CONTENTS

Dear Colleagues,

2009 was a remarkable year for ISSP. The Institute went through its first external evaluation, jointly performed by ESF and ALLEA. The procedure started by the preparation of a detailed self-evaluation report, submitted to and considered by the auditors in advance to the visit. Several Divisions of the Institute were later visited by the auditing panel members and a scrutinizing interview of the Institute administration by the auditors completed the evaluation. Our final evaluation scores are well known, BAA: B for quality and productivity, A for relevance and impact and A for prospects. These are the highest scores among the physics institutes and are a guaranty for a better future of ISSP. All the staff is to be congratulated for the efforts exercised during the evaluation.

The 2009 productivity of ISSP in total is 334 papers printed and in press. New monographs were published by S. Kaschieva et al., and by Z.Dimitrova et al. A textbook was published by D. Pushkarov. The total impact factor for 2009 of 20 of our scientific coworkers is higher than 4.0. They fully deserve the admirations of the whole staff.

New large scientific projects were funded by the National Science Fund with substantial levels of funding. A new clean room facility was installed as a result from a joint project with Fabless Ltd. Thanks to all these efforts, the annual income of the Institute was substantially increased and the target of 1 Mln Lev was overcome.

The system of internally funded projects is well established in ISSP in the last four years. The results from the third session of the Internal Project Competition were highly encouraging, therefore a fourth session was called. The interest of the groups having no other funding, is considerable. 9 projects were funded with a total amount that was by 64% higher compared to 2008. Unfortunately, due to the unfolding crisis the call for a next session in 2010 is temporary suspended.

Professor E. Atanasova received the Pythagoras Award of MON for the best woman-scientist. Awards for the best scientific achievements of the year 2009 in ISSP were presented to teams lead by Assoc. Professors P. Rafailov and S. Andreev. Professors N. Vuchkov, S. Kaschieva, D. Zhechev and Assoc. Professor M. Primatarowa were awarded the Georgi Nadjakov Sign of Honour 1st degree. Assoc. Professors D. Arsova, P. Danesh, T. Tsvetkova, E. Keskinova and Z. Ivanova were awarded the Georgi Nadjakov Sign of Honour 2nd degree. Medals and diplomas brought pride and satisfaction not only to their winners, but to the Institute as a whole.

The 16th edition of our broadly recognized International School of Condensed Matter Physics is scheduled for September 2010. The School will be devoted to the memory of the late Professor Joseph Marshall, Honorary Chairman of the School. The topic is: Progress in Solid State and Molecular Electronics, Ionics and Photonics. Proceedings of the 15th School were already published by JOAM, Buharest.

Alexander G. Petrov

GEORGI NADJAKOV INSTITUTE OF SOLID STATE PHYSICS
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The Georgi Nadjakov Institute of Solid State Physics (ISSP) is specialized in fundamental and applied research in the field of condensed matter physics, microelectronics, optics, spectroscopy and laser physics.

The main scientific and applied achievements of the Institute are in the field of condensed matter theory, critical phenomena and phase transitions, superconductivity and superconducting materials, low temperature physics, liquid crystal physics, soft and living matter physics, structure and properties of crystals and amorphous materials, nanophysics, atom and plasma physics, high precision thermometers, integrated optics, optical fibres, acoustoelectric and microelectronic sensors, metal vapour lasers.

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, UV/VIS/NIR Spectrometer Perkin Palmer Lambda 1050;
- 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, 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 videomicroscopy and micromanipulation of lipid membranes;
- Lasers of various systems - metal vapour, hollow cathode, picosecond lasers for plasma physics and laser analysis of materials with possible application in ecology.

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 Experemental 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 Insitute of Solid State Physics was Academician Milko Borissov. The second Director (1991-1999) was Professor Nikolay Kirov.*

ORGANIZATION OF THE INSTITUTE OF SOLID STATE PHISICS

DIRECTORATE

Director:	Academician A.G. Petrov, D.Sc.
Deputy Directors:	Assoc. Prof. S. Andreev, Ph.D. Assoc. Prof. V. Lovchinov, Ph.D.
Scientific Secretary:	Assoc. Prof. M. Primatarowa, Ph.D.
Secretaries:	Mrs. L. Dedinska, Dipl. Eng. Assist. Prof. E. Vlaikova (FP7 of EU)

ADMINISTRATIVE STAFF

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Administration's office:	Head: Mrs. I. Velkova, Dipl. Eng.
Accountant's office:	Head: Mrs. E. Popova

DIVISIONS

Theory	Head: Prof. D. Pushkarov, D.Sc.
Material Physics	Head: Prof. M. Gospodinov, D.Sc.
Nanophysics	Head: Assoc. Prof. D. Nesheva, Ph.D.
Micro- and Acoustoelectronics	Head: Assoc. Prof. S. Andreev, Ph.D.
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Physical Optics and Optical Methods	Head: Prof. M. Petrov, D.Sc.
Soft Mater Physics	Head: Acad. A. G. Petrov, D.Sc.
Laser, Atomic, Molecular and Plasma Physics	Head: Acad. N. Sabotinov, D.Sc.
Innovation Department:	Head: Assoc. Prof. S. Andreev, Ph.D.
Education Department:	Head: Prof. K. Blagoev, D.Sc.

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Secretary: Assoc. Prof. M. Grozeva, Ph.D.

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12. Assoc. Prof. D. Dimitrov, Ph.D.
13. Assoc. Prof. S. Tonchev, Ph.D.
14. Assoc. Prof. H. Chamati, Ph.D.
15. Assoc. Prof. T. Milenov, Ph.D.

DIVISION THEORY

THEORETICAL DEPARTMENT

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RESEARCH SCIENTISTS: **8**

Prof. N.B. Ivanov, DSc; Prof. P.C. Ivanov, DSc; Assoc.Prof. M.T. Primatarowa, PhD; Assoc.Prof. K.T. Stoychev, PhD; Assoc. Prof. E.R. Korutcheva, DSc; Assoc.Prof. H. Chamati, PhD; Assist. Prof. R. S. Kamburova

RESEARCH ACTIVITIES:

We derive the finite-size scaling behavior of various dynamical quantities in critical films with periodic and free boundary conditions via the renormalization group method. Explicit results for the scaling functions of temperature--dependent finite-size susceptibilities at temperatures in the neighborhood of the critical temperature and of layer and surface susceptibilities for the φ^4 model at the bulk critical point are given to orders φ and $\varphi^{3/2}$.

The discrete nonlinear Schrödinger equation with third- and fifth-order nonlinearities was investigated. Effects of discreteness for the homogeneous case were analyzed. Exact analytical solutions were found for wide static solitons in the presence of impurities. The bound soliton-defect solutions can be single-peak for attractive impurities or double-peak for repulsive impurities. In contrast to the standard cubic nonlinear case, where the positions of the peaks do not depend on the nonlinearity, now they are strongly influenced by the quintic nonlinearity. The model plays an important role in numerous physical systems with complicated nonlinear interactions.

Two discrete nonlinear Schrödinger chains were investigated for both linear and nonlinear coupling. The scattering of solitons from point defects in these systems was studied numerically. The soliton dynamics depends on the interchain coupling, the soliton parameters (velocity and width) and the defect strength. It is obtained that solitons which are excited in one of the two chains can be perfectly switched and at the same time transmitted, trapped or reflected by the impurity.

Enhanced scattering intensities are observed for crystals doped with Co, V and Co+V. In crossed polarizations intrinsic and impurity-induced intensities are superimposed, whereas the latter is due to emerging anisotropic exciton bands and/or anisotropic exciton-impurity interaction. Doping with Co yields much stronger scattering intensities than doping doping with V, which can be ascribed to the polarization of the CoO6 octahedra as compared to the neutral GeO4 tetrahedra.

A hypothesis is proposed that because of the neuroautonomic responsiveness in young subjects, fractal and nonlinear features of cardiac dynamics exhibit a pronounced stratification pattern across sleep stages, while in elderly these features will remain unchanged due to age-related loss of cardiac variability and decline of neuroautonomic responsiveness. The variability and the temporal fractal organization of heartbeat fluctuations across sleep stages in both young and elderly was analyzed. It was found that independent linear and nonlinear measures of cardiac control consistently exhibit the same ordering in their values across sleep stages, forming a robust stratification pattern. Despite changes in

sleep architecture and reduced heart rate variability in elderly subjects, this stratification surprisingly does not break down with advanced age. Moreover, the difference between sleep stages for some linear, fractal, and nonlinear measures exceeds the difference between young and elderly, suggesting that the effect of sleep regulation on cardiac dynamics is significantly stronger than the effect of healthy aging.

A new cross-correlations test Q(CC)(m) was introduced (with m for the number of degrees of freedom). If there are no cross-correlations between two time series, the cross-correlation test agrees well with the X-2(m) distribution. If the cross-correlations test exceeds the critical value of the X-2 (m) distribution, then we say that the cross-correlations are significant. It was shown that if a Fourier phase-randomization procedure is carried out on a power-law cross-correlated time series, the cross-correlations test is substantially reduced compared to the case before Fourier phase randomization. The effect of periodic trends on systems with power-law cross-correlations was investigated as well.

Numerical lattice simulations of an excitable medium were performed. It was shown that the interaction of a spiral wave with a periodic train of planar fronts leads to annihilation of the spiral wave even when i) the period of the fronts is longer than the period of the spiral and ii) the annihilating fronts are released at a significant distance from the spiral. The observed annihilation is not due to spiral drift, and occurs well inside the lattice.

It has been suggested that dynamical processes, influenced by inputs and feedback on multiple time scales, may be sufficient to give rise to 1/f scaling and scale invariance. Two examples of physiologic signals that are the output of hierarchical multiscale physiologic systems under neural control are the human heartbeat and human gait. We showed that while both cardiac interbeat interval and gait interstride interval time series under healthy conditions have comparable 1/f scaling, they still may belong to different complexity classes. Our analysis of the multifractal scaling exponents of the fluctuations in these two signals demonstrates that in contrast to the multifractal behavior found in healthy heartbeat dynamics, gait time series exhibit less complex, close to monofractal behavior. Further, we find strong anticorrelations in the sign and close to random behavior for the magnitude of gait fluctuations at short and intermediate time scales, in contrast to weak anticorrelations in the sign and strong positive correlation for the magnitude of heartbeat interval fluctuations-suggesting that the neural mechanisms of cardiac and gait control exhibit different linear and nonlinear features. These findings are of interest because they underscore the limitations of traditional two-point correlation methods in fully characterizing physiological and physical dynamics.

Statistical analysis of digital images and biological time series (EEG) introduces a method for detecting the unusual parts inside the images or the time series. The method could be used in the analysis of large medical data base and might be directly used inpractice for detecting anomalies.

Statistical analysis of written texts introduces the statistical mechanics formulation for these systems (written texts). By analyzing the frequency and the distribution of the words inside a given text, one can find the parts that give the maximal information. The results could be used in compression and information processing related tasks.

The phase diagram of a symmetric spin-1/2 Heisenberg diamond chain with additional cyclic four-spin exchange interactions was investigated. The presented analysis supplemented by numerical exact diagonaliation results for finite periodic clusters implies a rich phase diagram containing, apart from standard magnetic and spin-liquid phases, two different tetramer-dimer phases as well as an exotic four-fold degenerate dimerized phase. The

characteristics of the established spin phases as well as the nature of quantum phase transitions are discussed, as well.

The impact of the diagonal frustrating couplings on the quantum phase diagram of a two-leg ladder composed of alternating spin-1 and spin-1/2 rungs was studied. As the coupling strength is increased the system successively exhibits two gapped paramagnetic phases (a rung-singlet and a Haldane-like nondegenerate states) and two ferrimagnetic phases with different ferromagnetic moments per rung. The first two states are similar to the phases studied in the frustrated spin-1/2 ladder, whereas the magnetic phases appear as a result of the mixed-spin structure of the model. A detailed characterization of these phases is presented. The study was motivated by the recent synthesis of the quasi-one-dimensional ferrimagnetic material $Fe^{II}Fe^{III}$ (trans-1,4-cyclohexanedicarboxylate) exhibiting a similar ladder structure.

Refined theoretical investigations are presented of the frustrated three-leg ladder compound $[(CuCl_2tachH)_3Cl]Cl_2$ on the use of several complementary methods. The key result is that the thermal behavior of the spin tube is that of an effective spin-3/2 chain at low-temperature with additional delocalized gapped excitations at higher temperatures related to the local triangles.

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1. N.I. Papanicolaou and H. Chamati, Diffusion of a vacancy on Fe(100): a molecular-dynamics study, Comput. Mater. Sci. 44, 1366-1370 (2009), ISSN 0927-0256.
2. H.W. Diehl and H. Chamati, Dynamic critical behavior of model A in films: Zero-mode boundary conditions and expansion near four dimensions, Phys. Rev. B **79**, 104301-104324 (2009), ISSN 1098-0121.
3. H. Chamati and N.S. Tonchev, Comment on "Quantum critical paraelectrics and the Casimir effect in time", arXiv:0903.5229v1 [cond-mat.stat-mech], (2009).
4. K. Koroutchev and E. Korutcheva, Fast Algorithm for Detecting the Most Unusual Part of 2d and 3d Digital Images. Application to Large Medical Databases, WSEAS Transactions on Information Science & Applications, **5** (11) (2009), ISSN 1790-0832.
5. K. Koroutchev and E. Korutcheva, Detecting the most unusual part of two- and three-dimensional digital images, Pattern Recognition **42**(8) 1684 (2009), ISSN 0031-3203.
6. K. Koroutchev, E. Korutcheva, K. Kanev, A.R. Albarino, J.L.M. Gutierrez, F.F. Balseiro, Detection of unusual objects and temporal patterns in EEG video recording, ISVC 2009, Part I, LNCS 5875, pp. 965-974, (Springer-Verlag, Berlin 2009), ISBN 978-3-540-78274-2.
7. B. Podobnik, I. Grosse, D. Horvatic, P. Ch. Ivanov, H. E. Stenley, Quantifying cross-correlations using local and global detrending approaches, European Physical Journal B, **71** (2), 243-250 (2009); ISSN 1434-6036 (electronic); ISSN 1434-6028 (printed)
8. D.T. Schmitt, P.K. Stein, P.Ch. Ivanov, Stratification Pattern of Static and Scale-Invariant Dynamic Measures of Heartbeat Fluctuations Across Sleep Stages in Young and Elderly, IEEE Transaction on Biomedical Engineering, **56** (5), 1564-1573 (2009); ISSN 1558-2591, 1558-2531; ISSN 0018-9294
9. M.A. de la Casa, F.J. de la Rubia, P.Ch. Ivanov, Spiral wave annihilation by low-frequency planar fronts in a model of excitable media, EPL **86** (1) Article Number: 18005 (2009) ISSN 1286-4854 (online), ISSN 0295-5075 (printed)
10. P.Ch. Ivanov, Q.D. Quanli Ma, R.P. Bartsch, V. Schulte-Frohlinde, H.E. Stanley, M. Yoneyama, Levels of complexity in scale-invariant neural signals, Physical Review E, **79** (4) Article Number: 041920 (2009)ISSN 1539-3755 (printed)

11. N. B. Ivanov, J. Richter, and J. Schulenburg, Diamond chains with cyclic multispin exchange interactions, Physical Review B **79**, 104412 (2009), ISSN 1098-0121.
12. N. B. Ivanov, Spin models of quasi-1D quantum ferrimagnets with competing interactions, Condensed Matter Physics **12**, 435 (2009), ISSN 1454-4164.
13. N. B. Ivanov, J. Richter, and J. Schulenburg, Phase diagram of diamond chains with four-spin exchange interactions Journal of Optoelectronics and Advanced Materials **1**, 502 (2009), ISSN 1454-4164.
14. K. T. Stoychev, M. T. Primatarowa and R. S. Kamburova, Interaction of solitons with defects and inhomogeneities in crystals, JOAM, 11, 1128-1134 (2009), ISSN 1454-4164.
15. M. T. Primatarowa, R. S. Kamburova and K. T. Stoychev, Interaction of narrow solitons with point defects in nonlinear lattices, JOAM, 11, 1388-1391 (2009), ISSN 1454-4164.
16. K. T. Stoychev, M. T. Primatarowa and R. S. Kamburova, Interaction of solitons with point defects in molecular chains, JOAM – symposia, 1, 513-516, (2009).
17. R. S. Kamburova, K. T. Stoychev and M. T. Primatarowa, Interaction of discrete solitons with bond defects in NLS chains, JOAM – symposia, 1, 509-512, (2009).
18. D.I. Pushkarov,- Is the supersolid superfluid, arXiv:0901.3218v1, 2009.
19. K. Koroutchev, E. Korutcheva, K.Kanev, Apolinar Rodriguez Albariño ,José Luis Muñiz Gutiérrez, Fernando Fariñas Balseiro, Detection of Unusual Objects and Temporal Patterns in EEG Video Recordings, in the Proceedings of ISVC, Las Vegas, to be published in LNCS, Springer-Verlag, 2009.
20. M. T. Primatarowa and R. S. Kamburova, Bound Soliton-Impurity Solutions in Lattices with Cubic-Quintic Nonlinearities, Proc. 7th BPU General Conference, Alexandroupolis, Greece, 9-13 Sept 2009 (2010).
21. R. S. Kamburova and M. T. Primatarowa, Interaction of Solitons with Impurities in Two Coupled Nonlinear Chains, Proc**.** 7th BPU General Conference, Alexandroupolis, Greece, 9-13 Sept 2009 (2010).
22. K. Stoychev, L. Konstantinov and R. Titorenkova, Enhanced Raman Scattering from LO Phonons in Doped Semiconductors, Proc. 7th BPU General Conference, Alexandroupolis, Greece, 9-13 Sept 2009 (2010).

TEXTBOOKS:

1. D.I. Pushkarov - Mathematical Methods of Physics, Bahcesehir University, Istanbul, 2009, ISBN: 978-975-6437-84-1 (in English)

ONGOING RESEARCH PROJECTS:

1. Quantum effects in spin systems with strong competing interactions (NSF Project DO02-264)
2. Defects and Nanoclusters in Classical and Quantum Crystals (NSF Project F-1517)

DIVISION THEORY

RESEARCH GROUP

COLLECTIVE PHENOMENA
in Condensed Matter

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

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

RESEARCH

- On the basis of a theory developed by members of and experimental data from leading laboratories in France and Japan the phase diagrams of a class of inter-metallic compounds (UGe_2, URhGe, $ZrZn_2$, ...) have been theoretically outlined in some details. These compounds are anisotropic itinerant ferromagnets and exhibit the phenomenon of coexistence of ferromagnetism and superconductivity with a spin-triplet Cooper pairing of electrons (5f electrons foe the U-based compounds and 4d-electrons for the Zr-based ones). The superconductivity appears in the ferromagnetic phase in a broad domain of the T-P diagram for temperatures $T \sim 1$ K and pressures below 1.6 GPa. Criterion for the existence of the phase of coexistence has been derived as well as a classification of the ferromagnetic spin-triplet superconductors has been introduced on the basis of simple ratios between the parameters of our theory. Our results are in an excellent agreement with the experimental data for all T and P of interest to the description of these systems.

- A field theoretical model of a class of dimer systems described by pseudo-spin antiferromagnetic lattice model has been derived. The new field model in under investigation with the aim of explaining the thermodynamics of these systems.

PAPERS

1. D. V. Shopova and D. I. Uzunov, Phys. Rev. B **79** (2009) 064501. "Thermodynamics of ferromagnetic superconductors with spin-triplet electron pairing."
2. D. V. Shopova and D. I. Uzunov," Comparison of experimental and theoretical phase diagrams of ferromagnetic unconventional superconductors." In: Advanced aspects of theoretical electrical engineering, Part I (Plenary lectures) ed. by V. Mladenov (Sozopol School, Sept 99), page 36-47. ISSN: 1313-9479.
3. D. I. Uzunov, "Frustration and Chirality in anisotropic layered antiferromagnets". In: Advanced aspects of theoretical electrical engineering, Part I (Plenary lectures) ed. by V. Mladenov (Sozopol School, Sept 09), page 31-35. ISSN: 1313-9479.

CURRENT PROJECTS, GRANTS

1. Phases and phase transitions in super-fluids, superconducting and magnetic materials (Research contract, Central Administration of BAS).

2. National Foundation of Scientific Research Grant "Physics 1507/05: Coexistence of spin-triplet superconductivity and ferromagnetism in some metallic compounds."

INTERNATIONAL COLLABORATION

Collaborative visits have been accomplished in Tokyo University, the International Institute of Condensed Matter Physics (Brasilia, Brazil), and The African University of Science and Technology (AUST) (Abuja, Nigeria) (in total 7.5 months).

Seminar talks have been given at Tokyo University, RIKEN – Tokyo and Osaka University.

Conference participations have also been accomplished [Tokyo University, "International Seminar on Superconductivity Theory" (June 2009) - 1 report, and Technical University of Sofia "Advanced aspects of theoretical electrical engineering" (an International School held in Sozopol, Bulgaria, Sept 2010) - 2 plenary lectures].

Three one-month (60 hour-) lecture courses have been delivered in AUST-Abuja for the students in the Master Programs of Physics and Materials Science.

DIVISION MATERIAL PHYSICS

LABORATORY

ELECTRON-PHONON INTERACTIONS

HEAD: **Assoc. Prof. Kate Christova, Ph.D.**
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RESEARCH SCIENTISTS: **4**

Assoc. Prof. O. Ivanov, Ph.D.; L. Mihailov, Ph.D.; I. Boradjiev – physicist; B. Stoyanov and Z. Stoyanov - technical ass.

RESEARCH ACTIVITIES:

STRUCTURE AND DYNAMICS OF MANY-ELECTRON SYSTEMS

Nuclear motion, nuclear mass and nuclear size exert an influence over the processes in the electronic system also. Many theoretical studies concern the effects of these nuclear characteristics on the electronic system. It is concerned for the first time and studied the effects resulting from the shape of the nuclei and their deformation on the formation of the electronic energy quantities of multiply charged He like ions. In the current stage, the investigations are performed on the base of obtained numerical results for the ground state energies, mass corrections and mass correlations of the electronic systems for multiply charged He like ions having charge Z from 2 to 118. The nuclides of all existing isotopes are included. A modified by us method is used based on explicitly correlated wave functions (ECWF) approach. Staggering effects of the electronic energy quantities with nuclear magic numbers by N (number of protons) and A (mass number) are investigated for each value of Z (nuclear charge). The effects of nuclear deformations on the electronic energy quantities are investigated through the formation of all nuclear deformation multyplets (by N-Z). The extremely high precision of the obtained numerical results allows their usage in the spectral analysis and plasma diagnostics.

Relativistic and methods will be developed and applied to many-body systems and processes: atomic nuclei, atom clusters, molecular complexes, bio-molecules, solid states surfaces, nano-structures, energy transfer and quantum transport. Moreover these approaches allow to study surface effects, excited states, spin polarization and reactivity. In all these cases using of standard methods is complicated or practically impossible. These methods can be applied also in molecular electronics, biochemistry pharmacology, nonlinear optics, astrophysics and may be used in development of ultra-fast lasers, energy saving technologies with ecological effect, synthesis of new materials and pharmacological surrogates, new approaches in nano-technologies, in the laser transfer and the new information technologies.

These approaches are especially applicable in studying of different forms of astrophysical plasma. The project will allow to calculate the electronic properties of high-density plasma, treated by high intensity magnetic field. Such conditions are preliminary in the neutron stars corona. The results of these calculations will give the necessary microscopic components for stimulation of variety of astrophysical phenomena, for example neutron stars cooling. Development of few-particle approaches for investigation of two- and three-electron atomic systems plays fundamental role in studying of properties and processes in high-temperature astrophysical (for example in the corona solar) and laboratory plasma.

TWO-PHOTON RESONANCE AT STIMULATED RAMAN ADIABATIC PASSAGE (STIRAP)

The technique of STIRAP is a highly efficient tool for coherent population transfer in a chainwise connected three-state quantum system, 1-2-3. It is widely accepted that the two-photon resonance between the two end states 1 and 3 of the chain is a crucial condition for STIRAP. This assumption is easily justified when the two driving fields, pump and Stokes, produce nearly equal couplings for the two transitions, 1-2 and 2-3. It is shown analytically, supported by numerical examples, that when the peak values of the pump and Stokes couplings differ significantly, the two-photon population transfer profile is distorted and its center is shifted away from the two-photon resonance; hence the optimal operation of STIRAP demands a certain two-photon detuning. A simple analytical valuation of the center and the width of the two-photon profile are derived. The results are of potential importance for a number of applications of STIRAP, particularly in situations when the pump and Stokes fields are of different physical nature (e.g., laser and cavity fields), or when two-photon resonance is unwanted (e.g. because of the presence of residual light).

MECHANICAL STRESS IN FILM-SUBSTRATE SYSTEMS

The influence of MeV electron radiation on the electronic characteristics and mechanical stress of Si-SiO_2 structures was reported. To study the electronic defect characteristics, quasi-static capacitance-voltage and thermally-stimulated current methods were applied. It was found that radiation defects induced at the interface and in the oxide correlated with measured stress changes, in a manner that depends on the irradiation dose. Both kinds of defect influence the electrical and mechanical characteristics of the structures. High energy electron irradiation generates changes in the magnitude and direction of strain, which is explained by the predominating influence of the oxide charge. At lower doses of MeV electron irradiation, a primary role in the mechanical stress changes is assigned to the radiation induced interface states.

SURFACE PHOTO-CHARGE EFFECT (SPCE) AND ITS APPLICATION

Surface photo-charge effect (SPCE) in the “Si - liquid crystal” - structure has been studied. A leap in the measured signal during heating of “Si - liquid crystal” - structure has been registered. It is supposed that this jump is caused by a phase transition in the liquid crystal. An account of a contract with a Bulgarian Company successfully ended up. In these studies has been experimentally shown that: for the materials we are interested in, each sample generates a specific signal which actually reveals the opportunity to control the parameter of our interest; a few recommendations are made to improve the production technology. The company sent a letter of thanks addressed to the ISSP for the work. A considerable amount of work on establishing contacts with Bulgarian and foreign institutions and partners is fulfilled in order to prepare projects; such projects have been prepared and submitted. Our research results, related to the opportunity to control foods with a direct possibility for practical application, have been processed. An article with the heading “Application of Surface Photo Charge Effect for Milk Quality Control” has been accepted for printing in the “Journal of Food Science”. It has the status of an invited article. A technology for getting inhibitors in some type of foods is suggested.

OPERATION AND DEVELOPMENT OF SCIENTIFIC APPLICATIONS IN PRACTICE

Our systems “Dynamic Traction Force Integration” and “Optimal Distribution of Engines” are implanted in the system for development of Train Schedules in Bulgaria. There are developed additional inquiries. **The systems are in operation on 65 working positions.** Copyright belongs to L. Mihailov. Future work is currently in negotiation stage concerning energetic calculations to be included in schedule projects.

PUBLICATIONS:

1. K. Christova, I. Boradjiev, D. Spassov, G. Beshkov, Stress in boron nitride nanofilms prepared by rapid thermal annealing, JOAM, 11, #10, 2009, 1557, ISSN 1454-4164.
2. S. Kaschieva, K. Christova, S. N. Dmitriev, Changes in Si-SiO_2 structure characteristics generated by MeV electron irradiation, JOAM, 11, #10, 2009, 1494, ISSN 1454-4164.
3. O. Ivanov and S. Radanski, Application of Surface photo charge effect for milk quality control, Journal of Food Science **(invited)**, 74, R79 – 83 (2009)), ISSN 0022-1147
4. R. L. Pavlov, L.M.Mihailov, Ch.J.Velchev, M.Dimitrova-Ivanovich, and J.Maruani, Variational correlation corrections and their contributions in nonrelativistic and relativistic energies of multiply charged Helium like ions, Progress in Theoretical Chemistry and Physics, eds. G. Delgado Barrio et all, Springer, The Netherlands, ISBN 9781402087066.
5. R. L. Pavlov, L.M.Mihailov, Ch.J.Velchev, M.Dimitrova-Ivanovich, and J.Maruani, Variational correlation corrections and their contributions in nonrelativistic and relativistic energies of multiply charged Helium like ions, Fourteenth International Workshop "Quantum Systems in Chemistry and Physics" (QSCP XIV), September 13-19, 2009, San Lorenzo del Escorial, Madrid, Spain, ISBN 9781402087066.
6. R.L. Pavlov, L.M. Mihailov, Ch.J. Velchev, M. Dimitrova-Ivanovich, Zh. K. Stoyanov, D. Van Neck, J. Maruani, Contributions of Mass Correlations in Nonrelativistic and Relativistic Ground State Energies of Multiply Charged Helium Like Ions in High-Temperature Plasma, XXVIII Int. Workshop on Nuclear Theory, June 22-27, 2009, Rila Mountains
7. I. Boradjiev, A. A. Rangelov, N. V. Vitanov, Is two-photon resonance optimal for STIRAP? 2nd Vienna Symposium on the foundation of modern physics, Vienna (Austria), 10-14.06.2009-poster session.
8. I. Boradjiev, A. A. Rangelov, N. V. Vitanov, Is two-photon resonance optimal for Stimulated Raman Adiabatic Passage (STIRAP)? 41 European Group on Atomic Systems Conference, Gdansk (Poland), 07-11.07.2009 – poster session.
9. I. Boradjiev, FASTQUAST network meeting and 1st Summer School on "Ultrafast control of quantum systems by strong laser fields", 23-27.09.2009, Retimno (Greece)
10. I. Boradjiev, A. A. Rangelov, N. V. Vitanov, Is two-photon resonance optimal for Stimulated Raman Adiabatic Passage (STIRAP)? CAMEL 2009 – Control of Quantum Dynamics of Atoms, Molecules and Ensembles by Light, Nessebar (Bulgaria), 23-28.06.2009. – oral presentation.
11. R. L. Pavlov, L.M.Mihailov, Ch.J.Velchev, M.Dimitrova-Ivanovich, Zh. Stoyanov, J. Maruani, D. Van Neck, Correlation effects in multiply charged Helium-like ions, XII Winter Seminar "Physics in different subjects – the modern physics" of young scientists and PhD students of BAS Institutes; Dec 4-6, 2009, BAS house, Vitosha Mountain

ONGOING RESEARCH PROJECTS:

1. Experimental and theoretical study of many-electron and multicomponent systems (BAS)
2. Contemporary problems of the nuclei theory and other many-electron systems. (NSF)
3. Optimal distribution of traction force engines. (Bulg. State Railways)
4. Many-electron systems and their behaviour in electromagnetic field. (Equivalent, Belgium)
5. COST Chemistry Action 2009, OC-2008-2-3081
6. New applications of hollow cathode discharge for depth profile analysis of recent nano - structure and in optogalvanic spectroscopy" (Inst. of Phys., Krakow, Poland)
7. Dynamic optogalvanic signals in a hollow cathode discharge as a plasma diagnostics technique. (Inst. of Phys., Academy of Sci. of Serbia)
8. Studying of the possibilities for coal-middling slime quantity control at ceramic manufacturing (Prolife technology firm}

DIVISION MATERIAL PHYSICS

LABORATORY

STRUCTURAL METHODS

HEAD: **Assoc.Prof. Malina Baeva, Ph.D.**
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TOTAL STAFF: **5**
RESEARCH SCIENTISTS: **3**

Assoc. Prof. M. Kalitzova, Ph.D.; Assist. Prof. D. Petrova-Kerina, Ph.D.; T.Malakova, physicist; V. Tomov, physicist; G. Avdeev, physicist

RESEARCH ACTIVITIES:

1. In 2009 seventy X-ray structural analyses were made related to the orientation of single crystals and determination of their crystal phases. The purposeful and systematical work allows us to index the crystalline lattice of several new compounds. Their unit-cell sizes and the structural class to which they belong were determined. This provides an opportunity for more detail investigation of subtitutional atoms influence in a row of solid solutions, which are obtained by the classical solid-solution reaction.

2. Crystals $Bi_2Fe_4O_9$ (the so-called ferroic crystals) were synthesized by high temperature solutions method. The results of X-ray structural analysis proved that these ferroics crystallize in the space group *Pbam* and that they have orthorhombic structure with unit-cell sizes 7.965 Å*;* b = 8.440 Å*;* c = 5.994 *Å*, correspondingly. Additionally, by Differential Thermal Analysis a second order phase transition at temperature 550^o C was established.

3. Relaxor crystals $Pb_{0.78}Ba_{0.22}Sc_{0.5}Ta_{0.5}O_3$ (having perovskite structure) were grown. The changes in their structure at pressure of 9.8 GPa were studied. The results show that the substitution of Pb by Ba in the perovskite ABO_3 structure leads as to a diffusion phase transition induced by the pressure, so as to an availability of local structural deformations in the vicinity of A-positioned barium cations.

4. The influence of rhodium doping onto holographic properties of $Bi_4Ge_3O_{12}$ crystals is investigated. A photohromic effect and nonlinear photoconductivity dependence on the light intensity was established. The transport mechanism of electric carriers in $Bi_4Ge_3O_{12}$ crystals doped by rhodium was investigated.

5. By neutron diffraction experiment was proved that the steels from the N-Fe-Ni-Mn-Mo-V alloy system consist only from ferrite crystalline phase (volume centered unit-cell). The cast alloys appear as experimental ones. Our results demonstrate the possibility to dope by nitrogen steels without chrome atoms presence in them.

6. For reduction of risk of gallstones and renal stones formation, per oral administration of natural clinoptilolite combined with vitamin C is proposed. The clinoptilolite is able to absorb toxic products of metabolism. Based on our patent *"Modified clinoptilolite and its application as nutrient supplement"* a permission of its per oral acceptance is obtained.

PUBLICATIONS:

1. T. Ivanova, K. Gesheva, M. Kalitzova, F. Hamelmann, U. Heinzmann, Electrochromic mixed films based on WO_3 and MoO_3, obtained by APCVD method, *Journal of Optoelectronics and Advanced Materials* **11**, № 10, (2009) 1513 - 1516.

2. V. Marinova, D. Petrova, S.H. Lin, M. L. Hsieh and K.Y. Hsu, The influence of Rh doping on the light-induced properties of $Bi_4Ge_3O_{12}$ single crystals, *J. Opt. A: Pure Appl. Opt.* **11** (2009) 015201 (6pp).

3. A. M. Welsch, B. J. Maier, J. M. Engel, B. Mihailova, R. J. Angel, C. Paulmann, M. Gospodinov, A. Friedrich, R. Stosch, B. Güttler, D. Petrova, and U. Bismayer, Effect of Ba incorporation on pressure-induced structural changes in the relaxor ferroelectric $PbSc_{0.5}Ta_{0.5}O_3$, *Phys. Rev*. B **80**, (2009) 104118.

4. T.I. Milenov, D. Petrova, P. M. Rafailov, M. N. Veleva, L. Yankova, G.V. Avdeev, Growth and study of the dielectric properties of $PbSc_{0.5}Nb_{0.5}O_3$ crystals doped with La, *Journal of Optoelectronics and Advanced Materials – Symposia* **1**, № 3, (2009) 295-297.

5. T.I. Milenov, P. M. Rafailov, G. V. Avdeev, C. Thomsen, Chemical vapor deposition of carbon layers on Si {001} substrates, *Journal of Optoelectronics and Advanced Materials* **11**, № 9, (2009) 1273 - 1276.

6. P.M. Rafailov, T.I. Milenov, M. Monev, G.V. Avdeev, C. Thomsen, U. Dettlaff-Weglikowska, S. Roth, Spectroscopic studies on electrochemically doped and functionalized single-walled carbon nanotubes, *Journal of Optoelectronics and Advanced Materials* **11**, № 9, (2009) 1339 - 1342.

7. N. Izmirova, E. Djurova, B. Alexiev, M. Baeva, P. Blagoeva, Natural clinoptilolite for supporting the balance in the organism, *Farmaceutical Monitor* **10**, № 4, (2009) 16-19.

8. T. Ivanova, K. Gesheva, S. Bojadjiev, M. Kalitzova and O. Lebedev, Atmospheric Pressure Chemical Vapour Deposition of Electrochromic Mo-W Oxide Films: Structure and Optoelectronic Properties, 216th ECS Meeting, Simpisium F3 – Euro CVD 17, Viena, Austria, 4- 9 October, 2009.

9. M. Baeva, A.I. Beskrovnyi, I. Parshorov, S.G. Vasilovskii, Microstructural investigation of Fe-Ni-Mn-Mo-V-C-N ferritic steels by neutron diffraction, *AIP Conference Proceedings* **1203**, (2009) 394-397.

ONGOING RESEARCH PROJECTS:

1. "Georgi Nadjakov" ISSP – BAS Bulgaria / Energetics Department of Rome University, "La Sapienza" – Italy, "Ion beam synthesis nanoclusters and new structures in semiconductors and isolators for microelectronic purposes".
2. Grant No. PF 16 / 2009 from Bulgarian Nuclear Regulatory Agency
"Microstructure investigation of Fe-Ni-Mn-Mo-V-N(C) steels by neutron diffraction",
Contract for experimental work between laboratory Structural Methods – ISSP, Bulgaria and laboratory Neutron Physics – JINR, Russia

INTERNATIONAL COLLABORATION:

1. ISSP – BAS Bulgaria / EMAT, RUCA, University of Antwerp, Belgium.
2. Institute of Solid State Physics – BAS, Bulgaria and Frank Laboratory of Neutron Physics – Joint Institute of Nuclear research, Dubna, Russia.

DIVISION MATERIAL PHYSICS

LABORATORY

CRYSTAL GROWTH

HEAD: **Prof. Marin Gospodinov, D.Sc.**
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TOTAL STAFF: **9**
RESEARSCH SCIENTISTS: **8**

Assoc. Prof. T.I. Milenov, Ph.D.; Assoc. Prof. S.G. Dobreva, Ph.D.; Assoc. Prof. P.M. Rafailov, Ph.D.; Asist. Prof. Z. I. Dimitrova, Ph.D.; Asist. Prof. M.N. Veleva; Asist. Prof. L.K. Yankova; Asist. Prof. D.I. Toncheva; O.B. Mihailov, Technician

RESEARCH ACTIVITIES:

Crystals of $LnMnO_3$ (Ln= Ho, Er, Yb, Tm, Lu), Bi_2NiMnO_6 (BNMO), La_2CoMnO_6 (LCMO), La_2NiMnO_6 (LNMO) and $Bi_2Fe_4O_9$ are grown by the high temperature solution growth method. The nature of magneto-electric interactions and magnet symmetry of Mn-moments. The structure of BNMO, LCMO and LNMO was studied by X-ray diffraction and Raman spectroscopy methods. Three shallow levels in the band gap of LCMO were determined by temperature dependence of the resistivity. The observed strong two-phonon interaction in the $Bi_2Fe_4O_9$ crystals was explained by the Franck- Condon effect and degeneration of d-d electron excitations of Fe^{3+}.

The effect of local elastic bending of structure of the pure, Ba- and Bi- doped $PbSc_{0.5}Nb_{0.5}O_3$**,** as well as the structure- induced changes in $Pb_{0.78}Ba_{0.22}Sc_{0.5}Ta_{0.5}O_3$ and the dielectric properties of $0.9Pb(Zn_{1/3}Nb_{2/3})O_3$ - $0.1PbTiO_3$ are also studied.

$Bi_{12}SiO_{20}$ doped with Cu (BSO:Cu) and Se (BSO:Se) are grown by the Czochralski method. They were characterized by scanning electron microscopy, energy dispersive X-ray analysis, and single crystal diffractometry. The distortions of the bismuth frame of the sillenite structure of BSO:Cu crystals were determined by polarized Raman spectroscopy. The influence of doping with Se of BSO was evaluated by UV-VIV and IR absorption and Raman vibration spectroscopy, and single crystal diffractometry. It was assumed that the doping takes place in the tetrahedral positions by replacement of $3Si^{4+}$ ions by (Se^{6+}+ 2 Fe^{3+}) ions.

Specimens with different orientations were examined by transmission electron microscopy. Low- angle misoriented sub-grains were found along the [001] and the [111] zone axes. The observed weak reflections elongation along <001> and <011> is attributed to some kind of stacking faults lying in planes perpendicular to these directions. A complex image of the electron diffraction patterns observed along the [011] zone axis was discussed and it was concluded that these patterns are caused by a second-phase inclusion consisting of BSO, meta-stable phase Bi_2SiO_5 and SiO_2.

Single crystals of $BaBiBO_4$ were grown and studied by single crystal diffractometry, UV-VIS and IR absorption and Raman spectroscopy.

Carbon layers with different structure were grown by CVD of acetone in Ar flow at different temperatures and were characterized by X-ray diffraction and Raman spectroscopy.

The influence of the electrochemically doping of the single-walled carbon nanotubes was determined by Raman spectroscopy. A double resonant Raman scattering study was focused on the variable doping sensitivity of the TO phonon dispersion branch of metallic

nanotubes. Kohn Anomaly and Electron-Phonon Interaction at the K-Derived Point of the Brillouin Zone of Metallic Nanotubes was also investigated.

PUBLICATIONS:

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2. M. N. Iliev, M. M. Gospodinov, and A. P. Litvinchuk, PHYSICAL REVIEW B **80**, 212302 (2009).
3. V. Skumryev, M. D. Kuz'min, M. Gospodinov and J. Fontcuberta, Phys. Rev. B **79**, 212414 (2009).
4. E. Ressouche, V. Simonet, B. Canals, M. Gospodinov, and V. Skumryev, PHYSICAL REVIEW LETTERS **103**, 267204 (2009).
5. B. Maier, B. Mihailova, C. Paulmann, J. Ihringer, M. Gospodinov, R. Stosch, B. Güttler, and U. Bismayer, Phys. Rev. B **79**, 224108 (2009).
6. T. Scholz, B. Mihailova, G. A. Schneider, N. Pagels, J. Heck, T. Malcherek, R. P. Fernandes, V. Marinova, M. Gospodinov, and U. Bismayer, J. Appl. Phys. **106**, 074108 (2009).
7. A.-M. Welsch, B. J. Maier, J. M. Engel, B. Mihailova, R. J. Angel, C. Paulmann, M. Gospodinov, A. Friedrich, R. Stosch, B. Güttler, D. Petrova and U. Bismayer, Phys. Rev. B **80**, 104118 (2009).
8. A-M Welsch, B Mihailova, M Gospodinov, R Stosch, B Güttler and U Bismayer, Journal of Phys. - Condensed Matter Volume 21, Number 23 (2009).
9. A.V. Egorysheva, T.I. Milenov, P.M. Rafailov, C. Thomsen, R. Petrova, V.M. Skorikov, M.M. Gospodinov, Sol. St. Commun.,V. 149, Issue 39-40 (2009) pp.1616-1618.
10. T. I. Milenov, P. M. Rafailov, M. V. Abrashev, R. P. Nikolova, R. Titorenkova, and M. M. Gospodinov**,** Cryst. Res. & Technol. V. 44, Issue 11 (2009) pp. 1192-1196.
11. P. Rafailov, J. Maultzsch, C. Thomsen, U. Dettlaff-Weglikowska,and S. Roth, Phys. Status Solidi B 246, No. 11–12, 2713–2716 (2009) / DOI 10.1002/pssb.200982286.
12. P. Rafailov, J. Maultzsch, C. Thomsen, U. Dettlaff-Weglikowska, and S. Roth, Nano Letters Vol. 9, No. 9 (2009) pp. 3343-3348.
13. P. M. Rafailov, T. I. Milenov, M. Monev, G. V. Avdeev, C. Thomsen, U. Dettlaff-Weglikowska, S. Roth, J. Optoelectr. & Adv. Mater., Vol. 11, No. 9, September 2009, p. 1339 – 1342.
14. T. I. Milenov, P. M. Rafailov, G. V. Avdeev, C. Thomsen, J. Optoelectr. & Adv. Mater., Vol. 11, No. 9, September 2009, p. 1273 – 1276.
15. T.I. Milenov, D. Petrova, P.M. Rafailov, M.N. Veleva, L. Yankova, G.V. Avdeev, J. Optoelectr. & Adv. Mater.-Symposia, Vol. 1, No. 3 (2009) pp.295-297.
16. D. Petrova, V. Marinova, L. Yankova, M. Veleva, D. Kaisheva, O. Petrov, M. Gospodinov, J. Optoelectr. & Adv. Mater.-Symposia, Vol. 1, No. 3 (2009) pp.298-300.
17. N. K. Vitanov, I. P. Jordanov, Z. I. Dimitrova, Communications in Nonlinear Science and Numerical Simulation **14**, 2379-2388 (2009).
18. N. K. Vitanov, I. P. Jordanov, Z. I. Dimitrova, Applied Mathematics and Computation **215**, 2950-2964 (2009).
19. S. Dobreva, T. Milenov, P. Rafailov, R. Petrova, Compt. Rend. Bulg. Acad. Sci. Vol. 62. Is. 5 (2009) pp. 565 – 570.
20. А.В.Егорышева, В.Д.Володин, Т.Миленов, П.Рафаилов, .М.Скориков, Б.В. Костова, *Рост нелинейно-оптических монокристаллов* $BaBiBO_4$ IX Международная Научная Конференция «ХИМИЯ ТВЕРДОГО ТЕЛА: МОНОКРИСТАЛЛЫ, НАНОМАТЕРИАЛЫ, НАНОТЕХНОЛОГИИ», Кисловодск (2009), Россия

21. B. Kostova, T. Milenov, P. Rafailov**,** A. Egorysheva, L .Yankova, M. Veleva, S. Dobreva, V. Skorikov, *Optical Spectroscopy Characterization of Se-doped BiSiO Crystals,* 7th BPU General Conference, Alexandroupolis, Greece, 9-13 Sept 2009, AIP Conferences Series
22. T.I. Milenov, P.M. Rafailov, C. Thomsen, A.V. Egorysheva, R. Titorenkova, L.Yankova, M.N. Veleva, S. Dobreva and V.M. Skorikov, *Raman Spectroscopy Characterization of Se- Doped Bi12SiO20 Crystals,* 7th BPU General Conference, Alexandroupolis, Greece, 9-13 Sept 2009, AIP Conferences Series
23. T.I. Milenov, V.I. Dimov, P.M. Rafailov, B. V. Kostova, *Electron Diffraction Study of Two- and Three-dimensional Deffects in* $Bi_{12}SiO_{20}$ *Crystals,* 7th BPU General Conference, Alexandroupolis, Greece, 9-13 Sept 2009, AIP Conferences Series

ONGOING RESEARCH PROJECTS

Financed by the Bulgarian National Scientific Research Foundation at the Bulgarian Ministry of Education and Science:

1) TKX-1712/2007: "Growth, characterization and investigation of the physical properties of new crystals in the systems Bi-Co(Ni)- Mn(Ru)-O and La-Co(Ni)-Mn(Ru)-O with magneto-electric/ multiferroic behaviour"

COLLABORATION

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

2. Growth and characterization of oxide crystals for optical applications- Research Institute of Solid State Physics and Optics, Budapest, Hungary.

DIVISION MATERIAL PHYSICS

LABORATORY

BIOCOMPATIBLE MATERIALS

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

TOTAL STAFF: **3**
RESEARCH SCIENTISTS: **2**

Assist.Prof. E. Pecheva, Ph.D.; BSc Todor Hikov, physicist;
MSc Dimitrinka Fingarova, PhD student

RESEARCH ACTIVITIES:

The research activities of the Laboratory for Biocompatible Materials (BCM) in 2009 were:

1. 3D calcium phosphate (CaP) matrices were prepared from natural resources found in big amounts in nature (powdered egg-shells micex with phosphoric acid). Such 3D matrices characterized by high degree of porosity are used as bone scaffolds and thus they play an important role in tissue engineering. In the current experimental direction, the matrices are additionally functionalized through the immersion in several functional fluids (through bilateral project with the Hungarian Academy of Sciences).
2. The process of hydroxyapatite (HA) growth was investigated through the surface modification with detonational nanodiamond (DND) particles in three methods: simple soaking, electrodeposition and plasma polymerization of bioactive polymers. Novel HA-DND composite coatings with biomedical applications have been prepared with improved hardness and adhesion on various materials due to the incorporation of the DND particles in the HA coating. Cell culture experiments showed good cell adhesion and spreading over the HA coating grown on the modified surfaces and absence of toxic reactions (on the basis of a project with the Bulgarian Ministry of Education and Science, TK-X1708/07).
3. DND particle distribution in several solutions is extensively investigated since it gives and idea for the behavior of these easily aggregating nanoparticles (on the basis of a project with the Bulgarian Ministry of Education and Science, TK-X1708/07).
4. Modification of the surface of various materials by plasma polymerization of hexamethyldisiloxane (PPHMDS, a bioactive polymer) was attained. It was observed that the modified surfaces are bioactive, i.e. they induce the growth of the biomaterial HA in a simulated body fluid (SBF). Additional treatment of the modified surfaces by NH_3 leads to the creation of surface hydrophilic groups and a decrease of the surface contact angle with liquids, which is an advantage for a better HA adhesion on the modified surfaces (on the basis of a project with the Bulgarian Ministry of Education and Science, TK-X1708/07).
5. Various durations of the NH_3 treatment of the PPHMDS polymer have been undertaken to examine the cell behaviour on surfaces with varying hydrophilicity (on the basis of a project with the Bulgarian Ministry of Education and Science, TK-X1708/07).
6. Aiming at surface modification of various biomaterial surfaces, deposition of the natural polymer cellulose acetate has been carried out by applying the method of electrospinning.

Polymer fiber network suitable for the incorporation of HA or DND particles has been obtained (through bilateral project with the Hungarian Academy of Sciences).

7. Development and improvement of novel technique for analysis of thick and rough HA layers by using adapted white light interferometry. Topography, layer profile, roughness and optical parameters of HA and HA-DND layers were successfully investigated with the technique, named coherence probe microscopy (CPM) and the results were compared with classical techniques such as SEM, AFM, optical microscopy and stylus profilommetry. It was possible to reveal the presence of hidden layers and interfaces by CPM. CPM is based on the interferometry of white light, combined with a precise scanning of the sample in depth and mathematical algorithms for analysis, and allows quick, non-destructive measurements of thick layers, and without any sample preparation for the measurement (based on the collaboration with a French partner from InESS, CNRS, Strasbourg, France, PICS project 4848).
8. The CPM system for thick and rough HA layers characterization has been improved in terms of increasing the lateral resolution for getting better images, comparable to the AFM and SEM techniques. It became possible to construct a model of the layer growth in direction of the optical axis (Oz) (based on the collaboration with a French partner from InESS, CNRS, Strasbourg, France, PICS project 4848).

PUBLICATIONS:

In international journals with IF

1. P. Montgomery, D. Montaner, L. Pramatarova, E. Pecheva, Characterisation of the internal structure and local optical properties of thick layers of hydroxyapatite by coherence probe microscopy, Journal of Optoelectronics and Advanced Materials 11(9) (2009) 1175-1181
2. E. Pecheva, L. Pramatarova, D. Fingarova, T. Hikov, I. Dineva, Z. Karagyozova, S. Stavrev, Advanced materials for metal implant coatings, Journal of Optoelectronics and Advanced Materials 11(9) (2009) 1323-1326
3. T. Hikov, L. Pramatarova, E. Radeva, L. Vanzetti, E. Iacob, R. Dimitrova, E. Pecheva, S. Stavrev, D. Fingarova, Study of plasma polymer structures to induce composite layers, Journal of Optoelectronics and Advanced Materials 11(9) (2009) 1327-1330
4. E. Radeva, L. Pramatarova, R. Dimitrova, S. Popova, T. Hikov, D. Fingarova, E. Pecheva, Infrared analysis of plasma polymerized hexamethyldisiloxane for biocompatible composites, J. of Optoel. and Adv. Materials 11(10) (2009) 1432-1435
5. D.D. Radev, L. Pramatarova, M.Marinov, Titanium- and nickel-based alloys for medical applications, obtained by a powder metallurgy technique, Journal of Optoelectronics and Advanced Materials 11(10) (2009) 1525-1528
6. E. Pecheva, L. Pramatarova, T. Hikov, Y. Tanaka, H. Sakamoto, H. Doi, Y. Tsutsumi, T. Hanawa, Apatite-nanodiamond composite as a functional coating of stainless steel implants, Surface and Interfacial Analysis, in press

In proceedings

1. E. Pecheva, L. Pramatarova, A. Toth, T. Hikov, D. Fingarova, S. Stavrev, E. Iacob, L. Vanzetti, Effect of Nanodiamond Particles Incorporation in Hydroxyapatite Coatings, ECS Transactions 25(3) (2009) 403-410, "Analytical Techniques for Semiconductor Materials and Process Characterization 6 (ALTECH 2009)", B. Kolbesen, C. Claeys, L. Fabry, M. Bersani, D. Giubertoni, G. Pepponi (eds.), 216th ECS Meeting, 4-9 October 2009, Vienna, Austria

FUTURE RESEARCH PLANS OF THE LABORATORY INCLUDE:

1. Control of the process of plasma polymerization of hexamethyldisiloxane on the surfaces of stainless steel, titanium, titanium alloys and glass. Growth of HA and HA-DND composite layers on the modified by plasma polymerization surfaces (on the basis of a project with the Bulgarian Ministry of Education and Science, TK-X1708/07; team leader Assoc. Prof. Dr. L. Pramatarova).
2. Preparation of titanium alloys with biomedical applications and DND incorporation and study of their bioactivity through the deposition of HA (on the basis of a project with the Bulgarian Ministry of Education and Science, TK-X1708/07; team leader Assoc. Prof. Dr. L. Pramatarova).
3. Cell culture experiments with various cell lines for biocompatibility investigation of the prepared samples and layers. Investigation of the protein adsorption and reorganization on the modified surfaces for improving their biocompatibility with living cells (on the basis of a project with the Bulgarian Ministry of Education and Science, TK-X1708/07; team leader Assoc. Prof. Dr. L. Pramatarova).
4. Study of the process of laser-liquid-solid interaction for stimulated HA growth by using different wavelengths, laser power, pulse repetition, time duration, etc. (on the basis of a project with the Bulgarian Innovation Fund and a SME "Lightsystems" Ltd, Sofia, НИФ 02-54/2007; team leader Assoc. Prof. Dr. L. Pramatarova).
5. Measurements by classical and novel techniques for complementary characterization of the surfaces (mainly through bilateral projects with the Hungarian Academy of Sciences, Latvian Academy of Sciences and a PICS project with CNRS-France, as well as on the basis of a cooperation with the collaborators at the ISSP-BAS and other Institutes of BAS; team leader Assoc. Prof. Dr. L. Pramatarova).
6. Preparation of CaP scaffolds with additional functionalization for cell culture experiments (on the basis of a project with the Bulgarian Ministry of Education and Science; team leader Assoc. Prof. Dr. L. Pramatarova, as well as through bilateral project with the Hungarian Academy of Sciences; team leader Assist. Prof. E. Pecheva).
7. Characterization of cellulose acetate polymer fiber network (through bilateral project with the Hungarian Academy of Sciences; team leader Assist. Prof. E. Pecheva).
8. Preparation of CaP scaffolds with incorporated DND nanoparticles for bone scaffolds with improved properties (through bilateral project with the Latvian Academy of Sciences; team leader Assist. Prof. E. Pecheva).

DIVISION NANOPHYSICS

LABORATORY

PHOTOELECTRICAL AND OPTICAL PHENOMENA IN WIDE BAND GAP SEMICONDUCTORS

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TOTAL STAFF: **12**
RESEARCH SCIENTISTS: **10**

Assoc.Prof. D. Arsova, Ph.D; Assoc.Prof. Z. Ivanova, Ph.D; Assoc.Prof. V. Pamukchieva, Ph.D; Assoc.Prof. Z. Aneva, Ph.D; Assoc.Prof. K. Kolentsov, Assoc.Prof. S. Balabanov, Ph.D.; Assist.Prof. L. Yurukova; Assist.Prof. Z.Levi, Ph.D; Asist.Prof. I. Bineva, Ph.D, E. Zaharincheva, technologist; B. Stoianova, physicist

RESEARCH ACTIVITIES:

1. NANOSTRUCTURED THIN FILMS

The microstructure and morphology of SiO_x layers (x = 1.1 или 1.3) with thickness of ~ 15 nm have been investigated by X-ray diffraction and reflection, transmission electron microscopy and atomic force microscopy. It has been shown that upon high temperature annealing the roughness of the c-Si substrate/SiO_x interface increases and a layer of silicon nanocrystals is formed which is situated at a distance of more than 3 nm from the substrate. On the other hand, for both compositions studied the high temperature annealing decreases the surface roughness of the SiO_x layers. This result is important for inclusion of such layers in non-volatile memory structures. The composition of the layers has been determined by X-ray photoelectron spectroscopy (XPS). The x-values obtained are very close to the expected ones. This observation has confirmed that the developed deposition technique allows preparation of SiO_x layers with desired composition. For the layers annealed at 1000^{o}C the XPS results have indicated that at this temperature a complete phase separation takes place and the matrix composition is SiO_2. This result is in good agreement with the conclusion made previously on the basis of infra red transmission measurements.

A technique has been developed for deposition of $Zn_xCd_{1-x}Se$ ternary semiconductor thin films by thermal vacuum evaporation. Layers of five different compositions in the range x = 0.4-0.8 have been prepared by applying this technique. The optical transmission of the layers have been investigated in the wavelength range 400 – 2 500 nm. The optical absorption curves, the layer thickness and refractive index of the layers in the week absorption region have been calculated from the transmission curves using the Swanepoel's method. The optical band gap of the layers has been determined; it is in the energy range 2.0 - 2.31 eV. The obtained results have proven that $Zn_xCd_{1-x}Se$ thin films with considerable variations in the composition can be produced by means of the new deposition technique.

2. DISORDERED MATERIALS - CHALCOGENIDE GLASSES AND THIN FILMS

Using Judd-Ofelt analysis, basic spectroscopic and radiative parameters of Er-doped $(GeS_2)_{80}(Ga_2S_3)_{20}$ glasses at different excitation sources that are important from a practical point of view have been determined. Samples enriched with Ga (25 и 33 мол% Ga_2S_3) were investigated as well and higher Er^{3+} ion concentration has been reached, keeping the matrix homogeneity. A broadening PL effect at ~1540 nm has been established with increasing Er

content from 1.05 to 1.56 at. %. The peculiarities in emission changes and the corresponding optical transitions in Er^{3+} ions have been specified by spectra deconvolution. The results obtained so far have been compared with those for other glasses doped with Er, Pr and Ho ions. Enhanced re-absorption of the glass matrix luminescence at Er (Pr)-doped telluride samples has been observed.

Up-conversion compositional trends of chalcohalide GeGaS-CsBr glasses at 795 nm excitation have been evaluated. Based on the observed emission bands at 530, 554 and 644 nm, possible radiative transitions in the energy level diagram of Er^{3+} ions have been clarified. Low temperature PL study at 20 K has been carried out in these glasses, as well. In the frames of joint collaboration with Czech Republic and Korea, the results obtained have been presented at Intern. Conf. on Physics of Non-Cryst. Solids (Brazil).

New "light annealing effect" of reversible photodarkening (PD) has been ascertained in annealed Ge-As-S films with thickness about 700 nm. With increasing the illumination time PD shows an unusual dependence: after reaching a maximal value PD begins to decrease and at long time (~180 min) it disappears completely. The observation has been explained assuming dual action of the light. Light induces a structural ordering predominantly in the near-surface region leading to photobleaching (PB) in competition with the disordering process attendant on PD. Summarizing all previous results it has been concluded that in thinner films ~90-100 nm only PB takes place. The transition of PD to PB is a classical nano-sized effect which is due to the increase of the surface/volume thickness ratio.

The correlations between reversible and irreversible changes in the optical band gap (E_g) and refractive index (n) due to photo- and thermal treatment have been analyzed in films from the Ge_2S_3-AsS_3 system. It has been shown that the observed large irreversible photoinduced (PI) changes of E_g and n agree qualitatively with the Moss relation ($n_o^4 E_g$= const). Moreover, the thermoinduced changes of E_g also correlate with that of n. The quantitative deviations from the Moss relation have been explained taking into account some changes in the film thickness. A part of these results are presented on the International Conference ANC-4 in Romania.

Microscopic investigations have been carried out in collaboration with colleagues from Czech Republic on thin $Ge_{26}As_7S_{67}$ films, which show the highest photosensitivity among the films from the Ge_2S_3-AsS_3 system. Considerable photoexpansion in virgin as well as in annealed films has been observed, although the accompanying photoinduced changes in optical band gap are different in sign and magnitude. The surface roughness monitoring of the illuminated and non-illuminated part of the films has revealed that the oxidation is not the main reason for photo-expansion. The observed features have been related to the network rigidity of Ge-rich films.

A neutron diffraction structural study has been performed on newly synthesized Ge-As-(Se,Te) chalcogenide glasses. Oscillations in the structural factor, S(Q), have been measured with gigh resolution (up to 35 $Å^{-1}$). Reverse Monte Carlo simulations have been used to model the 3-dimensional atomic configuration.

Nonlinear optical properties of thin $Ge_xSb_{40-x}S_{60}$ (x = 10÷35) films have been investigated by SHG- and Z-scan techniques, for the first time. It has been found that for a number of compositions SH intensity has unusual dependence on the pump incident angle. These peculiarities have been onsidered as an indication of structural inhomogeneity on the nano-scale level.

3. AC ELECTROLUMINESCENCE, ELECTROLUMINESCENT STRUCTURES AND DISPLAYS

Electroluminescent (EL) display consisting of seven segments has been produced which emits yellow light with high brightness. It is intended for inclusion in elevator systems and is able to display luminous digital symbols from "0" to 9. As a first step the size and shape of

the segments have been designed and constructed in accordance with the requirements of the company assigning the task. Secondly, a pulse-generator has been produced that provides an ac voltage in the range 50-200 V with frequency 300 Hz - 3 kHz. It ensures optimal brightness of the display. The display has been tested for determination of its lifetime. It has been proven that the brightness drops down to 50% after display operation for more that 20,000 hours.

PUBLICATIONS:

1. J. Terrazas, N. Nedev, E. Manolov, B. Valdez, D. Nesheva, M. Curiel, R. Haasch, I. Petrov, "Effect of oxygen to argon ratio on the properties of thin SiOx films deposited by r.f. sputtering", J. Mat. Sci.: Materials in Electronics, 2009, published online: 17 July 2009.
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3. D. Nesheva, Z. Aneva, B. Pejova, I. Grozdanov, A. Petrova, Photoelectrical characterization of nanocrystalline $AgBiS_2$ thin films, J. Optoelectron. Adv. Mater, **11,** No 9, 1347-1350 (2009).
4. D. Nesheva, M. J. Šćepanović, Z. Levi, S. Aškrabić, Z. Aneva, A. Petrova, Z. V. Popovic Structural characterization and photoluminescence of ZnSe nanolayers, J. Optoelectron. Adv. Mater., **11,** No 9, 1351-1354 (2009).
5. N. Nedev, E.Manolov, D.Nesheva, J.M. Terrazas, B. Valdez, M. A. Curiel and R. Zlatev, Electrical and infrared characterization of thin SiO_2 films deposited by r.f. magnetron sputtering, J. Optoelectron. Adv. Mater., **11**, No 9 1300-1303 (2009).
6. M. Ščepanovic; M. Grujic-Brojcin, D. Nesheva, Z. Levi, I. Bineva and Z.V. Popovic, Characterization of ZnSe Nanolayers by Spectroscopic Ellipsometry, Acta Physica Polonica A, **116**, No 4, 708-711 (2009).
7. Z.G. Ivanova, K. Koughia, G. Soundararajan, J. Heo, D. Tonchev, M. Jayasimhadri, S.O. Kasap, "The influence of CsBr addition on optical and thermal properties of GeGaS glasses doped with erbium", J. Mater. Sci.: Materials in Electronics, **20**, S421-S424 (2009).
8. Z.G. Ivanova, M. Jayasimhadri, M. Kincl, "Optical properties of Er-doped GeS_2-Ga_2S_3 glasses", J. Optoelectron. Adv. Mater., **11**, No 9, 1269-1272 (2009).
9. Z.G. Ivanova, E. Cernoskova, Z. Cernosek, Mil. Vlcek, "Features in the photoluminescence line-shape of heavily Er-doped Ge-S-Ga glasses", J. Non-Cryst. Solids, **355,** 1873-1876 (2009).
10. D. Arsova, E. Vateva, V. Pamukchieva, "Photoinduced changes in sulphur rich Ge-As-S thin films", J. Optoelectron. Adv. Mater., **11,** 1253-1256 (2009).
11. P. Kincl, D. Arsova, E. Vateva, L. Tichy, "Photo-expansion in Ge-As-S amorphous film monitored by digital holographic microscopy and atomic force microscopy", J. Optoelectron. Adv. Mater., **11,** 391-394 (2009).
12. V. Pamukchieva, A. Szekeres, D. Arsova, "Study of photo- and thermally-induced changes in Ge-As-S thin films by spectroscopic ellipsometry", J. Optoelectron. Adv. Mater., **11**, 1249-1252 (2009).

13. V. Pamukchieva, A. Szekeres, K. Todorova, E. Svab, M. Fabian, "Compositional dependence of the optical properties of new quaternary chalcogenide glasses of Ge–Sb–(S,Te) system", Optical Materials, **32**, 45-48 (2009).
14. V. Pamukchieva, A. Szekeres, K. Todorova, M. Fabian, E. Svab, Zs. Revay and L. Szentmiklosi, "Evaluation of basic physical parameters of quaternary Ge-Sb-(S,Te) chalcogenide glasses", J. Non-Cryst. Solids, **355.** 2485-2490 (2009).
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18. J. M. Terrazas, N. Nedev, E. Manoov, B. Valdez, D. Nesheva**,** R. Brueggemann, "Properties of thin SiO_2 films deposited by r.f. sputtering", J. Optoelectron. Adv. Mater. - Symposia, 2009, **1**, No 3, 384-397.
19. D. Nesheva, I. Bineva, Z. Levi, N. Nedev, Zh. Dimitrov, "Transport of photoexcited charge carriers via metal-insulator-silicon structures containing Si nanoparticles", Mugla Turkey, 26-28 May 2008, J. Optoel. Adv. Mat. - Symposia, **1**, 277-280 (2009).
20. D. Todorova, V. Donchev, D. Nesheva, E. Valcheva, Computer simulation of infra-red transmission spectra of SiO_2 films containing amorphous Si nanoparticles", Proc. 9^{th} Workshop on Nanosci. Nanotechnol., Sofia, November 2008, Eds. E. Balabanova and I. Dragieva, Nanoscience and Nanotechnology, vol**. 9**, 17-20 (2009).
21. E. Ivanov, D. Nesheva, E. Krusteva, T. Dobreva, R Kotsilkova "Reological and electrical properties of epoxy nanocomposites filled with multiwalled carbon nanotubes", Proc. 9^{th} Workshop on Nanosci. Nanotechnol., Sofia, November 2008, Eds. E. Balabanova and I. Dragieva, Nanoscience and Nanotechnology, vol**. 9**, 40-43 (2009).

ONGOING RESEARCH PROJECTS:

Financed by the Bulgarian Academy of Sciences:

1. Semiconductor nanoparticles in amorphous thin film matrix: formation, structure and properties.

Financed by the Bulgarian Ministry of Education and Sciences (BMES):

1. Multilayer structures and nanocomposite materials for applications in electronics. Module 1: Multilayer structures containing silicon nanoparticles, suitable for fabrication of electronic memories and single electron deviices, Contract NNP-4-1.
2. Three–dimensional assembles of semiconductor quantum dots: structure, optical, electrical and photoelectrical properties, Contract BM-1.
3. Construction, development and preparation of digital electroluminescent displays, Contract D01–202.
4. New amorphous and glassy materials based on Ge suitable for sensor applications, Contract D002-123.

COLLABORATION:

1. Investigation of Ge-chalcogenide glasses for optoelectronic use, Joint Laboratory of Solid State Chemistry, Pardubice, Czech Republic.
2. Nanostructures semiconductor thin films suitable for application as gas sensors, Institute of Physics, Belgrade, Serbia.
3. Structural and optical properties of multicomponent chalcogenide glasses, Institute of Solid State Physics & Optics, Budapest, Hungary.
4. Investigation of properties and characteristics of ZnS electoluminophores and making structures on their basis“, Moscow State University of Railway Engineering, Russia.
5. Investigation of optical and electrical properties of nanostructures chalcogenide semiconductors suitable for memory applications, Sankt Peterburg, Russa.
6. Gas sensitivity and photoinduced changes of multicomponent chalcogenide films, Institute of Applied Physics, Kishinev, Moldova

DIVISION NANOPHYSICS

RESEARCH GROUP

SEMICONDUCTOR HETEROSTRUCTURES

HEAD: **Assoc.Prof. Parvaneh Danesh, Ph.D.**
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TOTAL STAFF: **7**
RESEARCH SCIENTISTS: **7**
Prof. S. Kaschieva, D.Sc.; Assoc.Prof. S. Alexandrova, Ph.D.; Assoc.Prof. A. Szekeres, Ph.D.; Assoc.Prof. N. Peev, Ph.D.; Assoc. Prof. S. Simeonov, Ph.D.; E. Vlaikova, Research Scientist

RESEARCH ACTIVITIES:

1. CHARACTERIZATION OF NANOSTRUCTURED AlN FILMS

By pulsed laser-deposition (PLD) technique, AlN films with different thicknesses ranging from 100 nm to 1 μm have been synthesized onto Si(111) substrates. The growth dynamics has been studied by applying XRD, AFM, FTIR measurements. Detailed analysis of the experimental data reveals that initially (below 200 nm) the films grow in 2D forming predominantly amorphous structure with internal strains and smooth surface. As the deposition proceeds, the film growth mechanism transforms into 3D crystalline growth, leading to formation of large crystallites of cubic phase and rough film surface. An increase in nitrogen pressure leads to a change in film texture, different crystallite orientations and smaller sized crystallites, and thus, it results in reduced film roughness.

The DC conductivity and admittance (AC conductivity and capacitance) at 1 MHz of AlN:Cr-(p)Si MIS structures with AlN:Cr films prepared by pulsed laser deposition, have been analyzed. The trap space charge limited current has been established as electrical charge transport mechanism in these doped with Cr AlN:Cr films.

2. CHARACTERIZATION OF NANOSTRUCTURED SiOx FILMS

Silicon oxide films, vacuum evaporated and annealed at temperatures of 1000^{o}C and 1100^{o}C, have been studied by spectroscopic ellipsometry. Two-layer optical models well described the films' structure, revealing a $SiO_{1.2}$ suboxide of the as-deposited state. After annealing, Si clusters appeared in the crystalline phase in the $SiO_{1.61}$ and SiO_2 oxide matrices, respectively. The AFM imaging has showed a homogeneous surface morphology and a smooth surface.

The interface defects in oxide/hydrogenated Si(100) и Si(111) have been investigated for oxide thickness in the range 7 to 40 nm. From electrical and optical measurements the presence of characteristic oxide thickness of 9 and 13 nm, reapectively, was established, below which the oxide layer has a composition of SiO_x. This thickness is related to a surface region on the Si substrate that has been modified during plasma pre-oxidation treatment.

3. DEFECTS IN IRRADIATED Si/SiO_2 STRUCTURES

An X-ray Si $L_{2,3}$-emission spectroscopy study of a SiO_2/n-Si heterostructure containing a thin oxide layer of $d = 20$ nm thickness implanted by Si^+-ions with an energy 2 keV is reported. The maximum concentration of implanted Si^+-ions is located close to the SiO_2/Si interface at a depth of 18 nm leading to an ion-beam mixed SiO_2/Si interface layer in this region, consisting of a non-stoichiometric SiO_x matrix. Atomic collision cascades

(collisionally-displaced processes) during ion implantation, associated by partial phase separation into silicon precipitates and SiO_2 are discussed as possible mechanism for these procecesses.

The radiation-induced defects in a 20-nm-thick SiO_2 film on a silicon wafer are studied by optically stimulated electron emission. Accelerated (12-keV) silicon ions is found to generate various oxygen-deficient centers, among which E'-type defects are dominant. Subsequent irradiation by 23-MeV electrons changes the defect structure of the SiO_2 film: the defects induced by ion implantation decompose.

4. HYDROGENATED AMORHOUS SILICON AND CHALCOGENIDE FILMS

Ion beam-induced hydrogen migration in hydrogenated amorphous silicon (a-Si:H) has been studied using SiO_2/a-Si:H/SiO_2 layer stacks irradiated with MeV ^{15}N. Hydrogen concentration in the layer stacks decreases during the initial irradiation stage and then remains constant. In contrast, hydrogen loss from the a-Si:H layer proceeds gradually and continuously with increasing radiation fluence. It has been suggested that the hydrogen atoms liberated by the MeV ion irradiation do not recombine in molecules and that the hydrogen migration in a-Si:H is related to the diffusion of the hydrogen atoms. The symmetric hydrogen concentration profile in the as-prepared layer stack becomes asymmetric due to increase in the hydrogen concentration in the bottom SiO_2 layer.The radiation-induced asymmetry of the hydrogen profiles in the layer stack suggests that there is a difference in the diffusion parameters at the inner and outer interface.

The nonlinear optical properties of thin chalcogenide films $Ge_xSb_{40-x}S_{60}$ ($x = 10 \div 35$) have been studied by second harmonic generation (SHG). It has been found that for certain compositions the angular dependence of SHG reveals characteristic features that are realated to nanoscale structural inhomogenities.

PUBLICATIONS:

1. A. Szekeres, S. Bakalova, S. Grigorescu, A. Cziraki, G. Socol, C. Ristoscu, I.N. Mihailescu, "AlN:Cr thin films synthesized by pulsed laser deposition: Studies by X-ray diffraction and spectroscopic ellipsometry", Applied Surface Science 255 (2009) 5271–5274.
2. A. Szekeres, E. Vlaikova, T. Lohner, P. Petrik, G. Huhn, K. Havancsak, I. Lisovskyy, S. Zlobin, I. Z. Indutnyy, P. E. Shepeliavyi, "Ellipsometric characterization of SiOx films with embedded Si nanoparticles", Vacuum, 84 (2009) 115-118.
3. S. Bakalova, A. Szekeres, G. Huhn, K. Havancsak S. Grigorescu, G. Socol, C. Ristoscu, I. N. Mihailescu, "Surface morphology studies of AlN films synthesized by pulsed laser deposition", Vacuum, 84 (2009) 155-157.
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6. S. Simeonov, I Minkov, K. Ivanova, A Szekeres, M. Gartner, M. Niculescu, M. Anasstasescu, "Effect of deep levels on the admittance characteristics of sol-gel TiO_2/Si structures", J. Optoelectron.&Adv. Mater. 11(9) (2009) 1505 – 1508.
7. S Alexandrova, A Szekeres, "Nano-sized silicon oxide thermally grown on plasma hydrogenated silicon", J. Optoelectron.&Adv. Mater. 11(9) (2009) 1284-1287.

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9. S. Simeonov, I Minkov, A Szekeres, K. Ivanova, S. Grigorescu, G. Socol, C. Ristoscu, I. N. Mihailescu, "Influence of deep levels on the admittance of AlN/Si structures with pulsed laser deposited AlN films", J. Optoelectron.&Adv. Mater. 11(9) (2009) 1292-1295.
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11. E. Halova, S. Alexandrova, A. Szekeres, **"**Fixed oxide charge, interface traps and border traps in MOS structures, grown on plasma hydrogenated (100)-pSi**",** J. Optoelectronics&Adv. Mater. J. Optoelectronics&Advanced Materials, **11**(10) (2009) 1498-1501.
12. G. Dobrescu, M. Anastasescu, M. Stoica, A. Szekeres, N. Todorova, C. Trapalis, M. Gartner, "A Fractal Analysis Of TiO2 Sol-Gel Films Treated Under Different Atmospheres", J. Optoelectron.&Adv. Mater. 11(9) (2009) 1359 – 1362.
13. V. Pamukchieva, A. Szekeres, K. Todorova, M. Fabian, E.Svab, Zs. Revay, L. Szentmiklosi, "Evaluation of basic physical parameters of quaternary Ge-Sb-(S,Te) chalcogenide glasses", J. Non-Cryst. Solids, 355 (2009) 2485–2490.
14. V. Pamukchieva, A. Szekeres, K. Todorova, E. Svab, M. Fabian, "Compositional dependence of the optical properties of new quaternary chalcogenide glasses of Ge–Sb–(S,Te) system", Optical Materials, 32 (2009) 45-48.
15. S.Kaschieva, Ch.Angelov, S.N.Dmitriev, "MeV electron irradiation of O^+ or P^+ implanted Si-SiO_2 structures" Journal of Optoelectronics and Advanced Materials Vol. 11, No. 10, pp. 1502–1504 (2009).
16. A. Zatsepin, S. Kaschieva, D. Yu. Biryukov, S.N. Dmitriev, E.A. Buntov, "Formation and Electron-Beam Annealing of Implantation Defects in a Thin-Film Si–SiO_2 Heterostructure", Technical Physics, (2009) Vol. 54, No. 2, pp. 323–326.
16-a. А.Ф. Зацепин, С. Касчиева, Д.Ю. Бирюков, С.Н. Дмитриев, Е.А. Бунтов, "Образование и электронно-лучевой отжиг мплантационных дефектов в тонкопленочной гетероструктуре Si-SiO_2", Журнал технической физики Vol. 54, No. 2, pp. 323–326, (2009)
17. S.Kaschieva, S.N.Dmitriev, "Radiation defects introduced by MeV electrons in Ar implanted MOS structures", Appl. Phys.A. 94, 2, 257-261 (2009).
18. D.Zatsepin, Panin E.A. S.Kaschieva, H.J.Fitting, Shamin S.N., "Formation of the Buffer Layer of Si Suboxides SiO_x in the Si/SiO_2 Low Dimensional Hetero-system after Si Ion Implantation: Si $L_{2,3}$ X-ray Emission Spectra", Physics of the Solid State Vol.51 N 11, 2241-2246 (2009)
18-a. Зацепин Д.А., Е.А.Панин,С. Касчиева, H.J.Fitting, Шамин С.Н., "Формирование буферного слоя субоксидов кремния в низкоразмерной гетеросистеме Si/SiO_2 после имплантации ионами Si: рентгеновские Si $L_{2,3}$ эмиссионные спектры", Физика Твердого Тела, 51, 11, 2113 (2009)
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20. B Pantchev, P Danesh, B Schmidt, D Grambole and W Möller, "Ion beam-induced hydrogen migration in SiO_2/a-Si:H/SiO_2 layer stack", Semicon. Sci. and Technol. 24 (2009), 035012 (5pp).
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22. A. Szekeres, E. Vlaikova, G. Huhn, K. Havancsak, S. Zlobin, P.E. Shepelyavyi, „Spectroscopic Ellipsometry Study Of The Stability Of Nanostructured SiOx Films To Atmospheric Conditions”, Nanoscience & Nanotechnology, vol. 9, eds. E. Balabanova, I. Dragieva, 2009, pp 121-123.
23. S. Kaschieva and S. N. Dmitriev, Radiation Defects in Ion Implanted And/Or High-energy Irradiated MOS Structures (Electrical Engineering Developments), Nova Science Publishers Inc.
https://www.novapublishers.com/catalog/product_info.php?cPath=23_29&products_id=10963

ONGOING RESEARCH PROJECTS:

“Structure and properties of semiconductor heterostructures with nano-sized and nanostructured dielectric and semiconductor films” ***Financed by the Bulgarian Academy of Sciences***

COLLABORATION:

1. “Electron-beam annealing of implantation-induced defects in □□□□□□ heterostructures”, ***with the Joint Institute for Nuclear Research, Dubna, Russia***
2. “Optimization of properties of nanostructures based on silicon, metal oxides and nitrides for nano-electronic usage”, ***with the Eotvos L. University, Budapest, Hungary***
3. “Multifunctional structures based on silicon prepared by physical and chemical methods for application in electronics and optoelectronics”, ***with the Institute of Physical Chemistry, RA, Bucharest, Romania***
4. “Preparation of Si-based nanostructured thin dielectric films and investigation of their structure and properties for micro- and nanoelektronics purposes”, ***with the Institute of Semiconductor Physics, NASU, Kyiv, Ukraine***
5. “Innovative nano-structured and nano-composite media: diluted magnetic semiconductors” ***with the National Institute for Lasers, Plasma and Radiation Physics, Bucharest, Romania***

DIVISION MICRO- AND ACOUSTOELECTRONICS

LABORATORY

PHYSICAL PROBLEMS OF MICROELECTRONICS

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TOTAL STAFF: **19**
RESEARCH SCIENTISTS: **10**

Prof. E. Atanassova, D.Sc.; Assoc. Prof. S. Andreev, Ph.D.; Assoc.Prof. S. Georgiev, Ph.D., Assoc.Prof. J. Koprinarova, Ph.D.; Assoc.Prof. N. Nedev, Ph.D.; Assoc.Prof. A. Paskaleva, Ph.D.; Res.Assist. M. Georgieva; Res.Assist. Ts.Ivanov; Res.Assist. E. Manolov; Res.Assist. J. Pazov; Res.Assist. D. Spasov, Ph.D.; V.Krastev, Ph.D, physicist; E. Gajdarzhieva, physicist; L. Petkanov, physicist; S.Sajkov, physicist; K. Kozarova, technologist; M. Kuntorov, engineer; L. Stamenov, technologist; S. Tsvetanov, technologist

RESEARCH ACTIVITIES:

The scope of the research activities of the Laboratory is related to the development of the submicron electronics and the nanoelectronics as follows:

- investigation of the properties of thin and ultra-thin dielectric,semiconductor and metal (incl. ferromagnetic) layers important for the production of large-scale integrated microelectronic products and for development of solid state sensors based on the silicon and the thin-film microelectronics (incl. thin films of high-k dielectrics for dynamic memories, gas-sensitive layers for sensor devices, mono- and polycrystal silicon, nanolayers of , AlN and BN, 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 etc.)

During the year a new facility for microtechnologies is set in action.A new clean room with clean area of 110m^2 is built and equipment for deposition of thin films,high-temperature, photolithographic and chemical processes is installed. A possibility is provided for flexible further development and updating of the as-built technology line with new items of equipment (incl. equipment for nanotechnologies)

1. HIGH-K DIELECTRICS FOR NANOELECTRONICS

As a result of wide range of electrical and structural investigations storage capacitors (MOS implementation) are developed based on Ta_2O_5 layers (4-15nm) doped with Hf, Ti, Al and on mixed oxides HfO_2:Ta_2O_5. The capacitors developed are dedicated for application in nanoscaled dynamic memories (DRAMs) with characteristic minimum dimensions under 50nm and equivalent thickness of the dielectric under 1nm. The doping is an original idea of the research group. It is shown that doping of Ta_2O_5 layers with appropriate metal dopants, as well as its mixing with HfO_2 up to the creation of a new kind of high-k dielectric enhances the abilities of Ta_2O_5 like a storage medium. Capacitors with doped Ta_2O_5 or mixed HfO_2:Ta_2O_5 feature better parameters compared with those based on “pure” (un-doped) Ta_2O_5, as follows: higher dielectric constant, very low level of the leakage currents (under 10^{-10} A/cm^2), better stability after constant-voltage and constant-current stresses.

Capacitors are implemented in integrated versions and for each specific doped layer the most appropriate metal electrode is selected and used. The results obtained concerning the mechanisms of the electrical degradation, the long-term reliability, the conductivity and trapping mechanisms, the effects of the Si nitridation and the kind of the metal electrode as well as the results about the local characteristics (of nanosized areas (spots) and investigated by Conductivity-Atomic-Force Microscopy) **are prioritaire.** It is shown that short-term microwave irradiation (2.45 GHz, duration in seconds, room temperature) of structures with doped Ta_2O_5 or mixed HfO_2:Ta_2O_5 layers could be used as an alternative to the high-temperature annealing processes for high-k dielectrics.

TiN/$Zr_xAl_{1-x}O_2$/TiN MIM structures are investigated in view of their application in DRAMs of next generations. Layers with equivalent oxide thickness under 1nm and leakage currents under 10^{-7} A/cm^2 at V=1 V are optimized. Their dielectric behaviour (non-linearity of the C-V characteristics, dielectric relaxation and losses) depend strongly on the Al concentration in ZrO_2, the thickness of the dielectric and the amorphous state of the layers. The significant increasing of of the dielectric constant at crystallization of $Zr_xAl_{1-x}O_2$ in a tetragonal phase is accompanied by intensified processes of dielectric relaxation and dielectric losses due to the increased trapping at the crystal-grain boundaries. The dielectric behavior of the structures is controlled by two kinds of processes: partial crystallization of the layers and interface phenomena. By means of stimulation of the crystallization of the layers an increasing of the capacitance together with reduction of its non-linearity could be obtained that is very important for high-frequency and analog applications of MIM structures.

2. MAGNETORESISTIVE THIN LAYERS AND DEVICES.

The project “High-immunity magnetoresistive sensors (supported by the National Competitiveness Program) was finalized during the year. Three types of original magnetoresistive sensors were developed as follows: switch-mode sensor with rotated anisotropy axis, gradiometric sensor, analog sensor. “Golden samples“ and test data of the three types of sensors are archived. A technology flow-chart for industrial production of such sensors as well as design rules for their integration in smart subsystems are developed.A patent is obtained for the analog sensor.

3. THIN FILMS FOR THE MICROELECTRONICS

The possibility for preparation of boron nitride nanolayers with thickness of 3-7 nm, using Rapid Thermal Annealing (RTA), as well as the properties of the obtained films in dependence of the technological conditions are investigated. Boron nitride layers were prepared as follows: thin boron films were deposited on sapphire (Al_2O_3) substrates by vacuum evaporation. The resulting B/Al_2O_3 structures were submitted to RTA in ammonia (NH_3) ambient at annealing temperatures of 800, 1000, 1200 and 1400 ^oC, for annealing times of 15, 30, 60 and 180 s.

The effects of γ – irradiation on the physical and electrical properties of ZrO_2-based high-k MOS structures were studied. A shift of the C-V characteristics is observed after the γ – irradiation.

Raman scattering measurements of the undoped ZrO_2 thin films grown by RF magnetron sputtering on silicon substrate have been investigated. The impact of γ – irradiation doses on the ZrO_2 thin films Raman spectra was analyzed. The intensity of the Raman signal originating from monoclinic ZrO_2 is found to decrease with increasing gamma radiation. We also observed peak shift with the gamma radiation dose.

Hysteresis behaviour in sandwich structure — zirconium oxide/chemical silicon oxide was studied. High-frequency capacitance–voltage (HF C–V), current–voltage (I–V)

and current– time (I–t) measurements were carried out on the $Al/ZrO_2/ZrSi_xO_y/SiO_x/Si$ capacitors.

The transconductance of a nano-clustered organic subsurface layer of a thickness of about 100 nm, formed in polymethylmethacrylate (PMMA) by implantation with silicon ions at an energy of 50 keV, is examined as a function of the Si^+ fluence in the range $10^{15} – 10^{17}$ cm^{-2}. Depending on the implantation regime, the ion-modified region of the Si^+ implanted PMMA exhibits a transconductance and a field effect that can be used for electronic applications.

A field-effect transistor-like memory element based on chargeable organic dielectric as gate in polymethylmethacrylate (PMMA) implanted with Si^+ ions (50 keV energy, dose 10^{16} ions/cm^2) is observed. The observed memory function is attributed to both the charged gate dielectric and organic interface formed in Si^+-implanted PMMA. The ON and OFF-states can be written to the device by applying appropriate voltages to the gate electrode. Key feature of the memory element is the low writing voltage.

The composition and the microstructure of thin SiO_2 layers enriched with Si (SiO_x, $x<2$) and the alterations resulting from high-temperature annealing processes are investigated.XRD(diffraction), XRR(reflection), XPS (photoelectronic.spectrometry) as well as VASE elipsometry and TEM methods are used for analysis.SiOx layers prepared by RF magnetron sputterin or thermal evaporation are investigated.

XRD and TEM results show amorphous state of the layers prepared both ways and before and after thermal annealing (1000^o C, 1 h).The values of thicknesses of the layers determined by XRR and VASE agree very well with the results of TEM and the prescribed values according to the deposition parameters. The composition of the as grown layers defined by the peak of the XPS spectra also is in a very good agreement with the previewed based on the deposition conditions. For both types of samples the XPS results show **:** the existence of bonds corresponding to the three allowed compositions (SiO_2, Si_2O_3, Si_2O) ; existence of bonds Si-Si in the as grown samples; formation of a pure phase of Si in a matrix of stoihiometric SiO_2 after annealing at 1000^OC for 1h. For thermally evaporated SiO_x samples with x=1.3 and after high-temperature annealing the size of the nanocrystals formed (estimated by plane-view TEM) is 4-5nm.The nanocrystals are distributed homogeneously in the amorphous matrix. The VASE results are also in very good agreement with the results of XPS and TEM and confirm the formation of a Si phase in the matrix of stoihiometric SiO_2

The influence of different parameters on the performance of solar cells based on amorphous silicon is investigated theoretically.The solution of the exact equations describing the processes in such a cell is possible in a numerical form only but in this case the influence of the different parameters is not expressed evidently. The creation of an efficient approximate analytical model would be very usefull.Two models are considered- the first of them representing a rough approximation of the processes in a thin-film solar cell. The second model takes into account more parameters but that means more complex calculations. The model is being developed further.

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2. E.Atanassova, N.Stojadinovic, A.Paskaleva, Degradation behavior of Ta_2O_5 stacks and its dependence on the gate electrode, Microel. Reliab. **48** (2009) 1193-1197.
3. A.Paskaleva, E.Atanassova, N.Novkovski, Constant current stress of Ti-doped Ta_2O_5 on nitrided Si, J. Phys. D: Appl. Phys. **42** (2009) 025105 (8 pp).

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5. D.Spassov, E.Atanassova, A.Paskaleva, N.Novkovski, A.Skeparovski, Electrical behavior of Ti-doped Ta_2O_5 on N_2O- and NH_3-nitrided Si, Semicond. Sci. Techn. **24** (2009) 075024 (10 pp).
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22. E.Atanassova, N.Novkovski, A.Paskaleva, D.Spassov, Constant current stress-induced leakage current in mixed HfO_2-Ta_2O_5 stacks, Microel. Reliab., accepted
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24. E.Atanassova, M.Georgieva, D.Spassov, A.Paskaleva, High-*k* HfO_2-Ta_2O_5 mixed layers: electrical characteristics and mechanisms of conductivity, Microel. Engin., accepted
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32. Mario Curiel, Ivan Petrov, Nicola Nedev, Diana Nesheva, Mauro Sardela, Yuya Murata, Benjamin Valdez, Emil Manolov, and Irina Bineva, Formation of Si nanocrystals in thin SiO_2 films for memory device applications, Proc. AEM-Nanomat'09, 28th September – October 2nd, 2009 Saltillo (Coahuila) Mexico, accepted

ONGOING RESEARCH PROJECTS:

1. Physics and technology of thin layers for applications in the modern microelectronics.
2. Alternative dielectric layers based on Ta_2O_5, (Hf:Ta_2O_5; Al:Ta_2O_5; Ti:Ta_2O_5) for 65-70 nm generation integrated memories (supported by NSF).
3. Trapping phenomena and their impact on the long-term reliability of nanostructures metal electrode/high-k dielectric(supported by NSF).
4. Investigation of the electronic states in amorphous silicon and materials based on it (supported by NSF).
5. Synthesis and investigation of AlN and BN nanolayers (supported by NSF).

6. High-immunity magnetoresistive sensors (supported by the National Competitiveness Program)
7. Building a “clean room” facility for micro technologies (supported by industrial partners).

COLLABORATION:

International cooperation:

1. Institute of Semiconductor Physics ИФП-Kiev, Ukraine
2. Insitute of Physics ,Universty of Scopije, Macedonia
3. University of Nish, Serbia
4. Technical University, Ankara, Turkey

Industrial cooperation:

1. Belmicrosystem ,Minsk,Belarus
2. FACET ,Sofia, Bulgaria
3. EUROEngineering , Botevgrad,BulgariaI

DIVISION MICRO- AND ACOUSTOELECTRONICS

LABORATORY

ACOUSTOELECTRONICS

HEAD: **Assoc.Prof. Velichka Georgieva, Ph.D.**
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TOTAL STAFF: **13**
RESEARCH SCIENTISTS: **7**
Prof. Lozan Spassov, Ph.D., D.Sc., Corresponding member of BAS, Honorary member of ISSP-BAS; Assoc.Prof. I. Avramov, Ph.D., D.Sc.; Assoc.Prof. E. Radeva, Ph.D.; J. Lazarov PhD, engineer; Ts. Yordanov, researcher; M. Atanassov, researcher; V. Gadjanova, researcher; Z. Raicheva, chemist; L. Vergov, engineer; P. Angelova, physicist; S. Staikov, technician; I. Mitev, technician

RESEARCH ACTIVITIES:

In 2009 the scientific and applied research of Acoustoelectronics laboratory was focused on creation of new materials, technologies and elements in accordance with the Academy's basic strategic goal - delivery of the society based on knowledge and active partner in the European scientific area.

The scientific investigations in the laboratory are being carried out mainly in the following directions:

- Semi – analytical modelling of resonators.
- Mass sensitive quartz sensors.
- Plasma polymers – synthesis, structure, properties and application.
- Resonant structures using surface transverse waves (STW), Rayleigh surface acoustic waves (RSAW) and bulk acoustic waves (BAW) and their applications.

- SEMI-ANALYTICAL MODELNG OF MASS-SENSITIVE STRIP RESONATORS

A theoretical analysis of the frequency spectra of acoustic modes propagating in the cross-section of an AT-cut quartz strip plate is carried out. An appropriate quartz plate dimensions ratio – width to thickness is determined using the theoretical analysis results. This assures a minimal contribution of unwanted anharmonic modes during the resonator's operation. A quartz strip resonator operating at 20 MHz fundamental frequency is designed. Experimental series of miniature quartz strip mass-sensitive resonators are made.

- PIEZOELECTRIC MICROSENSORS USED AT CRYOGENIC TEMPERATURES

Basic research for novel piezoelectric temperature sensors for cryogenic applications was developed. The sensors are based on thermo sensitive quartz resonators. The target of this research activity is development and production of multifunction sensor for "Nuclotron" in JINR – Dubna.

The team entered a competition of the Ministry of Education, Youth and Science on the topic: "Encourage research in priority areas" with the project: „Multifunctional piezoelectric quartz sensor for monitoring of helium contaminations at cryogenic temperatures" № TK02-42. It is provided for the implementation of the final product in a new generation of accelerators in JINR, Dubna, Russia. The project was not approved for financing at the first

session. Pending analysis of the admitted shortcomings in the design and processing for participation in the new competitions.

- MASS – SENSITIVE QUARTZ RESONATORS

The staff of laboratory AE is working on a project under a contract with MES titled" Creation of acoustic sensor for detection of contaminating substances in the environment" NT3 headed by Research Scientist Dr.Velichka Georgieva. The project consists of the four modules; two of them were realized in the Laboratory of Acoustoelectronics. The other two modules were carried out in the Institute of General and Inorganic Chemistry and in Central Laboratory of Solar Energy and New Energy Source. The total amount of the contract for the whole period is 120 000 lv.

Module NT3 – 04 *"Designing and creation of sensor elements used in quartz crystal microbalance (QCM)"*

Series of quartz resonators necessary for the implementation of NT3 project were produced according the previously accepted programme. The dynamic parameters and spectral characteristics of the samples were measured and discussed. It was obtained the change in dynamic resistivity (Rs) in the range from 7Ω to 20Ω, while the calculated quality factor (Q) showed values from 45 000 to 65 000. The prepared samples were suitable on purpose of QCM investigations.

In order to improve QCM sensitivity a technology based on chemical methods was developed for increasing the infolded surface area of quartz resonators. A technology for increasing the unfolded surface of the mass-sensitive quartz resonators through chemical methods for raising QCMs sensitivity was developed. For that purpose, experimental series of samples etched in a $[NH_4]\ F_2$: H_2O=1:1 solutions in the temperature interval 70^0C - 90^0C were manufactured. Resonators' dynamic parameters such as Rs and Q were determined. The measured average Rs changes from 12.72 to 7.88Ω, whereas Q average take values from 60 200 to 95 000 respectively. An analysis of the typical spectral characteristics of the experimental series accompanied with relevant comments was carried out. The created samples possess appropriate parameters for sensors application.

Module NT3 – 03 *"Investigation of the sorption properties of the metal-oxide layers by the QCM method"*

The surface, structure and sorption properties of the MoO_3 layers obtained through r.f. magnetron sputtering were investigated. Their characterization was carried out using different methods such as: XPS, SEM, XRD and ellipsometry. The layers were studied targeting their application as NH_3 sensors based on QCM. The sorption properties of MoO_3 were defined as a function of QCM's frequency change (ΔF) as a result of its mass-loading. In the NH3 concentration interval 50ppm - 1000ppm an change of ΔF from 96 Hz to 312 Hz was measured. It was obtained that the layers are sensitive in the all investigated interval. The measured ΔF shift and times of response, saturation and unloading are a function of the NH_3 concentration. The reversibility of the NH_3 sorption processes for the QCM-MoO_3 system makes it repeatedly applicable. Analogical investigations were carried out on TiO_2 layers obtained by e-beam evaporation. The XPS investigations showed that they have non-stoichiometric and represent composition of 2/3 TiO_2 and 1/3 TiO. Their structure is a mix of two crystal phases situated in an amorphous matrix. When the NH_3 sorption is measured in dynamic regime, the TiO_2-QCM system shows rapid response and repeatability. The ΔF values from 8Hz to 216 Hz were measured in the interval from 10ppm to 1000ppm NH_3. The received data for TiO_2-QCM system are considerably lower than the ones of the MoO_3 – QCM system. Their comparison showed that both investigated systems are appropriate for creation of sensor elements applicable for NH_3 detection.

The results form the experiments in accordance with the programmes of both NT3-03 and NT3-04 modules were presented at four international forums in Bulgaria and abroad. In 2009 five articles on the projects' subject were published.

As a sequel to the NT3 contract, a project focusing on competition of the Ministry of Education, Youth and Science on the topic: "Encourage research in priority areas" was proposed named "Creation and investigation of QCM sensor systems – thin layer for detection of CO_2 contaminations in the air". The work crew included participants form IFTT BAS, IGIC, CLSENES and Technical University, Sofia.

*"Development of new sensitive layers (coatings) based on nano-sized semi-conducting structures for analytical application using mass-sensitive piezoresonance sensors"*A project of Vernadsky Institute of Geochemistry and Analytical Chemistry of RAS and Georgi Nadjakov Institute of Solid State Physics BAS (2009-2011).

Investigations of the methods for forming nano-crystal semi-conducting structures for analysis of organic compounds were carried out throughout 2009. The optimal conditions for deposition of thin ZnO and TiO_2 layers were discovered. A part of the obtained structures were investigated in their capacity of ion emitters for organic compounds under the influence of impulsive laser radiation by our partners of RAS in their Laboratory for Instrumental method and Organic Regents. The generation of positive ions from the deposited ZnO layers under the influence of ultraviolet laser radiation was also detected. Reserpine and Gramisidin were used as test substances. It was defined that the ZnO layers are stable and possess good sensitivity to the investigated substances, which makes them perspective for their application in the SALDI method, where they serve as a platform. Another part of the samples was studied as sensitive coatings of the mass-sensitive piezoresonance sensors in the laboratory set for mass-loading testing in a flow of gas regents. The set was created by the AE laboratory of ISSP-BAS. The sensitivity limits of the systems QCM- TiO_2 and QCM –humus acid to NH_3 in gas phase were determined.

Mutual tests of special constructions of electron generators for sensors were also carried out. The maximum sorption loading of the sensors using micro-scheme generator GK46-B-16000kHz was determined. The generator was developed by Vernadsky Institute of Geochemistry and Analytical Chemistry of RAS. The measurements will be continued in order to obtain statistical data for development of sensors allowing big loading, which possess great sensitivity. The obtained scientific results from the mutual work on the project throughout 2009 were systematized in three works and were reported at two international conferences.

– SYNTHESES AND STUDY OF PLASMA POLYMERS, OBTAINED FROM HEXAMETHYLDISILOXANE

The study on plasma polymer layers obtained from hexamethyldisiloxane (PPHMDS) was continued under two projects as new materials with biomedical application in bone implants. The polymers modified in ammonia plasma (from 0.5 to 10 min) were synthesized. Preliminary experiments for plasma deposition from the mixture of monomer and nanodiamond particle were made. The structure of the obtained polymer films was studied by FTIR, AFM, XRD and PES. The contact angle measurements were made.

The effect of ammonia plasma treatment on biological performance of HMDS polymer films with osteoblast-like cells was studied. The biological experiments showed the direct connection between the contact angle of the samples and cells' behaviour. It was established that water contact angles (WCA) of the unmodified PPHMDS samples possessed similar surface wettability independently on the technological regimes of polymer deposition, while ammonia modification resulted in an increased hydrophilicity of about 15º WCA. Long-term cultures experiments (cells cultivated for 3, 7 and 10 days) did not show any significant

differences among polymer materials in terms of the cell viability and morphology. In the terms of cell growth, however, NH_3-treated surface demonstrated significantly higher rate of cell proliferation compared to PPHMDS materials.
The spectral and microscopic analyses showed that the films obtained from suspension from monomer and nanodiamond particles have different morphology, structure and smaller WGA than the pure PPHMDS. The results are promising for application of the obtained polymers in biocomposites.

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

The electrical and phase noise characteristics of novel IC-compatible film plate acoustic resonators (FPAR) using Lamb waves in thin AlN membranes on Si have been investigated. It has been shown that FPARs can dissipate orders of magnitude higher RF power levels and have comparable or lower flicker phase noise than the best Rayleigh SAW resonators built to date. The new FPAR devices demonstrate significant potential for future applications in integrated low-noise microwave oscillators.

An interface sensor oscillator for measuring density and viscosity of highly viscous liquids by means of quartz crystal microbalance (QCM) has been designed, built and tested with glycerol solutions of 40 to 100 wt% concentrations. It demonstrates a measurement accuracy of about 5% which is one of the best achievements in the field. The oscillator has also been adapted to gas concentration measurements with QCMs spin-coated with chemosensitive polymer films.

For the first time a highly efficient surface transverse wave (STW) sensor resonator has been coated with a polymer containing Au nanoparticles that have been stabilized with functional ligants for increased sensitivity to chemical gases at high concentrations. Since the STW resonator retains high Q and low loss after polymer deposition, the sensor oscillator stabilized with this device demonstrates high short-term stability which results in detection limits of a few ppm at gas concentrations in the 100 000 и 400 000 ppm range.

COLLABORATION WITH PRIVATE FIRM

The specialists from the “Acoustoelectronics” Laboratory are involved in the preparation of 2 projects of "Denima 2001" an company working in the range of energy sourses.

1. “Technological modernization of the production of lighting devices in Denima 2001 LTD” - Programs of the EU.
2. "Research on optical systems and thermal processes at LED lighting devices and creation of luminaries for mass production” – programs of the Ministry of Education, Youth and Science.

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2. B. Dulmet, Y. Lazarov, On Lagrangian methods in the analysis of piezoelectric resonators and sesnors, J. of Optoelectronics and Advanced Materials, Vol. 11 ISS.9, 1150-1156 (2009).

3. Z. Raicheva, Y. Lazarov, L. Spassov, V. Georgieva, V. Gadjanova, Ts. Angelov, L. Vergov, M. Atanasov, Investigation of Quartz Resonators for QCM Application, Journal of Optoelectronics and Advanced Materials, Vol. 1, No. 3, 539-542 (2009).
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5. S. Boyadziev , V. Lazarova (Georgieva), K. Makita, Y. Kotani, Yordanova, Y. Matsumura, M. Rassovska, Characterization of Reactive Sputtered Molybdenum Oxide Thin Films for Gas Sensors, e-Journal of Surface Science and Nanotechnology, Vol. 7, 796-800 (2009).
6. V. Strashilov, G. Alexieva, V. Velichkov, I. Avramov, S. Evans, STW Resonator With Organo-Functionalized Metallic Nanoparticle Film for Vapour Sensing, IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control, Vol. 56, No. 5, 1018-1023(2009).
7. I. Avramov, A Quartz Crystal Sensor Oscillator Appropriate for Highly Viscous Liquid Measurments, Measurment Science and Technology 20, 124006 (8pp), (2009).
8. V. Strashilov, G. Alexieva, V. Velichkov, R. Mateva, I. Avramov, Polymer Coated Quartz Microbalance Sensors for Volatile Organic Compound Gases, Sensor Letters, Vol. 7, No. 2, 203-211 (2009).
9. H. Nichev, O. Angelov, D. Dimova-Malinovska, V. Georgieva, V. Mikli, Comparison of the room temperature sensitivity of ZnO and ZnO: Co thin films to NH_3 exposure, Journal of Optoelectronics and Advanced Materials-symposia, Vol. 1, No. 3, 371-374 (2009).
10. E. Radeva, L. Pramatarova, R. Dimitrova, S. Popova, T. Hikov, D. Fingarova, E. Pecheva, Infrared analysis of plasma polymerized hexamethyldisiloxane for biocompatible composites, Journal of Optoelectronics and Advanced Materials 11(10) 1432-1435 (2009).
11. T. Hikov, L. Pramatarova, E. Radeva, L. Vanzetti, E. Iacob, R. Dimitrova, E. Pecheva, S. Stavrev, D.Fingarova, Study of plasma polymer structures to induce composite layers, Journal of Optoelectronics and Advanced Materials 11(9) 1327-1330 (2009).
12. Z. Raicheva, V. Georgieva, L. Spassov, V. Gadjanova, L. Vergov, Ts. Angelov, M. Atanasov, Y. Lazarov, The influence of quartz resonator design and thin metal oxide layers on QCM parameters, Namostructured materials, thin films and hard coatings for advanced applications, 129-132 (2009).
13. I. Avramov, L. Arapan, I. Katardjiev, V. Strashilov, V. Yantchev, IC-compatible Power Oscillators Using Thin Film Plate Acoustic Resonators (FPAR), Proc. 2009 International Ultrasonics Symposium, Rome, Italy, Sept. 20-23(2009).
14. M. Atanassov, T. Iordanov, P. Manoilov, K. Rainova, D. Tchakalov, Multifunctional measurement and control SoC using cryogenic quartz sensors, Proceedings of the International Conference Engineering, Technologies and Systems TECHSYS 2009, Plovdiv, Bulgaria, 29-30, 383-388 (2009).
15. M. A. Taslakov, I. D. Avramov, Method for nondestructive testing the film coating behavior of surface acoustic wave (SAW) sensors, presented at the 16-th Int. Summer School on Vacuum, Electron and Ion Technologies (VEIT2009), Sept. 28-Oct. 2, Sunny Beach, Bulgaria, (2009).

RESEARCH PROJECTS:

1. Project financed by Bulgarian Academy of Sciences

1.1 Applications of surface transverse waves (STW), Rayleigh surface acoustic waves (RSAW) and bulk acoustic waves (BAW) in low-noise microwave oscillators, communications and sensor systems using thin polymers layers obtained by plasma.

1.2 Quartz strip mass sensitive resonator.
1.3 Technological center “Microelectronics”

2. Projects financed by National Foundation of Scientific Research at the Ministry of Science and Education

2.1 Designing and creation of sensor elements used in the quartz crystal microbalance.
2.2 Investigation of the sorption properties of metal dioxide layers by the quartz crystal microbalance method.
2.3 New nanobiocomposite materials for bone implants.
2.4 Formation and investigation of solid state and organic thin layers for sensor function

3. Projects extra financed by departments and Bulgarian companies (Projects financed by Bulgarian SME Promotion Agency).

3.1 Digital Electroluminescent Display – Design, Constructional Development and Preparation.
3.2 Nanostructured coatings – new biomaterials for bone implants obtained by interaction laser- solution-substrate.

4. Projects financed by international sources:

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

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

5.1 Development of new sensitive layers (coatings) based on nano-sized semi-conducting structures for analytical application using mass-sensitive piezoresonance sensors.
5.2 Investigation of impurities in helium gases on the base of quartz crystal microbalance.
5.3 Investigation of properties and characteristics of zincsulphiden electoluminophors and making of set-ups of their base.

COLLABORATION:

1. “Development of mass sensitive quartz resonators for operation at cryogenic temperatures” - Join Institute for Nuclear Research, Dubna, Russia.
2. “Design of an improved Rayleigh surface acoustic wave (RSAW) resonator with gold electrode structure and improved corrosion immunity for sensor applications in highly reactive chemical gas-phase environment”- Research Center Karlsruhe, Germany.
3. “Development of new sensitive layers (coatings) based on nano-sized semi-conducting structures for analytical application using mass-sensitive piezoresonance sensors”- Russian Academy of Science, Russia.

DIVISION LOW TEMPERATURE PHYSICS

LABORATORY

LOW TEMPERATURE PHYSICS

HEAD: **Assoc. Prof. Elena Nazarova, Ph.D.**
Tel:979 5679; e-mail: nazarova@issp.bas.bg

TOTAL STAFF: **15**
RESEARCH SCIENTISTS: **14**

Prof. V. Kovachev, Ph.D., D.Sc.; Assoc. Prof. M. Bushev, Ph.D.; Assoc. Prof. E. Vlakhov, Ph.D.; Assoc. Prof. B. Terziyska, Ph.D.; Assoc. Prof. K. Kalaydjiev, Ph.D.; Assoc. Prof. N. Balchev, Ph.D; Assoc. Prof. J. Georgiev, Ph.D.; Assist. Prof. A. Zahariev, Ph.D.; Assist. Prof. A. Stoianova-Ivanova, Ph.D.; Assist. Prof. K. Lovchinov; Res. Assist. S. Terzieva; G. Mihova, chemist; Ph.D. student K. Buchkov

RESEARCH ACTIVITIES:

The connection between the critical properties of two intensively studied models in the theory of quantum phase transitions, the Dicke model, concerning the interaction of the electromagnetic field with a matter and the Lipkin-Menshov-Gluck model, which describes interaction in quasispin systems, is investigated. It is shown that their critical properties are similar under certain conditions (even when the size of systems is finite), which is a prerequisite to observe some similar effects, e.g. concerning the so called entangled states in the vicinity of the quantum critical point.

Superconducting and magnetic properties of synthesized $MoSr_2YCu_2O_{8-\delta}$ and $MoSr_2Y_{0.8}Ca_{0.2}Cu_2O_y$ samples were studied. It is found that the Ca doping increased T_c of samples, prepared at different conditions. It was shown that doping does not destroy antiferomagnetic correlation in Mo-1212, but decreases vastly the remanent magnetization. The influence of Mo deficit and irregular Ca distribution on the superconducting and magnetic properties of the doped samples is discussed. For a first time samples of $MoSn_xSr_2YCu_2O_{8-\delta}$ ($0 \leq x \leq 0.1$) were synthesized and investigated. The preliminary results show that the optimal Ca doping increases vastly the second critical magnetic field $H_{c2}(0)$ of non doped $MoSr_2YCu_2O_{8-\delta}$.

The influence of magnetic (Pr) and nonmagnetic (Ca) substitutions on the intragranular critical current ($J_{intra,\ c}$) in polycrystalline YBCO samples is investigated. It is shown that at 4.2 K and low concentration (2.5 – 5%) both substitutions are almost equally effective and lead to $J_{intra,\ c}$ higher than that for the non-substituted sample. At high concentration (20%), however, both substitutions cause a decrease of the $J_{intra,\ c}$ due to the Cooper pair breaking effect. The experimental evidence demonstrating the phase separation in the carriers system for the overdoped Ca substituted samples has been shown.

Structural, magnetic and transport properties of $NdBaCo_2O_{5+x}$ ($0.52 < x < 0.72$) ceramics and magnetron sputtered cobaltite thin films of $NdBaCo_2O_{5+x}$ deposited on single crystal substrate SAT-CAT-LA(100) and $SrTiO_3$(100) are investigated. The systematic analysis is carried out of magneto-transport properties of "hole" doped cobaltites $NdBaCo_2O_{5+\ x}$ ($x > 0.50$) at low temperatures and strong magnetic field. The technological regime for deposition of thin and ultra-thin $NdBaCo_2O_{5+x}$ cobaltite films is optimized using magnetron sputtering and *ex-situ* adjustment of the oxygen stoichiometry. The potential

application of these thin films in perspective power devices like oxide fuel cell (working in temperature range 500˚C -700˚C) is analyzed.

The improved spectrophotometric method for oxygen content determination in superconducting materials is presented. The sensibility of the method was increased. The analysis was carried out with very small sample's mass (2 mg) allowing to determine the oxygen content in superconducting films.

The multifunctional materials including different phases with specific properties are of special interest. The composite material containing superconducting $Bi_{1,6}Pb_{0,4}Sr_2Ca_2Cu_3O_x$ phase (T_c=86.6 K) and ferromagnetic $La_{0,6}Pb_{0,4}MnO_3$ phase in proportion 90:10 is synthesized by Pechini method. Systematic investigations are carried out on phase formation and microstructure of this material and the optimal temperature regimes for its obtaining are found.

The method for defining of the thermal diffusion factor above 1 atm. using a thermal diffusion column was developed.

PUBLICATIONS:

1. N.S.Tonchev, J.G. Brankov and V.A.Zagrebnov, Overview of the superradiant phase transition: the Dicke model, Journal of Optoelectronics and Advanced Materials (JOAM), v.11, No9, pp.1142-1149 (2009). ISSN 1454-4164
2. H.Chamati and N.S.Tonchev, Comment on ``Quantum critical paraelectrics and the Casimir effect in time". arXiv: cond-mat/ 0903.5229 (2009).
3. E. Nazarova, A. Zaleski, A. Zahariev, K. Buchkov, V. Kovachev, Implication for phase separation in overdoped Y-Ca-Ba-Cu-O superconducting system J. of Optoelectr. & Adv. Matter. **11**, p.1545-1548 (2009) ISSN 1454-4164
4. E. Nazarova, K. Buchkov, A. Zahariev, J. Georgiev, K. Nenkov, H. Ignatov, V. Kovachev, E. Burzo, I. Balasz, AC Magnetic Susceptibility Studies of Ag – SheatheY$_{1-x}$-Ca$_x$-Ba$_2$-Cu$_3$-O$_{7-\delta}$ Tapes (x = 0 and 0.3), J. Matter. Sci. & Technol. **17** p. 226-235 (2009) ISSN 0861-9786
5. E. Vlakhov, R. Szymczak, M. Baran, K. Piotrowski, A. Szewczyk, W. Paszkowicz, L. Lobanovski, S. Matyasik, K. Nenkov, H. Szymczak , Structural, Magnetic and Transport Properties of $NdBaCo_2O_{5+x}$ Thin Films Deposited by Magnetron Sputtering, „Acta Physika Polonika A" **115** (2009) 89 -91. ISSN 1898-794X
6. J.Georgiev, A.Zahariev, Thermal Diffusion factor of He-N_2 Mixture above 1 atm., Separation Science and Technology, **44**, p.1422-1435 (2009) ISSN 0149-6395
7. N.Balchev, K.Nenkov, G.Mihova, B.Kunev, J.Pirov, D.A.Dimitrov, Structure, Magnetic and Superconducting Properties of $MoSr_2HoCu_2O_{8-\delta}$, Journal of Magnetism and Magnetic Materials, **321**, p.388-391 (2009) ISSN 0304-8853
8. T. Nedelcheva, St. Georgieva, L. Vladimirova, A. Stoyanova-Ivanova, "Increasing the sensitivity of the spectrometric determinations of the oxygen content in YBCO superconducting samples using the I3 - starch compound", "Talanta",**77**, p.1745-1747 (2009). ISSN 0039-9140
9. A. Stoyanova-Ivanova, St. Georgieva, T. Nedelcheva, L. Vladimirova, S. Terzieva, "Spectrophotometric determination of oxygen stoichiometry in modification RE (rare earth elements)Ba2Cu3Oz superconducting samples", Journal of Optoelectronics and Advanced Materials-Symposia,1,3, **2009,** 476-478.
10. A. Staneva, A. Stoyanova-Ivanova, S. Terzieva, J. Shoumarova, K. Grigorov, A. Zaleski, V. Mikli, Ch. Angelov, Y. Dimitriev,"BSCCO ceramics doped with ferromagnetic manganite phases", Journal of Optoelectronics and Advanced Materials,**11**, p.1541-1544 (2009). ISSN 1454-4164

11. S. Terzieva, A. Stoyanova-Ivanova, B. Shivachev, B. Terzijska, A. Zaleski, H. Misiorek, V. Mikli, "Microstructure and thermal properties of quasi-equal rare earth substitution Y0.5Gd0.5Ba2Cu3O6.94 superconductor", Central European Journal of Physics, **7**(1), p.84-88 (2009) ISSN 1895-1082
12. K. Lovchinov, K. Kalaydjiev, V. Lovchinov, D.Dimitrov, An attempt for explanation of Dichev's rings, Journal of Optoelectronics and Advanced Materials-Symposia,1,3, **2009**, 476-478.
13. B. Terziyska, I. Bivas, K. Nenkov, Modeling of low-temperature specific heat data for $Ge_{27}As_{13}S_{60}$ and $As_{40}S_{60}$ glasses by means of phenomenologically modified soft potential model", Cryogenics, v.49 (2009), pp. 171-175. ISSN 0011-2275

ONGOING RESEARCH PROJECTS:

I. Projects financed by Bulgarian Academy of Sciences

1. New materials and multifunctional magnetic materials
2. Cryogenics, superconductivity and superconducting materials

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

1. Overdoping of 1-2-3 HTS materials and its influence on the ac losses, critical current, flux pinning, activation energy-EURATOM-FU07-CT-2007-00059

INTERACADEMIC COLLABORATION:

1. Obtaining and investigation of thin film structures of magnetic oxides (manganites and cobaltites), Institute of Physics, Polish Academy of Sciences, Warshaw, Poland

2. Synthesis and structure investigation of multifunctional materials, Center for Materials Research, Tallin Technical University, Tallin, Estonia

International Laboratory for High Magnetic Fields and Low Temperatures – Wroclaw, Poland.

TEACHING ACTIVITIES:

Ph.D. Student K. Buchkov, supervisor Assoc. Prof. E. Nazarova

DIVISION LOW TEMPERATURE PHYSICS

LABORATORY

ENVIRONMENTAL PHYSICS

HEAD: **Assos. Prof. Vasil Lovchinov, PhD**
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TOTAL STAF: **5**
RESEARCH SCIENTIST: **4**
Assos. Prof. P. Simeonova, PhD; Assos. Prof. D. Dimitrov, PhD; Asist. Prof. I. Radulov, PhD; Dimitar Petrov, PhD student

RESEARCH ACTIVITIES:

In 2009 the scientific activity of the Laboratory of Environmental Physics continues with respect to the already traditional goals of its research – classification, modeling and interpretation of complex multiparametric environmental systems. The importance of these studies was proved by the involvement of the Laboratory to many regional and nation-wide activities like The Program for Global Monitoring of the Environment and Security (GMES), the "Food for Life" platform, the Program "Environment – rational use with respect to its sustainable development" under the guidance of the Council "Resources of the non-living nature".Due to this activity the Laboratory of Environmental Physics has won the project financed by the National Science Fund – Ministry of Education and Science (DO-02-352) entitled "Improving of the life quality by sustainable management of surface waters – application for the catchments of the rivers Struma and Mesta" During 2009 the members of the Laboratory worked on the execution of this project. Altogether 8 scientific papers are published on the topics by members of the scientific team.

During 2009 the activity of the Laboratory was concentrated in realization of the time-table of ISSP activity with respect to the Budget subsidy of BAS, as well as for realization of a number of international and internal projects.

Together with Portuguese scientists the quality of air and the global influence of air transport was assessed by environmetric approaches for a specific sampling site such as Azorean Island. The results were presented at the 5th International Workshop on Biomonitoring of Air Pollution (5th BioMAP), Buenos Aires, Argentina (2009) and published in Journal of Radioanalytical and Nuclear Chemistry.

An environmetric estimate of the high mountain lake pollution (Rila Mountain) was pereformed and the results obtained were published in the international journal Environmental Monitoring and Assessment.

Together with scientists from University of Medicine, Sofia epidemiological data for diabetes mellitus type 2 patients were modeled and interpreted aiming the clarification of the role of the metabolic syndrome in appearance of the specific disease. The results were published in the international journal Central European Journal of Medicine.

In 2009 the Laboratory continues its activity in another field of research – magnetism and superconductivity.

The influence of additives of nanosize magnetic particles to polymer composite materials was investigated and it has been found that this addition improves the propoties of the composites helping in their spatial orientation.

Using sol-gel method monocrystals of $EuAlO_3$ were synthesized. The monocrystals obtained were characterized by the use of X-ray diffraction, Scanning Electron Microscopy, Energy Dispersive Analysis and Transmission Electron Microscopy. For the first time the

temperature dependence of the AC magnetic susceptibility was measured in the interval 300 – 2 K and it has been established that the material is paramagnetic within the whole interval.

Asist. Prof. I. Radulov who has won a competition in the field of educational ecological projects financed by the World Federation of the Scientists, Cern, Switzerland in 2008, finishedhis project in 2009. The tutor of this educational project was the head of the Laboratory Assoc. Prof. Dr. V. Lovchinov.

The collaboration with L'Universite de Liege, Depart. Physique, Group SUPRA.TECS- Liege, Belgium on the joint project entitled: "Thermal and magnetic properties of HT superconducting and related magnetic materials**"** based on between-academic collaboration /IBR/ has successfully continued.

With active participation of all members of Laboratory of Environmental Physics in 2009 a unique apparatus for physics measurement - PPMS was supplied. A new Research center for measurement of physics property of materials and structures was organized and started its activity in 2009 using the new equipment. For leader of center the head of Laboratory of Environmental Physics Assoc. Prof. Dr. V. Lovchinov was elected.

Assos. Prof. D. Dimitrov was appoined as lecturer in Technical University of construction and offered a new course of construction physics for students from this University.

Asist. Prof. I. Radulov has taken one year leave as post doc in Creta Island University, Greece.

In this year the PhD candidate Assist. Prof. Dimitar Petrov, University of Food technologies, Plovdiv was accepted as distant graduate to the Laboratory. The tutors will be Assos. Prof. V. Lovchinov from ISSP-BAS and Prof. B. Angelov from University of Food technologies, Plovdiv. The provisionaltitle of the dissertation is "Optical, electrical and magnetic properties of rare earth aluminates".

The members of the Laboratory participated in total at 5 conferences during 2009 in Bulgaria and abroad with oral and poster communications.

PUBLICATIONS:

1. Pavlina Simeonova, Vasil Lovchinov, Dimitar Dimitrov, Ilia Radulov. Environmetric Approaches for Lake Pollution Assessment. *Environmental Monitoring and Assessment (EMAS)*, DOI 10. 1007/s10661-009-0888-7(2009).
2. S. Tsakovski, P. Simeonova, V. Simeonov, M.C. Fraitas, B. Vieira, I. Dionisio, A. M. G. Pacheco. Air-quality assessment of Pico mountain (Azores archipelago) environment by the use of chemometrics. *J. Radioanal. Nucl. Chem.*, Vol.28, No 1, 17-22, 2009,.
3. M. Nikolov, P. Simeonova, V. Simeonov. Chemometrics as an option to assess clinical data from diabetes mellitus type 2 patients. *Centr. Eur. J. of Med.* 4 (4), 433-443, (2009),.
4. I. Radulov, V. Lovchinov, D. Dimitrov, P. Simeonova, V. Nizankovski. Correlation between magnetostriction and polarization in orthorhombic manganites. *Journal of Optoelectronics and Advanced Materials*, vol.1, No.3, (2009) 436-439.
5. I. Radulov, V. Lovchinov, D. Dimitrov, P. Simeonova, PH. Vanderbemden. Magnetic and transport properties of $HoMnO_3$ monocrystal. *Journal of Optoelectronics and Advanced Materials*, vol. 11, No 9 ,p.1553-1556, (2009)
6. Marian Nikolov, Pavlina Simeonova and Vanio Mitev. Heavy Metal Distribution in the Different Parts of Mollusks by Using Multivariate Analysis. *Ecol. Chem. Eng.* A, vol.16, No3, 223-229 ,(2009)
7. D. Petrov, B. Angelov, V. Lovchinov and P. Simeonova. Characterization and Properties of Nanocrystalline $EuAlO_3$,. *American Institute of Physics conference proceedings v.1203, p 1063-1067,* (2009)

8. Vasil Lovchinov, Pavlina Simeonova, Ilia Radulov, Ivan Nedkov, Rumen Kalionski "Some Medical Application of Nanomaterials". (2009). *Solid State Phenomena* (in press).

ONGOING RESEARCH PROJECTS:

1. Improving of life quality by sustainable management of surface waters – application for the catchments of the rivers Struma and Mesta - project of National Science Fund to the Ministry of Education and Science № DO- 02-352 (2009 г.).
2. Global and local pollution in particular: Management of water quality - World Federation of Sciences – Switzerland.
3. "Thermal and magnetic properties of HT superconducting and related magnetic materials" - Liege, Belgium. L'Universite de Liege, Depart. Physique, Group SUPRA.TECS. in frame of project for between-academic collaboration /IBR/.
4. Internal project of ISSP-BAS for financing of fundamental and applied research in 2009 entitled**:** "Computerization of vibrational magnetometer and creation of a system for measuring of the magnetic moment of Bulgarian coins", presented at 16.04.2009 and approved by the Scientific council of ISSP (№ RD-09-43 /17.04.2009).
5. Project entitled "Instrumental completion of apparatus QD-PPMS-9 for investigation of the physical properties of the matter" National Science Fund 2009 - presented. Approval in 2010.
6. Projects with the National Science Fund: № NT-2-02, № VU-TH-102/05 and № TH-1512

INTERNATIONAL COLABORATION:

1. Universite de Liege, Belgium - L'Universite de Liege, Depart. Physique, Group SUPRA.TECS.
2. World Federation of Sciences – Switzerland.
3. International Laboratory for High Magnetic Fields and Low Temperatures – Wroclaw, Poland.

DIVISION PHYSICAL OPTICS AND OPTICAL METHODS

LABORATORY

OPTICS AND SPECTROSCOPY

HEAD: **Prof. Minko Petrov, D.Sc.**
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TOTAL STAFF: **26**
RESEARCH SCIENTISTS: **25**

Prof. N. Kirov, D.Sc.; Prof. S. Rashev, D.Sc.; Prof. K. Panayotov D.Sc.; Assoc E. Angelova, Ph.D.; 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. P. Pavlova, Ph.D.; Asist. Prof. M. Kaneva, Ph.D; Asist. Prof. T. Tenev, Ph.D.; Asist. Prof. B. Katranchev, Ph.D.; Asist. Prof. B. Panchev; Asist. Prof. H. Naradikian; Asist. Prof. B. Petrov; Asist. Prof. B. Bozhkov; Asist. Prof. E. Karakoleva; I. Milushev, Ph.D.; Y.Velkova.

RESEARCH ACTIVITIES:

I. PHOTONICS

- OPTICS AND SPECTROSCOPY OF WAVEGUIDES

A combination of methods was used for analysis of the phase composition of proton-exchanged layers in Y-cut lithium niobate obtained at different technological regimes. The demonstrated method can contribute to adjustment of fabrication conditions for obtaining of defined phase compositions needed for waveguide devices with improved stability and characteristics. It was shown that deep and strongly protonated waveguides in Y-cut $LiNbO_3$ could be obtained at specific technological regimes.

Mode spectra measurement and infrared absorption spectra registering were performed after obtaining of samples and after a period of ten years as well. Phase composition is estimated and some conclusions are made concerning the stability of such waveguides.

A comparative analysis of the most popular contemporary methods for modification of surface layers of ferroelectrics regarding their application in integrated optics is performed and the contribution of the team working in the field of integrated optics in the Institute of Solid State Physics to the development of proton exchange technology is discussed as well. Some modifications of its parameters (new proton sources) and steps (two-step exchange separated by annealing, for example) are pointed out in respect of their effect on the waveguide properties of proton-exchanged layers. The spectroscopic methods used for phase content characterization of waveguides obtained are also described. These include infrared absorption and reflection spectrometry, X-ray photoelectron spectroscopy, mode spectroscopy and micro & waveguide Raman spectroscopy.

A review of the main results on integrated-optical elements and devices developed in the Institute is made with the emphasis put on the novelties, advantages and disadvantages of each of them and on the specific problems of their fabrication.

The phenomenon of radiation-induced hydrogen migration has been studied in hydrogenated amorphous silicon (a-Si:H) using layer stacks of SiO_2/a-Si:H/SiO_2. The samples were irradiated with MeV ^{15}N ions during nuclear reaction analysis of hydrogen

concentration. It has been established that the irradiation leads to the hydrogen migration and redistribution, which depend on the a-Si:H deposition temperature. The symmetric hydrogen concentration profile in the as-prepared layer stack becomes asymmetric after the irradiation due to increase in the hydrogen concentration in the bottom SiO_2 layer. It has been established that hydrogen out-diffusion from the layer stack is not essential - hydrogen concentration in the layer stacks decreases during the initial irradiation stage and then remains constant. On the contrary, hydrogen loss from the a-Si:H layer proceeds gradually and continuously with increasing radiation fluence. It has been suggested that the hydrogen atoms liberated by the MeV ion irradiation do not recombine in molecules and that the hydrogen migration in a-Si:H is related to the diffusion of the hydrogen atoms. The radiation-induced asymmetry of the hydrogen profiles in the layer stack implies that there is a difference in the diffusion parameters at the inner and outer interface.

- FIBER OPTICS

An investigation of the photoluminescence of Y_2O_3 thin films doped with Er/Yb was conducted. These films were prepared by pulse laser deposition (PLD). The spectral emission in the visible (500 – 700 nm) and infrared (1500 – 1600 nm) wavelength range for the layers deposited on the different substrates such as crystal quartz, fused quartz, YAG, Si, MnO, as well as on the side-polished single mode fiber's surface were measured and compared.

In collaboration with a group of the Institute of Photonic Technology, Jena, Germany, the possibility of the fiber-optic bio-sensor development were investigated. The fiber-optic bio-sensor consists of coupled optical fiber and metal-oxide planar waveguide. The planar waveguide of Ta_2O_5 was deposited on the side-polished fiber surface through magnetron sputtering. The behaviour of the waveguide structure under the bio functionalizing of the surface and the subsequent capturing of the specifically DNA molecules have been researched. A significant spectral change was demonstrated in the case of the biomoleculs marked by golden nanoparticles.

In collaboration with a laboratory "Gas lasers and laser technology" –IE, BAS, Sofia, a fiber -optic gas sensor based on a nanostructured thin film consisting of ZnO nanorods was realized. The thin films are prepared using the PLD. The sensor element response under NH_3 gas flow at room temperature has been measured. The sensitivity of the nanostructured film exceeds the sensitivity of the nonstructured films several times (5-8).

- HOLOGRAPHIC DIFFRACTION GRATINGS

A laboratory prototype of a monolithic diffraction optical element was prepared consisting of diffraction gratings with different periods, which provides a possibility to form the interferogramme at a long distance from the phase mask. Its optical functions have been experimentally demonstrated as an effective phase mask in a stationary regime and in a „write-on-the-fly" scheme for the fabrication of long grating tracks.

An experimental demonstration and characterization is made of the plasmon-mediated resonant transmission through an embedded undulated continuous thin metal film under normal incidence. 1D undulation is shown to enable a spatially resolved polarization filtering whereas 2D undulations lead to spatially resolved, polarization-independent transmission. The spectral and angular dependence in the vicinity of resonance are investigated and the question of the excess losses exhibited by surface plasmon is discussed. The effect observed could find application in optical encoding systems and elements for safety of documents and valuable papers.

It was shown that it is possible to print periodic structures of 50 nm characteristic dimensions by means of a phase mask with the astute combination of a high-index material with the exposure wavelength. An optical set was designed and experimentally demonstrated which permits the fabrication of a binary diffraction grating with 50 nm wide stripes.

- MICRO- AND NANO-PHOTONICS "Georgy Zartov"

Using properly determined optical parameters of single layers of MgF_2 and LaF_3, we design, manufacture and characterize a high-reflecting mirror in the UV region (230 nm). Using four such mirrors a narrow band-pass tunable (205-225nm) UV filter (15 nm FWHM) is proposed, that suppress all visible wavelengths by 35 dB.

Back and front mirrors for eye-safe laser generation at 1538 nm wavelength are designed and produced in collaboration with Optix Co. Panagyurishte. The back mirror has high transmission at wavelength of 1067 nm and high reflection at 1351 and 1538 nm wavelengths. The front mirror has high transmission at 1067 nm, high reflection at 1351 nm and partial reflection at 1538 nm. The so prepared laser mirrors passed the laser damage and durability tests.

We investigate the nonlinear polarization- and transverse-mode dynamics of vertical-cavity surface-emitting lasers (VCSELs) induced by optical injection (OI) or current modulation. Due to the surface emission and cylindrical symmetry, VCSELs lack strong polarization anisotropy and may undergo polarization switching (PS). Furthermore, VCSELs may emit light in multiple transverse modes. This provides new features to the rich nonlinear dynamics induced in VCSELs by an external perturbation. We demonstrate for the case of orthogonal OI that new Hopf bifurcation on a two-polarization-mode solution delimits the injection locking (IL) region and that PS and IL of first-order transverse mode lead to a new resonance tongue for large positive detunings. Similarly, the underlying polarization-mode competition leads to chaotic-like behaviour in case of gain switching and the presence of two transverse modes additionally reduces the possibility of regular dynamics.

We experimentally and numerically observe synchronization of chaos in two mutually coupled vertical-cavity surface-emitting lasers VCSELs with time delay. We observe in-phase and antiphase synchronization of polarization-resolved chaotic temporal wave forms under the condition of wavelength matching. We investigate leader-laggard relationship between two chaotic wave forms of mutually coupled VCSELs and find that the laser with longer wavelength becomes the leader.

We show that a 40-μm-diameter vertical-cavity surface-emitting laser (VCSEL) is capable of supporting spatially localized structures with linear polarization, orthogonal to the principal polarization. The VCSEL is biased above the lasing threshold and emits a well-defined linear polarization (principal polarization). A holding beam with orthogonal polarization is injected into the cavity, and a localized structure is spontaneously switched on. The orthogonally polarized localized structure is shown to be bistable when the injection current is varied. Numerical results based on a rate equation model support the experimental findings.

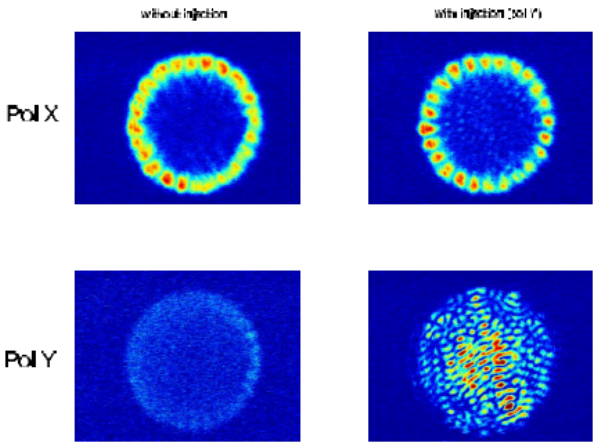

Figure. Near field of the VCSEL for principal *x* and orthogonal *y* polarizations without (left column) and with (right column) injection of a holding beam with orthogonal polarization. With a holding beam, a pattern in the orthogonal polarization is created in the whole VCSEL area.

We present a self-consistent analysis of InP-based 1300 nm AlInGaAs photonic-crystal vertical-cavity surface-emitting lasers (PhC VCSELs) and tunnel-junction PhC VCSELs, and analyze the influence of the electrical confinement, the PhC hole diameter and etching depth, and the size of the single defect optical aperture on the threshold current and the transverse mode discrimination. We also investigate the thermal performance of the two VCSEL configurations. As a result we determine the optimal PhC parameters assuring stable, single-mode operation in a broad range of driving currents.

We also present self-consistent electrical-thermal-optical-gain modeling of threshold characteristics of an InP-based 1300 nm AlInGaAs photonic-crystal vertical-cavity surface-emitting diode laser. We show that low threshold characteristics and strong transverse-mode discrimination can be simultaneously achieved for optimized photonic crystal structure and current aperture.

We demonstrate experimental evidence of polarization switching accompanied by polarization-mode hopping in quantum-dot vertical-cavity surface-emitting lasers. In our case, the polarization switching is associated with a change of linearly polarized light to elliptically polarized one, hence switching takes place between elliptically polarized states. Current-modulation measurements show that the polarization switching is of thermal origin.

We also analyze theoretically the effects of the material properties and the resonator enhancement of absorption on the performance of a semiconductor saturable absorber mirror (SESAM) utilizing the Franz–Keldysh. Bulk as well as extremely shallow quantum well materials are shown to be suitable for fabrication of devices of this type. The saturation flux and recovery time of the proposed device when operated with picosecond incident pulses, as well as the thermal properties, are shown to compare favorably with existing all-optical SESAM constructions.

II. OPTICS AND SPECTROSCOPY OF ANISOTROPIC AND NONLINEAR MEDIA

- OPTICS AND SPECTROSCOPY OF THERMOTROPIC LIQUID CRYSTALS

Using coherent laser diffraction, at normal and oblique illumination, the dynamical characteristics in the regime of electroconvection (EC) in nematics with short range smectic C order are studied. It is found that, in the low-temperature nematic range, below a characteristic temperature T^*, where big enough supramolecular complexes (clusters) form, the dynamical parameters characteristic for the electroconvective instability, the times of the response and the decay of the system, differ from those characteristic for the high-temperature region, where a classical nematic behaviour prevails. As a result the initial light scattering level (scattering background) below T^*, where the clusters form, is on a order higher than the scattering level above this temperature. This effect allows, the influence of both the degree of the alignment of the system and the order parameter on the dynamical characteristics to be accounted. Furthermore, we found for the first time, that the structural transition at T^* dramatically changes the director modulation characteristics of the electroconvecion instability, as well as the nonlinarity of the system, thus leading to inducing of the forth harmonic of the excited *ac* electric field, coexisting with the second harmonic one, typical for the classical nematics. Using Fourier analysis of the director field modulation we state that the higher harmonics indicate reinforcement of the smectic fluctuations within the quasi-smectic supramolecular complexes, as well as the increase of the degree of freedom of molecules both modifying the azimuthal director fluctuations, and in turn the EC instability of the nematics with short range smectic C order.

The morphology of the electro-deformation of lipid vesicules at the electric field parameters variation was observed. The deformation transition “prolate-to- oblate”

dependences on the electric field frequency, the vesicule's radius and suspension electroconductivity were measured.

- THEORETICAL METHODS IN MOLECULAR PHYSICS

A calculation of the rate of ISC (intersystem crossing) relaxation at 0 K requires a knowledge of the spin-orbit coupling, and the vibrational overlap integrals (Franck-Condon factors) between the T_1 and S_0 states. At elevated temperatures the population of the rotational states needs to be taken into account through the overlap of the rotational wavefunctions between the interacting T_1/S_0 electronic states.

Here, we discuss the effect of the ISC singlet–triplet selection rules on the number and magnitude of the rotational overlap factors for the J=0, 5 and 10 rotational of levels of thiophosgene, Cl_2CS. Of equal importance is the influence of the spin-spin and spin-rotation coupling on the rotational fragmentation factors and the ISC survival probability.

- MULTY-PHOTON PROCESSES. NONLINEAR OPTICS

Related to the possible usefulness as luminescent labels for sensing and imaging of biological molecules, the luminescence response of four new europium coordination complexes containing diamine ligands was probed in aqueous media. The compounds were resonantly excited in their ligand absorption band by means of high-power nanosecond UV laser pulses.

Being of importance as considering photonic applications of ion-implanted optically-transparent polymers, a laser-induced thermo-lens effect in ion-implanted polymethylmethacrylate was studied as a function of the implant dose, the incident laser power and incidence angle, and was linked to the structure formed. Having a gradient refractive-index in-depth profile, the subsurface organic-carbonaceous layer produced in the polymer by ion implantation, is responsible for the observed thermo-lensing.

The structure and photophysical properties of three modified viologens were characterized by optical spectroscopy (IR and electronic spectra). The results obtained show that the examined compounds are promising for light conversion applications. Like viologens and polyviologens currently used in practice, they can be applied in various photo-voltaic, photo-galvanic and photonic devices.

The electro-optical response of single-layered polymer-dispersed liquid crystal thin film containing spherical droplets of nematic E7 was studied. A wedge-formed thin film of thickness varying from a few to 25 micrometers was examined. The linear-gradient size distribution along the film length, as well as the single-layer arrangement and compact packing of the micrometer-sized PDLC structure render the ellectrically-commanded optical properties controlled by liquid crystal/polymer interface.

- LASER SPECTROSCOPY APPLIED TO BIOLOGICAL SYSTEMS: CHROMATIN STRUCTURE AND DYNAMICS

Fast conformational changes of biological macromolecules such as DNA – protein interactions play a crucial role in their biological functions. The development of appropriate dynamic methods possessing both high space (1 nucleotide) and time resolution is of important interest.

The used approach is based on the UV – laser induced photofootprinting of DNA – protein complexes. In this approach we exploited the DNA conformational sensitivity of the generation of nucleotide photomodification induced by a single high-intensity laser pulse. The UV laser-induced DNA photodamage proceeds via biphotonic absorption and generation of base radical cation by ionization.

Briefly, the distribution of the DNA damage spectrum changes drastically upon protein binding. By coupling and synchronizing the laser with a quench-flow device, millisecond DNA-protein interaction dynamic experiments at a nucleotide resolution have been realised. We found that the transcription factor NF-κB binds first to the center of the target DNA with fast rate limited by the diffusion, followed by a slow (1s) rearrangements towards the periphery

- *COLORIMETRY AND ITS APPLICATIONS IN INDUSTRY AND ENVIRONMENT*
A programme was elaborated for the use of a miniature USB colorimeter.

- *OPTICAL METHODS IN ARCHAELOGY*

The technique of optically stimulated luminescence (OSL) is widely used all over the world, except in Bulgaria, for dating research in geology and archaeology. The method requires interdisciplinary work of archaeologists, geologists, chemists and mainly of physicists – in the field of optical spectroscopy as well in the field of dosimetry. In 2009 a lot of preparative activities were realized in order to implement this modern dating technique in the Institute of Solid State Physics: (i) a detailed review of the publications on OSL dating was carried out in order to determine the necessary apparatuses for forthcoming experiments; (ii) attempts were made for creating an interdisciplinary scientific staff in Bulgaria; (iii) contacts for international collaboration with similar groups in Greece and Turkey were established; (iv) a general review of the archaeological megalithic monuments in Bulgaria was elaborated in order to find out the archaeological objects which are most suitable for OSL dating.

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DIVISION SOFT MATTER PHYSICS

LABORATORY

LIQUID CRYSTALS

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

Prof. I. Bivas, Ph.D., D.Sc.; Assoc. Prof. H. Hinov, Ph.D., D.Sc.; Assoc. Prof. A. Zheliaskova, Ph.D.; Assist. Prof. V. Vitkova, Ph.D.; Assist. Prof. J. Genova, Ph.D.; Assist. Prof. R. Marinov, Ph.D.

RESEARCH ACTIVITIES:

Eight projects were developed in the Laboratory "Liquid Crystals" during 2009 on different contracts: six of them with BAS, (one with CU, one with ISSP, four international co-operations – with Ljubljana University, Slovenia, Institute of Electro-chemistry, Moscow, Russia, with Austrian Academy of Sciences, Graz, and with Free University of Luxemburg, Belgium) and two with NSFB (one from session 15 and one from the programme Bulgaria – Slovenia).

The exact expressions describing the DC threshold voltage U_c, leading to appearance of the flexoelectric domains of Vistin'-Pikin-Bobylev as well as the threshold wave number qc of the same domains are obtained. By computer calculations, U_c and q_c as a function of the parameter μ and the modulus of the difference between the flexoelectric coefficients of splay and bend are obtained. It is emphasized on the case when the ratio K_{22}/K_{11}, where K_{22} is the elastic constant of twist and K_{11} is the elastic constant of splay, tend to 1/3 or 3, values determined by the theory. The theoretical results obtained are compared to new experimental ones, obtained by us and to old experimental results, obtained by other authors, and on the basis of these comparisons, the value of the difference between the flexoelectric coefficient of splay and bend for a number of usual calamitic or bent-core nematics is obtained. For the first time, the penetration of the flexo-dielectric walls near the cathode of a nematic cell with a thickness of 100 microns is determined to be 40 microns.

A new simple and easy electroformation procedure for preparation of neutral and negatively charged giant unilamellar vesicles, without any visible defects, in different aqueous solutions, of great importance for medicine, biology and electrochemistry (pure phosphate buffer solution, PBS, pure physiological solution and mixed sugar-buffer solution), is developed. For negatively charged liposomes cardiolipin is used in two different mass ratios. The bending elastic modulus of the lipid membrane is determined in the case of mixed water solution of sucrose and PBS and of pure maltose in the aqueous solution. These values are in good agreement with published data for different conditions.

Electroformed as well as spontaneously swelled vesicles prepared from various synthetic lipids (SOPC and DphPC) have been used to study the dynamics of thermally induced shape fluctuations. A large number of giant fluctuating vesicles, without any visible defects, have been recorded and analysed to select those without trend of membrane tension for further consideration. The detailed procedure of preparation, selection and analysis of the dynamics of thermally induced fluctuations is specified.

The shape fluctuations of nearly spherical lipid vesicles are accompanied by a lateral displacement of the monolayers, comprising their bilayers. A theory for the influence of these displacements on the fluctuations was developed. As a result, the time correlation functions of each of the fluctuation modes of the vesicle were calculated. The correlations of the shape fluctuations of nearly spherical emulsion droplets were also calculated for different viscosities of the liquid inside and outside the droplet.

Simple experimental procedure is developed for the formation of vesicular suspensions in asymmetrical conditions, on which the aqueous solution (internal phase), enclosed by the vesicle membrane, differs from the suspending medium (external phase). The vesicles are formed in sucrose solution, then – re-suspended in isoosmotic glucose solution. The density difference between the external and the internal media is neutralized by adding an appropriate concentration of the biocompatible polymer dextran to the suspending medium. In this way, iso-density conditions are assured without changing the osmolarity of the solution or the optical contrast, which is necessary for the investigation of the tri-dimensional thermal fluctuations of vesicle membranes by digital holographic microscopy (studies to be performed during 2010 in Microgravity research center in Université Libre in Brussels).

The behaviour of vesicles with long tubular protrusions (tethers), connected to their membranes was studied. The objects were put in symmetrical and asymmetrical (with respect to the membrane) aqueous solutions with same or different osmolarity and temperature. It was shown that when a solution with different osmolarity was put into the outside solution of the membrane of the vesicle, the connected to the membrane tether changed its shape into chainlike structure, containing small spherical beats. In most of the cases this process was reversible with time. The same effect was observed during the temperature change of the suspension. Formed and cooled down the vesicle suspension was put under the microscope at room temperature. The previously described change of the shape of the vesicle with tether was observed with time: the connected tether transformed into chainlike structure and after some time it restores its initial form. The same experiment was done when solution with the same osmolarity was added outside of the vesicle membrane. In this case the shape transformations were not observed.

Erythrocytes ghost (from healthy human blood) are isolated using the method of Burton *et al.* and the thermal fluctuations of their membranes are observed in phosphate buffers (with pH from 7.4 to 8.0). Using the method of Folch the lipid fraction of erythrocyte ghosts membranes was obtained and giant vesicles were electroformed at T=26°C.

Small-angle X-ray scattering from human erythrocyte ghosts and small unilamellar vesicles from erythrocyte membrane lipid extract is studied in order to determine the structural parameters of their membranes (thickness, area per lipid molecule, etc.).

PUBLICATIONS:

1. H.P.Hinov, “Complex zigzag flexoelectric walls in the Schlieren textures of MBBA: possibility for determination of two basic Schlieren textures with singular or non-singular surface points”, Cryst. Res. Technol., **44**, N 3, 327-30 (2009).
2. H. P. Hinov, Y. G. Marinov, A. G. Petrov, Uma S. Hiremath, and C. V. Yelamaggad: “Observation of flexo-dielectric walls in a bent-core calamitic nematic liquid crystal”, J. Optoel. Adv. Mater. (JOAM) **11**, N 9, 1194-1197 (2009).
3. H. P. Hinov and Y. G. Marinov: “A complete solution of the mathematical problem for the behaviour of the flexoelectric domains in a d.c. voltage for the case of anisotropic elasticity” ”, J. Optoel. Adv. Mater. (JOAM) **11**, N 9, 1202-1205 (2009).
4. H. P. Hinov and Y. Marinov: “Theoretical considerations and experimental illustration of

the electro-optic behaviour of the longitudinal flexoelectric domains under the joint action of DC and AC voltages: the case of strong anchoring", Mol. Cryst. Liq. Cryst. **503**, 45-68 (2009).
5. Pramoda Kumar, Y. G. Marinov, H. P. Hinov, Uma S. Hiremath, C. V. Yelamaggad, K. S. Krishnamurthy, and A. G. Petrov: "Converse flexoelectric effect in bent-core nematic liquid crystals", J. Phys. Chem B **113**, 9168-9174 (2009).
6. Bonka Terziyska, Isak Bivas , and Konstantin Nenkov, Modeling of low-temperature specific heat data for Ge27As13S60 and As40S60 glasses by means of the phenomenologically modified soft potential model, Cryogenics, **49**, 171-175, (2009).
7. J. Genova, A. Zheliaskova, V. Vitkova, M. D. Mitov, "Stroboscopic illumination study of the dynamics of fluctuating vesicles", J. Optoel. Adv. Materials, **11, No** 9, 1222-1225, (2009).
8. V. Vitkova, G. Coupier, M.-A. Mader, B. Kaoui, C. Misbah and T. Podgorski, "Tumbling of Viscous Vesicles in a Linear Shear Field Near a Wall" J. Optoel. Adv. Mater. **11,** No 9, 1218-1221, (2009).
9. Vitkova, M.-A. Mader, B. Polack, C. Misbah and T. Podgorski, "Microscopic signature on the rheology of erythrocyte and vesicle suspensions", Proceedings of Softflow-2009-Complex- and bio-fluids, Cargèse - June 22nd - July 4th, 2009, pp. 47-48.
10. Y. G. Marinov, H. P. Hinov, G. B. Hadjichristov, A. G. Petrov, Uma S. Hiremath, and C. V. Yelamaggad: "Observation of flexoelectricity in mixtures of calamitic and bent-core liquid crystals", AIP electronic format (in press).
11. H. P. Hinov: "On the coexistence of the flexo-dioelectric walls and flexoelectric domains in MBBA: determination of □e1z – e3x □", Mol. Cryst. Liq. Cryst. (in press).
12. 1.J.Pavlic, J. Genova, A. Zheliaskova, A. Iglic and M. D. Mitov, "Electroformation of neutral and negatively charged phospholipid giant vesicles under physiological conditions", Compt. Rend. Acad. Bulg. Sci. (in press).

DIVISION SOFT MATTER PHYSICS

LABORATORY

BIOMOLECULAR LAYERS

HEAD: **Assoc. Prof. Stanimira Naydenova, Ph.D.**
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TOTAL STAFF: **6**
RESEARSCH SCIENTISTS: **4**

Acad. Alexander G. Petrov; Asist. Prof. Y. Marinov, Ph.D.; Asist. Prof. L. Todorova; M. Dencheva-Zarkova, chem. engineer; Hr. Basheva, chemist

RESEARCH ACTIVITIES:

The concept of bilayer lipid membrane sensing is elaborated. Disposable bilayer lipid membrane sensors permit both stochastic and deterministic sensing regimes. Detection of cyano-bacterial toxins in waters by means of a stochastic sensing (ion channel induction) reveals a signature for a particular toxin type. Flexoelectricity of membranes provides a way of deterministic sensing. Detection of environmental pollution of waters by heavy metal ions (Cd and Hg is thereby rendered possible.

The converse flexoelectric effect in two bent-core nematic liquid crystals with opposite dielectric anisotropies was studied. The results are based on electro-optic investigations of inplane field-driven distortions in homeotropic samples (the Helfrich method). They are interpreted by an extension of the Helfrich theory that takes into account the higher order distortions. The bend flexocoefficient for both the compounds is of the usual order of magnitude as in calamitics, unlike in a previously investigated bent-core nematic for which giant values of the bend flexocoefficient are reported. In order to resolve this discrepancy, we propose a molecular model with nonpolar clusters showing quadrupolar flexoelectricity. The study also includes measurements on surface polarization instabilities in the dielectrically positive material; the splay flexocoefficient thereby deduced is also of the conventional order.

Membrane Electromechanics in Biology, with a Focus on Hearing was reviewed. Cells move with the electric fields that appear across their membranes, and this electromotility occurs on a scale of nanometers to microns. The motility results from two effects: the general properties of polarizable interfaces and protein rearrangement in response to the electric field. These effects allow animals to hear sounds at thermal noise levels at frequencies above 100 kHz. Electromotility provides cells with mechanical responses in response to changes in voltage that are much faster than those that occur in muscles. Nature's ability to utilize soft materials under salt water to produce high-frequency low-noise acoustic amplifiers should serve as design guides for industry.

A morphology study of single-layered optical material of linear-gradient microscale polymer-dispersed liquid crystal (PDLC) was carried out. E7/NOA65 composite films formed by pulsed UV laser photopolymerization-induced phase separation exhibited two morphology types, namely a bipolar and a hybrid alignment of liquid crystal droplets. The specific structural properties of the produced PDLC layers, such as the droplet shape uniformity and alignment, as well as the droplet size control through the film thickness, facilitate the efficient control on the uniformity and electro-optical (EO) response, thus being of practical interest for EO device applications.

PUBLICATIONS:

24. A. G. Petrov, and S. Naydenova, Soft matter biosensors: stochastic and deterministic membrane sensing, J. Indian Inst. Sci. **89**, 195-209 (2009).
25. John Harden, Nicholas Diorio, Alexander G. Petrov, Antal Jakli, Chirality of lipids makes fluid lamellar phases piezoelectric, Phys Rev E **79**, 011701 (2009).
26. F. Sachs, W.E. Brownell, and A.G. Petrov, Membrane Electromechanics in Biology, with a Focus on Hearing, MRS Bulletin **34**, 665-670 (2009), ISSN 0883-7694.
27. Pramoda Kumar, Y. G. Marinov, H. P. Hinov, Uma S. Hiremath, C. V. Yelamaggad, K. S. Krishnamurthy and A. G. Petrov, Converse Flexoelectric Effect in Bent-Core Nematic Liquid Crystals, J. Phys. Chem. B **113**, 9168–9174, 2009, ISSN 1520-6106.
28. Y. G. Marinov, G. B. Hadjichristov, A. G. Petrov, Gradient microscale PDLC single layers for light control, JOAM, **11**, 1186-1189 (2009), ISSN 1454-4164.
29. Y. G. Marinov, G. B. Hadjichristov, and A. G. Petrov, Single-layered microscale linear-gradient PDLC material for electro-optics, Cryst. Res. Technol., **44**, 870-878 (2009).
30. G. B. Hadjichristov, Y. G. Marinov, A. G. Petrov, Optical interference effects in microscale PDLC two-dimensional layers, JOAM, **11**, 1190 – 1193 (2009),.
31. G.B. Hadjichristov, V.K. Gueorguiev, Tz.E. Ivanov, Y.G. Marinov, V.G. Ivanov, E. Faulques, The transconductance of a nano-clustered subsurface layer in Si+-implanted PMMA, JOAM **11**, 1206 – 1209 (2009), ISSN 1454-4164.
32. H.P.Hinov, Y.G.Marinov, A.G.Petrov, U.S.Hiremath, C.V.Yelamaggad, Observations of flexo-dielectric walls in bent-core-calamitic nematic liquid crystal, JOAM 11, 1194 – 1197 (2009), ISSN 1454-4164.
33. H. P. Hinov, Y. G. Marinov, A complete solution of the mathematical problem for the behaviour of the flexoelectric domains in a d.c. voltage for the case of anisotropic elasticity JOAM **11**, 1202 – 1205 (2009), ISSN 1454-4164.
34. G.B. Hadjichristov, Tz.E. Ivanov, V.K. Gueorguiev, Y.G. Marinov, I. Stefanov, V. G. Ivanov, E. Faulques, Silicon ion implanted PMMA field-effect structure with electronic memory, J. Ovonic Res. 5 (1), 9-13 (2009).
35. Hinov H. P. and Marinov Y. G., Theoretical Considerations and Experimental Illustration of the Electro-optic Behaviour of Longitudinal Flexoelectric domains under the joing action of d.c. and a.c. voltages: The Case of Strong Anchoring, Mol. Cryst. Liq. Cryst., **503** 45-68 (2009), ISSN 1563-5287.
36. G. B. Hadjichristov, Y. G. Marinov, A. G. Petrov, Linear size gradient single layers of polymer-dispersed liquid crystal micrometer-sized droplets for diffractive optics, Opt. Mater., 31, 1578-1585 (2009), ISSN 0925-3467.
37. Л. Тодорова, М. Денчева-Заркова, Ст. Найденова, Оптичен Метод за Тестване на Сух Винен Остатък с Помоща на Нематичен Течен Кристал, сп. ХВП, №12.

ONGOING RESEARCH PROJECTS:

Projects, additionally financed by contracts with Ministry of Education and Science:
1. Indo-Bulgarian intergovernmental programme, contract Bin-5/07, NSF, “Flexoelectric properties of liquid crystals”.

TEACHING ACTIVITIES:

Alexander G. Petrov - lecture courses on Bioelectronics for Chemistry Dept. of St.Kliment Ohridski University of Sofia.

DIVISION LASER, ATOMIC, MOLECULAR AND PLASMA PHYSICS

LABORATORY

ATOMIC SPECTROSCOPY

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TOTAL STAFF: **9**
RESEARCH SCIENTISTS**: 8**

Prof. D. Zechev, D.Sc.; Assoc. Prof. P. Pramatarov, Ph.D.; Prof. R. Dyulgerova, D.Sc.; Assoc. Prof. M. Stefanova, Ph.D.; V. Mihailov, Ph.D.; E. Dimova, Ph.D.; G. Malcheva, Ph.D.; PhD student: V. Steflecova

RESEARCH ACTIVITIES:

1. Atomic physics and spectroscopy

Silver and bronze samples from Trebenishte necropolis have been investigated, using LIBS method. For first time a spectral analysis both, quantitative and qualitative analysis have been performed. The results are compared with those of SEM and XRF methods. The conclusion is that the investigated samples could not be attributed to one determined origin.

The experimental set-up for spectral analysis of metal samples based on Laser Induced Breakdown Spectroscopy is under construction.

The influence of UV laser light on the characteristics of the luminescence of AC structures has been investigated. The 337 nm laser light is used. The registration is performed by multichannel spectral analyzer. The results illustrate that the fluorescence is shifted to the shorter wavelength, compare to the fluorescence due to application of electric field.

An experimental set-up for laser cooling of Rb atoms is under development.

2. Plasma physics

An experimental method and set-up for determination of gas mixture in closed devices is developed. The method is based on the plasma-electron spectroscopy. The electron distribution maxima, due to the different atom processes in the plasma, carry out information about the content of the different gasses in the gas mixture.

Decay time of the $2p_i$ levels of Ne I in the hollow cathode discharge as a function of discharge current are obtained, using fit of measured optogalvanic signals from these levels with theoretical function.
The spatial distribution of luminescence of hollow cathode discharge is investigated in the case when the discharge transform to the Townsend and normal glow discharge. The explanation of peculiarities of profiles of the luminescence and their connection with discharge electrical parameters is given.

PUBLICATIONS:

Articles

1. G. Malcheva, R. Mayo, M. Ortiz, J. Ruiz, L. Engström, H. Lundberg, H. Nilsson, P. Quinet, É. Biémont, K. Blagoev, "Radiative decay data for highly excited Zr I levels", Mon. Not. R. Astron. Soc. **395**, 1523-1528 (2009).
2. G. Malcheva, S. Enzonga Yoca, R. Mayo, M. Ortiz, L. Engström, H. Lundberg, H. Nilsson, É. Biémont, K. Blagoev, "Radiative lifetimes and transition probabilities in Hf I and Hf III", Mon. Not. R. Astron. Soc. **396**, 2289-2294 (2009).
3.D. Zhechev, G. Todorov, V. Steflekova, D. Slavov, V. Polischuk and A. Gorbenko, Self-alignment and conductivity of a glow discharge, J. Phys. B: At. Mol. Opt. Phys. 42 (2009)
4. V. Steflekova, N. M. Sisovic and N. Konjevic, Influence of thin porous Al_2O_3 layer on aluminum cathode to the H_α line shape in glow discharge, J. Appl. Phys. **105**, Issue 11, 2009
5. V. Steflekova, D. Slavov, D. Zhechev, G. Todorov, E. Dimova, Magneto-Galvanic Resonances in Hollow Cathode Discharge Lamps, Spectr. Letters, **42**(08), pp. 513 - 517.
6. Jovana Petrovic, David McCabe,a Duncan England, Hugo Martay, Melissa Friedman, Alexander Dicks, Emiliya Dimova and Ian Walmsley, "A pump–probe study of the photoassociation of cold rubidium molecules", *Faraday Discussions* 142, 403 – 413 (2009)
7. David J. McCabe, Duncan G. England, Hugo E. L. Martay, Melissa E. Friedman, Jovana Petrovic, Emiliya Dimova, Beatrice Chatel, and Ian A. Walmsley, "A pump-probe study of the photoassociation of rubidium molecules", *Phys. Rev. A* 80, 033404 (2009).
8. E. Radeva, K.Kolentsov, L.Yourukova, D.Zhechev, E.Dimova, "Optical and photoluminescent properties of plasma polymer films used in electroluminescent display structures", *J. of Phys. and Chem. of Solids*, 70 (1), 169-172 (2009).
9. R. Djulgerova, V. Mihailov, M.D. Todorov, J. Koperski, M. Ruszczak, T. Dohnalik, Z. Lju Petrovic "Restoration of the pure dynamic optogalvanic signals in Ne hollow cathode discharge" IEEE – TRANSACTIONS ON PLASMA SCIENCE 37, 159-163 (2009)
10. E. Dimova, "Magneto-Optical Trap for ^{87}Rb atoms", *Modern trends in Mathematics and Physics, ed. S. S. Tinchev, Heron Press, Sofia,* 86-93 (2009)
11. G. Malcheva, "Applications of Laser-Induced Breakdown Spectroscopy", Suppliment to Bulgarian Journal of Physics, Vol. 36 (s2), 94 (2009), Heron press.

Conference reports

1. V. Steflekova, N. M. Šišović, S. Stojadinović, N. Konjević Spectroscopic study on the H_α line shape in spray discharge, Colloquium Spectroscopicum Internationale XXXVI, August 30-September 3, 2009, Budapest, Hungary, p. 368.
2. V. Steflekova, "Backscattering coefficient of low energy hydrogen ions from Copper and Tungsten", GLADNET meeting, EMPA-Thun, Switzerland, 26-30 January 2009
3. G. Malcheva, S. Enzonga Yoca, R. Mayo, M. Ortiz, L. Engström, H. Lundberg, H. Nilsson, É. Biémont, K. Blagoev, "Radiative lifetimes and transition probabilities in Hf I and Hf III", EGAS 41, Gdansk, Poland, (2009).
4. A pump-probe study of the photoassociation of cold rubidium molecules, McCabe, D.J. England, D.G. Martay, H.E.L. Friedman-Yalonetzky, M.E. Dimova, E. Petrovic, J. Walmsley, I.A**.,** Lasers and Electro-Optics 2009 and the European Quantum Electronics Conference. CLEO Europe - EQEC 2009. 14-19 June 2009
5. Influence of the UV laser light on the brightness characteristics of AC electroluminescence structures - L. Yurukova, Kr. Kolenzov, E. Dimova, G. Malcheva, D. Zhechev, N. Darmenov, P. Popov, EGAS 41, Gdansk, Poland
6. D.Maric, N.Skoro, G. Malovic, Z. Lju. Petrovic, V. Mihailov, R. Djulgerova – "Hollow cathode Discharges: Volt-Ampere Characteristics and Space-Time Resolved Structure of the Discharge" - JOURNAL OF PHYSICS: Conf. Series, 162 (2009) 012007

7. Z. Petrovic, D. Maric, N. Skoro, G.Malovic, M.Radmilovic-Radenovic, V. Mihailov, R. Djulgerova –"Volt-Amper Characteristics and Regimes of Operation of Hollow Cathode Discharges" – Second Workshop "Plasma for Environmental Issues", 2-3 July, 2009, Sofia
8. V. ihailov, R. Djulgerova, M. Todorov, J. Koperski, M. Stroechki, Z. Petrovic – "Time resolved optogalvanic signal modeling in Neon hollow cathode plasma" – First Conf. Euro-American Consortium for Promoting of Application of Mathematics in Technical and Natural Sciences, 22-27 June 2009, Sozopol, Bulgaria.

TEACHING ACTIVITIES:

PhD student: V. Steflekova, supervisor Prof. D. Zhechev
Betchelor degree student V. Tankova, supervisor Dr. G. Malcheva
Organization of the 11th winter seminar of young scientists

NEW ACTIVITIES

1. Investigations of traces of elements in archeological artifacts using Laser Induces Breakdown Spectroscopy.
2. Laser cooling and trapping of atoms

ONGOING RESEARCH PROJECTS:

1. Physics of atoms, molecules and plasma - project in the framework of Bulgarian Academy of Sciences
2. Radiative properties of ionic spectra (supported by Bulgarian National Science Fondation – contract 1516/2005)
3. Project "Radiative constants of Nb excited states" (LLC 001431/2008) financed by EC, Laserlab-Europe project for Access to Research Infrastructures.
4. Project "Laser-induced breakdown spectroscopy (LIBS) analysis of finds from Trebeniste necropolis" (ULF-FORTH 001441/2008) financed by EC, Laserlab-Europe project for Access to Research Infrastructures.
5. Project "Laser diagnostic in archaeology" supported by Bulgarian National Science Fondation.
6. Coding, treatment and measurements of quantum information with ultracooled atoms – BNSF; project № ВУ-И-301/2007
7. Bileteral agreement with Republic of China Theoretical and experimental investigation of quantum information translation in the process of interaction of ultracooled atoms and molecules; ДО02-1/2008
8. NATO reintegration grant; *Cold gas target: a novel and precision method for detection of collision processes*; EAP.RIG.982778

INTERNATIONAL COLLABORATION:

1. Radiative constants of NbI excited states - LaserLab in Europe (LLC 001431/2008).
2. Laser-induced breakdown spectroscopy (LIBS) analysis of finds from Trebeniste necropolis - LaserLab in Europe (ULF-FORTH 001441/2008).
3. Dinamic optogalvanic signals in a hollow cathode glow discharge as a technique for plasma Institute of Physics of Belgrade, Serbia and Montenegro – Assoc. Prof. DSc R. Dyulgerova

DIVISION LASER, ATOMIC, MOLECULAR AND PLASMA PHYSICS

LABORATORY
METAL VAPOUR LASERS

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TOTAL STAFF: **19**
RESEARCH SCIENTISTS: **14**

Nikolay Kirilov **Vuchkov**, D.Sc.; Peter Karolev **Telbizov**, Ph.D.; Dimo Nikolov **Astadjov**, Ph.D.; Margarita Georgieva **Grozeva**, Ph.D.; Todor Stefanov **Petrov**, Ph.D.; Krassimir Angelov **Temelkov**, Ph.D.; Krassimir Dimitrov **Dimitrov**; Vesselina Dimitrova **Gentcheva**, Ph.D; Nikolay Ivanov **Minkovski**, Ph.D.; Nikolay Vitanov **Vitanov**, D.Sc.; Peter Vassilev **Zahariev**, Ph.D.; Lubomir I. **Stoichev,** PhD; Ognian N. **Sabotinov**, PhD; Ph.D. student Nikolay Petrov **Denev;** PhD student: Radoy **Ekov**; Blagovela G. **Blagoeva**; Georgi D. **Toshev**; Ivan S. **Radkov**; Emilian P. **Atanasov**; Ivailo P. **Ivanov**

Scientific researches

In 2009 the following scientific activities were developed at **the Laboratory of Metal Vapor Lasers**:
-- Scientific research for the creation of both copper ion lasers of new types generating in the deep ultraviolet region, and of infrared lasers oscillating on self-terminating transitions of Sr, (reported in 10 publication works);
-- High-End-Performance Solid-State-Power-Supply Copper Lasers for Fine Material Processing; (2009-2012); (Project Partners: 1) LabMVLs, ISSP, BAS; 2) Laser System Engineering Division Center of Advanced Technology (CAT), Indore, India); (reported in 3 publication works);
-- Scientific studies of gas discharges in hollow cathode for the use in both lasers and gas-discharge sources of non-coherent light, (reported in 3 publication works);
-- Scientific studies of both the interaction of laser output with metals (Cu, Al, Ti) and of the processes on metal surfaces;
-- Scientific investigations of new materials for non-linear optics;
-- Scientific studies and theoretical scientific analysis in quantum physics, (reported in 19 publication works).

1) High-power mid-infrared He-$SrBr_2$ and deep-ultraviolet Ne-CuBr lasers – physics and applications, (1-7; 29-31)
On the base of both high-power mid-infrared He-$SrBr_2$ and deep-ultraviolet Ne-CuBr lasers, two laser systems equipped with opto-mechanical systems to control laser beam have been developed for application to the treatment of PEDOT films with DUV laser output and to determine optical linear properties of $Ca_xSr_{1-x}F_2$ crystals in the mid-infrared, visible and deep-UV spectral regions. Some fundamental parameters of the gas discharge plasma such as gas temperature and electron temperature have been determined.

2) High-End-Performance Solid-State-Power-Supply Copper Lasers for Fine Material Processing, (13, 32, 33).
In 2009 scientific studies were performed about the application of the method of Fourier – transformations to convert annular beams at their focusing. It was shown that large changes in the energy radial distribution of the focused beam occurred only at high annularity.

3) Eexperimental and modeling studies of the plasma in a hollow cathode discharge for laser excitation, (34-36)

As a result of experimental and modeling studies of the plasma in a hollow cathode discharge for laser excitation, we have defined an optimal ratio of the cathode length and diameter at which the discharge is homogeneous in the whole discharge volume. At these conditions the excitation efficiency is improved and higher laser output power is achieved. Based on the obtained results a new (patent protected) multi-cathode laser construction is designed.
This is a joint work with the Technical University of Eindhoven, The Netherlands.

4) Development of a packet of techniques (some with experimental demonstrations) for high effective and selective excitation of atomic levels by laser pulses, (14-28, 38-41)

Description: A method for optimization of the population transfer through the STIRAP technique has been developed in cooperation with Prof. Axel Kuhn of Oxford.
The optimization consists in selecting such a shape for the laser pulses so that to eliminate the non adiabatic processes, (18). In cooperation with Dr. Bruce W. Shore of Livermore, the technique STIRAP has been extended with the so called structured pulses that enable better control of the population transfer, for example creation of coherent super positions and quantum switches, (40). It was shown for the first time that adiabatic transfer of population in a two-level system could be performed and without traditional level crossing, (38). Important analogies of the STIRAP technique have been found in classical physics, for example, in the movement of a charged particle in a magnetic field, in the revolution of magnet's magnetisation, the Coriolis force, etc., (24). In cooperation with Dr. Uli Gaubatz of the research laboratory of Nokia-Siemens in Munich, a new broadband method has been proposed for rotation of laser beam polarization that is an adiabatic version the Faraday's effect, (41). Unlike the ordinary lambda-lamellas that work only at a particular wavelength this method is appropriate for any wavelength and is independent of the thickness of the lamella (or medium).
A detailed theory has been developed for the so called dynamical phase gate that is a primary operation in quantum informatics (23). A systematic theory has been developed for the symmetries and asymmetries in the different kinds spectral lines under coherent atomic excitation (39). In cooperation with Dr. Matthias Wollenhaupt and Prof. Baumert from Chassell, a new method combining theory and experiments for selective excitation of highly excited electronic states in the sodium atom by femtosecond pulses, (26).

Scientific research projects

Totally **7** projects including:
-- Projects supported only by the budget of BAS: **2**
-- Projects with additional support from the National Science Fund of the Bulgarian Ministry of Education and Science: **2**
-- Projects with additional support from ministries, institutions and companies in Bulgaria: **1**
-- Projects under agreements for cooperation between academies and institutes: **2**

Patents:

-- Patents: **4**

PhD students

-- PhD students: **3**

Scientific publications

Totally: **33** published in 2009 and **4** accepted for print

Papers published in international journals and proceedings

1) K A. Temelkov, N.K. Vuchkov, I Freijo-Martin, A Lema, L Lyutov and N.V. Sabotinov, (IF 2.104), Experimental study on the spectral and spatial characteristics of a high-power He–SrBr2 laser, J. of Phys. D: Appl. Phys., 42, 115105 (6pp) (2009)

2) Krassimir A. Temelkov, Nikolay K. Vuchkov, Bangning Mao, Emilian P. Atanassov, Lyudmil Lyutov, Nikola V. Sabotinov, (IF 2.413), High-power Sr atom laser excited in nanosecond pulsed longitudinal He-SrBr2 discharge, IEEE J. of Quantum Electronics, vol. 45, No. 3, pp. 278-281, (2009)

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APPLIED RESEARCH UNIT

MOLECULAR BEAM EPITAXY

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TOTAL STAFF: **3**
RESEARCH SCIENTISTS: **2**

Assist. Prof. T. Mincheva, Ph.D.; L.M. Trendafilov, physicist

RESEARCH ACTIVITIES:

BIOSENSOR SYSTEMS

Stage I of the Innovation Project "Nanoscope for enterprises and schools" subsidized by NIF of BSMEPA was successfully realized. Portable, inexpensive, and two-mode (atomic-force and tunneling) Scanning nanoscope "Atommer" (see Fig. 1) was designed and build. As a field research equipment it will open up all the new world for nano-size field observations: on the surface of geological formations (the processes of the surface erosion and transformation on a nano level); of the archeological artifacts (before their surface transformation/destruction in consequence of their air exposure); of the surface transformations of biological objects in their natural (ecologic) environment; of the surface transformations of engineering installations (destroying, corrosion, protection …) etc.

The universal approach for identification of nano-sized bio-objects (bacterial spores, viruses, macromolecules, molecular complexes etc.) is to immobilize them with conform antibodies, followed by measuring of the cantilever mass change. Microcantilever sensor is among the most sensitive instruments for registration of mass changes. Real world tasks of security, ecology, food-processing industry etc. require biosensor multi-channel measuring systems, sensitive to the nanodimensional structure of the, macromolecules and using conform reactions antigen-antibody. During 2009 the work was directed to providing the needed basis for functionalization of the biosensors developed, and to the extending the understanding of their action and the ranges of their resources. It was proposed a technique that gives precise guidelines for constructing of holders that provide fixing without loss of liquid sample exact operational micro-volumes in laboratory conditions.

Fig. 1

ONGOING RESEARCH PROJECTS:

Budget Project No 13: "Observation of the nano-sized structure of two-dimensional surface crystalline formations and the nano-sized structure of immobilized on the surface bio-makromolecules using purposely-modified Scanning probe microscopes" financed by the budget.

Innovation Project No 5IF-02-51/20.12.2008: "Nanoscope for enterprises and schools" financed by Ministry of Economy and Energy, NIF (250 000 BGN).

MUSEUM

HISTORY OF THE PHYSICS IN BULGARIA

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

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

RESEARCH ACTIVITIES:

Some quantitative indicators elucidate history of Bulgarian university physics during the last 120 years. Physics differentiation as a subject in the Sofia University and Bulgarian Academy of Sciences (BAS) is long process, starting by theoretical physics chair in the Sofia University (1921), and finishing by the Centre of Physics at the BAS (1972 – 1988). Applied physics, and public finance are some of reforms in University physics during the second half of XX century. Bulgarian physicists made nuclear research abroad mainly. Solid-state physics has national priority and base of experimental research [1].

Museum at the Georgi Nadjakov Institute of Solid State Physics has brief history, noble aims, wide activities and some funds. Museum objects (documents, apparatuses and publications on physics) are important as a source of knowledge for science and historical inversigations [2].

COLLABORATIONS:

Museum initiates and manages historical documentary film. Collaborators are Sofia University physicists (Prof. DSc I. Lalov and Prof. DSc V. Strashilov), and colleagues from Bulgarian Academy of Sciences (DSc D. Stoyanov – Institute of Electronics, DSc E. Vateva – ISSP, Dr R. Kakanakov – Central Laboratory of Applied Physics – Plovdiv, Dr O. Ivanov – ISSP) [3-4]. New museum funds came from administrative office (07.VII.2009), corresponding member L. Spassov, Dr E. Nazarova (01.VII.2009), K. Kolentsov, Acad. Tch. Palev, P. Peykov, and S. Pakeva (26.II.2009). Some pieces of reporting show latest important scientific results in ISSP [5-9]. Acad. Tch. Palev (INRNE-BAS) initiates filming acad. I. Todorov's lecture in 22 October 2009 [10].

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