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Dear Colleagues,

2010 was a difficult year for ISSP. The Institute went through a severe 30% cut of its budget, moreover the funding of the projects of the National Science Fund was also cut down to 50%. All the staff is to be congratulated for the efforts exercised during the struggle to overcome this hard financial reality.

Despite severe economic situation the 2010 productivity of ISSP in total is 254 publications, printed and in press. Three new monographs abroad were published by D.I. Uzunov, by S. Kaschieva et al., by M. Petrov; one book was edited by O. Ivanov. Five books were published in Bulgaria, among them the book of K. Kolentsov about history of the applied physics in our institute.

The system of internally funded projects is well established in ISSP in the last four years. Unfortunately, due to the unfolding crisis the call for a next session in 2010 was temporary suspended. However, in 2011 the Internal Project Competition will be resumed.

Highly distinguished international recognition in this year was received by Professor Plamen Ivanov, elected Fellow of the American Physical Society. The Marin Drinov Sign of Honor of BAS was given to Professor Elena Vateva and the Sing of Honour "For Service to BAS" was given to Professor Veselin Kovachev. Assoc. Professor K. Kolentsov was elected Honorary Member of the Institute. Professor I. Bivas and Mrs. Anka Tsenova were awarded the Georgi Nadjakov Sign of Honour 1st degree. Assoc. Professors K. Stoychev, A. Angelov and G. Minchev were awarded the Georgi Nadjakov Sign of Honour 2nd degree. Awards for the best scientific achievements of the year 2010 in ISSP were presented to teams lead by Assoc. Professors K. Temelkov and Assist. Professors V. Vitkova and Y. Marinov. 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 took place in September 2010. The School was devoted to the memory of the late Professor Joseph Marshall, Honorary Chairman of the School. The topic was: Progress in Solid State and Molecular Electronics, Ionics and Photonics. Best poster prize of the School received a team under the leadership of Assoc. Professor N. Nedev. Proceedings of the 16th School were already published by Journal of Physics: Conferences Series.

Alexander G. Petrov



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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, 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-Symposium on contemporary problems in condensed matter physics (ISCOMP).

EQUIPMENT, METHODS AND TECHNOLOGIES

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

- Equipment and methods for electron microscopy and electron diffraction investigations, atomic, electric and magnetic force microscopy, X-ray diffraction with topographic, diffractometric and spectrometric facilities, ellipsometric measurements, spectroscopy from VUV to IR spectral regions, time-resolved spectroscopy, EPR spectroscopy;
- Equipment and know-how for single crystal growth from oxide materials for laser techniques and photorefractive effect applications, techniques and technology for thin layer deposition for microelectronic, optoelectronic and acoustoelectronic sensors and laser technology, 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;
- High-tech experimental sets for laser cooling of atoms ($\sim 0.0001\text{K}$) and application of lasers to archaeology;
- Equipment (Physical Properties Measurement System produced by Quantum Design, USA) for studies of electrical, magnetic and thermal properties of materials, surfaces and structures.

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

ORGANIZATION OF THE INSTITUTE OF SOLID STATE PHYSICS

DIRECTORATE

<i>Director:</i>	Academician A.G. Petrov, D.Sc.
<i>Deputy Director:</i>	Prof. K. Blagoev, D.Sc.
<i>Scientific Secretary:</i>	Assoc. Prof. M. Primatarowa, Ph.D.
<i>Secretaries:</i>	Mrs. L. Dedinska, Dipl. Eng. Assist. Prof. E. Vlaikova (FP7 of EU)

ADMINISTRATIVE STAFF

<i>Administrative Director:</i>	Mr. Chr. Popov, Dipl. Eng.
<i>Administration's office:</i>	Head: Mrs. I. Velkova, Dipl. Eng.
<i>Accountant's office:</i>	Head: Mrs. E. Popova

DIVISIONS

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

SCIENTIFIC COUNCIL

Chairman: Prof. N. Tonchev, D.Sc.
Secretary: Assoc. Prof. M. Grozeva, Ph.D.

- | | |
|------------------------------------|--|
| 1. Acad. A. G. Petrov, D.Sc. | 8. Prof. I. Bivas, D.Sc. |
| 2. Acad. N. Sabotinov, D.Sc. | 9. Assoc. Prof. D. Nesheva, D.Sc. |
| 3. Prof. V. Kovachev, D.Sc. | 10. Assoc. Prof. M. Mitov, Ph.D. |
| 4. Prof. M. Petrov, D.Sc. | 11. Assoc. Prof. M. Primatarowa, Ph.D. |
| 5. Prof. M. Gospodinov, D.Sc. | 12. Assoc. Prof. D. Dimitrov, Ph.D. |
| 6. Prof. S. Rashev, D.Sc. | 13. Assoc. Prof. S. Tonchev, Ph.D. |
| 7. Prof. K. Blagoev, D.Sc. | 14. Assoc. Prof. H. Chamati, D.Sc. |
| 15. Assoc. Prof. T. Milenov, Ph.D. | |

DIVISION THEORY

THEORETICAL DEPARTMENT

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TOTAL STAFF: 7

RESEARCH SCIENTISTS: 7

Prof. N.B. Ivanov, D.Sc.; Prof. P.C. Ivanov, D.Sc.; Assoc. Prof. E.R. Korutcheva, D.Sc.;

Assoc.Prof. H. Chamati, D.Sc.; Assoc.Prof. M.T. Primatarowa, Ph.D.;

Assist. Prof. R. S. Kamburova

RESEARCH ACTIVITIES:

The mechanism of creation and stabilization of nanoclusters of Andreev-Pushkarov was further investigated. It is shown that a new gap-less branch may appear near the phase-separation line of the solid solutions $^3\text{He} - ^4\text{He}$. This branch may have effect on the fast mass transport in the separation effect in quantum solid solutions.

We study 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. As the coupling strength is increased the system successively exhibits two gapped paramagnetic phases a rung-singlet and a Haldane-type 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 using density-matrix renormalization-group calculations, exact diagonalizations of periodic clusters, and an effective Hamiltonian approach inspired by the analysis of numerical data. The present theoretical study was motivated by the recent synthesis of the quasi-one-dimensional ferrimagnetic material FeIIFeIII trans-1, 4-cyclohexanedicarboxylate exhibiting a similar ladder structure.

We report on theoretical and experimental results concerning the low-temperature specific heat of the frustrated spin-tube material $[(\text{CuCl}_2 \text{ tach})_3\text{Cl}]\text{Cl}_2$ (tach denotes 1,3,5-triaminocyclohexane). This substance turns out to be an unusually perfect spin-tube system which allows to study the physics of quasio-one-dimensional antiferromagnetic structures in rather general terms. An analysis of the specific-heat data demonstrates that at low enough temperatures the system exhibits a Tomonaga-Luttinger liquid behavior corresponding to an effective spin-3/2 antiferromagnetic Heisenberg chain with short-range exchange interactions. On the other hand, around 2 K the composite spin structure of the chain is revealed through a Schottky-type peak in the specific heat. We argue that the dominating contribution to the peak originates from gapped magnon-type excitations related to the internal degrees of freedom of the rung spins.

Nonlinear effects in ferromagnetic Heisenberg chains of classical spins with both inter-site and on-site anisotropy have been studied. We obtained the condition for the appearance and stability of dark solitons in these systems. For narrow excitations the effect of the discreteness on the soliton properties and propagation is considered. The scattering of dark solitons from point defects in the discrete spin chain is investigated numerically and the role of the anisotropy is demonstrated.

Vector solitons formed of pairs of nonlinear optical vibrations with orthogonal polarizations in biaxial crystals are investigated. They are described by a system of coupled

nonlinear Schrödinger equations, which take account of linear birefringence, cross-phase-modulation and group-velocity-dispersion (GVD) mismatch. The equations are solved numerically for different initial conditions and parameters. The stability of the coupled solution is investigated. The GVD mismatch, which has been neglected in previous studies, modifies the properties of vector solitons and seems to stabilize the fast-mode component.

We devoted our work to the description and analysis of effects related to the nature of the interaction in conjunction with the finite geometry of the system. Because of the essence of the interactions and geometry considered here, the investigation of the systems requires the use and development of suitable mathematical apparatus. This aims at gaining insights in the thermodynamics of these systems. The models considered are some of the most popular models in the theory of classical and quantum theory of phase transitions. They involve different kinds of interactions characteristic of a given material. They describe ferromagnetic with long range or anisotropic interaction, systems with randomly quenched disorder and fluids. We considered finite geometries subject to different boundary conditions. We investigated different thermodynamic quantities such as: the free energy, the susceptibility, specific heat etc. Special attention was paid to their scaling behaviors in the different regions of the phase diagram. Furthermore we investigated the effect of classical and quantum fluctuations in some models and check various scaling hypotheses, some of which were predicted by in our works.

PUBLICATIONS:

1. D.I. Pushkarov, Vacancy-impurity nanoclusters in solid solutions 3He- 4He, J. Phys.: Conf. Ser. **253** (2010) 012019; 9 pages.
2. V. Ravi Chandra, N. B. Ivanov, and J. Richter, Frustrated spin ladder with alternating spin-1 and spin-1/2, Phys. Rev. B **81**, 024409 (2010).
3. N. B. Ivanov, J. Schnack, R. Schnalle, J. Richter, P. Kögerler, G. N. Newton, L. Cronin, Y. Oshima, and H. Nojiri, Heat capacity reveals the physics of a frustrated spin tube: Phys. Rev. Lett. **105**, 037206 (2010).
4. M.T. Primatarowa and R.S. Kamburova, Bound Soliton-Impurity Solutions in Lattices with Cubic-Quintic Nonlinearities, AIP Conference Proceedings **1203**, 240-245 (2010).
5. R.S. Kamburova and M.T. Primatarowa, Interaction of Soliton with Impurities in Two Coupled Nonlinear Chains, AIP Conference Proceedings **1203**, 261-266 (2010).
6. M. T. Primatarowa and R. S. Kamburova, Dark soliton dynamics in classical one-dimensional spin systems, J. Phys.: Conf. Ser. **253** 012022, 6 pages, (2010).
7. K. T. Stoychev, R. S. Kamburova and M. T. Primatarowa, Vibrational vector solitons in biaxial crystals, J. Phys.: Conf. Ser. **253** 012021, 5 pages, (2010).
8. H. Chamati and S. Romano, Interaction anisotropy and random impurities effects on the critical behaviour of ferromagnets, J. Phys.: Conf. Ser. **253**, 012011, 11 pages, (2010).

THESIS:

H. Chamati, *Effects of Interaction and Anisotropy on the Critical Behavior of Finite-Size Systems*, Dissertation for awarding of scientific degree DOCTOR of SCIENCE (DSc) in Physics

ONGOING RESEARCH PROJECTS:

Quantum effects in spin systems with strong competing interactions (National Science Fund, Project DO02-264)

DIVISION THEORY

RESEARCH GROUP

COLLECTIVE PHENOMENA in Condensed Matter

HEAD: Prof. Dimo I. Uzunov, Ph.D., D.Sc.

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TOTAL STAFF: 2

RESEARCH SCIENTISTS: 2

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

RESEARCH

The diamagnetic susceptibility in zero external magnetic field above the phase transition from ferromagnetic phase to phase of coexistence of ferromagnetic order and unconventional superconductivity has been calculated. For this aim we use generalized Ginzburg-Landau free energy of unconventional ferromagnetic superconductor with spin-triplet electron pairing. The possible application of the result to some intermetallic compounds is briefly discussed.

PAPERS

1. H. Belich, D. V. Shopova and D. I. Uzunov, Phys. Lett. A **374** (2010) 4161. Title: Diamagnetic susceptibility of spin-triplet ferromagnetic superconductors.

BOOKS

An intensive and volume work (6 months) has been made by the author of the monograph "Introduction to the theory of critical phenomena" by Dimo I. Uzunov (World Scientific, 1993; 456 pages) on the second largely extended and completely revises edition which appeared in August 2010 under the same title (673 pages basic text, World Scientific, 2010, Singapore-London-New Jersey).

CURRENT PROJECTS, GRANTS

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

INTERNATIONAL COLLABORATION

Collaborative visits have been accomplished in International Institute of Physics, Natal, Brazil (12 months, the total 2010) (30 hour course of lectures for doctorate students and young scientists have been given on modern aspects of phase transitions and critical phenomena, and The African University of Science and Technology (AUST) (Abuja, Nigeria) (in total 7.5 months). Three seminar talks and two invited reports at conferences in Brazil have been given.

Several tens projects, submitted to various programmes of EC have been evaluated and reported.

Papers submitted for publication to PRL, PRB, PRA, PLA, etc. have been a subject of peer reviews and referee reports have been presented.

DIVISION MATERIAL PHYSICS

LABORATORY

ELECTRON-PHONON INTERACTIONS

HEAD: Assoc. Prof. Kate Christova, Ph.D.

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TOTAL STAFF: 6

RESEARCH SCIENTISTS: 4

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

RESEARCH ACTIVITIES:

The method of Explicitly Correlated Wave Functions (ECWF) for calculation of electronic energies is developed in an original manner using **completely new** minimization procedure. An eigenvalue problem is solved for each value of the wave vector, minimizing by one parameter only, instead of minimization by hundreds of unknown coefficients. The inclusion of mass polarization in the minimization procedure improves the precision significantly as well. The obtained results, arranged in tables, give possibility to use very **precise data for electronic energies** and thus to fill in data, **which are not available experimentally**.

The work on stimulated Raman adiabatic passage (STIRAP) for coherent transfer of the population in quantum mechanical systems of 3 states is finalized, by now. The influence of pump and Stokes fields on two-photon resonance of STIRAP is studied. Analytical expressions for the transition time of different pump and Stokes couplings are derived.

Stress characterization has been implemented using Raman spectroscopy and wafer curvature measurements for very thin films (up to 200 nm) of microcrystalline silicon. On the basis of this correlation, a material constant is estimated experimentally **first of all**, which is called (by others) Raman Mechanical Coefficient.

Based on the research on electromagnetic field-matter interaction it has been worked on the possibility to control inputs in different industries. The target is to improve the technological conditions of production and also to improve the security against terrorist attacks. More specifically, the possibility to control the materials for the manufacture of ceramic products was considered. Initial research on scanning of structures for diffraction gratings created on germanium substrates was conducted. These results show that in principle is possible to visualize the studied structures on the screen of a computer by appropriate scanning laser beam. A manuscript has been accepted for editing as a part of an international publisher's book. O. Ivanov is the editor of this collection.

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. Additional inquiries are developed in 2010. **New working positions are set up** in National Company "Railway Infrastructure". These products of Information Technology (**IT**) are in **regular operation** with copyright, which belongs to L. Mihailov. The work on these projects is of **national** effective concern and cater for the **needs of the state**. The copyright for using the products is unexclusive.

PUBLICATIONS:

1. K. Christova, S. Alexandrova, A. Abramov, E. Valcheva, B. Rangelov, C. Longeaud, S. Reynolds, P. Roca i Cabarrocas, Structure-related strain and stress in thin hydrogenated microcrystalline silicon films, *Journal of Physics: Conference Series* 253, 1, 012056, 8 pages, 2010
2. K. Christova, M. Kuneva, S. Tonchev, Stress in LiNbO₃ proton-exchanged waveguide layers, *J. Phys.: Conf. Ser.* 253, 1, 012057, 7 pages, 2010
3. Iavor I. Boradjiev and Nikolay V. Vitanov, Stimulated Raman adiabatic passage with unequal couplings: Beyond two-photon resonance, *Phys. Rev. A* **81**, 053415 2010
4. Iavor I. Boradjiev and Nikolay V. Vitanov, Transition time in the stimulated Raman adiabatic passage technique, *Phys. Rev. A* **82**, 043407 2010
5. R. Pavlov, L. Mihailov, Ch. Velchev, M. Dimitrova-Ivanovich, Zh. Stoyanov, N. Chamel and J. Maruani, Effects induced by nuclear deformations and electron correlations on the ground-state energy of low and multiply charged Helium like ions in high-temperature plasmas, *J. Phys.: Conf. Ser.* 253, 1, 012075, 6 pages, 2010
6. O. Ivanov and M. Kuneva, Application and Experience of Quality Control, Ivanov O. (editor), INTECH, Vienna, (in press)
7. R. L. Pavlov, **L. M. Mihailov**, Ch. J. Velchev, M. Dimitrova-Ivanovich, **Zh. K. Stoyanov** and N. Chamel, Effects Induced by Nuclear Deformations in Ground State Electron Energy and Electron Correlations of Multiply Charged Helium Like Ions in High-Temperature Plasma”, XXIX International Workshop on Nuclear Theory, 21-26 June 2010, the Rila Mountains, Bulgaria – oral presentation.
8. R. L. Pavlov, **L. M. Mihailov**, Ch. J. Velchev, M. Dimitrova-Ivanovich, **Zh. K. Stoyanov** and N. Chamel, Effects Induced by Nuclear Deformations in Ground State Electron Energy of Multiply Charged Helium Like Ions in High-temperature Plasma, IV International Workshop on Plasma Physics, July 5 – 10 (2010), Kiten, Bulgaria - oral presentation.

ONGOING RESEARCH PROJECTS:

1. Electronic properties of solid state systems (BAS)
2. Correlation, relaxation and relativistic effects in quantum systems interacting with electromagnetic field - # DKOΦ7RP O2/1, Joint program of COST, 7 RP and BMES.
3. Coherent control of quantum systems - DYS 02/19, BMES.
4. Control of quantum systems with coherent fields - # 074, BMES.
5. Quantum computers and quantum information - D 002-90, BMES.
6. Correlation, spin and relativistic effects in many-particle quantum systems, interactions between them and with external electromagnetic and laser fields as well - LTP INRNE, Dubna
7. Study on strongly correlated electronic systems in laboratory and astrophysical plasma – FNRS, Acad. Bilateral Agreements (ABA).
8. New applications of hollow cathode discharge for depth profile analysis of recent nano - structure and in optogalvanic spectroscopy – ABA.
9. Spatiotemporal study of low pressure and low temperature hollow cathode discharge - ABA

DIVISION MATERIAL PHYSICS

LABORATORY

STRUCTURAL METHODS

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tel: 979 5701; e-mail: malina@issp.bas.bg

TOTAL STAFF: 4

RESEARCH SCIENTISTS: 2

Assist. Prof. D. Petrova-Kerina, V. Tomov, physicist; G. Avdeev, physicist

RESEARCH ACTIVITIES:

Single crystals of $\text{Pb}_3\text{Ni}_{1.5}\text{Mn}_{5.5}\text{O}_{15}$ were grown by the high temperature solution growth method. Their composition was determined by energy dispersive X-ray analysis. The phase homogeneity of the growth crystals was examined and confirmed by powder X-ray phase analysis. The structure was characterized by X-ray single diffractometry and was indexed in the trigonal space group (No. 165) with lattice parameters $a = 0.9914$ [nm] and $c = 1.3492$ [nm]. The dielectric properties of $\text{Pb}_3\text{Ni}_{1.5}\text{Mn}_{5.5}\text{O}_{15}$ were investigated in the temperature range 150 –500 K. The AC measurements were carried out for 3 different frequencies: 10 kHz, 100 kHz and 1 MHz. From the DC measurements thermal activation energy was estimated.

By two structural methods (neutron diffraction and X-ray synchrotron diffraction) the phase transitions appearing at high pressure in relaxor ferroelectrics $\text{PbSc}_{0.5}\text{Ta}_{0.5}\text{O}_3$ and $\text{Pb}_{0.7}\text{Ba}_{0.2}\text{Sc}_{0.5}\text{Ta}_{0.5}\text{O}_3$ with perovskite structure were investigated and characterized. The both relaxor crystals are sintesized in the laboratory “Crystal Growth”- ISSP. The relaxor crystals have great technological importance for application as memory devises. These ferroelectrics possess high dielectric and electro-optical properties. They consist of polarized nano-areas, which are dispersed in paraelectric matrix.

In 2010 year ten X-ray structural analysis were made related to phase determination of polycrystalline ceramic $\text{Pb}_3\text{Mn}_7\text{O}_{15}$ magnetite. This material is interesting with its unusual magnetic properties, which are perspective for application in electronics. The parameters of crystal unit-cell were determined for its hexagonal structure (space group $P63/mcm$, coordination number $Z=4$).

PUBLICATIONS:

1. V. Tomov, T.I. Milenov, R.P. Nikolova, G.V. Avdeev and P.M. Rafailov, Growth, composition and dielectric properties of $\text{Pb}_3\text{Ni}_{1.5}\text{Mn}_{5.5}\text{O}_{15}$ single crystal, *Materials Science and Engineering* **15**, (2010) 012042–49.
2. Bernard J. Maier, Ross J. Angel, Willian G. Marshall, Boriana Mihailova, Carsten Paulmann, Jens M. Engel, Marin Gospodinov, Anna-Maria Welsch, Dimitrina Petrova and Ulrich Bismayer, Octahedral tilting in Pb-based relaxor ferroelectrics at high pressure, *Acta Cryst.* **B 66**, (2010) 280-291.

3. N. Izmirova, P. Uzunov, I. Tomova, M. Baeva, Minerals and health, *Farmaceutical Monitor* **11**, № 3, (2010) 19–22.
4. N. Izmirova, P. Uzunov, I. Tomova, M. Baeva, B. Alexiev, E. Djurova, P. Blagoeva, C. Mircheva, Natural zeolite for decreasing of radiochemical elements concentration, *J. Infofarma* **18**, № 3, (2010) 34–37.
5. K. Petrov, G. Avdeev, Ti^{4+} coordination in $\text{LiMn}_{2-y}\text{TiO}_4$ spinels, *Second National Crystallographic Symposium* 2010, October 21-23, Sofia, Bulgaria, page 34.
6. A. Shoumkova, V. Stoyanova, Ts. Tsacheva, G. Avdeev, Preliminary study on zeolitization of bulgarian fly ashes: SEM-EDX and XRD analyses, *Second National Crystallographic Symposium* 2010, October 21-23, Sofia, Bulgaria, page 63.

ONGOING RESEARCH PROJECTS:

Grant No. PF 19 / 2010 year from Bulgarian Nuclear Regulatory Agency
“Investigation of structure and substitution mechanism in cation subsystem of manganese in ceramic magnetic $\text{Pb}_3\text{Mn}_7\text{O}_{15}$ by X-ray and neutron diffraction methods”, Contract for experimental work between laboratory Structural Methods – ISSP, Bulgaria and Laboratory Neutron Physics – JINR, Russia.

INTERNATIONAL COLLABORATION:

Georgi Nadjakov 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
RESEARSH SCIENTISTS: 8

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

RESEARCH ACTIVITIES:

- synthesis and characterization of complex oxides with ferroelectric/ferromagnetic behavior

The crystal and magnetic structure of $\text{Bi}_2\text{Fe}_4\text{O}_9$ are studied by neutron diffraction, polarized Raman spectroscopy and magnetic measurements. The B-site ordering in the ferrite crystals NiFe_2O_4 with inverse spinel lattice is investigated.

The experimental results show that Ni^{2+} and Fe^{3+} possess B- site short range ordering. The effects of substitution of Pb with Ba and Bi in ferroelectric- relaxor $\text{Pb}_2\text{ScTaO}_5$ crystals is studied by neutron and synchrotron single crystal diffraction at high pressures and temperatures close to the phase-transition temperature. The phase transitions and B-site disorder in $\text{Pb}_2\text{ScTaO}_5$ crystals are investigated by dielectric spectroscopy and acoustic emission and existence of two phases- cubic (paraelectric) and rhombohedral (ferroelectric) around the transition temperature is suggested.

Crystals of $\text{La}_2\text{CoMnO}_6$ doped with Pb are successfully grown and characterized by SEM/EDAX, single crystal XRD and polarized Raman spectroscopy. It was established that orthorhombic and monoclinic lattice co-existed in these crystals.

- sillenites, complex oxides and carbon nanostructures

BaBiBO_4 and $\text{CaBi}_2\text{B}_2\text{O}_7$ non-linear optical crystals are synthesized and characterized by SEM/EDAX, X-ray diffraction, IR transmission and polarized Raman spectroscopy. Classification and normal mode assignment based on the spectroscopic investigations are carried out.

The glass- formation area in the systems $\text{CaO-Bi}_2\text{O}_3\text{-B}_2\text{O}_3$ and $\text{SrO-Bi}_2\text{O}_3\text{-B}_2\text{O}_3$ is studied and structural and optical properties and thermal behavior are also investigated.

Investigation of electrochemical doping of single walled carbon nanotubes is carried out in practically all its stages: from electrostatic double-layer charging to intercalation and functionalization.

-dynamics of non-linear systems

There are two important steps in the study of behavior and properties of non-linear systems: system modeling and extracting of maximum information from experimental data. It was established that solutions of “drifting wave” type could be applied in the investigation of differences in optical phonons modes by principal component analysis, low-dimensional dynamics of blood flow in small peripheral human arteries and non-linear waves of migration.

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2. E. Dul'kin,¹ B. Mihailova,² G. Catalan,³ M. Gospodinov,⁴ and M. Roth, *Phase transformation above T_m in $PbSc_{0.5}Ta_{0.5}O_3$ relaxor as seen via acoustic emission*, PHYSICAL REVIEW B **82**, 180101, (R) (2010).
3. Iliev, M.N., Litvinchuk, A.P., Hadjiev, V.G., Gospodinov, M.M., Skumryev, V., Ressouche, E., Phonon and magnon scattering of antiferromagnetic $Bi_2Fe_4O_9$, *Physical Review B - Condensed Matter and Materials Physics* 81 (2), art. no. 024302 (2010).
4. Maier, B.J., Welsch, A.-M., Angel, R.J., Mihailova, B., Zhao, J., Engel, J.M., Schmitt, L.A., (...), Bismayer, U., A-site doping-induced renormalization of structural transformations in the $PbSc_{0.5}Nb_{0.5}O_3$ relaxor ferroelectric under high pressure, *Physical Review B - Condensed Matter and Materials Physics* 81 (17), art. no. 174116 (2010).
5. Maier, B.J., Angel, R.J., Marshall, W.G., Mihailova, B., Paulmann, C., Engel, J.M., Gospodinov, M., (...), Bismayer, U., Octahedral tilting in Pb-based relaxor ferroelectrics at high pressure, *Acta Crystallographica Section B: Structural Science* 66 (3), pp. 280-291 (2010).
6. Ivanov, V.G., Abrashev, M.V., Iliev, M.N., Gospodinov, M.M., Meen, J., Aroyo, M.I., Short-range B -site ordering in the inverse spinel ferrite $NiFe_2O_4$, *Physical Review B - Condensed Matter and Materials Physics* 82 (2), art. no. 024104 (2010).
7. Vermette, J., Jandl, S., Mukhin, A.A., Ivanov, V.Y., Balbashov, A., Gospodinov, M.M., Pinsard-Gaudart, L., Raman study of the antiferromagnetic phase transitions in hexagonal $YMnCO_3$ and $LuMnO_3$, *Journal of Physics Condensed Matter* 22 (35), art. no. 356002 (2010).
8. T.I. Milenov, P.M. Rafailov, M.V. Abrashev, R.P. Nikolova, A. Nakatsuka, G.V. Avdeev, M.N. Veleva, S. Dobrev, L. Yankova, M.M. Gospodinov, *Growth and characterization of La_2CoMnO_6 crystals doped with Pb*, Materials Science and Engineering B 172 (2010) 80–84.
9. P.M. Rafailov, A.V. Egorysheva, T.I. Milenov, V.D. Volodin, G.V. Avdeev, R. Titorenkova, V.M. Skorikov, R. Petrova and M.M. Gospodinov, *Synthesis, Growth and Optical Spectroscopy Studies of $BaBiBO_4$ and $CaBi_2B_2O_7$ Crystals*, Applied Physics B 101 (2010) 185.
10. Егорышева А.В., Володин В.Д., Миленов Т., Рафаилов П., Скориков В.М., Дудкина Т.Д., *Стеклообразование в системах $CaO-Bi_2O_3-B_2O_3$ и $SrO-Bi_2O_3-B_2O_3$* , Russ. J. Inorg. Chem., 55 (2010) 1810.
11. Peter M. Rafailov, Milko Monev, Rita Bretzler, Svetla Evtimova, Boris Arnaudov, Christian Thomsen, Urszula Dettlaff-Weglikowska, and Siegmund Roth, *Evolution of the Raman intensity and the transport properties of SWNTs in various electrochemical doping stages – Exciton effects and functionalization-induced DOS changes*, Phys. Status Solidi B, 1–4 (2010) / DOI 10.1002/pssb.201000181.
12. Nikolay K. Vitanov, Zlatinka I. Dimitrova, *Application of the method of simplest equation for obtaining exact traveling-wave solutions for two classes of model PDEs from ecology and population dynamics*, Communications in Nonlinear Science and Numerical Simulation 15, 2836-2845 (2010).
13. Nikolay K. Vitanov, Zlatinka I. Dimitrova and Holger Kantz, *The modified method of simplest equation and its application to nonlinear PDEs*, Applied Mathematics and Computation 216, 2587-2595 (2010).

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16. H P Hinov, J I Pavlič, Y G Marinov, A G Petrov, S Sridevi, P M Rafailov and U Dettlaff-Weglikowska, *Influence of single-walled carbon nanotubes (< 0.001 wt %) and/or zwitter-ionic phospholipid (SOPC) surface layer on the behaviour of the gradient flexoelectric and surface induced polarization domains arising in a homeotropic E7 (a mixture of 5CB, 7CB, 8OCB and 5CT) nematic layer*, 2010 J. Phys.: Conf. Ser. 253 012061
17. A. G. Petrov, Y. G. Marinov, H. P. Hinov, L. Todorova, M. Dencheva-Zarkova, S. Sridevi, P. M. Rafailov and U. Dettlaff-Weglikowska, *Observation of Flexoelectricity in a Mixture of Carbon Single Walled Nanotubes with a Nematic Liquid Crystal*, Mol. Cryst. Liq. Cryst. (in press).
18. Zlatinka I. Dimitrova and Daniela Gogova, *Investigation of differences in optical phonons modes by principal component analysis*, Comptes rendus de l'Academie bulgare des Sciences 63(10), pp.1415-1420 (2010).
19. Zlatinka I. Dimitrova, *On the low-dimensional dynamics of blood flow in small peripheral human arteries*, Comptes rendus de l'Academie bulgare des Sciences 63(1), pp.55-60 (2010).
20. I. Jordanov, Zlatinka I. Dimitrova, *On nonlinear waves of migration*, Journal of Theoretical and Applied Mechanics, 40(1), pp.89-96 (2010).
21. Titorenkova, R., Mihailova, B., Petrova, R., Gospodinov, M., Konstantinov, L., *Effect of doping on the structure and Raman spectra of Bi₄Ge₃O₁₂*, AIP Conference Proceedings 1203, pp. 289-293 (2010).
22. Kostova, B., Gospodinov, M., Konstantinov, L., *Optical absorption of Bi₁₂SiO₂₀:M (M = Cr, P, Cr+P)*, AIP Conference Proceedings 1203, pp. 193-198 (2010).

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.

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TOTAL STAFF: 3

RESEARCH SCIENTISTS: 2

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

RESEARCH ACTIVITIES:

The research activities of the Laboratory for Biocompatible Materials (BCM) in 2010 were:

1. 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).
2. DND particle distribution in several solutions is extensively investigated since it gives an 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).
3. 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).
4. 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).
5. 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).

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 profilometry. 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. 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 Interface Analysis* (2010) 42, 475-480.

In proceedings

1. L. Pramatarova, E. Pecheva, R. Dimitrova, T. Spassov, N. Krasteva, T. Hikov, D. Fingarova, D. Mitev, Hydroxyapatite Reinforced Coatings with Incorporated Detonationally Generated Nanodiamonds, *Proceedings of AIP* 10(1) (2010) 937-942
2. E. Pecheva, P. Laquerriere, S. Bouthors, D. Fingarova, L. Pramatarova, T. Hikov, D. Dimova-Malinovska, P. Montgomery, Polycrystalline Silicon: a Biocompatibility Assay, *Proceedings of AIP* 10(1) (2010) 909-913
3. E. Radeva, L. Pramatarova, E. Pecheva, T. Hikov, E. Iacob, L. Vanzetti, R. Dimitrova, N. Krasteva, T. Spassov, D. Fingarova, Study of Organosilicon Plasma Polymer Used in Composite Layers with Biomedical Application, *Proceedings of AIP* 10(1) (2010) 949-954
4. N. Krasteva, K. Hristova, E. Radeva, E. Pecheva, R. Dimitrova, L. Pramatarova, Effect of Ammonia Plasma Treatment on the Biological Performance of Plasma Polymerized Hexamethyldisiloxane, *Proceedings of AIP* 10(1) (2010) 688-693

Works presented at international events

1. L. Pramatarova, R. L. Sammons, E. Pecheva, A. Wang, D. Fingarova, T. Hikov, T. Spassov, Csaba Balazsi, Biomineralization by *Serratia* Bacteria on a variety of substrata, 17 International Microscopy Congress, 19-24 September, 2010, Rio de Janeiro, Brazil (poster)

2. L. Pramatarova, E. Pecheva, N. Krasteva, K. Hristova, T. Hikov, D. Fingarova, J. Werckmann, Microscopic investigation of detonational nanodiamond with biomedical applications, 17 International Microscopy Congress, 19-24 September, 2010, Rio de Janeiro, Brazil (poster)
3. N. Krasteva, G. Toromanov, K. Hristova, E. Radeva, E. Pecheva, R. Dimitrova, G. Altankov and L. Pramatarova, Initial biocompatibility of plasma polymerized hexamethyldisiloxane films with different wettability, 16th International school on condensed matter Physics, 29 August – 3 September, 2010, Varna, Bulgaria (poster)
4. PC Montgomery, F Anstötz, J. Montagna, D Montaner, L Pramatarova, E Pecheva, Towards real time 3D quantitative characterisation of *in situ* layer growth using white light interference microscopy, 16th International school on condensed matter Physics, 29 August – 3 September, 2010, Varna, Bulgaria (oral, invited)
5. L. Pramatarova, N. Krasteva, E. Radeva, E. Pecheva, R. Dimitrova, T. Hikov, D. Mitev, S. Stavrev, O. Angelov, Study of detonational nanodiamond – plasma poly(hexamethyldisiloxane) composites for medical application, 16th International school on condensed matter Physics, 29 August – 3 September, 2010, Varna, Bulgaria (poster)
6. T. Hikov, L. Pramatarova, R. L. Sammons, A. Wang, E. Pecheva, A. Wright, W. Palin, J. Wilson, L. Macaskie, P. Yong, T. Spassov, Bacterial biosynthesis of hydroxyapatite on titanium and titanium alloys, 3rd International Nanobio conference, 24-27 August, 2010, Zurich, Switzerland (poster)
7. L. D. Pramatarova, S. Y. Stavrev, E. V. Pecheva, e. I. Radeva, N. A. Krasteva, R. P. Dimitrova, D. C. Fingarova, T. A. Hikov and D. P. Mitev, Composites to control cell behavior, Explosive production of new materials: science, technology, business, and innovations, 7-11 June 2010, Bechichi, Montenegro (oral, invited)
8. 10th Expert Evaluation & Control of Compound Semiconductor Materials & Technologies (Exmatec) May 19-21 2010 Darmstadt/Seeheim, Germany, L. Pramatarova, E. Pecheva, T. Hikov, D. Fingarova, P. Montgomery, D. Montaner, P. Laquerriere, J-P. Stoquert, L. Jacomine, T. Spassov, R. Dimitrova, Solid Surface modification by growth of nanodiamond/hydroxyapatite composite layers (poster)

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, NIF 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

HEAD: Assoc.Prof. Diana Nesheva, D.Sc.

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TOTAL STAFF: 11

RESEARCH SCIENTISTS: 9

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. Z. Levi, Ph.D.; Assist.Prof. I. Bineva, Ph.D., E. Zaharincheva, technologist; B. Stefanova, physicist

RESEARCH ACTIVITIES:

1. NANOSTRUCTURED THIN FILMS

Thin films of $\text{Zn}_x\text{Cd}_{1-x}\text{Se}$ with five different compositions $x = 0.39, 0.51, 0.59, 0.69, 0.8$ were deposited by simultaneous thermal vacuum evaporation of CdSe and ZnSe and by applying an original preparation technique. Atomic force microscopy measurements have shown that the films are nanocrystalline with a grain size ≤ 20 nm. Raman scattering results have confirmed the film's crystalline structure. The obtained results have proven that the new deposition approach used allows preparation of ternary $\text{Zn}_x\text{Cd}_{1-x}\text{Se}$ thin films with well controlled, desired composition.

The equivalent parallel conductivity of $\text{Al/n-Si/SiO}_x/\text{SiO}_2/\text{Al}$ structures ($x = 1.15$) containing crystalline or amorphous silicon nanoparticles has been measured as a function of the applied gate voltage. On the basis of the obtained curves, existence of defects situated very close to the c-Si/ SiO_x interface has been assumed. The structures with a-Si nanoparticles showed a lower defect density which has indicated to a better interface in these structures. In structures with $x = 1.15$ and $x = 1.3$ containing crystalline Si nanoparticles a counterclockwise hysteresis has been observed, which makes them suitable for memory devices. Significant differences have been registered in the behaviour of the structures with $x = 1.15$ and $x = 1.3$, that indicates a number of advantages from practical point of view for these with $x = 1.3$.

Electrical properties of glasses from a new chalcogenide system $(\text{GeSe}_2)_x(\text{Sb}_2\text{Se}_3)_y(\text{AgJ})_z$ have been studied. It has been ascertained that at applied fields of ≥ 1 V/cm the transport mechanism in all silver containing glasses, is percolation of silver ions. It has been shown that the conductivity of glasses increases with increasing the amount of AgJ. The increase followed a power law with an exponent which indicated a three-dimensional percolation of silver ions. The determined dark conductivity activation energies were independent of the atomic percentage of silver. Having in mind the supposed transport mechanism a conclusion has been made that the energy of activated diffusion of silver in these materials is in the range 0.33-0.46 eV. These activation energies are significantly lower than those reported by other authors and the difference has been explained assuming formation of nanosized AgJ regions.

2. DISORDERED MATERIALS - CHALCOGENIDE GLASSES AND THIN FILMS

It has been ascertained that strong photodarkening (PD) taking place in annealed thin films ($d < 1 \mu\text{m}$) from $\text{AsS}_3\text{-Ge}_2\text{S}_3$ can be fully restored after prolonged illumination by the same light source. The observed new light annealing effect has been explained by assuming a dual action of the light, which may provoke not only an increase of the network disorder during PD, but also a disorder decrease leading to photobleaching (PB). To confirm this supposition, changes of two typical parameters of disorder were studied: the Tauc slope $B^{1/2}$, which depends on the network bonding character, and the Urbach energy E_u , that is associated with tailing of the band edges. It has been found that $B^{1/2}$ decreases during PD and increases when PB is the dominating process. This observation is a direct evidence for the dual action of the light. Changes in the Urbach parameter E_u have also been found which are inversely proportional to the $B^{1/2}$ changes. These results are of use for the analysis of the structural changes in chalcogenides.

Compositional dependences of the optical properties of quaternary chalcogenide glasses from $\text{Ge}_x\text{Sb}_{40-x}\text{S}_{50}\text{Te}_{10}$ и $\text{Ge}_x\text{Sb}_{40-x}\text{S}_{55}\text{Te}_5$ ($x = 10, 20$, and 27) have been studied by spectroscopic ellipsometry in the 400-820 nm range. The optical constants (n , k , ε) and the optical band gap energy have been determined. The dispersion behavior of the refractive index n has been examined by applying the single-oscillator Wemple-DiDomenico's model and the oscillator energies E_0 and E_d have been determined.

Neutron and high-energy X-ray diffraction measurements were used to investigate the structure of $\text{As}_{40}\text{Se}_{60}$ and $\text{As}_{40}\text{Se}_{50}\text{Te}_{10}$ glasses. The traditional Fourier transformation technique and a reverse Monte Carlo (RMC) simulation of the experimental data were applied to model the 3-dimensional atomic configurations. From the analysis of the partial atomic correlation functions and structure factors of the first and second neighbour distances, coordination numbers and bond-angle distributions have been calculated.

The sensitivity to ammonia of as-deposited and illuminated Ge-As-S thin films has been investigated in the range 10 to 10000 ppm by using 16 MHz AT-cut quartz resonators. The films were deposited on both sides of the quartz crystal microbalance by vacuum thermal evaporation. It has been established that only the illuminated Ge-As-S films are sensitive to NH_3 . The sensitivity was appreciable at concentrations higher than 250 ppm. Time-frequency dependences were measured and both the rate of adsorption and desorption as well as the mass of the absorbed NH_3 have been determined.

Compositional dependences of low-temperature photoluminescence (LTPL) of heavily Er-doped $(\text{Ga}_2\text{S}_3)_x(\text{GeS}_2)_{100-x}$ ($x = 20, 25$ и 33) glasses were investigated. With decreasing temperature the PL efficiency has been enhanced considerably. A pronounced narrowing and consequent evolution of all the basic optical transitions of Er^{3+} ions has also been observed. The influence of Ga and Er contents on the up-conversion PL of Er-doped chalcogenide GeGaS-CsBr glasses has been specified, as well. The doping effect and the mechanism of Er^{3+} transitions for 1.5 μm LTPL at 20 K under 514.5 nm light excitation have also been studied. Basic radiative and spectroscopic parameters at optimal PL efficiency, in particular the role of excitation source and doping level on the stimulated emission cross-section, have been analyzed by Judd-Ofelt theory.

Sulfide $\text{Ge}_{25}\text{Ga}_{10}\text{S}_{65}$, $(\text{GeS}_2)_{80}(\text{Ga}_2\text{S}_3)_{20}$ and telluride $\text{Ge}_{20}\text{Se}_{80-x}\text{Te}_x$ ($x \leq 15$) glasses doped with Er, Pr and Ho were characterized by optical spectroscopy and LTPL. In the case of S-based samples, Er doping led to a decrease of the native defects in the glassy matrix, while re-absorption of intrinsic PL has been observed for the Te-containing ones.

Photo-induced effects in amorphous GeS_2 and $\text{Ge}_{39}\text{Ga}_2\text{S}_{59}$ thin films (150, 350 nm) were studied. Results from optical and Atomic Force Microscopy measurements have shown a photo-induced expansion of $\sim 4.8\%$ related to the decrease of the refractive index under illumination of as-deposited films. The introduction of Ga has led to less pronounced photo-

induced changes. The UV irradiation has resulted in photo-oxidation, which has been confirmed by AFM, IR and Raman spectroscopies.

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 SiO_x films deposited by r.f. sputtering", *J. Mat. Sci.:Materials in Electronics*, **21**, 481-485 (2010).
2. M. Curiel, I. Petrov, N. Nedev, D. Nesheva, M. Sardela, Y. Murata, B. Valdez, E. Manolov, I. Bineva, "Formation of Si nanocrystals in their SiO₂ films for memory device application", *Materials Science Forum: Special volume of AFM-NANOMAT*, **664**, 101-104 (2010).
3. E. Manolov, M. Curiel, N. Nedev, D. Nesheva, J. Terrazas, B. Valdez, R. Machorro, J. Soares, M. Sardela, "Influence of thermal annealing on the properties of sputtered Si rich silicon oxide films", *Solid State Phenomena*, **159**, 101-104 (2010).
4. M. A. Curiel, N. Nedev, D. Nesheva, J. Soares, R. Haasch, M. Sardela, B. Valdez1, B. Sankaran, E. Manolov, I. Bineva and I. Petrov, "Microstructural Characterization of Thin SiO_x Films Obtained by Physical Vapor Deposition", *Mat. Sci. Eng. B*, **174**, 132-136 (2010).
5. D. Nesheva, B. Stefanova, G. Vassilev, V. Vassilev, "Electrical characterization of GeSe₂-Sb₂Se₃-AgI glasses", *J. Optoelect. Adv. Mater.*, **12**, No 9, 1852-1856 (2010).
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7. N. Nedev, D. Nesheva, M. Curiel, E. Manolov, I. Petrov, B. Valdez and I. Bineva, "Electrical characterization of MOS structures with self-organized three-layer gate dielectric containing Si nanocrystals", *J. Phys.: Conf. Series*, **253**, 012034 (2010).
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15. J. Zavadil, P. Kostka, J. Pedlikova, Z.G. Ivanova, K. Zdansky, "Investigation of Ge based chalcogenide glasses doped with Er, Pr and Ho", *J. Non-Cryst. Solids*, **356**, 2355-2359 (2010).

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21. V Pamukchieva, A Szekeres, K Todorova, "Single-oscillator description of spectral dependence of the refractive index of new chalcogenide Ge-Sb-(S,Te) glasses", *J. Phys.: Conf. Series*, **253**, 012033(2010).
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23. D. Nesheva, Z. Levi, Z. Aneva, I. Miloushev, B. Pejova, „Optical Properties of $\text{Zn}_x\text{Cd}_{1-x}\text{Se}$ Single Layers Prepared by Thermal Vacuum Evaporation", *AIP Conf. Proc.* **1203**, pp. 358-363 (2010).
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TEXTBOOKS:

1. K.Kolentsov, "Achievements in the Applied Physics in BAS. Discoveries and Inventions of the Scientists from PI with ACEB and IPSS in the XX-th Century", *Academy Publishing House Prof. Marin Drinov*, Sofia (2010) 308 pages.

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, Youth and Sciences:

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 devices, Contract NNP-4-1.
2. Three-dimensional assemblies of semiconductor quantum dots: structure, optical, electrical and photoelectrical properties, Contract BM-1.
3. New amorphous and glassy materials based on Ge suitable for sensor applications, Contract D002-123.

Financed by FP7 of European Union:

1. Structure analysis of selenite glasses by means of neutron diffraction, MNI3 No. 226507.

COLLABORATION:

1. Investigation of Ge-chalcogenide glasses for optoelectronic use, Joint Laboratory of Solid State Chemistry, Pardubice, Czech Republic.
2. Optical and photoelectrical characterization of thin films and nanostructured layers based on ZnSe, Institute of Physics, Belgrade, Serbia.
3. Investigation of disordered materials based on Se-Te chalcogenide glasses by means of neutron diffraction and IR spectrophotometry, Research institute for Solid State Physics and optics, Hungary.
4. Investigation of optical and electrical properties of nanostructures chalcogenide semiconductors suitable for memory applications, Sankt Peterburg, Russia.
5. Gas sensitivity and photoinduced changes of multicomponent chalcogenide films, Institute of Applied Physics, Kishinev, Moldova.

DIVISION NANOPHYSICS

LABORATORY

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ASSOC. MEMBERS: 4

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Assoc. Prof. S. Simeonov, Ph.D.; Assoc. Prof. P. Danesh, Ph.D.; Prof. S. Kaschieva, D.Sc.;
Prof. S. Alexandrova, D.Sc.

RESEARCH ACTIVITIES:

1. CHARACTERIZATION OF NANOSTRUCTURED AlN FILMS

The structure and optical properties of AlN thin films, synthesized on single crystalline Si substrates by pulsed laser deposition (PLD) at 850°C varying the parameters of the KrF* excimer laser and the nitrogen pressure in the deposition chamber, have been studied. The PLD AlN films, deposited with short laser pulses (7.4 ns) and low laser fluence (3.7 J/cm²) show a weak dependence on N₂ pressure and they are polycrystalline with cubic phase crystallites. Increase of the pulse duration to 24 ns and the laser fluence to 10 J/cm² leads to the change of crystalline phase and to a strong dependence of the optical parameters on nitrogen pressure. The films deposited in vacuum have high quality polycrystalline structure with hexagonal phase. The ~ 35 nm large crystallites grow along the *c*-axis (perpendicular to the substrate surface) resulting in columnar and strongly textured structure. The AlN films, grown in nitrogen ambient are amorphous as determined via X-ray diffraction (XRD) and transmission electron microscopy (TEM) data analysis, but contain some amount of ~ 10 nm sized cubic crystallites, according to spectroscopic ellipsometry (SE) and TEM analysis, with a tendency to increase the amount of crystallites by increasing the nitrogen pressure during deposition. The optical parameters determined from the SE data analysis are in good agreement with the TEM and XRD observations.

2. DEFECTS IN IRRADIATED Si/SiO₂ STRUCTURES

The generation of defects by irradiation of MOS structures with 23 MeV electrons with different doses has been studied. Three different types of radiation-induced defects are observed as revealed by the analysis of the C-V and G-V characteristics. The interface traps that are located at the interface exhibit distinct energetic levels in Si bandgap. These defects are identified as donor type P_{b0} and P_{b1} centers, with concentrations depending on irradiation dose. The higher density of positive oxide charge, build-up due generation of E' centers for the lower dose is attributed to the higher interface density near the valence band edge. Bulk defect are also generated in the Si substrate which are ascribed to impurity-vacancy defect complexes.

The electroreflectance spectra of (100)Si substrates, hydrogenated by plasma immersion ion (PII) implantation with H⁺ ions with different fluences (10¹³ -10¹⁵ cm⁻²) and oxidized up to 10 nm SiO₂ thickness at considerably low Si oxidation temperatures (700 and

750°C), have been analyzed. It is established that hydrogenation through PII allows for a substantial increase of the oxidation rate up to the values typical for wet oxidation. The direct electron transition energies of Si are determined as their shift is related to the process induced stress in implanted Si that does not exceed 10^9 N/m². The slight increase of the phenomenological broadening parameters Γ (130 meV) as compared to the unimplanted Si is due to incomplete anneal of ionization induced defects. These results show a potential for growing high quality oxide for modern Si technology at considerably low Si oxidation temperatures.

A monograph on “Radiation Defects in Ion Implanted and/or High-energy Irradiated MOS Structures” by S. Kaschieva and S. N. Dmitriev has been published, in which are theoretically discussed ion implanted metal-oxide-semiconductor (MOS) structures with a thin semiconductor surface layer having high concentration of compensating defects. The basic theoretical conclusions are confirmed by the experimental results. Radiation defects induced by exposure of MOS structures with high energetic (MeV) electrons and by double treatments (implantation and irradiation) of MOS structures are discussed. Novel methods are demonstrated for annealing of radiation induced defects in MOS structures and for enhancement of radiation hardness of oxide-semiconductor structures through cyclic treatment (radiation/annealing) post-oxidation cooling and lowering uncontrollable impurities.

3. HYDROGENATED AMORHOUS SILICON

Plastic and elastic properties of thin a-Si:H films deposited by plasma enhanced CVD using 10% silane diluted in hydrogen have been studied. The influence of hydrogen on the mechanical properties is clarified. The effect of ion implantation on elastic modulus (E) and nanohardness (H) of a-Si:H is considered. The obtained E value (117 - 131 GPa) is smaller than that for crystalline silicon, while the H value (12.2 – 12.7 GPa) is comparable with that for crystalline silicon. It is established that ion implantation leads to reduction of both E and H values and flattening of the film surface. It is shown that the presence of hydrogen in the Si matrix does not affect the elastic modulus but leads to an increase of the material hardness. Hydrogen plasma treatment of a-Si:H films increases considerably the hardness in the surface region of the films. This result is of interest for practical application showing possibility for the mechanical hardness recovery of the silicon surface.

4. FORMATION AND CRYSTALLIZATION MECHANISM OF NANOPARTICLES

Theoretical investigation of three dimensional nanoparticles formation in amorphous media (gases and liquids) has been carried out. An equation, describing the change of the particles density with time has been derived. It is shown that at equilibrium conditions the density of the particles exponentially depends on their size and on the chemical potential μ , density of atoms in the system S_0 and temperature T . The size N_0 of the largest particles in the system has been determined. Correlation between the largest particle size and the size of the critical nucleus, initiating spontaneous crystallization has been established. The analysis of the dependences of the crystal growth rate on the initial super saturation and on the cooling rate reveals at least two mechanisms of crystallization, namely the normal growth mechanism and crystal growth through screw dislocations.

MONOGRAPH:

S. Kaschieva and S. N. Dmitriev, Monograph: Radiation Defects in Ion Implanted and/or High-energy Irradiated MOS Structures, Nova Science Publishers Inc, New York, 2010.

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8. S Alexandrova, A Szekeres, R Yu Holiney, L Matveeva, "Electroreflectance spectroscopy study of hydrogen plasma immersion ion implanted silicon with ultrathin oxide film", *J. Phys.: Conf. Series*, **253**, 012037 (2010). ISSN: 1742-6596.
9. V Pamukchieva, A Szekeres, K Todorova, "Single-oscillator description of spectral dependence of the refractive index of new chalcogenide Ge-Sb-(S,Te) glasses", *J. Phys.: Conf. Series*, **253**, 012033(2010). ISSN: 1742-6596.
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15. B. Pantchev, P. Danesh and J. Wiezorek, "Nanoindentation of hydrogenated amorphous silicon", *Philosophical Magazine*, **90**, 4027–4039 (2010). ISSN: 1478-6435.
16. B. Pantchev, P. Danesh, J. Wiezorek and B. Schmidt, "Nanoindentation-induced pile-up in hydrogenated amorphous silicon", *Journal of Physics: Conference Series*, **253**, 012054 (2010). ISSN: 1742-6596.

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20. E. Halova, S. Alexandrova, S.Kaschieva and S.N. Dmitriev, "Interface trap generation in MOS structures by high-energy electron irradiation", *Journal of Physics: Conference Series*, **253**, 012047 (2010). ISSN: 1742-6596.
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22. A. Szekeres, Zs. Fogarassy, P. Petrik, E. Vlaikova, A. Cziraki, S. Grigorescu, G. Socol, C. Ristoscu, I. N. Mihailescu, "Structural characterization of AlN films synthesized by pulsed laser deposition", *Appl. Surf. Sci.*, in press
23. N. Peev, "Addition to the Theory of Liquid Phase Epitaxial Growth. II. Crystallization Mechanisms", accepted for publication in the "Journal of Research in Physics" No.34 Vol.1., in press
24. P. Danesh, B. Pantchev, J.Wiezorek, B. Schmidt and D. Grambole, "Effect of hydrogen on hardness of amorphous silicon", *Appl Phys A.*, in press

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*

INTERNATIONAL COLLABORATION:

1. "Modification of ion implantation created defects in Si-SiO₂ structures with high energy electrons", ***with the Joint Institute for Nuclear Research, Dubna, Russia***
2. "Structure and properties of new materials and thin films for nano-technologies in optoelectronics", ***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. "Silicon oxide films with embedded silicon nanoinclusions for advanced opto- and nanoelectronics applications", ***with the Institute of Semiconductor Physics, NASU, Kyiv, Ukraine***
5. "Characterization of diluted magnetic semiconductor nanostructured thin films" ***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: 11

RESEARCH SCIENTISTS: 9

Prof. E. Atanasova, D.Sc.; Assoc.Prof. A. Paskaleva, Ph.D.; Assoc.Prof. S. Georgiev, Ph.D., Assoc.Prof. J. Koprinarova, Ph.D.; Assoc.Prof. N. Nedev, Ph.D.; Assoc. Prof. D. Spasov, Ph.D.; Res.Assist. M. Georgieva; Res.Assist. Ts.Ivanov; Res.Assist. E. Manolov; E. Gajdarzhieva, physicist; 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, 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.)

1. HIGH-K DIELECTRICS FOR NANO-ELECTRONICS

Measurements of the local electrical and nanohardness parameters of doped and mixed high-k dielectrics (Hf:Ta₂O₅; Al:Ta₂O₅; HfO₂:Ta₂O₅) for nanoscale dynamic memories applications are realized using conductive atomic force microscopy (C-AFM) technique. An approach for interpretation of the local current-voltage characteristics (analyzed area of ~10 nm²) considering the effects of both the type of dopant and the microwave treatment is presented. It is established that short time microwave treatment (seconds) could be used as a tool to control electrical degradation of ultrathin (~4 nm) high-k dielectrics. The results are prioritized for elucidation the mechanisms(s) of electrical degradation of high-k dielectrics at nanoscale.

Storage capacitor based on the lightly Al-doped Ta₂O₅ film (5-10 nm), stable under combined thermal and electrical stress is developed. The stack capacitor parameters guarantee its application as a memory element in nanoscale integrated circuits. The mechanisms of charge trapping/detrapping processes are studied, and the traps involved in the stress-induced leakage current are identified.

Summary of electrical and structural investigations on different families of high-k dielectric materials (ZrO₂-, Ta₂O₅-, HfO₂-based) is performed. An attempt is made to

differentiate the effects common for all high-k dielectric stacks and those typical of each individual material. A big diversity of conduction mechanisms are observed to operate depending on dielectric material. One and the same trap could mediate different conduction mechanisms in a given high-k dielectric depending on the specific stack parameters and measurements conditions. Despite of this diversity, the results strongly suggest that in most of the cases, irrespectively of the dielectric material, the conduction is realized through singly positively charged oxygen vacancies. By mixing or doping of high-k dielectrics it is possible to change the intrinsic trap parameters (e.g. their energy location), hence to control to some extent the electrical behavior of the structures.

An algorithm for interpretation of ellipsometric measurements of thin high-k dielectric stacks is developed. By this algorithm information on the change of high-k film composition in depth as well as on the composition and thickness of interfacial region at Si could be obtained.

2. THIN FILMS FOR MICROELECTRONIC APPLICATIONS

Microstructure and composition of control SiO_x ($x < 2$, $d_{\text{ox}} \sim 15$ nm) films as well as the changes caused by high temperature annealing at 700 or 1000 °C have been studied. The films have been obtained by two methods: r.f. magnetron sputtering and thermal evaporation. The results obtained by X-ray diffraction and Transmission Electron Microscopy (TEM) show that the as-deposited films are amorphous. In both cases the high temperature annealing does not change the amorphous character of the matrix but leads to a phase separation and formation of a pure silicon phase, amorphous at 700 °C and crystalline at 1000 °C in a stoichiometric SiO_2 . Using X-ray reflectivity the thicknesses of the as-deposited and annealed samples were measured. The obtained results are in excellent agreement with the ones set by the deposition conditions or determined using the cross-sectional TEM images.

The high frequency Capacitance-Voltage measurements of MOS structures with a-Si nanoparticles or Si nanocrystals in a SiO_2 layer show hysteresis when are scanned from positive to negative biases and in the reverse direction, which is due to charging and discharging of the nanoparticles from the crystalline Si substrates.

The obtained results show that the studied films are attractive for application in non-volatile memory devices because of the following advantages: higher density and reliability, higher operation speed and lower power consumption.

The electrical conductivity and the field effect in polymethylmetacrylate (PMMA) subjected to ion implantation with Si ions is investigated. A significant field effect is observed which makes this material very suitable for implementation in soft electronic devices. The biocompatibility and biosensitivity of the Si ion implanted PMMA are very promising for application in biomedical systems.

The reverse diode characteristics measured in dark have been investigated to assess the quality of large (1 m^2) photovoltaic solar panels and to obtain a high yield.

PUBLICATIONS:

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2. E. Atanassova, R. V. Konakova, V. F. Mitin, D. Spassov, "Trap parameters and conduction mechanisms in HfO_2 - Ta_2O_5 mixed stacks in response to microwave irradiation", *Microel. Engin.* 87, 2294-2300, (2010).

3. M. Tapajna, A. Paskaleva, E. Atanassova, E. Dobročka, K. Husekova, K. Fröhlich, "Gate oxide thickness dependence of the leakage current mechanism in Ru/Ta₂O₅/SiON/Si structures", *Semicond. Sci. Technol.* 25, 075007 (9pp) (2010).
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6. P. Dankov, P. Stefanov, V. Gueorguiev, Tz. Ivanov, „Hairpin-resonator probe design and measurement consideration”, *Journal of Physics: Conference Series*, 207 (1), 012015 (2010).
7. G. B. Hadjichristov, V. K. Gueorguiev, Tz. E. Ivanov, Y. G. Marinov, V. G. Ivanov and E. Fauques, „Electrical properties of PMMA ion-implanted with low-energy Si⁺ beam”, *Journal of Physics: Conference Series*, 207 (1), 012022 (2010).
8. E. Manolov, M. Curiel, N. Nedev, D. Nesheva, J. Terrazas, B. Valdez, R. Machorro, J. Soares, M. Sardela, Influence of thermal annealing on the properties of sputtered Si rich silicon oxide films, *Solid State Phenomena Vol. 159* (2010) pp 101-104,
9. M. A. Curiel, N. Nedev, D. Nesheva, J. Soares, R. Haasch, M. Sardela, B. Valdez, B. Sankaran, E. Manolov, I. Bineva and I. Petrov, Microstructural characterization of thin SiO_x films obtained by physical vapor deposition, *Materials Science & Engineering B*, Vol. 174, pp. 132-136 (2010),
10. J. M. Terrazas, N. Nedev, E. Manolov, B. Valdez, D. Nesheva, M. A. Curiel, R. Haasch and I. Petrov, Effect of oxygen to argon ratio on the properties of thin SiO_x films deposited by r.f. sputtering, *Journal of Materials Science: Materials in Electronics*, Vol. 21, No 5, pp. 481-485 (2010)
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12. N. Nedev, D. Nesheva, M. Curiel, E. Manolov, I. Petrov, B. Valdez and I. Bineva, Electrical characterization of MOS structures with self-organized three-layer gate dielectric containing Si nanocrystals, *Journal of Physics: Conference Series*, 253 012034 (2010)
13. A. Paskaleva, M. Lemberger, E. Atanassova, A. J. Bauer, „Traps and trapping phenomena in high-*k* capacitor stacks, 16th Workshop on Dielectrics in Microelectronics, WODIM'2010, Bratislava, Slovakia, 28-30 June, 2010, **invited lecture**.
14. E. Atanassova, D. Spassov, "High-*k* HfTaO stacks in response to microwave irradiation", 16th Intern. School on Condensed Matter Phys., ISCMP'2010, Varna; J. Phys.: Conf. Series 253 (2010) 012038.
15. E. Atanassova, A. Paskaleva, D. Spassov, "Doping of Ta₂O₅ as a way to extend its potential for DRAM applications", *Proc. 27th Intern. Conf. on Microel. (MIEL'2010)*, Nish, Serbia, 16-17 May, IEEE El. Dev. Soc., 427-434 (2010), **invited lecture**.
16. I. Manić, E. Atanassova, N. Stojadinović, D. Spassov, "Effects of constant voltage stress in Hf-doped Ta₂O₅ stacks", *Proc. 27th Intern. Conf. on Microel. (MIEL'2010)*, Nish, Serbia, 16-17 May, IEEE El. Dev. Soc., 483-486 (2010).
17. A. Skeparovski, N. Novkovski, D. Spassov, E. Atanassova, V. Lazarov, "Properties of Al-doped Ta₂O₅ based MIS capacitors for DRAM applications", *Proc. 27th Intern. Conf. on Microel. (MIEL'2010)*, Nish, Serbia, 16-17 May, IEEE El. Dev. Soc., 455-458 (2010).

18. I. Manić, E. Atanassova, N. Stojadinović, D. Spassov, “Constant voltage stress in Hf-doped Ta₂O₅”, Proc. 54th ETRAN Conf., Donji Milanovac, 7-10 June 2010, Serbia, 1.2-1.4 (2010).

ONGOING RESEARCH PROJECTS

Physics and technology of thin films for application in micro- and nanoelectronics
(supported by Bulgarian Academy of Sciences)

Trapping phenomena and their implication on long-term reliability of nano-scale metal gate/high-k dielectric-based devices (supported by National Science Fund).

COLLABORATION:

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

DIVISION MICRO- AND ACOUSTOELECTRONICS

LABORATORY

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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; Prof. I. Avramov, Ph.D., D.Sc.; Assoc.Prof. E. Radeva, Ph.D.; J. Lazarov PhD, engineer; Ts. Yordanov, researcher; M. Atanasov, researcher; V. Gadjanova, researcher; Z. Raicheva, chemist; L. Vergov, engineer; P. Angelova, physicist; Karekin Dikran Esmerian, physicist, PhD student; S. Staikov, technician; I. Mitev, technician

RESEARCH ACTIVITIES:

In 2010 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:

- Theoretical analysis, designing and investigation of quartz resonators.
- Mass sensitive quartz sensors - preparation, investigation and application.
- 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.

- THEORETICAL ANALYSIS, DESIGNING AND INVESTIGATION OF QUARTZ RESONATORS

The investigations on the internal laboratory project N VK 9-7 namely “Quartz strip mass-sensitive resonator” were finished. The motional parameters and amplitude-frequency characteristics of the produced experimental series were measured. The results show that 12.5 % of the samples have motional resistance between 15 and 50 Ω while others - between 50 and 100 Ω . The miniaturized quartz strip resonators can be investigated as quartz microbalance with high mass-sensitivity. The results are presented on 11th International Balkan Workshop on Applied Physics, 2010, Constanta, Romania.

- PIEZOELECTRIC MICROSENSORS USED AT CRYOGENIC TEMPERATURES

The research activity was development and production of novel piezoelectric multifunctional temperature sensor for “Nuclotron” in JINR – Dubna. A working set of sensor element, generator and interface for process control was made. The results obtained were estimated by the Russian team and the contract was extended until 2014. The working program for 2011-2012 was planed and coordinated.

- MASS – SENSITIVE QUARTZ RESONATORS

“Design and fabrication of sensor elements used in the quartz microbalance (QCM)”. The quartz resonators (260 pcs.) have been designed and produced. The influence of

different quartz roughness obtained by mechanical treatment on resonator parameters has been investigated. The change of the resonator's characteristics depending on the nanometric size of the quartz surface was investigated by measuring QCM dynamic parameters and sorption properties. The increase in quartz plate's roughness resulted in deterioration of resonators' parameters. Nevertheless, quartz resonators treated with SiC abrasive (grain size of 14 μm and 20 μm) and covered with WO_3 showed increased capability of NH_3 sorption. The comparison between the polished and roughened surfaces (20 μm grain size SiC) showed an 250 fold increase of the nanosized surface of quartz resonators, resulting in 3 times higher sorption ability. The obtained results showed that with increasing the resonator' surface roughness, the piezoelectric resonator characteristics were change within acceptable limits, while the sensor sensitivity was improved.

The analysis of structural parameters and technological regimes of the quartz resonators with increased roughness, obtained by chemical treatment, indicated difference of 0.63 nm for the samples etched at 70 $^{\circ}\text{C}$ and 75 $^{\circ}\text{C}$. The measured sensitivity raised 6, 9 and 7.5 times for NH_3 concentrations of 100, 250 and 500 ppm respectively when 200 nm thick MoO_3 layer was used. Varying the etching temperatures from 75 $^{\circ}\text{C}$ to 90 $^{\circ}\text{C}$, the roughness grew up with 0.33 nm and the sensor sensitivity was changed from 1 to 1.5 times, respectively. The greatest crystals were defined at etching temperatures of 70 $^{\circ}\text{C}$, leading to stronger NH_3 sorption. The spectral characteristics of the samples showed only a small attenuation of the basic mode, which ensure their sustainable operation in the generator circuit.

"Study of sorption properties of thin layers using the quartz microbalance (QCM)"
The results of the experiments for different systems of a thin sensitive layer - QCM can be summarized as follows:

- *The system LPD TiO_2 - QCM:* The TiO_2 layers were obtained by the LPD method. Some of them were doped with silver. The growth of doped layers was confirmed by XPS analysis. The influence of Ag on the sorption properties of TiO_2 was evaluated by the QCM method through comparing the two types of layers. The measured response of both systems to NH_3 gas sorption showed that Ag- TiO_2 layers were more sensitive and they reacted faster throughout the whole range of NH_3 concentrations. LPD TiO_2 /QCM and LPD Ag- TiO_2 /QCM structures can be used as a sensor element with different sensitivity for detection of NH_3 in the range of 10 - 1000 ppm.
- *The system Ge-As-S - QCM:* The chalcogenide layers were evaporated from $\text{Ge}_{32}\text{As}_5\text{S}_{63}$ glass. They possess sensitivity after illumination and are suitable for measuring NH_3 concentrations above 250 ppm. The sorption process is reversible. The Ge-As-S/QCM system is stable; its parameters do not change with time, which make it suitable for repeated measurements.
- *The system Sn_xNi_y - QCM:* SEM images of Sn_xNi_y layers obtained by electrochemical deposition showed dendrite structure. XRD analysis identified mixed crystalline phases (Sn_2Ni_3 , SnNi_3 and Sn) in the powdered samples, and XPS analysis of Sn_xNi_y on QCM demonstrated a stoichiometry close to that of SnNi . In studying Sn_xNi_y sorption capacity two types of sorption and desorption mechanisms were registered : one – stage (10 – 100 ppm NH_3) and a two - stage (250 – 1000 ppm NH_3). The sorption process was reversible. A change of frequency from 5 Hz to 77 Hz was measured and the sorbed mass from 1.13 ng to 17.33 ng for the whole NH_3 range is calculated. The results obtained indicate that the system Sn_xNi_y - QCM is suitable for NH_3 detection in the investigated range.
- *The System WO_3 - QCM:* The impact of surface roughness of the quartz plate on the dynamic parameters of the resonator structures, the mechanism of sorption and desorption processes, the sensitivity of the system WO_3 – QCM and the capability of mass-loading was studied. It has been found that depending on the application of the thin film - QCM structure can make a choice among keeping the dynamic resonator' parameters, sensitivity and sorption capacity with increasing the effective quartz surface.

As results of investigations seven papers were published in 2010 and two papers are presented on international conference.

– SYNTHESSES AND STUDY OF PLASMA POLYMERS, OBTAINED FROM HEXAMETHYLDISILOXANE

In order to to design optimal biocompatible surface for tissue engineering the controlled modification of plasma polymerized hexamethyldisiloxane (PPHMDS) was achieved.

- Ammonia plasma treatment in order to increase surface wettability and the corresponding biological response was carried out. The physico-chemical properties of the polymer films were characterized by contact angle (CA) measurements and FTIR analysis. Human umbilical vein endothelial cells were used as model system for the initial biocompatibility studies following their behaviour upon pre-adsorption of polymer films with three adhesive proteins. The results obtained suggested that ammonia plasma treatment can modulate the biological activity of the adsorbed proteins on PPHMDS surfaces and thus to influence the interaction with endothelial cells.

- Novel composites have been produced using modified DND (Ag-DND, and Si-DND) nanoparticles as fillers in PPHMDS layers. FTIR spectroscopy was performed in order to determine if the DND nanofiller can modify the chemical composition and structure of the polymer matrix. The kinetic of CA of composite surfaces as a function of the as-used nanofiller DND's in polymer matrix was measured. By incubation of MG-63 osteoblast-like cells on the surface of DND (Ag-DND and Si-DND) - PPHMDS composite, the influence of the fillers on the adhesion behaviour of the cells were tested. It was shown that by varying the DND filler, the property of hydrophobic PPHMDS films can be modified. The study with cells demonstrates that via appropriate material design it is possible to generate surfaces allowing considerably better cell attachment. The results suggest the potential of using ammonia treated and DND-based polymer composites for application in engineering implantable scaffolds and devices.

PPHMDSs on film plate acoustic resonators (FPAR) using Lamb waves were synthesized. The deposition parameters and the film thickness were optimized for polymer application in gas sensors.

The seven segment electroluminescent display having protective layer of PPHMDS, with improved characteristics for application in elevators, were prepared and presented at national conference.

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

A novel voltage controlled microwave oscillator (VCMO) with 3% tuning bandwidth, using dielectrically stacked bulk acoustic wave resonator (DSBAR) filters has been successfully demonstrated and tested. These filters are extremely small ($150 \times 150 \mu\text{m}^2$), have an insertion loss below 1 dB and, compared to their surface acoustic wave (SAW) counterparts, can dissipate orders of magnitude higher radio frequency (RF) power levels. Moreover, they can be cascaded without additional matching and retain their filter characteristics while the phase slope and loaded Q ingreases proportionally to the number of cascaded filter elements. Thus oscillator phase noise can be minimized for the desired tuning bandwidth. Laboratory VCMO prototypes at 1,55 GHz demonstrate 45 MHz tuning bandwidth with -83 dBc/Hz phase noise suppression at 1 KHz carrier offset frequency and thermal noise floor levels below -180 dBc/Hz. It is believed that DSBAR stabilized miniature tunable oscillators can be very competitive in future generations multiple-channel communication systems in which

small size, low power consumption, high efficiency and low phase noise are of major importance.

Film plate acoustic resonators (FPAR) using the Lamb wave mode have been coated with thickness optimized polymer films for gas sensor applications. This type of acoustic devices use thin aluminium nitride (AlN) membranes on a silicon (Si) and are compatible with current semiconductor integrated circuit (IC) technology. We believe that they may be very attractive for future gas sensing systems fully integrated on the Si chip.

PUBLICATIONS:

1. Z. Raicheva, V. Georgieva, L. Spassov, V. Gadjanova, L. Vergov, Ts. Angelov, M. Atanasov, Y. Lazarov, The Influence of Quartz Resonator Design and Thin Metaloxide Layers on QCM Parameters, Solid State Phenomena, Vol. 159, 129-132(2010).
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3. A.Grechnikov, V.B.Georgieva, S.S.Alimpiev, A.S.Borodkov, S.M.Nikiforov, Ya.O. Simakovsky, D.Dimova-Malinovska, O.I. Angelov, Investigation of thin ZnO layers in view of laser desorption-ionization Journal of Physics: Conference Series 223 (2010) 012038.
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5. V. Georgieva, Tz. Yordanov, V. Pamukchieva, D. Arsova, V. Gadjanova, L. Vergov, Gas Sensing Properties of Ge-As-S Thin Films, AIP Conf. Proc. vol.1203, pp.1079-1084 (2010).
6. V. Georgieva, P. Stefchev, P. Stefanov, R. Kirilov, C. Dikov, V. Gadjanova, M. Atanasov, Detection of NH_3 by quartz crystal microbalance with Sn_xNi_y coating, Journal of Optoelectronics and Advanced Materials, vol.12, iss.9-2010,pp. 1957-1961 (2010).
7. V. Georgieva, Z. Raicheva, A. Grechnikov, V. Gadjanova, M. Atanasov, J. Lazarov, E. Manolov, Quartz roughness affect on WO_3 coated QCM, Journal of Physics: Conference Series 253, 012046, pp.1-6 (2010).
8. S. Bojadzhiev, V.Georgieva, M.Rassovska, Characterization of Reactive Sputtered TiO_2 Thin Films for Gas Sensing Application, Journal of Physics: Conference Series 253, 012040 pp. 1-6 (2010).
9. V. Safonov, A. Zykova, J. Smolik, R. Rogovska, N. Donkov, V. Georgieva, The Surface Parameters Modifications at Nanoscale for Biomedical Applications, Journal of Physics: Conference Series 253, 012068 pp. 1- 4 (2010).
10. E. Radeva, L. Pramatarova, E. Pecheva, T. Hikov, E. Iacob, L. Vanzetti, R. Dimitrova, N. Krasteva, T. Spassov, D. Fingarova, Study of organosilicon plasma polymer used in composite layers with biomedical application, AIP Conf. Proc. 1203, 949-954 (2010).
11. N. Krasteva, K. Hristova, E. Radeva, E. Pecheva, R. Dimitrova and L. Pramatarova, Effect of Ammonia plasma treatment on the biological performance of plasma polymerized hexamethyldisiloxane, AIP Conf. Proc. 1203, 688-693 (2010).
12. L. Pramatarova, N. Krasteva, E. Radeva, E. Pecheva, R. Dimitrova, T. Hikov, D. Mitev, K. Hristova, G. Altankov, Study of detonation nanodiamond – plasma polymerized hexamethyldisiloxane composites for medical application”, JOP: Conference Series 253, 012078 (2010).
13. N. Krasteva, G. Toromanov, K. Hristova, E. Radeva, E. Pecheva, R. Dimitrova, G. Altankov, L. Pramatarova, Initial biocompatibility study of plasma polimerized hexamethyl-disiloxane films with different wettability, JOP:ConferenceSeries 253, 012079 (2010).

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15. I. D. 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, Sept. 20-23, 2009, Rome, Italy, pp. 855-858 (излязла от печат през 2010 г.)
16. I. Avramov, S. Gilbert, R. Ruby, "1.5 GHz Voltage Controlled Oscillator with 3% Tuning Bandwidth Using a Two-pole DSBAR Filter", 2010 International Frequency Control Symposium Proceedings, pp. 618 – 623.
17. K. Kolentsov, L. Yourukova, and E. Radeva, Preparation, characteristics and application of digital seven-segment electroluminescent display, In: Proc. of National Conference with International Participation " Electronics ' 2010 ", House of the Science and the Technics, Sofia, 28 May 2010, Sofia (in Bulgarian).

RESEARCH PROJECTS:

1. Project financed by Bulgarian Academy of Sciences

- 1.1 Quartz strip mass sensitive resonator
- 1.2 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 Nanostructured coatings – new biomaterials for bone implants obtained by interaction lazer - 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

COLLABORATION:

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

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TOTAL STAFF: 13

RESEARCH SCIENTISTS: 12

Prof. N. Tonchev, Ph.D., D.Sc.; Prof. V. Kovachev, Ph.D., D.Sc.; Assoc. Prof. E. Vlahov, Ph.D.; Assoc. Prof. N. Balchev, Ph.D.; Assoc. Prof. J. Georgiev, Ph.D.; Assoc. Prof. A. Stoianova-Ivanova, Ph.D.; Assist. Prof. A. Zahariev, Ph.D.; Assoc. Prof. K. Kalaydjiev, Ph.D.; Assist. Prof. K. Lovchinov; Assist. Prof. S. Terzieva; Assist. Prof. K. Nenkov; G. Mihova, chemist; Ph.D. student K. Buchkov

RESEARCH ACTIVITIES:

A method for studying finite-size scaling effects in systems with short-range and/or long range interactions, including systems with strong anisotropy as well has been presented.

The nonuniversal critical behavior in the vicinity of a quantum critical point of a model system describing structural phase transition has been studied.

(B, T) phase diagram of HTS is considerably complicated when compared with classical superconductors and consist many different phases. Vortex-glass - vortex -liquid phase transition is especially important from the practical point of view as it is connected with the appearance of AC losses in the material. The influence of Ca substitution (in the YBCO system) on this phase transition and irreversibility line was investigated by using the method of higher harmonics of AC magnetic susceptibility. It is found that small amount of Ca (2.5%) keeps the critical temperature close to 90 K and the irreversibility field at nitrogen temperature is 6.9 T which is almost 2 T higher than that for no substituted YBCO.

For the purpose of practical application AC losses in ROEBEL cables assembled from YBCO coated tapes are measured. Investigations are carried out in transverse magnetic field and transport current through the cable. It is found good distribution of the current between the strands in the cable and reduction of the losses due to the magnetization when the cable thickness increases.

Superconducting composite materials comprising ferromagnetic nanoparticles have been synthesized. SEM, EDHA and XRD characterization techniques have been employed to investigate structure, phase formation and obtaining of new original composites containing superconducting phases of Bi-Pb-Sr-Ca-Cu-O system and additives of $\text{La}_{0.6}\text{Pb}_{0.4}\text{MnO}_3$ nano-powder. Perspective for practical application composites have been proposed by using new technological schemes and optimizing superconducting phase / ferromagnetic phase ratio.

We synthesized for the first time samples with nominal compositions $\text{MoSn}_x\text{Sr}_2\text{YCu}_2\text{O}_{8-\delta}$ ($0 \leq x \leq 0.075$) and investigated their superconducting and magnetotransport properties. It was established that the optimum Sn-doping ($x=0.02$ and 0.03) increases the T_c of the undoped $\text{MoSr}_2\text{YCu}_2\text{O}_{8-\delta}$. The upper critical fields of the samples were determined using magnetization, susceptibility and resistivity measurements. It was established that the Sn-doping weakly affects the first and the intragrain second critical field of Mo-1212 but enhances the extrapolated to $T=0$ (i.e. the intergrain) upper critical field. The temperature dependence of the real part of the susceptibility of Mo-1212 was described for the first time

by the proposed phenomenological relation: $\chi'(T) = \chi_1 + \chi_2 \tanh(T/T_0 + A)$, where the parameters χ_1 , χ_2 , T_0 and A are dependent on the magnetic field. It was suggested that χ_1 and χ_2 represent the values of the superconducting and magnetic component of the real part of the susceptibility at $T=0$.

Structural and transport (electro-resistivity and thermoelectric power) properties of $\text{NdBaCo}_2\text{O}_{5+x}$ ($0.50 < x < 0.75$) ceramics have been investigated. New experimental data concerning magnetic properties have been obtained in the temperature range 280 K – 400 K. Metal-Insulator transition as well as spin state transition have been registered at $T = 346$ K. Thin films of $\text{NdBaCo}_2\text{O}_{5+x}$ have been deposited by magnetron sputtering on single crystal substrate SAT-CAT-LA(100) and $\text{SrTiO}_3(100)$. For the first time 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 systematic analysis of magneto-transport properties of “hole” doped cobaltites $\text{NdBaCo}_2\text{O}_{5+x}$ ($x = 0.52$; $x=0.56$ and $x=0.72$) has been carried out at low temperature and in strong magnetic field up to 47 T. The technological regime for deposition of thin and ultra-thin $\text{NdBaCo}_2\text{O}_{5+x}$ cobaltite films is optimized using magnetron sputtering and *ex-situ* adjustment of the oxygen stoichiometry.

PUBLICATIONS:

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2. E.S. Pisanova, N.S. Tonchev and Hr.T. Kisov, Some Applications of the Lambert W-function to Critical Phenomena, Proceedings of 7th BPU General Conference, Alexandroupolis, Greece, 9-13 Sept 2009, ISBN 9780735407404
3. N. Tonchev, E. Pisanova, 2010 *J. Phys.: Conf. Ser.* 253 012073, Volume 253, Number 1, doi: 10.1088/1742-6596/253/1/012073
4. N. Balchev, K. Nenkov, G. Mihova, J. Pirov, B. Kunev, “Superconducting Properties of Ca-doped $\text{MoSr}_2\text{YCu}_2\text{O}_{8-\delta}$ ”, *Physica C* 470, p.178-182 (2010); ISSN: 0921-4534; IF=0.723
5. N. Balchev, K. Nenkov, V. Antonov, J. Pirov, B. Kunev, “Superconductivity and critical fields in undoped and Sn-doped $\text{MoSr}_2\text{YCu}_2\text{O}_{8-\delta}$ ”, *Physica C* 470, p.2040-2046 (2010); ISSN: 0921-4534; IF=0.723
6. E. Nazarova, A. Zaleski, A. Zahariev, “Doping dependence of irreversibility line in $\text{Y}_{1-x}\text{Ca}_x\text{Ba}_2\text{Cu}_3\text{O}_{7-\delta}$ ”, *Physica C* 470, (2010) 421-427; ISSN: 0921-4534; IF=0.723
7. S. Terzieva, M. Vojenčiak, E. Pardo, F. Grilli, A. Drechsler, A. Kling, A. Kudymow, F. Gömöry and W. Goldacker, “Transport and magnetization ac losses of ROEBEL assembled coated conductor cables: measurements and calculations”, *Supercond. Sci. Technol.* **23** 014023 (2010); ISSN 0953-2048; IF=2.694
8. Rozina Yordanova, Donka Angelova, Zoya Mitreva, Angelina Stoyanova –Ivanova, V. Mikli, “Rotating- bending fatigue in a low-carbon steel”, *Integritet i vek konstrukcija structural integrity and life*, Vol. 10, №2, 89-94; ISSN 1451-3749
9. D. Todorov, M. V. Abrashev, V.G. Ivanov and E. Vlahov, Optical phonons of $\text{NdBaCo}_2\text{O}_{5+x}$: lattice dynamics calculations, AIP Conf. Proc.1203 (2010) pp. 1003-1006. 7th International Conference of the Balkan Physical Union; doi:10.1063/1.3322298.
10. A. Zahariev, E. Nazarova, K. Nenkov, T. Mydlarz and V. Kovachev, Intragranular Critical Current Density in YBCO Substituted with Pr or/and Ca, AIP Proc. of 7BPU Conference, pp 367-372, Alexandroupolis, Greece, ISBN 9780735407404

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16. L. Dimova, G.N. Kirov, A. Stoyanova-Ivanova and V. Mikli, "EDS and XRD study of ZnCl₂ occluded clinoptilolite", Zeolite 2010 – 8th International Conference of the Occurrence, Properties, and Utilization of Natural Zeolites, Sofia, Bulgaria, 10–18 July 2010, 82-83.
17. L. Dimova, O. Petrov, N. Lihareva, A. Stoyanova-Ivanova and V. Mikli, "Preparation and characterization of Ag-exchanged clinoptilolite", Zeolite 2010 – 8th International Conference of the Occurrence, Properties, and Utilization of Natural Zeolites, Sofia, Bulgaria, 10–18 July 2010, pp 84-85.

TEACHING ACTIVITIES:

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

ONGOING RESEARCH PROJECTS:

- I. Projects financed by Bulgarian Academy of Sciences
 1. New materials and multifunctional magnetic 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**

INTERNATIONAL COLLABORATION:

1. Obtaining and investigation of thin film structures of magnetic oxides (manganites and cobaltites), Institute of Physics, Polish Academy of Sciences, Warsaw, Poland
2. Synthesis and structure investigation of multifunctional materials, Center for Materials Research, Tallin Technical University, Tallin, Estonia
3. International Laboratory for High Magnetic Fields and Low Temperatures – Wroclaw, Poland.

DIVISION LOW TEMPERATURE PHYSICS



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RESEARCH SCIENTIST: 4

Assoc. Prof. P. Simeonova PhD; Assist. Prof. I. Radulov PhD; Dimitar Petrov PhD student;
Petja Papazova PhD student

RESEARCH ACTIVITIES:

In 2010 the Laboratory of Environmental Physics concentrated its activities in completing the tasks and goals of the project “Improvement of the life quality by the use of sustainable management of surface waters – application to the catchments of the rivers Struma and Mesta” (DO-02-352) granted by the National Science Fund.

The results obtained could be summarized as follows:

1. A software package was prepared to calculate the long-term trends in all physicochemical parameters for the water quality of the rivers Struma and Mesta;
2. Original integral indices for pollution and for climate impact were created;
3. A software package to determine the geographic coordinates of each monitoring station along the River Struma flow was prepared;
4. Analysis of monitoring data from River Struma flow was performed using neuron nets (self-organizing maps of Kohonen) and the original approach (Hasse diagrams) for ranking the factors impacting the water quality;
5. Environmetric analysis of another type of surface water monitoring data (high mountain lakes from Pirin Mountain) has been carried out in order to check the adequacy of the original strategy for assessment (and management) of surface water quality;
6. In a very original and specific study performed in cooperation with Polish colleagues from Gdansk University of Technology our original strategy for assessment and modeling of surface water quality has been successfully applied.

Except for the activity with Project DO-02-352 the members of the Laboratory worked on other projects funded by BAS and EBR. The most important results could be presented as follows:

- For the first time classification and modeling of different-sized aerosol particles (0.01 – 30 μm) was performed in order to clarify the nanoparticles impact on atmospheric pollution;
- A methods for spectrophotometric determination of silver in photographic waste solutions was created;
- Nanocrystal samples of RAlO_3 (R = Nd, Sm, Eu, Dy, Gd) using the modified method of Pechini were prepared. Using the system Physical Property Measurement System (PPMS-9 QD) the temperature and field dependence as well as the magnetization of the nanostructured aluminates obtained were measured. The results were compared with similar data from bulk monocrystal samples of the same aluminates.

- In cooperation with colleagues from University of Sofia an environmetric modeling of monitoring data from high-mountain lakes (Rila and Pirin Mountain) was performed in order to assess the water quality depending on temporal and spatial parameters.
- Using environmetric modeling the impact of different pollutants on three type of forest systems located in mountainous and coastal regions was assessed.
- A vibrational magnetometer to measure magnetic moments of strong magnetic systems within the temperature interval 77 – 550 K and magnetic fields of 0 to 1.5 Tesla was constructed. The apparatus created was applied for measurement of the magnetic moments of a series of Bulgarian coins. The practical aspect of the measurements was initiated by the Bulgarian National Bank.
- Using an original method for synthesis of superconducting iron oxide with cyclodextrin layer a study has been performed indicating the role of the contrast agent and the medium for hypothermic treatment.
- Classification (self-organizing maps of Kohonen approach) of a group of patients suffering from diabetes type 2 as well as of the clinical parameters characterizing the disease was performed aiming an optimization of the clinical analysis of this type of patients.

The successful cooperation with L'Universite de Liege, Department Physique, Group SUPRA.TECS, Liege, Belgium on a joint project entitled: "Thermal and magnetic properties of HT superconducting and related magnetic materials" within the frame of a treaty for interacademic cooperation /EBR/ continues. In 2010 the Laboratory of Environmental Physics presented three communications related to the project topic during the International School of the Condensed Matter Physics in Varna. Prof. Ph. Vanderbemden presented a plenary lecture in co-authorship with Dr. V. Lovchinov.

With the active participation of all members of the Laboratory a series of measurements using the unique apparatus for physical measurements PPMS for local and external clients were performed. By the use of the same system one of the PhD students of the Laboratory made the required measurements of materials and structures for the experimental part of his dissertation. We would like to proudly announce that in 2010 another PhD candidate won the competition and was attributed to the members list of the Laboratory meaning that the PhD students of the Laboratory are already two.

All members of the Laboratory participated at 4 conferences in Bulgaria and abroad with oral communications and posters.

PUBLICATIONS:

1. V. Simeonov, P. Simeonova, S. Tsakovski and Vasil Lovchinov. Lake Water Quality Assessment by Multivariate Statistics. *Journal of Water Resources and Protection*- (2010), 2 354-362. ISSN: 1945-3094.
2. Pavlina Simeonova, Danail Simeonov, Lyubomir Spasov, Vasil Simeonov, Vasil Lovchinov. Environmetric Assessment of Pollutant Concentrations Effects on Forest Ecosystems. *Asian Chemistry Letters*. (2010). ISSN: 0971-9822.
3. Aleksander Astel, Marian Nikolov, Vladimir Christov, Pavlina Simeonova, Vasil Simeonov. Chemometric Assessment of Clinical Data for Diabetes Mellitus 2 Type Patients Using Self-Organizing Maps. *Journal of Environmental Science and Health, Part A* vol. 45, No. 5, (2010), 560-568. ISSN: 1093-4529.

4. Vasil Lovchinov, Pavlina Simeonova, Ilia Radulov, Ivan Nedkov, Rumen Kalionski. Some Medical Application of Nanomaterials. *Solid State Phenomena* vol. 159 (2010) 185-188. ISSN: 1012-0394.
5. Pavlina Simeonova, Vasil Lovchinov, Dimitar Dimitrov, Ilia Radulov. Environmetric approaches for lake pollution assessment. *Environ. Monit. Assess.* (2010) 164, 233-248. ISSN: 0167-6369.
6. Marian Nikolov, Pavlina Simeonova and Vanio Mitev Spectrophotometric determination of silver with brilliant green and its application in photographic fixing solutions. *Ecological Chemistry and engineering A*, vol.16. N (2010) ISSN: 6188.
7. V Lovchinov, D Petrov, P Simeonova and B Angelov. Magnetic properties of some rare-earth nanostructured aluminates 2010 *J. Phys.: Conf. Ser.* 253 012073, Volume 253, Number 1, doi: 10.1088/1742-6596/253/1/012073 ISSN: 1742-6596.
8. P Vanderbemden, B Rivas-Murias, V Lovchinov and B Vertruyen. Measurement of dielectric properties at low temperatures: application to the study of magnetoresistive manganite/ insulating oxide bulk composites 2010 *J. Phys.: Conf. Ser.* 253 012006, Volume 253, Number 1 ,doi: 10.1088/1742-6596/253/1/012006 ISSN: 1742-6596.
9. I. Radulov, L. Spalek and Z. Viskadourakis. A miniature capacitance dilatometer for magnetostriction and thermal expansion measurements. *J.of Physics* (2010) DOI: 10.1088/1742-6596/253/1/012072. ISSN: 1742-6596.
10. K. Kalaydzhiev, V. Lovchinov, D. Dimitrov, Ch. Popov. Vibration magnetometer research in wide range temperatures and magnetic field. 10-th International Scientific Conference VSU' 2010. vol.1, I - 116-119. ISSN: 1314-071X.

ONGOING RESEARCH PROJECTS:

1. Improving of life quality by sustainable management of surface waters – application for the catchments of the rivers Struma and Mesta - № DO - 02-352.(2010).
2. “Thermal and magnetic properties of HT superconducting and related magnetic materials” -Liege, Belgium. L’Universite de Liege, Depart. Physique, Group SUPRA.TECS.
3. Internal project of ISSP-BAS for financing of fundamental and applied research entitles: “Computarization of vibrational magnetometer and creation of a system for measuring of the magnetic moment of Bulgarian coins (№ RD 09-43).

INTERNATION COLABORATION:

1. Universite de Liege, Belgium - L’Universite de Liege, Depart. Physique, Group SUPRA.TECS.
2. 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: 21

RESEARCH SCIENTISTS: 20

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

RESEARCH ACTIVITIES:

I. PHOTONICS

- OPTICS AND SPECTROSCOPY OF WAVEGUIDES

The phase composition of proton-exchanged layers in Y-cut lithium niobate was studied by a combination of spectroscopic methods. Mode spectra were used for the determination of phases. Vibration spectra allow some comparative and semi-quantitative estimates of the thickness of phase sub-layers to be done.

A correlation between stress and the level of doping (respectively, between stress and the phase composition of the measured layer) was obtained. Proton-exchanged waveguide layers in X, Y and Z-cut LiNbO₃ were produced at different technological conditions. These layers were studied by spectroscopic methods for analyzing their phase composition and by the optical integral method for stress measurements. The intrinsic stress which contributes to the better characterization of such optical waveguides was calculated. An attempt to indicate stress correlation to the relative quota of the different phases in the proton-exchanged layer was made.

A review was published on the contributions of the integral optics group at ISSP BAS to the development of the proton exchange technology designed for production of optical waveguides in lithium niobate and lithium tantalite: new protonating sources, new technological steps, new methods for investigation of the phase composition of the waveguiding films, basically new optic modulators, etc. Another review covers the main integral-optic elements and devices, developed in our integral optics group so far, with an emphasis on their novelty, advantages and drawbacks, as well as the solution of specific problems of their fabrication. One more review paper was written on the technologies for fabrication of optical waveguides in LiNbO₃ и LiTaO₃.

We have described in a chapter from a book the applications of the transverse acousto-electrical effect and the surface photocharge effect for quality control of a number of production parameters in a wide technological range, as well as the novel developments of methods and sensors, based on these two effects.

We have published a bibliography and library-metrical analysis of the publications of lecturing mathematicians at Sofia University, that have been summarized by renowned refereeing journals for the period 1904-1939. We have also published a compilation of introductory talks of newly appointed associate professors of mathematics in the period 1909-1963.

- HARDNESS AND ELASTICITY OF a-Si:H LAYERS

In the recent years a number of MEMS/NEMS were developed, based on a-Si:H, which demonstrated the applicability of the material in this fastly progressing field. The advantages of a-Si:H are primarily connected with their compatibility and easy integration into silicon electronic devices and solar elements. Besides, a-Si:H is obtained at relatively low temperatures, which makes it suitable for combining with biomaterials, for the purposes of biomedical applications. Hence, the possibilities for control and modification of the mechanical properties of a-Si:H are important.

Our studies were aimed at:

- determination of the parameters of plastic and elastic deformations of thin a-Si:H layers, obtained by plasma decomposition of silane;
- studying the effect of hydrogen on their mechanical properties, by improving the electronic properties of a-Si:H;
- studying the effect of ion implantation on the elasticity module and the nano-hardness of a-Si:H.

The determined value of the elasticity module of a-Si:H was in the range 117-131 GPa, lower than that reported for crystalline silicon. The nanohardness of a-Si:H was in the range 12.2–12.7 GPa, comparable to that for crystalline silicon. It was established, that ion implantation leads to reduction of the elasticity module and nanohardness. It also makes the layer surface smoother, reducing its roughness from RMS=1.5 nm to RMS=0.4 nm. It was shown, that using shallow low energy ion implantation it is possible to modify the a-Si:H surface, by preserving the high material hardness. By a comparative study of the mechanical properties of hydrated and non-hydrated amorphous silicon it was found, that the presence of hydrogen in the silicon matrix does not change the elasticity module, but it increases substantially the material hardness. It has been shown, that treatment of amorphous silicon in hydrogen plasma can enhance the material hardness at the surface. This result is interesting for various purposes of practical applicability.

- FIBER OPTICS

Thin ZnO films were produced by pulsed laser deposition on a side-polished single-mode fiber in view of optical gas sensor applications. The experimental conditions used for preparation of the samples were chosen so as to obtain smooth, porous and nanostructured films. The influence of the film structure on their sensitivity to ammonia was investigated. For all samples, a shift of the spectral position of the resonance minimum to the longer wavelengths was observed under gas exposure at room temperature. The nanostructured sensor element demonstrated a substantially higher sensitivity as compared to the only smooth and porous samples.

- HOLOGRAPHIC DIFFRACTION GRATINGS

Unique possibilities for obtaining very large diffraction gratings were achieved by the development of special phase masks based on a system of diffraction gratings and providing a stable highly coherent interference pattern. The method allows for very-low-period gratings to be obtained (of 45 nm stripe width) as well as very-large-period ones (of 2 μm) by varying the construction of the phase mask. The special design of an achromatic phase mask allows an interferogram with spatial frequency independent from the wavelength of the exposing light to be formed.

A new planar technology for the production of resonant optical elements used as laser cavity mirrors was developed. It allows for significant lowering of their cost together with high reproducibility. Such diffraction mirrors give an opportunity for their functional angle, wavelength and polarization selectivity to be used for controlling the wavelength and polarization distribution as well as the spatial coherence of the laser.

A high sensitivity (~ 1 nm resolution) sensor for X-Y translations based on a diffraction grating interferometer was developed and demonstrated. An effective technology for replication of the monolithic sensor head was created. Numerical modeling of the measuring head by geometrical tracing of the beam allows for the possible deviations of the geometric parameters, surface smoothness and refractive index to be determined; these ensure the correct propagation of the beam. These developments were performed within the European 6FP NEMO (Network of Excellence on Micro-Optics).

- MICRO- AND NANO-PHOTONICS “Georgy Zartov”

The investigation and optimization of the optical multilayer structures have been our main activities. The time dependences of the obtained structures were investigated too.

Back and front mirrors for eye-safe laser generation at 1538 nm wavelength were 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.

Optical birefringence $\Delta n \sim 10^{-7}$, induced in suspension of giant lipid vesicles by high-frequency (500 kHz) AC electric field was measured. The amplitude of the applied electric field was varied in the interval $5 \div 30$ V/mm. The observed effect was explained as the result of electro-deformation of the giant vesicles leading to an optical anisotropy.

II. OPTICS AND SPECTROSCOPY OF ANISOTROPIC AND NONLINEAR MEDIA

- OPTICS AND SPECTROSCOPY OF THERMOTROPIC LIQUID CRYSTALS

The electroconvective instability (ECI) in nematic liquid crystals (NLCs), appearing beyond smectic C upon cooling, known as N with short range smectic C order, presents an unique electrooptical phenomenon due to generation and frustration of the smectic layering, which manifests itself inside the N temperature range. This structural effect results in an increase of the relaxation times in NLCs with short range smectic C order. We found that the response times below a specific temperature T^* , within this nematic medium, are about two times shorter than those in the classical Ns, due to an equalization of both response and decay times, which is preferable in LC display techniques. On the basis of results obtained from polarization analysis of the azimuthal in-plane director deflection in the EC regime we suggested that the electroconvective instability N with short range smectic C order has a twist-type character. We found that the specificity of the temperature variation of the electroconductivity and the EC in NLCs with short range smectic C order is determined by the smectic tilt angle magnitude and the dimer's compactness within the supramolecular complexes (clusters). For the first time harmonics higher than fourth order were detected in NLCs.

-LASER STUDIES OF POLYMERS AND LIQUID CRYSTALS

The applicability of layers of ion-implanted optically-transparent polymer, in our case polymethylmethacrylate (PMMA) silicon-ion implanted at a relatively low ion energy of 50 keV, was examined for beam splitting/coupling of laser light at the telecom wavelength of $1.55 \mu\text{m}$ that is of interest for optical communication networks, integrated optics and photonic devices. Bulk PMMA was studied, subjected to Si^+ implantation at various ion

fluences in the range from 10^{14} to 10^{17} cm⁻². Due to ion-produced modification of the optical properties (the refractive index and related characteristics) of nanostructured subsurface region of Si⁺-implanted PMMA, the formed ultra-thin near-surface ion-implanted layer of about 100 nm thickness buried in a depth ~100 nm in this plastic, has a potential for low-loss reflective-type beamsplitter (or beam coupler) applications.

A strong laser-induced thermo-lens (LITL) effect was found in Si⁺-implanted PMMA upon irradiation by a cw laser with a power up to 100 mW ($\lambda = 532$ nm). The thermo-lensing was attributed to the modification of the subsurface region of the ion-implanted polymer having a nearly Gaussian distribution of refractive-index in-depth profile. The LITL observed in reflection geometry occurs due to optical absorption of the ion-implanted layer, and subsequent non-local laser-induced non-linear change in the refractive index of the Si⁺-implanted PMMA. The results are of practical interest for ultra-thin reflection-type laser beam splitters, diffraction-optic elements and micro-components based on ion-implanted PMMA.

The electrically and spatially controllable coherent light diffraction by single-layered polymer-dispersed liquid crystal (PDLC) films were studied, being of interest for device applications. Microscale PDLC films formed from nematic LC in the photo-cured NOA65 polymer were examined. The films contain LC droplets with a linear-gradient size distribution along the film length. The single-layer arrangement and compact packing of the PDLC structure render the electrically-commanded coherent light diffraction controlled by LC/polymer interface. Upon applying an electric field, a spatial redistribution of the intensity of the diffraction beam splitting, namely diffraction peaks of six-fold symmetry, can be achieved by single-layered PDLC film illuminated with laser light. The effect is determined by PDLC film morphology and LC droplet arrangement, and is related to the electrically-produced optical phase retardation. Complemented with the spatial control by simple translation of the linear-gradient PDLC film across the incident laser beam which utilizes the well-controllable and continuously tunable LC droplet size, this effect can further facilitate the diffractive optics in two-dimensional PDLC films.

Homeotropically oriented samples of guest-host liquid crystalline materials being mixtures of a small content of photochromic azobenzene dye in a photoinactive nematic were analyzed by digital conoscopy upon application of a DC electric field parallel to the layers in the absence of, and under UV light illumination conditions. By conoscopy were registered the bend deformation of molecular orientation in the layers caused by an in-plane applied DC electric field, and influenced by continuous UV irradiation. The results obtained by this optical technique give evidence for a UV light-induced flexo-electrical effect in the mixtures driven by *trans-cis* photoisomerization of the azobenzene dopant possessing asymmetric molecular structure. The dependence of the observed photoflexoeffect on both field strength and UV light intensity was also explored.

- ELECTRIC FIELD INDUCED BIREFRINGENCE AND ORIENTATIONAL ORDER

The electric field-induced birefringence and orientational order in the isotropic phase of aqueous suspensions of exfoliated natural beidellite clay particles, thin ($L = 0.65$ nm) flat charged sheets with high aspect ratio, $D/L \approx 300$ is studied. In isotropic and biphasic samples, strong field-induced birefringence $\Delta n(E)$, saturating at moderate E^{sat} field to a plateau Δn^{sat} proportional to the volume fraction ϕ is observed. The field-induced order parameter $S(E)$ is negative and saturates to $S^{sat} = -0.5$ above E^{sat} . This corresponds to a perfect “anti-nematic” order, i.e. the normals of the beidellite particles are perpendicular to the field, without any preferred azimuthal direction. The estimated equivalent conductivity of the beidellite particle is several orders of magnitude larger than the bulk conductivity of the electrolyte, resulting in a metal-like behavior of the beidellite disks under field.

The prolate-to-oblate shape transition of quasi-spherical electroformed vesicles is observed at higher frequencies of the electric field compared to the case of spontaneously swollen vesicles. This effect is a consequence of the elevated suspension conductance for the electroformed samples. Electrochemical impedance spectroscopy technique is applied to check the conductivity of identical giant vesicle suspensions (same lipids and suspending media), prepared by the two methods. The study is intended to point out possible implications of the electroformation method in cases, when phenomena, related to the ionic strength of the suspending medium, are investigated.

Birefringence $\Delta n \sim 10^{-7}$, induced in suspension of giant lipid vesicles by high-frequency (500 kHz) AC electric field of amplitude in the interval 5÷30 V/mm is measured. The liquid phases inside and outside the vesicles are iso-osmolar solutions of sucrose and glucose (0.22 mol/L) respectively. The two solutions have different optical densities and different specific weights. The observed effect is supposed to be a result from the electro-deformation of the giant vesicles leading to an optical anisotropy. The measured value of Δn is in the same range as for suspensions of large unilamellar vesicles with considerably higher lipid concentrations, as reported in the literature.

-NANOPHOTONICS

Nanophotonics is a promising area with potential to revolutionize the telecommunications industry and optical processing. Nanotechnology was able to offer many new devices and new materials with a fast range of applications, including metamaterials as components of a nanophotonic system.

Our report at the MediterianNano-3 Conference (Beograd, 2010) contained a study of the *behavior of light on the nanometer scale* (main subject of *Nanophotonics*) by the methods of Quantum Mechanics. The lack of shortwave coherent radiation sources reduces the applicability of free electron lasers. Various schemes of X-ray FELs have been considered. Understanding the undulator effects is of critical importance for the design of x-ray FEL, but up to now a quantum mechanical treatment of the electron motion in the undulator was missing.

Our approach for solving the problem of charged particles moving in an FEL-undulator is based fully on QM, namely using linear integrals of motion for a quantum particle with quadratic Hamiltonians to find the exact solutions of such equations and to find expressions for all three second order central statistical moments.

- THEORETICAL STUDIES OF INTRAMOLECULAR ELECTRONIC AND VIBRATIONAL TRANSITIONS

We have carried out calculations on the rate of the intersystem crossing (ISC) electronic radiationless transition between the T_1 and S_0 states in thiophosgene, Cl_2CS . In our calculations of the ISC rate constant, we have explicitly taken into account the intramolecular vibrational redistribution (IVR) in the S_0 state, in order to explain the experimentally observed extremely low phosphorescence quantum yield of the T_1 state.

We have set up a variational code designed for exact calculation of extremely highly excited vibrational levels in formaldehyde, H_2CO . The code is based on a full expression for the molecular vibrational kinetic energy operator in terms of curvilinear bond-angle coordinates, and on an artificial intelligence search-selection algorithm and Lanczos tridiagonalization procedure. We have calculated our own ab initio PES for the molecule. Using our code, we have been able to perform calculations on extremely highly excited vibrational levels in S_0 formaldehyde (above 16000cm^{-1}).

-ION IMPLANTATION IN POLYMERS AND IN AMORPHOUS SILICON CARBIDE

We studied the observed effect of luminescence amplification (up to 5 fold) in certain

polymeric materials upon ion implantation with silicon. The ion-beam induced structural modifications of the studied polymeric materials, that have induced the observed photoluminescent effects, have been further studied using various optical and structural methods such as IR and Raman spectroscopy, as well as the method of diffuse optical scattering.

We have investigated the optical contrast formation in amorphous silicon carbide layers using focused ion beams, as well as the possibilities for applications in nano-dimensional optical recording of information and the formation of sub-micron lithographic masks. We found an effect of optical contrast formation in the studied materials under bombardment by a high-energy (~ 1 MeV) beams of protons and alpha-particles. The obtained micro- and nano-dimensional optical images, using the two types of focused ion beams, were studied by means of various near-field methods: atomic-force microscopy (AFM), scanning near-field optical microscopy (SNOM), as well as X-ray photo-electron spectroscopy (XPS).

- COLORIMETRY AND ITS APPLICATIONS IN INDUSTRY AND ENVIRONMENT

A programme code designed for the use of a miniature USB colorimeter was further elaborated.

- OPTICAL METHODS IN ARCHAEOLOGY

An on-line catalogue of the megalithic objects in Bulgaria was created that can be further developed to form a database for the entire Balkan Peninsula. It demonstrates the position, orientation and photographs of all known objects and also gives references to the respective scientific publications about them. Analyzing the material so collected and comparing it with similar objects from Western Europe and THE Caucasus, following conclusion could be made: the widely accepted dating of Bulgarian (Balkan) megaliths is not sufficiently accurate and convincing at present. Therefore the employment a new supplementary physical dating method is proposed and recommended: the optically stimulated luminescence dating (OSL dating). The collaboration between Bulgaria, Greece and Turkey in OSL dating will provide more accurate measurement results that will help to include the Balkan megalithic group into the frames of the Pan-European megalithic culture in a more precise and reliable manner. This research activity will also stimulate the tourist interest in the Balkan cultural heritage.

PUBLICATIONS

Monographs and collections

PUBLISHED PAPERS:

1. T. K. Tenev, I. K. Miloushev and R. A. Peyeva, "Mirror coatings for eye-safe laser generation", Journal of Physics: Conference Series 223 (2010) 012021, ISSN 1742-6588.
2. K. Antonova, V. Vitkova, M. D. Mitov, "Deformation of giant vesicles in AC electric fields dependence of the prolate-to-oblate transition frequency on vesicle radius", EPL, 89, 38004-pp.1-5, (2010)., ISSN 1286-4854, IF 2.893.
3. V. Vitkova, K. Antonova, G. Popkirov, M. D. Mitov, Yu A. Ermakov and I Bivas, "Electrical resistivity of the liquid phase of vesicular suspensions prepared by different methods", Journal of Physics: Conference Series 253 (2010) 012059, IOP Publishing, doi:10.1088/1742-6596/253/1/012059.
4. K. Antonova, V. Vitkova, G. Popkirov, T. Tenev, I. Miloushev, and I. Bivas, "Experimental study of the electrically induced optical birefringence in suspension of densely packed giant lipid vesicles", Journal of Physics: Conference Series 253 (2010) 012058, IOP Publishing, doi:10.1088/1742-6596/253/1/012058.

5. A.Og. Dikovska, G. B. Atanasova, N. N. Nedyalkov, P. K. Stefanov, P. A. Atanasov, E. I. Karakoleva, A. Ts. Andreev, "Optical sensing of ammonia using ZnO nanostructure grown on a side-polished optical fiber", Sensors and Actuators B, vol. 146, iss.1, pp. 331-336 (2010)
6. G.B. Hadjichristov, I.L. Stefanov, S.S. Stanimirovc, I.K. Petkov, "The luminescence response of Eu(III)-thenoyltrifluoroacetate complexes upon preresonant excitation with femtosecond laser pulses", Spectrochim. Acta A: Mol. Biomol. Spectrosc. 75 (1) 448-452 (2010), ISSN 1386-1425.
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8. G.B. Hadjichristov, Y.G. Marinov, A.G. Petrov, "Single-layered PDLC for diffractive optics", Mol. Cryst. Liq. Cryst. 525, 128-139 (2010), ISSN 1542-1406.
9. G.B. Hadjichristov, I.L. Stefanov, "Ion-implanted polymethyl methacrylate beam splitter/coupler for 1.55 μm applications", Appl. Opt. 49 (10) 1876-1879 (2010), ISSN 1559-128X.
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11. Y.G. Marinov, G.B. Hadjichristov, A.G. Petrov, S. Sridevi, U.S. Hiremath, C.V. Yelamaggad, S.K. Prasad, "Conoscopic evidence of the UV light-induced flexoelectric effect in homeotropic layers of nematic liquid crystal doped with azobenzene derivatives", J. Phys. Conf. Ser. 253, 012060-7 (2010), ISSN 1742-6588.
12. G.B. Hadjichristov, I.L. Stefanov, S.S. Stanimirov, I.K. Petkov, "Femtosecond laser spectroscopy of europium complexes in solutions", Proc. SPIE 7501, art. no. 75010O, 1-8 (2009).
13. I.L. Stefanov, V.G. Ivanov, G.B. Hadjichristov, "Laser-induced thermo-lens in ion-implanted optically-transparent polymer", Proc. SPIE 7501, art. no. 75010Q, 1-9 (2009).
14. G.B. Hadjichristov, Y.G. Marinov, A.G. Petrov, "Electro-optical switching of gradient 2D-PDLC films", AIP CP1203, 182-187 (2010).
15. Y. G. Marinov, H. P. Hinov, G. B. Hadjichristov, A. G. Petrov, Uma S. Hiremath, C. V. Yelamaggad, "Observation of flexoelectricity in mixtures of calamitic and bent-core liquid crystals", AIP CP1203, 329-334 (2010).
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COLLABORATION:

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

2. Forschungszentrum Rossendorf, Institut fuer Ionenstralphysik und Materialforschung, Germany.
3. Pluridisciplinary Laboratory Joliot Curie at the Ecole Normale Supérieure, Lyon (CNRS UMR 5161) France, The Institute Albert Bonniot, UJF & INSERM U309, and CEA, Grenoble, France and funded by Ministry of Education and Science BG (K 1402/ 2004), and 6th FP ECC MCRTN “CLUSTOxDNA”.
4. Ecole Normale Supérieure de Lyon, Laboratoire Pluridisciplinaire Joliot-Curie, (CNRS USR 3010) France; UJF, Institute Albert Bonniot, INSERM U309 and CEA-CENG, Grenoble, France
5. Research Institute of Solid State and Optics, Budapest, HAS, Hungary.
6. Institute of Ion Beam Physics and Materials Research, AIM – Center, POB 510119 01314 Dresden Germany

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:

Five projects were developed in the Laboratory “Liquid Crystals” during 2010 on different contracts: four of them with BAS, (one with CU, three international co-operations – with Institute of Electro-chemistry, Moscow, Russia, with Austrian Academy of Sciences, Graz, Austria, and with Free University of Luxemburg, Belgium) and one with NSFB (the programme Bulgaria – Slovenia). One Slovenian PhD student, Janez Pavlic prepared part of its PhD thesis that was successfully defended latter in Ljubljana, Slovenia.

The surface energy and the flexoelectric coefficient of the nematic mixture E7 have been measured. For measuring its flexoelectric coefficients an extended Helfrich's theory for flexoelectric bending-splaying of a nematic E7 layer containing an inclusion of minute amounts of single-walled carbon nanotubes (SWCNTs) was applied. A 3-4 times increase of flexoelectric effect due to the contribution of carbon nanotubes to quadrupolar part of the flexoelectric coefficient was achieved.

The influence of single-walled carbon nanotubes and a dried zwitter-ionic phospholipid on the behaviour of the gradient flexoelectric and surface polarization induced domains arising in a homeotropic nematic E7 has been studied. For the first time different polar on/off formation of the surface polarization induced domains in the region of the liquid crystal cell without surface deposited lipid SOPC layer has been observed. The observed effect was explained by means of the redistribution of bulk electric charges as a result of nanotube drift.

A new algorithm and software for the determination of the contour of a fluctuating vesicle, observed under phase contrast microscope, was developed.

The influence of the ITO coatings and the polymer PDMS spacers on the electrical resistivity of the liquid medium of electroformed vesicle suspensions was examined by electrochemical impedance spectroscopy (EIS). The possible implications of the electroformation method, used cells and materials, especially when phenomena, related to electrical properties of the vesicle membranes, are investigated.

The optical birefringence, $\Delta n \sim 10^{-7}$, induced in suspension of giant lipid vesicles by high-frequency (500 kHz) AC electric field was measured. The liquid phases inside and outside the vesicles were iso-osmolar solutions of sucrose and glucose (0.22 mol/L). The two solutions have different optical densities and different specific weights. The estimated volume fraction of the vesicles in the studied suspension was 48 vol%. The amplitude of the applied electric field was varied in the interval $5 \div 30$ V/mm. The observed effect was supposed to be a result from the electro-deformation of the giant vesicles leading to an

optical anisotropy. The measured value of Δn in our case was in the same range as for suspensions of large unilamellar vesicles with considerably higher lipid concentrations, as reported in the literature.

Through a specially developed experimental procedure, suspensions of fluctuating quasi-spherical giant lipid vesicles were formed in the way the refractive index of the aqueous solution, which is inner for the vesicle membrane, to be different than that of the suspending solution. By digital holographic record of fluctuating vesicles formed in various media the possibilities and the applicability of the digital holographic microscopy were explored.

The rheology of concentrated vesicular and erythrocyte suspensions was experimentally investigated. The effective viscosity of suspensions at various volume fractions of deformable particles (red blood cells or vesicles) was measured as a function of the ratio between the viscosity of the aqueous phase, enclosed by the lipid membrane, and the viscosity of the suspending medium. The viscoelasticity of erythrocyte suspensions was studied in oscillatory shear flows, which is relevant to the real physiological conditions.

A mechanoformation method for preparation of giant lipid vesicles in high ionic strength solutions is developed using different experimental set-ups. Mechanoformation method is an alternative to electroformation method. The mechanoformation procedure is not limited to high ionic strength aqueous solutions, because there is no applied electric potential (no current flow through the formation cell) to create electric field and possibly electrolysis.

Thermally induced shape fluctuations of giant quasi-spherical lipid vesicles are used to study the influence of the disaccharide maltose, dissolved in the aqueous solution, on the curvature elasticity k_c of a lipid membrane. The influence of the carbohydrate solute is investigated throughout a considerably wide interval of concentrations. The values of the bending elastic modulus for 200 mM and 400 mM of maltose in the water solution are obtained. The data for k_c in presence of maltose is compared with previously obtained results for this constant for the most popular hydrocarbons: monosaccharides glucose and fructose and disaccharides sucrose and trehalose. It is shown that the presence of maltose, dissolved in the aqueous phase surrounding the membrane does not influence on the bending elasticity with the increase of its concentration in the aqueous solution.

The bending elastic modulus of SOPC membrane in presence of different concentrations (5,5; 27,5 и 55 $\mu\text{g/ml}$) of the peptide beta 2 GPI is measured. It is shown that the studied peptide connects to the neutral membrane as well.

PUBLICATIONS:

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2. H. P. Hinov: "On the coexistence of the flexo-dielectric walls – flexoelectric domains for the nematic MBBA – A new estimation of the modulus of the difference between the flexoelectric coefficients of splay and bend $\square e_{1z} - e_{3x}\square$ ", Mol. Cryst. Liq. Cryst. 524, pp 26-35 (2010).
3. Y. G. Marinov and H. P. Hinov: "On the threshold characteristics of the flexoelectric domains arising in a homogeneous electric field: the case of anisotropic elasticity", European Physical Journal E 31, pp 179-189 (2010).
4. I. Bivas, Shape fluctuations of nearly spherical lipid vesicle and emulsion droplet, Phys. Rev. E, 81, 061911 (2010).

5. K. Antonova, V. Vitkova and M. D. Mitov, "Deformation of giant vesicles in AC electric fields —Dependence of the prolate-to-oblate transition frequency on vesicle radius", *Europhys. Lett. EPL*, 89 38004 (2010).
6. J. Pavlič, J. Genova, A. Zheliaskova, A. Iglic, M.D.Mitov, "Electroformation of neutral and negatively charged phospholipids vesicles under physiological conditions", *C. R. Acad. Bulg. Sci.* 63 (4), p. 497 (2010).
7. H P Hinov, J I Pavlič, Y G Marinov, A G Petrov, S Sridevi, P M Rafailov and U Dettlaff-Weglikowska, Influence of single-walled carbon nanotubes (< 0.001 wt %) and/or zwitter-ionic phospholipid (SOPC) surface layer on the behaviour of the gradient flexoelectric and surface induced polarization domains arising in a homeotropic E7 (a mixture of 5CB, 7CB, 8OCB and 5CT) nematic layer, 2010 J. Phys.: Conf. Ser. 253 012061.
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9. K. Antonova, V. Vitkova, G. Popkirov, T. Tenev, I. Miloushev, and I. Bivas, "Experimental study of the electrically induced optical birefringence in densely packed suspensions of giant lipid vesicles" *J. Phys.: Conf. Ser.* 253 012058 (2010).
10. J. Genova, A. Zheliaskova, M. D. Mitov „Does Maltose Influence the Elasticity of SOPC Membrane? *J. Phys.: Conf. Ser.* 253 012063 (2010).
11. J. Pavlic, J. Genova, A. Zheliaskova, M.D.Mitov „Bending Elasticity of Lipid Membrane in Presence of Beta 2 Glycoprotein I in Its Membrane", *J. Phys.: Conf. Ser.* 253 012064 (2010).
12. A. G. Petrov, Y. G. Marinov, H. P. Hinov, L. Todorova, M. Dencheva-Zarkova, S. Sridevi, P. M. Rafailov, and U. Dettlaff-Weglikowska: "Observation of flexoelectricity in a mixture of carbon single-walled nanotubes with a nematic liquid crystal", *Mol. Cryst. Liq. Cryst.*, Proc of the 23 International Liquid Crystal Conference, Krakow 2010, (in press).

DIVISION SOFT MATTER PHYSICS

LABORATORY

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RESEARSH SCIENTISTS: 4

Acad. Alexander G. Petrov; Assist. Prof. Y. Marinov, Ph.D.; Assist. Prof. L. Todorova; M. Dencheva-Zarkova, chem. engineer; V. Devenska, biologist

RESEARCH ACTIVITIES:

As a part of Indo-Bulgarian joint research project new results on guest-host nematic systems featuring an optical degree of freedom based on the trans-cis photoisomerization of a single azo-bond or two azo-bonds in guest mesogens, with or without a longitudinal dipole moment have been obtained. A marked, reversible UV increase of the flexoelectrooptic effect (i.e. the electrically driven increment of the polarized light transmission as due to the modified birefringence of the flexoelectrically bent nematic structure) was found in case of guest molecules with a longitudinal dipole moment. Our findings confirm experimentally the hypothesis of the molecular nature of the photoflexoeffect in homeotropic nematics, advanced earlier. A conclusion on the decisive role of surface adsorbed layer of polar azocompounds is drawn. New types of opto-optic and electro-optic switches and displays could be constructed based on the photoflexoelectricity employing the newly reported guest-host nematics.

Homeotropically oriented samples of two guest-host liquid crystalline materials being mixtures of a small content of photochromic azobenzene dye in a photoinactive nematic were examined by digital conoscopy upon application of a DC electric field parallel to the layers in the absence of, and under UV light illumination conditions. The results obtained by this optical technique give evidence for a UV light-induced flexo-electrical effect in the mixtures driven by *trans-cis* photoisomerization of the azobenzene dopant possessing asymmetric molecular structure.

The modulus of the flexo-surface polarization term of the nematic mixture E7 has been measured. The extension of the theory of Helfrich to flexoelectric bending-splaying of a nematic E7 layer containing an inclusion of minute amounts of single-walled carbon nanotubes (SWCNTs) was applied for measuring its flexoelectric coefficients. A 3-4 times increase of flexoelectric effect due to carbon nanotube contribution to quadrupolar part of the flexoelectric coefficient was achieved.

The influence of single-walled carbon nanotubes and a dried zwitter-ionic phospholipid on the behaviour of the gradient flexoelectric and surface polarization induced domains arising in a homeotropic nematic E7 has been studied. For the first time different polar on/off formation of the surface polarization induced domains in the region of the liquid crystal cell without surface deposited lipid SOPC layer has been observed. The observed effect was explained by means of the redistribution of bulk electric charges as a result of nanotube drift.

Using a single-layered film of micrometer-size polymer-dispersed liquid crystal (PDLC), we achieved an electrically controllable reflection of coherent light in a pair of two

beams with a complementary voltage-dependent intensity change. The reciprocal switching behaviours of reflected light pair (or transmission/reflection light pair) are controlled by the electrically produced optical phase shift for the laser beams within the PDLC cell. Such an effect of intensity change of a laser beam pair may be useful in miniature PDLC-based EO devices for active light control applications.

PUBLICATIONS:

1. Marinov, Y. G.; Hinov, H. P.; Hadjichristov, G. B.; Petrov, A. G.; Hiremath, Uma S.; Yelamaggad, C. V., Observation of Flexoelectricity in Mixtures of Calamitic and Bent-Core Liquid Crystals, 7th International Conference of the Balkan Physical Union. AIP Conference Proceedings, Volume **1203**, pp. 329-334 (2010).
2. Marinov Y. G., Hinov H.P., On the threshold characteristics of the flexoelectric domains arising in a homogeneous electric field: The case of anisotropic elasticity. Eur. Phys. J. E **31**, 179-89 (2010).
3. Yordan G. Marinov, Georgi B.Hadjichristov, Alexander G. Petrov, Single-layered PDLC films for electrically variable laser light reflection application, Opt Lasers Eng, 48, 1161-1165 (2010).
4. G. B. Hadjichristov, Y. G. Marinov, A. G. Petrov, Single-layered PDLC for diffractive optics, Mol. Cryst. Liq. Cryst., 525, 148–159 (2010).
5. Todorov S., A. Damianova, A. Antonov, L. Todorova, Investigation of natural waters spectra from lakes of Rila Mountain National Park, Compt. rend. Acad. bulg. Sci., Vol. 63, N 4, pp. 555–560 (2010).
6. Todorov Stefan, Anna Damianova, Lidia Todorova, Natural waters investigation from rivers and lakes of Rila Mountain National Park, Compt. rend. Acad. bulg. Sci., Vol. 63, N 11, pp. 1559–1564 (2010).
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8. G.B. Hadjichristov, V.K. Gueorguiev, Tz.E. Ivanov, Y.G. Marinov, V.G. Ivanov, E. Faulques, “Electrical properties of PMMA ion-implanted with low-energy Si⁺ beam”, J. Phys. Conf. Ser., 207 (2010) 012022.
9. Тодорова Л., С. Тодоров, Промени на енергетичния спектър на водота в резултат на аерация, Сбор.доклади науч.конф. на СУБ с междунар. участие, серия Б., том 12, с.351-355 (2010).
10. Тодоров С., Л. Тодорова, Влияние на околната среда върху водните структурни свойства, Сбор.доклади науч.конф. на СУБ с междунар. участие, серия Б., том 12, с.346-350 (2010).
11. H P Hinov, J I Pavlič, Y G Marinov, A G Petrov, S Sridevi, P M Rafailov and U Dettlaff-Weglikowska, Influence of single-walled carbon nanotubes (< 0.001 wt %) and/or zwitter-ionic phospholipid (SOPC) surface layer on the behaviour of the gradient flexoelectric and surface induced polarization domains arising in a homeotropic E7 (a mixture of 5CB, 7CB, 8OCB and 5CT) nematic layer, 2010 J. Phys.: Conf. Ser. 253 012061.
12. Y G Marinov, G B Hadjichristov, A G Petrov, S Sridevi, U S Hiremath, C V Yelamaggad and S K Prasad, Conoscopic evidence of the UV light-induced flexoelectric effect in homeotropic layers of nematic liquid crystal doped with azobenzene derivatives, 2010 J. Phys.: Conf. Ser. 253 012060.

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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RESEARCH SCIENTISTS: 5

Assoc. Prof. M. Stefanova, Ph.D.; Assist. Prof. V. Mihailov, Ph.D.; Assist. Prof. E. Dimova, Ph.D.; Assist. Prof. G. Malcheva, Ph.D.; G. Dobrev - physicist; I. Temelkov- physicist; PhD student: V. Steflekova;

RESEARCH ACTIVITIES:

1. Atomic physics and spectroscopy

An experimental set up for spectroscopic studies of laser-induced plasma was created. The apparatus contains Nd:YAG laser, optical system and optical multichannel analyzer. The test spectra of Cu have been registered.

Radiative lifetimes of Niobium (Nb_I) high-lying states $5py^6D^{\circ}_{9/2}$, $5px^6D^{\circ}_{7/2}$, $5pw^4G^{\circ}_{7/2,9/2,11/2}$, $5s5pv^4D^{\circ}_{1/2,3/2,5/2,7/2}$, $5s6pn^4D^{\circ}_{1/2,3/2,5/2,7/2}$, $5s6po^4F^{\circ}_{3/2,5/2,7/2,9/2}$ were measured with the method of plasma-induced fluorescence. The data are confirmed by theoretical calculations using the method of Hartree-Fock. The results obtained for 15 of the analyzed states were for the first time.

Radiative lifetimes of excited states of Y II and Y III were determined experimentally.

Emission spectra of $Co_xFe_{2-x}O_4$ have been registered in the purpose to develop a method for determining their stoichiometry. The correlation of Co and Fe spectral lines intensity in samples with different content of those elements was determined. Appropriate calibration lines - Co 422.67; FeI 427.18 have been found.

2. Quantum optics

A new activity in the field of quantum optics has been started by a scientific team from the Institute of Solid State Physics and the Faculty of Physics of the Sofia University "St. Kliment Ohridski". A high-tech experimental set-up "Magneto-optical trap" has been created in which a system of stabilized diode lasers was used for Doppler cooling of Rubidium isotopes (^{85}Rb и ^{87}Rb) in a magnetic trap. The atomic temperature achieved is ~ 0.0001 K.

3. Plasma physics

An experimental and theoretical investigation of the cathode discharge region of the Grimm discharge has been performed. The Grimm lamp operates with hydrogen gas at low pressure. Stark polarization spectroscopy of the Balmer-beta H_{β} line has been used in order to measure the electric field distribution in the discharge. Investigation of elementary processes occurring in the discharge including the interaction of gas particles with the cathode surface in the cathode region are also objectives of this study.

Dynamic optogalvanic signals relevant to Zn atomic optical transitions are recorded as a function of discharge current in Ne/Zn hollow cathode lamp. Peculiarities in the amplitude and shape of the signals have been explained with the increased role of the Penning collisions between Ne metastable atoms and several excited Zn ion states.

The realization of an experimental arrangement for registration and study of impurities in helium and development of ionization detector is being continued. The main blocks of the probe circuit for probe characteristics examination are done during the year, as follows: 1) strobbing pulse scheme; 2) differential sine voltage supply; 3) optocoupler transistor switch for temporary switching of the probe circuit and 4) saw-tooth generator for probe potential sweeping. A power supply is constructed, providing the anode to be grounded. The final adjustment of the registration arrangement is forthcoming.

PUBLICATIONS:

Articles

1. G. Malcheva, H. Nilsson, L. Engström, H. Lundberg, É. Biémont, P. Palmeri, P. Quinet, K. Blagoev, "Radiative parameters of Nb I excited states", *Mon. Not. R. Astron. Soc.* (2010) DOI: 10.1111/j.1365-2966.2010.18020.x
2. V. Steflekova, D. Slavov, D. Zhechev, G. Todorov, "Two self-sustained unstable modes for operation of a hollow cathode discharge" *Spectroscopy Letters*, 43 (03), pp. 167 – 171 (2010) DOI: 10.1080/00387010903284315
3. D. Zhechev and V. Steflekova, "Spatially resolved profile and shift of the spectral line in a hollow cathode discharge", *Spectroscopy Letters* (accepted)
4. D. Sofikitis, G. Stern, L. Kime, E. Dimova, A. Fioretti, D. Comparat, and P. Pillet, "Loading a dipole trap from an atomic reservoir", *Eur. Phys. J. D* (2010) accepted
5. V. Mihailov, R. Djulgerova, J. Koperski, N. Skoro, D. Maric, Z. Lj. Petrovic, "Dynamic optogalvanic signals behaviour in Ne/Zn hollow cathode discharge" *Proc. 20th ESCAMPIG*, IOP Publishing, Vol. 34B, 2010, P3.19, ISBN 2-914771-63-0
6. V. Steflekova, Dj. 2. Spasojević, N. M. Šišović, N. Konjević, "Study of cathode sheath in hydrogen glow discharge" *Proc. 20th ESCAMPIG*, IOP Publishing, Vol. 34B, 2010, ISBN 2-914771-63-0

Conference reports

1. G. Malcheva, "Laser-induced breakdown spectroscopy (LIBS) analysis of silver and bronze finds from Trebeniste necropolis", 10th European Conference on Atoms Molecules and Photons 4 –9 July 2010, Salamanca (Spain)
2. G. Malcheva, L. Engström, H. Lundberg, H. Nilsson, K. Blagoev, "Radiative lifetimes of high lying excited states in Nb I", 10th European Conference on Atoms Molecules and Photons 4 –9 July 2010, Salamanca (Spain)
3. V. Steflekova, Dj. Spasojević, N. M. Šišović, N. Konjević, "Study of cathode sheath in hydrogen glow discharge "20th European conference on the Atomic and Molecular Physics of Ionized Gases, 13 – 17 July 2010, Novi Sad, Serbia
4. V. Steflekova, N. M. Šišović, N. Konjević, "Spectroscopic study of the axial distribution of strong near infrared ArI lines and Ar metastables in Grimm discharge in argon and argon-oxygen gas mixture" 25th Summer School and International Symposium on the Physics of Ionized Gases, Donji Milanovac, Serbia, 30 August-3 September, 2010
5. V. Steflekova, "Study of the cathode fall region parameters of Grimm discharge in hydrogen" GLADNET meeting, Oviedo, Spain, 01-05 March, 2010

6. V. Steflekova, "Distribution of electric field in cathode sheath in Grimm discharge, Influence of thin porous Al₂O₃ layer on aluminum cathode to the H α line shape in glow discharge and Spectroscopic study of the axial distribution of strong near infrared Ar I lines and Ar metastables in Grimm discharge in Ar and Ar-O₂ gas mixture" GLADNET meeting, Albi, France, 22-27 August, 2010
7. V. Mihailov, R. Djulgerova, J. Koperski, N. Skoro, D. Maric, Z. Lj. Petrovic, "Dynamic optogalvanic signals behaviour in Ne/Zn hollow cathode discharge" 20th European conference on the Atomic and Molecular Physics of Ionized Gases, 13 – 17 July 2010, Novi Sad, Serbia

TEACHING ACTIVITIES:

PhD student: V. Steflekova

Bachelor degree student V. Tankova

Organization of the 11th winter seminar of young scientists, Sofia

NEW ACTIVITIES:

1. Investigations of traces of elements in archeological artifacts using Laser Induced 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, BNSF – contract 1516/2006-2010
3. Coding, treatment and measurements of quantum information with ultracooled atoms – BNSF; project № BY-II-301/2007-2010

INTERNATIONAL COLLABORATION:

1. "Radiative constants of Nb excited states" (LLC 001431/2008) financed by EC, Laserlab-Europe project for Access to Research Infrastructures Lund University, Sweden 2009-2010.
2. "Theoretical and experimental investigation of quantum information translation in the process of interaction of ultracooled atoms and molecules", Bilateral agreement with Republic of China, Shanxi University, Taiyuan; ДО02-1/2008-2010.
3. "New applications of hollow cathode discharge in depth profile analysis of recent developed nano-structures and optogalvanic spectroscopy", Bilateral agreement with Institute of Physics – Jagellonian University, Krakow, Poland, 2008-2010.

DIVISION LASER, ATOMIC, MOLECULAR AND PLASMA PHYSICS

LABORATORY

METAL VAPOUR LASERS

HEAD: Prof. Nikola Sabotinov, D.Sc., Member of BAS
tel./fax: (+359 2) 8756 009; e-mail: n.sabotinov@issp.bas.bg

TOTAL STAFF: 19
RESEARCH SCIENTISTS: 14

Prof. Nikolay Vuchkov, D.Sc.; Assoc. Prof. Peter Telbizov, Ph.D.; Assoc. Prof. Dimo Astadjov, Ph.D.; Assoc. Prof. Margarita Grozeva, Ph.D.; Assoc. Prof. Todor Petrov, Ph.D.; Assoc. Prof. Krassimir Temelkov, Ph.D.; Assist. Prof. Krassimir Dimitrov; Assist. Prof. Vesselina Gentcheva, Ph.D.; Assist. Prof. Peter Zahariev, Ph.D.; Assist. Prof. Lubomir Stoychev, Ph.D.; Assist. Prof. Ognian Sabotinov, Ph.D.; Physicist Stefan Karatodorov; Physicist Blagovela Blagoeva; Technician Georgi Toshev; Engineer Ivan Radkov; Technical assistant Emilian Atanasov; Ph.D. student Stefka Slaveeva; PhD student Nina Koleva

RESEARCH ACTIVITIES:

RESEARCH AND DEVELOPMENT OF METAL VAPOR LASERS: new laser sources; optimization of the excitation and the geometry aimed at increased laser efficiency and beam quality; processes in the gas discharge plasma.

- The distribution of gas temperature along the radius of a nanosecond pulsed longitudinal discharge was determined theoretically at the cases of uniform and non-uniform power input in the discharge. The evaluations are for gas discharge tubes, typical to the created at the laboratory high-power lasers, generating in the deep ultraviolet (DUV), visible, and mid-infrared (MIR) spectral regions, as well as in different gas mixtures. Thermal conductivities of binary gas systems are calculated on the basis of 12-6 Lennard-Jones and rigid sphere inter-atomic interaction approximations for the case of gas discharges in He and Ne with small admixtures of copper, bromine, hydrogen and strontium. Assuming that the gas temperature varies only in the radial direction and using the calculated thermal conductivities, an analytical solution of the steady-state heat conduction equation is found. The average gas temperature is found by averaging the radial gas temperature distribution over the radius. By measuring the relative intensities of some He and Ne spectral lines, originating from different upper levels, the average electron temperature in the developed gas discharge tubes was evaluated.
- CuBr laser beam profile transformations are studied in a beam focusing experiment. A modeling via Fourier transform is also performed with annular beams of simplified flat two-level geometry of near field: bright outer ring with a darker core. The pattern of focal beam profile i.e. far field is calculated and characterized with respect of its intensity structure. As found beam annularity has small effect on far-field intensity pattern.
- A kinetic model based on a Monte-Carlo technique that computes the electron behaviour in a hollow cathode discharge is developed as a part of the PLASIMO toolkit. The model is tested by varying the input parameters and by comparing the output with the output obtained by the freeware Boltzmann equation solver BOLSIG+. Reliable information about the behavior of the electrons in the discharge is obtained. The Monte-Carlo module is applied to the case of a sputtering hollow cathode discharge excited Cu vapor laser. By modeling the

plasma at different discharge configurations the optimal conditions for efficient excitation of the plasma, produced by laser ablation in the hollow cathode discharge are determined.

LASER APPLICATIONS:

- A specialized optical bench was equipped for experiments with a spatial light modulator for manipulation and control of laser light, aimed at application of copper lasers for precision materials processing.
- Preliminary experiments for determination of the optical nonlinear characteristics of synthesized new 3-component glasses are done. It is found that the nonlinearity of the samples is of negative type in the terms of Z-scan techniques. Unique spectral properties of the newly synthesized TGN glass were found, compared to the Hoya V-10 glass.
- For diagnostics of archeological artifacts two laboratories for qualitative and quantitative spectral analysis were equipped: based on laser induced plasma (LIBS) and on the combination of laser ablation and emission analysis in a hollow cathode discharge (LA-HCD). The first test spectrums of Cu were obtained.
- An experimental bench for registration of thermo luminescence (TL) and optically stimulated luminescence (OSL) was built. Preliminary results of the archeological age of ceramic artifacts were obtained.

PUBLICATIONS:

1. K. A. Temelkov, N. K. Vuchkov, I. Freijo-Martin, R. P. Ekov, Theoretical and experimental determination of gas and electron temperatures for gas discharges in Ne and He mixtures with copper, bromine, hydrogen and strontium, *Journal of Physics D: Applied Physics* **43**, 075206, 8 pages (2010).
2. J. T. Mouchovski, K. A. Temelkov, N. K. Vuchkov, The growth of mixed alkaline-earth fluorides for laser host application, review-paper in *Progress in Crystal Growth and Characterization of Materials*, 1-41 (2010).
3. I. P. Iliev, S. G. Gocheva-Ilieva, K. A. Temelkov, N. K. Vuchkov and N. V. Sabotinov, An improved radial temperature model of a high-powered He-Sr-Br₂ laser, *Optics & Laser Technology* **43**, 642-647 (2011).
4. K. A. Temelkov, N. K. Vuchkov, I. Freijo-Martin and R. P. Ekov, Analytical calculation of the gas temperature and measurement of the electron temperature for gas discharges in Ne and He mixtures with copper, bromine, hydrogen and strontium, *Journal of Physics: Conference Series* **223**(1), art. No. 012004, (2010).
5. I. P. Iliev, S. G. Gocheva-Ilieva, K. A. Temelkov, N. K. Vuchkov, and N. V. Sabotinov, Temperature Model of a New High-powered SrBr₂ Laser, *AIP Conference Proceedings* **1301**, 138-145 (2010).
6. D Mihailova J van Dijk, M Grozeva, G J M Hagelaar, and J J A M van der Mullen, A hollow cathode discharge for laser applications: influence of the cathode length., *J. Phys. D: Appl. Phys.* **43** (2010) 145203, (2010)
7. D N Astadjov and S V Nakhe, CuBr laser beam transformations, *Journal of Physics: Conference Series* **253** (2010) 012076 / doi:10.1088/1742-6596/253/1/012076, (2010)
8. S. Ulm1, J. F. Eble1, P. Zahariev, F. Schmidt-Kaler, K. Singer, "Feedback-Optimized Operations with Linear Ion Crystals", *Journal of the Optical Society of America B* **27**, A99 (2010).

PATENTS: 5

ONGOING RESEARCH PROJECTS:

- Metal vapour lasers: processes in the gas discharge plasma and interaction between laser emission and materials (funded by the budget subsidy of BAS).
- Novel multi-component glass-like telluride matrixes having variable nonlinear optical properties (funded by NSF DO 02-305/2008)
- Laser methods for diagnostics in archaeology (funded by NSF DO 02-274/2008)
- High-End-Performance Solid-State-Power-Supply Copper Lasers for Fine Material Processing ('Indo-Bulgarian Programme of cooperation in Science & Technology: supported by Ministry of Education and Science of Bulgaria by Grant BIn3/07).
- Standardization of laser techniques for investigation and restoration of cultural heritage (Bulgarian-Romanian bilateral agreement: funded by NSF HTC 02-21/2010)
- Plasma technologies and their applications (under the Academy's bilateral agreements – IFFM, Gdansk, PAN, Poland)

APPLIED RESEARCH UNIT

MOLECULAR BEAM EPITAXY

HEAD: **Assoc.Prof. Gencho M. Minchev, Ph.D.**

Tel.: 9795683; e-mail: mbe@issp.bas.bg

TOTAL STAFF: **3**

RESEARCH SCIENTISTS: **2**

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

APPLIED RESEARCH ACTIVITIES:

METROLOGICAL SYSTEM FOR NANOMETER RANGE

Stage II of the Innovation Project “Nanoscope for enterprises and schools” subsidized by NIF of BSMEPA was successfully realized – i.e. second prototype “NanoSchubler” were design and build. It is a portable, inexpensive, ultra-linear ($< 0.01\%$) metrological instrument operating within nanometer range (10^{-9}m), thus being the exact instrument for small and medium enterprises that use or implement novel nanotechnologies.

The “NanoSchubler” unique linearity is based on novel approach that utilizes an intrinsically linear by its nature fundamental physical effect. The challenge was in precise manipulating of electric charge displacement (capacitive currents), what results in several inventions.



APPLIED RESEARCH RESULTS:

Within the scope of the Innovation Project four inventions were developed, what results in four pending patents: **№ 110 556**, **№ 110 557**, **№ 110 688** and **№ 110 689**.

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-macromolecules using purposely-modified Scanning probe microscopes”.

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:

New dynamic theory, some world recognized applied results in ballistics, and new for the country theoretical research in meteorology, astronomy and physical-chemistry are shown. Descriptions of non-holonomic mechanical system, kinetic theory of molecular crystal growth and condensation law are the first considerable theoretical results, obtained in Bulgaria. Extending third principle of Newton, Maneff's dynamic theory described motion by rotation around movable center. [1].

The new centre for history of physics "Echophysics", the sense of research for industry [2] and the future of European Physical Society are considered [3].

Some scientific results, obtained in the ISSP up to 2009 are shown in the nine documentary videos [4-12].

PUBLICATIONS:

1. G. Kamisheva, *The Roots of Theoretical Physics in Bulgaria*, Symposium "The Roots of Physics in Europe", (27-29 May 2010) Echophysics, EPS/HoP Proceedings 2010 (in press)
2. G. Kamisheva, *Symposium The Root of Physics in Europe*, World of Physics, No. 4, pp. 435-440, (2010) (in Bulgarian)
3. G. Kamisheva, *The future of European Physical Society*, The World of Physics, No. 3, pp. 348-349, (2010) (in Bulgarian)
4. *ISSP Presentation 1* http://www.youtube.com/watch?v=_7KHegkDoQ0 (13:12) 18.10.2010
5. *ISSP Presentation 2* <http://www.youtube.com/watch?v=Cs4J-QkNxmg> (8:42) 29.11.2010
6. *ISSP Discussion 1* <http://www.youtube.com/watch?v=9n5uqKKibek> (12:25) 01.12.2010
7. *ISSP Discussion 2* <http://www.youtube.com/watch?v=BcJeX2oZnlU> (12:12) 08.12.2010
8. *Acoustoelectronics* <http://www.youtube.com/watch?v=lWWZB9Hk3T4> (10:09) 31.07.2010
9. *Acoustoelectronics Lab.* <http://www.youtube.com/watch?v=1NCZCD6GRV4> (5:18) 2010
10. *Metal Vapour Lasers* <http://www.youtube.com/watch?v=sRsdiTGGmhg> (7:39) 11.09.2010
11. *Vesicles and Membranes* <http://www.youtube.com/watch?v=86aiGTe0QW4> (6:01) 30.07.2010
12. *Atomic Force Microscope* http://www.youtube.com/watch?v=N3sQ7A_aIzI (4:24) 30.07.2010