICS

HEAD: **Assoc. Prof. Albena Paskaleva, D.Sc.**
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TOTAL STAFF: **10**
RESEARCH SCIENTISTS: **6**

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

RESEARCH ACTIVITIES:

The research activities of the Laboratory are in the field of nanoelectronics and address the following topics:

• investigation of thin and ultra-thin dielectric, semiconductor and metal layers important for nanoelectronic devices 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 dielectric and electrical properties of Al-doped HfO_2 layers deposited by plasma-enhanced atomic layer deposition (PE-ALD) in dependence on the thickness and the added Al amount in the films have been investigated. It is shown that Al-doping has two effects on the trap density – 1.) it decreases the oxygen vacancy–related defects in HfO_2 (trap level at 0.7eV) and, 2) it introduces deep traps (1.2-1.4 eV) which can trap and de-trap electrons reversibly, hence can be used for charge storage. The results imply that by adding a proper amount of Al into HfO_2 it is possible to tailor dielectric and electrical properties of high-k layers toward meeting the criteria for particular applications. The doping level should be carefully optimized to obtain the desired properties of the dielectric layer (e.g., layers with reduced electrically active defects or layers with increased trapping ability) suitable for the particular application.

The electrical properties of multilayered $HfO_2/Al_2O_3/HfO_2/SiO_2$ and $ZrO_2/Al_2O_3/ZrO_2/SiO_2$ metal oxide semiconductor capacitors fabricated by magnetron sputtering were investigated to evaluate the possibility of their application in charge trapping non-volatile memory devices. High density of the stored charge and long retention times were obtained. The conduction mechanisms in structures were studied, and trap participating in the processes of the conduction and charge trapping were identified.

The resistive switching effects in metal-insulator-metal (MIM) structures with TaO_x dielectric layer have been investigated in dependence on both the deposition process parameters and the bottom electrode. The results show that the resistive switching effect is

very sensitive to the oxygen concentration in the gas ambient used for deposition. The layers with oxygen concentration gradient demonstrate the largest ratio between the ON and OFF states – this ratio reaches 120. It is demonstrated that the resistive switching effect depends not only on the type of electrode, but also on its deposition technology.

The possibility to use Metal-Oxide-Silicon (MOS) structures containing silicon nanoparticles (SiNPs) for light sensing purposes has been studied in three different gate dielectrics: single SiO_x layer (c-Si/SiNPs-SiO_x), two-layer (c-Si/thermal SiO_2/SiNPs-SiO_x) or three-layer (c-Si/thermal SiO_2/SiNPs-SiO_x/SiO_2) oxides. The results from TEM and X-ray Photoelectron Spectroscopy have proven the existence of amorphous or crystalline silicon nanoparticles in SiO_x (x=1.15) layers annealed at 700 or 1000 °C , respectively. Annealed and control MOS structures with semitransparent aluminum top electrodes were characterized electrically by current/capacitance–voltage measurements in dark and under light illumination. A strong dependence of the current at negative gate voltages on the light intensity has been observed in the control and annealed at 700 °C c-Si/SiNPs-SiO_x/Al structures. The obtained results indicate that MOS structures with $SiO_{1.15}$ gate dielectric have potential for application in light sensors in the NIR–Visible Light–UV range.

The electrical, structural and optical properties of sol-gel TiO_2 films doped with Nb and V were investigated. The chosen deposition technique provides films with high doping levels. The obtained films demonstrated excellent transparency in the visible and near infrared optical range. The deposition process, however, is accompanied by a generation of substantial amount of deep traps, which compensate the dopant element with a significant effect on the electrical conduction through the films. It was established that Nb doping results in higher density of the generated defects.

ZnO layers doped with donor-acceptor pair In-N were deposited by combination of sol-gel and hydrothermal methods on various types of substrates. The electrical and structural characteristic of the films were examined. It was shown that the deposition on glass and Si substrates provide homogenious ZnO layers, while the use of Al_2O_3 substrates leads to thinner non-homogenious layers with higher resistivity. A presence of donor-type defects responsible for the charge trapping in the films was found.

Electrical properties of ion-implanted PMMA with ultrathin planar gate nanostructured dielectric (NSD) and nanocomposite (NC) buried layer, both with a thickness of about 80 nm, are characterized. The ion implantation is carried out with low energy (50 keV) Si^+ ions at the fluence of 3.2×10^{16} cm^{-2}. The structure under study exhibits a feasible field effect which has a potential for electronic applications, e.g. in organic FET-like devices based on ion implantation-modified PMMA. The most important performance parameters, such as the charge carrier field-effect mobility and amplification of this particular type of PMMA-based transconductance device with NC *n*-type channel and gate NSD top layer, are determined.

PUBLICATIONS:

1. Paskaleva, A., Rommel, M., Hutzler, A., Spassov, D., Bauer, A.J.. “Tailoring the Electrical Properties of HfO2 MOS-Devices by Aluminum Doping”. ACS Applied Materials and Interfaces, 7, 31, 2015, 17032 - 17043. ISI IF:6.723

2. Paskaleva, A., Weinreich, W, Bauer, A.J., Lemberger, M, Frey, L.. Improved electrical behavior of ZrO2-based MIM structures by optimizing the O3 oxidation pulse time. Mater. Sci. Semicond. Proc., 29, 2015, 124 - 131. ISI IF:1.955

3. Arias, A., Nedev, N., Curiel, M., Nedev, R., Mateos, D., Manolov, E., Nesheva, D., Valdez, B., Herrera, R., Sanchez, A.. Application of Metal-Oxide-Semiconductor Structures for Visible and Near UV Light Sensing. Sensor Letters, 13, 7, American Scientific Publishers, 2015, ISSN:1546-198X, DOI:10.1166/sl.2015.3336, 556 - 560. SJR:0.216, ISI IF:0.558

4. Arias, A., Nedev, N., Nesheva, D., Curiel, M., Manolov, E., Mateos, D., Dzurkov, V., Valdez, B., Contreras, O., Herrera, R., Bineva, I., Siqueiros, J. M.. UV Dosimeters Based on Metal-Oxide-Semiconductor Structures Containing Si Nanocrystals. Sensor Letters, 13, 7, American Scientific Publishers, 2015, ISSN:1546-198X, DOI:http://dx.doi.org/10.1166/sl.2015.3337, 561 - 564. SJR:0.216, ISI IF:0.558

5. Herrera, R., Curiel, M., Arias, A., Nesheva, D., Nedev, N., Manolov, E., Dzhurkov, V., Perez, O., Valdez, B., Mateos, D., Bineva, I., de la Cruz, W., Contreras, O.. Structural, compositional and electrical characterization of Si-rich SiOx layers suitable for application in light sensors. Materials Science in Semiconductor Processing, 37, ELSEVIER SCI LTD, 2015, ISSN:1369-8001, 229 - 234. ISI IF:1.955

6. Nesheva D., Nedev N., Curiel M., Dzhurkov V., Arias A., Manolov E., Mateos D., Valdez B., Bineva I., Herrera R.. Application of Metal-Oxide-Semiconductor structures containing silicon nanocrystals in radiation dosimetry. Open Physics, 13, 2015, ISSN:2391-5471, DOI:10.1515/phys-2015-0006, 63 - 71. ISI IF:1.085

7. Novkovski N., Skeparovski A., Paskaleva A., Spassov D., Progress in materials for microelectronics and further challenges, CONTRIBUTIONS, Section of Natural, Mathematical and Biotechnical Sciences, MASA, Vol. **36,** No. 2, pp. 85–92 (2015)

COLLABORATION:

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

DIVISION MICRO- AND ACOUSTOELECTRONICS

LABORATORY

ACOUSTOELECTRONICS

HEAD: **Assoc. Prof. Velichka Georgieva, Ph.D.**
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TOTAL STAFF: **11**
RESEARCH SCIENTISTS: **5**

Prof. Lozan Spassov, Ph.D., D.Sc., Corresponding member of BAS, Honorary member of ISSP-BAS, Prof. I. Avramov, Ph.D., D.Sc.; Assoc.Prof. E. Radeva, Ph.D.; J. Lazarov Ph.D., engineer; Ts. Yordanov, researcher; Z. Raicheva, chemist; L. Vergov, engineer; Assist. Prof. K. Esmerian, Ph.D.; S. Staikov, technician; I. Mitev, technician

RESEARCH ACTIVITIES:

In 2015 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.

NO_2 gas sorption ability of thin indium tin oxide (ITO) coated quartz crystal microbalance (QCM) was investigated. ITO films were grown on AT-cut quartz resonators by RF sputtering of indium/tin target in oxygen environment. The thin films were characterized by X-ray photoelectron spectroscopy (XPS) measurements and by the method of ellipsometry. The film properties such as: structure, morphology and composition were defined. The ITO films were 150nm thick and possessed amorphous structure. The surface composition in atomic % was defined as: In-40.6%, Sn-4.3% and O-55%. The frequency shift of the QCM-ITO structures was measured at NO_2 concentrations from 100ppm to 5000ppm. The initial sensitivity of the QCM-ITO structure was found at 500ppm. The sorption/desorption processes of NO_2 were estimated for each studied NO_2 concentration. The obtained results demonstrated that the realized QCM-ITO structure could be used as gas sensor for NO_2 in the air at room temperature. Further investigations were requires in aim of improving gas-sensing properties.

The ZnO nanostructured (NS) layers as sensitive coating for NO_2 detection were studied by QCM method. The influence of the quartz roughness on the NS ZnO sorption properties was investigated also. For this purpose AT- cut quartz plates with different treated surface - flat polished and unpolished ones were used. The nanostructured ZnO layers were deposited by electrochemical method on the Au electrodes of the quartz resonators. The ZnO films were deposited by an electrochemical process from acid aqueous solution of $ZnCl_2$ ($5.\ 10^{-3}$ M) and KCl (0.5 M) with pH 4.0 at 80ºC and -1000mV (vs SCE) using a three-electrode electrochemical cell. The structure of the ZnO layers deposited on the polished and unpolished

quartz surface were studied by SEM, AFM and the optical spectroscopy - by the spectra of specular and diffused reflection. The surface morphology on the grown ZnO depends on the roughness of the quartz substrate of QCM. The results from optical measurements were compared to the corresponding data obtained for the QCM before ZnO growing. The values of reflectance decrease more pronounced after deposition of ZnO on unpolished quartz surface The sorption ability of the ZnO thin layers was defined by measuring the resonant frequency shift (Δf) of the QCM-ZnO structure in the interval of 50 - 5000 ppm NO_2 concentration. The correlation between the sorption ability of the ZnO and the different state of the quartz surface is defined from the QCM response. The QCM with ZnO deposited on the polished quartz demonstrate better sorption ability compared to QCM fabricated on unpolished quartz surface. The QCM formed on polished quartz surface shows good response to NO_2, higher sensitivity that QCM on the rough quartz substrate. The electrochemically deposited NS ZnO layer grown on QCM on polished quartz surface can be used for detection of NO_2.

Experiments were carried out in aim to study the NO_2 gas sensitivity of thin ZnO layers obtained by ALD method. Pure ZnO and doped with Li and Ni ZnO layers were investigated too. Similar studies have been conducted with TiO_2 layers - pure and mixed with other metal oxide layers synthesized by Sol-gel method. All received experimental results were presented as poster presentations at international scientific conferences. Some of obtained results are presented as articles and are in press.

Very thin (~8 nm) TiO_2 films were deposited by ALD and their sensitivity to NO_2 was studied applying the QCM method. The films were prepared using ALD deposition performed at 200 ^oC substrate temperature with titanium tetraisopropoxide (TTIP) and H_2O as precursors. The film morphology was investigated by SEM and the composition was studied by energy dispersive X-ray analysis (EDX) in a JEOL JSM-5500LV scanning electron microscope. The thickness of the films was measured by UV-Vis reflectometry. The ALD TiO_2 films were of good quality, stable and seemed capable for measurements for long terms. These very thin ALD TiO_2 films showed good sensitivity to NO_2 at room temperature and capability to register as low concentrations as 50 ppm. The sorption was fully reversible. The ALD method was found to be suitable for gas sensor applications.

The experimental investigations on the gas sorption ability of superhydrophobic (SH) carbon soot coated QCMs were carried out. The surface analyses show that the non-polar and rough soot coating alters the sensor surface into a superhydrophobic one. As a result, superhydrophobicity induces approximately 5 times lower humidity sensitivity of the carbon soot coated QCM compared to a WO_3 coated QCM. The SH QCMs demonstrate reversible gas sorption at low NO_2 concentrations, up to 500 ppm. The results validate the hypothesis that superhydrophobicity mitigates the sorption of water vapor on the sensor surface. This allows the development of QCM based NO_2 detectors with negligible sensitivity to the ambient humidity.

The gas sensitivity of the QCM coated with a layer of two-component epoxy resin and carbon nanoparticles to the vapors of various organic solvents was examined. The results confirm the hypothesis that superhydrophobicity improves the gas sorption ability of QCM, at the expense of the sorption of water vapor, allowing the development of gas sensors which can operate effectively in an environment with uncontrolled humidity.

The most commonly used metal oxide film coated acoustic wave sensors, as well as their operation principle and practical application were reported briefly. Several advantages and disadvantages of each particular acoustic wave device were identified and the selectivity of the sensors was presented and discussed.

The influence of thin mass sensitive polymer layers obtained from hexamethyldisiloxane (HMDSO) in plasma, on the temperature sensitivity of the QCM for sensor applications was studied in details. The clear dependence of the thermal stability of such devices as a function of mass sensitive layer thickness was demonstrated. This

relationship allows to predict and minimize the temperature dependence of the sensor over a range of thicknesses, in which the sensor achieves its maximum mass sensitivity. A simple practical method for correcting the sensor readings for thermally induced frequency shifts, based on an additional temperature measurement at each sensor reading, is suggested and verified experimentally.

A novel highly efficient method for stabilizing superhydrophobic carbon nanoparticle layers (patent pending) for applications in acoustic wave based liquid phase sensors has been developed. The stabilization effect is achieved by additional treatment of the nanoparticle layer with hexamethyldissiloxane (HMDSO) obtained in a RF-plasma reactor. Due to their high energy, the plasma polymer HDMSO particles penetrate deeply into the porous structure of the carbon nanoparticle layer and binds to the substrate surface. In this way, they form a stable mask that holds the carbon particles in place so that they do not get flushed away by the liquid under test. The carbon nanoparticle layers stabilized in this way retain excellent superhydrophobic properties, high durability and excellent mechanical stability when working with water based liquids.

The influence of thin mass sensitive HMDSO coatings on the thermal stability of quartz crystal microbalances (QCM) for sensor applications has been studied in detail. An unambiguous dependence of the QCM temperature stability versus HMDSO thickness has been derived. This dependence allows predicting and minimizing the thermal drift of QCM-based sensors operating in a range of layer thicknesses where maximum mass sensitivity and dynamic range is achieved.

By polymerization in a suspension of plasma - HMDSO and diamond nanoparticles (DNs) as well as modified with the silicon and silver forms of NDs - composite materials for use in bioengineering were synthesized. Morphological and structural studies of both the NDs and the composite polymer were carried out. In order to create optimum surface of biocompatible materials a controlled modification of the composite layers was achieved. Elasticity and toxicity of the obtained materials were studied. The initial adhesion, growth and functioning of osteoblastic, endothermic and stem cells obtained on hydrophilic surfaces were established experimentally. The results indicate that the diamond nanoparticles in various forms are non-toxic and can be used as fillers to increase the hydrophilicity of the resulting composite, and thereafter modulating the biological activity of the test cells.

PUBLICATIONS:

1. K D Esmeryan, V Georgieva , L Vergov, J Lazarov, “A superhydrophobic quartz crystal microbalance based chemical sensor for NO2 detection”, Bulgarian Chemical Communications, Volume 47, Number 4 , 2015 , IF: 0.349
2. H. Nichev, B. Georgieva, M. Petrov, K. Lovchinov, V. Georgieva, L. Vergov, G. Alexieva, P. Stefanov, D. Dimova-Malinovska, “Effect of quartz plate roughness on ZnO/QCM response to NO2”, Bulgarian Chemical Communications, Special issue A, 2015, IF: 0.349
3. A A Grechnikov, V B Georgieva, N Donkov, A S Borodkov, A V Pento, Z G Raicheva, Tc A Yordanov, “Comparison of different substrates for laser-induced electron transfer desorption/ionization of metal complexes”, Journal of Physics: Conference Series, 2015
4. Milena Keremidarska, Kamelia Hristova, Todor Hikov, Ekaterina Radeva, Dimitar Mitev, Ivailo Tsvetanov, Radina Presker, Damjana Drobne, Barbara Drašler, Sara Novak, Veno Kononenko, Kristina Eleršič, Lilyana Pramatarova, Natalia Krasteva, Development of Polymer/Nanodiamond Composite Coatings to Control Cell Adhesion, Growth, and Functions, In: Aleš Iglič, Chandrashekhar V. Kulkarni and

Michael Rappolt, editors, *Advances in Planar Lipid Bilayers and Liposomes, Vol. 21*, Burlington:Academic Press, 2015,Chapter 1, pp. 1-26, ISBN: 978-0-12-802116-3 © Copyright 2015 Elsevier Inc. Academic Press.

5. Karekin D. Esmeryan, Tsvetan A. Yordanov, Lazar G. Vergov, Zdravka G. Raicheva, and Ekaterina I. Radeva, Humidity Tolerant Organic Vapor Detection Using a Superhydrophobic Quartz Crystal Microbalance, IEEE SENSORS JOURNAL, VOL. 15, NO. 11, NOVEMBER 2015, pp. 6318-6325
6. Esmeryan K. D., Avramov I. D. Radeva E. I., Temperature behavior of solid polymer film coated quartz crystal microbalance for sensor applications, Sensors and Actuators B 216 (2015) 240–246.
7. Karekin D Esmeryan, Detection of Biological Environments for Endometrial Stromal and Mesenchymal Stem Cells Growth through a Quartz Crystal Microbalance Based Biosensor, Biosens J 2015, 4:2, http://dx.doi.org/10.4172/2090-4967.1000120
8. Esmeryan KD, Application of Thin Metal Oxide Films in Acoustic Wave Chemical Sensors, J Biosens Bioelectron 2015, 6:1, http://dx.doi.org/10.4172/2155-6210.1000163
9. V. Strashilov, G. Alexieva and G. Tsutsumanova, I. Kolev and I. Avramov, „Gas Adsorbtion in ZnO Nanowires as Studied by Surface Acoustic Wave Resonators", приета за печат в *Bulgarian Chemical Communications* под номер 3792 и се очаква да излезе от печат в брой 4, том 47 на списанието. Impact Factor (2014): 0,349
10. K. D. Esmeryan, E. I. Radeva and I. D. Avramov, "Durable Superhydrophobic Carbon Soot Coatings for sensor Applications", приета за печат в Journal of Physics D: Applied Physics под номер JphysD-107072.R1. Impact Factor (2014): 2,721

ONGOING RESEARCH PROJECTS:

"Investigation of devices based on different acoustic wave modes bulk (BAW) Lemb (LAW), Rayleigh (RSAW) and surface transverse waves (STW) for sensor application" 2013-2016.

"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

HEAD: **Assoc. Prof. Elena Nazarova, Ph.D.**
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TOTAL STAFF: **8**
RESEARCH SCIENTISTS: **6**

Prof. N. Tonchev, D.Sc.; Assoc. Prof. E. Vlakhov, Ph.D.; Assoc. Prof. N. Balchev, Ph.D.; Assist. Prof. A. Zahariev, Ph.D.; Assist. Prof. K. Buchkov, Ph.D.;
Technical Assistants: S. Simeonov, R. Todorov

RESEARCH ACTIVITIES:

The work of "Low temperature physics" Laboratory is related to theoretical research in condensed matter physics, obtaining and experimental studies of new superconducting materials. This activity is linked to the priority areas (New materials and new energy sources) of the Bulgarian Academy of Sciences.

THEORETICAL STUDIES

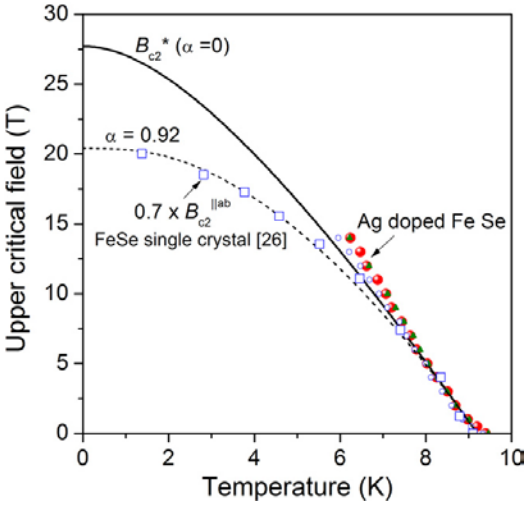
An analytical approach is developed to the problem of computation of monotone Riemannian metrics (e.g. Bogoliubov-Kubo-Mori, Bures, Chernoff, etc.) on the set of quantum states. The obtained expressions originate from the Morozova, ˘ Cencov and Petz correspondence of monotone metrics to operator monotone functions. The used mathematical technique provides analytical expansions in terms of the thermodynamic mean values of iterated (nested) commutators of a model Hamiltonian T with the operator S involved through the control parameter h. Due to the sum rules for the frequency moments of the dynamic structure factor new presentations for the monotone Riemannian metrics are obtained. Particulary, relations between any monotone Riemannian metric and the usual thermodynamic susceptibility or the variance of the operator S are discussed. If the symmetry properties of the Hamiltonian are given in terms of generators of some Lie algebra, the obtained expansions may be evaluated in a closed form. These issues are tested on a class of model systems studied in condensed matter physics.

SUPERCONDUCTING MATERIALS

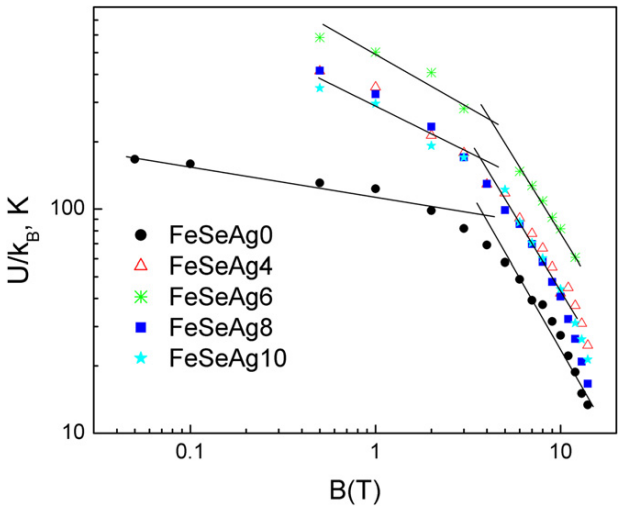
We investigated crystals and polycrystalline samples of FeSe (undoped and with silver addition). It was established that Ag is present in three different forms: at the grain boundaries, in the crystal lattice unit cell and as an Ag_2Se impurity phase. The silver addition improves the critical temperature, magnetoresistance, activation energy and upper critical field of the material, making some of these parameters comparable with those of single crystals. The Ag addition reduces the amount of the non superconducting hexagonal phase, decreases the transition width and shifts the irreversibility line to higher temperatures and magnetic fields. It is established that the silver addition disturbs the balance of carriers (electrons and holes) in this multiband superconductor and this is probably the reason for the increase of the magnetoresistance.

We obtained plate-like $Fe_{1.02}Se$ crystals (~6-8 mm^2) using the flux method. They have a domain structure due to the simultaneous growth of two phases: a tetragonal superconducting (~82%) and a hexagonal ferromagnetic one, which strongly affects the properties of the crystals. Using a series of AC and DC magnetic and electrical field measurements, we determined the main

superconducting parameters of the crystals- upper critical field, irreversibility line, anisotropy. We analyzed the AC magnetic response by the fundamental and third harmonic AC magnetic susceptibility. The latter is more sensible to the changes of the vortex dynamics: the critical state, the vortex glass – vortex liquid transition, as well as to the registration of a geometric barrier. We determined the critical current and pinning force and their temperature and field dependences by using DC magnetic measurements. The domain structure of the crystals leads to the formation of S-N-S (superconductor-normal metal-superconductor) Josephson junctions. Vortex avalanches were also identified, which is an indication that the complex morphology of the crystals change the pinning topology. The high values of the pinning energy and the upper critical field, as well as the high degree of isotropy show that the Fe-based superconductor materials may be a competitive of the cuprates in the application at high magnetic fields.



Temperature dependences of the upper critical field for Ag doped FeSe with different Ag concentrations and FeSe single crystal. The lines mark $B_{c2}(T)$ of the WHH model for Maki parameters α = 0 (orbital B_{c2}) and α = 0.92.



Field dependences of the pinning activation energy U/k_B for all the investigated samples

The chemical modification of the niobium (Nb) surface after irradiation with femtosecond laser pulses was investigated by scanning electron microscopy coupled with energy dispersive spectroscopy, atomic force microscopy, grazing incidence X-ray diffraction, and micro-Raman spectroscopy. The physical-chemical analyses indicated that the laser treatment results in oxidation of the Nb surface, as well as in the formation of Nb hydrides. Remarkably, after the samples' washing in ethanol, a strong Surface-Enhanced Raman Scattering (SERS) signal originating from the toluene residual traces was evidenced. Further, it was observed that the laser irradiated Nb surface is able to provide a SERS enhancement of ~$1.3x10^3$ times for rhodamine 6G solutions. Thus, for the first time it was shown that Nb/Nb oxide surfaces could exhibit SERS functionality, and so one can expect applications in biological/biochemical screening or for sensing of dangerous environmental substances.

EXPERIMENTAL SUPPORT

Low Temperature Physics Laboratory provides liquid nitrogen for different laboratories at the Institute of Solid State Physics, for the unique apparatus for Physical Properties Measurements (Quantum Design) and for other Institutes of Bulgarian Academy of Sciences (about 8000 liters).

PUBLICATIONS:

1. N.S.Tonchev, “Monotone Riemannian metrics and dynamic structure factor in condensed matter”, arXiv:1509.06870v1 [cond-mat.stat-mech] 23 Sep 2015
2. E.Nazarova, K.Buchkov, S.Terzieva, K.Nenkov, A.Zahariev, D.Kovacheva, N.Balchev and G.Fuchs, “The effect of Ag addition on the superconducting properties of $FeSe_{0.94}$”, Journal of Superconductivity and Novel Magnetism **28**, p.1135 (2015)
3. E.Nazarova, N.Balchev, K.Nenkov, K.Buchkov, D.Kovacheva, A.Zahariev and G.Fuchs, “Transport and pinning properties of Ag-doped $FeSe_{0.94}$”, Superconductor Science and Technology **28**, 025013 (2015)
4. E.Nazarova, N.Balchev, K.Nenkov, K.Buchkov, D.Kovacheva, A.Zahariev and G.Fuchs, “Improvement of the superconducting properties of polycrystalline FeSe by silver addition”, Superconductor Science and Technology **28**, 125013 (2015)
5. K.Buchkov, M.Polichetti, K.Nenkov, E.Nazarova, D.Mancusi, N.Balchev, D.Kovacheva, A.Zahariev, S.Pace, “Investigation of the vortex dynamics of $Fe_{1.02}Se$ crystals by fundamental and 3-rd harmonic AC magnetic susceptibility analysis”, Superconductor Science and Technology **28**, 035009 (2015)
6. A.Galluzzi, M.Polichetti, K**.**Buchkov, E**.** Nazarova, D. Mancusi, S.Pace, “Evaluation of the intragrain critical current density in a multidomain FeSe crystal by means of DC magnetic measurements” Superconductors Science and Technology **28**, 115005 (2015)
7. A.Leo, G.Grimaldi, A.Guarino, F.Avitabile, A.Nigro, A.Galluzzi, D.Mancusi, M.Polichetti, S.Pace, K.Buchkov, E.Nazarova, S.Kawale, E.Bellingeri, C.Ferdeghini, “Vortex pinning properties in Fe-chalcogenides” Superconductors Science and Technology **28**, 125001 (2015)
8. Victor G. Ivanov, Emil S. Vlakhov, George E. Stan, Marian Zamfirescu, Catalina Albu, Natalia Mihailescu, Irina Negut, Catalin Luculescu, Marcela Socol, Carmen Ristoscu, and Ion N. Mihailescu, “Surface-enhanced Raman scattering activity of niobium surface after irradiation with femtosecond laser pulses” Journal of Applied Physics **118**, 203104 (2015)

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” -EUROFUSION- *WP14-ER-01/INRNE-04*

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, Ph.D.**
Tel: 9795774; e-mail:poly-sim@issp.bas.bg

TOTAL STAF: **9**
RESEARCH SCIENTIST: **8**
Assoc. Prof. Dr. Pavlina Simeonova; Assoc. Prof. Dr. Angelina Stoyanova – Ivanova; Assoc. Prof. Dr. Vasil Lovchinov; Prof. Dr. Dimitar Dimitrov; Assist. Prof. Dr. Stanimira Terzieva; MS Mihaela Yerusalimova; PhD Student Ivana Ilievska; Technical Assistants: Plamen Zashev, Alexandar Vasev

The Laboratory of Environmental Physics deals with classification, modeling and interpretation of complex multiparametric systems from the environment using multivariate statistical methods. The other scientific directions in 2015 were: magnetic properties of the matter, porosity of construction materials, surface properties of materials and material science.

RESEARCH ACTIVITIES:

- A multivariate statistical expertise for classification of biofuel plant sources is developed. Class modeling of known plant sources is performed which allows classification of samples with unknown origin to the defined classes.
- Data sets of four types of urban aerosol samples from City of Thessaloniki, Greece are interpreted.
- Environmetric expertise of the water quality of springs from the region of Kavala municipality, Greece is realised. Possible pollution sources are defined.
- Water quality in the urban sector of Banshtitsa and Dragovishtitsa Rivers are studied and the anthropogenic impact on the rivers catchment is shown.
- Methodology for assessment of the probability for flood or drought events along the catchments of the rivers Struma and Mesta on Bulgarian territory is presented.
- The properties of nickel – titanium orthodont arches are studied using modern methods.
- The chemical composition of thermo- activated orthodontic arches with or without inclusion of copper was studied.
- The elementary composition and structure of thermo- activated orthodontic arches (TMA) having three zones of elasticity were investigated.
- The application of multi-functional materials like cuprate superconducting ceramics of the type BISCCO (2223, 2212, 2201) as additive to zinc electrode in nickel – zinc batteries aiming increase of their durability was investigated.
- Magnetic properties of monocrystals of pure $MgSO_3.6H_2O$ as well as of monocrystals doped with 0,17 atomic % Ni were studied.
- Cathodic – luminescent investigation of nanopowders $EuAlO_3$ and $GdAlO_3$ was performed.

In 2015 the activity of the "Center for investigation of physical properties of materials, surfaces and structures" successfully continued by the management of Assoc. Prof. Dr. V. Lovchinov. Series of measurements using the unique instrumentation PPMS and AFM were carried out for local and external users. In 2015 the Center contributed financially to the budget of ISSP with 19500 lv.

TEACHING ACTIVITIES:

Ph.D.Students: Ivana Ilievska (01/09/2015, Order No РД-09-123/17.07.2015г.). Supervisor: Assoc. Prof. A. Stoyanova-Ivanova. In 2015 M. Yerusalimova defended her Master of Science thesis. Assoc. Prof. Dr. V. Lovchinov taught and examined two PhD students in ISSP (special course "Physics and Technics of low temperatures"). Assoc. Prof. Dr. A. Stoyanova – Ivanova and Dr. S. Terzieva had a course of lectures and laboratory exercises on superconductivity at UCTM, Sofia, Center of Material Sciences. Prof. Dr. D. Dimitrov created a course of lectures on energy effectiveness and heat transfer. For the summer semester of the academic year 2015/2016 Prof. D. Dimitrov had totally 110 academic hours.

INTERNATIONAL COLLABORATIONS:

1. Project „Electrical and magnetic properties of Perovskite magnetic materials" within the frame of EBR with University of Liege, Belgium.
2. Project "Structural and physical studies of nanostructured materials based on porous dielectric matrices" within the frame of EBR with "A.F. Yoffe", Peterburg, Russian Academy of Sciences.
3. Project „Investigation on the structural and magnetic properties of high anisotropic magnetic structures based of hexaferrites for application in microelectronics within the frame of EBR - Polish Academy of Sciences, Wroclaw, Poland.
4. Assoc. Prof. Dr. V. Lovchinov participated in 2015 at the 83-d session of the scientific council of the International laboratory for strong magnetic fields and low temperatures in Wroclaw, Poland.
5. Project "Synthesis and structural investigations of nanomaterials" - Bilateral contract with Tallin Technological University, Estonia.

PUBLICATIONS:

1. Z. Mustafa, R. Milina, P. Simeonova, S. Tsakovski, V. Simeonov. Prediction of Class Membership of Biodiesels using Chemometrics. *J. Environ. Sci. Health, Part A,* 50 (1), (2015), 72 – 80. IF 1.61
2. T. Spanos, A. Ene, P. Simeonova. Chemometric expertise of the quality of groundwater sources for domestic use. *J. Environ. Sci. Health, Part A,* 50 (4), (2015), 1099-1107. IF 1.61
3. P. Simeonova, D. Simeonov, L. Spassov, V. Simeonov. Cluster analysis interpretation of aerosol samples. *Bulg. J. Chem.,* 4(4), (2015), in press.
4. M. Yerusalimova, P. Simeonova, V. Lovchinov, A. Sotirov. Environmetric expertise of the water quality of the urban section of Banshtitsa River. *Bulg. J. Chem.,* 4(4), (2015), in press.
5. P. Simeonova, D. Simeonov, L. Spassov, V. Simeonov. Risk assessment of extreme events along river flows in Bulgaria using integral indices. *Int. J. Adv. Earth & Environ. Sci.* 3(2), (2015), 38-50, IF 1.4
6. V.Petrov, S.Terzieva, V.Tumbalev, V. Mikli, L. Andreeva, A. Stoyanova-Ivanova, „Influence of the treatment period on the morphology and the chemical composition of the thermally activated orthodontic archwires", *Bulg. Chem. Commun.,* 47(1), (2015) 234–238, IF 0.35
7. V.Petrov, L.Andreeva, S.Terzieva, A.Stoyanova-Ivanova, D.Kovacheva, V.Mikli, I.Ilievska, "Study of the Impact of the Treatment Period on the Surface Characteristics of Nitinol Heat-Activated Orthodontic Wires", *Int. J. Sci. & Res.,* 4(4), (2015), 3190 – 3193. IF 4.43
8. V.Petrov, L.Andreeva, M.Gueorguieva, S.Terzieva, A.Stoyanova-Ivanova, V.Mikli, "Influence of the Autoclaving Processes on the Most Commonly Used Orthodontic Archwires", *Int. J. Sci. & Res.,* 4(7), (2015) 2479 – 2482. IF 4.43

9. V. I. Petrunov, L. S. Andreeva, S. I. Karatodorov, V. I. Mihailov, S. D. Terzieva, I. Ilievska, A. K. Stoyanova-Ivanova, V. G. Tumbalev, V. Mikli, "Analysis of elemental composition of a heat activated, multi-force, nickel titanium othodontic archwire", *Bulg. Chem. Commun.*, 47(1), (2015) 229–233, IF 0.35
10. A. K. Stoyanova-Ivanova, S. D. Terzieva, G. D. Ivanova, M. A. Mladenov, D. G. Kovacheva, R. G. Raicheff, S. I. Georgieva, B. S. Blagoev, A. J. Zaleski, V. Mikli, „The use of high-temperature superconducting cuprate as a dopant to the negative electrode in Ni-Zn batteries",*Bulg. Chem. Commun.*, 47(1), (2015) 41–48. IF 0.35
11. V.Petrunov, L.Andreeva, S.Terzieva, A.Stoyanova-Ivanova, V.Mikli, „Elemental composition and structure study of a heat activated multiforce, nickel titanium archwire", *Europ. J. Orthodont*., (Abstracts of lectures and scientific posters), European Orthodontic Society, 91st Congress, Venice, Italy, 2015; 37, (2015), 5.
12. L. Stoyanov, S. Terzieva, A. Stoyanova, A. Stoyanova-Ivanova, M. Mladenov, D. Kovacheva, R. Raicheff, „Superconducting BSCCO Ceramics as Additive to the Zinc Electrode Mass in the Rechargeable Nickel-Zinc Batteries", *J. Progr. Res. Chem.,* 2(2), (2015) 83 – 91. IF 4.43
13. D. Petrov, M.Zamoryanskaya, K.Guliaeva, V. Lovchinov, Cathodoluminescence of EuAlO3 and GdAlO3 nanopowders, *Optik*, 127, (2016), 107-109. IF 0.974.

CITATIONS 2015 – 78
PATENTS:
Pretenders: ISSP and IEES "Electrode mass of zinc electrode for alkaline charged batteries".
Inventors: M.Mladenov, R.Raichev, L.Stoyanov, D.Kovacheva, A.Stoyanova – Ivanova, S. Terzieva.

CONFERENCES:
1. T. Spanos, A. Ene, E. Mitkidou, P. Simeonova. Application of chemometric methods for assessment of groundwater quality in Kavala Prefecture, Northern Greece. "New Frontiers in Environmental and Water Management" March 19-21, 2015, Imaret Hotel, Kavala, GREECE (*plenary lecture*)
2. A. Vassilev, D. Dimitrov. „Establishment of modern "atrium" building as a model for sustainable energy efficient architecture", International Conference with Exhibition "Environment and Architecture" May 19-20 2015, Budva, Montenegro (*poster*).
3. Sotirov, A., Yerusalimova, M., Taseva, R., Kulkina, L., Yordanov, S. "Influence of river water contamination on distribution of fish species". SES 2015 Eleventh Scientific Conference with International Participation**,** Space, Ecology, Safety, November 4–6, 2015, Sofia, Bulgaria (*poster presentation*).
4. Sotirov, A., Jordanov, S., Yerusalimova, M., Taseva R., Kulkina, L.. "Ecological monitoring of river Dragovishtica" SES 2015 Eleventh Scientific Conference with International Participation**,** Space, Ecology, Safety, November 4–6 2015, Sofia, Bulgaria (*poster presentation*).
5. V.Petrov, A.Ivanova, A.Vasev, V.Ivanova, L.Andreeva, I.Ilievska, S.Terzieva, A.Stoyanova-Ivanova „Etude de la composition de l'élément et la morphologie des arcs orthodontiques activé thermiquement" XII Poster Session of young scientist and PhD students, UCTM, May 22, 2015 (*poster presentation*).
6. L. Stoyanov, G.Ivanova, A. Stoyanova-Ivanova, S. Terzieva, A. Stoyanova, M. Mladenov, R. Raicheff "Superconductive BSCCO ceramics as additive to the zinc electrode mass in the nickel-zinc rechargeable batteries, Sofia electrochemical days, Pravets – RSE-SEE, June 10. 2015, (*poster presentation*).

7. A.Vasev, A.Ivanova, V.Ivanova, I.Ilievska, S.Terzieva, A.Stoyanova-Ivanova "Influence of additives on the life time of nickel- zinc batteries" XII Poster Session of young scientist and PhD students, UCTM, May 22, 2015 (*poster presentation*).
8. V. I. Petrunov, L. S. Andreeva, S. D. Terzieva, A. K. Stoyanova-Ivanova, V. Mikli "Elemental composition and structure study of a heat activated multiforce, nickel titanium archwire", European Orthodontic Society, 91st Congress, Venice, Italy, 2015, June 13-18, (*poster presentation*).
9. V.Petrov, I.Ilievska, L.Andreeva, S.Terzieva, A.Stoyanova-Ivanova, D.Kovacheva, V.Mikli „Structure characteristics of Nitinol heat-activated orthodontic wires during treatment" Conference – 6th Young Researcher Meeting „L'Aquila Italy, October 12 – 14, 2015, (*poster presentation*).
10. V.Petrov, I.Ilievska, L.Andreeva, S.Terzieva, A.Stoyanova-Ivanova, D.Kovacheva, V.Mikli „Structure characteristics of Nitinol heat-activated orthodontic wires during treatment", Conference - INERA Conference 2015 „Light in Nanoscience and Nanotechnology ", October 19-23, 2015, Hissar, Bulgaria, (*poster presentation*).
11. A.Vasev, S.Terzieva, A.Stoyanova-Ivanova, M.Mladenov „Light in Nanoscience and Nanotechnology", October 19-23, 2015, Hissar, Bulgaria, (*poster presentation*).
12. I. Ilievska, S.Karatodorov, V.Mihailov, S.Terzieva, V.Petrov, L.Andreeva, A.Stoyanova-Ivanova, A.Zaleski, V.Mikli „Elemental and structural analyses of orthodontic archwire by LIBS and XRD" Conference – „LASER and plasma matter interaction" November 18-20, 2015, Plovdiv, Bulgaria (*poster presentation*).
13. G. Ivanova, S. Terzieva, L. Stoyanov, A. Stoyanova-Ivanova, A. Stoyanova, M. Mladenov, R. Raicheff "Synthesis, properties and application of BSCCO (2201) ceramics in the Ni/Zn rechargeable batteries", NaNo 2015, November 27-29, Sofia 2015 (*poster presentation*).
14. I. Ilievska, V. Petrunov, A. Ivanova, S. Terzieva „Structure and properties of thermo-activating orthodontic arches", Physics days – International year of light, TU – Sofia, April 21-25, 2015 *(oral presentation)*

ONGOING RESEARCH PROJECTS:

1. „Environmental physics" – project financed by Bulgarian Academy of Sciences.
2. „Obtaining and characterization of high-temperature superconductive ceramics for potential application in Ni – Zn batteries" – Contract for cooperation between Institute of solid state physics and Institute ot electrochemistry and energy systems.
3. EBR - „Electric and magnetic properties of Perovskite magnetic materials" with partner L'Universite de Liege, Depart, Physigue, Group SUPRA.TECS., Liege, Belgium.
4. EBR - „Structural and physical investigations of nanostructured thin layer and bulk materials based on porous dielectric matrices" with partner Department of physics of dielectrics and semi-conductors, Physicotechnical institute "Yoffe", Peterburg, Russian Federation.
5. EBR **–** „Symthesis and investigation of the structure of multifunctional materials", ISSP and Institute of Low Temperature and Structure Research, Polish Academy of Sciences.
6. Project - „Energy efficiencvy of modern atrium spaces and public buildings", (01/2015, HCU).

INTERNATIONAL COLABORATION:

Universite de Liege, Belgium, Depart. Physigue, Group SUPRA.TECS.
Physicochemical Technical Institute „A.F. Yoffe", Russian Academy of Sciences.
Institute of low temperatures and structural studies, Polish Academy of Sciences, Wroclaw.
International laboratory of strong magnetic fields and low temperatures, Wroclaw, Poland.
Tallin Technological University, Estonia.

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: **20**
RESEARCH SCIENTISTS: **17**

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.; Assoc. Prof. E. Karakoleva, Ph.D.; Assist. Prof. B. Katranchev, Ph.D.; Assist. Prof. H. Naradikian, Ph.D.; I. Milushev, Ph.D.; E. Stoyanova; M. Ilieva; Y. Velkova; Yu. Sarafov

RESEARCH ACTIVITIES:

Nanocomposites of dimer liquid crystals: We studied an array of nanocompsites, mixtures of H-linked dimer liquid crystals, alkyloxybenzoic acids (nOBA), serving as a matrix, and single walled carbon nanotubes, hydroxypyridine (HOPY), perfluorooctanoic acid (PFOA) or bent-core TK admixture D14F3. We studied the phase transitions and electrooptic effects of the obtained nanocomposites. In the studied nanocomposites we identified two types of ferroelectricity: developing in the mixtures 9OBA/HOPY, 7,8,9OBA/PFOA and developed ferroelectricity, characteristic for 8OBA/SWCNT, 8OBA/ChB. We presented a model for the interaction between a LC matrix and single walled carbon nanotubes, describing the induction of a ferroelectric smectic C_G phase.

Molecular dynamics, optics and electrooptics of mesomorphous media. We have studied experimentally electrically and spacially controlled: (i) diffraction of coherent light; (ii) electro-optic (EO) phase modulation; and (iii) amplitude-frequency EO modulation, by using monolayer phase gratings made of polymer-dispersed liquid crystal (PDLC MLG), of interest for applied photonic devices.

By changing the interaction geometry of the laser beam, the gradient PDLC MLGs can be applied for highly effective tunable amplitude and phase special modulators, as well as for other photonic devices for active control of the laser light.

Investigation of new nanostructured optical materials. In view of their practical application, we have studied experimentally the electro-optical properties of thin (25 μm) films of nanocomposite gel, formed by nematic liquid crystal (NLC) heptylcyanobiphenyl (7CB) and 3 wt.% silicon nanoparticles of ~ 7 nm. It was established, that by applying alternating electric field, films made of such nanostructured material have reversible electro-optical characteristics and their optical transmission increases with the increased field intensity.

We have studied experimentally electrooptically controlled diffraction of visible laser radiation (~ 633 nm) using thin (25 μm) films NLC pentylcyanobiphenyl (5CB), based on electrically controlled spacially periodic textures, induced in such films under the action of constant electric field.

Infrared spectra and devices: Measurements of IR spectra of samples for the plant Optics-Panagyurishte antireflective coatings on Ge and Si substrates for special applications, 20 pieces; Measurement of IR spectra of pigments from frescoes in Rila Monastery for composing of a Catalogue of spectra for the needs of the Archaelogical museum of BAS, 90 pc.; Measurement of IR spectra of thin layers from AlN on Si-substrates, deposited using a pulsed laser in the National Inst. for Lasers, Plasma, and Radiation Physics, Romania – 6 pc.

Electrooptical experiments with colloidal suspensions (3 pieces) of biological objects with admixtures of metal (Fe, Pb) salts, prepared in the Biological department of Sofia University. The experiments are supplemented with a measurement of UV-VIS-NIR spectra of dried thin layers from the same material -12 pc. The purpose of these studies was the possibility for employment of new materials as biosensors for heavy metals. The first results have been discussed and the preparation of another type of samples has been proposed for other measurements.

Semiconductor lasers with vertical emission (VKSELs). We have studied the polarization bistable characteristics (of types 1 and 2) of VCSELS with emission wavelength of 1550nm. We measured threshold current, nonlinear dichroism, differential amplification and switching current in temperature dependence. These studies were carried out in collaboration with the University in Cantabria, Santander, Spain.

We observed experimentally asymmetrical static distribution of the time for staying of the VCSELs in quantum dots. The theoretical explanation is based on the noncoincidence of the axes for absorption and those for birefringence.

Liquid crystals. In collaboration with the University of Gent, Belgium, we have pursued our theoretical and experimental studies on a system of liquid crystal (nematic or cholerestic), optically connected to a VCSEL. The laser set up was optimized for maximum tuning of the emitting wavelength by means of the electrooptic effect.

Solitons. In collaboration with the Free University of Brussels and the University of Glasgow, Scotland, we have carried on our experimental and theoretical studies on space solitons and VCSELs with 80 mkm aperture. Prof. Krassimir Panajotov is Editor for photonic crystals of Opto-Electronics Review journal of Springer-Verlag.

Thin layer and multilayer optics. Fulfilment of Order РД-09-93/08.10.2013 concerning Contract BG161PO003-1.2.04-0027-C0001 of Project “Rennovation of the technological equipment and apparatus for innovative scientific-applied works on multilayer optical structures” in the Operative program “Development of the competitiveness of Bulgarian Economy” 2007-2013.

Finally accepted (after the required tests) is the Final acceptance-delivery protocol for delivery of FT-IR spectrophotometer Vertex 70 (Bruker Optics) ser. № 1612. The equipment was delivered under Contract BG161PO003-1.2.04-0027-C0001/Su-02, Special position 2 of the Public order with the object of “Delivery, installation commissioning and warranty service of technological equipment and measuring set up for multilayer optical structures”.

We have measured the spectrophotometric characteristics of various samples in the spectral ranges UV, VIS, NIR и IR for the needs of colleagues at the Institute, as well as for external users.

Physics and archaeology. We have analyzed the archaeological objects that stand outside the scope of the professional archaeological community and have not yet been explored thoroughly, although they carry unexhausted potential for the so-called cultural tourism in our country. We clarify the necessity and usefulness of luminescent dating of megalithic and other antique cultural objects in Bulgaria. We propose a new aspect in the exploration of megaliths in Bulgaria, namely: the interconnection between the prehistoric megaliths and other pagan sanctuaries on one side and objects, worshiped in the Christian times, on the other side. On both topics has been done a lot for a wide popularization by means of lectures, TV emissions and organized 2 public photoexhibitions.

Raman spectroscopy. We have performed a bibliographic description and analysis of published results to date on the use of vibrational spectroscopy to study the proton-exchanged waveguides in lithium niobate and lithium tantalate. Discussed are the most important applications and conclusions of relevant research materials and in groups.

Explored were the possibilities of infrared and Raman spectroscopy for characterization (phase composition, quality and properties) of optical waveguides obtained with proton exchange in lithium niobate and lithium tantalate.

We analyzed various methods for the characterization of fluids with the aid of surface photocharge effect and discussed the possibilities and advantages of the transducers based on this effect to detect liquids, determination of octane number, level measurement, quality control of milk and the like.

Diffraction gratings: In 2015 work continued on developing ways to control the laser generation using resonant diffraction gratings. After demonstrating the selective properties of the resonant diffraction gratings for determining the polarization of laser emission and the wavelength (longitudinal mode), the employment of such gratings in the resonator was demonstrated for selecting the basic transverse mode of the laser and filtering the higher modes. Designed, optimized and prepared were two different resonance strucures, one for an erbium-doped microchip laser generating in the C-band (1530-1565 nm) and a second one for Yb: YAG disc laser at 1030 nm wavelength and higher power. The experimental results confirm the successful design and technological solutions.

Calculation of the vibrational structure of polyatomic molecules. The developed by us in recent years theoretical apparatus to calculate the vibrational structure of polyatomic molecules is applied to perform calculations and studies of vibrational structure and vibrational relaxation of the molecule thiophosgene Cl2SS, at very high energies of vibrational excitation in the range of dissociation. To this end, the potential surface of the grpund electronic state was modified and updated. Applied are a number of statistical methods in the research. The theoretical results are compared to experimental measurements.

Giroscopes and quantum effects. In 2015 we worked on the problems of the Fiber-optic laser gyroscope. Studied, realized and compared are two different methods of fiber-optic modulation of a laser gyroscope, in order to improve its sensitivity. We proposed a new method of modulation, namely modulation of the current of the laser diode. This method has led to more than two times better sensitivity. Both methods are compared in theoretical and experimental aspects. For this new case a new formula was derived for the intensity of laser radiation in the adiabatic approximation.

Fiber optics. A collaboration was started with the Laboratory "composite and nanostructured optical materials", Institute of optical materials and technologies - BAS to create and study optical gas sensors based on the use of nanosized thin layers of zeolite as a gas sensitive material. The zeolite layers are coated on the surface of the planar waveguides which are optically connected with side polished fibers. The principle of operation of the manufactured sensor element is based on a change of the refractive index of the zeolite layer resulting from the attachment of the molecules of the gas to be measured into the pores of the layer. This change results in a shift of the spectral position of resonance minima of the relevant planar modes that are related to the fiber optical mode. Measurements were performed with monochromator MDR-41 with its mounted CCD line as outgoing receiver. Performed were initial experiments for registration of acetone vapors. The results showed a successful feasibility study of optical circuit as gas sensitive element.

We solved Maxwell's equations in the case of a four layer planar waveguide consisting of two layers with total thickness of the Ta2O5 and zeolite and two semiinfinite environments of SiO2 and air, to obtain characteristic equation and expressions describing the distribution of the fields of the modes propagating in the planar waveguide. Created earlier computer codes are modified, in order to calculate the characteristic equation and distributions of fields.

A competition for the position of associate professor was won by Elka Karakoleva.

Ion implantation. We continued the work started on a new topic related to the study of a new material - diamond-like carbon - and its application for the purposes of nano-sized electric (I) and optical (II) record.

We continued work on the established and launched in early 2013 project under FP7, in which our Division and the Institute as a whole is partner: CareRAMM ("Carbon resistive random access memory materials" - "Materials for resistive memory based on carbon ') on thematic priority NMP.2012.2.2-2' Materials for data storage ', funded under the scheme SP1-Cooperation: Collaborative project (Small or medium scale focused research project).

PUBLISHED PAPERS:

1. **Angelow A.**, **Stoyanova E.**. Fundamental Quantum Limit in Mach-Zehnder interferometer. Bulgarian Chemical Communications, 47, special issue b, 2015, ISSN:0324-1130, 275 - 281. SJR:0.156, ISI IF:0.201
2. **Berova M.**, **Sandulov M.**, **Tsvetkova T.**, Bischoff L.. Ion implantation applications for high density data archiving in diamond-like carbon. University of Plovdiv, Sci. Studies, 39, FASC. 4, 2015
3. **Hadjihristov, G. B.**, **Marinov, Y. G.**, **Petrov, A. G.**, Bruno, E., Marino, L., Scaramuzza, N.. Electro-Optics of Nematic/Gold Nanoparticles Composites: the Effect From Dopants. Molecular Crystals and Liquid Crystals, 610, 1, Taylor & Francis Group, 2015, DOI:10.1080/15421406.2015.1025619, 135 - 148. ISI IF:0.49
4. **Karakoleva E.**, **B. Zafirova**, **A. Andreev**. Calculations of photonic crystal fibers by the Galerkin method with sine functions without a refractive index approximation. Bulgarian Chemical Communications, 47, Spatial Issue B, Bilgarian Academy of Sciences, 2015, ISSN:0324-1130, 21 - 28. SJR:0.156, ISI IF:0.349
5. **Karakoleva E.**, **Zafirova B.**, **A. Andreev**. Calculations of Photonic Crystal Fibers by the Galerkin Method with Sine Functions without a Refractive Index Approximation. arXiv, Cornell University Library, 2015, DOI:arXive: 1501.06199
6. **Katranchev, B**, **Petrov, M**, Dyankov, G, Zhelyazkova, K. An anisotropic stratified structure for surface plasmon excitation. Proc. SPIE, 9447, 2015, SJR:0.2
7. **Kuneva, M. K.**, Pérez-Díaz, J.. Surface photo-charge effect: applications for fluids. Annual of the UACEG, XLVII, UACEG, 2015, ISSN:1310-814X, 299 - 306
8. **Kuneva, M. K.**. Bibliographical review on vibration spectroscopy of proton exchanged LiNbO3 and LiTaO3. Trends in Applied Spectroscopy, 11, 2015, ISSN:0972-4516, 73 - 75
9. Lyndin, N., Kämpfe, T., **Tonchev, S.**, Reynaud, S., Parriaux, O.. Transverse-mode selective resonant grating-mirrors for high power and high brightness emission. Optics Express, 23, 13, OSA Publishing, 2015, DOI:10.1364/OE.23.017275, 17275 - 17289. ISI IF:3.488
10. **Panajotov, K.**, 2. C. Belmonte, L. Frasunkiewicz, T. Czyszanowski, H. Thienpont, J. Beeckman, K. Neyts. Optimization of electrically tunable VCSEL with intracavity nematic liquid crystal. Opt. Express, 23, The Optical Society of America, 2015, ISSN:1094-4087, 15706 - 15710. ISI IF:3.525
11. **Panajotov, K.**, 3. A. Quirce, A. Valle, L. Pesquera, H. Thienpont. Measurement of Temperature-Dependent Polarization Parameters in Long-Wavelength VCSELs. IEEE J. Selected topics in Quant. Electr., 21, IEEE Photonics Society, 2015, ISSN:1800207, 1800207 - 1800209. ISI IF:3.465
12. **Panajotov, K.**, 4. M. Virte, E. Mirisola, M. Sciamanna. Asymmetric dwell-time statistics of polarization chaos from free-running VCSEL. Opt. Lett., 40, The Optical Society of America, 2015, ISSN:0146-9592, 1865 - 1869. ISI IF:3.179

13. **Rashev, S.**, David. C. Moule. A Refined quartic potential energy surface and large scale vibrational calculations for S0 thiophosgene. Spectrochimica Acta A, 140, ELSEVIER, 2015, ISSN:1386-1425, 305 - 310. ISI IF:2.129
14. **Sandulov M.**, **Berova M.**, **Tsvetkova T.**, Wright D.. Ion implantation uses for nanoscale RAM memories in diamond-like carbon. University of Plovdiv, Sci. Studies, 39, FASC. 4, 2015
15. **Tsonev, L.**. Technological Comparison between three Specific Megalithic Monuments on the Balkans and in Caucasus. Archaeoastronomy and Ancient Technologies, 3, 1, 2015, ISSN:2310-2144, 88 - 147
16. **Tsonev, L.**. Three Special Megaliths in Bulgaria and Caucasus: Similarity and Problems. Advances in Bulgarian Science in 2014, май 2015, НАЦИД, 2015, ISSN:1314-3565, 18 - 27
17. **М. Кънева**. Вибрационна спектроскопия на оптични вълноводи, получени с протонен обмен в LiNbO3 и LiTaO3. Годишник на УАСГ, XLVII, УАСГ, 2015, ISSN:1310-814X, 341 - 348
18. **Цонев, Л.**, Колев, Д.. Прибързани разкопки на уникална долменна могила в Сакар планина. Паметници, реставрация, музеи, януари-април 2015, 2015, ISSN:1312-3327, 23 - 28
19. **Цонев, Л.**. България: приемственост от мегалитизма до християнството. Будител, окт-дек 2015, 2015, ISSN:1312-7829
20. **Цонев, Л.**. Мегалитните находища около Черно море. Авитохол, 35, Дукати, 2015, ISSN:1312-2185, 55 - 66

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 and funded by Ministry of Education and Science BG (K 1402/ 2004), and 6th FP ECC MCRTN “CLUSTOXDNA”.
4. Institute of Ion Beam Physics and Materials Research, AIM – Center, POB 510119 01314 Dresden Germany
5. Laboratory on physics of complex systems in the University “Jules Vernes”, Amien, France.
6. Assoc. Prof. Tanya Tsvetkova continued work on established and launched in early 2013 project under FP7, in which our division and ISSP is partner: CareRAMM ("Carbon resistive random access memory materials" - "Materials for resistive memory based on carbon") on thematic priority NMP.2012.2.2-2 'Materials for data storage', funded under the scheme SP1-Cooperation: Collaborative project (Small or medium scale focused research project).
7. Collaborative work of K.Antonova on 4-years of Action COST - "European network for development of electroporation-based technologies and treatments - EP4Bio2Med".
8. Work G.Hadzhihristov on a three-year (2013 - 2015) Project for International Cooperation Bulgaria - India, funded by the Ministry of Education, on the topic: "Investigation of photo-stimulation effects in nano-structured liquid crystalline systems", (DNTS / In- 01/4/2013), headed by Assoc. Prof. Y. Marinov.
9. Three-year (2014 - 2016) project on a thematic Competition 2014 NSF entitled "Nano-structured liquid crystals for tunable photonic devices" (DFNI-TO2 / 18) head: Assoc. Prof. Y. Marinov, ISSP-BAS.

DIVISION SOFT MATTER PHYSICS

LABORATORY

LIQUID CRYSTALS

HEAD: **Prof. Isak Bivas, Ph.D., D.Sc.**
tel.: 979 5725; e-mail: bivas@issp.bas.bg

TOTAL STAFF: **4**
RESEARCH SCIENTISTS: **3**
ASSOC. MEMBERS: **2**
Assoc. Prof. V. Vitkova, Ph.D., Assoc. Prof. J. Genova, Ph.D.; Eng. D. Mitkova, PhD student
Associated members: Assoc. Prof. H. Hinov, D.Sc.; Assoc. Prof. A. Zheliaskova, Ph. D.

RESEARCH ACTIVITIES:

The scientific work of the laboratory "Liquid Crystals" performed during the reported period is concentrated in the field of "Soft Matter Physics". The scientific research on the physical properties of thermotropic liquid crystals and the physical and physicochemical properties of model lipid membranes was continued. The most important results obtained at the laboratory in 2015 are presented below.

A book, authored by the associated member of the laboratory Assoc. Prof. DSc. Hristo Hinov has been published during the reported period. There the main achievements in his long and fruitful scientific career are described. The most important results presented in the book are given below. A summary of the growth of smectic A or smectic C from nematic or developed long-step cholesteric phase ordered at the center of the liquid crystal cell and with strongly deformed border areas is made. On the basis of these experiments the development of laser-addressed displays and methods for evaluation the edge energy are suggested. New electro-optical effects in long-step cholesterics and mixtures of nematic and smectic C ferroelectric liquid crystal are examined. New electro-optical effects of unidirectional spirals are observed and a possible flexoelectric model have been proposed. New flexoelectric oscillations of the liquid crystal layer in simultaneously applied constant and low-frequency electric fields have been observed and explained and their significant amplification have been achieved. New flexoelectric deformation in gradient electric field has been observed. Novel and improved methods for measurement of some physical constants of thermotropic liquid crystals have been provided.

Direct phase measurements were performed on dilute vesicular suspensions by means of a new optical method exploiting holographic microscopy. For the bending constant of phosphatidylcholine bilayers the value of $23k_BT$ is reported in agreement with values previously measured by micropipette aspiration, electrodeformation and flicker spectroscopy of giant lipid vesicles. The application of this novel approach for the evaluation of the bending elasticity of lipid membranes opens the way to future developments in the phase measurements on lipid vesicles for the evaluation of their mechanical constants.

A modification of the light source for phase contrast microscopy was successfully implemented in a way that the traditional tungsten lamp has been replaced with white light emitting diode LED Synchro, 10 W electrical power, 850 lm luminous flux and color temperature of 4000 K. LED lighting offers many advantages over the traditional implementations of microscope illumination, namely high efficiency, very good control over the focus, long life (~50 000 hrs.), excellent color quality, constant intensity throughout the operation, instant start, absence of UV and IR radiation, low voltage supply, absence of

mercury, complete recyclability, stability over vibration, stability at low temperatures, small size, environmentally friendly production, etc.

Amphotericin B is an antibiotic with high antifungal activity. Its destructive effect on the fungal cells is associated with its ability to bind to cell membrane components and form transmembrane channels. Using a modified CellASIC ONIX Microfluidic Platform morphological study of SOPC vesicles at asymmetrical presence of amphotericin B antibiotic was performed. The setup has been modified thus opening new opportunities for a variety of experimental realizations. The results of the study showed a strong and irreversible effect on the shape of lipid vesicles after the addition of amphotericin B at concentration of 10^{-5} g/l in the surrounding membrane environment. At concentration of 10^{-3} g/l AmB the observed effect is less visible and in 15-20 minutes the vesicles regained its initial spherical shape.

The membrane bending stiffness of nearly spherical lipid vesicles can be deduced from the analysis of their thermal shape fluctuations. The theoretical basis of this analysis [Milner and Safran, Phys. Rev. A:, 1987, 36, 4371–4379] uses the mean field approximation. In this work we apply Monte Carlo simulations and estimate the error in the determination of the bending stiffness due to the approximations applied in the theory. It is less than 10%. The method can also be used to determine the changes of the bending stiffness of biological membranes due to their chemical and/or structural modifications. A figure of the article, containing these results was chosen for a cover page of the volume, where the paper was published (Samo Penič, Aleš Iglič, Isak Bivas and Miha Fošnarič, Bending elasticity of vesicle membranes studied by Monte Carlo simulations of vesicle thermal shape fluctuations, *Soft Matter* **11**, 5004 (2015)).

In 2015 Assoc. Prof. V. Vitkova performed a two-week research stay in Moscow, at the Laboratory of Bioelectrochemistry of A. N. Frumkin Institute of Physical Chemistry and Electrochemistry (IPCE) – Russian Academy of Sciences (RAS). During her visit there, the electroformation method for obtaining giant lipid vesicles was realized and validated in order to become one of the routine experimental techniques used in the Laboratory of Electrochemistry, IPCE-RAS. An experimental set-up for performing micromanipulation experiments with lipid vesicles and biological cells was implemented and tested on lipid vesicles, prepared in the Laboratory of Bioelectrochemistry at IPCE-RAS.

TEACHING ACTIVITIES:

S. Penic,"Spectral analysis of thermally fluctuating membranes using phase-contrast microscopy and Monte-Carlo simulations, PhD Thesis (2015), University of Ljubljana, Faculty of Electrical Engineering, supervisor Prof. Isak Bivas

Ph.D. student Denitsa Mitkova Brankova, supervisor Assoc. Prof. V. Vitkova

PUBLICATIONS:

- Hristo Petkov Hinov, Electro-Optical Effects in Thermotropic Liquid Crystals, Nova Science Publishers, Materials Science and Technologies, New York (2015)

- D. Haustov, T. Hikov, D. Mitev, I. Tsvetanov, L. Pramatarova and J. Genova, Bending elasticity of lipid membranes in presence of nanodiamond particles in the aqueous solution, Nanosci. Nanotechnol. – Nanostructured materials application and innovation transfer 14 (2014) 159–161.

- Samo Penič, Aleš Iglič, Isak Bivas and Miha Fošnarič, Bending elasticity of vesicle membranes studiedby Monte Carlo simulations of vesicle thermal shape fluctuations, Soft Matter 11, 5004 (2015).

- J. Genova, N. Poklar Ulrih, V. Kralj-Iglič, A. Iglič, I. Bivas, Bending Elasticity Modulus of Giant Vesicles Composed of Aeropyrum Pernix K1 Archaeal Lipid, Life 5 (2015) 1101–1110.

- J. Genova, M. Dencheva-Zarkova, J. I. Pavlič, Morphological study of lipid vesicles in presence of amphotericin B via modification of the microfluidic CellASIC platform and LED illumination microscopy, Journal of Physics: Conference Series 682 (2016) 012029.

- C. Minetti, V. Vitkova, F. Dubois, I. Bivas, New optical method for measuring the bending elasticity of lipid bilayers Journal of Physics: Conference Series 682 (2016) 012031.

PARTICIPATION IN SCIENTIFIC FORUMS:

International forums:

1 10th International Frumkin Symposium on Electrochemistry, Moscow, Russian Federation, October 21-23, 2015: Microsymposium 5 "Bioelectrochemistry", oral presentation: “Electrochemical and mechanical properties of cell-mimetic membranes studied by flicker spectroscopy, electrodeformation and electroporation of lipid vesicles”, D. Mitkova, K. Antonova, R. Dimova, V. Vitkova

2 9th International Physics Conference of the Balkan Physical Union, August 24-27, 2015 at Istanbul University, Science Faculty, Istanbul, Turkey, поканен лектор: “MECHANICAL PROPERTIES OF MODEL LIPID MEMBRANES AND BIOMEMBRANES” Isak BIVAS

3 Light in Nanoscience and Nanotechnology 20 -22 October 2015, LNN 2015, Hissar, Bulgaria, Poster (P5-3): Digital Holographic Microscopy for Studying the Thermal Shape Fluctuations of Lipid Vesicles C. Minetti, V. Vitkova, F. Dubois, I. Bivas

4 Light in Nanoscience and Nanotechnology 20 -22 October 2015, LNN 2015, Hissar, Bulgaria, постерен доклад: Morphological study of lipid vesicles in presence of amphotericin B via modification of the microfluidic CellASIC platform and LED illumination microscopy, J. Genova, M. Dencheva-Zarkova, J. I. Pavlič

5 Laser and Plasma Matter Interaction, 18-20 November 2015, Plovdiv, Bulgaria, постерен доклад: Elasticity, morphology and channel formation studies in presence of Amphotericin B in lipid membranes, J. Genova, M. Dencheva-Zarkova

Workshops:

1 VIII Spring Workshop “Interdisciplinary Chemistry”, Vitosha, April 24-26, 2015, oral presentation: Denitsa Mitkova, Rumiana Dimova, Krassimira Antonova, Angelina Stoyanova-Ivanova, and Victoria Vitkova, Cell-mimetic lipid membranes – electrochemical and mechanical properties

2 INERA Workshop “Mobility and exchange of knowledge in 2015”, November 11-12, 2015, Sofia; oral presentation: V. Vitkova – “Lipid vesicles as a tool to study physical properties of cell-mimetic membranes”

3 XVIII Winter Workshop “Interdisciplinary Physics”, Vitosha December 5-6, 2016 oral presentation: J. Genova- „LED illumination for light microscopy of lipid vesicles“

4 INERA Stakeholders meeting “Nanotechnolody and nanomaterials: New equipment at ISSP-BAS”, December 10, 2015, Sofia, oral presentation: J. Genova – “Automated Microfluidic Platform and Automated Handheld Cytometer”

ONGOING RESEARCH PROJECTS:

COST Action TD1104 (EP4Bio2Med) “European network for development of electroporation-based technologies and treatments”

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)

Bilateral Research Project /ISSP – BAS and Centre National de la Recherche Scientifique – France/ “La rhéologie de suspension de vésicules et cellules sanguines: de la compréhension au diagnostic de pathologies hématologiques”

Bilateral Research Project /ISSP – BAS and Wallonie Bruxelles International – Belgium/: “Etude des propriétés mécaniques par holographie digitale”

INTERNATIONAL COLLABORATION:

BELGIUM: Dr Christophe MINETTI, Université libre de Bruxelles

FRANCE: Dr Thomas PODGORSKI, Laboratoire Interdisciplinaire de Physique, UMR 5588 (CNRS – Université Joseph Fourier)

GERMANY: Dr. habil. PD Rumiana DIMOVA, Max Planck Institute of Colloids and Interfaces, Science Park Golm

RUSSIA: Prof. Yury Ermakov, Dr Oleg Batishchev, Frumkin Institute of Physical Chemistry and Electrochemistry, Russian Academy of Sciences

SLOVENIA: Prof. Damijan Miklavcic, Chair of the COST TD1104 Action, EU, University of Ljubljana, Faculty of Electrical Engineering

DIVISION SOFT MATTER PHYSICS

LABORATORY

BIOMOLECULAR LAYERS

HEAD: **Assoc. Prof. Yordan Marinov, Ph.D.**
tel.: 979 5684; e-mail: ymarinov@issp.bas.bg

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

Academician A. G. Petrov, D.Sc., Honorary Member;
Assist. Prof. L. Todorova; Chem. Engineer M. Dencheva-Zarkova

RESEARCH ACTIVITIES:

In 2015, science activity of BML laboratory involved investigations on of nematic liquid crystals (LC) composites properties by the methods of flexo-dielectro-optical spectroscopy and dielectric spectroscopy.

Thin films (25 μm) of nanocomposites formed from nematic liquid crystal (LC) pentylcyano-biphenyl (5CB) doped with 0.5% wt. silver (Ag) nanospheres with a mean diameter ~ 10 nm were characterized by electrical measurements and dielectric spectroscopy in the frequency range from 1 mHz to 100 kHz. By using LC cells in which the electrodes are stripes of 1.2 mm width separated by a distance of 50 μm, it was possible to study the properties of Ag-5CB nematic nanocomposites by applying the external electric field either in the plane or perpendicular to the plane of the films. The results were compared with those obtained for undoped nematic 5CB in identical configurations of the experiments.

We evaluated the electro-optic (EO) response of a three-component photosensitive nanostructured soft-matter system produced from nanocomposite nematic by doping of photoactive azobenzene-containing mesogen at concentration up to 3 wt.%. The photo-insensitive nanocomposite was a soft gel formed from the nematic liquid crystal 4'-heptyl-4-biphenylcarbonitrile (7CB) and 3 wt.% hydrophilic silica (SiO_2) nanospheres (Aerosil 300) of size ca. 7 nm. Thin films (25 μm thick) of Aerosil/7CB nano-gel were prepared in cells in which the ITO electrodes are coated with polyimide. The effect from relatively weak UV light illumination on the EO modulation by the Aerosil/7CB films was characterized by laser beam transmission through the films. The study aimed to determine the applicability of such photo-sensitized nematic nanocomposite structures for photo-controllable EO applications. By applying alternating-current (AC) electric field, an effect from UV light illumination (by LED at the wavelength of 375 nm) on the voltage-dependent optical transmittance curve of the azo-doped nanocomposite films was found, as well as on the amplitude-frequency EO modulation achieved with them. The photo-induced effect is well controllable (electrically commanded by the amplitude of the driving AC field) and reversible (blue-light illumination restores the initial state of the system).

A comparative study was carried out on Flexo-Dielectro-Optical Spectroscopy of Confined Nematics: PDLC and Nanofilled Nematics. The method of flexo-dielectro-optical spectroscopy is employed in order to record and compare the frequency sweep response of PDLC (E7 in NOA65) and nanofilled nematic cells (7CB with Aerosil 300 nanoparticles) in the low frequency range (0.1 to 10000 Hz). PDLC spectra are characterised by deep minima at specific frequencies, while nanofilled nematics' spectra show rather gradual frequency

decay, reflecting viscoelastic damping. Under the defined boundary conditions of PDLC droplets a time-modulated director reorientation produces changes in spatial distribution of scattered laser light. The minima are explained by a pronounced spatial filtering (deflection) of modulated light components at frequency minima, diminishing their amount in the forward scattering direction. On the other hand, the electrooptics of nanofilled nematics is rather based upon a "polycrystal-monocrystal" textural transition, which is faster and lacks a specific frequency response. As a conclusion, PDLCs can be used as notch filters in low frequency electrooptic devices, while nanofilled nematics provide a smooth light modulator performance extending to higher frequencies.

Diffractive electro-optics of electrically-induced spatially periodic texture patterns (namely, wide-formed stationary parallel stripes) in planarly-aligned films of the nematic liquid crystal 4-n-pentyl-4'-cyanobiphenyl (5CB) is examined under static electric field in view of its practical application. The longitudinal textural domains electrically-induced with well defined threshold and spatial period have flexo-dielectric nature and differ from the known flexoelectric domains, as well as from the electroconvective domains of frequency-dependent morphology. The low-voltage-controlled grating effect through the flexo-dielectric domains can be useful for nematic diffractive optics.

PUBLICATIONS:

1. Flexo-Dielectro-Optical Spectroscopy as a Method of Studying Nanostructured Nematic Liquid Crystals, M. Vijay Kumar, S. Krishna Prasad, Y. Marinov, L. Todorova, A. G. Petrov, Mol. Cryst. Liq. Cryst., Vol. 610, issue 1, 51-62 (2015). ISSN 1542-1406, DOI: 10.1080/15421406.2015.1025205

2. Electro-Optics of Nematic/Gold Nanoparticles Composites: the Effect From Dopants, Georgi B. Hadjichristov, Yordan G. Marinov, Emanuela Bruno, Lucia Marino and Nicola Scaramuzza, Mol. Cryst. Liq. Cryst., Vol. 610, issue 1, 135-148 (2015). ISSN 1542-1406, DOI: 10.1080/15421406.2015.1025619

3. Y.G. Marinov, G.B. Hadjichristov, A.G. Petrov, and S. Krishna Prasad, 'Thin films of silica nanoparticle doped nematic liquid crystal 7CB for electro-optic modulation', Photonics Lett. Poland 7 (4), 94-96, 2015.

CITATIONS FOR 2015:

69

ONGOING RESEARCH PROJECTS:

1. Project financed by the National Science Fund of Bulgaria:

DFNI-TO2/18 "Nanostructured liquid crystals for tunable photonic devices" (2015-2016).

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".

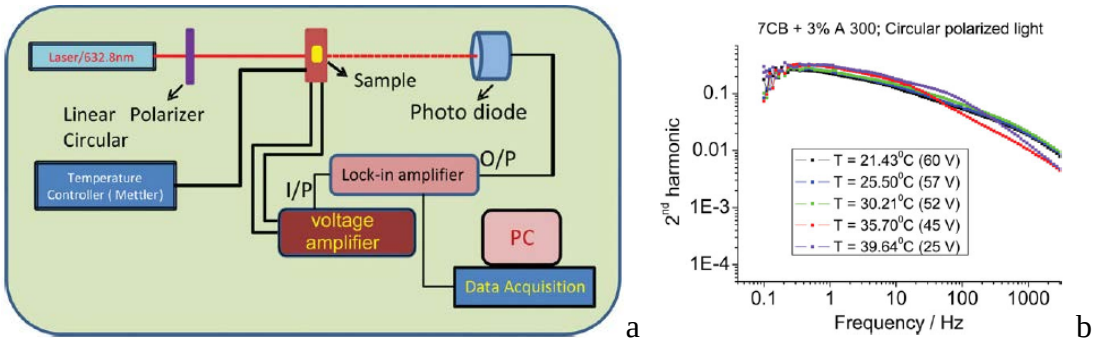


Fig. 1. Schematic of Flexo-dielectro-optical spectroscopy method (a). Nanoconfined nematic/aerosil system displays interesting electrooptical properties, e.g.broad frequency range of 2nd harmonic light modulation (b). Flexo-dielectro-optical spectroscopy is demonstrated to be a powerful method to evaluate nanostructural parameters of filled nematics by macroscopic measurements.

DIVISION LASER, ATOMIC, MOLECULAR AND PLASMA PHYSICS

LABORATORY

ATOMIC SPECTROSCOPY

HEAD: **Prof. Kiril Blagoev, D.Sc.**
tel.: 979 5790; e-mail: kblagoev@issp.bas.bg

TOTAL STAFF: **11**
RESEARCH SCIENTISTS**:** 7

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 G. Dobrev, Physicist I. Temelkov, Ph.D. student V. Tankova

RESEARCH ACTIVITIES:

Atomic structure and properties

The results for high lying energy levels of Ti II are treated and prepared for publication. Radiativeconstants of Ti II are important for astrophysics and in particular for study of evolution of galaxes. Titanium is one of the elements discovered in the Sun photosphere, in meteorites as well as in Red Giant atmosphere. All togather radiative lifetimes of 10 excited states were measure using TRLIF method. Five of them were measured for first time. Transition probabilities from measure states were determined, as well.

Radiative lifetimes of 7 excited states of Ni II were measure using TRLIF method. The measured states are high lying and two step laser excitation method was employed. The transition probabilities from these states were also determined. These data are important for modeling of star atmosphere and supernova explosion.

Quantum optics

We continue the work on developing new methods for quantum control, based on composite pulses. To be specific, we developed new type of composite pulses, which allow for even broader (or narrower) excitation profile, at the expense of a finite error tolerance. A new method for error-resilient implementation of Householder reflection has been developed, again by using composite pulses.

It has been presented a new analytic solution for a two-level quantum system, with an exponential temporal shape of the external field in the presence of dephasing. In the case of no dephasing, the model reduces to the well known Demkov model, which has been used for describing collisions of slow particles. The solution is expressed in terms of hypergeometric function 1F2 (a;b1,b2;x). Several limiting cases have been explored, in the case of small and large dephasing, strong external field and exact resonance.

Several experiments on creation and testing of two types of polarization rotators have been realised, using theoretical models, based on the thoery of composite pulses and adiabatic transitions.

Plasma physics

The current-voltage characteristics in Grimm lamp for both cathodes: pure Al and Al cathode covered with thin porous dielectric layer Al_2O_3 are measured and compared. The

discharge with Al cathode looks much brighter and cathode homogeneously illuminated. With aluminum oxide layer the discharge is diffuse with irregularly moving bright spots on the cathode surface.The profile of Balmer Hα line is registered for both cathodes – with pure Al and Al+Al_2O_3. In the case with Al cathode in profile of Hα line clearly visible wings with excessive Doppler broadening (EDB) and completely disappear in the case with Al+Al_2O_3 cathode. The complete disappearance of EDB wings in the case when oxide layer is present at cathode surface can be explained by the lack of cathode sheath. In Al cathode glow discharge the presence of cathode sheath resulted in appearance of EDB wings. All parameters of the Hα line profile differ according to the cathode (with/without porous dielectric layer). Therefore, the replacement of Al cathode with oxide layer changed completely electric and emission characteristics of Grimm discharge.

A new technique for measurement of the laser ablation threshold of silicon using photo-induced signal generated as a result of irradiation with a pulsed laser beam is proposed. Experimental results show that there are two regimes characterizing the laser–target interaction depending on laser power. When the laser pulse energy is less than ablation threshold strong and fast relaxing photo-induced signal is observed. With increasing the laser power beyond this limit abrupt change in the shape of the signal are registered.

Analytical spectroscopy

In collaboration with the colleagues from the laboratory "Metal vapour lasers", the emission characteristics of a scheme combining laser ablation as sample introduction source and hollow cathode discharge as excitation source is demonstrated. The described technique allows independent control of the processes of laser ablation and plasma excitation. The spatial separation of the sample material introduction by laser ablation and hollow cathode excitation is achieved by optimizing the gas pressure and the sample-cathode gap length.

Considerable progress in the development of a novel miniature analytical detector for the determination of impurities in gases has been made. Admixtures of Kr, O_2, and CO_2 are used as examples of atomic and molecular impurities to prove the possibility for detecting and identifying their presence in high pressure He plasma (50–250Torr). The experimental results reveal the potential of the collisional electron spectroscopy (CES) method for the analysis of gaseous pollutants using different noble gases as the buffer gas. This study represent an important step in the creation of innovative portable gas detector for chemical sensing in gas phase environments.

PUBLICATIONS:

1. **Dimova, E**., E. Kyoseva, A. Rangelov. *Broadband and ultra-broadband polarization rotators with adiabatic modular design.* **Journal of Optics**, 17, 7, IOP Publishing Ltd, 2015 ISI IF:2.06

2. Kudryavtsev A. A., **Stefanova M. S., Pramatarov P. M..** *Use of dc Armicrodischarge with nonlocal plasma for identification of metal samples*. **Journal of Applied Physics**, 117, 13, AIP Publishing, 2015 ISI IF:2.18

3. Kudryavtsev A. A., **Stefanova M. S., Pramatarov P. M.**. *Use of nonlocal helium microplasma for gas impurities detection by the collisional electron spectroscopy method.* **Physics of Plasmas**, 22, 10, AIP Puplishing, 2015 ISI IF:2.14

4. **Malcheva G.**, Engström L., Lundberg H., Nilsson H., Hartman H., **Blagoev K.**, Palmeri P., Quinet P.. *Radiative lifetimes and transition probabilities in Rh I.* , **MNRAS** 450, 1, 2015, 223 - 228. ISI IF:4.9

5. S. Karatodorov, **V. Mihailov**, M. Grozeva. *Emission characteristics of laser ablation-hollow cathode glow discharge spectral source*. **Open Chemistry,** 13, 1, DE GRUYTER, 2015, 187 - 192. ISI IF:1.33

6. Petrunov, V. I, Andreeva, L. S., Karatodorov, S. I., **Mihailov, V**. I., Terzieva, S. D., Ilievska, I., Stoyanova-Ivanova, A. K., Tumbalev, V. G., Mikli, V.. *Analysis of elemental composition of a heat activated, multi-force, nickel titanium othodontic archwire.* **Bulgarian Chemical Communications,** 47, 1, 2015, ISSN:0324- 1130, 49 - 53. ISI IF:0.35

7. Ivanov O., **Mihailov V**., Pustovoit V. I., Abbate A., Das P.. *Surface photo-charge effect in solids*. **В. И. Пустовойт - Избранные труды**, Наука, Москва, 2015, ISBN:978-5-02-036939-9, 733 -736

8. **Torosov, B.** T., ElicaKyoseva, Nikolay V Vitanov. *Fault-tolerant composite Houselholder reflection.* **J. Phys. B:** At. Mol. Opt. Phys., 48, IOP Publishing Ltd, 2015, 135502 - (5pp). ISI IF:1.98

9. **Torosov**, B. T., Kyoseva E. S., Vitanov N. V.. *Composite pulses for ultrabroad-band and ultranarrow-band excitation.* **Phisical Review A,** A 92, American Physical Society, 2015, ISI IF:2.99

10. **Torosov, B.** T., Stefano Longhi, Giuseppe Della Valle. Mixed Rabi *Jaynes–Cummings model of a three-level atom interacting with two quantized fields*. **Optics Communications**, Volume 346, 2, ELSEVIER, 2015 ISI IF:1.45

11. Zhechev, D, **Steflekova, V**, Costello, J.T, Bundaleska, N. *On the Conductance of the Gas Discharge Plasma at Space Anisotropic Excitation.* **Contributions to Plasma Physics**, 55, 7, 2015, 538 - 544. ISI IF:0.84

12. Zhechev, D, **Steflekova, V**. *Nonselective and polarization effects in time-resolved optogalvanic spectroscopy.* **Journal of Physics: Conference Series** (JPCS), IOP Publishing, 2016, SJR:0.27

TEACHING ACTIVITIES:

PhD student V. Tankova, supervisor Prof. K. Blagoev

ONGOING PROJECTS:

- New techniques for quantum control and their application – BNSF
- INTERACTIONS À N-CORPS DANS DES GAZ D'ATOMES DE RYDBERG FROIDS – BNSF, Drila
- Experimental and theoretical study of physical processes in glow discharges - Academy’s bilateral agreements, Serbia - Serbian Academy of Sciences and Arts
- Coherence effects in atomic gases - Academy’s bilateral agreements - Poland – Institute of Physics, Jagiellonian University, Krakow

INTERNATIONAL COLLABORATION:

- Institute of Physics - Belgrade, Serbia
- Institute of Physics, Jagiellonian University - Krakow, Poland
- Laboratoire Aime Cotton - Orsay, France

DIVISION LASER, ATOMIC, MOLECULAR AND PLASMA PHYSICS

LABORATORY

METAL VAPOUR LASERS

HEAD: **Assoc. Prof. Margarita Grozeva, Ph.D.**
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TOTAL STAFF: **19**
RESEARCH SCIENTISTS: **11**

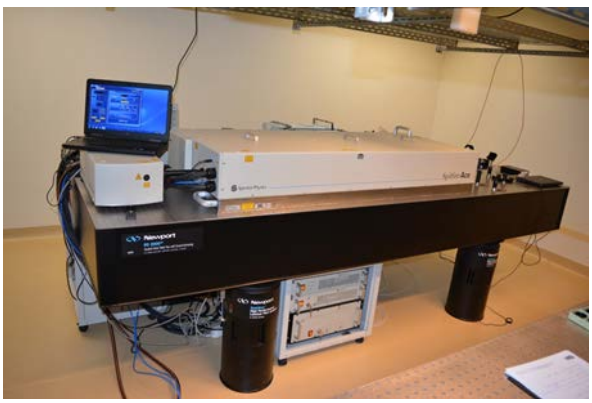
Prof. Nikolay **Vuchkov**, D.Sc.; Assoc. Prof. Dimo **Astadjov**, Ph.D.; Assoc. Prof. Todor **Petrov**, Ph.D.; Assoc. Prof. Krassimir **Temelkov**, Ph.D.; Assoc. Prof. Peter **Zahariev**, Ph.D.; Assist. Prof. Krassimir **Dimitrov**; Assist. Prof. Lubomir **Stoychev**, Ph.D.; Assist. Prof. Ognian **Sabotinov**, Ph.D.; Assist. Prof. Stefka **Slaveeva**, Ph.D.; Physicist Stefan **Karatodorov**, Ph.D. student; Physicist Viktoria **Atanasova**, Ph.D. student; Physicist Danka **Iordanova**; Physicist Blagovela **Blagoeva**; Physicist Kaloyan **Zlatanov**;
Honorary Member: Prof. Nikola **Sabotinov**, D.Sc., member of BAS;
Associated Members: Assist. Prof. Ekaterina **Yordanova**, Ph.D.; Assist. Prof. Georgi **Yankov**, Ph.D.

RESEARCH ACTIVITIES:

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

RESEARCH AND DEVELOPMENT of new laser systems; optimization of laser parameters; beam quality control; laser-matter interaction.

A new laser laboratory equipped within the INERA project with Spectra Physics femtosecond laser system was built. The Spitfire Ace Ti:Sapphire amplifier emits 35 fs pulses with energy up to 6 mJ and repetition rate of 1 kHz. The TOPAS Prime optical parametric amplifier converts the laser wavelength in the range 240-2600 nm. Experiments related to laser micro- and nanomachining of materials and nanostructuring of surfaces with the new laser system began.

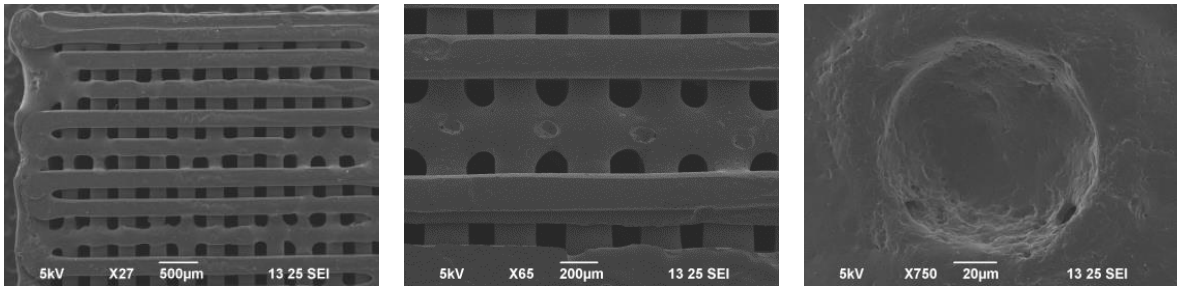


The femtosecond laser system

The femtosecond laser pulses interaction with two groups of materials: metals (stainless steel, brass, aluminum, copper, titanium, zinc, nickel) and plastics (acetal, polypropylene, polycarbonate, nylon, PTFF) was studied. The crater dimensions, the heat affected zone (HAZ) and the ablation threshold were analyzed under various processing parameters – laser wavelengths, pulse energy and cutting speed. The size of the crater formed as a result of laser ablation increases with increasing pulse energy, and decreases at larger wavelengths. Due to different absorption the effect of the laser wavelength depends

strongly on the type of the material. Generally at higher processing speed smaller craters are formed in the material. Also, when the speed increases, the process is less dependent on the material type and sample thickness. It was demonstrated that shortening the duration of the laser pulse to the range of femtoseconds significantly reduces HAZ, which results into higher quality of the machined material. These experiments were performed in collaboration with colleagues from IFFM, Poland.

The potential for the formation of microstructures on the surface of various materials with femtosecond laser pulses was investigated in collaboration with colleagues of IE-BAS. First attempt for performing laser-induced surface micro-modification of poly ε-caprolactone (PCL) using femtosecond laser technique was demonstrated. The possibility to create different surface micro formations by applying different laser fluences on gelatin biopolymer 3D PCL scaffolds was studied. The preliminary SEM investigations confirmed that the obtained laser created modifications of 3D PCL rapid prototyped samples result in minimum HAZ and collateral damage in the low fluence regime. The preliminary results of the present study are utilized to explore the potential of femtosecond laser radiation to create micro topographical features by improving the surface porosity which is a crucial factor for cell–surface interaction.



SEM images of 3D–PCL scaffolds at different magnifications.
Laser fluence F = 6.37J/cm^2 at 800nm and exposure time 1 sec.

Laser ablation of iron sulfide (FeS) target by nanosecond pulses at 1064 nm in vacuum is investigated. The laser induced plasma evolution is studied by optical emission spectroscopy with space and time resolution. From the time resolved spectral observations the electron temperature and number densities are extracted. The electron temperature is calculated by the Boltzmann plot method and the electron number density is evaluated by the Stark broadening of the excited emission lines. The Boltzmann plot of the line emission intensities shows an electron excitation temperature of 0.84 eV in the first few tenths of ns after the ablation pulse. For the same time window the Stark broadening of the Fe I emission line shows electron number density of 2.7x1016 cm−3 which decays fast in the next 200 ns.

Graphene production by ablation of graphite target in liquid nitrogen using quasi-CW CuBr vapor laser, generating nanosecond pulses (30 ns) at 20 kHz in the visible range (511 nm and 578 nm) was demonstrated. The threshold conditions – laser power, focal length and exposure time, were determined. The generated due to laser ablation material was characterized by Scanning Electron Microscopy (SEM) and Raman Microscopy, showing that different carbon nanostructures, including graphene, were produced.

Portable LIBSCAN 25+ system for near-field measurements was used to perform analysis of the elemental composition of two precious metal artefacts, found in the region of Stara Zagora: silver pectoral and gold pectoral. Elemental composition analysis at characteristic spots on the surface and in depth is done. As the investigated objects are of high value, the desire was to obtain reliable spectra for analysis causing as less damage as possible, causing craters hardly visible by a naked eye. The analysis of the recorded data and the in-

depth profile of some lines provide information also about previous restoration treatment of the object.

Scanning system for precise laser cleaning is built. The system includes Galvanometer Scanner, laser (either CuBr laser or the second harmonic of Nd:YAG laser) and several mirrors guiding the laser beam. Different test samples made of paper and textile were artificially contaminated with graphite, marker, toner and ink. Preliminary experiments were done with fluence, scanning rate and number of scans varied.

An exact analytic solution is derived for a two-state quantum system driven by a time-dependent external field with an exponential temporal shape in the presence of dephasing. In the absence of dephasing the model reduces to the well-known Demkov model originally introduced in slow atomic collisions. The solution is expressed in terms of the generalized hypergeometric function. Various limiting cases are examined in the limits of weak and strong dephasing, strong driving field, and exact resonance.

Using the results for the time- and spatially-averaged electron temperature, which were previously obtained by the line ratio method of optical emission spectroscopy for several metal halide vapor lasers excited in nanosecond pulsed longitudinal discharge and analytically solving steady-state heat conduction equation for electrons as well, radial distribution of time-averaged electron temperature, i.e. spatially-resolved electron temperature, is obtained. 2D (r, t) numerical solution of nonstationary heat conduction equation for electrons is also found out.

INNOVATION:

Most of the Laboratory members are participants of WG 5 “Lasers and Laser Assisted Anealing of nanostructures”, part of INERA project.

Two patents are in procedure and seven patents are held by laboratory members.

TEACHING ACTIVITIES:

In 2015 three PhD students were working in the Laboratory under thr supervision of assoc.prof. M.Grozeva.
D.Yordanova has started her Ph.D. study and S.Karatodorov and V.Atanasova are approved for defence.

Assist. Prof. Ognian Sabotinov is organizing series of introductory courses for medical doctors for work with laser systems.

Students from Technical University, Sofia undertook a two-week traineeship course in the MVL lab in July.

The young scientists of the Laboratory participated in the traditional XV Winter Seminar of PhD Students and Young Scientist, as well as in a number of training workshops organised in the frame of INERA project.

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

PUBLICATIONS:

1. Barbucha, R., Kocik, M., Garasz, K., Tański, M, **Petrov, T**., Radzewicz, C. Femtosecond laser system for micromachining of the materials. Proc. of SPIE, Volume 94470J, 2015, doi:10.1117/12.2086473.
2. Chernogorova, T. P., **Temelkov, K. A.**, **Slaveeva, S. I.**, Vuchkov, N. K.. Determination of spatially- and time-resolved electron temperature in nanosecond pulsed longitudinal discharge used for excitation of powerful gas discharge lasers. Proc. of SPIE, Volume 944719, 2015, doi:10.1117/12.2175633.

3. Petrunov, V. I, Andreeva, L. S., **Karatodorov, S. I.**, **Mihailov,** V. I., Terzieva, S. D., Ilievska, I., Stoyanova-Ivanova, A. K**.**, Tumbalev, V. G., Mikli, V.. Analysis of elemental composition of a heat activated, multi-force, nickel titanium othodontic archwire. Bulgarian Chemical Communications, 47, 1, 2015, 49 - 53.
4. **S. Karatodorov**, **V. Mihailov**, **M. Grozeva**. Emission characteristics of laser ablation-hollow cathode glow discharge spectral source. Open Chemistry, 13, 1, 2015, 187–192.
5. **Zlatanov K. N.**, Vasilev G. S., Ivanov P. A., Vitanov N. V.. Exact solution of the Bloch equations for the nonresonant exponential model in the presence of dephasing. Phys. Rev., A 92, 043404, 2015.

Participation at 8 international conferences with total of 18 reports.

ONGOING RESEARCH PROJECTS:

- Lasers and Laser Assisted Annealing of nanostructures (WG 5) – part of "Research and Innovation Capacity Strengthening of ISSP-BAS in Multifunctional Nanostructures" (INERA/FP7-REGPOT-2012-2013-1).
- Lasers, laser technologies and applications (funded by the budget subsidy of BAS).
- Femtosecond laser applications (under the Academy's bilateral agreements with IFFM, Gdansk, PAS, Poland).
- Ultrafast laser applications in material processing and characterization (under the Academy's bilateral agreements with National Institute for Lasers Plasma and Radiation Physics, RAS, Romania).
- Laser induced fluorescence analysis for cultural heritage investigation and preservation (funded by NFS MDU 03/79 2012).

APPLIED RESEARCH UNIT

MOLECULAR BEAM EPITAXY

HEAD: **Assoc.Prof. Gencho M. Minchev, Ph.D.**
Tel.: 9795665; e-mail:mbe@issp.bas.bg

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

APPLIED RESEARCH RESULTS:

In the last several years an universal approach for registration of nanosized biological objects (bacterial spores, viruses, molecular structures, bio-macromolecules, etc.) has been created. It is based on their immobilization by conform antibodies and then measuring the resulted mass increase (although it is ultra small ~ 10^{-18} g).

An Innovation Project for creation of a universal approach (instrument and method) for obtaining the physical-chemistry values that underlay the bio-chemical fundament of live, have been prepared for submitting.

ONGOING RESEARCH PROJECTS:

Budget Project: "Method and equipment for parameter determination of stereo-conform bio-chemical reactions".

Today *Life Sciences* are the mainstream of scientific research. The life itself, in general, is based on a limited class of biochemical reactions (stereoconform). However, the evolution has created an incredible variety of bio-molecules, bio-reactions, regulatory cycles and mechanisms. A significant portion of current research in the *Life Sciences* is aimed at detecting, understanding and cataloguing of this variety. In medical research, where immune reactions are the main stereoconform reactions, their investigation is of basic significance.

The goal of the Budget Project is to use the created through the Innovation Project first-of-a-kind instrument to measure activation energies and reaction constants of different type stereoconform (immune) reactions in their own natural environment (solutions, serums, body fluids etc.).

MUSEUM

HISTORY OF THE PHYSICS IN BULGARIA

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

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

RESEARCH ACTIVITIES:

Patent application was announced, and PhD dissertation was defended [1] last 2015 year. Associate Professor Competition finished successfully.

Seven documentary inquires were made in the Museum. Four customers were external visitors and three orders were made by administrative officer. They concern documents about Georgi Nadjakov, Nikolay Kirov, and Stefan Marinov. Personal library of Stefan Kanev was used. Georgi Nadjakov permanent exhibition accepted some groups of visitors and many individual attendances during the Institute open door days.

Twelve donations were accepted to the Museum. New materials about Stefan Kanev came from the Central Laboratiry of Solar Energy and New Energy Sources. Professor Angel Popov (member of BAS), Professor Alexander Dreischuh, Professor Nikolay Tonchev, Professor Simeon Angelov and Professor Minko Balkanski gave their donations to the Museum. Complementary historical sources were obtained from Professor Bogomil Kovachev, Iskren Azmanov, and the wife of Vasil Stefanov.

Museum took part in the new book presentation [2].

PUBLICATIONS:

1. Г. Камишева, Ранни проучвания по физика на кондензираната материя в България 1889–1945, Дисертация, ИФТТ-БАН, София (2015).
2. Г. Камишева, Представяне новата книга на акад. А. Г. Петров “Физика на живата материя”. – Списание на БАН, приета за печат (2015).