

CONTENTS

Foreword	3
About the Institute of Solid State Physics	5
Organization of the Institute of Solid State Physics	6
<i>THEORY</i>	
THEORETICAL DEPARTMENT	7
COLLECTIVE PHENOMENA IN CONDENSED MATTER	10
<i>MATERIAL PHYSICS</i>	
ELECTRON-PHONON INTERACTIONS	12
ELECTRON MICROSCOPY AND ELECTRON DIFFRACTION	15
X-RAY DIFFRACTION AND MAGNETIC RESONANCE	17
CRYSTAL GROWTH	20
MOLECULAR BEAM EPITAXY AND SURFACE ANALYSIS	23
<i>NANOPHYSICS</i>	
PHOTOELECTRICAL AND OPTICAL PHENOMENA IN WIDE BAND GAP SEMICONDUCTORS	25
SEMICONDUCTOR HETEROSTRUCTURES	29
<i>MICRO- AND ACOUSTOELECTRONICS</i>	
PHYSICAL PROBLEMS OF MICROELECTRONICS	33
ACOUSTOELECTRONICS	37
<i>LOW TEMPERATURE PHYSICS</i>	
LOW TEMPERATURE PHYSICS	41
CRYOGENIC TECHNOLOGY	45
<i>PHYSICAL OPTICS AND OPTICAL METHODS</i>	
OPTICS AND SPECTROSCOPY	46
<i>SOFT MATTER PHYSICS</i>	
LIQUID CRYSTALS	55
BIOMOLECULAR LAYERS	57
<i>LASER, ATOMIC, MOLECULAR AND PLASMA PHYSICS</i>	
ATOMIC SPECTROSCOPY	59
METAL VAPOUR LASERS	62

Dear Colleagues,

The year 2006 was by far the most successful year since the present administration took office. This annual report gives an account of it. The number of papers in prestigious foreign and international journals is markedly increased as well as the number of book chapters prepared by invitation.

Last year the Scientific Council of the Institute adopted a new structure of the Institute, combining existing 18 Laboratories in 8 Divisions. New heads of divisions were appointed with greatly increased responsibilities, among them the formation of program teams of scientists for successful participation in the scientific programs of united Europe.

Last year we celebrated the 110 Anniversary of the birth of Academician Georgi Nadjakov. On this occasion the historical exhibition in his office was reopened as a part of the Museum of the History of Physical Sciences, hosted by our Institute. The 14th edition of our broadly recognized International School on Condensed Matter Physics was devoted to him. More than 140 colleagues from all over the world took part in the School. The Georgi Nadjakov Memorial Lecture was presented by Professor S. Kasap (Canada). The proceedings of the School are already published by JOAM, Buharest.

Three of our younger colleagues have received NATO reintegration grants, which greatly increased their research possibilities and broadened their scientific perspective. The 5 FP Project QxSens lead by Prof. L. Spassov, Corresponding Member of BAS, was successfully completed. Five projects received fresh funding from the National Innovation Fund at the Ministry of Economics and Energy to developed new scientific products in cooperation with SME business. Thanks to all these efforts, the annual income of the Institute has reached its highest level so far.

Teams lead by Prof. I. Bivas, P. Alexandrova, Dr. E. Nazarova and Prof. K. Blagoev received Institute diplomas for the best scientific achievements of the year 2006. During the year 2006 the Institute of Solid State Physics elected Professor Bernard Dulmet (France) Honorary Member of the Institute and awarded him the Georgi Nadjakov Sign of Honour on a ribbon. This is our tribute to his great role in putting forward the international recognition of the Institute. Prof. N. Tonchev received the Sign of Honour of the Bulgarian Academy of Sciences and the Georgi Nadjakov Sign of Honour of ISSP on a ribbon. Prof. E. Atanassova and Assoc. Prof. E. Nadjakova have also received the Georgi Nadjakov Sign of Honour on a ribbon, while Drs. E. Skordeva, L. Yurukova, V. Pamukchieva, N. Todorov and L. Pramatarova were awarded the Georgi Nadjakov Sign of Honour 2nd degree. B. Katranchev received the Ivan Geshov price for youngest scientists of BAS. M. Dimitrova received the price of the Union of Chemists in Bulgaria for a best Master Thesis. Medals and diplomas brought pride and satisfaction not only to their winners, but to the Institute as a whole.

The year 2007, the first year of our membership in EC, is very demanding as it is also the first year of the 7 Framework Program, which we all hope will bring us several successful projects that will enhance our perspectives.

Alexander G. Petrov



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

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

Every second year since 1980, ISSP organizes at the Black Sea coast an International School-Symposium 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, X-ray diffraction with topographic, diffractometric and spectrometric facilities, ellipsometric measurements, spectroscopy from VUV to IR spectral regions, time-resolved spectroscopy, EPR spectroscopy;
- Equipment and know-how for single crystal growth from oxide materials for laser techniques and photorefractive effect applications, techniques and technology for thin layer deposition for microelectronic, optoelectronic and acoustoelectronic sensors and laser technology, complex equipment for molecular beam epitaxy, equipment for synthesis and investigation of high temperature superconducting materials;
- Equipment for polarization measurements in mesophases and polymer liquid crystals for display techniques, equipment for videomicroscopy and micromanipulation of lipid membranes;
- Lasers of various systems - metal vapour, hollow cathode, picosecond lasers for plasma physics and laser analysis of materials with possible application in ecology.

HISTORICAL REFERENCE: ISSP at BAS is created by a Decree No 362 / October 16, 1972, of the Ministry Council of Bulgaria. This Decree splits the existing Institute of Physics with Atomic Scientific Experimental Center (IP with ASEK) 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 of (1973-1991) the Institute of Solid State Physics was Academician Milko Borissov. The second Director (1991-1999) was Professor Nikolay Kirov.

ORGANIZATION OF THE INSTITUTE OF SOLID STATE PHYSICS

DIRECTORATE

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

ADMINISTRATIVE STAFF

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

DIVISIONS

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

SCIENTIFIC COUNCIL

Chairman: Prof. N. Tonchev, D.Sc.
Vice-chairman: Prof. V. Kovachev, D.Sc.
Secretary: Assoc. Prof. S. Aleksandrova, Ph.D.

1. Acad. A. G. Petrov, D.Sc.
2. Acad. N. Sabotinov, D.Sc.
3. Prof. M. Petrov, D.Sc.
4. Prof. S. Rashev, D.Sc.
5. Prof. M. Gospodinov, D.Sc.
6. Prof. N. Vuchkov, D.Sc.
7. Prof. K. Blagoev, D.Sc.
8. Prof. I. Bivas, D.Sc.
9. Assoc. Prof. S. Andreev, Ph.D.
10. Assoc. Prof. D. Nesheva, Ph.D.
11. Assoc. Prof. V. Gueorguiev, Ph.D.
12. Assoc. Prof. M. Mitov, Ph.D.

DIVISION THEORY

THEORETICAL DEPARTMENT

HEAD: **Prof. Dimitar I. Pushkarov, D.Sc.**
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TOTAL STAFF: **8**
RESEARCH SCIENTISTS: **8**

Prof. N.B. Ivanov, D.Sc.; Assoc.Prof. M.T. Primatarowa, Ph.D.;
Assoc.Prof. K.T. Stoychev, Ph.D.; Assoc. Prof. E.R. Korutcheva, D.Sc.;
Assoc.Prof. P. Ivanov, Ph.D.; Assoc.Prof. H. Chamati, Ph.D.; Assist.Prof. R. S. Kamburova

RESEARCH ACTIVITIES:

The theoretical investigations during the last year were focused on the priority problems, traditional for the Theoretical department: nonlinear phenomena and solitons in condensed media, structural investigations of solids and material science, theory of magnetism, statistical physics and its applications to biological systems, neuron networks etc.

A model was considered consisting of particles that carry multicomponent magnetic momenta, and associated with a two-dimensional square lattices; each site can host one particle at most, the pair interaction, restricted to nearest neighbors, is ferromagnetic and involves only two components. A parameter p was introduced to control the anisotropy in the third direction. The model was investigated extensively via Monte Carlo simulations for different values of p . Our results show that for small integer p , the critical behavior of the system is the same as that for the XY model ($p=1$). For large p the second order phase transition turns to a discontinuous transition. This model can be used to describe various experimental situations.

Molecular dynamics simulations were used to determine the temperature dependence of a number a physical quantities of Fe: thermal expansion coefficient, the phonon dispersion curves and phonon density of states, mean-square displacements and surface relaxation. The results obtained show a very good agreement with the experimentally measured data. Our potential may be used in conjunction with computer simulation to investigate several physical properties of the element: epitaxial growth, surface diffusion, nanostructures and other thermal properties.

The interaction of nonlinear Schrödinger (NLS) solitons with extended defects with modified linear, nonlinear and dispersion coefficients is investigated numerically. Repulsive potentials lead to transmission or reflection of the incoming soliton, similarly to the classical-particle case. Attractive potentials yield nonclassical behaviour, associated with the wavelike character of the solitons and for a given range of parameters the scattering patterns exhibit periodically repeating regions of trapping and transmission as a function of the length of the defect segment. It is shown that the escape of the soliton is due to a resonance between the period of the shape oscillations of the soliton inside the segment and the length of the latter. Scattering from inhomogeneities involving two modified coefficients is also investigated and peculiarities associated with the complex potential profiles at the boundary are obtained.

The interaction of solitons with nonlinear point defects is investigated. Analytical solutions are obtained for bright and dark static solitons placed over the defect. The

interaction of propagating solitons with nonlinear defects is studied numerically. Depending on the parameters, the solitons can be trapped, transmitted, reflected or split.

We have considered a special class of quantum spin ladders constructed of different types of quantum spins. The importance of these systems for the physics of quantum magnetism is related to the opportunity to study one-dimensional (1D) ferromagnetic quantum phase transitions. In a recent work [9] we have shown that a large class of such systems exhibit similar magnetic phase diagrams which are closely related to the generic phase diagram of the boson Hubbard model in 1D.

Bump formations in attractor neural networks. This line of activity is related to recent experiments in neural networks systems with lateral connectivity, where a nonlocal neural (bump) activity has been registered. Based on a general attractor neural networks we were able to find the minima conditions for the occurrence of the bumpy behaviour. Extended studies of this kind of states permit to find their application for extracting the signature of natural images and therefore to look for a possible applications in image recognition.

Dynamic critical behaviour of finite-size systems with quenched impurities. A method to study the critical dynamics of finite-size disordered systems with short-range correlated quenched impurities has been developed. Based on our previous investigation on the statics of these systems, we extended the analysis to the case of the dynamics and we were able to give the explicit form of the dynamical critical exponent for a general $O(n)$ model, when $1 < n < 4$.

PUBLICATIONS:

Books:

1. J. Buceta, E. Korutcheva, J.-M. Pastor, *Temas de Biofísica*, Ed. Cuadernos de la UNED, 2006, 328 pp. (textbook).

Papers:

1. H. Chamati, A. Ts. Djankova and N.S. Tonchev, On the application of nonextensive statistical mechanics to the black-body radiation, *Physica A* **360**, 297-303 (2006).
2. H. Chamati and N.S. Tonchev, Generalized Mittag-Leffler functions in the theory of finite-size scaling for systems with strong anisotropy and/or long-range interaction, *J. Phys. A: Math. Gen.* **39**, 469-478 (2006).
3. L.A.S. Mól and A. R. Pereira, H. Chamati and S. Romano, Monte Carlo study of 2D generalized XY-models, *Eur. Phys. J. B* **50**, 541-548 (2006).
4. H. Chamati, N. Papanicolaou, Y. Mishin and D.A. Papaconstantopoulos, Embedded-atom potential for Fe and its application to self-diffusion on Fe(100), *Surf. Sci.* **600**, 1793-1803 (2006).
5. H. Chamati and S. Romano, Berezinskii-Kosterlitz-Thouless transition in two-dimensional lattice gas models, *Phys. Rev. B* **73**, 184424; 6 pages (2006).
6. H. Chamati and E. Korutcheva, Relaxation time in confined disordered systems, ICTP preprint IC/2006/033.
7. H. Chamati and S. Romano, Phase transitions in three dimensional generalized xy models, *Eur. Phys. J. B* **54**, 249-254 (2006).
8. K.T. Stoychev, M.T. Primatarowa, and R.S. Kamburova, Interaction of solitons with segments with modified dispersion, *Phys. Rev. E* **73**, 066611 (2006).
9. N.B. Ivanov and J. Richter, Magnetic phase diagram of a frustrated ferrimagnetic ladder: Relation to the one-dimensional boson Hubbard model, *Phys. Rev. B* **73**, 132407 (2006).
10. H. Chamati and N.I. Papanicolaou, Phonon density of states of iron from molecular dynamics simulations, *JOAM* **9**(1) (2007).

11. M.T. Primatarowa, R.S. Kamburova, and K.T. Stoychev, Interaction of solitons with localized nonlinear defects, *JOAM* **9**, 152-154 (2007).
12. K.T. Stoychev, M.T. Primatarowa, and R.S. Kamburova, Resonant interaction of solitons with extended defects, *JOAM* **9**, 155-158 (2007).
13. K.T. Stoychev, M.T. Primatarowa, and R.S. Kamburova, Resonant interaction of solitons with extended inhomogeneities, *Proc. of the BPU6, Istanbul*, August 2006.
14. M.A. de la Casa, F.J. de la Rubia and P.Ch. Ivanov. Patterns of spiral wave attenuation by low-frequency periodic planar fronts, *Chaos*, **17** (2007).
15. Plamen Ch. Ivanov, Scale-invariant aspects of cardiac dynamics across sleep stages and circadian phases, Special Issue on "Rhythms from Seconds to Days - Physiological Importance and Therapeutic Implications", *IEEE Engineering in Medicine and Biology Magazine* (ISSN 0739-6175).
16. K.Koroutchev and E.Korutcheva, Bump formations in binary attractor neural network, *Physical Review E***73**, 026107 (2006.)
17. K.Koroutchev and E.Korutcheva, Improved Storage Capacity of Hebbian Learning Attractor Neural Network with Bump Formations, in the Proceedings of ICANN'06 Conference, Athens, Greece, LNCS, Ed. Springer ,2006, vol. 4131, p.234.
18. K.Koroutchev and E.Korutcheva, Bump formations in attractor neural network and their application to image reconstruction, in the Proceedings of 9th Granada Seminar of Statistical Physics 2006, Spain. To be published by AIP.

ONGOING RESEARCH PROJECTS:

1. Spectra and Nonlinear Dynamics of Low-Energy Elementary Excitations in Quasi-One-Dimensional Systems (NSF Project F-1414)
2. Defects and Nanoclusters in Classical and Quantum Crystals (NSF F-1517)

DIVISION THEORY

LABORATORY

COLLECTIVE PHENOMENA in Condensed Matter

HEAD: **Prof. Dimo I. Uzunov, PhD, DSc**
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TOTAL STAFF: **3**
RESEARCH SCIENTISTS: **2**

Assoc. Prof. D.V. Shopova; Mr. Tsvetomir E. Tsvetkov, MS, post-graduate student

RESEARCH ACTIVITIES:

- **A new class of universality** of critical behaviour has been predicted during investigations of phase transition properties of itinerant ferromagnetic superconductors (UGe₂, URhGe, and ZrZn₂) [1-3]. The **new critical behaviour** has been described in some details with the help of RG methods [1-3].
- New results have been obtained for the phase diagram of ferromagnetic compounds exhibiting spin-triplet superconductivity (UGe₂, URhGe, and ZrZn₂). A review of the possible phases and phase transitions in spin-triplet ferromagnetic superconductors has been performed on the basis of a quite general Ginzburg-Landau model and mean-field analysis [4]. A reliable prediction about the order of the phase transition from the disordered phase to the phase of coexistence of ferromagnetism and superconductivity has been made and justified (**unpublished result**).
- Gauge effects in Abelian-Higgs models of natural systems [superconductors, liquid crystals, early universe, elementary particles (standard model)] have been reviewed **with a special emphasize on dimensional effects and, in particular, on the quasi-2D case (thin films)** [5].

PAPERS:

1. D. I. Uzunov, *Phys. Rev.* **B74** (2006) 134514. "Critical behavior in unconventional ferromagnetic superconductors."
2. D. I. Uzunov, *Europhys. Lett.* (2006-2007) in press. "New magnetic effects on the phase transitions in unconventional superconductors."
3. D. I. Uzunov, *E17-2006-128 (Communication of JINR-Dubna)*. "New fluctuation-driven phase transitions and critical phenomena in unconventional superconductors." (a preliminary version of [2]).
4. D. V. Shopova and D. I. Uzunov, Chapter of the book: *Progress in Ferromagnetism Research*, ed. by V. N. Murray (Nova Science Publishers, Inc., New York, 2006) pp 223-254. (ISBN: 1-59454-335-6). "Phases and phase transitions in spin-triplet ferromagnetic superconductors."

5. D. V. Shopova, T. E. Tsvetkov, and D. I. Uzunov, *J. Phys. Studies*, (2006-2007) in press (invited review article for the jubilee issue of the Journal). “Gauge effects on phase transitions in superconductors.”

CURRENT PROJECTS, GRANTS:

1. Phases and phase transitions in super-fluids, superconducting and magnetic materials (Research contract, Central Administration of BAS).
2. Theory of superconductivity; EC-6thFP, European Superconductivity Network: GRST-CT-2002-05077.
3. National Foundation of Scientific Research, Contract "Physics 1507/05": “Coexistence of spin-triplet superconductivity and ferromagnetism in some metallic compounds.”

INTERNATIONAL COLLABORATION:

This collaboration has been performed through:

1. Memberships (D. I. Uzunov):

- (a) The Editorial Board of *J. Phys. Studies* (Lviv, Ukraine)
- (b) The Board of Advisors of the American Biographical Institute (USA).

2. Collaborative visits, including seminar talks and discussions with colleagues (D. I. Uzunov):

- (a) ESConet Workshop, Slovenia (22nd-24th June 2006)
- (b) 12 days in JINR-Dubna (Russia)
- (c) 15 days in ICTP-Triest (Italy)
- (d) 62 days in MPI-PKS-Dresden (Germany)

3. Referee reports (D. I. Uzunov, D. V. Shopova) for issues of The Institute of Physics - **IoP** (London, UK) : *J. Physics A*, **B**; *J. Physics: Condensed Matter*, *Supercond.& Supercond. Techn.*, *New J. Physics*, etc. North-Holland (D. V. Shopova): *Phys. Lett. A*.

DIVISION MATERIAL PHYSICS

LABORATORY

ELECTRON-PHONON INTERACTIONS

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TOTAL STAFF: 8

RESEARCH SCIENTISTS: 6

Assoc.Prof. O. Ivanov, Ph.D.; L. Mihailov, Ph.D.; Z. Dimitrova, Ph.D.; Assist.Prof. G. Kamisheva; I. Boradjiev – physicist; M. Gancheva and S. Avramaska - technical ass.

RESEARCH ACTIVITIES:

MANY-PARTICLE SYSTEMS: CORRELATION, SPIN AND RELATIVISTIC EFFECTS. INTERACTION WITH EXTERNAL ELECTROMAGNETIC FIELD

Mass corrections and mass polarizations to the non-relativistic energy for the ground state of He isoelectronic series are studied. Non-conventional optimization method for energy minimization is developed. The reason is that the existing standard programs do not allow the solution of the system for an arbitrary number of coefficients. There is no strict examination of the convergence, depending on the number of the coefficients. The minimization procedure is complicated in order to fit the correct energy local minimum and corresponding set of Hylleraas coordinates. The obtained results are compared to existing experimental data and available theoretical data by other authors. One should note that until now, such data have been computed only for atoms from Helium to Carbon, while our analysis include atoms from Helium to Xenon.

MECHANICAL STRESS IN FILM-SUBSTRATE SYSTEMS

The mechanical stress (MS) in n- and p-type Si-SiO₂ structures and nanohardness change for thermally grown SiO₂ are studied as a function of the dose of 23MeV energy electron radiation. It is shown, that mechanical properties variations are not only due to different radiation defects generated by high-energy electrons at the interfaces, and also to the main impurities in the Si substrate. MS for n-type structures increases two orders at low doses; increasing the dose, it decreases up to values comparable to those of unirradiated samples; MS change is very poor at doses higher than $5 \times 10^{15} \text{ cm}^{-2}$. The peak is attributed to the generation of defects like vacancies and di-vacancies. Increasing the dose, a regrouping of the collected simpler defects into more complicated ones, leads to MS decrease. MS changes for p- type structures are small for all the dose studied. Since the radiation-induced defects like boron-vacancy complexes and interstitial Si atoms start to form at even low doses, though the concentration of these defects increases with increasing dose, MS change is very poor for all the dose studied. Oxide nanohardness increase with irradiation dose is monotonous for all the range of doses and is similar for n- and p- type structures. The reason for this could be found in a decrease of the positive charge in the film.

SURFACE PHOTO-CHARGE EFFECTS (SPCE) AND ITS APPLICATION

- i) The temperature dependence of SPCE is studied for different materials: semiconductors, metals, materials in superconductivity state etc. The temperature range studied is 77-300 K.
- ii) SPCE is applied to food analysis, and especially – to milk. Optimal ways for an express

analysis are not yet found although a number of methods exists. A laboratory model of a device distinguishing different types of milk (cow's, goat's, buffalo's) have been developed. Coordinates of the nitrogen atoms of the chlorophyll molecule were found. On the basis of that, the distances between center of mass, the orientation factor and the Förster constant were calculated. Using these results, the dynamics of the pigment populations were modelled after excitation with laser impulse for chlorophyll A and chlorophyll B.

OPTIMAL DISTRIBUTION OF TRACTION FORCE ENGINES

Stage 3 of the contract N 9999 with Bulgarian State Railways was finished. This includes programming of system "Optimal Distribution of Traction Force Engines" on the base of the developed object-oriented model. The problem for the optimal distribution in the transport tasks includes significant troubles due to the large number of requirements, restrictions and frequent changes in the exploitation conditions. For that reason, despite of many existing management systems, recently French and German administrations have good results. The management system developed by us is applicable in the Eastern-European dynamic changing conditions. The classic linear problem for two criteria optimization includes definition of matrix with time and distance as elements. The optimal solution could be obtained by permutation of the rows or columns so the trace becomes minimal. The problem seems very slow for computer realization, but it could be solved in reasonable time. The obtained optimal solution however is not applicable because of the existence of huge number and variable type of restrictions. Our object-oriented model accounts for all possible requirements and restrictions.

DYNAMICS OF ADAPTING POPULATIONS

We interested in the models of interacting populations which contains second kind of functional response terms. We have investigated such model for the dynamics of three interacting populations and we have shown that Hasting-Powell food chain model is one particular case. Another interesting case is the dynamics of a system of three interacting populations in presence of extinction and substitution. We investigate dynamics of the system states: each population whose number of individuals drops under some threshold value becomes extinct, and it is substituted by another population with different fitness and different coefficients of interaction with other populations. The extinction can destabilize each state of the system: fixed points, limit cycles or chaotic attractors. We observe two possible kinds of evolution in the destabilized system: (i) it remain forever in the trap of extinction or (ii) it can avoid the trap of extinction by means of the substitution by species with better fitness and coefficient of interaction between the populations. The obtained results are discussed from the point of view of products competing for the preference of buyers that can change their opinion.

HISTORY OF PHYSICS IN BULGARIA

Three stages of the theoretical studies in the field of the physics science are described and the specialities between them are marked. Results by the first Prof. in theoretical physics, G. Manev, are presented. Scientific appraisals of these results for 1925-1935 period are given. Bulgarian mathematical literature edited in XIX century is perused. It is found that textbooks on mathematics exceed those on physics, but there are not differences in teaching level.

PUBLICATIONS:

1. O. Ivanov. Sensor applications of field-matter interactions, *ENCYCLOPEDIA of SENSORS*, Ed. Rudolph Marcus, American Scientific Publ., California, **9**, 165 (2006)
2. N. K. Vitanov, Z. I. Dimitrova and H. Kantz. On the trap of extinction and its elimination. *Phys. Lett. A* 349, 350-355 (2006)

3. G.Kamisheva. Bulgarian Mathematical Culture in XIX century, History and Pedagogy of Mathematics Newsletter No 61, 16-20 (2006)
4. Zlatinka I. Dimitrova. On a second kind of functional response model of interacting populations. *Compt. rend. Acad. bulg. Sci.* **59** (5), 493 (2006)
5. R. L. Pavlov, J. Maruani, L. M. Mihailov, S. Drenska, M. Dimitrova-Ivanovich. Effects Induced by Nuclear Structure and Nuclear Motion on the Ground State Energies of Helium Isoelectronic Ions. XI International Workshop "Quantum Systems in Chemistry and Physics" August 20 - 25, 2006, St. Petersburg, Russia.
6. R. L. Pavlov, J. Maruani, L. M. Mihailov, Ch. Velchev, L. I. Pavlov, M. Dimitrova-Ivanovich and V. O. Nesterenko. Effects Induced by Nuclear Motion and by Nuclear Structure on the Ground State Energies of 1s-Helium Isoelectronic Series. *Proc. XXV Int. Workshop on Nuclear Theory, Rila mountain 2006*, ed. by S. Dimitrova, 2006, p. 335
7. G. Kamisheva. History of physics in acad. M. Borissov creative work. Symposium "Session in memory of acad. M. Borissov", Univ. Ed. "Konstantin Preslavski Bishop", Shoumen, 2006, p. 18-31.
8. S. Kaschieva, K. Christova, I. Boradjiev, A. Petrova, J. Koprinarova, S. N. Dmitriev. The role of the high-energy electron irradiation induced defects in some mechanical properties of Si-SiO₂ structures. *JOAM*, in press.
9. L. M. Mihailov, R. L. Pavlov, Ch. Velchev, L. I. Pavlov, M. Dimitrova-Ivanovich, J. Maruani. Non-Conventional Optimization Procedure for Mass Effects Investigation in the Ground State Energies of the 1s Core-Ionized Helium-Like Atoms from Helium to Xenon. *J. of Optoel. and Adv. Mat.*, in press.
10. M. Kamenova, K. Dankov. Modelling of Interaction between Polarized Femtosecond Laser Pulses and a Plant Light Harvesting Complex II, *Frontiers in Optics*, Rochester, New York (2006), in press.
11. G. Kamisheva. Bulgarian Physical and Mathematical Culture in 19 Century. *BPU6, Istanbul*, 21-26 August 2006, Ed. AIP, in press.
12. G. Kamisheva. Scientific information on research activity of acad. M. Borissov. Symposium on a spread and progress of physical-mathematical knowledge in Bulgaria, Oct. 16-17 2006 Sofia, in press.
13. G. Kamisheva. Theoretical study in the field of physical science in Bulgaria during the first half of XX century. Symposium on a spread and progress of physical-mathematical knowledge in Bulgaria, Oct. 16-17 2006 Sofia, in press.

ONGOING RESEARCH PROJECTS:

1. Mechanical properties of high-energy electron irradiated Si-SiO₂ structures. (BAS)
2. Light-induced effects in low-temperature plasma and solid state surface - photoresonant and surface photo-charge effects. (contract with BAS)
3. Correlation properties of nonlinear systems. (contract with BAS)
4. Contemporary problems of the nuclei theory and other many-electron systems. (NSF)
5. Optimal distribution of traction force in rolling composition. (Bulg. Govern. Railway)
6. Investigations of optogalvanic effect in gas mixture hollow cathode discharge plasma – peculiarities and interpretations. (Institute of Physics, Belgrad, Academy of Sciences of Serbia and Montenegro)
7. Possibilities of the hollow cathode discharge as a plasma sputtering source for production and investigation of new materials and metrology. (Inst. of Phys. of Jagellonian Univ., Poland)
8. Dynamic optogalvanic signals in a hollow cathode discharge as a plasma diagnostics technique. (Inst. of Phys., Academy of Sci. of Serbia)
9. History of mathematical and theoretical physics in Sofia University until 1939. (NSF)

DIVISION MATERIAL PHYSICS

LABORATORY

ELECTRON MICROSCOPY AND ELECTRON DIFFRACTION

HEAD: **Assoc.Prof. Maria Kalitzova, Ph.D.**
tel: 9795000/340/440; e-mail: markaliz@issp.bas.bg

TOTAL STAFF: **4**
RESEARCH SCIENTISTS: **3**

Prof. N. Pashov; Assist. Prof. A. Peeva, Ph.D.; M. Georgieva, technical assist.

RESEARCH ACTIVITIES:

1. Nanocluster evolution in high-fluence implanted Si and high-k dielectric layers under the action of different annealings.

a) Te and Bi nanoclusters (NCs) embedded in amorphized layer (a-Si) by ion bombardment of (100) Si have been studied. The NCs have been formed by ion implantation. Post-implantation treatment with 0.45 MHz High Frequency Electromagnetic Field (HFEMF) reorganizes the cluster shape and distribution by stimulation of spinodal decomposition and ordering of Te NCs to a percolation system. The effect of HFEMF on Bi NCs is assumed to be connected with the formation of electrical microcurrents causing local heating of their interfaces with the a-Si matrix. This assumption was verified by Cross-sectional High Resolution Transmission Electron Microscopy (XHRTEM) and Fast Fourier Transformation (FFT) of corresponding part of the XHRTEM image. The results of electrical measurements by using four-point probe technique show that the HFEMF application reduces the sheet resistance by a factor 6 for Te⁺ and about 3 for Bi⁺ irradiation.

b) Ion implantation induced nanoclusters were synthesised in reactive sputtered Ta₂O₅ films by Ge⁺ implantation and subsequent Rapid Thermal Annealing (RTA). The effects of ion fluence and post-implantation thermal treatment on the kinetics of the nanoclustering were investigated. Ge⁺ ions with energy of 40 keV and fluences of 5×10^{15} , 1×10^{16} , and 5×10^{16} cm⁻² were implanted in Ta₂O₃ layers at room temperature. The samples were thermally annealed in vacuum at 700°C and 1000°C for 30, 60 and 180 s. Structural studies of all samples were done by Cross-sectional Transmission Electron Microscopy in diffraction and phase contrast mode. Under optimized conditions (high implantation fluence, subsequent annealing) nanoclusters are formed around the projected ion range of the implanted Ge⁺ ions. The structure of the implanted Ta₂O₃ matrix changes from amorphous to orthorhombic when the annealing was performed at 1000°C. Although the Ta₂O₃ matrix crystallizes, no evidence is obtained for crystallization of the embedded nanoclusters even after annealing at 1000°C.

2. Defect structure of Silicon implanted with Ge ions.

The defect structure of Ge-implanted and annealed silicon was investigated. A stacked structure of alternating layers of vacancy-type defects (cavities) and interstitial-type defects (dislocation loops) was detected. These defects form a substructure within the basic dual structure consisting of a near surface vacancy-dominated region and of dislocation loops in the vacancy dominated region indicates significant vacancy-vacancy and interstitial-

interstitial clustering in addition to the vacancy-interstitial defect recombination. The observed defect structure is in contrast to the widely accepted +1 model which predicts the complete local recombination of ion-generated vacancies and interstitials. Limits of the +1 model are discussed.

PUBLICATIONS:

1. M. Kalitzova, A. Peeva, V. Ignatova, O.I. Lebedev, G. Zollo, G. Vitali, Ion beam synthesis of Te and Bi nanoclusters in silicon: The effect of post-implantation high frequency electromagnetic field, *Nuclear Instruments and Methods in Physics Research B*, 242, 209-213 (2006).
2. A. Peeva, M. Kalitzova, G. Zollo, G. Vitali, G. Beshkov, W. Skorupa, Thermal Behaviour of Nanoclusters in Ge⁺ Ion implanted Ta₂O₅ Layers, *Materials Letters* (2006), in press.
3. R. Kogler, A. Peeva, A. Mucklish, F. Eichhorn, and W. Skorupa, Alternating layers of vacancy-type and interstitial -type defects in Ge ion implanted silicon, *Appl. Phys. Letters* 88, 101918 (2006).
4. T. Ivanova, K.A. Gesheva, M. Kalitzova, B. Marsen, B. Cole, E.L. Miller, "Technology and ion intercalation process parameters and their relation with the structure and optical performance of electrochromic W/Mo oxide thin films", presented at 14th International School on Condensed Matter Physics, Advances in the Micro and Nano-Physics of Solid and Soft Matter, 17-22 Sept. 2006, Varna, Bulgaria
5. A. Peeva, A. Dikovska, P.A. Atanasov, M. Jimenes de Castro, W. Skorupa, Rare-Earth Implanted Y₂O₃ thin films, presented at European MRS, 2006, Strasburg, France.

ONGOING RESEARCH PROJECTS:

1. Φ1310: "Ion-activated crystal nucleation in amorphous media: effects of high-dose implantation with heavy ions", financed by the National Science Found at the Ministry of Science and Education of Bulgaria.
2. "Georgi Nadjakov" ISSP – Bulgaria / Energetics Department of Rome University "La Sapienza" – Italy, "Ion beam synthesis of nanoclusters and new structures in semiconductors and insulators for microelectronic purposes".
3. "Georgi Nadjakov" ISSP – BAS, Bulgaria / Institute of Ion Beam Physics and Materials Research Forschungszentrum Rossendorf – Germany, "Radiation defects and ion beam synthesis of nanoclusters in semiconductors and insulators for microelectronic purposes".
4. ISSP – Bulgaria / University of Reims – France, "Investigation of defects created by heavy ions implantation in diamond type monocrystals by electron microscopy and electron diffraction".

COLLABORATION:

1. ISSP – Bulgaria / EMAT, RUCA, University of Antwerp, Belgium.

DIVISION MATERIAL PHYSICS

LABORATORY

X-RAY DIFFRACTION AND MAGNETIC RESONANCE

HEAD: **Assoc.Prof. Malina Baeva, Ph.D.**
tel: 9795000/275; e-mail: malina@issp.bas.bg

TOTAL STAFF: **6**
RESEARCH SCIENTISTS: **4**

Assoc. Prof. L. Pramatarova, Ph.D.; Assist. Prof. E. Pecheva, Ph.D.;
Assist. Prof. A. Boianova; physicist P. Botev; physicist T. Malakova; chemist M. Dimitrova;
technician H. Paskovski

RESEARCH ACTIVITIES:

1. X-RAY STRUCTURAL INVESTIGATIONS OF POLYCRYSTALS AND SINGLE CRYSTALS

1) According to the Strategic Aims of Bulgarian Academy of Sciences to the period till 2007 for the improvement of the material base of BAS in the Lab RDMR – ISSP the X-ray apparatus – Diffractometer DRON – 3M was brought up-to-date: computer operation of goniometry and programmed treatment of the experimental data was made possible. So, this modernised apparatus will give possibility to measure the diffractograms of polycrystalline samples and their structural characteristics to be concretised.

2) By neutron diffraction the development of the phase composition of the chrome-manganese steels is investigated depending on the Mn concentration. The neutron diffraction experiments [carried out by TOF method in the Pulse reactor IBR-2 in JINR – Dubna- Russia] reveal that these steels represent a mixture of austenite and ferrite phases.

3) The preliminary investigated by x-ray diffraction human renal stones reveal availability of only one crystal phase. The availability of second crystalline phase lower than 3 volume percents by this method cannot be established. In this aspect the neutron diffraction experiments give information about crystal phases if they persist in amount less than 3 volume %. By this reason, the same renal stones were investigated by neutron diffraction. It was proved that the second crystalline phase is absent.

4) By x-ray diffraction the structure of Pb-Sc-Ni-O composition is measured and it is proved that these are crystals with perovskite structure.

5) The investigations of spherulites [the spherulites are crystal type structures appearing as absorbents and molecular seeds in some biological liquids in the organism] are in process. Polymorphism of the spherulites is observed – they transformed into anisotropy and isotropy dendrite crystals. The x-ray structural analysis determined spherulites as K-Na complexes of the amidinourea.

6) X-ray topography of single crystals of Cd-Te single crystals is made.

PUBLICATIONS:

1. S. Dobreva, L. Yankova, M. Baeva, Investigation on the optical properties of $\text{Pb}_2\text{ScNbO}_6$ crystals. *Compt. Rend. Acad. Bulg. Sci.* **59**, № 7 (2006) 713-716

2. M. Baeva, A.I. Beskrovnyi, E.L. Jadrovski, Phase Composition of the Four-Component Nitrified Steels at Increasing Manganese Concentration, 6th Int. Conference of the BALKAN PHYSICAL UNION, 22-26 August 2006, Istanbul-Turkey (in press by AIP)
3. M. Baeva, A.I. Beskrovnyi, A. Boianova, I. Shelkova, Investigation of Renal Stones by X-ray and Neutron Diffraction, 6th Int. Conference of the BALKAN PHYSICAL UNION, 22-26 August 2006, Istanbul-Turkey (in press by American Institute of Physics)
4. N. Izmirova, B. Alexiev, E. Djourova, M. Baeva, P. Blagoeva, P. Uzunov, I. Tomova, Z. Mircheva, A. Boianova, Changes in the spherulite structures in after intoxication, Second National Congress of Clinical Toxicology, 12-14 October, 2006, Sofia, Bulgaria, p-39

ONGOING RESEARCH PROJECT:

“Structural investigations of cystin and phosphate concrements” – Joint Institute of Nuclear Research – Dubna, Russia.

PROJECT: DEVELOPMENT OF AN IN-VITRO SYSTEM FOR STUDYING THE PROCESS OF BIOMINERALIZATION

(project leader Assoc.prof. Dr. L.Pramatarova)

SCIENTIFIC SUBJECT OF THE PROJECT:

The aim of the project is to develop a controllable in-vitro system for growth of hydroxyapatite (HA, bioactive material) on solid state substrates. It is related to national and international important topics, such as Improving Human Potential and Quality of Life, Nanostructures and Nanotechnologies of the 7 FP of the EC. The progress in understanding the process of biomineralization, particularly the HA growth, modification of the various surfaces as well as the interactions between an implanted in the living body material and different cells, is attained through in-vitro experiments.

SUMMARY.

The bioactivity of poly-Si layers obtained by aluminium induced crystallization (AIC) is demonstrated through the formation of hydroxyapatite (HA) from simulated body fluid (SBF) by applying a Laser-Liquid-Solid-Interaction (LLSI) method, i. e. simultaneously interaction of a laser beam, aqueous solution and the poly-Si surface. Enhancement of HA growth and increasing crystallinity is observed due to the LLSI process.

Extracellular Matrix (ECM) coatings are prepared on the surface of three types of substrates (silica glass, silicon and stainless steel). The bioactivity of these layers was observed due to the HA growth. Mechanical properties (Elastic Modulus and Hardness) of these composites were measured through Nanoscan, for the first time. The lowest values were measured for composite coatings obtained over silicon surface (S/ECM/HA) comparing to coatings obtained over silica glass and stainless steel surface. Prolonging the soaking process from 0h up to 24h respectively increasing the thickness of HA, and, lead to slow increase in Elastic Modulus.

The bioactivity of Calcium Phosphates layers obtained by LLSI method is tested through the osteoblast cells culture activity. The layers grown by LLSI or soaking in SBF are not toxic for the osteoblast, which proliferate fast and after 3 days form a confluent monolayer. The surface roughness influences the number of adhering cells.

PROJECT: CALCIUM PHOSPHATE/NANODIAMOND COMPOSITES: SYNTHESIS AND CHARACTERIZATION

(project leader Assoc.prof. Dr. L.Pramatarova)

SCIENTIFIC SUBJECT OF THE PROJECT

The project is related to national and international important topics, such as New Nanostructured Biomaterials of 7 FP of the EC. The progress in understanding the process of HA/ nanodiamond composites growth, changes of their mechanical and chemical properties as well as the interaction of nanostructured material and different cells, is attained through *in vitro* experiments.

SUMMARY.

It is demonstrated that TiCu amorphous alloys can stimulate Calcium Phosphate (CaP) growth from supersaturated solutions, (SBF). Use of supplement of detonation generated nanodiamond (DND) suspension and its clear solution provide different layer morphology. A porous bone like structure is observed.

The influence of DND over HA growth in the process of LLSI was investigated. It is shown that the use of DND influences the crystal growth. The morphology of the grown nanocomposites is examined by coherence probe microscopy (CPM) and scanning electron microscopy (SEM). The elemental composition is measured by energy dispersive X-ray spectroscopy (EDX). The layer structure is studied by X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR) and Raman spectroscopy. Mechanical properties are tested by Nanoindentation. Addition of the DND suspension to the SBF increases the hardness and decreases the elasticity of the grown composite, depending on the thickness of the layer. Bladder carcinoma cells, T24, carried bioactivity test. Cells showed good adhesion and spreading on the newly obtained composite. The refractive index of the nanocomposite has been found to be 1.45 (using CPM).

The results of the projects for 2006 are summarized in one monograph and 14 papers. At the end of the year a diploma thesis was successfully defended in Sofia University, Chemistry Faculty. The diploma thesis was awarded by the Union of Chemists in Bulgaria - Best thesis for 2006.

Seven posters on four international conferences were presented one of which won a prize for best poster.

DIVISION MATERIAL PHYSICS

LABORATORY

CRYSTAL GROWTH

HEAD: **Prof. Marin Gospodinov, D.Sc.**
tel.: 9795000/263; e-mail: gospodinov@issp.bas.bg

TOTAL STAFF: **8**
RESEARCH SCIENTISTS: **7**

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

RESEARCH ACTIVITIES:

The research work of the Laboratory of Crystal Growth was focussed on:

- growth of $\text{Bi}_{12}\text{MO}_{20}$ (M= Ge, Si and Ti) crystals with application in the field of non-linear optics and optical information storage;
- investigation of two and three-dimensional defects in face- centered cubic (fcc) and body- centered cubic (bcc) structures;
- growth and investigation of complex oxides with perovskite and spinel structures.

Single crystals of $\text{Bi}_{12}\text{SiO}_{20}$ doped with Re, Rh, Ru and Os (BSO:Re, BSO:Rh, BSO:Ru and BSO:Os) with diameter of about 40 mm and length of 80- 100 mm were grown by the Czochralski method. The distribution coefficients of Re, Rh, Ru and Os in BSO and were determined. The optical absorption, the photoinduced absorption and the Raman spectra as well as photoconductivity of these crystals were measured. The observed effects are explained in the framework of the Rose model assuming that doping creates deep levels in the gap that act as recombination centers with a very little cross-section for electron capture. We also studied the kinetic curves of photocurrent increase and decrease in BSO:Os which enabled us to determine the magnitude of the cross-section for a photon capture at an impurity center. Slices of these crystals were studied by X- ray double crystal traverse topography. It was that the BSO:Os crystal is probably free of two-dimensional defects [1,2].

A specimen from a melt-grown CdTe crystal was prepared by the “suspension” method. A lot of dislocations, stacking faults as well as first-order and second-order twin boundaries, accompanied by many dislocations lying in (or close to) the grain boundary plane were observed in diffraction contrast mode image. The main types of the existing defects were modeled and the corresponding SAED pattern images were successfully simulated- [3].

A Czochralski grown $\text{Bi}_4\text{Ge}_3\text{O}_{12}$ crystal plate of (BGO) was examined by several X- ray diffraction methods. The X- ray diffraction double crystal traverse topography (XRDT) images reveal that the core area of the crystal is strained and occupied by dislocations with density that does not exceed $(20- 30) \text{ cm}^{-2}$. It was established that the almost entire crystal surface is occupied by two- dimensional defects, probably some form of stacking faults- [4]. The electrical, optical and magneto- optical properties of doped with Al and Mn single crystals of $\text{Bi}_4\text{Ge}_3\text{O}_{12}$ were studied. It was established that the photosensitivity of the doped crystals is shifted reasonably to the visible region- [5,6]. A Raman Spectroscopic Study of Ru, (Ru+Mn), Fe and (Al+Mn) doped $\text{Bi}_4\text{Ge}_3\text{O}_{12}$ Crystals was carried out- [7].

We have studied magnetotransport in a set of nanocrystalline samples of composition $\text{La}_{0,6}\text{D}_{0,4}\text{MnO}_3$, where the divalent ion is changed. The data show that at low temperatures

inter-grain tunneling model applies, providing good crossover to the metallic range where scattering in the presence of disorder takes place- [8]. $\text{La}_{0.7}\text{Pb}_{0.3}\text{MnO}_3$ crystals are grown by high temperature solution growth (HTSG) method and the crystals are studied by analysis of complex conductivity- [9].

Thermal expansion measurements were done on single-crystal RMn_2O_5 (R=Tb,Dy,Ho) along the principal crystallographic axes. Distinctive anomalies were observed in the linear thermal expansivities at critical temperatures marking the onset of long-range antiferromagnetic order, ferroelectricity, as well as at temperatures when anomalous changes in the polarization, dielectric constant, and spin wave incommensurability have been previously reported. These observations suggest that the coupling between the magnetic orders and the dielectric properties is mediated by the lattice distortion. Neutron diffraction measurements on HoMn_2O_5 show a spin reorientation at 23 K corresponding to a step-like anomaly in the dielectric constant- [10].

Strong anomalies of the thermal expansion coefficients at the magnetic and ferroelectric transitions have been detected in multiferroic $\text{R Mn}_2\text{O}_5$. Their correlation with anomalies of the specific heat and the dielectric constant is discussed [11].

The polarized Raman spectra of orthorhombic R MnO_3 series (R=La, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Y) were studied at room temperature. The variation of phonon frequencies with R ionic radius r^{R} as a whole confirms the commonly accepted Raman line assignments with two noticeable exceptions revealed in Ag- O modes- [12].

We report on the synthesis of a new relaxor compound with chemical formula $\text{Pb}_{0.78}\text{Ba}_{0.22}\text{Sc}_{0.5}\text{Ta}_{0.5}\text{O}_3$ (PBST). The frequency dependence of the dielectric constant of PBST shows a strong dielectric dispersion in a wide temperature range and a dielectric-constant maximum near 200 K at 10 kHz. The local atomic environment was probed by Raman scattering and optical absorption spectroscopy- [13].

Single crystals of $\text{Pb}_2\text{ScNbO}_6$ were grown by the high temperature solution growth (HTSG) method. The transmission spectrum and the reflection spectrum were measured and the absorption coefficient was calculated. The bandgap was determined. From the value of the bandgap and the behaviour of the absorption coefficient $\alpha(h\nu)$ the character of the transitions was determined- [14].

$\text{Pb}_2\text{ScTaO}_6$ (PST) single crystals are obtained by high-temperature solution growth (HTSG) method. The dielectric measurements performed in the frequency range 10 kHz – 1 MHz and the temperature range - 40 °C to 60 °C show that the crystals prepared in oxygen and mixed oxygen/hydrogen atmosphere conditions possess more relaxor type behavior with diffuse ferroelectric phase transition at lower temperature. Moreover the frequency dependence of the dielectric properties is stronger in these crystals as well- [15].

PUBLICATIONS:

1. V. M. Skorikov, T. I. Milenov, A.V. Egorysheva, P. M. Rafailov, T.D. Dudkina, M. N. Veleva, A.Ya. Vasil,ev and M.M. Gospodinov, *An optical absorption study of Ru, Rh, Re and Os doped $\text{Bi}_{12}\text{SiO}_{20}$ crystals*, physica status solidi (2007) – in press.
2. T. I. Milenov, P. M. Rafailov, A.V. Egorysheva, V. M. Skorikov, R. Petrova, M. N. Veleva, T.D. Dudkina, C. Thomsen, A.Ya. Vasil,ev and M.M. Gospodinov, *XRD and Raman spectroscopic study of Ru and Os doped $\text{Bi}_{12}\text{SiO}_{20}$ crystals*, Journal of Optoelectronics and Advanced Materials (2007) – in press.
3. T. I. Milenov, V.I. Dimov, and M. M. Gospodinov, *TEM observation of two-dimensional defects in CdTe crystals*, JOAM (2007) – in press.
4. T. I. Milenov, P.A. Botev, P. M. Rafailov, R. Petrova, Yu.F. Kargin and M. M. Gospodinov, *X- Ray Diffraction Study of a $\text{Bi}_4\text{Ge}_3\text{O}_{12}$ Crystal*, Mater. Sci. Eng. B (2007) - in press.

5. D. Toncheva, *Growth and electrical properties of doped Bi₄Ge₃O₁₂ single crystals*, Journal of Optoelectronics and Advanced Materials (2007) – in press.

6. P. Petkova, V. Marinova, M. Veleva, T. Dimov, I. Iliev, *Optical and magneto-optical properties of Bi₄Ge₃O₁₂ doped with aluminium and manganese*, (2007) – in press.

7. P. M. Rafailov, T. I. Milenov, M. N. Veleva, C. Thomsen and M. M. Gospodinov, *A Raman Spectroscopic Study of Ru, (Ru+Mn), Fe and (Al+Mn) doped Bi₄Ge₃O₁₂ Crystals*, Comptes Rend. de l'Acad. Bulg. des Sci., 59 (2006) 255-260.

8. Antunes, A.B., Gospodinov, M., Baibich, M.N., *Electronic transport on doped La_{0.6}D_{0.4}MnO₃ ceramic manganites*, Physica B: Condensed Matter 384 (2006) 47-50.

9. S. Dobрева, K. Ivanova, L. Yankova and I. Yanchev, *AC Conductivity of La_{0.7}Pb_{0.3}MnO₃ Crystals*, Comptes Rend. de l'Acad. Bulg. des Sci. 59 (2006) 489-492.

10. Dela Cruz, C.R., Yen, F., Lorenz, B., Park, S., Cheong, S.-W., Gospodinov, M.M., Ratcliff, W., Lynn, J.W., Chu, C.W., *Evidence for strong spin-lattice coupling in multiferroic RMn₂O₅ (R = Tb, Dy, Ho) via thermal expansion anomalies*, Journal of Applied Physics, 99 (2006), Article number 08R103.

11. Dela Cruz, C.R., Yen, F., Lorenz, B., Gospodinov, M.M., Chu, C.W., Ratcliff, W., Lynn, J.W., Park, S., Cheong, S.-W., *Structural anomalies at the magnetic and ferroelectric transitions in RMn₂O₅ (R=Tb, Dy, Ho)*, Phys. Rev. B **73** (2006)1-4.

12. Iliev, M.N., Abrashev, M.V., Laverdière, J., Jandl, S., Gospodinov, M.M., Wang, Y.-Q., Sun, Y.-Y., *Distortion-dependent Raman spectra and mode mixing in RmnO₃ perovskites (R=La, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Y)*, Phys. Rev. B **73** (2006) 1-6.

13. Marinova, V., Mihailova, B., Malcherek, T., Paulmann, C., Lengyel, K., Kovacs, L., Veleva, M., Gospodinov, M., Güttler, B., Stosch, R., Bismayer, U., *Structural, optical and dielectric properties of relaxor-ferroelectric Pb_{0.78}Ba_{0.22}Sc_{0.5}Ta_{0.5}O₃*, Journal of Physics Condensed Matter, 18 (2006) L385-L393.

14. S. Dobрева, L. Yankova, M. Baeva, *Investigation on the optical properties of the Pb₂ScNbO₆ crystals*, Comptes Rend. de l'Acad. Bulg. des Sci. 59 (2006) 713-716.

15. A. Amova-Kostova, M. Veleva, V. Marinova, *Growth of ferroelectric Pb₂ScTaO₆ single crystals in oxygen and hydrogen atmosphere and investigation of their dielectric properties*, Journal of Optoelectronics and Advanced Materials (2007) – in press.

ONGOING RESEARCH PROJECTS:

Financed by the National Science Found at the Bulgarian Ministry of Education and Science:

F 1207: Growth of complex oxide crystals from mixed valence compounds. Investigation of their structure, defects, electrical, optical and magnetic properties.

F 1308: Growth and investigation of wide band gap semiconductor and oxide crystals with application in photorefractive optics and nuclear detectors

COLLABORATION:

1. Growth and investigation of single crystals, layers and glasses from compounds based on Bi₂O₃ and Cd_{1-x}Zn_xTe - Institute of Common and Inorganic Chemistry, Russian Academy of Sciences, Moscow, Russia

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

3. Static moments of short-lived exotic nuclei studied via hyperfine interaction on the nuclear spins with crystalline electric field gradients- Instituut voor Kern en Stralingsfysica, Leuven, FWO- Flanders, Belgium

4. Synthesis of multiferroic materials- Institute of Materials Science, Barcelona, Spain

DIVISION MATERIAL PHYSICS

LABORATORY

MOLECULAR BEAM EPITAXY and SURFACE ANALYSIS

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

tel.: 71-44-217; E-mail: mbe@issp.bas.bg

TOTAL STAFF: **4**

RESEARCH SCIENTISTS: **2**

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

RESEARCH ACTIVITIES:

During 2006 year were accomplished literature search, technological studies, and applied research in preparation for new research and innovative projects, which will be under developing from 2007 to 2010 year. These cover: (i) creating of new diluted magnetic III-V type single crystal materials, as a base for a novel spin-based electronics (spintronics); (ii) creating of III-V single crystals with artificially built-in nano-dimensioned internal heterostructures for the novel nanoelectronics, based on control of excitons (excitronics); (iii) a range of innovations based on the development of novel scanning probe microscopy techniques, especially with intelligent probes that precisely quantify the energy dissipation channels in all physically existing resonances in any type materials; (iv) investigation of the structure of giant bio-macromolecules (DNA giant macromolecules packed in chromosomes) that determines their unorthodox properties and specific functions because of nanometer range dimensions.

The work on **“Studying human chromosomes structure by analyzing their topography obtained through Scanning Tunnelling Microscopy on ultra thin coating water films”** was continued in several directions. The process of STM tips electrochemical etching during the tips preparation was investigated. It was written a complete program package allowing the transparent programming of the scanning tunneling microscope hardware, which ensures the microscope use in various modes of operation, including the mode of nanomanipulator. A program package for transformation and comparison of images obtained by scanning tunneling microscopy and standard optical microscopy technique was also created.

Two reports were present and published in “Proceedings of the 20th European Frequency and Time Forum (EFTF 2006), Braunschweig, Germany, 2006” on “Visualization of acoustic waves in piezo materials”.

PUBLICATIONS:

1. G. Minchev, T. Sukhikh, “Piezoelectric resonances measuring system operating in a novel *lock-on-resonance* mode”, Proceedings of the 20th European Frequency and Time Forum (EFTF 2006), Braunschweig, Germany, pp.120-124 (2006).
2. G. Minchev, T. Sukhikh, D. Dinchev, L. Trendafilov, “Novel scanning probe method for visualization of standing acoustic waves in piezoresonators”, Proceedings of the 20th

European Frequency and Time Forum (EFTF 2006), Braunschweig, Germany, pp.113-119 (2006).

3. Gencho M. Minchev, “109309.Method and measuring system for visualization of standing acoustic waves in piezomaterials”, Bulgarian Patent No 109309.

ONGOING RESEARCH PROJECTS:

1. Investigation of the structure of giant bio-macromolecules (DNA giant macromolecules packed in chromosomes) that determines their unorthodox properties and specific functions because of nanometer range dimensions.
2. Technological research for creating new diluted magnetic III-V type single crystal materials, as a base for a novel spin-based electronics (spintronics).
3. Technological research for creating III-V single crystals with artificially built-in nano-dimensioned internal heterostructures for the novel nanoelectronics, based on control of excitons (excitonics).
4. A range of innovations based on the development of novel scanning probe microscopy techniques, especially with intelligent probes that precisely quantify the energy dissipation channels in all physically existing resonances in any type materials.

DIVISION NANOPHYSICS

LABORATORY

PHOTOELECTRICAL AND OPTICAL PHENOMENA IN WIDE BAND GAP SEMICONDUCTORS

HEAD: **Assoc.Prof. Diana Nesheva, Ph.D.**
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TOTAL STAFF: **14**
RESEARCH SCIENTISTS: **11**

Assoc.Prof. E. Skordeva, Ph.D; Assoc.Prof. Z. Ivanova, Ph.D; Assoc.Prof. D. Arsova, Ph.D; Assoc.Prof. V. Pamukchieva, Ph.D; Assoc.Prof. Z. Aneva, Ph.D; Assoc.Prof S. Balabanov, Ph.D. Assoc.Prof. K. Kolentsov, Assist.Prof. L. Yurukova; Assist.Prof. Z.Levi, Ph.D; Asist.Prof. I. Bineva, Ph.D.; A. Rachkova, chemist; E. Zaharincheva, technologist; G. Tschuschew, physicist.

RESEARCH ACTIVITIES:

1. DISORDERED MATERIALS - CHALCOGENIDE GLASSES AND THIN FILMS

The dependences of the parameters of the irreversible photoinduced changes on the film thickness (between 0.4-1.4 μm) and illumination time (up to 3h) have been investigated in one of the most sensitive composition of the $\text{AsS}_3\text{-Ge}_2\text{S}_3$ line. Extremely high irreversible changes of the optical band gap (~ 600 meV), the refractive index (~ 0.2) and the thickness increase (11%) have been found in thin films from $\text{Ge}_{30.8}\text{As}_{5.7}\text{S}_{63.5}$ glass having thickness of ~ 0.6 μm . It has been established for the first time, that the magnitude of the irreversible photo-bleaching in thin chalcogenide films is comparable and even higher than that of the irreversible thermally induced bleaching. The local structure and the electronic properties of Ge-As-S glasses from the same $\text{AsS}_3\text{-Ge}_2\text{S}_3$ line have been studied by ^{119}Sn Mössbauer and X-ray photoelectron spectroscopies. Although the glasses consist of non-stoichiometric components, preferentially, the structural units $\text{AsS}_{3/2}$ и $\text{GeS}_{4/2}$, form the glass matrix.

The components of the specific heat (C_p) of the $\text{Ge}_x\text{As}_{40-x}\text{S}_{60}$ glasses have been completely analyzed in accordance with the theoretical models of the soft potential modes (SPM) and the temperature range of the validity of the model has been ascertained. The main results from the investigation of the thermal properties in the temperature range 3 - 300 K, specific heat (C_p) and thermal conductivity (k), of the $\text{Ge}_x\text{As}_{40-x}\text{S}_{60}$ glasses have been reviewed and concurrently analyzed. The nonmonotonic dependences of the parameters of the universal low-temperature features on the composition (defined by the average coordination number Z) have been correlated with the degree of the thermodynamic fragility of the glassy compositions. The correlation is based on the prevalence of the excess of vibrational soft modes (SM) in the less fragile glasses. Some assumptions of the soft-potential model have been checked and new Z dependences have been found for the energetic parameter connected with the delocalization of the SM. A relation between the crossover temperature for the soft-mode delocalization and the temperature dependence of the calculated thermal diffusivity D has been found. The complete analysis of the thermal characteristics leads to new scaling laws and new insight into some implications of the SPM clarifying the peculiarities of the peak in the C_p/T^3 vs T plot and the plateau of $k(T)$.

The compositional dependence of the photoluminescence (PL) in Er-doped Ge-S-Ga glasses has been investigated. It has been established that the direct excitation of Er³⁺ ions leads to rather more pronounced emission than that via the matrix. The temperature decrease down to 4.2 K leads also to an improved PL signal. To obtain more enhanced PL efficiency, a new glassy host with higher Ga concentration has been prepared, ensuring enlarged Er solubility. A quenching PL effect has been observed at 1.22 at % Er-doping level, which is accompanied by maximal optical absorption.

2. NANOSTRUCTURED THIN FILMS

Photoluminescence measurements were carried out at room temperature on SiO_x thin films having oxygen content $x=1.5$ or 1.7 . The samples were furnace annealed for various times ($t_a=5-60$ min) at 770 and 970 K. The effect of the annealing conditions and wavelength of the exciting light on the shape of the photoluminescence from these films has been explored. In the PL spectra of the samples annealed at 770 K for $t_a \leq 40$ min two distinct PL bands at around 2.3 and 2.5 eV have been resolved. They do not shift appreciably with increasing annealing time. In addition, at longer annealing times, a weak third band is resolved centered in the range 2.0-2.1 eV. It exists in the spectra of all samples annealed at 970 K being more prominent in the samples with $x=1.5$. The obtained results are discussed in terms of radiative recombination via defect states in the SiO_x matrix (the 2.5 eV band) and the a-Si-SiO_x interface (the 2.3 eV band) while the band centered in the 2.0-2.1 eV range is related to recombination in amorphous silicon nanoparticles grown upon annealing.

Silicon suboxide thin films with different oxygen content ($1.15 \leq x \leq 1.7$) have been rapidly thermal annealed (RTA) at 1100°C in vacuum for 15 s and 30 s and analyzed using infrared (FTIR) and photoluminescence (PL) spectroscopy. In the FTIR spectra of the SiO_x samples annealed for 15 s the usual blue-shift of the stretching mode has been observed. The mode shows a red shift in the samples annealed for 30 s. This behaviour has been interpreted in terms of a decrease of the oxygen content and film density upon annealing in vacuum. The obtained PL results are in good agreement with the observations on furnace annealed films.

Multilayers of ZnSe/SiO_x having different ZnSe layer thicknesses (2.0 to 10 nm) have been prepared by thermal evaporation in vacuum. Raman scattering measurements have been performed at room temperature using the 442 nm line of a He-Cd laser. Two bands, which appear at about 250 and 500 cm⁻¹, have been observed attributed to the 1LO and 2LO modes from “pure” ZnSe in multilayers. Both modes show a large homogeneous broadening. The 1LO Raman mode displays an asymmetric shape and redshift, which can be related to the phonon confinement effect, due to the nanometric size of the ZnSe layers. The size effect on the band shape has been simulated by using an one-dimensional phonon confinement model for ZnSe nanolayers. The comparison of experimental and calculated data also implies the existence of surface phonon modes.

3. AC ELECTROLUMINESCENCE, ELECTROLUMINESCENT STRUCTURES AND DISPLAYS

The brightness characteristics of electroluminescent structures showing blue emission have been investigated for three fullerene C₆₀/C₈₀ concentrations. The best result has been achieved for a concentration of 2.4×10^{-3} g/l. In order to clarify the underlying mechanism of the observed brightness increase, optical transmission and diffusive light scattering have been studied in the visible and near ultraviolet spectral ranges.

Layer of SnO₂ and Si-containing polymer films were produced and changes in their absorption caused by an electron beam irradiation (energy of 22 MeV; density of 6.10^{11} electron/mm²) have been investigated. It has been established that the irradiation causes an absorption decrease of about 50%, as the initial state recovers for four months. Photoluminescence of thin Si-containing polymer films implanted with carbon ions has been

studied. An increase of 12 % has been observed caused by this implantation. Since these material is suitable for application in electroluminescent structures, one can expect that the observed PL increase will result in an increase of the display brightness.

Several different polymers (PE, PP, PMMA, PTFE /Teflon/) were implanted with Si⁺ or C⁺ ions at doses varying between $5 \times 10^{-12} \text{ cm}^{-2}$ and $1.2 \times 10^{-17} \text{ cm}^{-2}$. The changes of absorption, reflection and diffuse reflection spectra in the visible and near-ultraviolet (230-400 nm) spectral ranges as well as PL as well have been investigated. The distribution of the implanted ions as well as the microhardness changes in a thin surface layer of PMMA polymers have been obtained by Auger spectroscopy.

PUBLICATIONS:

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2. E. Vateva, Remembrances, Homage Book - Prof. Radu Grigorovici, Ed. M. Popescu, INOE&INOE, Publ. House, Bucharest, 2006.
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4. Z. Aneva, D. Nesheva, E. Vateva, Computational analysis of thermally stimulated currents in Bi₁₂TiO₂₀ single crystals, J. Appl. Phys. 100, 053704-53711 (2006).
5. D. Nesheva, Z. Aneva, S. Reynolds, C. Main, A.G. Fitzgerald, Preparation of micro- and nanocrystalline CdSe and CdS thin films suitable for sensor applications, J. Optoelectron. Adv. Mater. 8, 2120-2125 (2006).
6. V. Pamukchieva, D. Gonbeau, M.-F. Guimon, E. Skordeva, R. Dedryvere, D. Arsova, XPS study of photo- and thermally induced changes in amorphous Ge_xAs_{40-x}S₆₀, Physica B 371, 302-308 (2006).
7. E. Vateva, Electrophotographic Studies in Bulgaria - on the Way to Include Nanotechnology in Electrophotography, RechargeEast Magazine 32, 34-38 (2006).
8. C. Main, N. Souffi, S. Reynolds, Z. Aneva, R. Bruggemann, M. J. Rose, Thermally Stimulated Currents in Thin-Film Semiconductors: Analysis and Modeling, Mat. Res. Soc. Symp. Proc., San Francisco, April 17-21, 2006, p. A9.1.
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11. L. Yourukova, K. Kolentsov, T. Kehlibarov, E. Radeva, The Influence of various Factors upon Brightness and Colorimetric Parameters of AC Luminescent Structures, Proc. Workshop WG4 "Color aspects for light sources colorimetry and it's applications in industry and environment", Varna 2006, pp.70 – 72.
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13. S. Balabanov, K. Kolentsov, L. Yourukova, A. Rachkova, Optical Properties of Fullerenes in Xylene and Polyepoxy Oligomer Media, Annual de L'Universite de Sofia "St. Kliment Ohridski", Faculte de Chimie, 98-99, 215-221 (2006).

ONGOING RESEARCH PROJECTS:

Financed by the Bulgarian Academy of Sciences:

1. Semiconductor nanoparticles in amorphous thin film matrix: formation, structure and properties.
2. Photostructural changes in the short and medium range order of glasses and films from Ge-As-S.
3. Luminescence of chalcogenide glasses doped with rare earth elements.
4. Fabrication of electroluminescence structures based on new materials and investigation of their electroluminescence characteristics.

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

1. Photoinduced structural changes in Ge-As(Sb)-S glasses and films (F 1309).
2. Defect states in photoconductors of various dimensionality (F 1306)
3. Multilayer structures and nanocomposite materials for applications in electronics (NT-4-2005). Modul 1: Multilayer structures containing silicon nanoparticles, suitable for fabrication of electronic memories and single electron devices.

COLLABORATION:

1. Optoelectronic properties of semiconductor thin films suitable for application as gas sensors (NATO CLG Grant No 980656) Dundee University, Dundee, Scotland, Institute of Photovoltaics, Juelich, Germany.
2. Electrical and optical properties of multilayer structures with silicon nanoparticles for electronic applications (DAAD-BMES), Carl von Ossietzky Universität Oldenburg, Oldenburg, Germany.
3. Raman scattering and photoluminescence from semiconductor nanoparticles, Institute of Physics, Belgrade, Serbia.
4. Thermodynamical and optical investigations on chalcogenide glasses, Joint Laboratory of Solid State Chemistry, Pardubice, Czech Republic.
5. Investigation of properties and characteristics of zincsulphide electroluminescentors and making of set-ups of their base“, MIIT (Moscow State University of Railway Engineering), Russian.

DIVISION NANOPHYSICS

LABORATORY

SEMICONDUCTOR HETEROSTRUCTURES

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RESEARCH ACTIVITIES:

1. STRUCTURES WITH VERY THIN SiO₂ FILM

The electrical properties of the Si/SiO₂ interface, where the thin silicon oxide layer was thermally grown on rf plasma- hydrogenated (100) and (111) silicon substrates, have been investigated. The results concerning the interface properties are obtained from a detailed study of the C-V and G-V characteristics of MOS structures at varying frequencies between 500 Hz and 300 kHz. From frequency characterization, information is gained on the charged defects at the Si/SiO₂ interface. The frequency dispersion properties reveal the presence of interface traps and/or laterally inhomogeneous distribution of defect centres within the oxide near the interface Si/SiO₂. From frequency characterization information is gained on the concentration of charged defects and their location in the Si/SiO₂ interface region. A procedure is suggested to overcome the problem with usually observed increase of the leakage through the oxide on p-Si, which hinders the accurate determination of the interface trap densities even in thicker oxides.

2. DEFECTS IN IRRADIATED Si/SiO₂ STRUCTURES

The influence of high-energy electron irradiation on the redistribution of the implanted ions in Si-SiO₂ structures have been investigated by Rutherford backscattering spectroscopy (RBS). n-type Si-SiO₂ samples with oxide thickness of 20 nm are implanted by silicon ions with doses of $1 \times 10^{12} \text{ cm}^{-2}$ or $1 \times 10^{16} \text{ cm}^{-2}$. The structures are irradiated with 20 MeV electrons for different durations (from 60 s up to 120 min). The redistribution of the oxygen and silicon atoms in the samples implanted with $1 \times 10^{12} \text{ cm}^{-2}$ Si⁺ ions after different doses electron irradiation is not essential. A significant redistribution is found only after 60 s electron irradiation of the Si-SiO₂ samples implanted with dose of 10^{16} cm^{-2} ions.

p-type silicon MOS structures irradiated with 23 MeV electrons are measured by capacitance-voltage, current-voltage and conductance-voltage methods before and after irradiation. Our results show that high-energy electron irradiation generates positive charge in the oxide and interface states at Si-SiO₂ interface which are frequency dependent. After electron irradiation two kinds of interface traps are determined. The traps energy position

evaluation by these three independent methods is very close to $E_v+0.16$ eV and $E_v+0.36$ eV, which can be attributed to the boron-vacancy (V/B) and vacancy-oxygen (V/O) complexes.

3. CHARACTERIZATION OF PULSED-LASER-DEPOSITED AlN FILMS: STRUCTURE AND PROPERTIES

Aluminum Nitride (AlN) thin films obtained by Pulsed Laser Deposition (PLD) with a KrF* laser source ($\lambda=248$ nm, $\tau \geq 7$ ns) at a substrate temperature of 800°C and different values of ambient nitrogen pressure up to 10 Pa have been studied. The plasma diagnostic by optical multichannel emission spectroscopy has revealed the presence of atomic, single and multiple ionized Al and N species and AlN molecular species in the plasma plume. The analysis of the XRD patterns has established that all the films have a polycrystalline film structure with predominantly cubic phase. By increasing the nitrogen pressure from 0.1 to 10 Pa, the predominant (111) cubic texture changed to (001) one as the lattice parameter, $a=0.4049$ nm decreased to $a=0.3949$ nm and the average crystallite size decreased from 55 nm to 30 nm. The crystallites grew up to a larger size along the preferential orientation. Post-deposition cooling rates only affected the structural ordering, as fast quenching resulted in more disordered film structure. The small size of the crystallites was considered to be the reason for the observed high Knoop hardness values ranging between 12 and 16 GPa. From the analysis of the refractive index spectra and using single-oscillator theory, the threshold energy level E_t was found to be in the range of 3.13-3.33 eV, suggesting the presence of a rather high amount of structural defects in the AlN films. The analysis of the C-V characteristics of AlN-MIS structures, measured at different frequencies revealed the presence of traps in the volume of AlN films and at the AlN/Si interface which contribute to the capacitance values of these structures. The frequency dispersion of the films conductivity has revealed that up to 200 kHz the conductance was proportional to the signal frequency, as the dependence exponent index s was close to 1. In this frequency region the carrier transport mechanism is inter-trap tunnelling, i.e. the electron hopping is toward the next nearest unoccupied trap.

4. HYDROGENATED AMORPHOUS SILICON AND CHALCOGENIDE FILMS

The processes of second harmonic generation (SHG) have been investigated in structures PECVD a-Si:H/glass substrate. Substantial dependence on deposition temperature, film thickness and type of the glass substrate has been found. The contribution of the mechanical stress to the SHG has been considered. The role of the thermal stress and film/substrate match components on SHG has been discussed. The surface morphology of the films has been studied by atomic force microscopy (AFM). The presence of micro voids has been established that could have influence SHG.

Thickness homogeneity of thin chalcogenide $\text{Ge}_{\text{sb}40}\text{-xs}_{60}$ films evaporated on a glass substrate has been investigated. The problem has been tackled by studying the optical transmission spectra. The effects of thickness variation and surface roughness on the transmission spectrum have been considered. It has been found that the film thickness is rather homogeneous over the film area. The inconsistency of the experimental and theoretical oscillations in the transmission spectra indicated in homogeneities due to surface roughness. The AFM study has shown roughness below 50 nm over an area of $10 \times 10 \mu\text{m}$. The SHG scanning has also revealed rather good film homogeneity over the film area.

PUBLICATIONS:

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2. S.Kaschieva, Ch.Angelov, S.N.Dmitriev, G.Tsutsumanova, RBS investigation of ion implanted Si-SiO₂ structures irradiated with 20 MeV electrons, *Plasma Process.&Polym.* **3, 233-236 (2006)**
3. S.Kaschieva, E.Halova, E.Vlaikova, S.Alexandrova, E.Valcheva and S.N.Dmitriev, Investigation of p-type MOS structure irradiated with 23 MeV electrons, *Plasma Process.&Polym.* **3, 237-240 (2006)**
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10. S. Kaschieva, V.Georgiev, E.Halova, S.N.Dmitriev, Defect formation in 18 MeV electron irradiated MOS structures, *Bulg. J. Phys.* **33 p48-54 (2006)**
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12. K. A. Gesheva, T. Ivanova, A. Szekeres, OI Trofimov, "Surface Characterization Of Chromium Oxide Thin Films in Dependence on CVD Growth Process Parameters", *"ECS Transactions - Denver" Volume 2, "Fundamental Gas-Phase and Surface Chemistry of Vapor-Phase Materials Processing III", 2006. pp.*
13. S. Simeonov, S. Bakalova, E. Kafedjiiska, A.Szekeres, S. Grigorescu, A. Popescu, C. Cojanu, F. Sima, G. Socol, I. N. Mihailescu, " Characterization of pulsed-laser-deposited AlN films as a gate dielectric in AlN-Si MIS structures", *CAS 2006, Intern. Semiconductor Conference, 29th Edition, 27-29 Sept., Sinaia, Romania, Proc. 2006, Vol. 2, pp 261-264.*
14. S. Alexandrova, I. A. Maslyanitsyn, V. Pamukchieva and V. D. Shigorin "Optical study of Ge_xSb_{40-x}S₆₀ chalcogenide thin films "Wissenschaftlich-technische Jubiläums-konferenz mit internationaler Terilnahme" 15 Jahre FDIBA 2006", *Научни известия на научно-техническия съюз по машиностроене, год. XII, бр. 11/94, ноември 2006, стр. 9.*

15. S. Simeonov, S. Bakalova, E. Kafedjiiska, A.Szekeres, G. Socol, S. Grigorescu, I. N. Mihailescu, "Admittance study of MIS structures with pulsed laser deposited AlN films", *J. Optoelectr. & Adv. Mater (JOAM 9(2))*, 398-401 (2007)
16. S. Alexandrova, A. Szekeres, E. Valcheva and E. Vlaikova, "Electrically active defect centers in MOS structures with nanosized SiO₂ thermally grown on plasma hydrogenated silicon", *JOAM 9(2)*, 330-333 (2007)
17. E.Vlaikova, A. Szekeres, S. Georgiev and G. Beshkov, "Optical properties of PECVD carbon films on silicon subjected to rapid thermal annealing", *JOAM 9(1)*, 379-381 (2007)
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21. S. Alexandrova, I. A. Maslyanitsyn, V. Pamukchieva and V. D. Shigorin, Thickness homogeneity of Ge_xSb_{40-x}S₆₀ chalcogenide thin films, *JOAM 9(2)*, 323-325 (2007)
22. S. Tinchev, Y. Dyulgerska, P. Nikolova, S. Alexandrova, E. Valcheva, Electrical properties of a-C:H/Si and (a-C:H)/Ti heterostructures, *JOAM 9(2)*, 386-389 (2007)
23. S. Kaschieva, K. Christova, I. Boradjiev, A. Petrova, J. Koprinarova, S. N. Dmitriev, The role of high-energy electron irradiation induced defects in some mechanical properties of Si-SiO₂ structures, *JOAM 9(2)*, 394-397 (2007)

ONGOING RESEARCH PROJECTS:

1. "Structure and properties of micro and nano-sized semiconductor heterostructures"- *Financed by the BAS*

COLLABORATION:

1. "Study of nano-formations in Si – SiO₂ structures irradiated with high energy electrons", *with JINR, Dubna, Russia*
2. "Micro and nanotechnologies going to Eastern Europe through Networking", *Specific Supportive Action, with Coordinator National institute for research and development in microtechnologies, Bucharest, Romania*
3. "Optical, magnetic and electrical properties of nano-structured layers obtained by pulsed laser deposition", *with Institute of Atomic Physics, RA, Bucharest, Romania*
4. "Structural, optical and electrical properties of nanostructures", *with "Eotvos L." University, Hungary*
5. "Investigation of radiation defect annealing in semiconductor structures subjected to high energy irradiation", *with Institute of Semiconductor Physics, NASU, Kyiv, Ukraine*
6. "Investigation of nanostructures with doped oxide films for environment usage", *with Institute of Physical Chemistry, RA, Bucharest, Romania*
7. "Surface and interface properties of thin film semiconductor heterostructures: investigation by non-linear optical methods", *with Institute of General Physics, RAN, Moskva, Russia*
8. "Preparation of based on silicon nano-structured thin dielectric films and investigation of their structure and properties for micro and nano-electronics purposes" *with Institute of Semiconductor Physics, NASU, Kyiv, Ukraine*

DIVISION MICRO- AND ACOUSTOELECTRONICS

LABORATORY

PHYSICAL PROBLEMS OF MICROELECTRONICS

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RESEARCH SCIENTISTS: **14**

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RESEARCH ACTIVITIES:

1. HIGH-K DIELECTRICS FOR NANOELECTRONICS

The effect of a post-metallization annealing in H₂ of MOS capacitors with high-k dielectric (Ta₂O₅, 5-25nm) is investigated. The Ta₂O₅ layer is deposited onto Si substrates with nitridated surface. The part of H₂ in the trapping mechanisms in high-k dielectrics is very important but not well understood practically. This investigation is a contribution to a better understanding of the nature of the charges influenced by H₂ and how they are affected. It is found that annealing in H₂ reduces by 1 – 2 orders the amount of all kinds of charges in the bilayer structure Ta₂O₅/nitridated Si. A general conclusion is drawn that the post-metallization annealing in H₂ is a prospective technology step for producing memorizing high-k dielectric capacitors.

The effect of several types of upper electrodes on a set of important electrical characteristics of thin-film Ta₂O₅ capacitors is studied. With the introduction of the high-k dielectrics into the silicon nanoscale technology replacing the poly-Si electrodes with metal electrodes becomes inevitable. But at the present state the metals compatible to the different high-k dielectrics are not still well defined. On these grounds complex investigation works are carried out on the influence of the type of the upper metal electrode and the strong effect of the deposition technique applied. It is concluded that sputtered W meets the requirements as an upper electrode for Ta₂O₅ memorizing capacitor. But sputtering is not a convenient technique for deposition of TiN layers as upper electrode to high-k dielectrics. The general conclusion is that not only the material of the upper electrode but the deposition technique as well are critical in the case of the high-k dielectrics.

The conductivity mechanisms of Ta₂O₅ layers on nitridated Si are studied and high density of negatively charged traps located in the nitridated interface region is observed. Electrically they behave like slow states resulting in a strong frequency dependence of the charge. Thus the conductivity mechanism is strongly modified. It is found that rapid thermal nitridation yields better parameters of the memorising capacitors

compared with the ion implantation. The rapid thermal nitridation in NH_3 is found to be most convenient for modification of the Si surface before deposition of a high-k dielectric (Ta_2O_5). An equivalent oxide thickness below 1.5 nm is obtained that is compatible to technology cycles below 70 nm.

It is found that rapid thermal annealing could be used as a successful technology step for reducing the concentration of the bulk traps in Ta_2O_5 .

The long-term reliability processes and the conductivity current after stress (Stress Induced Leakage Current, SILC) in thin and ultra thin high-k dielectric layers are investigated. As a result it is established that the processes generating SILC in high-k dielectrics are different from those in SiO_2 . Thus the degradation models for SiO_2 are not applicable for high-k dielectrics. These results are a contribution to the efforts for creation efficient models explaining the degradation of high-k dielectric layers that is directly connected with the problems of the reliability and the lifetime of the future generations of integrated circuits based on high-k dielectrics.

2. THIN FILMS FOR THE MICROELECTRONICS

The influence of a high-energy-electrons irradiation (23 MeV) on the characteristics of p-channel polysilicon transistors is investigated. Transistors are subjected to several different doses of irradiation. The leakage currents through the gate oxide and the transfer characteristics are measured. A computer model is developed describing the amplification of the electric field and the inhomogeneous current distribution at the interface poly Si/oxide. At doses of 3×10^{14} el/cm² a negligible degradation is observed, but at doses of 3×10^{14} el/cm² the deterioration of the transistors characteristics is significant.

The leakage currents of Al/ZrO₂/SiO₂/n-Si MIS capacitors are studied. The SiO₂ layers are deposited chemically onto P-doped Si wafers. The Zr layers are deposited by means of RF sputtering and annealed in O₂. A dielectric constant of 17.8 is observed for these layers. The presence of a thin ZrSi_xO_y due to the high-temperature annealing is detected. The temperature dependence of the leakage currents is explained making use of the Poole – Frenkel model.

Transistor and capacitor structures thin ZrO₂ insulating layers on Si are fabricated. Dedicated sets of photolithography masks for each technology version are prepared.

The technology for deposition of thin Ti-doped Ta_2O_5 layers is optimized. A technology cycle for deposition of thin Cr-Co and Cr-CoSm₅ hard-magnetic layers by means of RF sputtering is developed.

3. RAPID THERMAL ANNEALING (RTA)

Thin layers of CeO₂ deposited by means of RF sputtering in O₂ onto Si substrates are investigated. It is observed that layers are inhomogeneous, containing Ce atoms at +3 and +4 oxidation states. After RTA over 1100°C the formation of a CeSi₂ phase is observed and at higher temperatures a p-type doping of the substrate occurs.

4. MAGNETORESISTIVE THIN LAYERS AND DEVICES

The behavior of three types of Anisotropic magnetoresistance (AMR) structures is investigated (“barber-pole”, RAA -with rotated anisotropy axis and structures with shielded resistors) having in mind their application as positioning sensors. It is shown that RAA structures yield optimally shaped output signal and demonstrate stable work at the presence of parasitic fields. The inherent for these structures relatively large hysteresis at very low fields does not affect the stability of the signal at the fields used for positioning purposes. Thin layers of hard magnetic materials are investigated in order to use them for controllable modification of the behavior of the sensor structures.

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6. N. Novkovski, E. Atanassova, Wear-out and breakdown of thermally grown Ta₂O₅ insulating films on plasma oxynitrided Si substrates, *Phys. St. Sol. (a)* 203(8), 2012-2017 (2006).
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10. N. Novkovski, E. Atanassova, A comprehensive model for the I-V characteristics of metal-Ta₂O₅/SiO₂-Si structures, *Appl. Phys. A*. 83, 435-445 (2006).
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13. P. V. Aleksandrova, V. K. Gueorguev, Tz. E. Ivanov, S. Kaschieva, Influence of MEV electron irradiation on the properties of by ion implantation hydrogenated polysilicon TFTs, *Nuclear Instruments and Methods in Physics Research, B* (2006) 340-344
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19. E. Atanassova, A. Paskaleva, Challenges of Ta₂O₅ as high-*k* dielectric for nanoscale DRAMs, Proc. 25th Intern. Conf. On Microel. (MIEL 2006) Belgrade, Serbia 2006, IEEE El. Dev. Soc., 2006, vol. 1, pp. 47-54 **(invited lecture)**.
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 21. E. Atanassova, D. Spassov, A. Paskaleva, Effect of the metal electrode on the characteristics of Ta₂O₅ capacitors for DRAMs applications, Proc. 25th Intern. Conf. on Microelectronics, (MIEL 2006), Belgrade, Serbia, 14-17 May, 2006, IEEE El. Dev. Soc., 2006, vol. 2, 581-584.
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ONGOING RESEARCH PROJECTS

1. Physics and technology of thin layers for applications in the modern microelectronics.
2. Alternative dielectric layers based on Ta₂O₅, (Hf:Ta₂O₅; Al:Ta₂O₅; Ti:Ta₂O₅) for 65-70 nm generation integrated memories (supported by NSF).
3. Nanoengineering network, SONNET (supported sby the Swiss NSF).
4. Synthesis and investigation of AlN and BN nanolayers (supported by NSF).
5. Investigation of the electronic states in amorphous silicon and materials based on it (supported by NSF).
6. High-stability magnetoresistive sensors (supported by the National SMEs Program).

INTERNATIONAL COOPERATION

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

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RESEARCH SCIENTISTS: 8

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RESEARCH ACTIVITIES:

1. SEMI ANALYTICAL MODELING OF THERMOSENSITIVE STRIP RESONATORS

The development of a new piezoelectric quartz micro sensor, which was successfully started within the framework of QxSens EU project, is being carried out through enhancement of two-dimensional semi analytical model of coupled acoustic waves. Two modes with imaginary values of the wavenumber are included in the combination for the first time. Also the dispersion curves are obtained by taking into account the influence of the piezoelectric effect on the dispersion spectrum.

An improved structure of temperature micro sensors is offered on the basis of modeling results.

2. INVESTIGATION OF SHORT AND LONG-TERM STABILITY OF QUARTZ TEMPERATURE SENSORS.

Monitoring of long-term stability of temperature sensors is going on. It is shown that the frequency change does not exceed $5 \cdot 10^{-7}$ within 500 days. This guarantees the reliable function of the sensors without additional calibration. High short-term stability ($1 \cdot 10^{-9}$) is achieved through specially developed technology that permits recording temperature sensitivity of 0.0002°C .

3. MASS-SENSITIVE QUARTZ RESONATORS

The influence of quartz wave geometry and electrode configuration upon dynamic parameters and spectral characteristics of AT- cut quartz resonators with Au and Ag electrodes of (3mm, 4mm and 5mm) are investigated. Dynamic parameters are measured as follows: 15-16 MHz resonance frequency, 4-20 Ω equivalent dynamic resistance and quality factor – in the range of 50 000-90 000. Spectral characteristics show clearly expressed basic modes and sufficiently suppressed aharmonic mode.

Resonator systems with thin deposited dielectric layers are measured to determine the sorption ability to ammonium by the method of quartz crystal microbalance. The sensitive TiO_2 , Ta_2O_5 , SnO_2 and ZnO layers are obtained by different methods such as: liquid-phase deposition, electron-beam evaporation, reactive and magnetron sputtering. It is found that all investigated structures possess sorption properties. The amount of sorption mass depends on the dielectric layer type and its thickness. For the same layer type, the sorption is defined by

synthesis method of the dielectric layer too. The experimental data are presented in three posters at the 6th Int. Conf. of the Balkan Physical Union, 22-26 August 2006, Istanbul.

Resonator structure properties for mass – loading are studied and estimated by the changes of the initially measured frequency and dynamic resistance. It is established that the change in resistance value depends not only on the electrode loading but also on the layer uniformity.

Electrodes design of mass-sensitive resonant piezoelectric crystal sensors is optimized for using at cryogenic temperatures. The acoustic parameters of the produced sensors are measured in a large temperature interval. The sensors are installed in Cryogenic Complex of the Nuclotron Accelerator, JINR Dubna. Contaminations from O₂ and N₂ are detected in high purity helium flow by mass-sensitive sensors. Result analysis is in progress.

4. SYNTHESSES AND STUDY OF PLASMA POLYMERS

Plasma polymers obtained from hexamethyldisiloxane (HMDSO) are used as a sublayer in a humidity sensor element with a TiO₂ active layer. Humidity sensitivity of a TiO₂ layer slowly decreases while the layer thickness increase in 18-70 nm ranges. This is probably due to a sorption, mostly on the surface, and morphology changes of the TiO₂ layer resulting in a smoother film surface with increasing layer thickness. The sorption process is reversible. Results show that the two-layer structure can be used for humidity sensor development.

Experiments are performed for a carbon implantation in plasma polymers obtained from HMDSO. A photoluminescence increase is observed in the implanted samples. That will improve the parameters of electroluminescent display structures where this layer is used as protective one.

5. RESONANT DEVICES USING RAYLEIGH SURFACE ACOUSTIC WAVES (RSAW) AND SURFACE TRANSVERSE WAVES (STW) AND THEIR APPLICATIONS IN LOW-NOISE MICROWAVE OSCILLATORS, COMMUNICATIONS AND SENSORS

A successful workflow for designing RSAW two-port resonators using gold electrode structure for applications as gas sensors in highly reactive chemical environments has been suggested. RSAW resonators at 433 MHz with gold metalization and unprecedented electrical and sensor performance have been realized using the suggested design workflow.

The theoretical assumption that in a nonlinear RSAW/STW oscillator phase noise depends on the current conduction angle of the sustaining amplifier in the loop has been verified experimentally. Measurements have shown that oscillator phase noise can significantly be improved by using nonlinear AB-, B- and C-class of sustaining amplifier operation in which current flows over a small fraction of the duty cycle.

A novel crystal controlled comb spectrum oscillator (CCCSO) using a higher overtone bulk acoustic wave (BAW) crystal has been suggested. The CCCSO has been successfully implemented in injection locked GHz range STW based oscillators to reduce close-to-carrier phase noise and greatly improve temperature and medium-term stability. The system retains the high output power and very low thermal noise floor of the STW oscillator, while adopting the stability of the CCCSO.

6. DEVELOPMENT OF THIN FILM TECHNOLOGY FOR HIGH EFFECTIVE REFLECTORS

New technology for plastic reflectors based on the Al-Ag-SiO₂ was developed. The reflectors have high reflective properties. The design and high reflective abilities of the street lamp reflectors allow using them for replacement of old street lamps. The project is realized in collaboration with Denima 2001 Company – Sofia. The project is awarded with the

Second Place “Innovation Company – 2006” by Bulgarian Small and Medium Enterprises Promotion Agency.

7. DEVELOPMENT OF SOLAR PHOTOVOLTAIC PANELS FOR SPECIAL APPLICATIONS

Solar photovoltaic panel for energy-independent light sources is developed. A small production line project is designed and the specific equipment and materials are ordered. The project is in progress.

PUBLICATIONS:

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8. E.I. Radeva, I.N. Martev, D.A. Dechev, N. Ivanov, V.N. Tsaneva, Z.H. Barber, “Sensitivity to humidity of TiO₂ thin films obtained by reactive magnetron sputtering”, Surface & Coating Technology 201, 2006, pp. 2226-2229.
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12. V. Gadjanova, R. Velcheva, L. Spassev, Yu. Lazarov, L. Vergov, B. Dulmet, “Single Point Calibration and Investigation of Thermosensitivity, Thermal Response”, Proc. 20th European Frequency and Time Forum 27-30 March 2006, Braunschweig (in print).
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16. V.Georgieva, L.Spassev, D.Spassev, N.Donkov, P.Petkov, "Tantalum Pentoxide – Based Quartz Cristal Microbalance for NH₃ Detection ", J. of Opt. Adv. Materials, (in press).
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RESEARCH PROJECTS:

1. Project financed by Bulgarian Academy of Sciences
 - 1.1. "Investigation of the structure and physical-chemical properties of thin layers based on polymers obtained by plasma for sensor application".
2. Projects financed by the National Science Found at the Ministry of Science and Education
 - 2.1. "Design and Creation of Sensor Element Used in Quartz Microbalance".
 - 2.2. "Investigation of the Sorption Properties of Metal-Oxide Layers by Quartz Crystal Microbalance".
3. Projects extra financed by departments and Bulgarian companies (Projects financed by Bulgarian SME Promotion Agency).
 - 3.1. "Development and Test of New Technologies for Designing, Developing and Producing Energy-Efficient Lamps".
 - 3.2. "Technology Development for Production of Photovoltaic (PV) Batteries and a New Type Energy-Efficient Streetlights".
4. Projects financed by international sources:
 - 4.1. "Multi-channel measurement and control system based on resonant piezoelectric crystal sensors".
 - 4.2. "Development of mass sensitive quartz resonators for operation at cryogenic temperatures".
5. Projects in frames of Inter-academic and Inter-institute collaboration
 - 5.1. "Development of chemical sensors based on a piezoresonant type for hazardous substances in the air".
 - 5.2. "Piezoelectric crystal microsensors at cryogenic temperatures".

COLLABORATION:

1. "Multi-channel measurement and control system based on resonant piezoelectric crystal sensors". - France, Germany, Austria.
2. "Development of mass sensitive quartz resonators for operation at cryogenic temperatures". - Join Institute for Nuclear Research, Dubna, Russia.
3. "Design of an improved Rayleigh surface acoustic wave (RSAW) resonator with gold electrode structure and improved corrosion immunity for sensor applications in highly reactive chemical gas-phase environment"- Research Center Karlsruhe, Germany.
4. "Development of chemical sensors based on a piezoresonant type for hazardous substances in the air"- Russian Academy of Science.
5. "Piezoelectric crystal microsensors at cryogenic temperatures". - ENSMM – Besanson, France.

DIVISION LOW TEMPERATURE PHYSICS

LABORATORY

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RESEARCH ACTIVITIES:

1. SUPERCONDUCTING MATERIALS, NEW MATERIALS AND LOW TEMPERATURE PROPERTIES OF MATERIALS

The influence of calcium substitution on the superconducting properties of polycrystalline $R_{1-x}Ca_xBa_2Cu_3O_z$ ($R = Eu, Gd, Er; x = 0; 0.2; 0.25$ and 0.3) samples has been studied by X-ray powder diffraction, AC susceptibility and DC magnetization measurements. The superconducting parameters such as critical temperature, inter- and intra-granular critical current and flux pinning are found to be strongly dependent both on Ca content and type of R element. The best combination of these parameters is found for the system $Gd_{1-x}Ca_xBa_2Cu_3O_z$ forming $R_{1+y}Ba_{2-y}Cu_3O_z$ clusters. The level of overdoping and the type of intergrain connection, were found to be influenced by the R element and the Ca concentration. Flux pinning in $Gd_{1-x}Ca_xBa_2Cu_3O_z$ is connected with the presence of $R_{1+y}Ba_{2-y}Cu_3O_z$ clusters.

The possibility of increasing of number of carriers as well as centers of pinning were studied for superconducting Y123 phase by means of suitable chemical substitutions with Ca and Pr. The optimum effect was recorded at 30 % substitution of Y with Ca.

The synthesized polycrystalline material $Y_{1-x}Cu_xBa_2Cu_3O_z$ with $x=0$ and $x=0.3$ was used for obtaining of superconducting tapes by OPIT method. It was measured that the T_c of the tape was unchanged in comparison to the initial material however the critical current density (at $H=0$ and $T=77K$) was enhanced by two order of magnitude.

Samples with nominal compositions $RuSr_2R_{1.4}Ce_{0.6}Cu_2O_{10-\delta}$ ($R = Eu, Sm$) were synthesized and their superconducting (SC) and magnetic properties were compared. A coexistence of AFM and FM ordering below the FM transition temperature and a sizable low temperature magnetoresistance were observed in the two samples.

Thermal properties investigation of $Ge_xAs_{40-x}S_{60}$ glasses within 4-300 K is carried out to study the mechanisms controlling scattering and heat transfer processes in these materials. The observed universal low-temperature behaviour of the measured thermal characteristics (thermal conductivity, specific heat and thermal diffusivity) is explained in the frame of Soft Potential Model (SPM), postulating the existence in glasses of additional quasy-localized low-frequency modes over acoustic ones, reflecting a noticeable feature in their vibrational

density of state $g(v)/v^2$. A correlation between a degree of fragility of these ternary chalcogenides and compositional dependences of their specific thermal characteristics is established to change stronger at 2D-3D transition and weaker at chemical ordering.

2. MAGNETIC AND TRANSPORT PROPERTIES OF MANGANITES

We have investigated the detailed field and temperature dependence of the dielectric constant, electric polarization, magnetization and magnetostriction in orthorhombic HoMn_2O_5 single crystals. HoMn_2O_5 displays incommensurate antiferromagnetic ordering below 39 K, becoming commensurate on further cooling. The commensurate-incommensurate transition takes place at low temperatures. The inherent magnetic frustration in this material is lifted by a small lattice distortion, primarily involving shifts of the Mn^{3+} cations and giving rise to a canted antiferroelectric phase. Colossal magnetostriction effect was observed and a novel phase transition diagram was build.

Investigations of monocrystals with perovskite structure are settled as separate part of laboratory activities. Efforts in the past year were devoted to Sm-Pb-Mn-O, Ho-Mn-O and Pr-Sr-Mn-O systems. For first time Sm-Pb-Mn-O monocrystals with low percentage alkaline element was obtained and investigated. The results are an attempt to clarify the data existing in the literature for the Samarium system. Two different types of Ho-Mn-O monocrystals – hexagonal and orthorhombic were obtained and are under investigation. Some further investigations were carried out on these monocrystals in aspect to reveal their abilities concerning the new application of the magnetocaloric effect at ambient temperatures.

The influence of magnetic and electric field on magnetotransport properties of thin films of $\text{La}_{1-x}\text{Ca}_x\text{MnO}_3$ ($x=0.3$) deposited on LaAlO_3 substrates have been investigated. Compressively strained $\text{La}_{0.7}\text{Ca}_{0.3}\text{MnO}_3$ layers reveal semiconducting behaviour and charge ordered insulating (COI) state which melts to ferromagnetic metallic (FMM) above a certain magnetic field, accompanied by a significant hysteresis. Variable Range Hopping (VRH) mechanism well fits the conductance in zero magnetic field. The change of the slope of VRH dependence and magnetotransport of strained thin films are consistent with the model of inhomogeneous material coexistence and competition of FMM and COI phases. The nonlinear electronic transport and hysteretic behaviour are driven by a fine balance of competing charge order with strong tendency to localization, FM interactions and strain energy.

On the basis of the free energy expansion, the low-symmetry orbital phases originating from the high-temperature crystal phase with the Pnmm (D_{2h}^{16}) symmetry in $\text{Pr}_{1-x}\text{Ca}_x\text{MnO}_3$ ($x=0.3; 0.5$) manganite are investigated. The free order parameter susceptibilities and elastically clamped ones in these phases are calculated.

3. STATISTICAL PHYSICS AND INTERPRETATION OF QUANTUM MECHANICS

The finite – size scaling in d-dimensional $O(N)$ systems with strong anisotropy is studied. The anisotropic properties involve also the geometry of the systems. A prominent example is the case of slab geometry. The arising difficulties are avoided using a specially developed technique of calculations based on the analytical properties of the generalized Mittag-Leffler functions. Knowledge of the properties of these functions allows one to carry out all calculations analytically.

The “Chaos – Order square matrix” was built of the disciplines formed between deterministic causes and deterministic as well as non-deterministic sequences. The same pattern applies to non-deterministic causes which bring about deterministic and non-deterministic sequences. Thus the natural locus of many sciences – from chaos theory and different types of mechanics to statistical physics and synergetics – is revealed.

Work on the role of the electromagnetic 4-potential A in quantum mechanics was completed generalizing earlier approaches and demonstrating that A plays the role of basic electromagnetic field, whereas E and H are just subsidiary magnitudes.

4. ENVIRONMETRIC RESEARCH

Environmetric research to assess the air, soil and water quality using multivariate statistical methods is performed in order to detect and model pollution sources. Risk management estimation of the air quality in an industrial region was done as well as a trend study of the monitoring data (1962-2004) of the total B -activity of soil in the vicinity of the Nuclear Research Reactor. All of the studies are performed by environmetric approaches, which allow reliable modeling and apportioning.

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1. A. K. Stoyanova-Ivanova, S. D. Terzieva, A. D. Staneva, V. Mikli, R. Traksmaa, Y. B. Dimitriev and V. T. Kovachev “Phase formation and microstructure in $RE_{1-x}Ca_xBa_2Cu_3O_z$ (RE=Y, Eu, Er; $x=0,0.2,0.3$) superconducting ceramics”, *Central European J. Chem*, 4 (1), 167-174 (2006)
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Participation on Space, Ecology, Nanotechnology, Safety), 14-16 June 2006, Varna, Bulgaria, pp. 599-604, ISBN-10: 954-9401-12-7 (2006).

14. V. Simeonov, S. Tsakovski and P. Simeonova. Air Quality Assedssment by Multivariate Statistics. Proceedings of SENS'2006 (Second Scientific Conference with International Participation on Space, Ecology, Nanotechnology, Safety), 14-16 June 2006, Varna, Bulgaria, pp. 641-646, ISBN-10: 954-9401-12-7 (2006).

ONGOING RESEARCH PROJECTS:

1. Thermal Properties of HTSC Tapes for Practical Applications, Universite de Liege, Institute d'Electricite – SUPRATECS, Liege, Belgium.
2. Tailoring of thin film structures based on magnetic oxides (manganites and cobaltites), Joint Research Project between BAS (ISSP-Sofia, Bulgaria) and PAS (IP- Warsaw, Poland).
3. The influence of deformation on critical parameters of YBCO superconducting tapes, National Science Foundation, TH-1525 /2005-2007, Bulgaria.
4. Obtaining and investigations of high temperature superconductors, Ss" Cyril and Methodius" University, Skopje, Makedonia.

INTERNATIONAL COLLABORATION:

1. Universite de Liege, Institute d'Electricite – SUPRATECS, Liege, Belgium.
2. Institute of Physics, Polish Academy of Sciences, Warshaw, Poland .
3. Institute of Low Temperatures and Structural Research (ILTSR), Polish Academy of Sciences, Wroclaw, Poland.
4. International Laboratory for High Magnetic Fields and Low Temperatures – Wroclaw, Poland.
5. Ss "Cyril and Methodius" University, Skopje, Makedonia.

DIVISION LOW TEMPERATURE PHYSICS

LABORATORY

CRYOGENIC TECHNOLOGY

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TOTAL STAFF: **8**
RESEARCH SCIENTISTS: **3**

Assoc.Prof. J.K. Georgiev, Ph.D.; Assist.Prof. A.L. Zahariev, Ph.D.

RESEARCH ACTIVITIES:

1. NEW SUPERCONDUCTIVE MATERIALS

The effect of hole doping, on the transport and magnetic properties of Ca substituted YBCO bulk samples, has been investigated. The existence of bulk pinning (established by measurements of third harmonics of ac magnetic susceptibilities) and increasing of critical current density is found for 30% Ca substitution.

Ag-sheathed $Y_{1-x}Ca_xBa_2Cu_3O_{7-y}$ superconducting tapes has been prepared by OPID method. The influence of temperature and deformation treatment on the T_C and J_C of the tapes has been investigated.

RESEARCH PROJECTS:

1. INFLUENCE OF DEFORMATION ON THE CRITICAL PARAMETERS OF SUPERCONDUCTING YBCO TAPES.

NFSR financial support – contract No TH-1525.

Head: Prof. Dr.Sc. V.T. Kovachev.

2. COMPUTERISED SYSTEM FOR INVESTIGATIONS OF RESISTIVITY AND AC MAGNET SUSCEPTIBILITY OF DIFFERENT MATERIALS (including high temperature superconductors).

ISSP financial support.

Head: Assoc. Prof. Dr. E. Nazarova.

PUBLICATIONS

1. E. K. Nazarova, A. J. Zaleski, A. L. Zahariev, Doping dependence of the activation energy in $Y_{0.8}Ca_{0.2}Ba_2Cu_3O_z$, *Nanoscience & Nanotechnology*, 5, eds. E. Balabanova, I. Dragieva, Heron Press, Sofia, 31-33 (2006).

DIVISION PHYSICAL OPTICS AND OPTICAL METHODS

LABORATORY

OPTICS AND SPECTROSCOPY

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Prof. N. Kirov, D.Sc.; Prof. S. Rashev, D.Sc.; Prof. K. Panayotov D.Sc.; Assoc. Prof. D. Angelov, Ph.D.; Assoc. Prof. E. Angelova, Ph.D.; Assoc. Prof. L. Tsonev, Ph.D.; Assoc. Prof. A. Andreev, Ph.D.; Assoc. Prof. S. Tonchev, Ph.D.; Assoc. Prof. A. Angelov, Ph.D.; Assoc. Prof. G. Dyankov, 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. T. Kehlibarov; Assist. Prof. B. Zafirova, Ph.D.; Assist. Prof. M. Kaneva, Ph.D.; Assist. Prof. T. Tenev, Ph.D.; Assist. Prof. B. Panchev; Assist. Prof. H. Naradikian; Assist. Prof. B. Petrov; Assist. Prof. B. Bozhkov; Assist. Prof. E. Karakoleva; Assist. Prof. I. Savova Ph.D.; I. Milushev, Ph.D.; B. Katranchev, Ph.D. student; Y. Velkova

RESEARCH ACTIVITIES:

1. OPTICS AND SPECTROSCOPY OF WAVEGUIDES

Thin Er, Yb doped Y_2O_3 films were grown successfully on a periodically structured glass substrate by laser ablation. The smooth surface, good adhesion and possibility to repeat the substrate structure makes the deposition method suitable for preparation of structured waveguides. The estimated non-uniformity value of about 4.6% does not affect the waveguide propagation efficiency.

A systematic study of PE and APE planar waveguides in $LiNbO_3$ and $LiTaO_3$ was performed. The focus was put on the optical and structural characterization of PE layers formed on Z-cut substrates. The refractive index change was measured and the propagation losses were estimated. Raman spectroscopy was used as a method providing direct information about the phonon spectrum. The latter was related to the structure and the properties of the protonated waveguides.

Luminescence properties of lanthanide ions in lithium niobate and in other hosts were reviewed in relation to their application in active thin film optical devices. The technological problems reported by different authors were commented. The possibilities for producing active waveguiding devices in lithium niobate only by low-temperature processes were discussed.

A samarium-activated cerium dioxide with f-f luminescence under UV excitation was prepared using lithium as co-activator and hydroxide, oxalate and nitrate of Ce(III) as precursors. The activator ions were introduced in the precursors by co-precipitation or co-crystallization respectively. Incorporation of Sm^{3+} ions in CeO_2 was obtained during thermal decomposition and simultaneous Ce(III) to Ce(IV) oxidation by heating at 800-1100 °C after addition of lithium nitrate. The results obtained show that co-doping with lithium leads to considerably higher efficiency of the Sm^{3+} luminescence in comparison with samples doped with samarium only.

Thin ZnO films were successfully grown on periodically structured amorphous quartz substrates by laser ablation. The good adhesion and possibility for reproducibility of the

substrate structure makes this technology suitable for preparation of structured waveguides. The periodical structures prepared were successfully used for easy coupling of the light into the waveguide and to ensure an optical detection upon gas exposure. The sensitivity and its reproducibility of the ZnO periodical structures to 1000 ppm butane diluted in nitrogen were successfully proven. The response time of about 1 min was evaluated.

2. FIBER OPTICS

A process control in the pulsed laser deposition (PLD) of metal-oxide layers on the single-mode side-polished optical fiber has been improved. The optical characteristics of the gas sensor element, consisting of a side-polished fiber and evanescent coupled a metal oxide layer, at different temperatures (25⁰C – 225⁰C) have been investigated. The numerical evaluation of the spectral position of the fibers and the planar waveguide modes resonances, for different values of ZnO refractive index value, showed that a change in the film refractive index of 0.001 will produced a shift of the channel-dropping filter of at least 1nm. A spectral shift of 0.03nm for 1.5% butane diluted in N₂ and 1.2nm for pure butane were detected. These spectral shifts corresponds to the refractive index change in the ZnO film by 3×10^{-5} and 1.2×10^{-3} for the two gas concentrations, respectively. This work has been carried out in collaboration with Institute of Electronics, Bulgarian Academy of Sciences.

A technological and experimental work for creating a sensor element based on SPR for the biological application is accomplished. The sensor element include a thin metal layer deposited on the side-polished optical fiber. The initial experiments with propagating SPR (surface plasmon resonance) working in the spectral range 700-850nm, with Ag metal layer and thickness 25-40nm are carried out. The initial experiments with localized SPR and golden nano-sized particles with diameter about 30nm and absorption resonance in the spectral region 500- 600nm are performed.

3. HOLOGRAPHIC DIFFRACTION GRATINGS

A narrow band filter based on the longitudinal mode of solid state disk lasers has been proposed and experimentally demonstrated. The filter gives 100% reflection by combining a resonant diffraction grating with a multilayer interference mirror. The diffraction grating included does not cause additional losses in the system but does reduce the line-width of the generated light below 1 nm.

A resonant mirror has been fabricated and examined being monolithically integrated into Yb-doped laser microchip based on Y₃Al₅O₁₂ ceramics. The element so obtained uses the mechanism of constructive interference and ensures a 1000:1 linearly polarized emission at 1030 nm / 13 W output under 20 W pumping power. A similar resonant structure has been integrated monolithically into a Nd:YAG laser microchip which emits at 1064 nm. In this system we have examined the possibility of using the mechanism of destructive interference for a polarization control of the laser output.

Resonant diffraction gratings have been developed in order to form femto-second laser pulses. These gratings exhibit an efficiency of nearly 100% in a relatively wide spectral interval. The resonant structure includes only dielectric media and therefore has a stable behavior at middle and high power femto-second pulses.

In the frame of the NEMO project a method has been developed which enables the metrological comparison and unification of submicron measurements obtained by different AFM microscopes.

A fully analytical theory has been developed to derive the field diffracted by an infinitely long circular cylinder made of an arbitrary anisotropic homogeneous material, illuminated by an arbitrary plane wave. The differential theory of diffraction by arbitrary cross-section cylindrical objects is extended to the most general case of an incident field with a wave vector outside the cross-section plane of the object. The Fast Fourier Factorization

(FFF) technique is generalized to anisotropic and/or inhomogeneous media described in cylindrical coordinates. The FFF technique in cylindrical coordinates is adapted in order to study microstructured optical fibers (MOFs). This new differential method takes into account the truncation of Fourier series and the discontinuities of the fields across the diffracting surface with the help of new factorization rules.

4. MICRO- AND NANO-PHOTONICS “Georgy Zartov”

Different 2-, 3- and 4-layer antireflection coatings on the glass substrates have been fabricated. The utilized materials are SiO₂, ZnS and Na₃AlF₆. The refractive indices of the layers, as well as their dispersion are determined. The AR coatings characteristics are optimized, too. The most reproductive coatings are the 3-layer structures. Reflectances of 0.3% and less in a relatively wide spectral range have been obtained.

We continued our theoretical and experimental investigations of polarization properties of semiconductor lasers with vertical resonators (VCSELs). The experiments were concern mostly VCSELs with active medium of quantum dots and were carried out in the framework of 2 Erasmus mission of Bulgarian students in Vrije Universiteit Brussels. This research is carried out in collaboration with Technical University of Berlin.

We continued our theoretical and experimental investigations on stationary and dynamics regimes in VCSELs with optical feedback from an extremely short external cavity (ESEC). We proved the possibility of using ESEC feedback for control and/or stabilization of the polarization of the emitted light. This research is carried out in collaboration with Polytechnic University of Navarre, Spain and SNRC, Saint-Etienne, France.

We continued our theoretical and experimental investigations on orthogonal optical injection in VCSELs (the injected light is linearly polarized (LP) perpendicular to the LP direction of the slave laser). Determined is the bifurcation sequence with the frequency detuning and the dependence of the hysteresis width on the injected power. The influence of the higher order modes is also investigated. This research is carried out in collaboration with Supelec, Metz, France and the Institute of Physics of University of Cantabria, Santander, Spain.

In the framework of COST P11 action we determined theoretically the propagation constants of photonic crystal fibers (PCF). Furthermore, in collaboration with the group of liquid crystals at ISSP and Moscow State University, Russia we carry out experimental investigations of PCFs infiltrated by liquid crystals. Theoretical studies of the impact of the photonic crystal structure embedded in VCSEL DBRs have been carried out in collaboration with the Technical University of Lodz.

5. OPTICS AND SPECTROSCOPY OF THERMOTROPIC LIQUID CRYSTALS

The electroconvection (EC) in nematics with short range smectic C order, scanning both the high-temperature nematic region (N₁) and the low-temperature one (N₂), differentiated by a definite temperature T*, was investigated. The influence of the change of the magnitude and the sign of the electroconductivity, σ_a , anisotropy, as well as the influence of the director \mathbf{n} positions (both driven by temperature variation), on the EC mechanism and the corresponding optical patterns are discussed. The isotropic character of the EC instability initiated by the ‘loss’ of electroconductivity anisotropy below T*, and in the vicinity of the nematic-isotropic phase transition, is discussed.

Photonic Crystal Fibers (PCFs) is a new class of optical fibers. PCFs (micro-structured waveguides) are typically silica fiber and characterize with large number of air holes located in the cladding region. An optical polarization method for indication of infiltrated in photonic bandgap fibre nematic (E₇) liquid crystal alignment, was proposed. The alignment expressed by the angle θ (between the capillary axis and the nematic ‘easy’ axis), was detected. The found by the proposed method fairly good alignment could be base

for the future experimentation of Liquid Crystal Photonic Crystal Fibers (LC-PCFs) by both a.c. and d.c. electric fields. We found that chiral nematic liquid crystals, infiltrated in photonic crystal fibers, allow an effective electrical control of such optical waveguides. We succeeded in achieving an effective driving of the helix axis alignment at a diversity of electric field magnitudes and frequencies.

A survey is given on classical and new phenomenological approaches in describing glass-transition and the nature of glasses. A generalized approach in the phenomenology of glass-transition is developed, based on a quasi-linear extension of the formalism of the thermodynamics of irreversible processes.

Based on the theoretical approach developed, the applicability of the third principle of thermodynamics to non-equilibrium systems is reconsidered. It is shown that a formulation of the third principle of thermodynamics can be given – formulated as the principle of non-accessibility of the absolute zero temperature – comprising both equilibrium and non-equilibrium systems.

6. THEORETICAL METHODS IN MOLECULAR PHYSICS

Employing our earlier developed vibrational model, we have carried out further theoretical studies on the vibrational structure and force constants in benzene, at the higher excess vibrational energies. In this way we have been able to study the prominent Fermi resonances in the benzene vibrational spectrum.

We have studied theoretically the vibrational level structure and force constants, characterizing the ground electronic state potential surface of thiophosgene ($CSCl_2$). Computations have been performed on the thiophosgene vibrational spectrum, based on a specific molecular quantum mechanical model. The results from the calculations are in good agreement with the experimentally available data.

7. MULTY-PHOTON PROCESSES. NONLINEAR OPTICS

The second- and third-order nonlinear optical properties of the inorganic non-centrosymmetrical crystal magnesium sulfite hexahydrate were studied by second-harmonic generation and degenerate four-wave mixing. Nanosecond pumping by high-power Nd:YAG laser having a variable reflection output coupler was used. The effective quadratic ($\chi^{(2)}$) and cubic ($\chi^{(3)}$) nonlinear susceptibility values of the crystal are obtained at room temperature. The optical damage threshold and the Raman scattering response of the crystal, as well as the two-photon absorption and the role of other competing non-linear optical processes like the stimulated Raman scattering, are also analyzed.

The elastic incoherent neutron scattering of rotational and translational dynamics in liquid crystals is theoretically modeled. New theoretical approaches for the translational and rotational contributions to the elastic incoherent structure factor (EISF) of neutron scattering in mesomorphic systems are proposed. The influence of the molecular biaxiality and steric hindrance on the reorientational processes is considered. Molecular reorientation in anisotropic systems is considered by the model of the uncorrelated angular jumps and orientational-dependent residence time. This model is applied to liquid crystals.

8. LASER SPECTROSCOPY APPLIED TO BIOLOGICAL SYSTEMS: CHROMATIN STRUCTURE AND DYNAMICS

We show that nucleolin is a histone chaperone that is able to drastically increase the remodelling efficiency of the chromatin remodelers SWI/SNF and ACF. Nucleolin has also the capacity to promote the remodeling of nucleosomes containing macroH2A, but not H2ABbd histone variant, which are otherwise resistant to remodeling. Furthermore, nucleolin was able to remove H2A–H2B dimers from assembled nucleosomes. Finally,

nucleolin is acting as a FACT-like protein helping the passage of the RNA polymerase II through the nucleosomal particles. Our work defines new functions for histone chaperones in chromatin remodelling and regulation of transcription.

Using a number of single-molecules physical methods, including atomic force microscopy (AFM), electron cryo-microscopy and optical tweezers, combined with molecular biology approaches, we have dissected the role of the different domains of the variant histone H2A.Bbd in the structure and function of H2A.Bbd nucleosomes. We showed that the H2A.Bbd octamer is less stable and organizes 130 bp of DNA. These structural and functional properties are determined by the whole histone fold domain of H2A.Bbd, but with particular role of the docking domain.

9. COLORIMETRY AND ITS APPLICATIONS IN INDUSTRY AND ENVIRONMENT

We have investigated a set of experiments related to the colorimetric parameters (L^* , a^* , b^* , H , Cab and ΔE_{ab} in color space CIELAB) and their ability to be used for textile samples (experimental samples) exploration.

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2. S. Rashev, D.C. Moule, S.T. Djambova: "Empirical Determination of The Harmonic Force Constants in Benzene. 4. The Fermi Resonances", *J. Phys. Chem. A*, 110 (51) (2006) 13769.
3. N. Kirov, I. Dozov, J. Jordanova, M.P. Fontana, G.B. Hadjichristov: "Elastic incoherent neutron scattering of rotational and translational dynamics in liquid crystals", *J. Molec. Struct.* 788 (1-3) (2006) 7-15.
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6. I. Savova, I. Savatinova, H:LiNbO₃ and H:LiTaO₃ Planar Optical Waveguides: Formation and Characterization, *Frontiers in Planar Lightwave Circuit Technology*, S. Janz et al (eds.), Springer, 229-234 (2006).
7. A. Og. Dikovska, P.A. Atanasov, S. Tonchev, E. Escoubas. Periodically structured ZnO thin films for optical gas sensor application, E-MRS IUMRS ICEM 2006 Spring Meeting, Symposium **K**: "ZnO and Related Materials". Nice, France, May 29 – June 2, 2006, **KP-III 03**.
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10. J.-F. Bisson, O. Parriaux, J.C. Pommier, S. Tonchev, K. Ueda. A polarization-stabilized microchip laser using a resonant grating mirror, *Applied Physics B: Lasers and Optics*, **85**, 519-524 (2006).
11. M. Flury, N. Lyndin, R. Fechner, A. Schindler, S. Tonchev, M. Spajer, Y. Ouerdane, N. Destouches, D. Pietroy, S. Reynaud, O. Parriaux. Resonant grating pulse compression

- element with 99% flat top efficiency for high average power femtosecond laser machining, *Proc. SPIE* **6187**, 61871I (2006).
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 14. N. Destouches, H. P. Herzig, W. Nakagawa, H. Ottevaere, J. Pietarinen, S. Reynaud, J. Tervo, S. Tonchev, J. Turunen, J. Van Erps, M. Kujawinska. AFM benchmark for the profile characterization of subwavelength diffractive elements within the EC Network of Excellence on Micro-Optics (NEMO), *Proc. SPIE*, **6188**, 418-428 (2006).
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 16. D. Angelov, V. A. Bondarenko, S. Almagro, H. Menoni, F. Mongelard, F. Hans, F. Mietton, V. M. Studitsky, A. Hamiche, S. Dimitrov, P. Bouvet (2006) Nucleolin is a histone chaperone with FACT-like activity and assists the remodelling of nucleosomes, *EMBO J.* **25**, 1669-1679.
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 25. M. Arteaga, H. Unold, J. Ostermann, R. Michalzik, H. Thienpont and K. Panajotov, Investigation of polarization properties of VCSELs subject to optical feedback from an

- extremely short external cavity, part I: Theoretical Analysis, *IEEE Journ. Quant. Electr.*, **42**, 89-101, 2006.
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38. R. Aleksiyko, P. Byszewski, M. Berkowski, J. Fink-Finowicki, R. Diduszko, W. Gebicki, J. Baran, K. Antonova, Correlation between Raman Spectra and Structure in $(\text{La/Pr})_{1-x}(\text{Pr/Nd})_x\text{GaO}_3$ Solid Solution Crystals, *J. Mol. Str.*, **792-793**, 62-67, 3 July, (2006).
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40. M. Petrov, B. Katranchev, E. Keskinova and H. Naradikian, ‘The electroconvection in dimeric nematic liquid crystals’, *Journal of Optoelectronics and Advanced Materials*, in press.
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44. A. Angelov, "Covariance, Squeezed and Coherent States, Proposal for Experimental Realization of Covariance States", *AIP Conf.Proc.*, in press.
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46. L.I. Pavlov, G.B. Hadjichristov, S. Lazarov, Z. Bunzarov, I. Buchvarov, I. Nikolov, M. Iliev: "Nonlinear $\chi^{(2)}$ and $\chi^{(3)}$ spectroscopy of Magnesium Sulphate Hexahydrate single crystal", *SPIE Conf. Proc.*, in press.
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48. N. Maneva, M. Kuneva, and Th. Barthel, Samarium as activator in cerium dioxide, accepted in *JOAM*.
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51. T. Czystanowski, M. Dems, H. Thienpont, K. Panajotov, Validation of Plane Wave Admittance Method Applied to Vertical – Cavity Surface – Emitting Diode Lasers (submitted)
52. I. Genchev, M. Van Uffelen, K. Panajotov, F. Berghmans, H. Thienpont, Monte Carlo simulations of ionizing effects in semiconductor layered structures (submitted)
53. I. Gatere, K. Panajotov, M. Sciamanna, Frequency-induced polarization bistability in vertical-cavity surface-emitting lasers with orthogonal optical injection, *Phys. Rev. A*, accepted.
54. A. Valle, I. Gatere, K. Panajotov, M. Sciamanna, Transverse mode switching and locking in Vertical-Cavity Surface-Emitting Lasers subject to Orthogonal Optical Injection, *IEEE Journ. Quant. Electr.*, accepted.
55. P. Bienstman, S. Selleri, L. Rosa, H.P. Uranus, W.C.L. Hopman, R. Costa, A. Melloni, L.C. Andreani, J.P. Hugonin, P. Lalanne, D. Pinto, S.S.A. Obayya, M. Dems, K. Panajotov, Modelling leaky photonic wires: a mode solver comparison, *Opt. Quant. Electr.*, accepted.

ONGOING RESEARCH PROJECTS:

1. VI EU Framework - Project, 2004-2008, Network of Excellence: (3DTV) Integrated Three-dimensional Television – Capture, Transmission and Display; Contract No. 511568. (Assoc. Prof. S. Tonchev, PhD, Assist. Prof. M. Kuneva, PhD).
2. Contract No MRTN-CT-2003-505086 within the EC 6th Framework Programme (FP6) Selective formation and biochemistry of oxidative clustered and damage 'clustoxdna' contact person Dr. Dimitar Angelov

3. Ion Beam Modification of Polymer Surfaces 12924, MAAE, Assoc. Prof. T.Tsvetkova Ph.D.
4. Investigation of achiral and with induced chirality thermotropic liquid crystals - National grant for science 1307 (Prof. M. Petrov, D.Sc.).
5. Relaxation processes in polyatomic molecules - National grant for science 1415 (Prof. S.Rashev, D.Sc.).
6. Dynamic of DNA-protein interaction and mechanism of nucleosome remodeling, National Found of Science, grant K1402 to D. Angelov.
7. EC 6th Framework Programme (FP6) Contract N^o: MRTN-CT-2003-505086 to D. Angelov, "Selective formation and biochemistry of oxidative clustered DNA damage" (CLUSTOXDNA).

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

TEACHING ACTIVITIES:

1. Dimitar Dimitrov, Ph.D. students - thesis in Colorimetry
2. Erve Menoni, Ph.D. students - thesis in Biophysics.

DIVISION SOFT MATTER PHYSICS

LABORATORY

LIQUID CRYSTALS

HEAD: **Assoc.Prof. Marin Mitov, Ph.D.**
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TOTAL STAFF: **8**
RESEARCH SCIENTISTS: **7**

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

RESEARCH ACTIVITIES:

Two projects have been developed in the Laboratory “Liquid Crystals” during 2006 on different contracts: one of them with BAS and one with NSFB.

A novel method for determining of the flexoelectric coefficients of nematics has been proposed. It is based on the electro-optical behaviour of the surface-induced flexoelectric domains in an additional applied magnetic field in the Z direction. The electro-magneto-optical curves have a resonance character due to competition between the flexoelectric, dielectric and magnetic torques. From the resonance, where the intensity of the transmitted light is maximal, one can obtain formulae which permit calculation of a relation between the flexoelectric coefficients of bend e_{3x} , splay e_{1z} , and the values of the electric and magnetic fields. As a second relation, we choose the sum of the two flexoelectric coefficients. The obtained quadratic equations have been solved numerically with the aid of computer, for all permitted negative and positive values of the sum of the two coefficients. Finally, the values of the coefficients of bend and splay are discussed. Their variations for small values of the total flexoelectric coefficient $\pm 2 \cdot 10^{-4}$ dyne^{1/2} are the most interesting.

The contribution of the electrostatic interactions of a charged membrane, built up of amphiphilic molecules, to its bending elasticity moduli was determined. The free energy of the electric double layers on the two interfaces of the membrane was calculated, taking into account the dependence of the surface charge densities on its bending deformation. Explicit expressions for the corrections of the bending elasticity moduli due to the electrostatic interactions were obtained. Sufficient conditions, assuring the constancy of the surface charge of the membrane were deduced. A critical review of the existing in the literature experimental data concerning the influence of the electrostatic interactions on the mechanical properties of amphiphilic monolayers and bilayers has been made.

The bending elasticity modulus of quasi-spherical erythrocyte ghosts was studied experimentally via analysis of their thermally induced shape fluctuations. The obtained results show that the bending modulus of their membranes is equal to several times the Boltzmann factor $k_B T$ and belongs to the lower part of the existing interval of experimental values for the bending elasticity of red blood cell membranes, reported in the literature.

The influence of different (mono and di) sacharides in the aqueous phase on the bending modulus, k_c , of lipid bilayers have been investigated using the method of thermally induces shape fluctuations. The monosaccharides fructose and glucose and the disaccharide trehalose in concentration range of 0-400 mM have been studied. The results are compared to

those for the disaccharide sucrose obtained previously in the laboratory. The analysis reveal that all the sugars studied decrease the bending modulus of SOPC bilayers down to a saturation value.

PUBLICATIONS:

1. Y. Marinov, H.P. Hinov, and A.G. Petrov, "On a simple way for obtaining important material constants of a nematic liquid crystal: longitudinal flexoelectric domains under the joint action of dc and ac voltages", *Mol. Cryst. Liq. Cryst.* 449, 33 (2006)
2. I. Bivas, Electrostatic and mechanical properties of a flat lipid bilayer containing ionic lipids, *Colloids and Surfaces A: Physicochem. and Engineering Aspects*, v. 282-283, pp. 423-434 (2006).
3. V. Vitkova, P. Méléard, T. Pott and I. Bivas, "Alamethicin influence on the membrane bending elasticity", *Eur. Biophys. J.* 35, pp. 281-286 (2006)
4. V. Vitkova, J. Genova, M.D. Mitov, and I. Bivas, "Sugars in the aqueous phase change the mechanical properties of lipid mono- and bilayers", *Mol. Cryst. Liq. Cryst.* 449, pp. 95-106 (2006)
5. V. Vitkova, M. Mader et T. Podgorski, "Micro-écoulements de vésicules : déformation et mobilité", *La Houille Blanche*, N°2-2006, pp.65-70 (2006)
6. M. Mader, V. Vitkova, M. Abkarian, A. Viallat and T. Podgorski, "Dynamics of viscous vesicles in shear flow", *Eur. Phys. J. E* 19, pp.389-397 (2006)
7. J. Genova, A. Zheliaskova, M. D. Mitov, "The influence of sucrose on the elasticity of SOPC lipid membrane studied by the analysis of thermally induced shape fluctuations", *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, v. 282-283, pp. 420-422 (2006)
8. I. Bivas and Yu. A. Ermakov, Elasticity and Electrostatics of Amphiphilic Layers, in "Advances in Planar Lipid Bilayers and Liposomes", edited by A. Leitmannova Liu, Elsevier, Amsterdam, 2007, Volume 5, Chapter 11, pp. 313-343 (invited).
9. H. P. Hinov and Y. Marinov, "An electro-magneto-optical resonance method for determination of the value and sign of the flexoelectric coefficients in nematics", *J. Optoel. Adv. Mater.* **9**, 435 (2007)
10. J. Genova, A. Zheliaskova, M. D. Mitov, "Monosaccharides (fructose, glucose) and disaccharides (sucrose, trehalose) influence the elasticity of SOPC membranes", *J. Optoel. Adv. Mater.* **9**, 427 (2007)
11. V. Vitkova, V. Doltchinkova, M. D. Mitov and I. Bivas, "Membrane bending elasticity of human erythrocyte ghosts", *J. Optoel. Adv. Mater.* **9**, 431 (2007)

DIVISION SOFT MATTER PHYSICS

LABORATORY

BIOMOLECULAR LAYERS

HEAD: Acad. Alexander G. Petrov, D.Sc.
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TOTAL STAFF: 6
RESEARSH SCIENTISTS: 6

Assoc.Prof. S. Naydenova, Ph.D.; Assist.Prof. Y. Marinov, Ph.D.; Assist.Prof. L. Todorova;
T. Angelov, chemist; M. Dencheva-Zarkova, technologist

RESEARCH ACTIVITIES:

The direct flexoelectric effect in living membranes of astrocyte cells excited by electric pulses has been established for the first time.

Nematic droplets of variable size of E7 were dispersed in a photopolymer NOA65 matrix by the method of UV photopolymerization-induced phase separation. Dielectric and flexoelectric oscillation of the director orientation in the droplets were excited by an ac driving voltage in the range 1Hz to 3 kHz. Both the linear and quadratic electro-optical responses of the PDLC films were studied by the flexoelectric spectroscopy method and by laser light diffraction. The temperature and voltage dependence of the 1st and 2nd harmonic electro-optic spectra (amplitude and phase of the transmitted light vs frequency) were obtained, and strikingly deep minima in all spectra were found. These minima were interpreted as resulted from a spatial filtering (i.e. selective diffraction) of the time-modulated components of the transmitted light.

“Sliding on” nanolayers of PTFE were studied by a LC drop method. It was established that the preferred 5CB nematic director alignment is tilted opposite to the sliding direction. For previously observed unusual modulated domain pattern a possible relation between the domain origin and loosely deposited PTFE layers was suggested.

Medical applications of superparamagnetic particles based of ferro-oxides have been studied and suitably formulated for intravenous delivery. Magnetic resonance imaging of rabbits contrasted by these particles was carried out in Lozenetz Hospital. The results are promising.

New improved procedure for synthesis of superparamagnetic particles has been elaborated.

A novel method for determining of the flexoelectric coefficients of nematics has been proposed. It is based on the electro-optical behaviour of the surface-induced flexoelectric domains in an additionally applied magnetic field. From the maximum of the transmitted light intensity a relation between the flexoelectric coefficients of bend e_{3x} and splay e_{1z} , and the applied electric and magnetic fields was extracted. On the base of computer simulations the sum of the flexoelectric coefficients was evaluated.

Nanosecond UV laser photopolymerization is employed to fabricate a polymer dispersed liquid crystal (PDLC) single layer. The PDLC system contains droplets with a gradient size distribution. The formation of the PDLC structure, as well as the droplet gradient, is fully controlled by the PDLC cell geometry and UV laser. The electro-optical switching of the produced PDLC is probed.

PUBLICATIONS:

1. Alexander G. Petrov, Electricity and mechanics of biomembrane systems: Flexoelectricity in living membranes (Invited Review), *Anal.Chim.Acta*, **568**, 70-83 (2006)
2. Y.Marinov, H.P.Hinov, A.G.Petrov, On a simple way for obtaining important material constants of a nematic liquid crystal: longitudinal flexoelectric domains under the joint action of dc and ac voltages, *Mol.Cryst.Liq.Cryst.*, **449**, 33-45 (2006)
3. Y. Marinov, S. D'Elia, L. Todorova, A. G. Petrov, C. Versace, N. Scaramuzza, Orientation effects of PTFE nanolayers upon the nematic 5CB, *Liq. Cryst.*, **33** (10), pp. 1219-1225 (2006).
4. S. Naydenova, M. Dencheva-Zarkova, L. Todorova, A. G. Petrov, Photoisomerization effects of an azobenzene derivative on bilayer lipid membranes and living cells, *C.R.Acad.bulg.Sci*, **59**, 4, 405-410 (2006).
5. L. Slavov, T. Merodiiska, L. Todorova, M. Dencheva-Zarkova, S. Naydenova, V. Lovchinov, I. Nedkov, A.G. Petrov, Characterization of magnetic nanoparticles and their organization in magnetic fields, *Nanoscience & Nanotechnology*, 6, Heron Press, pp.46-48, 2006.
6. T. Angelov, P. Pavlova, E. Borisova, H. Naradikian, Y. Marinov, L. Avramov, A. G. Petrov, Temperature-concentration dependence of chromacity in polymer-dispersed cholesteric liquid crystal, *Nanoscience&Nanotechnology*, **6**, eds. E. Balabanova, I.Dragieva, Heron Press, Sofia, pp. 126-128 (2006).
7. R. Ugrinov, B. Farrell, C. Shope, W. Brownell, Voltage Dependency of the Membrane Resistance of Mammalian outer Hair Cells, *C.R.Acad.bulg.Sci*, **59**, 4, 411-416 (2006).
8. С. Найденова, Л. Тодорова, М. Денчева-Заркова, А. Г. Петров, “Течни кристали в медицината и биологията”, *Списание Физика*, Том **31**(49), кн.2, 2006г.
9. С. Найденова, Л. Тодорова, М. Денчева-Заркова, А. Г. Петров, “Възможности за приложение на субмикро- и наноразмерни течнокристални структури от амфифилни молекули”, *Светът на физиката*, Том **XXIX**, кн.2, с.131-143, 2006г.

ONGOING RESEARCH PROJECTS:

Financed by the Bulgarian Academy of Sciences and by the Bulgarian National Council “Scientific Studies”:

1. Project DNP1-03/04: “Lyotropic liquid crystalline nanostructures for the biology and medicine”.

COLLABORATION:

1. “Confined and nanostructured liquid crystals studied by the method of flexoelectric spectroscopy”- Dipartimento di Fisica, Universita degli Studi della Calabria, Joint Research Project between BAS and CNR, Italy.

TEACHING ACTIVITIES:

Rosen Ugrinov, Ph.D. student – thesis in the field of lyotropic liquid crystals.

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

DIVISION LASER, ATOMIC, MOLECULAR AND PLASMA PHYSICS

LABORATORY

ATOMIC SPECTROSCOPY

HEAD: **Prof. Kiril Blagoev, D.Sc.**

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TOTAL STAFF: **10**

RESEARCH SCIENTISTS: **8**

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

RESEARCH ACTIVITIES:

1. ATOMIC STRUCTURE, SPECTRA AND CONSTANTS

Transition probabilities of some high lying excited states of Cu II have been determined. The states belong to $3d^9 4s 4d, 5s$, $3d^8 4s^2$ electron configurations. Transition probabilities of states, belong to the $5d^9 6s 6d, 7s$ electron configurations of Au II have been determined. The experiment was carried out by using Laser Induced break Down Spectroscopy method. Theoretical calculations were performed by multiconfigurational Hartree- Fock method, taking in to account polarization of atomic core.

Investigation of possibility of obtaining of Bosse – Einstein condensate, which has larger atomic concentration, was carried out. The new method for filling of magneto-optical trap was developed. The characteristics of dipole trap were studied, when it is filled from magnetic trap or directly from optical molasses.

2. HOLLOW CATHODE DISCHARGE - PROPERTIES AND APPLICATION

The opto-galvanic signal polarization dependence is related to the different cross-sections, characterizing the interaction of either selfaligned and oriented ensemble of atoms. In order to find the real yield of sputtered atoms a potential ability of the program SRIM is realized, i.e. the subprogram *ion beam-gas medium*. In this way the effect of yield reduction due to the buffers has been taken in mind.

3. HOLLOW CATHODE DISCHARGE AS AN ACTIVE LASER MEDIUM

Theoretical and experimental studies on the UV nitrogen hollow cathode laser in He-Ne-N₂ mixture are carried out. Discharge conditions for stable operation of the laser are studied. The computer simulations show that conditions for lasing are reached at high current densities ≥ 2 A/cm² and at high pressures ≥ 40 Torr. For that reason laser tubes with narrow inside diameter of the cathode - 3 mm are created. It is shown that stable operation at high currents and pressures can be reached only when He is used as a buffer gases e.g. discharge in triple mixture. The emission of the nitrogen second positive band by the discharge conditions variations is studied.

The spontaneous emission of the gas mixture He-Ar-N₂ is studied in order to create a light source in the UV region, as well. The aim is to investigate the possibility of making an Hg free discharge lamps.

The experimental study of the UV lasing on the neon ion lines in the region 330 nm – 370 nm is in progress.

4. APPLICATION OF HOLLOW CATHODE DISCHARGE

Experimental results obtained from the investigations of the SnO₂/SiO₂/Si structure modified with hexamethyldisilazane are analysed and summarized.

A number of dynamic optogalvanic signals for both atomic transitions of Ar I, Fe I and Fe II are obtained in the 424-452nm and 212-226nm spectral ranges and study as a function of discharge conditions and laser characteristics.

The true resonant optogalvanic signals for Ne I transitions in 524-564nm spectral ranges are obtained from the experimental ones using deconvolution procedure. An approach is developed for fitting the obtained true signals with appropriate function. It enables to extract of various rate constants of the elementary processes in the hollow cathode plasma from the registered dynamic optogalvanic signals.

PUBLICATIONS:

1. R. Mayo, J. Campos, M. Ortiz, H. Xu, S. Svanberg, G. Malcheva and K. Blagoev, "Radiative lifetimes of Zr III excited levels", *Eur. Phys. J.* **D40**,169,2006.
2. G. Malcheva, K. Blagoev, R. Mayo, M. Ortiz, H. L. Xu, S. Svanberg, P. Quinet, and E. Biémont, "Radiative lifetimes and transition probabilities of astrophysical interest in Zr II", *Monthly Notices of Royal Astronomical Society - Main Journal*, **367**, 745(2006)
3. D. Comparat, A. Fioretti, G. Stern, E. Dimova, B. Laburthe Tolra, P. Pillet "Optimized production of large Bose Einstein Condensates", *Phys. Rev. A* **73** p. 043410 (2006)
4. E. Dimova, O. Morizot, G. Stern, C. L. Garrido Alzar, A. Fioretti, V. Lorent, D. Comparat, H. Perrin, P. Pillet "Continuous transfer and laser guiding between two cold atom traps", *EPJ D*, (2007) accepted
5. G. Stern, E. Dimova, A. Fioretti, D. Comparat and P. Pillet "Magnetic or optical molasses loading for a Cs dipole trap" *SPIE* (2006) accepted
6. K. Kowalski, E. Dimova-Arnaudova, K. Fronc, S. Gateva, M. Głódź, L. Lis, L. Petrov, J. Szonert, "System for magneto-optical cooling and trapping of Rb atoms", *Optica Applicata*, **36** (4), (2006).
7. R. Djulgerova, L. Popova, G. Beshkov, Z. Lju Petrovic, Z. Rakocevic, V. Mihailov, V. Gencheva, T. Dohnalik, "Investigation of modified thin SnO₂ layers treated by rapid thermal annealing by means of hollow cathode spectroscopy and AFM technique" *J.Phys.D: Appl Phys.* **39**(2006) 3267-3271
8. M. Ortiz, R. Mayo, É. Biémont, P. Quinet, G. Malcheva and K. Blagoev, Radiative parameters for some transitions arising from the 3d⁹4d and 3d⁸4s² electronic configurations in Cu II spectrum, *J. Phys. B:At&Mol Phys.* Accepted
9. В. Полищук, Н. Горбева, Д. Жечев, Г. Тодоров, "Влияние интерференции атомных состояний на гальванические свойства плазмы газового разряда", *Вестник Санкт Петербургского Университета, сер. Физика*, 2007 (to be published).
10. Application of Laser Induced Breakdown Spectroscopy (LIBS) for determination of transition probabilities of laser lines in Au II spectrum, M. Ortiz, R. Mayo, É. Biémont, P. Quinet, G. Malcheva and K. Blagoev, *Proc. SPIE 2006*(accepted)

TEACHING ACTIVITIES:

PhD students - N. Parvanova and V. Steflekova, supervisor Prof. D. Zhechev
Organization of the 9th winter seminar of young scientists

ONGOING RESEARCH PROJECTS:

1. Micro Hollow Cathode Discharge and applications (supported by Nat Sci Fund, 2003-2006)

Experiment on this light source is in progress.

2. Radiative properties of ionic spectra (supported by Bulgarian National Science Foundation – contract 1516/2005) Experimental investigation of Au II spectrum is in progress.

3. Photo-induced effects in low temperature plasma and solid state surface: photo-resonant and surface photo-charge effects" project in the framework of BAS.

4. Radiative lifetimes and transition probabilities of excited atomic and ionic states project in the framework of BAS. Cancellation effects in Zn II spectrum will be investigated.

5. Recombination and ionization processes in nonequilibrium low temperature plasma project in the framework of BAS. An experimental study of the UV lasing on the neon ion lines is in progress. Calculations have shown that population inversion on the UV neon ion transitions in the region 330 nm – 370 nm can be created.

INTERNATIONAL COLLABORATION:

1. International collaboration under the Problem "Laser spectroscopy of low-living isomers" with Laboratory

of Nuclear Reactions, Dubna, Russia – Prof. DSc. D. Zhechev

2. " Investigations of optogalvanic effect in gas mixture hollow cathode discharge plasma – peculiarities and interpretations" - Institute of Physics of Belgrade, Serbia and Montenegro – V. Mihailov (2004-2006)

3. "Analysis of multy-component materials – problems and applications " – Institute of Physics of Belgrade, Serbia and Montenegro – Dr. R.Djulgerova

DIVISION LASER, ATOMIC, MOLECULAR AND PLASMA PHYSICS

LABORATORY

METAL VAPOUR LASERS

HEAD: **Acad. Nikola Sabotinov, D.Sc.**

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TOTAL STAFF: **16**

RESEARCH SCIENTISTS: **12**

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

RESEARCH ACTIVITIES:

National and international scientific reserach projects

Research work for 2006 of the Laboratory of Metal Vapour Lasers was carried out within totally 9 scientific research projects. These projects were supported as follows:

- one scientific research project supported by the Bulgarian Academy of Sciences;
- three scientific research projects supported by the National Science Fund of the Bulgarian Ministry of Education and Science:

Contract #MSP-08, "Method for maintaining hydrogen partial pressure in the active medium of the copper bromide vapour laser", (2006-2008); Programme "Promotion of innovations in small and medium enterprises";

Contract #UNA-11, "High-energy scanning laser system for microprocessing of materials", (2005-2007); Programme "Development of research potential";

Contract #F-1204, "Metal vapour ultraviolet lasers";

- one scientific research project supported by the National Innovation Fund of the Bulgarian Small and Medium Enterprises Promotion Agency:

Contract #8, "Industrial investigation of a medical (dermatology) scanning laser system", (2005-2008);

- three scientific research projects under agreements for cooperation between Academies and Institutes;
- one project with a foreign industrial company.

Scientific activities abroad

In 2006 scientists of the Laboratory of Metal Vapour Lasers visited foreign scientific institutions in pursuance of scientific tasks as follows:

- long-term scientific investigations: 1;
- short-term scientific investigations: 3;
- giving lectures: 1;
- participations in international scientific conferences: 2.

TEACHING ACTIVITIES:

PhD students: 3

SCIENTIFIC ACHIEVEMENTS:

The scientific investigations in 2006 at the Laboratory of Metal Vapour Lasers were carried out in the following main directions: 1) Self-terminating pulsed lasers; 2) Technological applications of lasers generating in the visible spectral region; and 3) Theoretical studies in the field of coherent optics.

1) Self-terminating pulsed lasers

A strontium atomic laser pulsed by a longitudinal He-SrBr₂ discharge has been developed at the Laboratory. Laser generation was achieved on the following atomic and ion lines: 1.03, 1.09, 2.06, 2.20, 2.69, 2.92, 3.01, 3.07 and 6.45 μm. Spectral selection of the individual lines was performed with filters of glass and quartz which transmit in different regions but do not transmit the line at 6.45 μm. Optimum conditions for laser generation have been found including the following parameters: the helium pressure, the temperature regime, the values of the excitation capacitor battery; the electric power introduced into the discharge and the excitation pulse frequency. At simultaneous laser generation of all lines an average laser output power of 2.4 W was measured with more of 80% concentrated on the 6.45μm- line.

2) Technological applications of the visible lasers, created at the Laboratory

2.1) High-power copper and copper halide lasers for industrial applications

Initial measurements of the near and far fields of the copper vapour laser MOPA system were performed.

2.2.) Industrial investigation of a medical dermatological scanning laser system

All parameters of the laser resonator required for producing the optical components building it have been determined.

Spectral and pulse characteristics at different excitation frequencies for the copper bromide vapour laser were studied.

Three laser tubes produced by the company Pulslight were tested (each tube during an eight-week period) by power and identity in laser pulse energy.

3) Theoretical studies in the field of coherent optics

Studies were carried in processing quantum information.

A new method based on the adiabatic transfer of population has been suggested for the creation of maximum coherent superposition of two atomic states. The method employs the analogy between the equations of Bloch for two states and the equation of Schrodinger for three states. The suggested method is topologically analogical to the widely applied method STIRAP in lambda-systems and possesses analogical stability to fluctuations in the experimental parameters.

PUBLICATIONS:

Papers published in international journals and proceedings

1. K A Temelkov, N K Vuchkov and N V Sabotinov, Cross sections and rate constants for charge transfer into excited states, *Plasma Processes and Polymers* **3**(2), 147–150, (2006)
2. K.A. Temelkov, N.K.Vuchkov and N V Sabotinov, “Penning ionization cross sections and rate constants”, *Journal of Physics: Conference Series* 44 (1), art. no. 014, pp. 116-120, (2006)
3. Nikolay K. Vuchkov, “High discharge tube resource of the UV Cu+ Ne-CuBr laser and some applications”, *New Developments in Lasers and Electro-Optics Research*, Nova Science Publishers Inc., New York, (2006)
4. K.A. Temelkov, N.K. Vuchkov, B.L. Pan, N.V.Sabotinov, B.Ivanov, L.Lyutov, Strontium atom laser excited by nanosecond pulsed longitudinal He-SrBr₂ discharge, *J. Phys. D: Appl. Phys.*, vol. 39, pp. 3769-3772, (2006)
5. D.N.Astadjov, L.I.Stoychev and N.V.Sabotinov, Improvement of CuBr Laser Coherence Properties, *Proc. of SPIE Vol.6252*, 625229 (2006)
6. M.Grozeva, D.Mihailova and N.Sabotinov, Possibilities of UV Laser Oscillation on Aluminum Ion Lines, *Journal of Physics: Conference Series*, 44, 196-201, (2006)
7. P.Stefanov, N.Minkovski, I.Balchev, I.Avramova, N.Sabotinov, Ts.Marinova, XPS studies of short pulse laser interaction with copper, *Applied Surface Science* 253, 1046-1050, (2006)
8. Balchev, N. Minkovski, Ts. Marinova, M. Shipochka and N. Sabotinov, Composition and structure characterization of aluminum after laser ablation, *Materials Science and Engineering: B*, 135, 108-112, (2006)
9. G. S. Vasilev and N. V. Vitanov, Complete and robust population transfer by zero-area pulses, *Phys. Rev. A* 73, 023416(6), (2006)
10. E. S. Kyoseva and N. V. Vitanov, Coherent pulsed excitation of degenerate multistate systems: Exact analytic solutions, *Phys. Rev. A* 73, 023420(11) (2006)
11. N. V. Vitanov and B. W. Shore, Stimulated Raman adiabatic passage in a two-state system, *Phys. Rev. A* 73, 053402(4), (2006)
12. L. P. Yatsenko, A. A. Rangelov, N. V. Vitanov, and B. W. Shore, Steering population flow in coherently driven lossy quantum ladders, *J. Chem. Phys.* 125, 014302(7), (2006)
13. P. A. Ivanov and N. V. Vitanov, State reconstruction of a qutrit by a minimal set of discrete measurements, *Opt. Commun.* 264, 368-74, (2006)
14. P. A. Ivanov, E. S. Kyoseva, and N. V. Vitanov, Engineering of arbitrary U(N) transformations by quantum Householder reflection, *Phys. Rev. A* 74, 022323(8), (2006)
15. Rangelov, N. V. Vitanov, and B. W. Shore, Extension of the Morris-Shore transformation to multilevel ladders, *Phys. Rev. A* 74, 053402(9), (2006)

Papers accepted for publication in international journals and proceedings

1. Nikolay K. Vuchkov, Krassimir A. Temelkov and Nicola V. Sabotinov, “UV Cu+ Ne-CuBr laser for material treatment” in print in *Optics & Laser Technology*.
2. K A Temelkov, N K Vuchkov, N V Sabotinov, Experimental and theoretical determination of cross sections and rate constants for charge transfer population and radiative constants of some excited Ag⁺, I⁺, and Cu⁺ levels, in print in *Journal of Physics: Conference Series*
3. M. Ilieva, V.Tsakova, N.K.Vuchkov, K.A.Temelkov, N.V.Sabotinov, UV copper ion laser treatment of poly-3,4- ethylenedioxythiophene, in print in *Journal of Optoelectr. and Advanced Materials*.

4. K. A. Temelkov, N. K. Vuchkov, B. L. Pan, N. V. Sabotinov, B. Ivanov, L. Lyutov, Strontium bromide vapor laser excited by a nanosecond pulsed longitudinal discharge, in print in Proceed. of SPIE.
5. K. A. Temelkov, N. K. Vuchkov, P. K. Telbizov, and N. V. Sabotinov, He-Zn⁺ laser excited by nanosecond and microsecond pulsed longitudinal high-current discharges, print in Proceed. of SPIE.
6. Dimo N. Astadjov, Lyubomir I. Stoychev and Nikola V. Sabotinov, M2-Factor for MOPA CuBr laser system, Book of Abstracts, 14-th International School on Quantum Electronics "Laser Physics and Applications", Bulgaria, Books of Abstracts, PB4, full report to be issued in SPIE Proceedings, September, (2006)
7. G. S. Vasilev, S. S. Ivanov, and N. V. Vitanov, Degenerate Landau-Zener model: Exact analytic solution, Phys. Rev. A, in print, (2006)
8. P. A. Ivanov, B. T. Torosov, and N. V. Vitanov, Navigation between quantum states by quantum mirrors, Phys. Rev. A, in print, (2006)
9. V. Yannopoulos and N. V. Vitanov, Electromagnetic Green's tensor and photon local density of states calculations for collections of spherical scatterers, Phys. Rev. B, in print, (2006)
10. B. W. Shore and N.V. Vitanov, Overdamping in coherently driven quantum systems, Contemp. Phys., in print, (2006)
11. L. Pramatarova, E. Pecheva, P. Montgomery, V. Grigorov, D. Dimova-Malinovska, T. Petrov, A. L. Toth, Bioactivity of polycrystalline silicon layers, Journal of Nanoscience and Nanotechnology
12. M. Dimitrova, A. Petrova, E. Pecheva, **T. Petrov**, P. Montgomery, L. Pramatarova, Mechanical properties of extracellular matrix/hydroxyapatite composites, Journal of Optoelectronics and Advanced Materials (14th International School on Condensed Matter Physics, 17-22 September 2006, Varna, Bulgaria)

Papers published in full size in proceedings of conferences in Bulgaria

1. N.K.Vuchkov, K.A.Temelkov, N.V.Sabotinov, in Bulgarian, UV laser system for materials processing, The Journal of the Bulgarian Academy of Sciences, No.1, pp.39-41, (2006)
2. Ivaylo I. Balchev, Nikolai I. Minkovski, Ivan K. Kostadinov, Nikola V. Sabotinov, High-speed Laser Micromachining with Copper Bromide Laser, Bulgarian Journal of Physics, 33, 39-47, (2006)
3. N.K.Vuchkov, K.A.Temelkov, N.V.Sabotinov, Copper ion uv laser excited in a Ne-CuBr discharge, in Bulgarian, The Bulgarian Academy of Sciences, News, monthly information bulletin for science and technology, No.8, August, (2006)