CONTENTS

Dear Colleagues,

2012 marked the 40th anniversary of the Institute of Solid State Physics. The 17th edition of our broadly recognized International School of Condensed Matter Physics was held in September 2012, dealing with Open Problems in Condensed Matter Physics, Biomedical Physics and their Applications. This School was devoted to the jubilee of ISSP. Further jubilee activities formed the focus of the year as well. The Jubilee session of the Institute took place in the great assembly hall of the Bulgarian Academy of Sciences on 16 October 2012. On this occasion ISSP was awarded the Marin Drinov Memorial Plaque by the President of the Academy. A Jubilee Collection of scientific results 2003-2013 was published under the editorship of A.G. Petrov and M.T. Primatarowa.

In 2012 the regular Internal Project Competition of the Institute took place. Three scientific projects were supported by modest levels of funding. Nevertheless, this internal funding promotes the scientific activity and attracts much attention among the scientists. Accounts of the scientific results of ISSP were reported 20 times in the media.

The total 2012 productivity of ISSP is 255 publications, 182 of them printed and 72 in press. 122 papers have been published in high impact factor or impact rank journals, including papers in Nature Photonics, Nature Comm., Proc. Natl. Acad. Sci. USA, Phys. Rev. A and B, etc. The total number of citations in 2012 is 905. Five books on the history of physics were published in Bulgarian. Five invited book chapters in prestigious books by foreign editors were published. ISSP currently holds and supports 13 BG patents.

Professor Elena Vateva received the Marin Drinov Honorary Medal of BAS. V. Lovchinov and S. Balabanov received the Sign of Honor of the Bulgarian Academy of Sciences. Professor Jerzy Mizeraczyk (PAS, Gdansk) was elected Honorary Member of the Institute. L. Pramatarova, S. Balabanov, N. Ivanov, E. Popova, D. Nesheva, S. Simeonov, M. Baeva, A. Szekeres and P. Ivanov were awarded the Georgi Nadjakov Sign of Honor 1st degree. Z. Aneva, A. Andreev, B. Zafirova, E. Nazarova, O. Ivanov, J. Tsenkova, N. Nikolchovski, Y. Koprinarova, G. Dobrev, I. Angelov, P. Telbizov, V. Georgieva, B. Panchev, S. Georgiev, N. Balchev, V. Velinova, A. Zahariev, M. Stefanova, L. Nikolova, E. Vlaikova, R .Kamburova, T. Mincheva, K. Panayotov, E. Zaharincheva, A. Stoyanova-Ivanova, Y. Marinov, T. Petrov, L. Tsvetanova, I. Velkova and L. Dedinska were awarded the Georgi Nadjakov Sign of Honor 2nd degree. Awards for the best scientific achievements of the year 2012 in ISSP were presented to the teams lead by Professor N. Ivanov and Assoc. Professor A.Stoyanova-Ivanova.

M. Gospodinov and T. Milenov were awarded the Gold Medal of the National Chiao Tung University, Taiwan. V. Steflekova received the prize of UNESCO and L'Oreal "For Women in Science". S.Terzieva was Second prize winner in the contest "Young & Energetic Scientists", European Researchers Night 2012 and winner in the Young scientists Contest 2012 - "The Bulgarian contribution to the contemporary research area", Annual panel "A LOOK INTO THE FUTURE" Silk Road – Inspirations by Ikuo Hirayama. Teams lead by J. Genova, V. Lovchinov, E. Atanassova, S. Tonchev and O. Ivanov were awarded with medals and diplomas of international conferences and exhibitions. They brought pride and satisfaction not only to their winners, but to the Institute as a whole.

Alexander G. Petrov

GEORGI NADJAKOV INSTITUTE OF SOLID STATE PHYSICS
Bulgarian Academy of Sciences

72, Tzarigradsko chaussee Blvd., 1784 Sofia, BULGARIA
Tel: (+359 2) 875 80 61, ***http:// www.issp.bas.bg***

Director:
Academician
Alexander G. Petrov, D.Sc.
tel.: 875 80 61, 979 5792
director@issp.bas.bg

Deputy Director:
Professor
Kiril Blagoev, Ph.D., D.Sc.
tel.: 979 5790
kblagoev@issp.bas.bg

Deputy Director:
Professor
Isak Bivas, Ph.D., D.Sc.
tel.: 979 5725
bivas@issp.bas.bg

Scientific Secretary:
Associate Professor
Marina Primatarowa, Ph.D.
tel.: 979 5785
prima@issp.bas.bg

Chairman of the SC:
Professor
Nikolay Tonchev, Ph.D., D.Sc.
tel.: 979 5702
tonchev@issp.bas.bg

Administrative Director:
Christo Popov, Dipl. Eng.
tel.: 974 60 52, 979 5700
popov@issp.bas.bg

Secretary:
Ljubomila Dedinska, Dipl. Eng.
tel.: 875 80 61, 979 5792
buba@issp.bas.bg

Accountant Office:
Eleonora Popova
tel.: 875 50 59, 979 5744
nora@issp.bas.bg

Administration Office:
Irina Velkova, Dipl. Eng.
tel.: 877 34 92, 979 5780
velkova@issp.bas.bg

Switch board:
979xxxx

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

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

EQUIPMENT, METHODS AND TECHNOLOGIES

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

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

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

ORGANIZATION OF THE INSTITUTE OF SOLID STATE PHISICS

DIRECTORATE

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

DIVISIONS

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

SCIENTIFIC COUNCIL

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

1. Acad. A. G. Petrov, D.Sc.
2. Acad. N. Sabotinov, D.Sc.
3. Prof. K. Blagoev, D.Sc.
4. Prof. M. Petrov, D.Sc.
5. Prof. M. Gospodinov, D.Sc.
6. Prof. S. Rashev, D.Sc.
7. Prof. I. Bivas, D.Sc.
8. Prof. H. Chamati, D.Sc.
9. Prof. D. Nesheva, D.Sc.
10. Assoc. Prof. M. Primatarowa, Ph.D.
11. Assoc. Prof. T. Milenov, Ph.D.
12. Assoc. Prof. V. Vitkova, Ph.D.
13. Assoc. Prof. O. Ivanov, Ph.D.
14. Assoc. Prof. P. Rafailov, Ph.D.
15. Assoc. Prof. E. Vlakhov, Ph.D.
16. Assoc. Prof. A. Paskaleva, Ph.D.
17. Assoc. Prof. E. Radeva, Ph.D.
18. Assoc. Prof. A. Szekeres, Ph.D.
19. Assoc. Prof. V. Mihailov, Ph.D.
20. Assoc. Prof. E. Dimova, Ph.D.
21. Assoc. Prof. D. Astadjov, Ph.D.
22. Assoc. Prof. K. Temelkov, Ph.D.
23. Prof. D. Dimitrov, Ph.D.

DIVISION THEORY

THEORETICAL DEPARTMENT

HEAD: **Prof. Hassan Chamati, D.Sc.**
tel: 979 5778; e-mail: chamati@issp.bas.bg

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

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

RESEARCH ACTIVITIES:

The ferromagnetic spin chain with both first- and second-neighbor interactions has been studied. We obtained the condition for the appearance and stability of bright and dark solitons for arbitrary wave number inside the Brillouin zone. The influence of the second-neighbor interaction and the anisotropy on the soliton properties is considered. The scattering of dark solitons from point defects in the discrete spin chain is investigated numerically.

We study the evolution of discrete (narrow) solitons in a system of coupled Ablowitz-Ladik (AL) chains. Two types of interchain coupling are investigated: one which admits reduction of the system to the standard (integrable) AL model and one which couples opposite sites of the chains and does not admit reduction to the AL model. The condition for a perfect soliton switching between the two chains is obtained and the characteristics of the different couplings are analyzed.

We investigated the melting properties of bulk nickel and the crystallization of nickel nanocrystals via molecular dynamics using a potential in the framework of the second moment approximation of tight-binding theory. The melting behavior was simulated with the hysteresis approach by subsequently heating and cooling gradually the system over a wide range of temperatures. The crystallization of nickel nanoclusters consisting of 55, 147 and 309 atoms was achieved after repeatedly annealing and quenching the corresponding quasicrystals several times to avoid being trapped in a local energy minimum. The time over which the global minimum was reached was found to increase with the cluster size.

The low-temperature elementary spin excitations in the AFM molecular wheel Fe_{18} were studied experimentally by inelastic neutron scattering and theoretically by modern numerical methods, such as dynamical density matrix renormalization group or quantum Monte Carlo techniques, and analytical spin-wave theory calculations. Fe_{18} involves eighteen spin-5/2 Fe^{III} ions with a Hilbert space dimension of ~ 10^{14}, constituting a physical system that is situated in a region between microscopic and macroscopic. The combined experimental and theoretical approach allowed us to characterize and discuss the magnetic properties of Fe_{18} in great detail. It is demonstrated that physical concepts such as the rotational-band or *L* and *E*-band concepts developed for smaller rings are still applicable. In particular, the higher-lying low-temperature elementary spin excitations in Fe_{18} or AFM wheels, in general, are of discrete antiferromagnetic spin-wave character.

The human organism is an integrated network where complex physiological systems, each with its own regulatory mechanisms, continuously interact, and where failure of one system can trigger a breakdown of the entire network. Identifying and quantifying dynamical networks of diverse systems with different types of interactions is a challenge. Here we

develop a framework to probe interactions among diverse systems, and we identify a physiological network. We find that each physiological state is characterized by a specific network structure, demonstrating a robust interplay between network topology and function. Across physiological states, the network undergoes topological transitions associated with fast reorganization of physiological interactions on time scales of a few minutes, indicating high network flexibility in response to perturbations. The proposed system-wide integrative approach may facilitate the development of a new field, Network Physiology.

Postural displacements in response to emotional activation have recently been proposed as a direct and objective index of approach–avoidance behavior in humans. Here, we present the results of an experiment designed to assess spontaneous postural responses to discrete affective pictures, briefly presented in random order of valence. Our findings question the interpretation of phasic postural responses to emotional stimuli as approach–avoidance behavior. Further, we identify a robust dynamical pattern, characterized by specific features indicating that attentional processes may play a role in human postural responses to emotional stimuli.

Coupled Ising models are studied in a discrete choice theory framework, where they can be understood to represent interdependent choice making processes for homogeneous populations under social influence. Two different coupling schemes are considered: the nonlocal or group interdependence model is used to study two interrelated groups making the same binary choice and the local or individual interdependence model represents a single group, where agents make two binary choices that depend on each other. For both models, phase diagrams and their implications in socioeconomic contexts are described and compared in the absence of private deterministic utilities (zero opinion fields).

PUBLICATIONS:

1. H. Chamati and K. Gaminchev, *Crystallization of nickel nanoclusters by molecular dynamics*, J. Phys.: Conf. Ser. 398 (2012) 012042; ISSN 1742-6596**.**
2. M. T. Primatarowa, R. S. Kamburova, *Dark solitons in ferromagnetic chains with first- and second-neighbor interactions*, Cent. Eur. J. Phys. **10** (2012) 1102; ISSN 1644-3608.
3. M T Primatarowa and R S Kamburova, Dynamics of narrow solitons in two Ablowitz-Ladik chains with different interchain couplings, J. Phys.: Conf. Ser. 398 (2012) 012041; ISSN 1742-6596.
4. J. Ummethum, J. Nehrkorn, S. Mukherjee, N. B. Ivanov, S. Stuiber, Th. Streassle, P. L. W. Tregenna-Pigott, H. Mutka, G. Christou, O. Waldmann, and J. Schnack, *Discrete antiferromagnetic spin-wave excitations in the giant ferric wheel* Fe_{18}**,** Phys. Rev. B **86** (2012) 104403.
5. A. Fernandez del Rio, E. Korutcheva and F.J. de la Rubia, *Interdependent binary choices under social influence: phase diagram for homogeneous unbiased populations*, Complexity **17** (2012) 31.
6. C. Escudero and E. Korutcheva, *Origins of scaling relations in nonequilibrium growth*, J. Phys. A: Math. Theor. **45** (2012) 125005.
7. C. Carretero-Campos, P. Bernaola-Galván, P. Ch. Ivanov and P. Carpena, *Phase transitions in the first-passage time of scale-invariant correlated processes*, Phys. Rev. E 85 (2012) 011139.
8. A. Bashan, R. P. Bartsch, J. W. Kantelhardt, S. Havlin and P. Ch. Ivanov, *Network physiology reveals relations between network topology and physiological function*, Nature Communications 3 (2012) 702.

9. R.P. Bartscha, A.Y. Schumannc, J.W. Kantelhardtd, T. Penzele, and P. Ch. Ivanov, *Phase transitions in physiologic coupling*, Proc. Nat. Acad. Sci. USA **109** (2012) 10181.
10. P. Bernaola-Galvan, J.L. Oliver, M. Hackenberg, A.V. Coronado, P.Ch. Ivanov, P. Carpena, *Segmentation of time series with long-range fractal correlations*, Eur. Phys. J. B **85** (2012) 211.
11. P.E. Perakakis, S. Idrissi, J. Vila, P.Ch. Ivanov, *Dynamical patterns of human postural responses to emotional stimuli*, Psychophysiology **49** (2012) 1225**.**

DIVISION THEORY

RESEARCH GROUP

COLLECTIVE PHENOMENA
in Condensed Matter

HEAD: **Prof. Dimo I. Uzunov, Ph.D., D.Sc.**
tel: 979 5834; e-mail: uzun@issp.bas.bg

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

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

RESEARCH ACTIVITIES:

1. A reliable description of the phase diagrams of unconventional ferromagnetic superconductors (UGe_2, UCoGe, …) is proposed on the basis of a general Ginzburg-Landau model. For this aim an additional term ($\sim\mathbf{M}^6$) in the expansion of the free energy in powers of the magnetization **M** is taken into account and a quadratic dependence of the phase transition temperature on the pressure is assumed.
2. In the framework of a general phenomenological theory of Ginzburg-Landau type the dependence of the first and the second critical magnetic fields on the pressure is established for unconventional ferromagnetic superconductors with p-type of Cooper pairing of the electrons. This allows for a justification of the theoretical analysis of the experiments on the outline of the phase diagrams**.**
3. A detailed study of the effect of magnetic fluctuations on the phase transition properties of unconventional ferromagnetic superconductors with p-wave pairing of electrons has been accomplished. The investigation includes effects of the crystal anisotropy and quenched disorder, as well.

PUBLICATIONS:

1. Dimo I. Uzunov, in: "Superconductors – Materials, Properties, and Applications", ed. by A. Gabovich (Intech, Rieka, 2012), ISBN 979-953-307-798-6. Chapter, Title: "Theory of ferromagnetic unconventional superconductors with spin-triplet electron pairing"; pp 125-140.
2. Dimo I. Uzunov, Phys. Rev. B (2013), in press.
   "Comment on "Fluctuation-induced first-order transition *p*-wave superconductors."

DIVISION MATERIAL PHYSICS

LABORATORY

ELECTRON-PHONON INTERACTIONS

HEAD: **Assoc. Prof. Ognyan Ivanov, Ph.D.**
tel: 979 5723; e-mail: ogi124@yahoo.com

TOTAL STAFF: **6**
RESEARCH SCIENTISTS: **3**

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

RESEARCH ACTIVITIES:

Upon the request of a Bulgarian company was developed a technology for the control of raw materials in ceramics production. In this regard were solved technical problems about homogeneity of the incoming raw materials, mixtures homogeneity, the point in the technological process where one has to put the device, specifying the parameters of the interaction, the form of the studied material and more. Upon the request of a company from Macedonia work was started on a technology for quality control of the thickness of layers. The initial studies have shown that exposing layers with different thickness to laser radiation generates electrical signals with varying amplitude. These results open the possibility to start research in this direction. Both studies are based on the surface photo-charge effect.

The properties of the outer crust of cold non-accreting magnetars were studied using the latest experimental atomic mass data complemented with a microscopic atomic mass model based on the Hartree-Fock-Bogoliubov method. It was found that the Landau quantisation of the electron motion in the magnetic field has a significant influence on the composition and the equation of state of the matter in the crust. It was also shown that the external crust of magnetars can be much more massive than that of ordinary neutron stars.

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

Investigations were conducted on the phase composition of proton-exchanged waveguides on Z-cut lithium crystals tantalate that were based on mode spectroscopy, infrared absorption spectroscopy and measurement of the mechanical stress occurring in the layer. The two phases, α and δ, are indistinguishable only by the change in the refractive index. In this sense, at least stressed phase is α and the phase with strongest mechanical stress is the highest protonated δ phase. That is why only the α phase retains its electro-optic coefficients. At this point there are conflicting views in the literature. This contradiction is explained to some extent by the introduction of a sublayer with thickness where the mechanical stress is minimal. In the case of lithium niobium the thickness of this sublayer is about 0.35 μm. For the δ phase electro-optic coefficients are not preserved, but the optical losses are smaller.

The influence of the shape of the excitation pulse on the spectral line in the case of a system with two levels under the influence of the laser field was studied. It was shown that for the class of pulses, having asymptotes with the time to the power of a negative number t^{-n} (for n> 1), the spectral line shrinks as $\Omega_0^{-1/(n-1)}$, where Ω_0 is the amplitude of the Rabi frequency of the transition. A class of pulses with exponential asymptotes was also analysed.

Two international consortium projects, that we participate in, qualified for funding – one is a FP7-Security project with a budget of over € 4.5 million and the other one is for the NATO Science for peace programme with a budget of € 350,000. We are currently finalising the negotiations for the contract signings.

PUBLICATIONS:

1. O. Ivanov, Zh. Stoyanov, B. Stoyanov, M. Nadoliisky, A. Vaseashta, *Fast, Contactless Monitoring of the Chemical Composition of Raw Materials*, In: Technological Innovations in Sensing and Detection of Chemical, Biological, Radiological, Nuclear Threats and Ecological Terrorism, A. Vaseashta, E. Braman, Ph. Susmann, (Eds.), Springer, ISBN: 978-94-007-2487-7, 185 - 189 (2012)

2. R.L. Pavlov, L.M. Mihailov, Ch.J. Velchev, N. Chamel, Zh.K. Stoyanov, Y.D. Mutafchieva, and M.D. Ivanovich, *Nucleus deformation induced effects in the electron system of multiply charged Helium like ions*, Proc. 31 Intenernatoinal Workshop on Nuclear Theory, 24-30 June 2012, Rila Mountains, Bulgaria.

3. N. Chamel, R.L. Pavlov, L.M. Mihailov, Ch.J. Velchev, Zh.K. Stoyanov,Y.D. Mutafchieva, and M.D. Ivanovich, *Eqiation of state of magnetar crusts*, Proc. 31 Intenernatoinal Workshop on Nuclear Theory, 24-30 June 2012, Rila Mountains, Bulgaria.

4. M. Kuneva, K. Christova, S. Tonchev, *Proton-exchanged optical waveguides in $LiTaO_3$: phase composition and stress*, J. Phys.: Conf. Ser. 398, 1, 2012, 012047, 6 pages.

5. N. Chamel, R.L. Pavlov, L.M. Mihailov, Ch.J. Velchev, Zh.K. Stoyanov,Y.D. Mutafchieva, and M.D. Ivanovich, *Outer crust of strongly magnetized neutron stars for Hartree-Fock-Bogoliubov mass models*, Phys. Rev. C 86, 055804 (2012).

6. K. Christova, S. Alexandrova, A. Abramov, E. Valcheva, B. Ranguelov, C. Longeaud, S. Reynolds, P. Roca i Cabarrocas, *Stress Characterization of Thin Microcrystalline Silicon Films*, International Review of Physics 6, p. 106 (2012).

7. M. Nadoliisky, Zh. Stoyanov, O. Ivanov, *Express contactless control of raw materials used in construction,* In: Science & Practice*,* B. Petrov, K. Mladenov (Eds.), Publishing house-UACEG, Sofia,405-409 (2012)

8. I. I. Boradjiev, N. V. Vitanov, *Power narrowing in coherent atomic excitation by smoothly-shaped pulsed fields*, Opt. Commun. 288, 91 (2013).

9. O. Ivanov, A. Vaseashta, *A method for fast and contactless control of raw materials*, Ceramics International*,* (In press).

10. N. Chamel, R.L. Pavlov, L.M. Mihailov, Ch.J. Velchev, Zh.K. Stoyanov,Y.D. Mutafchieva, M.D. Ivanovich, A.F. Fantina, J.M. Pearson and S. Goriely, *Equation of state of magnetar crusts from Hartree Fock Bogoliubov atomic mass models*, ASP (Astr. Society of the Pacific), Conference Series (2012), in print.

ONGOING RESEARCH PROJECTS:

- Electronic properties of solid state systems (BAS)

- Quantum qimulations and adiabatic techniques in quantum-information technologies (NSF)

- Spatiotemporal study of low pressure and low temperature hollow cathode discharge (bilateral project)

DIVISION MATERIAL PHYSICS

LABORATORY

CRYSTAL GROWTH AND STRUCTURAL METHODS

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

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

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

RESEARCH ACTIVITIES:

In the research scope of the Laboratory following activities were undertaken: Phase transitions in PbSc0.5Ta0.5O3 (PST) crystals doped with La and Ba were investigated as well as their influence on the ferroelectric and the relaxor properties of the crystals. Optical spectroscopy and structural methods were applied to examine band structure changes in AWO4 (A = Mg, Zn, Cd and Mn) and structural transformations in relaxor-type perovskites ABO3 - 0.9PbZn(1/3)Nb(2/3)O(3)0.1PbTiO occurring under high pressure. Single crystals of HoMnO3 and LuMnO3 as well as hexagonal rare-earth manganates RMnO3 (R = Er, Tm, Yb) were investigated with infrared spectroscopy at low temperatures. The strong magneto-electric effects in HoMnO3 are due to charge transfer between the Ho3+ ions and the apical oxygen atoms. The Neel temperature in Neel в RMnO3 (R = Er, Tm, Yb) decreases with increasing of the lattice constant.

Results from magnetic measurements on a single crystal of La1.67Pb0.33Co0.90Mn1.05Pt0.05O6, a derivative of La_2CoMnO_6 doped with Pb and (Pb+Pt), suggest that it predominantly consists of an ordered Co2+/Mn4+ phase, as inferred from the determined saturation magnetization in the range of6.4 mB/f.u. Some amount of statistically randomly distributed Mn3+ in Co positions also contribute to this relatively high level, but complicates the determination of the crystal structure with X-ray diffraction. Additional verification with polarized Raman spectroscopy supports the conclusion for a predominant monoclinic structure. Single crystals of the mixed valence compound (Mn3+/Mn4+) Pb3Mn6.2Ni0.8O15 were successfully grown and their dielectric and transport properties were investigated in the temperatures and different frequencies. The results show an increase of the dielectric constant with temperature and frequency and indicate a relaxation process, attributed to polaron hopping. From DC results the activation energy has been calculated.

A single crystal of the sillenite compound $Bi_{12}(Fe0.86Bi0.14)O_{20}$ was tested with X-ray diffraction and Raman spectroscopy. The effects from the non-equivalence of Bi and Fe in tetrahedral positions turn out to be compensated by preferred absorption of Mn5+, As5+ and V5+ and Te6+ and Cr6+ ions from the melt during the crystal growth process.

Multiwalled nanotubes of WS_2 were investigated with Raman spectroscopy at different resonant conditions and under high pressure. We show that the A-exciton energy gradually diminishes with decreasing of the nanotube diameter due to the increasing curvature-induced deformation of the WS_2 layer. Carbon nanotubes were deposited with preferred orientation on a glass plate for application as a liquid crystal cell wall. The

necessary check of the orientational order of the nanotubes was accomplished with polarized Raman spectroscopy using the so-called antenna effect due to the highly anisotropic optical-absorption response of carbon nanotubes.

The behaviour of complex systems was modelled and following results were obtained: distribution of extremely high water levels of the river Elbe, saltiness limits for ocean water, non-linear waves in lattices and in population dynamics etc. The application of the regional-development theory of Nobel-price winner Paul Krugman to the Bulgarian regions is discussed.

PUBLICATIONS:

1. Dul'kin, E; Mihailova, B, Gospodinov, M., Roth, M., *Effect of A-site La and Ba doping on threshold field and characteristic temperatures of PbSc0.5Ta0.5O3 relaxor studied by acoustic emission*, JOURNAL OF APPLIED PHYSICS **112** Issue: 6 (2012) Article Number: 064107 DOI: 10.1063/1.4752400.

2. Waeselmann, N ; Maier, BJ ; Mihailova, B ; Angel, RJ 1,2,3; Zhao, J J.; Gospodinov, M; Paulmann, C ; Ross, N ,Bismayer, U , Pressure-induced structural transformations in pure and Ru-doped 0.9PbZn(1/3)Nb(2/3)O(3)-0.1PbTiO(3) near the morphotropic phase boundary, PHYSICAL REVIEW B Volume: **85** Issue: 1 (2012), Article Number: 014106 DOI: 10.1103/PhysRevB.85.014106.

3. Vermette, J ; Jandl, S 1; Orlita, M ; Gospodinov, MM , *Role of the apical oxygen in the low-temperature magnetoelectric effect in RMnO3 (R = Ho and Lu*), PHYSICAL REVIEW B Volume: **85** (2012) Article Number: 134445, DOI: 10.1103/PhysRevB.85.134445.

4. Ruiz-Fuertes, J ; Lopez-Moreno, S ; Lopez-Solano, J ; Errandonea, D 1; Segura, A, Lacomba-Perales, R 1; Munoz, A ; Radescu, S ; Rodriguez-Hernandez, P , Gospodinov, M ; Nagornaya, LL ; Tu, CY, *Pressure effects on the electronic and optical properties of AWO(4) wolframites (A = Cd, Mg, Mn, and Zn): The distinctive behavior of multiferroic MnWO4* **,** PHYSICAL REVIEW B Volume: **86** Issue: 12 (2012) Article Number: 125202 DOI: 10.1103/PhysRevB.86.125202.

5. Kovacs, L ; Lengyel, K ; Gospodinov, M, Optical Spectroscopy of Multiferroic Rare-Earth Manganites, FERROELECTRICS Volume **428**, pp. 82-86 (2012), DOI: 10.1080/00150193.2012.675292.

6. A. V. Egorysheva, V. D. Volodin, I. V. Berezovskaya, E. V. Zubar', V. M. Skorikov, T. Milenov, and P. Rafailov, *Effect of Eu2O3 Doping on the Crystallization Behavior of BaO–Bi2O3–B2O3 Glasses*, Inorganic Materials, 2012, Vol. **48**, No. 9, pp. 948–952.

7. T.I. Milenov, P.M. Rafailov, I. Urcelay-Olabarria, E. Ressouche, J.L. Garcı´a-Mun˜oz, V. Skumryev, M.M. Gospodinov, *Magnetic behavior of La2CoMnO6-d crystal doped with Pb and Pt*, Materials Research Bulletin **47** (2012) 4001–4005.

8. M. Staiger, P. M. Rafailov, K. Gartsman, H. Telg, M. Krause, G. Radovsky, A. Zak, and C. Thomsen, Excitonic resonances in WS2 nanotubes, PHYSICAL REVIEW B **86**, 165423 (2012), DOI: 10.1103/PhysRevB.86.165423.

9. M. Petrov, B. Katranchev, P. M. Rafailov, H. Naradikian, U. Dettlaff-Weglikowska and E Keskinova, *Optical properties of dimeric liquid crystals doped with single-walled carbon nanotubes*, Journal of Physics: ConferenceSeries **398** (2012) 012035.

10. Z. I. Dimitrova, N. Hoffmann, *On the probability for extreme water levels of the river Elba in Germany*, Comptes rendus de l'Academie bulgare des Sciences **65** (2), pp.153-159 (2012).

11. Z.I. Dimitrova and N.K. Vitanov, On the variational problem for the upper bounds of solute transport in double-diffusive convection, Comptes rendus de l'Academie bulgare des Sciences, **65** (7), pp. 905-912 (2012).

12. Z.I. Dimitrova, *On travelling waves in lattices: the case of Riccati lattices*, Journal of Theoretical and Applied Mechanics, **42** (3), pp. 3-22, (2012).
13. N.K.Vitanov.and Z.I. Dimitrova, On Waves and Distributions in Population Dynamics, Biomath, **12** (1), A013(1-6), (2012).
14. V. Tomov, Dielectric and Transport Properties of Pb3Mn 6.2Ni 0.8O15 Single Crystals, Comptes rendus de l'Academie bulgare des Sciences, **65** (3), 323 (2012).

ONGOING RESEARCH PROJECTS:

Financed by the Bulgarian National Scientific Research Foundation at the Bulgarian Ministry of Education and Science:
DRNF 02/1: "Structural characterization of novel crystalline materials" – April 2013.
Financed by the UINR – Dubna:
"Structure and properties of topological insulators in the systems Bi-Se and Bi-Te doped with copper and manganese"

COLLABORATION:

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

DIVISION MATERIAL PHYSICS

LABORATORY

BIOCOMPATIBLE MATERIALS

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

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

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

1. RESEARCH AREA OF THE LABORATORY

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

2. MAIN SCIENTIFIC RESULTS IN 2012

- Composite layers of hydroxyapatite/nanodiamond (HA/DND) and polymer/nanodiamond (PPHMDS/DND) were prepared on various substrates and they were investigated with AFM, SEM/EDX, CPM (coherence probe microscopy), FTIR based on our collaboration in the framework of the bilateral projects of the laboratory with the Hungarian and Latvian Academies of Sciences, as well as with the InESS-CNRS, France.
- A method of the simultaneous interaction of few stimuli was improved, namely laser-liquid-solid interaction (LLSI) method, and used for the preparation of the composite layers described above. The method utilizes the simultaneous use of a scanning pulsed laser beam and a liquid precursor solution (simulated body fluid) in the presence of the solid substrate. It is used to create micrometer-scale architecture on the substrate surface with precisely controlled shapes and sizes by a laser beam. This method can contribute significantly to coating of materials with complex shapes, thus having direct application in medicine, dentistry and tissue engineering.
- The biological activity of the composite layers was tested with osteoblast cells in cooperation with the Institute of Biophysics and Biomedical Engineering-BAS, more

specific the kinetics of deposition of a special human protein (fibronectin) on the composite layers was investigated.

3. NATIONAL AND INTERNATIONAL PROJECTS IN 2012

- "Biomaterials and surfaces: modification of solid surfaces by nanodiamond as models for the growth of implant coating", national project, leader Assoc. Prof. Dr. Lilyana Pramatarova, head of the laboratory, with the cooperation of the Institute of Biophysics and Biomedical Engineering-BAS.
- "Improving the method of white light interferometry for studying thick and rough coating of HA and HA/DND composite layers", international PICS project with the InESS-CNRS, Strasbourg, France, leader Assoc. Prof. Dr. Lilyana Pramatarova, with the cooperation also of the University of Strasbourg.
- "Growth and characterization of hydroxyapatite composites as scaffolds for hard tissue regeneration", international project with the Hungarian Academy of Sciences, within the frame of the bilateral agreements of the BAS, leader Assoc. Prof. Dr. Emilia Pecheva.
- "Investigation of hydroxyapatite - nanodiamond composite coating", international project with the Latvian Academy of Sciences, within the frame of the bilateral agreements of the BAS, leader Assoc. Prof. Dr. Emilia Pecheva.

4. PROJECTS IN 2013

- "Role of substratum elasticity in osteoblast differentiation of mesenchymal stem cells", national project with the Bulgarian Science Fund, leader for the ISSP Assoc. Prof. Dr. Lilyana Pramatarova, with the cooperation also of the Institute of Biophysics and Biomedical Engineering-BAS and the University of Chemical Technology and Metallurgy, 2012-2014.
- "Growth and characterization of hydroxyapatite composites as scaffolds for hard tissue regeneration", international project with the Hungarian Academy of Sciences, bilateral agreement of the BAS, leader Assoc. Prof. Dr. Emilia Pecheva, 2013-2015.
- "Investigation of hydroxyapatite - nanodiamond composite coating", international project with the Latvian Academy of Sciences, bilateral agreement of the BAS, leader Assoc. Prof. Dr. Emilia Pecheva, 2012-2014

5. TEACHING ACTIVITIES AT THE LABORATORY

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

6. PUBLICATIONS, PARTICIPATIONS AT INTERNATIONAL CONFERENCES AND CITATIONS IN 2012

- E. Pecheva, L. Pramatarova, T. Hikov, K. Hristova, G. Altankov, P. Montgomery, T. Hanawa, Electrodeposition of Hydroxyapatite-Nanodiamond Composite Coating on Metals. Interaction with Proteins and Osteoblast-like Cells, Ch.11, p. 21, in: Electrodeposition: Properties, Processes and Applications, Udit Surya Mohanty (Ed.), Nova Publishers, USA, September 2012, Ch.11, pp. 233-253
- T. Hikov, L. Pramatarova, N. Krasteva, E. Radeva, P. Petrik, E. Agocs, E. Pecheva, R. Presker, O. Sabotinov, Study of nanocomposite layers based on polymer and

nanodiamond particles: new materials for medical implants, Bulgarian J. Physics 39 (2012) 297-308

- L. Pramatarova, E. Pecheva, E. Radeva, T. Hikov, N. Krasteva, R. Dimitrova, T. Spassov, P. Petrik, Advantages of polymer composites with detonation nanodiamond particles for biomedical applications, participation at the 17th International School on Condensed Matter Physics, 2-7 September 2012, Varna, Bulgaria
- L Pramatarova, T Hikov, N Krasteva, P Petrik, R Dimitrova, E Pecheva, E Radeva, E Agocs, I. Georgiev, R. Presker, Protein Adsorption on Composite Layers of the Type Detionation Nanodiamond/Polymer, poster presented at the XXI International materials research congress, 12 - 17August 2012, Cancun, Mexico
- L. Pramatarova, R. Sammons, C. Balazci, P. Petrik, T. Hikov, L. Illes, E. Radeva, E. Pecheva, Biomineralisation on the Composites of Silicon-Based Polymer and Nanodiamond Particles by a Species of *Serratia* Bacteria, poster presented at the International symposium on new frontier of Advanced Si-Based Ceramics and Composites, 25-28 March, 2012, Seoul, Korea
- 16 citations for 2012 of the papers published by the laboratory

DIVISION NANOPHYSICS

LABORATORY

PHOTOELECTRICAL AND OPTICAL PHENOMENA IN WIDE BAND GAP SEMICONDUCTORS

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

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

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

RESEARCH ACTIVITIES:

1. NANOSTRUCTURED THIN FILMS

Atomic Force Microscopy (AFM) and X-ray diffraction (XRD) were applied to explore the evolution of the crystal structure, microstructure, composition and surface morphology upon furnace annealing of $Zn_xCd_{1-x}Se$ thin films (400 nm) with various composition at 200 °C and 400 °C in an inert atmosphere. It has been found that as-deposited films were nanocrystalline with a grain size less or around 10 nm and cubic structure. Upon annealing the cubic structure has been preserved, the nanocrystals size has increased and the root mean square roughness of the film surface has strongly decreased. AFM phase images have revealed existence of a second phase on the surface of as-deposited films which disappeared after annealing. Raman scattering measurements performed at different temperatures and laser beam intensities have revealed phase separation at high light intensities.

3D quantum dot assembles of In_2S_3 and pure chalcopyrite $CuInS_2$ prepared in thin film form by two approaches - template-free conventional chemical and sonochemical route - were investigated. The sonochemical route has resulted in additional crystal size decrease when compared with the conventional approach. According to AFM studies, the QD assemblies constituting the sonochemically deposited films have shown stronger tendency towards coagulation than those synthesized by conventional approach. For $CuInS_2$, XRD data have indicated that high internal strain exists in the as-prepared samples. Upon annealing, a process of phase transition to $Cu_{1.7}In_{0.3}S$ occurred. The observed temperature induced structural changes have occurred faster in the sonochemically obtained samples.

Metal-oxide-semiconductor (MOS) structures contain silicon nanocrystals were prepared which are suitable for dosimetric applications. Transmission electron microscopy results confirmed formation of Si nanocrystals (2-3 or 4-6 nm) in the $SiO_{1.15}$ layer of the sputtered SiO_2-$Si_{1.15}$-thermal SiO_2 three layer gate dielectric upon high temperature annealing for 30 min or 60 min in an inert atmosphere. Conductivity measurements performed have shown that the density of the interface states is $< 10^{10}$ cm^{-2} eV^{-1}. High-frequency current-voltage measurements have given a value of $\sim 10^{10}$ cm^{-2} for the charge fixed in the oxide. It is concluded that the procedure of formation of the three-layer gate and Si nanocrystals do not

deteriorates its excellent properties. The effect of the X-ray irradiation on the properties of electrically charged and uncharged MOS structures was investigated. It has been found that after several charging-discharging cycles the values of both interface defect density and fixed electrical charge kept constant. These results make possible development of dosimeter for ionizing radiations of manifold use.

2. CHALCOGENIDE GLASSES AND THIN FILMS

The structure of two-, three-and quaternary chalcogenide glasses of $As_{40}Se_{60}$, $As_{40}Se_{60-x}Te_x$ (x = 10 and 15), $Ge_xSb_{40-x}S_{50}Te_{10}$ and $Ge_xSb_{40-x}Se_{50}Te_{10}$ (x = 20 and 27) were studied by neutron and X-ray diffraction. Neutron diffraction data have shown that the synthesized glasses are completely amorphous. Both traditional Fourier transformation technique and reverse Monte Carlo modeling 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 the first and second neighbour distances, coordination numbers and bond-angle distributions have been calculated. On the basis of the density data and model simulation of the atomic glassy network for each composition, the basic physical parameters of packing density, average atomic volume and compactness have been evaluated. In the Ge-based glasses the results identify Ge related tetrahedral structural units and Sb related trigonal pyramidal units, which are more defective and/or distorted in the S-containing glasses.

The compositional dependence of optical parameters of thin chalcogenide films from Ge-Sb-Se and Ge-Sb-Se-AgI systems was studied by spectroscopic ellipsometry in the spectral range 190–1600 nm. The optical constants n, k, ε and optical band gap E_g were determined. The refractive index dependence was analyzed in the spectral region below the absorption edge by the Wempel-DiDomenico single-oscillator model and the oscillator energies E_0 and E_d were elucidated from the analysis of the dispersion dependences.

New results have been published on the light annealing effect (LAE) in photodarkened Ge-As-S films which has been explained only on the basis of dual action of light (DAL). It is established that initially light increases the magnitude of the photodarkening (PD), but the long term illumination provokes PD decrease leading to photobleaching (PB), competing with PD. We have shown that this PB is not related to photooxidation on the film surface (as accepted by many authors), because PB has been obtained upon illumination through the transparent substrate with highly absorbed monochromatic light with penetration depth about 5 times lower than the film thickness. The found direct evidence that the DAL governs the photoinduced phenomena in chalcogenides can clarify many of their peculiarities.

A switching effect, that is transition from high to low resistance state on application of high electric field, has been explored in thermally evaporated amorphous films from $Ge_{15}Sb_5Te_{80}$ и $(GeSe)_{81}(GeTe)_9(ZnTe)_{10}$ alloys in collaboration with scientists from the Joffe Physico-Technical Institute, St. Petersburg –Russia. This investigation was carried out because the chalcogenides are perspective materials for use in optical and electrical memory media. The obtained results have been compared with those of the widely studied $Ge_2Sb_2Te_5$ (GST 225) films, which are the main material considered for electrical switching application. It has been found that the $Ge_{15}Sb_5Te_{80}$ films develop stable memory media with switching parameters close to parameters of $Ge_2Sb_2Te_5$.

The effect of caesium halides CsX (X=Cl, Br, I) addition on the luminescence efficiency of chalcogenide Ge-S-In (Ga) glasses has been investigated by transmission and photoluminescence (PL) spectroscopy. It has been established that the PL band shift towards higher energies for CsI is considerably higher than that for CsCl and CsBr. The influence of doping element (Pr, Dy, Nd, Sm и Ho) on PL efficiency at $Ge_{25}Ga_{1.7}As_{8.3}S_{65}$ host is specified. It has been found that at 4 K the re-absorption of the matrix luminescence could be observed simultaneously with 4f-4f radiative transitions in Er^{3+} ions.

The glass formation in Sb_2O_3-PbO-ZnO and Sb_2O_3-PbO-ZnS systems has been studied. PL spectra of Er-doped samples measured at room temperature show all 4f-4f optical transitions in the range of 600–1600 nm. A broad PL band at ~1000 nm with enhanced intensity at higher Er-doping has been observed at low temperature. The effect of PL quenching is explained assuming non-radiative energy transfer from defect states in the matrix to Er dopants. Basic spectroscopic and radiative parameters of new heavy metal oxide Sb_2O_3-Na_2O-ZnO: xEr_2O_3 (x=0.25, 0.5 and 1.0 mol%) glasses have been determined by applying the Judd-Ofelt analysis. The results from PL spectroscopy show that the synthesized new glasses can be used as laser media and in telecommunications as optical amplifiers ~1.5 μm.

PUBLICATIONS:

1. V. Donchev, D. Nesheva; D. Todorova, K. Germanova; E. Valcheva, "Characterisation of Si-SiOx nanocomposite layers by comparative analysis of computer simulated and experimental infra-red transmission spectra", Thin Solid Films **520**, 2085-2092 (2012).
2. D. Nesheva, Z. AnevA, M. J. Šćepanović, Z. Levi, Z. V. Popović, I. Miloushev, "Raman scattering characterization of ZnSe/$Z_{n0.6}C_{d0.4}$Se multilayers prepared by thermal vacuum evaporation", Phys. Status Solidi (a) **209**, No.5, 949–952 (2012).
3. Nesheva,"Photoluminescence from SiO_x layers containing amorphous silicon nanoparticles", Physica Status Solidi, Phys. Status Solidi (a) **209**, No.4, 746–751 (2012).
4. N. Nedev**,** E. Manolov, D. Nesheva, K. Krezhov, R. Nedev, M. Curiel, B. Valdez, A. Mladenov, Z. Levi "Metal-Oxide-Semiconductor structures containing silicon nanocrystals for application in radiation dosimeters", Sensor Letters **10**, No 3/4, pp. 837-843 (2012).
5. N. Nedev, E. Manolov, D. Nesheva, K. Krezhov, R. Nedev, M. Curiel, B. Valdez, A. Maldenov, Z. Levi, "Radiation dosimeter based on Matal-Oxide-Semiconductor structures containing silicon nanocrystals", Key Engineering Materials **495,** 120-123 (2012).
6. Vateva, D. Arsova, I. Milouhev, "On dual action of light and light annealing effect in chalcogenide films", J. Optoelectron. Adv. Mater. – Rapid Comm. **6** (11-12) 997-998 (2012).
7. M. Fábián, E. Sváb, V. Pamukchieva, A. Szekeres, P.Petrik, S. Vogel, U. Ruett, "Study of As-Se-Te glassy by neutron-, X-ray diffraction and optical spectroscopic methods", Journal of Non-Crystalline Solids **358,** 860–868 (2012).
8. V. Pamukchieva, K. Todorova, O.C. Mocioiu, M. Zaharescu, A. Szekeres, M. Gartner," IR studies of impurities in chalcogenide glasses and thin films of the Ge-Sb-S-Te system", Journal of Physics:ConferenceSeries **356,** 012047 (2012).
9. I Bineva, D Nesheva, B Pejova, M Mineva, Z Levi and Z Aneva "Annealing induced changes in ternary nanostructured $Zn_xCd_{1-x}Se$ thin films: structure and morphology" 17 ISCMP, Journal of Physics: Conference Series **398,** 012015 (2012).
10. N Starbov, S Balabanov, I Bineva, A Rachkova, E Krumov and K Starbova „Al doped ZnO thin films – microstructure, physical and sensor properties" 17 ISCMP, Journal of Physics: Conference Series **398** 012019 (2012).
11. B Katranchev, M Petrov, I Bineva, Z Levi and M Mineva „Smectic C liquid crystal growth through surface orientation by $Zn_xCd_{1-x}Se$ thin films" 17 ISCMP, Journal of Physics: Conference Series **398** 012036 (2012).
12. D. Nesheva, N. Nedev, M. Curiel, I. Bineva, B. Valdez and E. Manolov, "Silicon Oxide Films Containing Amorphous or Crystalline Silicon Nanodots for Device Applications", глава в книгата Quantum Dots – A Variety of New Applications, Ed. A.-A Ameenah, InTech, April, 2012, chapter 9, 183-206.

13. D. Nesheva, Nanosized and nanostructured II-VI semiconductors: chemical sensor applications, Technological Innovations in Sensing and Detection of Chemical, Biological, Radiological, Nuclear Threats and Ecological Terrorism, Eds. A. Vaseashta, E. Braman, Ph. Susmann, NATO Science for Peace and Security Series A: Chemistry and Biology, 2012, pp.159-164.
14. D. Nesheva, M. Ailavajhala, P. Chen, D. A. Tenne, H. Barnaby, M. Mitkova, Studies of gamma radiation induced effects in Ge-rich chalcogenide thin films, Proc. First Int. Conf. Radiation and Dosimetry in Various Fields of Research, 25-27.04.2012, Nis, Ed. G. Ristic, University of Nis, Nis 2012, pp.19-22.

ONGOING RESEARCH PROJECTS:

Financed by the Bulgarian Academy of Sciences:

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

Financed by the Bulgarian Ministry of Education, Youth and Science:

1. New amorphous and glassy materials based on Ge suitable for sensor applications, Contract D002-123/12.2008.
2. Characterization of new chalcogenide materials by atomic force microscopy, Contract DMU 03-91/12.2011.
3. Electrical conductivity, photoconductivity and gas sensitivity of Ge-Se-Te thin films, Contract D02-743/08.2012.

COLLABORATION:

1. Preparation and investigation of optical properties of semiconducting glasses for photonic applications, Institute of Photonics and Electronics, Prague, 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. Multicomponent chalcogenide semiconductors thin films suitable for phase change memory, Joffe Physico-Technical Institute, St. Petersburg, Russia.

DIVISION NANOPHYSICS

LABORATORY

SEMICONDUCTOR HETEROSTRUCTURES

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

TOTAL STAFF: **7**
RESEARCH SCIENTISTS: **3**
ASSOC. MEMBERS: **4**
Assoc. Prof. A. Szekeres, Ph.D.; Assoc.Prof. N. Peev, Ph.D.; Assist. S. Bakalova, Ph.D;
Assoc. Prof. S. Simeonov, Ph.D.; Assoc. Prof. P. Danesh, Ph.D.; Prof. S. Kaschieva, D.Sc.; Prof. S. Alexandrova, D.Sc.

RESEARCH ACTIVITIES:

In 2012 we continued the research on the study of structure, and optical, mechanical and electrical properties of Si-based semiconductor heterostructures with nano-sized dielectric layers and with nanostructured semiconductor films obtained by applying advanced technologies of plasma immersion implantation and laser ablation concerning their possible applications in nanoelectronics and optoelectronics.

1. NANOSTRUCTURED AlN FILMS SYNTHESIZED BY PULSED LASER ABLATION

In 2012 the studies of the structure and properties of AlN films synthesized by pulsed laser deposition (PLD) under different incident laser fluences (4.8, 8.6 and 10 J/cm^2) were continued (Fig. 1). Results of XRD and TEM measurements showed that 4.8 J/cm^2 layers grow in stable polycrystalline structure with hexagonal crystallites. By increasing the laser fluence to 8.6 J/cm^2 the films are also polycrystalline, but the crystallites grow in both stable hexagonal and metastable cubic phases leading to a more defective structure. The large shift of the vibrational bands of Al-N chemical bonds, registered by surface-enhanced Raman spectroscopy (SERS), is an evidence for increased internal stresses in these films. Some of phonon frequencies in the SERS spectra cannot be observed with standard Raman spectroscopy and this is attributed to surface effects. Vibrational band related to Al-O chemical bonds (at 420 cm^{-1} in the SERS spectra) appears only for films deposited in vacuum or at low nitrogen pressure (10^{-4} Pa, 0.1 Pa) as a result of film surface oxidation. Surface roughness shows a slight tendency to increase with increasing the laser fluence. The root mean square roughness value is in the range of 0.2 - 5 nm, depending on N_2 pressure.

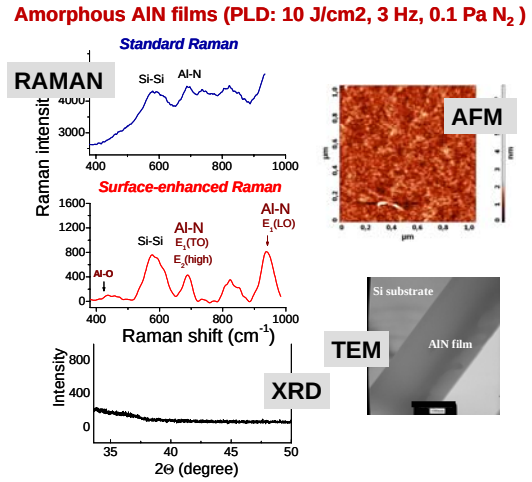


Fig. 1 Results on the study of PLD AlN films deposited with an incident laser fluence 10 J/cm^2 and laser repetition rate 3 Hz at N_2 pressure 0.1 Pa.

2. NANOSIZED SiO_2, SiO_x and SiO_xN_y LAYERS IN SILICON

Thin layers of silicon oxide and oxynitride were grown by annealing of silicon wafers, the surface of which are modified by RF Plasma Immersion Ion (PII) implantation of nitrogen with a dose of 10^{16} -10^{18} cm^{-2}. The annealing was performed at 1050°C in dry xygen for periods of 10 to 30 minutes. The profiles of the implanted atomic (N^+) and molecular (N_2^+) nitrogen particles were modeled with considering diffusion processes during annealing. From the VIS-ellipsometric data analysis, low refractive index values of SiO_xN_y layers and presence of Si particles were registered, being dependent on N^+ ion fluence. From the analysis of IR-ellipsometric data, Si-O, Si-N Si-NO and Si-Si chemical bonds in the formed layers were established. The XPS results were in good accordance with the ellipsometric models and confirmed the presence of Si-N and Si-Si bonds in the layers. Depending on N^+ ion fluence and annealing time, the grown layers on Si were identified as SiO_xN_y with low nitrogen content or SiO_2 enriched with nitrogen (Fig. 2).

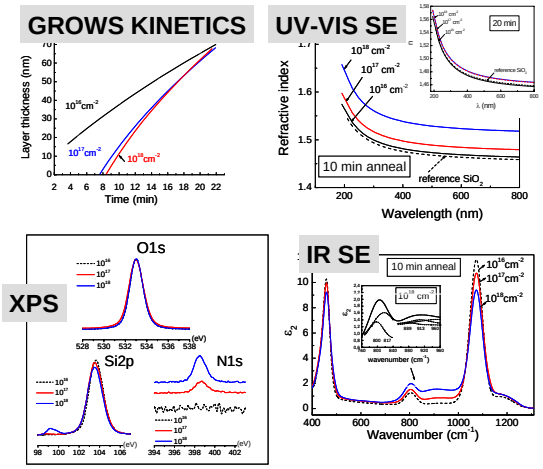


Fig. 2 Results on the study of SiO_xN_y layers grown into N^+ ion implanted Si during annealing at 1050°C in dry O_2.

In 2012 we started the study of the structure and optical properties of thin surface layers of silicon wafers hydrogenated by PII of H^+ ions with different (10^{13} - 10^{15} cm^{-2}) doses (Fig. 3). From the UV-VIS ellipsometric measurements, the composition and change of dielectric function of the modified near-surface layer of Si were obtained. By applying multilayer optical models, it was established that H^+ ion implantation into Si proceeds through a ~ 3 nm thick native SiO_2. The thickness of the hydrogenated near-surface Si layer varies from 23 nm to 14 nm, with a tendency of decrease with increasing H^+ ion fluence. This effect is explained with increased formation of highly hydrogenated surface, which prevents further penetration of H^+ ions inwards the Si depth. This is especially pronounced in the largest H^+ dose. The hydrogenation-induced stress in the Si layer causes energy shift of peaks in the ε_2 spectra at 3.4 eV and 4.2 eV related to interband transition of electrons in Si. From this energy shift, the tensile stress is estimated to be in the order of 10^8 N/cm^2 but still remaining rather low, below ~$3x10^8$ N/cm^2 , even in case of implantation with highest H^+ ion fluence.

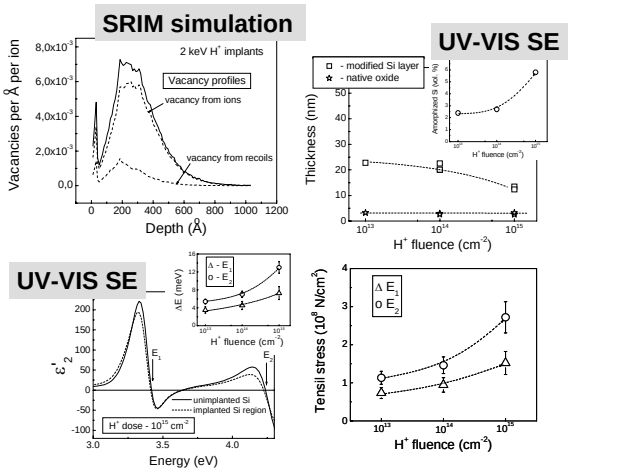


Fig. 3 Results on the study of thin Si surface layers modified by plasma immersion H^+ implantation with energy 2 eV and ion fluence 10^{13} -10^{15} cm^{-2}

3. THEORETICAL STUDY OF PROCESSES AT PHASE BOUNDARIES

The processes occurring at phase boundaries during liquid-phase epitaxy are theoretically studied considering smooth interphase boundaries. In the frame of the given assumptions the distribution of the components near phase boundaries is determined. The width of phase

boundary is estimated at concrete values of the growth rate (39 and 15 Å/sec), experimentally established for liquid-phase epitaxy of GaAs. On the basis of experimental results, the linear dependence of growth rate on the temperature drop rate is checked and confirmed.

PUBLICATIONS:

1. Alexandrova, S., Szekeres, A., Valcheva, E., Mechanical stress in silicon oxides grown on hydrogen implanted Si, Physica Status Solidi C 9 (10-11) (2012) 2203-2206
2. Gartner, M., Szekeres, A., Alexandrova, S., Osiceanu, P., Anastasescu, M., Stoica, M., Marin, A., Halova, E., Infrared ellipsometry as an investigation tool of thin layers grown into plasma immersion N + implanted silicon, Applied Surface Science 258 (18) (2012) 7195-7201
3. Dulgheru, N., Anastasescu, M., Nicolescu, M., Stoica, M., Gartner, M., Pamukchieva, V., Szekeres, A., Todorova, K, Surface topography and optical properties of Ge-Sb(As)-S-Te thin films by atomic-force microscopy and variable angle spectroscopic ellipsometry, J. Phys.: Conf. Series 356 (1) (2012) art. no. 012019
4. Pamukchieva, V., Todorova, K., Mocioiu, O.C., Zaharescu, M., Szekeres, A., Gartner, M., IR studies of impurities in chalcogenide glasses and thin films of the Ge-Sb-S-Te system, Journal of Physics: Conference Series 356 (1) (2012) art. no. 012047
5. Zaharescu, M., Nicolescu, M., Gartner, M., Barau, A., Predoana, L., Anastasescu, M., Stoica, M., Szekeres, A., Hybrid sol-gel silica films with (TiO 2-CeO 2) binary nanopowders, Journal of Physics: Conference Series 356 (1) (2012) art. no. 012018
6. Alexandrova, S., Halova, E., Szekeres, A., Vlaikova, E., Gartner, M., Anastasescu, M., Annealing of Si surface region modified by plasma immersion implantation of nitrogen, Journal of Physics: Conference Series 356 (1) (2012) art. no. 012031
7. Minkov, I.P., Simeonov, S., Szekeres, A., Cziraki, A., Socol, G., Ristoscu, C., Mihailescu, I.N., Study of the charge transport mechanism in pulsed laser deposited AlN:Si films, J.Phys.: Conf. Series 356 (1) (2012) art. no. 012038
8. Szekeres, A., Cziraki, A., Huhn, G., Havancsak, K., Vlaikova, E., Socol, G., Ristoscu, C., Mihailescu, I.N., Laser technology for synthesis of AlN films: Influence of the incident laser fluence on the films microstructure, Journal of Physics: Conference Series 356 (1) (2012) art. no. 012003
9. Fábián, M., Sváb, E., Pamukchieva, V., Szekeres, A., Petrik, P., Vogel, S., Ruett, U., Study of As - Se - Te glasses by neutron-, X-ray diffraction and optical spectroscopic methods, Journal of Non-Crystalline Solids 358 (4) (2012) 860-866.
10. A. Szekeres, S. Alexandrova, E. Vlaikova, E. Halova, "Oxidation of Si surface nitrogenated by plasma immersion N^+ ion implantation", Bulgarian Journal of Physics 39 (2012) 178–185
11. Kaschieva, S., Gushterov, A., Angelov, Ch., Dmitriev, S.N., Formation of Si nanocrystals in ion implanted Si-SiO_2 structures by MeV electron irradiation, *J. Physics: Conference Series* 356 (1) (2012) art. no. 012005
12. Yu Zhang, Hui Chen, Michael Dudley, Yi Zhang, J.H. Edgar, Yinyan Gong, Silvia Bakalova, Martin Kuball, Lihua Zhang, Dong Su, Yimei Zhu, "Growth mechanisms and defect structures of $B_{12}As_2$ epilayers grown on 4H-SiC substrates", J. Crystal Growth 352 (1) (2012) pp. 3-8.
13. Bakalova, S., Speller, R., Lacey, R.J., Frost, Ch., Kuball, M., Novel n-type Mg_2B_{14} on silicon diode: Demonstration of a thermal solid state neutron detector, Nuclear Instruments and Methods in Physics Research Section A, in press.

14. Szekeres, A., Alexandrova, S., Petrik, P., Fodor, B., Bakalova, S., Ellipsometric Study Of Crystalline Silicon Hydrogenated By Plasma Immersion Ion Implantation, Applied Surface Science, in press.

ONGOING RESEARCH PROJECT:

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

PROJECTS IN THE FRAME OF ACADEMIC EXCHANGE PROGRAMS:

1. "Structure and properties of new materials and thin films for nano-technologies in optoelectronics", ***with the Eotvos L. University, Budapest, Hungary***
2. "Ion beam modification of semiconductor surface layer for micro- and optoelectronics application purposes", ***with the Institute of Physical Chemistry, RA, Bucharest, Romania***
3. "Silicon oxide films with embedded silicon nanoinclusions for advanced opto- and nanoelectronics applicatios", ***with the Institute of Semiconductor Physics, NASU, Kyiv, Ukraine***
4. "Characterization of diluted magnetic semiconductor nanostructured thin films" ***with the National Institute for Lasers, Plasma and Radiation Physics, Bucharest, Romania***
5. "Enhancement of radiation hardness of semiconductor heterostructures by cyclic annealing" ***with the Joint Institute for Nuclear Research, Dubna, Russia***

DIVISION MICRO- AND ACOUSTOELECTRONICS

LABORATORY

PHYSICAL PROBLEMS OF MICROELECTRONICS

HEAD: **Assoc.Prof. Albena Paskaleva, Ph.D.**
tel.: 979 5742, e-mail: paskaleva@issp.bas.bg

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

Prof. E. Atanassova, 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; M. Stoicheva, technologist

RESEARCH ACTIVITIES:

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

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

Complex investigations on the influence of dopant (Ti; Hf; Al) on the conduction mechanisms; breakdown mechanisms and long-term reliability of high-k Ta_2O_5 thin films for nanoelectronic applications (EOT <1 nm; leakage currents $<10^{-8}$ A/cm^2) have been performed. Doping conditions which ensure improved electrical stability (including at high temperatures) and homogeneous ultrathin interfacial layer have been found which open up the way to implement doped Ta_2O_5 in the next generations of dynamic memory devices. The type, structural nature, energy distribution and cross-section of traps, which are precursors of the dielectric breakdown; the mechanisms causing breakdown at low and high injection levels and their dependence on the dopant have been established. The time dependent breakdown characteristics of capacitors with Ta_2O_5 and AlTaO high-*k* layers have been measured. It is established that the breakdown mechanism is different in pure and doped Ta_2O_5, and depends on the traps in the dielectric layer; Al doping decreases the traps in the pure Ta_2O_5, Weibull statistic is dominated by the intrinsic breakdown of the high-k layer and the degradation processes are well described by the percolation model. The results are important for the long-term reliability of high-k dielectric layers in DRAMs. An optimal concentration of Al dopant in Ta_2O_5 ensuring large enough time- and charge-to-breakdown are found which guarantees 10 year lifetime of the memory capacitors.

The local mechanical parameters of pure and doped Ta_2O_5 have been defined; the effect of dopant on the elastic modulus and hardness of the layers. From device perspective point of view Hf-doped Ta_2O_5 is noteworthy for micro-electro-mechanical system applications.

Variable angles spectroscopic ellipsometry (VASE) is used to study the influence of Hf doping on the interfacial properties of Ta_2O_5 layers deposited on pure or nitrided Si. It is concluded that the suitable combination of Hf-doped Ta_2O_5 and nitrided Si substrate form a unique stack with a homogeneous and interfacial layer with reduced thickness. The results show that spectroscopic ellipsometry with a proper algorithm for data interpretation can be successively used as a tool for investigating the complicated processes in very thin and ultrathin ILs of Ta_2O_5 high-k stacks.

The effect of resistive switching (RS) in MIM structures with TiO_2 has been investigated for application in future memory devices. It is shown that the RS effect is enhanced when a thin Al_2O_3 layer is deposited between TiO_2 and the bottom electrode. The investigations revealed that these structures demonstrate stable bipolar RS and the ratio between the two resistive states (ON/OFF) is >10 and it does not degrade with increasing the number of switching cycles.

MOS structures containing silicon nanocrystals in the gate dielectric suitable for application in radiation dosimetry were fabricated and characterized by Transmission Electron Microscopy (TEM) and electrical measurements. TEM results proved formation of silicon nanocrystals with diameters of 2-3 or 4-6 nm in three-layer gate dielectric structures sputtered $SiO_2/SiO_{1.15}$/thermal SiO_2/c-Si, in the $SiO_{1.15}$ film after high temperature N_2 annealing at 1000 ^oC for 30 or 60 min. The electrical characterization of nanocrystal MOS structures fabricated by deposition of Al as top and bottom contacts and N_2 annealing was carried out by Capacitance/Conductance-Voltage (C/G-V) measurements in the range 20 Hz – 2 MHz and Current-Voltage (I-V) measurements. The conductance method gives values $\leq 10^{10}$ cm^{-2} eV^{-1} for the interface defect density, while for the fixed oxide charge values of about ~ 10^{10} cm^{-2} were determined from the high frequency C-V dependencies. The obtained results show that the processes used to obtain multilayer gate dielectrics and to grow nanocrystals do not deteriorate the excellent properties of the thermal oxide and its interface.

Electrically charged and control nanocrystal MOS structures were subjected to X-ray irradiation. After several cycles charging – complete discharging due to X-ray irradiation the charged MOS structures, as well as the control ones, retained their excellent electrical characteristics. It may be expected that the results of this study open the pathway for fabrication of reusable X-ray dosimeters.

Thin aluminium nitride (AlN) films deposited by pulsed laser deposition technique have been investigated using the Surface Enhanced Raman spectroscopy (SERS). The results have revealed that PLD AlN films deposited at low pressure (10^{-4} Pa) are polycrystalline with hexagonal AlN (h-AlN) phase. In the SERS spectra the main characteristic E_1 and E_2 vibrational modes of h-AlN appears at 660 cm^{-1} and 670 cm^{-1}. For the films deposited in N_2 ambient at 0.1 and 10 Pa, in the SERS spectra the intensity of these bands decreases and the bands shift to higher frequencies due to the structural strains generated in the growing film.

PUBLICATIONS:

1. E. Atanassova, P. Lytvyn, S. N. Dub, R. V. Konakova, V. F. Mitin, D. Spasov, "Nanomechanical properties of pure and doped Ta_2O_5 and the effect of microwave irradiation", J. Phys. D: Appl. Phys. **45,** 475304 (13 pp) (2012).

2. E. Atanassova, D. Spassov, N. Novkovski, A. Paskaleva, "Constant current stress of lightly Al-doped Ta_2O_5", Mater. Sci. in Semicond. Proc. **15,** 98-107 (2012).
3. Y. Karmakov, A. Paskaleva, E. Atanassova, "Interface layers in Ta_2O_5-based stacks and consistent depth profiles by spectroscopic ellipsometry", Appl. Surf. Sci. **258,** 4507-12 (2012).
4. E. Atanassova, A. Paskaleva, D. Spassov, "Doped Ta_2O_5 and mixed HfO_2-Ta_2O_5 films for dynamic memories application", Microelectron. Reliab. **51,** 642-50 (2012), **invited paper**.
5. N. Nedev, E. Manolov, D. Nesheva, K. Krezhov, R. Nedev, M. Curiel, B. Valdez, A. Mladenov, Z. Levi, "Radiation Dosimeter Based on Metal-Oxide-Semiconductor Structures Containing Silicon Nanocrystals", Key Eng. Mat. **495**, pp. 120-123 (2012), DOI: 10.4028/www.scientific.net/KEM.495.120, ISSN: 1013-9826.
6. N. Nedev, E. Manolov, D. Nesheva, K. Krezhov, R. Nedev, M. Curiel, B. Valdez, A. Mladenov, Z. Levi, "Metal-Oxide-Semiconductor Structures Containing Silicon Nanocrystals for Application in Radiation Dosimeters", Sensor Letters **10**, 833-837 (2012) DOI: http://dx.doi.org/10.1166/sl.2012.2575, ISSN: 1546-198X.
7. E. Atanassova, D. Spassov, N. Novkovski, A. Paskaleva, "Stress-induced leakage current in lightly Al-doped Ta_2O_5", Proc. 28th Intern. Conf. on Microel. (MIEL'2012), Nish, Sebia, 13-16 May, 2012, IEEE El. Dev. Soc., 323-6 (2012), **best paper award**.
8 L. Georgievska, N. Novkovski, E. Atanassova, "Charge trapping at low injection currents in (TiN, Mo, Pt)/Ta_2O_5:Hf/SiO_2/Si structures", Proc. 28th Intern. Conf. on Microel. (MIEL'2012), Nish, Sebia, 13-16 May, 2012, IEEE El. Dev. Soc., 331-6 (2012).
9. A. Skeparovski, N. Novkovski, A. Paskaleva, "Charge trapping properties in Ti-doped Ta_2O_5 films on nitride Si", Proc. 28th Intern. Conf. on Microel. (MIEL'2012), Nish, Sebia, 13-16 May, 2012, IEEE El. Dev. Soc., 327-30 (2012).
10. E. Atanassova, N. Stojadinovič, D. Spassov, I. Manič, A. Paskaleva, "Time-dependent-dielectric-breakdowns in pure and lightly Al-doped Ta_2O_5 ", Microel. Eng., (in press).
11. D. Nesheva, N. Nedev, M. Curiel, I. Bineva, B. Valdez and E. Manolov, Silicon Oxide Films Containing Amorphous or Crystalline Silicon Nanodots for Device Applications, in "Quantum Dots – A Variety of New Applications", Ed. A. Al-Ahmadi, Ch. 9, pp. 183-206 (2012), InTech Publ., ISBN 978-953-51-0483-4.
12. W. Weinreich, A. Paskaleva, A. Shariq, K. Seidel, J. Sundqvist, M. Lemberger, A. Bauer „Detailed leakage current analysis of MIM capacitors with ZrO_2, ZSZ and ZAZ as dielectric and TiN electrodes", J. Vac. Sci. Technol. B., (in press).
13. A. Paskaleva, W. Weinreich, A. J. Bauer, M. Lemberger, L. Frey, "Improved electrical behavior of ZrO_2-based MIM structures by optimizing the O_3 oxidation pulse time", J. Phys.D: Appl. Phys., (in press).
14. D. Mateos, M.A. Curiel, N. Nedev, D. Nesheva, R. Machorro, E. Manolov, N. Abundiz, A. Arias, O. Contreras, B. Valdez, O. Raymond, J.M. Siqueiros, "TEM and Spectroscopic Ellipsometry Studies of Multilayer Gate Dielectrics Containing Crystalline and Amorphous Si Nanoclusters", Physica E: Low-dimensional Systems and Nanostructures, (in press), DOI: 10.1016/j.physe.2012.11.015, Available online 27 November 2012.
15. D. Mateos, N. Nedev, D. Nesheva, M. Curiel, E. Manolov, A. Arias, O. Contreras, B. Valdez, Z. Levy and J. Siqueiros, "Electrical Characterization of MOS Structures with Silicon Nanocrystals Suitable for X-ray Detection", Key Eng. Mat. (2013), (in press).
16. I.Karmakov, A.Paskaleva "Interfacial layer of Hf-doped Ta_2O_5 stacks studied by Spectroscopic ellipsometry", Appl. Surf. Sci., (in press).

Independent citations, (2012), 130.

ONGOING RESEARCH PROJECTS:

Physics and technology of thin and ultra 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. Insitute of Physics ,Universty of Skopie, Macedonia
5. University of Nish, Serbia

DIVISION MICRO- AND ACOUSTOELECTRONICS

LABORATORY

ACOUSTOELECTRONICS

HEAD: **Assoc.Prof. Velichka Georgieva, Ph.D.**
Tel.: 979 5681, e-mail: lazarova@issp.bas.bg

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 Ph.D., engineer; Ts. Yordanov, researcher; V. Gadjanova, researcher; Z. Raicheva, chemist; L. Vergov, engineer; P. Angelova, physicist; K. Esmerian physicist, Ph.D. student; S. Staikov, technician; I. Mitev, technician

RESEARCH ACTIVITIES:

In 2012 the scientific and applied research of Acoustoelectronics laboratory focused on creation of new materials, technologies and elements following the Academy's basic strategic goal - creation of a society based on knowledge that is an active partner in the European scientific area.

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

- Piezoelectric temperature microsensors – acoustic characteristics and metrological parameters.
- Application of bulk acoustic waves (BAW) in resonant structures for preparation and investigation of sensor devices for detection of harmful gases in the environment.
- Synthesis and investigation of thin plasma polymer films and composites for applications in sensors and biocomposites.
- Resonant structures using surface transverse waves (STW), Rayleigh surface acoustic waves (RSAW) and BAW and their applications in communications and sensor technologies.

- PIEZOELECTRIC TEMPERATURE MICROSENSORS

Leading research centers in the field of temperature measurements have become interested in quartz temperature sensors developed at the Acoustoelectronics laboratory. Samples of quartz temperature sensors have been sent to a company called Testo, Germany for conducting functional tests. A program for implementation of quartz temperature sensors in ongoing research projects is being negotiated with the company NPL, UK. Investigations on the factors having influence on the calibration accuracy of temperature sensors in gaseous environments are planned. Based on the results of those investigations, possibilities for cooperation will be discussed.

- MASS – SENSITIVE QUARTZ RESONATORS

The dynamic characteristics of quartz resonators with nanometric surface roughness made with SiC abrasive with grain sizes from 3 to 20 μm have been studied. QCM sorption properties have been studied at 100 ppm NH_3 concentration. Thin WO_3 film (200nm) has been used as a sensing layer. The comparison between polished and roughened surfaces indicate, that when the nanometric surface roughness increases about 1250 times, the sorption sensitivity increases more than 3 times for surfaces processed with 20 μm abrasive

grain size. The results show, that by increasing the surface roughness, the piezoelectric characteristics can fluctuate within acceptable limits, while the sensor sensitivity increases multiple.

A study on the NO_2 gas sorption ability of a quartz crystal microbalance (QCM) coated with amorphous $Ge_{33}Se_{67}$ has been investigated. Ge-Se bulk glass samples have been prepared using evacuated quartz ampoules at the temperature of 950 ^oC. The $Ge_{33}Se_{67}$ thin layers in range of 50 nm to 200 nm have been deposited on both sides of quartz resonators by thermal evaporation. The thin films have been characterized before and after sorption/desorption processes of NO_2 by using energy-dispersive X-ray spectroscopy (EDS), grazing angle X-ray diffraction (GAXRD), Raman spectroscopy, X-ray photoelectron spectroscopy (XPS) and atomic force microscopy (AFM). The $Ge_{33}Se_{67}$ sorption ability to NO_2 has been investigated over the concentration range from 100 to 5000 ppm. The studies indicate that physical sorption occurs when NO_2 gas molecules are introduced into the chalcogenide film and the thin film composition or structure does not change. The oxidation of Ge-Se bonds results in formation of an oxide surface which decreases NO_2 diffusion into the bulk of the QCM. The mass loading due to NO_2 gas sorption has been calculated by measuring the QCM's resonant frequency shift. In this experiment, up to 6.8 ng of the gas was sorbed into the 200 nm thick $Ge_{33}Se_{67}$ film at 5000 ppm NO_2 concentration. The $Ge_{33}Se_{67}$ thin films show relatively good physical sorption sensitivity towards NO_2 and the process is reversible. This makes them suitable for NO_2 sensor applications.

In order to improve the luminary efficacy characteristics of light emitting diodes (LEDs) investigations on different contacts using n- and p- type GaN / metal systems have been carried out under institute's contract BK02/2012.

- SYNTHESES AND STUDY OF PLASMA POLYMERS AND COMPOSITES

Plasma polymers synthesized from hexamethyldisiloxane at different plasma process conditions for various sensor applications have been studied. The effects of glow discharge current density, gas phase pressure in the reactor and ammonia plasma modification on the polymer structure, as well as the H_2O and NO_2 sensing properties of the plasma polymers are established. The results show that by optimization of the plasma process conditions the sensitivity to water vapor and NO_2 could be increased.

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

The influence of solid chemosensitive layers of hexamethyldissiloxane (HMDSO) on the temperature frequency characteristics (TFCs) of gas and liquid-phase sensors using the Rayleigh surface acoustic wave (RSAW) and the surface transverse wave (STW) mode on ST-cut quartz, respectively, has been investigated. Such sensors have been coated with 4 different HMDSO thicknesses (50, 100, 150 и 250 nm) in a plasma polymerization process and their TFCs have been measured over the (-110 to +100) °C range. The analysis of the TFCs, compared to an uncoated device shows that in RSAW devices the HDMSO causes a 2500 ppm exponential downshift of the sensor's frequency and a 40K downshift of its turn-over temperature (TOT) when the HMDSO thickness increases from 0 to 250 nm. In that process the TFC retains its generic parabolic shape. Furthermore, it has been shown that the TFC dependence on the HMDSO thickness can be predicted with a high precision using a 3-rd order polynomial function. This allows precise optimization of the sensor's TFC and adjustment of its TOT just by properly selecting the thickness of the chemosensitive HMDSO layer. Since the sensor operates in the thickness range of its maximum mass sensitivity, the TOT can be adjusted at the desired temperature for minimum overall temperature sensitivity without affecting the mass sensitivity of the sensor. This phenomenon

is of great practical importance to RSAW based sensors operating over a wide temperature range since the undesired temperature sensitivity of the sensor device can be minimized and measurement data can be precisely corrected for temperature induced frequency shifts during gas sensing measurements.

In sensor devices using the STW mode strong excitation of a 2-nd order Love mode (LM) has been observed at HMDSO thicknesses exceeding 100 nm. This LM mode is appropriate for liquid sensing applications. A partial thermo-compensation effect with the Love mode has been demonstrated in certain film thickness ranges which again allows minimizing the thermal sensitivity of LM based liquid sensing devices.

PUBLICATIONS:

1. Z. Raicheva, V. Georgieva, T. Angelov, V. Gadjanova, L.Vergov, Y. Lazarov, M. Atanassov,"Improvement of sensor sensitivity of Quartz Crystal Microbalance by roughening of the piezoquartz plate", Optoelectronics and Advanced Materials-Rapid Communications, Vol.6, 11-12, November-December 2012, pp.1160-1163

2. Velichka Georgieva, Maria Mitkova, Ping Chen, Dmitri Tenne, Kasandra Wolf, Viktoria Gadjanova, "NO_2 gas sorption studies of $Ge_{33}Se_{67}$ films using quartz crystal microbalance",Materials Chemistry and Physics 2012, pp. 1-6.

3. E. Radeva, V. Georgieva, J. Lazarov, L. Vergov, N. Donkov, "Plaama deposited polymers as gas sensitive films", Journal of Physics: Conference Series 356 (2012) 012013, doi:10.1080/1742-6596/356/1/012013, pp. 1-4.

4. V. Georgieva, N. Donkov, P. Stefanov, M. Sendova-Vassileva, A. Grechnikov, V. Gadjanova, "NO_2 sensing properties of amorphous silicon films", Journal of Physics: Conference Series 356 (2012) 012027, doi:10.1088/1742-6596/356/1/012027, pp. 1-5.

5. V. Safonov, A. Zykova, J. Smolik, R. Rogovska, N. Donkov, A. Goltsev, T. Dubrava, I. Rassokha, V. Georgieva, "Nanoscale biomaterial interface modification for advanced tissue engineering applications", Journal of Physics: Conference Series 356 (2012) 012046, doi:10.1088/1742-6596/356/012046, pp. 1-4.

6. Karekin D. Esmeryan, Ivan D. Avramov and Ekaterina I. Radeva "Temperature Frequency Characteristics of Hexamethyldisiloxane (HMDSO) Polymer Coated Rayleigh Surface Acoustic Wave (SAW) Resonators for Gas-Phase Sensor Applications", Micromachines 2012, 3, 413-426; doi:10.3390/mi3020413(2012), pp. 413-426.

7. N. Donkov, V. Safonov, A. Zykova, J. Smolik, I. Rossokha, A. Goltsev, T. Dubrava, R. Rogovska, V. Georgieva, "Nanoscale surface modification of plastic substrates for advansed tissue engineering applications", 17th International School on Condensed Matter Physics, 2-7 September, 2012 Varna, Bulgaria.

8. A. A. Grechnikov, A. S. Borodkov, V. B. Georgieva, S. M. Nikiforov, Ya. O. Simanovsky, S. S. Alimpiev, "Rapid screening of pharmaceutical drugs using thermal desorption-SALDI mass spectrometry", 17th International School on Condensed Matter Physics, 2-7 September, 2012 Varna, Bulgaria.

9. Z. Raicheva, V. Georgieva, A. Grechnikov, V. Gadjanova, Ts. Angelov, L. Vergov, Yu. Lazarov, "Improving Resonance Characteristics of Gas Sensors by Chemical Etching of Quartz Plates", 17th International School on Condensed Matter Physics, 2-7 September, 2012 Varna, Bulgaria.

10. I. D. Avramov and K. D. Esmeryan, "Thermal sensitivity of solid polymer coated surface transverse/Love wave based resonators on AT-cut quartz for sensor applications" Sensors@Transducers, ISSN 1726-5479.

ONGOING RESEARCH PROJECTS:

1. Project financed by Bulgarian Academy of Sciences

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

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

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

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

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

COLLABORATION:

1. "Development of new sensitive layers (coatings) based on nano-sized semi-conductive structures for analytical application using mass-sensitive piezoresonance sensors"- Russian Academy of Science, Russia.
2. "Development of mass sensitive quartz resonators for operation at cryogenic temperatures". - Join Institute for Nuclear Research, Dubna, Russia.
3. "Development of a leaky surface acoustic wave (LSAW) sensor on lithium tantalate for liquid analysis" - Research Center Karlsruhe, Germany.

DIVISION LOW TEMPERATURE PHYSICS

LABORATORY

LOW TEMPERATURE PHYSICS

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

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

Prof. N. Tonchev, Ph.D., D.Sc.; Assoc. Prof.. E. Vlakhov, Ph.D.; Assoc. Prof. N. Balchev, Ph.D.; Assoc. Prof. A. Stoianova-Ivanova, Ph.D.; Assist. Prof. A. Zahariev, Ph.D.; Assist. Prof. S. Terzieva, Ph.D.; Assist. Prof. K. Nenkov; Ph.D. student K. Buchkov

RESEARCH ACTIVITIES:

The Low temperature physics laboratory examined different problems in the field of condensed matter physics related to the materials and phenomena in magnetism and superconductivity. The theoretical studies of phase transitions (classical and quantum) and critical phenomena in various physical systems has been carried out. Experimental work is connected with obtaining and investigation of new magnetic, superconducting and composite materials and improvement of their characteristics with a view of practical application.

The main results obtained are summarized below.

THEORETICAL STUDIES

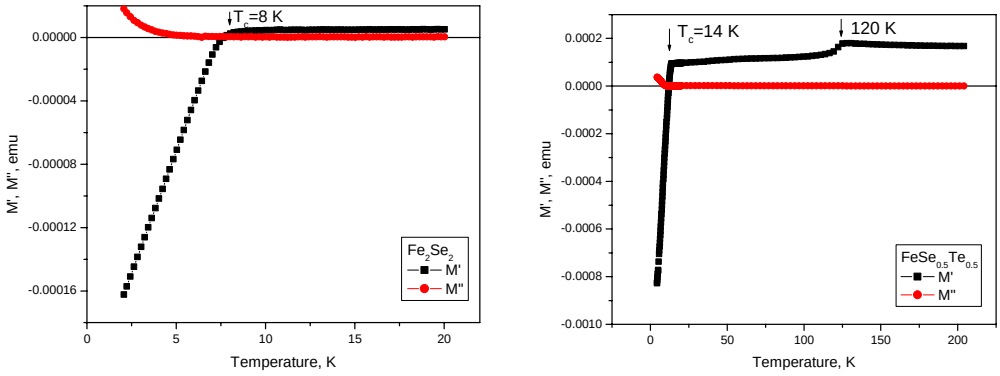
Precise upper and lower bounds on the fidelity susceptibility in terms of macroscopic thermodynamic quantities, like thermodynamic susceptibilities and thermal average values are obtained. The quality of the bounds is checked by the exact expressions for a single spin in an external magnetic field. Their usefulness is illustrated by two examples of N-particle models which are exactly solved in the thermodynamic limit: the Dicke superradiance model and the single impurity Kondo model. It is shown that as far as divergent behavior is considered, the fidelity susceptibility and the thermodynamic susceptibility are equivalent for a large class of models exhibiting critical behavior.

SUPERCONDUCTING AND COMPOSIT *MATERIALS AND APPLICATIONS*

The discovery of superconductivity in the iron based materials has aroused great interest in past four years. In addition to the relatively high transition temperature, T_c, these iron based superconductors were reported to have a very high upper critical field, H_{c2} and good in – field behaviour of the critical current density. All this increase the hope for future applications. On the other hand the establishment of mechanism of non-conventional superconductivity and interplay between magnetism and superconductivity in this superconducting family is also great challenge.

In spite of the fact that these materials have many common properties with cuprate high temperature superconductors a variety of differences exist. They started with the preparation conditions. We successfully construct the necessary laboratory equipment: furnace with vacuum in the tube and Glove box. We managed to synthesize the simplest compound FeSe (11 series) by solid state reaction (SSR) method. The other compound $FeSe_{0.5}Te_{0.5}$ was

prepared by SSR and melting as well. The superconducting transitions at 8 K and 14 K respectively were established. XRD analysis shows that more precise control of stoichiometry is needed for preparation of samples without impurity phases.



Magnetic moment vs. temperature for polycrystalline Fe_2Se_2 and $FeSe_{0.5}Te_{0.5}$ samples

We investigated the vortex pinning energies and H(T) characteristic lines of samples with nominal composition $MoSr_2YCu_2O_{8-\delta}$.The vortex pinning energies were obtained using two approximations of the resistive transition. The characteristic lines $H_{c2}(T)$ and $H_{irr}(T)$ were obtained using resistivity, susceptibility and magnetization measurements. The values of $H_{c2}(0)$, as well as the different irreversibility field values were discussed.

We synthesized samples with nominal composition $HoBa_2Cu_3O_z$ as well as the new material $(Ho_{0.97}Sn_{0.03})Ba_2Cu_3O_z$. It was established that the Sn-doping increases the irreversibility field and upper critical field of the undoped sample. The possible reasons for these phenomena are discussed.

Bulk superconducting (SC) composite ceramics, involving manganite phase, have been obtained by solid-state synthesis. The investigation of the local structural and phase transformation in the composites have been implemented by energy-dispersive X-ray microanalysis (EDXA), scanning electron microscopy technique (SEM) and X-ray analysis. Obtained bulk composites contain Bi-Pb-Sr-Ca-Cu-O (BPSCCO) and LaPbMnO ceramics. In the sintered composite $Bi_{1.6}Pb_{0.4}Sr_2Ca_2Cu_3O_z$ and $La_{0.6}Pb_{0.4}MnO_3$ phases has been established. The SC phase (2212) is of 75–86 mass % with the critical temperature T_c = 75 K. The obtained (in oxygen atmosphere) polycrystalline bulk $La_{0.6}Pb_{0.4}MnO_3$ possessed relatively high magneto resistance effect (-32.3% at 4K and H=10 kOe). The saturation magnetization M_{sat} (75.8 emu/g and 48 emu/g at 4 K and 300 K) and the spontaneous magnetization M_s (66.2 emu/g and 26 emu/g at 4 K and 300 K) values are similar to those for the single crystals. At 300 K the resistance, R showed a small progressive decrease in cyclic magnetic field, H which resembled at raining phenomenon in magnetic fields. The hysteresis arises in the R vs H dependence at low temperatures. The above examples demonstrated the possibility of coexistence of superconductivity and ferromagnetism in polycrystalline ceramic materials by mixing in appropriate proportion both phases and using obtained regime of heat treatment techniques.

The conditions for plastic deformation of composite material, consisted of silver tube filled with two phase superconducting ceramics with different properties, were developed. The plastic treatment includes filling and congestion of oxide composite in silver tube followed by deformation process and heat treatment. The used ceramic material was synthesized by solid state reaction and structured in proportion $Bi_{1.6}Pb_{0.3}Sr_2Ca_2Cu_2O_7$/ $La_{0.6}Pb_{0.4}MnO_3$ (97:3). After applying of 156 % general deformation the tape with thickness 0.3 mm was obtained. The magnetic measurements show ferromagnetic character of

obtained tape with $Bi_{1.6}Pb_{0.3}Sr_2Ca_2Cu_2O_7$/ $La_{0.6}Pb_{0.4}MnO_3$ (97:3) composition. We suppose insufficient thermal treatment of the tape. The study of silver coated tape properties will be continued.

Polycrystalline superconducting samples have been prepared in order to be used in electrochemical power sources. They contribute to longer battery life by reducing gas control during charging of the cell. Superconducting ceramics with different nominal composition as $Y_{0.95}Pr_{0.05}Ba_2Cu_3O_x$ (YPBCO); $Bi_{1.7}Pb_{0.3}Sr_2Ca_2Cu_3O_7$ (BPSCCO-2223; $Bi_{1.7}Pb_{0.3}Sr_3Ca_2Cu_3O_7$ (BPSCCO-2323); $Gd_1Ba_2Cu_3O_7$ (GdBCO-123); $Y_1Ba_3Cu_4O_7$ (YBCO-134) have been sintered by solid state reaction. X-ray analyses of YBCO phase demonstrated that it is remarkably stable in the electrolyte solutions used for this type of batteries. The electrochemical characteristics confirmed the positive effect of this superconducting ceramic, which improves the performance stability of the Ni/Zn cells and assists the prolongation of battery life. These results give reason to continue similar studies and to find out the optimal chemical composition between superconducting ceramics and Zn electrode, in order to obtain better properties of Ni/Zn battery.

PUBLICATIONS:

1. J.G.Brankov and N.S.Tonchev, *Lower and upper bounds on the fidelity susceptibility*, Phys. Rev. E, v.85, 031115:1-7 (2012).

2. K. Buchkov, K. Nenkov, A. Zaleski, E. Nazarova, M. Polichetti, *Fundamental and 3-rt harmonic AC magnetic susceptibility of overdoped policristalline $Y_{1-x}Ca_xBa_2Cu_3O_{7-\delta}$ (x=0.025 and x=0.20) samples,* Physica C 473 (2012) 48-56

3. K. Buchkov, E. Nazarova**,** K. Gurova, A. Zahariev, H. Sechenski, K. Nenkov, *Reduction of YBCO melting temperature by simultaneous Ca substitution and Ag addition,* J. Optoelect. Adv. Mater. 6 (2012) 1061-1062

4. N.Balchev, K.Nenkov, V.Antonov, "*Vortex pinning energies and H(T) characteristic lines in the $MoSr_2YCu_2O_{8-\delta}$ superconductor*", Journal of Superconductivity and Novel Magnetism, DOI 10.1007/s10948-012-1704-0

5. Vitkova, V., Mitkova, D., Stoyanova-Ivanova, A., Kozarev, N. and Bivas, I., *Bending rigidity of lipid membranes and pH of the aqueous surroundings,* C. R. Acad. Bulg. Sci., 2012, 65(3), p. 329-334

6. Stoyanova-Ivanova, A., Mitkova, D., Georgieva, S., Vitkova, V., *Lipid bilayers as biocompatible model systems – does the acidity of the aqueous solution alter the membrane elasticity?,* Advances in Natural Science : Theory and Applications, 2012, 1 (1), p.29-35

7. Mitkova, D., Stoyanova-Ivanova, A., Ermakov, Yu. A. and Vitkova V., *Experimental study of the bending elasticity of charged lipid bilayers in aqueous solutions with pH5*, Journal of Physics: Conference Series (JPCS) , 398(2012)012028(1-7)

8. Ivanova G., Stoyanova-Ivanova A., Terzieva S., Kovacheva D., Mladenov M., Blagoev B., Dimitrov D.,"*Opportunities For Improving The Electrochemical Characteristics Of Ni-Zn Batteries Using High Temperature Superconducting Ceramic",* Proceedings of the "12th Cryogenics International Conference" 2012, Dresden, Germany, September 11-14,2012, ISBN: 978-2-913149-93-9; ISSN: 0151-1637

9. Е. Назърова, *История на свръхпроводимостта в България*, Светът на физиката, N1 (2012) 7-15

10. E. Nazarova, *A look upon the history of superconductivity in Bulgaria*, Symposium "Dissemination and development of physics and mathematics on the Balkans", 17-18 October 2011, Sofia, Bulgaria (2012)

TEACHING ACTIVITIES:

Ph.D. Student K. Buchkov, supervisor Assoc. Prof. E. Nazarova
Graduate Student Eva Georgieva**,** supervisor Assoc. Prof. E. Nazarova
Graduate Student: N. Mladenova, supervisor Assoc. Prof. A. Stoyanova-Ivanova
Graduate Student: D. Mitkova, consultant Assoc. Prof. A. Stoyanova-Ivanova

AWARDS:

S.Terzieva:
Second prize winner in the contest "Young & Energetic Scientists", part of the European Researchers Night 2012;

Winner in the Young scientists Contest 2012 - "The Bulgarian contribution to the contemporary research area", part of the Annual panel "A LOOK INTO THE FUTURE" Silk Road – Inspirations by Ikuo Hirayama - The younger generation on the road to knowledge, given by Centre Ikuo Hirayama, Bulgaria.
A. Stoyanova-Ivanova, S. Terzieva at all - First place in the competition at the ISSP for the most important application research in 2012

ONGOING RESEARCH PROJECTS:

I. Projects financed by Bulgarian Academy of Sciences

1. New materials, structures and multifunctional magnetic systems

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

1. Preparation and study of iron based superconducting materials **-EURATOM-FU07-CT-2007-00059**

INTERNATIONAL COLLABORATION:

1. Synthesis and structure investigation of multifunctional materials, Institute of Low Temperature and Structure Research, Polish Academy of Sciences, Wroclaw, Poland.

2. Leibniz Institute for Solid State and Materials Research, Dresden, Germany

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

DIVISION LOW TEMPERATURE PHYSICS

LABORATORY

ENVIRONMENTAL PHYSICS

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

TOTAL STAF: **3**
RESEARCH SCIENTIST: **2**
Assoc. Prof. P. Simeonova PhD; Mihaela Jerusalimova, techn. assist;
Plamen Zashev, techn. assist.; Petja Papazova, PhD student

RESEARCH ACTIVITIES:

1. MAJOR TOPICS OF THE RESEARCH UNIT:

Laboratory of Environmental Physics is dealing with classification, modeling and interpretation of complex multi-parametric systems of the environmental physics by the use of the methods of the multi-variate statistics aiming prognosis, assessment, generalization and decision making in solving technological, ecological, economic and social problems.
This type of studies has an extremely important practical application as using them it is possible to:

- Identify sources of anthropogenic pollution and assess the contribution of each identified source in the overall system pollution;
- Receive visual information about the status of a certain environmental system and along with models obtained to assist in solving of a given environmental problem (pollution risk assessment);
- Reach responsible solutions in political or social aspect in favor of the community;
- Create adequate directives and laws supporting the sustainable development of the environmental systems;
- Contribute to the scientific background of the sustainable development principles.

2. RESULTS FROM THE SCIENTIFIC ACTIVITY IN 2012

In 2012 the Laboratory of environmental physics continued and successfully finished the research on the scientific project "Improving life quality by sustainable management of surface waters – application for the catchments of the rivers Struma and Mesta" (DO -02-352) financed by the National Fund "Scientific Research" (240000 Leva). In June 2012 the final report on the project was delivered to the National Fund.
The results obtained could be summarized as follows:
1. Software package for determination of trends in the long-term development of all physicochemical parameters for the water quality of both rivers was prepared and checked.
2. Original integral indices for estimation of pollution and climatic influence were defined and respective risk analysis for series of sampling locations along the flows of the rivers Struma and Mesta was carried out.
3. Software package for determination of the geographic coordinates of each sampling location along the stream of Struma River to be used for further geostatistical modeling.
4. Intelligent data analysis was carried out using monitoring data from the catchments of the rivers Struma, Mesta and Tundja by application of neuron nets (self-organizing maps of Kohonen) and an original approach (Hasse diagram technique) for partial ordering of the factors influencing the water quality; this new approach makes it possible to carry out a

specific expertise of the water quality and risk of pollution and is carried out for the first time in the field.
5. In collaboration with the analytical department of Gdansk University of Technology, Poland the new strategy mentioned above was applied to a set of data where except the traditional physicochemical water quality parameters as tracers for pollution organic markers (poly aromatic hydrocarbons) were used.
6. A pilot study has been carried out to assess the water quality of a polluted water catchment by the use of infrared thermal camera. Images from polluted areas were compared with images from clean areas to develop indication for environmental pollution.

Additionally, other studies were carried out and the most important results are as follows:
1. A systematic study of the application of environmetric strategies for modeling and interpretation of monitoring data of air-borne particulate matter has been performed and the results were published in an international scientific journal (№1 from the publications list). Atmospheric pollution sources from different European areas were modeled and interpreted.
2. A statistical approach for calibration of model solution of analytes was tested and published (№ 4 from the publication list). The major result is proving the role of chemometric methods in calibration of analytical procedures and improvement of the estimation of the analytical results.
3. A classification of clinical data for alcoholic patients was performed in order to get a model of the data set. This approach allows creating patterns of patients suffering alcoholism, which improves diagnostic and cure. The study is published in international scientific journal (№ 2 from the publication list);
4. Environmetric analysis of monitoring data from the catchments of the rivers Tundja and Maritsa has been carried out in order to assess their water quality and to identify pollution sources. The case for Tundja River was published in an international scientific (№ 2 from the publications list), since the other one is accepted for publication.
5. In 2012 two highly qualified professionals Assoc. Prof. Dr. N. Starbov and Assoc. Prof. Dr. K. Starbova joined the Laboratory as associated members. With their help and financial support from the Laboratory new equipment for electrospinning was prepared. Series of experiments were carried out using as materials CeO_2 and $FeAlO_3$. The new results were presented during the International Workshop on Physics of the condensed matter in Varna, September 2012. The study for synthesis of $FeAlO_3$ multi ferroic fibrous material was awarded as best poster of the Workshop. This study and the other two on synthesis of supported fibrous nanoceramics via electrospinning were published in Journal of Physics: conference series (№ 8 and № 6 from the publications list) и Ceramics International (№ 5 from the publications list). During the Workshop Prof. Ph. Vandenbemden in collaboration with Assoc. Prof. Dr. V. Lovchinov, associated member of the Laboratory presented a review on the influence of grain boundaries on transport and magnetic properties of high temperature superconductors (№ 7 from the publications list).
6. In 2012 the 100 anniversary of the first observation of the superconductivity was celebrated. A session dedicated to the jubilee within the frames of the International seminar Dissemination and development of physics and mathematics on the Balkans was organized and the Laboratory was presented by a review communication „Low Temperature Physics and Superconductivity" by Assoc. Prof. Dr.V. Lovchinov. The full text of the report was published in the Proceedings of the seminar with A. Petrov, G. Kamicheva and R. Kamburova as editors. (№ 9 from the publications list).
7. The successful activity of Assoc. Prof. Dr.V. Lovchinov as director of Center for investigation of the physical properties of materials, surfaces, and structures has to be mentioned. In 2012 the Center was equipped with two new apparatus – scanning electron microscope JEOL-200 and electrospinning installation. Series of measurements using the

unique instruments of the Center PPMS and AFM have been carried out both for local and external users with the participation of the PhD student K. Buchkov (Laboratory of low temperature physics) and Assist. Prof. I. Bineva (Laboratory of photoelectrical and optical phenomena in broad-zone semi-conductors).

In 2012 the members of the Laboratory took part in reviewing of 5 scientific publications for various international scientific journals. Assoc. Prof. Dr. P. Simeonova was elected as member of a scientific jury and for reviewer of a competition between 3 candidates for receiving the academic position "Professor" (Chair of Physics and Biophysics) in Medical University, Sofia. Assoc. Prof. Dr.V. Lovchinov was member of a scientific jury for delivering the educational and scientific degree "Doctor" at Faculty of Chemistry and Pharmacy, University of Sofia "St. Kl. Okhridski". Assoc. Prof. Dr. P. Simeonova is member of the Advisory board of the international scientific journal *Ecological Chemistry and Engineering S.*

All members of the Laboratory participated at 2 conferences in Bulgaria and abroad with oral communications and posters.

Most substantial research achievements

As the most important scientific achievement of the Laboratory could be accepted the study for statistical modeling of air pollution published in a journal with high impact factor (№ 1 from the publications list).

The study deals with the application of several environmetric methods (principal components analysis, apportioning of pollution sources, chemical mass balance, self-organizing maps of Kohonen) to monitoring data from aerosol samples from different European regions. It is shown that various latent factors explaining over 75 % of the total variance are responsible for the data structure and could be reliably identified and interpreted. The contribution of each identified source to the formation of the aerosol total mass or to the total concentration of each aerosol chemical component was correctly assessed. Thus, a reliable estimation of the air quality in the respective region is achieved. The classification by self-organizing maps makes it possible for better evaluation of the role of different discriminator components in the atmospheric pollution. The chemical mass balance models leads to adequate modeling of the pollution sources.

3. INTERNATIONAL COLLABORATION

In 2012 the Laboratory started activity with a new project „Electrical and magnetic properties of Perovskite magnetic materials". This project is within the frames of inter academic cooperation /EBR/ with the group of applied superconductivity SUPRA.TECS, Universite de Liege, Institute d'Electricite – SUPRATECS, Liege The Laboratory was visited by the manager of the project from the Belgian side Prof. Dr. Philipp Vanderbemden. Two papers related to the project studies were published in 2012 (№ 6 and № 7 from the publications list). During his visit at Universite de Liege in November 2012 Assoc. Prof. Dr.V. Lovchinov together with Prof. Dr. Ph. Vanderbemden prepared a suggestion to WBI and Bulgarian Academy of Sciences for a new project leader since 2013 - Assoc. Prof. Dr. P. Simeonova. The suggestion was approved by both sides.

The Laboratory was involved in another new international project in 2012 entitled "Structural and physical investigations of nano-structured thin layer and bulk materials based on ordered porous dielectric matrices" and the partner is the Physicochemical Technical Institute "A.F. Yoffe" , Russian Academy of Sciences. This project is within the frames of the contract for interacademic collaboration between BAS and Russian Academy of Sciences. The Russian

partner is the Department of Physics of dielectrics and semiconductors at Yoffe Physico-Technical Institute, St. Petersburg with leader Prof. Dr. R. Parfeniev and Bulgarian partners are Institute of Electronics (Prof. Dr. I. Nedkov) and Institute for Solid State Physics (Assoc. Prof. Dr.V. Lovchinov).
Assoc. Prof. Dr.V. Lovchinov is member of the scientific council of the International Laboratory for strong magnetic fields, Wroclaw, Poland. In 2012 he participated in the activities of the council for election of a new director of this International Laboratory.

4. EDUCATIONAL AND QUALIFICATION ACTIVITIES

Two distant-study PhD students are attributed to the Laboratory. Their tutors - Assoc. Prof. Dr.V. Lovchinov and Assoc. Prof. Dr. P. Simeonova have held the courses of lectures foreseen in the educational programs and supervised the respective exams. In 2012 the PhD student D. Petrov under the supervision of his tutor Assoc. Prof. Dr.V. Lovchinov defended successfully his dissertation. The research work of the second PhD student P. Papazova (tutors Assoc. Prof. Dr. P. Simeonova and Assoc. Prof. Dr.V. Lovchinov) continued. Two papers have been prepared and submitted for publication in international scientific journals with impact factor (№ 3 and № 10 from the publications list). The first study is already published and the second one is accepted for publication. In December 2012 P. Papazova took her last mandatory exam. She has collected the required number of credit points and is ready to prepare her dissertation for the official procedure of defense.

PUBLICATIONS :

1. S. Tsakovski, P. Simeonova, V. Simeonov. Statistical Modeling of Air Pollution. *Journal of Environmental Science and Health, Part A,* Vol. 47**,** no. 1**,** (2012), 31-43. IF = 1.73
2. V. Bardarov, P. Simeonova, L. Neikova, K. Bardarov, V. Simeonov, S. Tsakovski, K. Kanev. Statsitical Interpretation of Medical Data of Patients with Alcohol Abuse. *Central European Journal of Medicine*, Vol.7 no. 4, (2012), 465-474. IF = 0.85
3. P. Papazova, P. Simeonova. Long-Term Statistical Assessment of the Water Quality of Tundja River. *Ecological Chemistry and Engineering S*, Vol.19, (2012), 213-226. IF = 0.70
4. D. Simeonov, P. Simeonova, L. Spasov. Statistical Calibration of Model Solution of Analytes. *Ecological Chemistry and Engineering S*, Vol. 19, no. 1, (2012), 67-75. IF = 0.70
5. K.Starbova, D.Petrov, N.Starbov and V.Lovchinov; Synthesis of supported fibrous nanoceramics via electrospinning, *Ceramics International*, 38, (2012), 4645-4651. IF = 0.70
6. N.Starbov, K.Starbova, Ph.Vandrbemden, P.Simeonova and V.Lovchinov. New experimental approach for synthesis of FeAlO3 multiuferroic fibrous material, *Journal of Physics*: conference series, Vol. 398, (2012), 012050.
7. Ph.Vandrbemden and V.Lovchinov, Influence of grain boundaries on transport and magnetic properties of high temperature superconductors, *Journal of Physics*: conference series, Vol. 398, (2012), 012012.
8. K.Starbova, D.Nihtianova, D.Petrov, N.Starbov and V.Lovchinov; Synthesis of supported CeO_2 nanofibers via electrospinning, *Journal of Physics*: conference series, Vol. 398, (2012), 012051
9. V. Lovchinov, Low Temperature Physics and Superconductivity, Dissemination and development of physics and mathematics on the Balkans. Eds. A. Petrov, G. Kamicheva and R. Kamburova, 2012, pp.80-91

Submitted for publication in 2012:

10. P. Papazova, P. Simeonova. Environmetric data interpretation to assess the water quality of Maritsa River catchment. *Journal of Environmental Science and Health, Part A,* (accepted)
11. P. Simeonova, D. Simeonov, L. Spasov. Determination of Cadmium and Zinc in Mollusks from Black Sea. *Ecological Chemistry and Engineering S (accepted*);
12. M. Pekala, F.Wolff-Fabris, J-F.Fagnard, Ph.Vanderbemden, J.Muha, M.M.Gospodinov, V.Lovchinov,M.Ausloos , Magnetic properties and anisotropy of orthorhombic DyMnO3 single crystal , *Journal of Magnetism and Magnetic Materials (accepted).*

ONGOING RESEARCH PROJECTS:

1. Projects financed by Bulgarian Academy of Sciences.
2. "*Electric and magnetic properties of perovskite magnetic minerals*", Liege, Belgium. L'Universite de Liege, Depart. Physique, Group SUPRA.TECS.
3. "*Structural and physical investigations of nano-structured thin layer and bulk materials based on porous dielectric matrices*", Department of Physics of dielectrics and semiconductors, St. Petersburg, Physicochemical Technical Institute "A.F. Yoffe" , Russian Academy of Sciences, Russian Federation.

INTERNATIONAL COLABORATION:

Universite de Liege, Belgium - L'Universite de Liege, Depart, Physique, Group SUPRA.TECS.
Department of Physics of dielectrics and semiconductors, St. Petersburg, Physicochemical Technical Institute "A.F. Yoffe" , Russian Academy of Sciences, Russian Federation.
International Laboratory for strong magnetic fields and low temperatures, Wroclaw, Poland.

DIVISION PHYSICAL OPTICS AND OPTICAL METHODS

LABORATORY

OPTICS AND SPECTROSCOPY

HEAD: **Prof. Svetoslav Rashev, D.Sc.**
tel: 8757095, 979 5795; e-mail: rashev@issp.bas.bg

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

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

RESEARCH ACTIVITIES:

Well aligned local monocrystals of smectic C liquid crystal (heptyloxybenzoic acid - 7OBA) have been obtained, using spacially oriented, om SiO_x/ITO/glass surface, monolayer carbon nanotubes (SWCNT). It was shown that the orienting SWCNT/SiO_x/ITO/glass surface contributes to the formation of convenient to be studied local smectic C monocrystals with large surface, as well as for enhancing the surface memory and the anchoring energy. A group of nanocomposites have been synthesized and studied, built in H-bonded in dimer liquid crystals and monolayer carbon nanotubes - (7OBA/SWCNT) nanocomposites in a broad range of concentrations. It was shown, that the magnitude of surface anchoring, as well as the interaction of the nanotubes with the dimer molecular ring, determine both the symmetry type of the nanocomposite, the chirality and achirality, as well as its thermodynamic stability. As a result we obtained a system of phase transition and new phases (chiral smectic C, reentrant nematic and reentrant chiral nematic). For the first time the theoretically predicted by de Gennes chiral biaxial smectic phase (C_G) has been observed, with triclinic (lowest possible) symmetry C_1, not typical for the pure liquid crystal 7OBA. This phase has unique liquid crystal characteristics – doubled inclination angle and spontaneous polarization, that does not disappear in the oriented smectic system.

The flexoelectro-optical behavior of layers formed by a liquid crystal (LC)-polymer phase-separated composite was investigated by flexoelectric spectroscopy. The composite layers with a thickness of 6 μm contain micrometer-sized droplets of LC E7 dispersed in a transparent polymer matrix. The layers were prepared between glass substrates with rubbed teflon nanolayers initially deposited. Thus, LC-polymer composite layers with well ordered and aligned droplet morphology were obtained. The dispersed LC droplets were spherical in shape, with a mean size of about 14 μm. The flexoelectric response of LC droplets in this structure was studied as depending on both temperature and applied voltage. The LC-polymer composite single layers were characterized by the first-harmonic flexoelectro-optic spectra (the amplitude of transmitted light modulation versus the electric-field frequency). The results are of practical interest for electro-optical modulators.

The material in the ion-modified surface layer formed in polymethylmethacrylate (PMMA) is optically characterized by calculations based on multilayer model and optical

reflectance data. PMMA was subjected to a low energy (50 keV) silicon ion implantation at the fluences of 3.2×10^{15} cm^{-2} and 3.2×10^{16} cm^{-2}. Both real and imaginary components of the complex refractive index of this optically transparent polymer are modeled in a geometry that includes a gradient of their in-depth spatial distribution. Normally to the ion-modified surface, the modeled refractive index of ion-modified material shows changes close to the surface, in the depth of about 100 – 150 nm. At the surface, both components (the real one and the imaginary one) of the complex refractive index of Si^+-implanted PMMA have increased values over the ones of the intact polymer PMMA. The index depth profile is gradually decreasing according to the energy loss of the implanted ions. Information about the refractive index of the formed Si^+-implanted PMMA material would be useful for the further investigations on this ion implanted polymer and its photonic applications.

Optical interferometric technique is applied to characterize the nonlocal response of optically-transparent ion implanted polymers. The thermal nonlinearity of the ion-modified material in the near-surface region is induced by cw laser irradiation at a relatively low intensity. The interferometry approach is demonstrated for a subsurface layer of a thickness of about 100 nm formed in bulk polymethylmethacrylate (PMMA) by implantation with silicon ions at an energy of 50 keV and several fluence levels in the range 10^{14} – 10^{17} cm^{-2}. The laser-induced thermooptic effect in this layer is finely probed by interferometric imaging. The interference phase distribution in the plane of the ion implanted layer is indicative for the thermal nonlinearity of the near-surface region of ion implanted optically-transparent polymeric materials. The subsurface planar region of Si^+-implanted PMMA subjected to irradiation by a low-intensity cw laser beam at a wavelength of 532 nm exhibits a sizable laser-induced change of the refractive index, as well as a large laser-induced optical phase change. A strongly expressed nonlocality in the millimeter scale was found for this thermal medium, indicating strong thermal-diffusion-like processes as a most possible nonlocal mechanism.

In a paper, published in the prestigious journal Nature Photonics, K.Panajotov and coauthors report on the first laser diode, that is chaotic without external perturbation or noise. This new discovery not only revolutionalizes the knowledge on the dynamics of laser diodes, but it also makes possible their application in various new fields such as their application as optical generators of arbitrary numbers and for secret encoding of information in the polarization optical chaos.

The mechanical strains in protonated waveguide layers have been calculated, obtained at various technological regimes in lithium niobate crystals. The interferometric method was used, and the employed samples were obtained by varying the technological parameters in order to have layers with various phase compositions. For analysis of the phase composition, a combination of mode and absorption IR spectroscopy. A connection has been established between the mechanical strain and the phase composition of the proton-exchange layers. The thickness of the sublayers obtained for various phases at the borders of the entire protonated layer has been estimated and it was established, that a specific thickness exists corresponding to the most strongly protonated phase, where the mechanical strain is minimal. In this way, at a suitable choice of the technological parameters, waveguide layers can be obtained with a low internal strain value.

A review has been written of the entire research activity of the integrated optics group at ISSP, in the field of producing lithium niobate and lithium tantalite optical waveguides by proton exchange. This review includes the original contribution of our group on the technological modifications, mrthods for analysis of the waveguide and integral optial devices developed on the basis of such waveguides.

Two collections have been published, dedicated to the life and works of George Stoyanov – the first habilitated mathematitian in the Sofia University, and to Manol

Michailov – chief of the University administrative office, as well as an almanac for the lecturers in the Sofia Univ. in the period 1888-1939, grouped by their birthplaces.

A new intra-resonator design has been proposed and experimentally tested, for polarization selection of laser modes, based on the principle of TE/TM diffraction dichroism in a multilayer grating laser mirror. The grating diffracts the first orders between the edges of TE and TM bands of the angular specta of reflection of the laser mirror, but it transmits TM polarized radiation to the underlying dielectric mirror, while the TE transmittance diffraction order to the base is forbidden. This is not a resonance mechanism a therefore the spectral reflection band is relatively broad. Such a structure is demonstrated for a circular grating, monolithically bound to multilayer dielectric coating, that works as a laser mirror in the range from 1.0 μm to 1.1 μm wavelength a filters the radially polarized mode, by making the laser to generate only the azimuthally polarized mode. This is a joined project with the Bulgarian company "Laserproduct", that kindly offered the possibility for testing the structure in production conditions and for demonstrating generation of the azimuthally polarized mode of the Nd:YAG laser.

A new polarizer has been created, based on a resonance reflection grating, that allows to separate the azimuthal and radial polarization of nonpolarized or circularly polarized laser beam. The application range has been extended to the short wavelength spectral range. The extension of the holographic methods to the production various new types of diffraction gratings has been experimentally demonstrated.

Resonance diffraction gratings are also applied in the elements for protection of documents. A new solution has been shown, based on resonance transmission, that improves the level of security. The production of such an element with enhanced level of visual security has been tested in production conditions.

Work has been done on the numerical modelling of the characteristics of microstructured optical fibers using the method of local functions based on the method of Galerkine. Sin functions have been employed for approximating the flight of the local modes, propagating along the optical fibers with photon-crystal structure. A method has been proposed for for reducing the number of integrals, required for for the calculations in the case of holes in the photon-crystal fibers, that have symmetric shape (circular, elliptical, etc.) with respect to the axes of the local coordinate systems, whose origins are at the centers of holes. In the reak case, the shapes of the holes are not symmetrical but they are usually approximated by suitable symmetric shapes, or as a sum suitably located symmetric rectangles. The method does not require expansion of the refraction index of the medium in a set of functions. For the case of circular holes, all integrals are analytically calculated which is quite fast, compared to numerical integration.

Electrooptics of weakly chiralized nematic liquid crystals. The dymanics for unfolding the helix of weakly chiralized nematics has been studied by applying external electric field. We have measured experimentally the threshold voltages of nematic liquid crystals with a different degree of chiralization (step of 1.5 to 4 microns) in a cell with a carrying thickness of 300 nм до 50 мк. The effect on the critical field has been studied for capturing of the liquid crystal molecules on various polymer layers of the upper and lower surfaces of the cell. The role of the original (at zero field) mutually oriented configurations of liq. cryst. molecules on both surfaces of the cell has been estimated. In order to clarify the effect of homogeneity of the lateral electric field, the threshold voltages were measured at various distances between electrodes: 1mm и 50 μк. Qualitative assessment of the results shows a more critical effect of the characteristics of the applied field and weaker role of the variations at capturing the liquid crystal on both surfaces of the experimental cell.

This work was done in collaboration with the workers from the Laboratory of physics of complex systemsat the Unicersity “Jules Vernes” in Amien, France.

Electro-tabulation of lipid vesicles. In the framework of Action COST – “European network for development of electroporation-based technologies and treatments Acronym – EP4Bio2Med”, a preliminary experiment was performed on electrodeformation of lipid vesicles in the presence of fields with amplitudes around or above threshold, required for electroporation of the membrane. Besides the usual electro-induced deformation of the spherical vesicles into ellipsoids, also the formation of lipid tubes oriented along the field has been observed, connecting several vesicles to each other.

In 2012, the interdisciplinary research of megalithic and quasi-megalithic objects in Bulgaria was continued. A careful analysis of megaliths in Bulgaria was pareformed as a suitable occasion to master and practice the modern technique for luminescent aging in Bulgarian archeologic science.

In a special monograph on the “Rider of Madara” L.Tsonev critically considers the state of art in the literature, concerning the origin of this monument and similar monuments in Bulgaria. The author has summarized and critically compared all monuments of this type and on this basis he has come to the well grounded conclusion, that the “Rider of Madara” should be attributed to the Thracian culture instead of the early-bulgarian culture, i.e. to the period of IV century B.C. The monograph proposes to be created and preserved a full tri-dimensional copy of the monument in its present appearance, using the method of laser scanning, in view of its fastly progressing erosion and destruction by atmospheric forces.

We have carried out large scale theoretical calculations on the vibrational level structure of formaldehyde and its isotopomers D2CO and HDCO, using our variational vibrational method, based on an exact expression of the kinetic energy operator and a quartic potential energy field.

Studies have been performed on the optical properties of polycrystalline thin transparent layers of ZnO, obtained by sputtering UV pyrolisys. These studies were done in collaboration with other colleagues from ISSP, Institute of Inorganic chemistry and Institute of Electrochemistry.

Technological realization of thin layer structures on diffraction gratings in oreder tu study their plasmonic behavior. Participation in an experiment on studying a microplasmonic gas analyser. Advisory contribution to the research project № CVP01/002, of the National astronomic observatory “Rozhen”.

Our studies on the formation of optical contact in layers of amorphous silicon carbide have been carried on, using focused ion beams, as well as their applications in nano-dimensional optical recording of information for obtaining sub-micron lithographic masks. The effect of formation of optical contrast in the studied materials has been found, when bombarding with high energy (~1 MeV) beam of protons and alpha-particles. The obtained micro- and nano-size optical images with both types of focused ion beams were studied using various near-foeld methods: AFM, SNOM, as well as XPS.

PUBLISHED PAPERS:

1. I.L. Stefanov, G.B. Hadjichristov, "Interferometric pump-probe characterization of the nonlocal response of optically transparent ion implanted polymers", Appl. Surf. Sci. 258(10) (2012) 4770–4776.

2. H.Y. Stoyanov, I.L. Stefanov, G.G. Tsutsumanova, S.C. Russev, G.B. Hadjichristov, "Depth-profiled characterization of complex refractive index of ion implanted optically transparent polymers using multilayer calculations and reflectance data", Vacuum 86 (12) (2012) 1822–1827.

3. Y.G. Marinov, G.B. Hadjichristov, S. Marino, L. Todorova, S. D'Elia, C. Versace, N. Scaramuzza, A.G. Petrov, "Flexoelectro-Optical Behaviour of Layers Formed by Polymer-Liquid Crystal Phase-Separated Composites", Bulg. J. Phys. 39(1) (2012) 92-99.

4. Nair, V.M., Panajotov, K., Petrov, M., Thienpont, H., Xie, Y., Beeckman, J., Neyts, K., '850nm VCSEL with a liquid crystal overlay', Proceedings of SPIE - The International Society for Optical Engineering 8432 , art. no. 84321X, 2012.

5. M Petrov, B Katranchev, P M Rafailov, H Naradikian, U Dettlaff-Weglikowska and E Keskinova, 'Optical properties of dimeric liquid crystals doped with single-walled carbon nanotubes', J. Phys.: Conf. Ser., **398,** 012035, 2012.

6. B. Katranchev, M. Petrov, I. Bineva, Z. Levi, M. Mineva, 'Smectic C liquid crystal growth through surface orientation by $Zn_xCd_{1-x}Se$ thin films', J. Phys.: Conf. Ser., **398,** 012036, 2012.

7. S. Tonchev, T. Kämpfe, O. Parriaux, "High efficiency, high selectivity ultra-thin resonant diffractive elements", Optics Express, Volume **20**, Issue 24, p. 26714-26724, 2012, IF=3.587.

8. R. Saoudi, M. Moussaoui, S. Tonchev, A.V.Tishchenko, "Modified optical properties of glasses nanostructured by ZnS particles", J. Quant. Spectrosc. & Rad. Transfer (JQSRT), Vol. **113**, Issue 18, P. 2499-2502, 2012. IF=3.19.

9. Jourlin, Y.; Tonchev, S.; Parriaux, O.; Sauvage-Vincent, J.; Harzendorf, T.; Zeitner, U., "Waveguide grating radial polarizer for the photolithography of circularly symmetrical optical elements", IEEE Photonics Journal: Vol.**4**, Issue 5, p. 1728-1736, , 2012, IF=2.32.

10. S. Tonchev, O. Parriaux, « Bypassing and cutting through 1D photonic crystals by ultra-shallow wet-etched resonant gratings », Photonics and Nanostructures: Vol. **10**, Iss.4, 2012, p.651-656, IF=1.681.

11. S. Tonchev, Y. Jourlin, S. Reynaud, O. Parriaux; « Cylindrical Grating Projection by Single-Shot Normal Exposure of a Radial Phase Mask », IEEE Photonics Journal, Vol. **4** , Issue: 4, Pages: 1170–1177, Aug. 2012, IF=2.32.

12. S. Tonchev, Y. Jourlin, C. Veillas, S. Reynaud, N. Lyndin, O. Parriaux, J. Laukkanen, M. Kuittinen; « Subwavelength cylindrical grating by holistic phase-mask coordinate transform », Optics Express, Vol. **20**, No. 7, pp. 7946-7953, 2012, IF-3.587.

13. T. Kämpfe, S. Tonchev, A.V. Tishchenko, O. Parriaux; « Azimuthally polarized laser mode generation by multilayer mirror with wideband grating-induced TM leakage in the TE stopband », Optics Express, Vol. **20**, No. 5 pp. 5392-5401, 27 Feb. 2012, IF=3.587.

14. M Kuneva, K Christova and S Tonchev, « Proton-exchanged optical waveguides in $LiTaO_3$: phase composition and stress », Journal of Physics: Conference Series **398** (2012) 012047.

15. N. Vermeulen, P. Wasylczyk, S. Tonchev, P. Muys, H. Ottevaere, O. Parriaux and H. Thienpont; « High-performance wavelength tuning of a mid-infrared solid-state laser using a resonant diffraction grating », Proceedings SPIE **8433**, 843307 (2012).

16. J. Sauvage-Vincent, S. Tonchev, Y. Jourlin and O. Parriaux, « Holographic exposure of subwavelength circular gratings using a cone based interferogram », Proceedings SPIE **8428**, 84280D (2012).

17. J. Sauvage-Vincent, Y. Jourlin, S. Tonchev, C. Veillas, P. Claude and O. Parriaux; « Industrial fabrication of an optical security device for document protection using plasmon resonant transmission through a thin corrugated metallic film embedded on a plastic foil », Proceedings SPIE **8428,** 84280F (2012).

18. Y. Jourlin, S. Tonchev, A.V. Tishchenko, F. Lacour, and O. Parriaux; "Resonant-grating reflection extended to wideband, large-aperture beams by waveguide-mode coalescence", Optics Express, Vol. 20, No. 27, pp. 29155-29163, 2012, IF=3.587.

19. M. Kuneva, Bulgarian Chemical Communications, "Rare-earth doped optical waveguides in $LiNbO_3$"**44**, Special Issue (Proc. III NCS), pp. 108-113 (2012).
20. K. Antonova, I. Dozov P. Davidson, E. Paineau, C. Baravian, I. Bihannic, L.J. Michot, "Electric-Field Effects in Aqueous Suspensions of Beidellite Clay Detected By Electro-Optical and SAXS Experiments", Bulg.J.Phys., **39,** 70-89, (2012).
21. S.Rashev and D.C.Moule, "Variational Study on the Vibrational Level Structure and IVR Behavior of Highly Vibrationally Excited S_0 Formaldehyde.", Spectrochim.Acta A: Mol.Biomol. Spectr. **87**, 286-292 (2012).
22. S.Rashev, D.C.Moule and V.Rashev, "Variational Study on the Vibrational Level Structure and Vibrational Level Mixing of Highly Vibrationally Excited S_0 D_2CO." Spectrochim.Acta A: Mol. Biomol.Spectr. **97**, p.111-118 (2012).
23. S.Rashev and D.C.Moule, "Variational Calculations on the Vibrational Level Structure of S_0 HDCO."Cent.Eur.J.Chem. **11**(1), 1-7 (2013).
24. T.Tsvetkova, C.D.Wright, M.Craciun, L.Bischoff, O.Angelov and D.Dimova-Malinovska: "Thermal effects on the Ga^+ ion beam induced structural modification of a-SiC:H", 2012, J. Phys.: Conf. Ser., **398**, 012048.
25. Ultrasonically sprayed ZnO films: optical, electrical and gas sensing properties, O Dimitrov, D Nesheva, Z Levi, I Miloushev, T Tenev, V Blaskov, and I Stambolova, Journal of Physics: Conference Series **398** (2012) 012022;
26. M.Virte, K.Panajotov, H.Thiepont and M.Sciamanna, "Deterministic polarization chaos from a laser diode", Nature Photonics, 2012.
27. M. Kuneva, M. Nadoliiski, "Proton exchange technology for obtaining optical waveguides in $LiNbO_3$ and $LiTaO_3$", Proceedings of the UAECG International Jubilee Session, November 16-18, 2012, pp. 417-422.
28. Application of the He microdischarge with nonlocal plasma as a gas analysis sensor, A. Kudryavtsev, M. Stefanova, P. Pramatarov, N. Khromov, R. Peyeva, T. Patrikov, VII Intern. Conf., Plasma Physics and Plasma technology, vol. II, Minsk, Sept. 17-21, 2012, pp. 628-631.
29. A.Weis, T. L. Dimitrova, A. Angelow, G. Dyankov, Fiber-Optics Gyroscope on the base of Sagnac Interferometer, (Technical Description).
30. A.Weis, T. L. Dimitrova, A. Angelow, G. Dyankov, Fiber-Optics Gyroscope on the base of Sagnac Interferometer, (Laboratory Instruction)
31. T.Tsvetkova: "Ion Beam Applications for High-Density Data Storage in a-SiC", invited lecture to be published in the Proceedings of the IAEA Technical Meeting on "Advanced Materials for Energy Storage and Conversion", Sept. 24-28, 2012, Vienna, Austria, as a IAEA TECDOC publication.
32. Л.Цонев, Д.Колев: „Мегалитните паметници в България – състояние и експониране" – сп. *Паметници, реставрация, музеи,* брой 1-2, стр. 65-75,Май 2012г. ISSN 1312-3327
33. Л.Цонев: „За храмовите комплекси „Пропада" и „Мишкова нива" край Малко Търново" - сп. *Паметници, реставрация, музеи,* брой 1-2, стр. 40-64, Май 2012г. ISSN 1312-3327
34. Л.Цонев: „Храмът-кладенец в село Гърло: състояние и реставрация", сп. *Паметници, реставрация, музеи,* брой 1-2, февр.-април 2012, стр. 64-71. ISSN 1312-3327.
35. L.V.Tsonev, D.Z.Kolev: "Bulgarian megaliths: present state and perspectives for further future research directions", *Mediterranean Archaeology and Archaeometry, Journal edited by the Rhodes University*, Vol.12, No.2,2012.
36. Л.Цонев, „Подземният храм-кладенец до с.Гърло, Брезнишко", сп. *Будител*, кн. 2 (април-юни 2012), стр. 33-45.

Monographs

1. Д. Христов, М. Кънева, „Софийският университет „Св. Климент Охридски" – символ на София, гордост на България, венец и купол на българската образователна система. Алманах 1888-1939", Изд. Фараго, София, 2012, 129 стр., 1 ил., ISBN 978-954-2961-16-1
2. Д. Христов, М. Кънева, „Манол Михайлов, началник канцеларията на Софийския университет „Св. Климент Охридски", Изд. Фараго, София, 2012, 121 стр., 1 ил. ISBN 978-954-2961-29-1.
3. В. Баева, Д. Христов, М. Кънева, „Математикът от Нова Загора Георги Стоянов 1872-1912", Изд. Фараго, София, 2012, 77 стр., 4 ил. ISBN 978-954-2961-31-4.
4. Л.Цонев: „Отново за Мадарския конник" – монография, Изд. Домоплан, София 2012, ISBN 978-954-92793-3-7

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

DIVISION SOFT MATTER PHYSICS

LABORATORY

LIQUID CRYSTALS

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

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

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

RESEARCH ACTIVITIES:

Normal blood consists of highly deformable particles (red blood cells, RBC, or erythrocytes) suspended in a Newtonian fluid (blood plasma). As a rough physical model of erythrocytes, giant unilamellar vesicles (GUV) are successfully used to probe their membrane properties. In shear flows vesicles and red blood cells show rich variety of dynamical behaviours influencing the rheological properties of their suspensions. We focused on new experimental aspects of the problem in the case, when a combination of an oscillatory shear rate and a basic constant shear rate is applied to suspensions. Experimental examples with concentrated RBC suspensions are presented together with a discussion on the importance of the superposition of a constant shear flow to the pure oscillation, which is usually used to extract the viscoelastic properties of a complex fluid.

Exposure to high concentrations of contaminations due to air polluting gases, vapours and aerosols and possibly altering the normal pH in the body could lead to undesirable changes in the properties of biological cells. We studied experimentally the mechanical properties of synthetic phospholipid bilayers containing increasing molar fractions (up to 0.15) of charged lipid (synthetic phosphatidylserine) in aqueous solutions with controlled ionic strength and at pH 5, which is slightly lower than the physiological values of pH. For the quantitative determination of the membrane bending rigidity, we applied thermal fluctuation analysis of the shape of quasispherical lipid vesicles. As far as the liquid state of the bilayer is a necessary condition for the application of the experimental method, only vesicles satisfying this requirement were processed for determination of their membrane bending rigidity. The value obtained for the bending modulus of bilayers with 0.15 molar content of charged lipid is about two times higher than the bending modulus of uncharged membranes in the same bathing solution. These findings are in qualitative agreement with our previous results for the bending rigidity of charged bilayers, measured by vesicle micromanipulation.

The analysis of the form fluctuations of giant nearly spherical lipid vesicles observed under optical microscope is one of the widely used methods for the determination of the bending elasticity of the lipid membranes. Although the method is used already for three decades, the values of this material constant, obtained by different groups for membranes of the same composition, in identical conditions, differ significantly. The aim of the present

work is the improvement of the method, permitting to avoid the influence of artifacts on the value of the measured bending elasticity. This is achieved by rejection of some images of the vesicle or the whole vesicle when they do not satisfy the requirements of the applied theory. The bending modulus of SOPC lipid membranes is determined via the improved method. The obtained results are compared with the values published in the literature and their difference is discussed.

Thermally induced shape fluctuations of giant quasi-spherical lipid vesicles are used to study the influence of cholesterol, incorporated in the lipid membranes, on the bending elasticity modulus k_c of the lipid membrane. The influence of cholesterol is investigated throughout a considerably wide interval of concentrations. The values of the bending elastic modulus for 10, 20, 30 and 50 mol% of cholesterol in the SOPC membrane are obtained as a mean weighted value of 6-11 vesicles for each system. The dependence of the bending elasticity modulus on the concentration of cholesterol in the lipid membrane is obtained. At low concentration of cholesterol in the SOPC membrane (10 mol %) a decrease of the bending elasticity modulus is observed, compared to pure SOPC membrane. At high cholesterol content (50mol% and above) a twofold increase of the bending modulus is obtained. The data for k_c for mixed SOPC - cholesterol membrane is compared to the results obtained by different methods on different lipid matrices.

In recent years, liposomes encapsulated with nanoparticles have found enormous scopes in various biomedical fields such as drug design, transport, imaging, targeted delivery and therapy. These applications require a clear understanding about the interaction of nanoparticles with cell membranes. The present work aims to investigate the effect of encapsulation of uncharged and positively charged nanoparticles in three different types of lipids such as1-stearoyl-2-oleoyl-*sn*-glycero-3-phosphocholine (SOPC), 1-stearoyl-2-oleoyl-*sn*-glycero-3-phosphocholine and 1-palmitoyl-2-oleoyl-*sn*-glycero-3-phospho-L-serine (SOPC-POPS) mixture and archaeal lipids. Through the temperature dependent fluorescence anisotropy measurements, we have found that the entrapment of nanoparticles in the bilayer has decreased the lipid transition temperature and increased the membrane fluidity of all three types of lipid vesicles. The results were more predominant in SOPC-POPS mixture because of high density encapsulation of nanoparticles in the vesicles due to electrostatic interaction between negatively charged membrane and positively charged iron oxide nanoparticles.

The influence of single walled carbon nanotubes (SWCNTs) in combination with a deposited surface submicron lipid layer on the formation and dynamics of domains in the nematic E7 in the presence of a DC electric field has been studied in co-operation with scientists from Slovenia, India and South Korea. The formation of three types of domains: flexoelectric, surface polarization induced and electrohydrodynamic has been observed. It has been confirmed that the inhomogeneity of the DC electric field decreases in the presence of SWCNTs. A comparison in the electro-optic behaviour of liquid crystal cells without SWCNTs had been made. It is demonstrated that the double bond HC=CH in one of the two aliphatic chains of the lipid strongly interacts with the carbon nanotubes. This effect can be used in the fight against the cancer.

Systematic experimental study of the physico-chemical factors controlling the foaming and defoaming performance of several Pluronic nonionic block copolymers is performed in solutions of sodium caseinate. Dynamic light scattering measurements and microscopic observations confirm that a significant defoaming is observed above the cloud point of the nonionics, which is almost independent on the polymer structure. However significant differences are observed in the foaming below the cloud point, which do correlate with the polymer structure. Dynamic surface tension measurements allow more detailed analysis of the mechanism of polymer and protein adsorption, and of the role of the individual components for the overall stabilization or destabilization of the foams.

ONGOING RESEARCH PROJECTS:

- **DMU03-80/2011** "The deformability as a key feature of biomembranes and the influence of biologically relevant substances on it – experimental studies on model systems" **(National Science Fund, Bulgaria)**
- **Bilateral Research Project** /ISSP – BAS and ULB – Brussels/: „Thermal fluctuations of lipid membranes studied via digital holography" (Bulgarian Academy of Sciences and Wallonie-Bruxelles International, Belgium)
- **COST Action TD1104** "European network for development of electroporation-based technologies and treatments" (Acronym: **EP4Bio2Med**)

PUBLICATIONS

1. J. Genova, J. Pavlič, A. Zheliaskova, V. Kralj-Iglič, A. Iglič, and M. D. Mitov, "Vesicles with Tethers in Symmetrical and Non symmetrical conditions" Biotech.Biotech.Equip. 26 (1), pp. 205-208 (2012).
2. V. Vitkova, D. Mitkova, N. Kozarev, A. Stoyanova-Ivanova, and I. Bivas, Bending rigidity of lipid membranes and the pH of the aqueous surroundings, C. R. Acad. Bulg. Sci. 65 (3) (2012) 329.
3. D. Mitkova, A. Stoyanova-Ivanova, Yu. A. Ermakov and V. Vitkova, Experimental study of the bending elasticity of charged lipid bilayers in aqueous solutions with pH5, Journal of Physics: Conference Series 398 012028 (2012).
4. V. Vitkova, A. Farutin, B. Polack, C. Misbah, and T. Podgorski, Erythrocyte dynamics in flow affects blood rheology, Journal of Physics: Conference Series 398 012027 (2012).
5. J. Genova, V. Kralj-Iglič, A. Iglič, R. Marinov, I. Bivas, "Influence of Cholesterol on the Elastic Properties of Lipid Membranes" Journal of Physics: Conference Series. 398 012037 (2012).
6. P. B. Santhosh, S. Penič, J. Genova, A. Iglič, V. Kralj-Iglič and N. P. Ulrih, "A study on the interaction of nanoparticles with lipid membranes and their influence on membrane fluidity Journal of Physics: Conference Series 398 012034 (2012).
7. A. Stoyanova-Ivanova, D. Mitkova, St. Georgieva, and V. Vitkova, Lipid bilayers as biocompatible model systems – does the acidity of the aqueous solution alter the membrane elasticity?, Adv. Nat. Sci.: Theory and Applications 1 (1) 29-35 (2012).
8. J. Genova, J. Pavlič, "Realization of marin mitov's idea for the stroboscopic illumination used in optical microscopy", Bulg. J. Phys. 39(1), pp.065-071 (2012).
9. K.G. Marinova, L.M. Dimitrova, R.Y. Marinov, N.D. Denkov, A. Kingma, "Impact of the Surfactant Structure on the Foaming/Defoaming Performance of Nonionic Block Copolymers in Na Caseinate Solutions", Bulg. J. Phys. 39 (1), pp. 053-064 (2012).

DIVISION SOFT MATTER PHYSICS

LABORATORY

BIOMOLECULAR LAYERS

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

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

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

RESEARCH ACTIVITIES:

In 2012, science activity of BML laboratory comprises investigations on flexoelectricyty in nanostructured liquid crystals (LC) and electro-optical properties of polymer/LC composites. Detailed temperature investigations of the bend converse flexoelectric effect in POPDOB, a nearly symmetrically substituted mesogen with a rich polymorphism – specifically exhibiting the nematic-smecticA (N-SmA) transition – were carried out. The results were obtained from electric-induced birefringence measurements in homeotropic samples under horizontal dc electric field in the nematic phase. Other relevant material constants (dielectric anisotropy and bend elastic constant) were extracted by recording the sample capacitance through the electric Freedericksz transition in planar geometry under ac fields. The pretransitional behaviour of the flexoelectric effect on approaching the SmA phase suggests a quadrupolar origin of the flexoeffect.

An UV light-induced (not thermally-induced) effect of tilted anchoring in a photoactive guest-host LC system (1 wt.% guest) upon a relatively low intensity UV-light illumination (of the order of 10 mW/cm2) was investigated. This surface-induced effect is based on trans-cis photoizomerization of the guest azo-dye molecules. The near (sub)surface region of the LC layer rich with azo molecules is responsible for the observed trans-cis photoizomerization-induced surface anchoring. The tilted anchoring close to the surface is closely related to the LCs applications and has to be taken into account, especially at high light intensity, when this effect can limit and even frustrate the LCs laser-driven applications based on trans-cis photoizomerization.

Flexoelectric spectroscopy method was applied to characterize LC-polymer composite single layers. The layers with a thickness of 6 μm contain micrometer-sized droplets of LC E7 dispersed in a transparent polymer matrix demonstrated well ordered and aligned droplet morphology. The dispersed LC droplets were spherical in shape, with a mean size of about 14 μm. The flexoelectric response of LC droplets in this structure was studied as depending on both temperature and applied voltage. The results are of practical interest for electro-optical modulators.

In co-operation with scientists from Slovenia, India and South Korea the influence of single walled carbon nanotubes (SWCNTs) and deposited surface submicron lipid layer on the formation and dynamics of domains in the nematic E7 in the presence of a DC electric field was studied. The formation of three types of domains: flexoelectric, surface polarization induced and electrohydrodynamic one has been analyzed. It was confirmed that the inhomogeneity of the DC electric field decreases in the presence of SWCNTs.

Patent on quality evaluation of drinks by A. G. Petrov et al. has been issued. This method allows express visualization of various components affecting beverages quality. The

procedure consists in comparative texture pattern analysis of liquid crystal layer spreads on dried residue of drinks (wine, beer, coffee, tea, etc.), Fig.1.

The effect of some basic agrotechnical factors is investigated such as: mineral fertilization, mode of fertilizers introduction, soil tillage and companion crop rotation on the yield and quality of grain of maize (Kneja-509) grown on Leached Smolnitza. It is established, that among the factors tested, the fertilization has a dominant influence on formation of yield and grain quality. The energy spectrum of liquid of maize treated and untreated with various doses of herbicides mixtures is investigated. The liquids are taken during two different phenophases: at blossom and at 9 – 10 cheats. It is established that energy spectra of no treated variants (control) and of treated ones with lower herbicide doses are similar. Considerable difference with control is observed for variants treated with higher herbicide doses. Water probes from the region of Rila Mountain National Park are investigated using the same method of water spectra.

Properties of water sessile drop evaporation are discussed such as: evaporation time and evaporation spectrum. The hydrogen bond in water and the formation of the statistically stable net of water molecules interconnected by such bonds is discussed. Transition coefficients between two groups of water molecules: with formed and broken hydrogen bonds are considered. A system of first order differential equation is given describing the transition between these molecule groups.

PUBLICATIONS

1. Flexoelectricity in Lyotropics and in Living Liquid Crystals
Alexander G. Petrov.
In: Flexoelectricity, Chapter 6, N.Eber and A.Buka, Eds,
Imperial College Press, Singapoure (2012), pp. 169-202.

2. Trans-cis photoizomerization-induced tilted anchoring in photoactive guest-host liquid crystalline systems,Y. G. Marinov, G. B. Hadjichristov, A.G. Petrov, S. Sridevi, U. S. Hiremath, C. V. Yelamaggad and S. K. Prasad, Journal of Physics: Conference Series, (2012) 012038

3. Bend Flexoelectricity of a Polymorphic Mesogen, S. Sridevi, Uma S. Hiremath, C.V. Yelamaggad, A.G. Petrov, S. Krishna Prasad, Bulg. J. Phys. **39** no.1, 3-11 (2012).

4. Improved evaluation of the flexoelectric domains formation threshold: the case of weak anisotropic elasticity, Y.G. Marinov and H. P. Hinov, Bulg. J. Phys. **39**, 100–105 (2012).

5. Flexoelectro-Optical Behaviour of Layers Formed by Polymer-Liquid Crystal Phase-Separated Composites, Y.G. Marinov, G.B. Hadjichristov, S. Marino, L.Todorova, S.D'Elia, C. Versace, N. Scaramuzza, A.G. Petrov, Bulg. J. Phys. **39**, 92–99 (2012).

6. Mathematical modeling of sessile drop evaporation and kinetics of hydrogen bonds,
S. Todorov, L. Todorova, Годишник на СУБ, том VI, част I, Благоевград, 378-382 (2012).

7. Влияние на агротехниката върху количеството и качеството на добива от царевичното зърно, Р. Кънчева, С. Тодоров, Л. Тодорова, Годишник на СУБ, том VI, част I, Благоевград, 347-352 (2012).

8. Изследване на речни води по метода на водните спектри, С. Тодоров, Л. Тодорова, “Екология и здраве 2012”, Пловдив, 335-338 (2012).

PATENTS

Patent № BG66245B1, 2012.
Liquid crystal texture method for hard and soft drinks quality control

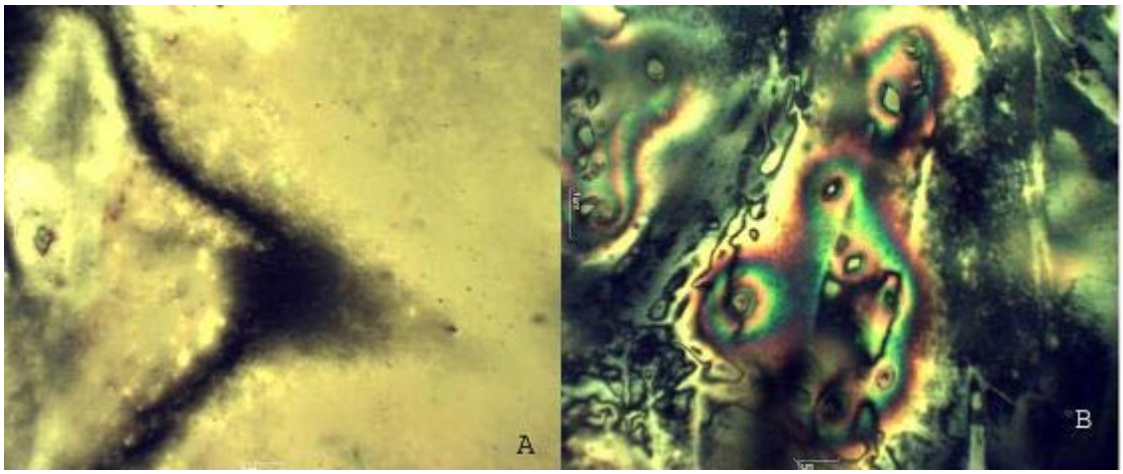


Fig. 1 Liquid crystal visualization of: A) dry red wine, B) same red wine with sugar (0.05 wt%).

ONGOING RESEARCH PROJECTS

Bilateral scientific contract between the Russian Academy of Sciences and the Bulgarian Academy of Sciences:
“Preparation and investigation of organic nano-structure for optoelectronics” (2012-2014)

TEACHING ACTIVITIES

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

DIVISION LASER, ATOMIC, MOLECULAR AND PLASMA PHYSICS

LABORATORY

ATOMIC SPECTROSCOPY

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

TOTAL STAFF: **9**
RESEARCH SCIENTISTS**: 6**

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

RESEARCH ACTIVITIES:

Atomic structure and properties

Radiative lifetimes of 11 even and 7 odd excited states of Tb I have been determined. The excited states are lying in 23031 cm^{-1} – 27528 cm^{-1} energy interval. The experiment was carried out by time resolved laser induced fluorescence method in Lund Laser Center under the EU Program LaserLab in Europe. The laser excitation of states of interest was carried out by single photon excitation from states of ground terms of both parity systems of terms. Radiative lifetime data for 8 states have been determined for first time. For rest of the states the measurements of other authors are checked and corrected.

Quantum optics

Software for computer control of Rb atom laser cooling experiments has been developed. Broad and narrow band composite retarders have been realized experimentally.

A new method for elimination of nonresonance state in Raman Λ system has been proposed. The traditional adiabatic elimination gives precise estimation for effective interaction and Stark detuning only at large frequency detuning. The proposed technique is based on adiabatic or super adiabatic approximation and allows more precise estimation of effective values of interaction parameters as well as broader interval of the detuning. In this respect, quasiresonance states, where traditional adiabatic elimination is impossible can be eliminating. A new technique, which combine two very popular methods for quantum control: composite pulses and stimulated Raman adiabatic transition (STIRAP) is proposed. This hybrid technique allows, using composite sequence of pulse couples having appropriate phases to obtain high precision of population transfer.

An analytical expression is proposed for composite phases having random length sequences. The obtained phases are universal, regardless the shape of the pulses, pulses delay as well as pulses area.

Analytical spectroscopy

A number of experiments for elemental analysis of artifacts of metal, ceramic and glass have been carried out using LIBS technique.

Different discharge configurations of hollow cathode discharge have been modeling in order to obtain appropriate geometrical configurations for receiving high sensitivity of analysis in the case of laser ablation in hollow cathode. A new design of discharge cell,

which allows measuring the space evolution and distribution of ablation cloud, has been proposed.

The influence of external magnetic field on the HCD in order to increase analytical possibilities has been investigated. This is important in the cases of investigations of element traces in different objects. As a result, the balance of the processes shifts to the lower energies and the intensities of the spectral lines of Cu I and Fe I increase.

Plasma physics

The investigations of electron collision spectroscopy have been continuing with application to analytical detector for different gases admixture. The traces of N_2 and CO_2 have been observed in discharge of He. The traces of Mo, Cu, Zn and W are also observed in HCD. The Ar and Kr admixture are used for calibration of energy scale. The discharge pressure is increase to 100 Torr, which promise to realize the miniature detector.

PUBLICATIONS

1. K.Blagoev, M.Grozeva, G.Malcheva, and S.Neykova, **Spectrochimica Acta Part B: Atomic Spectroscopy** (2012), doi: 10.1016/j.sab.2012.11.003, ISSN: 05848547, *Investigation by Laser Induced Breakdown Spectroscopy, X-Ray Fluorescence and X-Ray Powder Diffraction of the Chemical Composition ofWhite Clay Ceramic Tiles from Veliki Preslav.*
2. Dj. Spasojevic, V. Steflekova, N. M. Sisovic, N. Konjevic, **Plasma Sources Science & Technology, 21** (2) (2012) 025006, ISSN: 09630252, *Electric field distribution in the cathode-fall region of an abnormal glow discharge in hydrogen: experiment and theory*.
3. B. T. Torosov and N. V. Vitanov, **J. Phys. B: Atl Mol. Opt. Phys**. **45** (2012) 135502, ISSN: 09534075, *Adiabatic elimination of a nearly resonant quantum state.*
4. A. Kudryavtsev, P.Pramatarov, M. Stefanova and N. Khromov, **Journ. of Instrumentation** JINST **7 (**2012) PO7002 (13p), ISSN: 17480221, *Registration of gas impurities in nonlocal plasma of helium microdischarge by an additional electrode – sensor.*
5. V. Mihailov, R. Djulgerova, J. Koperski, Z. Lju. Petrovic, **Contributed Papers 26th SPIG,** eds. Milorad Kuraica, Zoran Mijatoviж, Novi Sad (2012) pp. 269-272, ISBN: 978-86-7031-242-5, *Optogalvanic signals from iron positive ions in hollow cathode discharge.*
6. D. Zhechev and V. Steflekova, **Contributed Papers 26th SPIG,** eds. Milorad Kuraica, Zoran Mijatovic, Novi Sad (2012) pp. 239-243, ISBN: 978-86-7031-242-5, *On magneto-induced properties of hollow cathode discharge.*
7. A.A. Kudryavtsev, M. Stefanova, P. Pramatarov N. Khromov, R. Peyeva, and T. Patrikov, **Contr. Papers VII International Conference Plasma Physics And Plasma Technology (PPPT-7) Volume II**, eds. V.M. Astashynski, V.S. Burakov, I.I. Filatova, Minsk, Belarus, (2012) pp 628–631, ISBN: 978-985-7055-03-6, *Application of Helium Microdischarge with non-local plasmas as a Gas-Analysis Sensor.*
8. .Dj. Spasojevic, V. Steflekova, N. M. Sisovic, N. Konjevic, **Plasma Sources Science & Technology, 21** (2) (2012) 025006, ISSN: 09630252, *Electric field distribution in the cathode-fall region of an abnormal glow discharge in hydrogen: experiment and theory*.
9. .B. T. Torosov and N. V. Vitanov, **J. Phys. B: Atl Mol. Opt. Phys**. **45** (2012) 135502, ISSN: 09534075, *Adiabatic elimination of a nearly resonant quantum state.*
10. A.Kudryavtsev, P.Pramatarov, M.Stefanova and N.Khromov, **Journ. Instrumentation** JINST **7 (**2012) PO7002 (13p), ISSN: 17480221, *Registration of gas impurities in nonlocal plasma of helium microdischarge by an additional electrode – sensor.*

11. N. Sabotinov, K. Blagoev and M.Grozeva, **40th Anniversary Jubilee Collection - Research Activities of Georgi Nadjakov Institute of Solid State Physics 2003 – 2012,** Editors: A.G. Petrov and M.T. Primatarowa, (2012) pp.151-168, *Laser, Atomic, Molecular and Plasma Physics.*

INTERNATIONAL COLLABORATION

1. Institute of Physics Beograd, Serbia

EDUCATION

One student for bachelor degree (supervisor Dr. E. Dimova) and one for master degree (supervisor Dr. G. Malcheva) prepared their diploma work in the Laboratory.

ONGOING PROJECTS

1. Laser Diagnostics in archaeology DO 02-274/2008 with NSF
2. Physics of atoms, molecules and plasma – project in the framework of Bulgarian Academy of Sciences.
3. EURATOM **–** "Transport of W atoms and ions near the wall"
4. New techniques for quantum control and their application – NSF

FUTURE INVESTIGATIONS

1. LIBS investigation in broader spectral range and application to artifacts from ceramic and metal as well as employing single and double pulse excitation. The LIBS method will be also applied to industry samples.
2. The manipulation of ensembles of cooled atoms will be carried out by external electromagnetic fields. Theoretical investigation will clarify the manipulation of quantum ensembles by composite pulses, having arbitrary pulse shape.
3. The Collision Electron Spectroscopy will be applied for investigation of plasma parameters and detection of admixture, including from solid samples. The computer compatible system for these analyses will be design.

DIVISION LASER, ATOMIC, MOLECULAR AND PLASMA PHYSICS

LABORATORY

METAL VAPOUR LASERS

HEAD: **Prof. DSc N.Sabotinov, member of BAS (until April 2012);**
Assoc. Prof. Margarita Grozeva, Ph.D. (since April 2012)
tel./fax: (+359 2) 979 5717; e-mail: margo@issp.bas.bg

TOTAL STAFF: **17**
RESEARCH SCIENTISTS: **11**

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

RESEARCH ACTIVITIES:

RESEARCH AND DEVELOPMENT of new laser sources; optimization of the excitation, laser efficiency and beam quality; processes in the gas discharge plasma:

The processes in the plasma of longitudinal hollow cathode discharge are investigated by numerical modeling under conditions of laser generation. It is shown that the potential longitudinal inhomogeneity is strongly affected by the cathode diameter and influences the generation parameters. The optimal ratio between the diameter and the length of the cathode segments is determined, allowing for obtaining homogeneous discharge and efficient excitation of the laser generation. The validity of the model is confirmed by measurements of the discharge parameters and the axial and radial distribution of the intensities of various lines in the hollow cathode.

A 2D model (r, z) to determine numerically the gas temperature distribution in laser tube is developed. By measurement of the relative time-resolved intensities of some He and Ne spectral lines, the time-resolved electron temperature is determined in the discharge afterglow for different He, Ne и He-Ne mixtures. A new method for experimental determination of the electron temperature and electron density in gas discharge tubes is proposed. The method is based on the measurement of the time dependence of the electrical discharge parameters – applied voltage and discharge current.

LASER APPLICATTIONS:

There is an on-going research in the application of powerful laser systems, developed in the laboratory, to crystallography, physical chemistry of conducting polymers and processing of various materials, including biological tissue.

The potential of the copper bromide laser for laser cleaning of different materials is investigated. Cleaning experiments are performed and the results for cleaning of stone, leather and metal samples, infected by the most common sources of contamination, are assessed by colorimetric and microscopic methods.

Various archeological artifacts - metallic, ceramic and glass – are analyzed by LIBS. A data base of laser ablation emission lines is created under different excitation in air and in argon flow.

Conservation and restoration analysis of sculptures of famous Bulgarian authors from the 40's of 20th century is performed in the framework of a Sofia Art Gallery project. The aim of the analysis is the determination of the composition of: the alloy, from which the statues are made of; the corrosion layer and the surface contamination. The analysis is performed with portable LIBSCAN 25 apparatus.

An *in situ* LIBS analysis of a silver gilded ritual knemida from the "Mogilanska tumulus" (IV BC) is done. The analysis aims at the determination of the surface condition and the composition of the silver alloy. Using in-depth analysis the thickness of the gilding in various points is determined. Modification and contamination of the surface from previous restoration work is found. This analysis is a part of the preparation study for the restoration of this valuable artifact from the collection of Regional Historical Museum – Vratsa.

A new experimental setup for elemental analysis by laser ablation in hollow cathode discharge is developed. By plasma modeling of different discharge configurations, optimum geometrical dimension of the electrodes are chosen, providing improved sensitivity of the method. A novel geometrical scheme of the hollow cathode is proposed, which allows measurement of the spatial distribution and evolution of the ablation plume. Preliminary experiments are performed and enhancement of the analytical signal is registered.

The $\mathbf{n_2}$ index of glass like matrices based on telluride oxide is obtained and the results are compared with those in literature. The results are described in the framework of the existing theoretical models of the z-scan method. A novel approach to z-scan method is developed, which allows for neglecting the diffraction problem. An equation for the description of the non-linear transmittance of the investigated samples is worked out.

PUBLICATIONS:

Journal articles:

1. K.Temelkov, S.Slaveeva, V.Kirilov, I.Kostadinov, N.Vuchkov, **Physica Scripta 149** (2012) 014015 (3 pages), ISSN: 00318949, *High-power metal halide vapour lasers oscillating in deep ultraviolet, visible and middle infrared spectral ranges*.
2. F.Gubarev, G.Evtushenko N.Vuchkov, V.Sukhanov, and D.Shiyanov, **Review Of Scientific Instruments 83,** (2012) 055111,. ISSN: 00346748, *Modelling technique of capacitive discharge pumping of metal vapor lasers for electrode capacitance optimization.*
3. Stefka Slaveeva, Krassimir Temelkov, Nikolay Vuchkov, **Comptes Rendus de l'Académie Bulgare des Sciences 65**(8) (2012) pp. 1043-1048, ISSN: 13101331, *A study on plasma parameters of He and Ne-He nanosecond pulsed longitudinal discharge for high-temperature large-volume tube*.
4. K.Temelkov, V.Kirilov, I.Kostadinov, N.Vuchkov, **Comptes Rendus de l'Académie Bulgare des Sciences 65(7)** (2012) pp. 899-904, ISSN: 13101331, *Laser Systems Oscillating in DUV and Visible Spectral Ranges for High-precision Material Processing*.
5. Iliycho P. Iliev, Snezhana G. Gocheva-Ilieva, Krassimir A. Temelkov, Nikolay K. Vuchkov, Nikola V. Sabotinov, **International Journal of Optoelectronic Engineering 2(1)** (2012) pp. 10-16, ISSN: 09525432, *Multivariate Statistical Analysis in Planning Experiments for a New Strontium Bromide Vapour Laser*.

6. S. I. Slaveeva, K. A. Temelkov, N. K. Vuchkov, **Journal of Physics: Conference Series 356 (**2012) 012011 (4 pages), ISSN: 17426588, *Analytical calculation of gas temperature measurement of average and time-resolved electron temperature for gas discharge in binary gas mixtures of He and Ne*.
7. T.Chernogorova, K.Temelkov, N.Koleva, N.Vuchkov, **Journal of Physics: Conference Series, 356 (**2012) 012012 (4 pages), ISSN: 17426588, *2D numerical modeling of gas temperature in large-volume high-temperature nanosecond pulsed longitudinal discharge in helium with small admixtures of neon, strontium and bromine*.
8. Krassimir Temelkov, Nikolay Vuchkov, **Bulgarian Journal of Physics 39** (2012) pp. 165-177, ISSN: 13100157, *High-Power SrBr2 Vapour Laser*.
9. D Mihailova, J van Dijk, G J M Hagelaar, S Karatodorov, P Zahariev, M Grozeva, and J J A M van der Mullen, **J. Phys. D: Appl. Phys**. **45** (2012) 165201 (10pp), ISSN: 00223727, *Geometrical features in longitudinal sputtering hollow cathode discharges for laser applications.*
10. K.Blagoev, M.Grozeva, G.Malcheva, and S.Neykova, **Spectrochimica Acta Part B: Atomic Spectroscopy** (2012), doi: 10.1016/j.sab.2012.11.003, ISSN: 05848547, *Investigation by Laser Induced Breakdown Spectroscopy, X-Ray Fluorescence and X-Ray Powder Diffraction of the Chemical Composition of White Clay Ceramic Tiles from Veliki Preslav.*
11. S Karatodorov, D Mihailova, J van Dijk, J van der Mullen and M Grozeva, **Journal of Physics:ConferenceSeries 356** (2012) 012043, ISSN: 17426588, *Monte Carlo simulation of electron kinetics in a hollow cathode discharge.*
12. M. Grozeva and P. Penkova, **The Unknown Face of the Artwork**, Editors: Roxana Rădvan, Sevim Akyüz, Monica Simileanu, © İstanbul: İstanbul Kültür University, (2012), ISBN: 978-605-4233-94-6, *In situ LIBS analysis of valuable museum objects: the Mogilanska Tumulus ritual knemida.*
13. S. Karatodorov, V. Steflekova, V. Mihailov, D. Mihailova, J van Dijk, M. Grozeva and P. Zahariev, **Contributions of 11th Kudowa Summer School, "Towards Fusion Energy**", (2012) *(OP-2), pp.165-168,* ISSN: 20835876, *A novel design of a laser-ablation hollow cathode discharge for elemental analysis.*
14. V.Atanassova, K.Dimitrov, M.Grozeva, M.Similianu and R.Radvan - **Proceedings of the Third Balkan Symposium on Archaeometry: The Unknown Face of the Artwork**, 2012, Bucharest, pp.74-78, ISBN: 13 978-973-88109-9-0, *Copper bromide laser in cultural heritage monuments restoration.*
15. T. Hikov, L. Pramatarova, N. Krasteva, E. Radeva, P. Petrik, E. Agocs, E. Pecheva, R. Presker, O. Sabotinov, **Bulg. J. Phys. 39** (2012) 297–308, ISSN: 13100157, *Study of Nanocomposite Layers Based onPolymer and Nanodiamond Particles: New Materials for Medical Implants.*
16. P.K. Agrawal, G.N. Tiwari, Dimo Astadjov, Akhilesh Karnewar, Pragya Tiwari and S.V. Nakhe, **Proceedings of DAE-BRNS National Laser Symposium** (NLS-20), Chennai, India, (2012), pp.865-868, Jan. 9-12, ISBN: 81-7764-378-9, *Micro-drilling in tungsten sheet using copper vapour laser.*
17. R.K.Mishra, S.V.Nakhe, G.N.Tiwari, D.N.Astadjov, **Proceeding of DAE-BRNS National Laser Symposium** (NLS-20), Chennai, India, (2012) pp.1-4 Jan. 9-12, ISBN: 81-7764-378-9, *Evaluation of power supply configurations for efficiency of copper bromide laser.*
18. Georgi Yankov, Louiza Dimowa, Nadia Petrova, Mikhail Tarassov, Krassimir Dimitrov, Todor Petrov, Boris L. Shivachev, **Optical Materials 35** (2), (2012) pp. 248-251, ISSN: 09253467 , *Synthesis, structural and non-linear optical properties of TeO_2–GeO_2–Li_2O glasses.*

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) – ended this year
- Laser methods for diagnostics in archaeology (funded by NSF DO 02-274/2008) – ended this year
- 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)
- Laser induced fluorescence analysis for investigation and preservation of cultural heritage (funded by NFS MDU 03/79 2012)

APPLIED RESEARCH UNIT

MOLECULAR BEAM EPITAXY

HEAD: **Assoc.Prof. Gencho M. Minchev, Ph.D.**
Tel.: 9795683; e-mail:mbe@issp.bas.bg

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

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

APPLIED RESEARCH RESULTS:

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

ONGOING RESEARCH PROJECTS:

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

MUSEUM

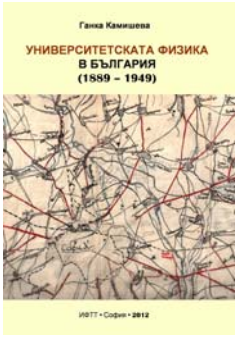
HISTORY OF THE PHYSICS IN BULGARIA

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

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

RESEARCH ACTIVITIES:

Professor Dr. Elisabeth Kara-Michailova successfully performed her duty to work for Bulgarian prosperity taking part in Bulgarian nuclear programme. Her cosmic rays investigations are reported [1] in European symposium "100 Years of Cosmic Particles in honour of Victor F. Hess" [2-3]. All reports of this symposium have filmed.



The level of education in physics at the Sofia University was equal to European since the beginning. University education on physics started modestly and developed slowly in Bulgaria from the end of nineteenth century. Sofia University organised five experimental chairs and one theoretical chair in the area of physics at its Faculty of physics and mathematics up to the middle of twenty century. One dozen physical laboratories and two university institutes are the main places for experimental research in our country. Theoretical physics specialization and results in Bulgaria prevail under the influence of slightly developed industry, expensive experimental studies and new analytical methods [4].

History of science and technology in Bulgaria has reported in the Workshop "Network for the History of Science in Southeastern Europe", Athens, 4 February 2012 [5]. All presentations about history of science teaching in Greece (E. Nicolaidis and K. Skordoulis), Turkey (M. Akbas, and T. Zorlu), Croatia (T. Petkovic), Serbia (A. Petrovic), Romania (G.-E. Iacobescu), Bulgaria (A. Kostov), and UNESCO (D. Poletto) can be seen on the web site of the Museum.

Proceedings of the international symposium "Dissemination and Development Physics and Mathematics on the Balkans" hold in the Institute of Solid State Physics - BAS in 2011, is prepared [6]. Two articles in Bulgarian [7] and foreign [8] magazines reflect this event. Historical research for the roots of theoretical physics [9] and superconductivity [10] in Bulgaria are published in it.

PUBLICATIONS:

1. G. Kamisheva, Professor Dr. Elisabeth Kara-Michailova, Joint symposium in honour of Victor F. Hess "100 Years of Cosmic Particles", Poellau, Austria, 4-5 May 2012.
2. Г. Камишева, Втора международна конференция "Корените на физиката в Европа" 100 години космични лъчи, Списание на БАН (6) 60-64(2012).
3. Г. Камишева, Европейска конференция 100 години космични лъчи, Светът на физиката (2012) (in print).
4. Г. Камишева, Университетската физика в България, ИФТТ, София (2012) 200 с. ISBN 978-954-91198-5-5.

5. G. Kamisheva, History of science and technology in Bulgaria, Newsletter for the history of science in Southeastern Europe, 2012, Nr 17 (in Print).
8. A. G. Petrov, G. Kamisheva, R. Kamburova (Eds.), Dissemination and Development of Physics and Mathematics on the Balkans, ISSP, Sofia (2012) 190 p. ISBN 97895491198-4-8.
6. Physics and Mathematics in the Balkans, Dissemination and Development, Newsletter for the History of Science in Southeastern Europe (16) 7-8 (2011).
7. Г. Камишева, Разпространение и развитие на физико-математическите знания на Балканите, Светът на физиката (1) 93-96 (2012).
9. G. Kamisheva, The roots of theoretical physics in Bulgaria, Dissemination and development physics and mathematics on the Balkans, ISSP, Sofia (2012) 34-43.
10. G. Kamisheva, Superconductivity in Bulgaria (Historical remarks), Dissemination and Development of Physics and Mathematics on the Balkans, ISSP, Sofia (2012) 109-113.