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Dear Colleagues,

In 2007 the present administration was appointed for a new mandate. Evidently, the former mandate was regarded successful. The number of papers in prestigious foreign and international journals was markedly increased as well as the number of book chapters prepared by invitation. A new monograph was published in 2007 by Prof. E. Atanasova and colleagues.

Election hold by the General Assembly of the Institute formed the new membership of the Scientific Council. The new structure of the Institute adopted in 2006 by the Scientific Council and combining existing laboratories in divisions has further been established. New heads of divisions were reelected with greatly increased responsibilities, among them the formation of program teams of scientists for successful participation in the scientific programs of united Europe.

Two new NATO reintegration grants were received by younger colleagues, which greatly increased their research possibilities and broadened their scientific perspective. Two scientific projects were funded by the Scientific Studies Fund of the Ministry of Education and Science with elevated levels of funding. Two applied 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 the target.

For a second year the Institute implicated the system of internally funded projects. The results from the first session of the Internal Project Competition were judged to be encouraging and the second session was called. The interest of the groups that have no other funding sources at their disposal, is considerable. Seven projects were funded with a total amount that was about tripled compared to 2006. Teams lead by Assoc. Professors K. Temelkov, S. Tonchev and N. Vitanov received Institute diplomas for the best scientific achievements of the year 2007. R. Ugrinov became a winner of the UK FAMELAB competition for best young talent in science communication and N. Bundalevska received the EUREKA price for best PhD-thesis of 2007. Prof. D. Pushkarov received the Sign of Honour of the Bulgarian Academy of Sciences. Assoc. Professors R. Peeva, R. Kakanakov and P. Stefanov were awarded the Georgi Nadjakov Sign of Honour 2nd degree. Academician A. G. Petrov received the Outstanding Contribution to Science Annual Award of the Ministry of Education and Science of Bulgaria for 2007. Medals and diplomas brought pride and satisfaction not only to their winners, but to the Institute as a whole.

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 ASEC) at BAS, founded by Academician G. Nadjakov in 1946, into ISSP and INRNE (Institute of Nuclear Research and Nuclear Energy), starting January 1, 1973. Since February 16, 1982 the Institute of Solid State Physics is named after Academician Georgi Nadjakov. The first Director 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.
Secretary: Assoc. Prof. M. Grozeva, Ph.D.

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

DIVISION THEORY

THEORETICAL DEPARTMENT

HEAD: **Prof. Dimitar I. Pushkarov, D.Sc.**
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TOTAL STAFF: **9**
RESEARCH SCIENTISTS: **9**

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, D.Sc.; 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 detailed investigation of complex systems (neural networks, texts and images) has been carried. The applicability of statistical-mechanical methods to these kind of problems is demonstrated including finite-size systems in the presence of irregularities.

The role of impurities on the thermodynamic properties of the two-dimensional XY model has been investigated and the phase diagram is determined. This model is widely employed in many condensed-matter problems. The validity of our hypothesis for the existence of a first-order phase transition at relatively high density of the impurities has been verified. This gave an explanation to recent experimental results and speculations.

The phase diagrams of two spin models have been investigated: a one-dimensional quantum plaquet model with quadruple exchange interaction and a model of interacting chains with two types of spin variables, describing a recently-synthesized material. The general type of the quadruple exchange interaction has been investigated and some phases of systems comprising two types of spins have been obtained.

The soliton dynamics in molecular chains in the presence of a modified intermolecular bond (bond defect) has been investigated. A perturbed nonlinear Schrödinger (NLS) equation has been derived on the basis of a microscopic model, describing the evolution of soliton pulses. It is shown that contrary to on-site defects, bond defects introduce several velocity-dependant perturbing terms in the NLS equation.

Static solutions for solitons localized on the defect have been obtained analytically. These solutions have one or two maxima depending on the defect potential (attraction or repulsion). The stability of the solutions has been investigated. It is shown, that the single-peak solution is extremely stable, while the double-peak solution is not and it is easily destroyed by asymmetric perturbations.

Scattering of solitons from bond defects is studied numerically. A rich variety of scattering patterns is obtained in the case of attractive defects. A phase diagram is constructed in the velocity-defect strength space showing the regions corresponding to different types of scattering.

PUBLICATIONS:

1. H. Chamati and N.I. Papanicolaou, Phonon density of states of iron from molecular dynamics simulations, *J. Optoelectron. Adv. Mater.* **9**, 159-161 (2007).
2. H. Chamati and S. Romano, First-order phase transitions in classical lattice gas spin models, *Phys. Rev. B* **75**, 184413 (2007).
3. M.T. Primatarowa, R.S. Kamburova, and K.T. Stoychev, Interaction of solitons with localized nonlinear defects, *JOAM* **9**, 152-154 (2007).
4. K.T. Stoychev, M.T. Primatarowa, and R.S. Kamburova, Resonant interaction of solitons with extended defects, *JOAM* **9**, 155-158 (2007).
5. K.T. Stoychev, M.T. Primatarowa, and R.S. Kamburova, Resonant interaction of solitons with extended inhomogeneities, *AIP* **899**, 621 (2007) Proc. of the BPU6.
6. K.Koroutchev and E.Korutcheva, Text as statistical mechanics object, ICTP Scientific Report IC/IR/2007/002, p.1-9.
7. K.Koroutchev and E.Korutcheva, Detecting the most unusual part of a digital image, accepted for publication in LNCS, 2008, Ed. Springer
8. N. B. Ivanov, J. Richter, and J. Schulenburg, Phase diagram of a spin diamond chain with cyclic four-spin exchange, *Phys. Rev. B* (2008).

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 Project F-1517)

DIVISION THEORY

LABORATORY

COLLECTIVE PHENOMENA in Condensed Matter

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

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TOTAL STAFF: 2

RESEARCH SCIENTISTS: 2

Assoc. Prof. D.V. Shopova; Tsvetomir E. Tsvetkov, MS, PhD-student (first half of 2007)

RESEARCH ACTIVITIES:

- The effect of magnetic fluctuations on the critical behaviour of unconventional ferromagnetic superconductors (UGe₂, URhGe, etc.) and superfluids has been investigated by the renormalization-group method. For the case of isotropic ferromagnetic order (Heisenberg symmetry), a new unusual critical behaviour has been predicted. It has also been shown that the uniaxial (Ising type) and bi-axial (XY type) magnetic symmetries produce fluctuation driven phase transitions of first order. The results can be used in interpretations of experimental data and for a further development of the theory of critical phenomena in complex systems (see Refs. [1]).
- Gauge effects on the fluctuation properties of the normal-to-superconducting phase transition in bulk and thin film superconductors are reviewed. Similar problems in the description of other natural systems (liquid crystals, quantum field theory, and early universe) are also discussed. The relatively strong gauge effects on the fluctuations of the ordering field at low spatial dimensionality D and, in particular, in thin (quasi-2D) films are considered in details. A special attention is paid to the fluctuations of the gauge field. It is shown that the mechanism, in which these gauge fluctuations affect the phase transition order and other phase transition properties varies with the variation of spatial dimensionality D . The problem for the experimental confirmation of theoretical predictions about the order of phase transitions in gauge systems is discussed. Related topics: gauge effects on the critical behavior of unconventional superconductors, disorder, quantum fluctuations in a close vicinity of ultra-low phase transition temperatures, are also briefly discussed (see [2, 3]).
- Some new preliminary results about the properties of the phases and the (T, P) phase diagram of a class of unconventional ferromagnetic superconductors with a spin-triplet Cooper pairing mechanism have been reported (see Refs. [4, 5]).
- A brief outline of problems of superconductivity research in Bulgaria has been prepared and published [6] for the needs of the European scientific community (this was performed in a response to an insisting request).

PAPERS

1. D. I. Uzunov, Europhys. Lett. **77** (2007) 20008; “New magnetic effects on the phase transitions in unconventional superconductors.” (See also arXiv.org: cond-mat/0607057.)
2. D. V. Shopova and D. I. Uzunov, in: Progress in Superconductivity Research, ed. by Oliver A. Chang (Nova Science Publishers, New York, 2008), pp. 25 -76. (to be publ. 2007 - 3rd Quarter, or, in the First Quarter of 2008); ISBN: 1-60021-694-3. Title: “Large Fluctuation

and Gauge Effects on the Critical Behavior of Superconductors.” [See also the preprint variant of the same paper (slightly different title, and typos), in: ArXiv.org, cond-mat/0701266].]

3. D. V. Shopova, T. E. Tsvetkov, and D. I. Uzunov, *J. Phys. Studies*, **10** No. 4 (2006), pp. 330-350, “Gauge effects on phase transitions of superconductors” (invited review article for the jubilee issue of the journal). (See also ArXiv.org, cond-mat/0611354.)

4. D. I. Uzunov, “Some aspects of unconventional superconductivity,” in: Proceedings of Summer School on Advanced Aspects of Theoretical Electrical Engineering (22-25 Sept 2007, Sozopol, Bulgaria), ed. by V. Mladenov, vol. 1, pp. 1-16; Publishing House “King,” Sofia, Oct 2007; ISBN 978-954-9518-45-0.

5. D. I. Shopova, “About the phase diagram of ferromagnetic superconductors,” in: Proceedings of Summer School on Advanced Aspects of Theoretical Electrical Engineering (22-25 Sept 2007, Sozopol, Bulgaria), ed. by V. Mladenov, vol. 1, pp. 1-16; Publishing House “King,” Sofia, Oct 2007; ISBN 978-954-9518-45-0.

6. D. I. Uzunov, “Superconductivity research in Bulgaria” (a brief historical overview and recent problems), IEEE/CSS & ESAS EUROPEAN SUPERCONDUCTIVITY NEW FORUM, No. 1 (2007).

TRAINING OF YOUNG SCIENTISTS

Our last post-graduate student Tsvetomir E. Tsvetkov successfully defended his PhD thesis on 18th June 2007. This was accomplished within the standard three-year post-graduate-ship term. The PhD degree has already been conferred to him in 2007.

T. E. Tsvetkov Thesis: Some properties of phases and phase transitions in ferromagnetic unconventional superconductors (ISSP-BAS, February 2007)].

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–FP6, European Superconductivity Network: GRST-CT-2002-05077 (2007 was the last year of this project).
3. National Foundation of Scientific Research Grant “Physics 1507/05: Coexistence of spin-triplet superconductivity and ferromagnetism in some metallic compounds.”

INTERNATIONAL COLLABORATION

1. Memberships:

1.1. *CP Laboratory*, in: ESAS – The European Society for Applied Superconductivity.

1.2. *D. I. Uzunov*, in: (a) The Editorial Board of *J. Phys. Studies* (Lviv, Ukraine).

(b) The Board of Advisors of the American Biographical Institute (USA).

2. **Collaborative visits:** (D. I. Uzunov): 12 days in JINR-Dubna (Russia).

3. **Conference participations:** (a) Membership in Int. Programme Committee, and

(b) two invited reports at an International Conference; see Refs. [4, 5].

4. **Referee reports:** (D. I. Uzunov, D. V. Shopova) for issues of *The Institute of Physics - IoP* (London, UK): *J. Physics A, B, D*; *J. Physics: Condensed Matter*, *Supercond.& Supercond. Techn.*, *New J. Physics*, etc. North-Holland (D. V. Shopova): *Phys. Lett. A*. (In general, 25 referee reports).

DIVISION MATERIAL PHYSICS

LABORATORY

ELECTRON-PHONON INTERACTIONS

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

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TOTAL STAFF: 8

RESEARCH SCIENTISTS: 6

Assoc. Prof. O. Ivanov, Ph.D.; L. Mihailov, Ph.D.; Z. Dimitrova, Ph.D.; 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

Nonrelativistic energies for the ground state of helium isoelectronic ions with $Z = 3-54$ are computed. Calculations are performed using explicitly correlated wavefunctions of a generalized Hylleraas type. A variational procedure is used which allows solving the two-electron Schrödinger equation with a practically unlimited number of parameters for trial wavefunctions expanded in products of positive powers of the Hylleraas coordinates. A non-conventional optimization procedure and nonlinear programming are used. The contribution of the various terms is analyzed, especially the so-called mass correction and polarization /correlation effects. Our results are compared to other theoretical results and to available experimental data.

MECHANICAL STRESS IN FILM-SUBSTRATE SYSTEMS

The mechanical stress (MS) in Mg_2Si films are studied on n-type Si substrates, since they are promising candidates for low-resistivity contacts, especially to n-Si. This material's advantages are: nontoxic; the constituting elements are largely found in the nature; the formation of nanocrystals in a particular matrix offers the possibility of semiconducting structures of interesting properties. Mg_2Si film formation by conventional methods is difficult due to a low condensation coefficient, and a high vapour pressure for Mg. This is why, the ion-beam synthesis method is used. With its 8 valence electrons per cell, it resembles much the more familiar DLC films (which have been studied before). Both display similar electronic structures, since the symmetries of their Bravais lattices and hence Brillouin zones are identical. Auger spectra and XPS of the films are also taken.

SURFACE PHOTO-CHARGE EFFECT (SPCE) AND ITS APPLICATION

The study of temperature dependence of SPCE for ceramics is finished. A specific increase of the signal is observed for YBCO ceramics, around nitrogen temperature, which could serve as oversight for the superconductivity transition. With regard to practical applications of the SPCE, the following projects are prepared and submitted: over the **European** program "STAIRS"; "EUREKA" program with subject "Elaboration of multiwrapped package for food" to the value of 2.57 millions euro; "Criotools" (subprogram "Kraft" of FP VII) – subject: "Tools coating" -2.5 mill.euro, Italy; **Innovation Fund** – "Cylinders' coatings for foil producing" – 800 000 lvs.

OPTIMAL DISTRIBUTION OF TRACTION FORCE ENGINES

The applied science project “Optimal Distribution of Traction Force Engines” was finished. The system is in regular exploitation with Bulgarian State Railways.

NONLINEAR SYSTEMS’ DYNAMICS

In 2007 the research on the models of the behavior of interacting populations has been continued. New terms have been included in the system of model equations. These terms describe additional phenomena of the evolution of the studied agent systems which in particular can be systems of biological, social or economic agents. A book on application of the methods of the theory of complex systems and synergetics to social dynamics has been completed. The title of the books is “Social dynamics without formulae”. The manuscript obtained sympathetic reports from **leading Bulgarian sociologists** and has been submitted and accepted for publishing by the Academic Publishing House “Prof. Marin Drinov” of the Bulgarian Academy of Sciences.

HISTORY OF PHYSICS IN BULGARIA

Specialities of physics and mathematics education before the Liberation of each of the following educational stages: elementary, junior high and high school and academic are considered. Work on G.Manev’s ‘reactionary theory’ which Manev tried to explain with some processes in the mechanics, electromagnetism and gravity. Data about research activity of acad. M. Borissov (1921-1998) are collected. The existing in G. Nadjakov’s lifetime documents and electrometers at this time (1896-1981) are exhibited again in Nadjakov’s museum. Both, the museum of History of Physics and of Nadjakov are poorly attended.

PUBLICATIONS

1. 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* **9**, 394-397 (2007)
2. L. Mihailov, R.Pavlov, Ch. Velchev, L. Pavlov, M. Dimitrova-Ivanovich, J. Maruani. Non-Conventional Optimization Procedure for Mass Effects Investigation in the Ground State Energies of 1s Core-Ionized Helium-Like Atoms from Helium to Xenon, *JOAM* **9**, 390-393 (2007)
3. O. Ivanov, Investigating solids, liquids and gases by Surface photo-charge effect (SPCE), *Sensors & Transducers Journal* **76**, 1018 (2007)
4. O. Ivanov, Technologies with possible application in the field of mechanical engineering based on Surface photo charge effect, *Machines, Technologies, Materials* **3**, 162-164 (2007)
5. O. Ivanov, E. Leyarovski, V. Lovchinov, C. Popov, M. Kamenova and M. Georgiev, Photo-induced electrification of solids. III. Temperature dependences, xxx.lanl.gov, Paper ID: cond-mat/ 0706.3877 (2007)
6. O. Ivanov, Investigating solids, liquids and gases by Surface photo-charge effect (SPCE), *Новости* **44**, 2 (2007)
7. Z. I. Dimitrova, Fluctuations and dynamics of the chaotic attractor connected to an instability in a heated from below rotating fluid layer, *Proceedings of the Bulg.Acad.of Sciences* **60** 1065 (2007)
8. G. Kamisheva, Bulgarian physical and mathematical culture in 19 century, AIP, Proc. VI Intern. Conf. of the Balkan Physical Union, ISBN 978-0-7354-0404-5, Aug 2006, Istanbul, Turkey, p. 521, 2007

9. Г. Камишева, Теоретични изследвания в областта на физическите науки в България през първата половина на XX век, Разпространение и развитие на физико-математическите знания в България, Колпринт, Пловдив, 2007, стр. 101-110
10. Г. Камишева, Наукометрични данни за научно-изследователската дейност на акад. М. Борисов (1921-1998), Разпространение и развитие на физико-математическите знания в България, Колпринт, Пловдив, 2007, стр. 41-47
11. Г. Камишева, Извори за акад. Георги Наджаков в Музея по история на физическите науки в България, Разпространение и развитие на физико-математическите знания в България, Колпринт, Пловдив, 2007, стр. 139-143
12. Н. К. Витанов, З. И. Димитрова, С. Панчев, глава от книга: „Приложение на социодинамиката за оценка на средата за сигурност, рисковете и заплахите за бъдещото развитие на България”, изд. “Марин Дринов” на БАН (“Научна поддръжка на трансформацията на сектора за сигурност“), стр.18-32, 2006
13. А. Г. Петров, Г. Камишева, Разпространение и развитие на физико-математическите знания в България, Колпринт, Пловдив, 2007
14. З. Димитрова, Размисли върху лошото финансово състояние на един български учен, Списание на БАН, кн. 3, 83-86 (2007)
15. Г. Камишева, А. Г. Петров, Въведение, Разпространение и развитие на физико-математическите знания в България, Колпринт, Пловдив, 2007
16. К. Коленцов, Г. Камишева, Успешен бизнес в областта на съвременната приложна физика в България, Разпространение и развитие на физико-математическите знания в България, Колпринт, Пловдив, 2007, стр. 168-170
17. Г. Камишева, Изложба за акад. Г. Наджаков; Някои съвременни направления в развитието на физиката (ученическа научна сесия), София, 2007, стр. 9-11.

ONGOING RESEARCH PROJECTS:

1. Experimental and theoretical study of many-electron and multicomponent systems (BAS)
2. Contemporary problems of the nuclei theory and other many-electron systems. (NSF)
3. Optimal distribution of traction force in rolling composition. (Bulg. Govern. Railway)
4. Many-electron systems and their behaviour in electromagnetic field. (Equivalent, Belgium)
5. 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)
6. Dynamic optogalvanic signals in a hollow cathode discharge as a plasma diagnostics technique. (Inst. of Phys., Academy of Sci. of Serbia)
7. Studying of the possibilities for carbon quantity control at brick manufacturing (Prolife technology firm}
8. Studying of the possibilities for scanning of metal surfaces as to develop hidden codes (“КЕИТ” ОД)

DIVISION MATERIAL PHYSICS

LABORATORY

ELECTRON MICROSCOPY AND ELECTRON DIFFRACTION

HEAD: Assoc.Prof. Maria Kalitzova, Ph.D.

tel: 979 5765, 979 5781; 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:

The research work in the Laboratory of Elektron Microscopy and Electron Diffraction was focussed on the investigation of:

- Defect structure in SiGe implanted with high energy ions;
- Nanoclusters formation in high – k dielectric layers;
- Structure of rare –earth implanted Y₂O₃ thin films;
- Structure morphology of Mo/W oxides.

Excess vacancies generated by high energy implantation with 1.2 MeV Si⁺ and 2 MeV Ge⁺ ions in SiGe were investigated after rapid thermal annealing at 900⁰C. Excess vacancies were probed by decoration with Cu and measuring the Cu profile by secondary ion mass spectrometry. Cross section transmission electron microscopy of cleaved specimen enabled to visualize nanocavities resulting from agglomeration of excess vacancies. The ion- induced damage in SiGe increases with increasing Ge fraction of the alloy [1].

Ion implantation induced nanoclusters were synthesised in reactive sputtered Ta₂O₅ films by Ge⁺ implantation and subsequent Rapid Thermal Annealing (RTA). 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 Ta₂O₅ matrix changes from amorphous to orthorhombic when the annealing was performed at 1000⁰C. Although the Ta₂O₅ matrix crystallizes, no evidence is obtained for crystallization of the embedded nanoclusters even after annealing at 1000⁰C [2].

Thin Er, Yb co-doped Y₂O₃ films were grown by pulsed laser deposition from ceramic target. Subsequent ion implantation with 1.1 MeV Er⁺ ions to a fluence of 6 x 10¹⁴ at/cm² at room temperature was performed in order to modify the structure of the as-deposited films. The as- deposited films have a polycrystalline column-like structure. Ion implantation induced defects into the as-deposited films. After annealing at 900⁰C for 1 h in oxygen atmosphere, the films recrystallize in roundly shaped grain-like structure with grain size of about 100 nm. The Er³⁺ photoluminescence response was obtained for all the films by excitation through cross-relaxation of Yb³⁺ ions [3].

The investigation is related to the electrochromic (EC) behavior of sputtered and CVD deposited films of WO₃ and W/Mo based mixed oxide films. The study is supported by results from the films structure in its dependence on deposition process parameters. The change in films microstructure and morphology, as well as bonds and their configuration is investigated by Raman and Fourier transform infrared (FTIR) spectroscopy, respectively, and by scanning electron microscopy (SEM). The electrochromic properties, as presented by

color efficiency (CE) and optical modulation (ΔT) of optimized CVD films are compared with the ones of sputtered WO_3 films [4].

A strong dependence of electrical resistance of Te^+ implanted (100) silicon was established after annealing with High Frequency (0.45 MHz) Electromagnetic Field for 30 and 60 minutes. The implantation was performed at 50 keV and fluence of $1 \times 10^{17} \text{ cm}^{-2}$. After 30 minutes treatment the sample electrical resistance dropped with about four orders of magnitude as compared to the one for as-implanted sample. Totally different is the situation after 60 minutes treatment, the sample resistance increased about seven orders of magnitude in the range of low frequencies as compared to the value for the as-implanted sample. In the high frequencies range the increase is about 3 orders of magnitude [5].

PUBLICATIONS:

1. R.Kogler, A.Mucklich W.Skorupa, A.Peeva, A.Yu.Kuznetsov, J.S.Christensen, B.G.Svensson, Excess vakansies in high energy ion implanted SiGe, Journal of Applied Physics 101, 033508 (2007)
2. A.Peeva, M.Kalitzova, G.Beshkov, G.Zollo, G.Vitali, W.Skorupa, Nanocluster Evolution in Ge^+ Ion Implanted Ta_2O_5 Layers, Materials Letters 61 (2007) 3620 – 3623.
3. A.Peeva, A.Og.Dikovska, P.A.Atanasov, M.Jiménez de Castro, W.Skorupa, Rare-earth implanted Y_2O_3 thin films, Applied Surface Science 253 (2007) 8165-8168
4. T.Ivanova, K.A.Gesheva, M.Kalitzova, B.Marsen, B.Cole, E.L.Miller, Electrochromic behavior of Mo/W oxides related to their surface morphology and intercalation process parameters, Materials Science and Engineering B 142 (2007) 126 – 134.
5. M.Kalitzova, K.A.Gesheva, E.Vlakhov, Y.Georgiev, T.Ivanov, O.Lebedev, Strukture and elektrikal resistance dependence on high frequency electromagnetic field annealing of Te^+ implanted silicon, presented at 15 International Summer School Vacuum, Electron and Ion Technologies, 17-21 sept.2007, Sozopol, Bulgaria.

ONGOING RESEARCH PROJECTS:

1. 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”.
2. 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”.

COLLABORATION:

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.

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TOTAL STAFF: 3

RESEARCH SCIENTISTS: 2

Assist. Prof. A. Boianova; physicist P. Botev; physicist T. Malakova

RESEARCH ACTIVITIES:

X-RAY STRUCTURAL INVESTIGATIONS OF SINGLE CRYSTALS

1) X-ray topography of single crystals – the topograms of bismuth titanate and bismuth germanate single crystals are obtained.

2). By Laue method the orientation is fulfilled of the single crystal ingots, as follow: bismuth titanate doped by ruthenium, bismuth titanate doped by chrome, bismuth germanate doped by vanadium, bismuth germanate doped by cobalt and bismuth silicate doped by osmium.

X-RAY STRUCTURAL INVESTIGATIONS OF POLYCRYSTALS

1) The study of bioactive spherulite (Sph) structures was continued with the aim to clarify their polymorphous transitions at intoxication of organisms. At endogenic/exogenic factor changes a retardation of Sph polymorphism was established which produces a precondition for billiary concrements formation. The introduction of ascorbic acid leads to restoration of the normal Sph reproduction which reduces the risk of urate and cholesterol crystals formation.

2) Profile analysis, theory and application of the Rietveld procedure. The theoretical part of Rietveld profile analysis of data obtained by Bragg scattering of thermal neutrons is developed. The scheme of experiments corresponds to Time-of-Flight method. For visualization and analysis of neutron spectra a pack of software programs Fd.exe and Mria.exe are used. By both programs the modeling of Fourier picture of diffraction data of dissipated at Bragg angle neutron intensities is obtained. The corresponding time evolution of the neutron spectrum of the original material is calculated.

3) Expert analyses of cuprum conductors taken by real fires from electrical shortcuts are carried out. These analyses are made due to judicial inquiry from several towns in Bulgaria.

4) It is continued the activity of renal stones type identification of stone former patients. The crystallographic identification of four renal stones is made on the basis of the Patent No 99992/1995.

PUBLICATIONS

1. N. Izmirova, M. Baeva, A. Boyanova et al, Natural clinoptilolite – mineral ballast addition to the nutrition with a special predestination, Journal Pharmaceutical Monitor, volume VII, No **32** (2006) 15-17.
2. N. Izmirova, E.Djourova, B. Aleksiev, M.Baeva, P. Blagoeva, P. Uzunov, I. Tomova, A. Boyanova, Tz. Mircheva, Utilization of natural clinoptilolite for reducing the risk of gall stones renall calculus and tumor formation, 1-st Conference Nanostructured Multifunctional Materials, Oct. 18-20, 2007, Sinaia Romania, p. 93-94.
3. M. Baeva, A.I. Beskrovnyi, E.L. Jadrovski, Phase Composition of the Four-Component Nitrified Steels at Increasing Manganese Concentration, AIP Conference proceedings, Melville, New York, 2007, volume **899**, p. 583.
4. M. Baeva, A.I. Beskrovnyi, A. Boianova, I. Shelkova, Investigation of Renal Stones by X-ray and Neutron Diffraction, AIP Conference proceedings, Melville, New York, 2007, volume **899**, p. 807.
5. N. Izmirova, M. Baeva, A. Boyanova et al, Contrivance for decreasing the risk of neoplasm appearance, Patent № 65218E1 / 07.11.2007, published by Patent Government Office of Bulgaria.
6. N. Izmirova, E. Djourova, B. Aleksiev, M. Baeva, P. Blagoeva, P. Uzunov, I. Tomova, A. Boyanova, Tz. Mircheva, Utilization of natural clinoptilolite for reducing the risk of gall stones and renal calculus formation, Second Int. Symposium Advanced micro- and mesoporous materials, Sept. 6-9, 2007, Varna Bulgaria, p. 186.

ONGOING RESEARCH PROJECT

“Structural investigations of Fe-Co-O spinel oxides of the transitional metals” – Joint Institute of Nuclear Research – Dubna, Russia , Grant №25/2007 from Nuclear Regulatory Agency-Bulgaria.

INTERNATIONAL COLABORATION

„Georgi Nadjakov” ISSP-BAS and Frank Laboratory of Neutron Physics JINR, Russia

DIVISION MATERIAL PHYSICS

LABORATORY

CRYSTAL GROWTH

HEAD: **Prof. Marin Gospodinov, D.Sc.**
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TOTAL STAFF: **8**
RESEARSH 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 for Crystal Growth was focused on four main tasks:

- 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;
- investigation of carbon and inorganic nanostructures.

Single-crystal ingots of $\text{Bi}_{12}\text{SiO}_{20}$ (BSO), doped with Ru and Os (BSO:Ru and BSO:Os) with diameters of about 40 mm and length of about 80 - 100 mm were obtained by the Czochralski method and were investigated with polarized Raman spectroscopy and X-ray diffraction methods.

With optical absorption spectroscopy we studied the influence of doping BSO crystals with 4d- and 5d- elements with special emphasize on the photo-induced properties of the doped crystals. From the kinetic curves of the photocurrent the cross-section of photon capture at an impurity center was determined.

The magneto-optical effect and photochromism of $\text{Bi}_4\text{Ge}_3\text{O}_{12}$ crystals doped with $Al+Mn$ were investigated in a broad spectral interval. It was established that doping considerably shifts the photosensitivity of these crystals towards the visible region.

A CdTe crystal specimen, melt-grown by the Bridgeman method, was studied with transmission electron microscopy (TEM). Various dislocations, stacking faults, as well as first- and second-order twin boundaries were observed in the bright-field image of diffraction contrast.

A plate-shaped specimen of a single-crystal ingot of $\text{Bi}_4\text{Ge}_3\text{O}_{12}$, grown by the Czochralski method, was examined by several X-ray diffraction methods. It was found that the central region of the crystal was deformed and occupied by dislocations with various Burgers vectors and that almost the entire surface of the crystal (excluding the central region) is filled with two-dimensional defects, probably stacking faults.

The ferroelectric properties of multiferroic RMn_2O_5 (R=Tb,Dy,Ho) were investigated under high pressure to explore the influence of pressure on the magnetic commensurability and the ferroelectricity in multiferroic HoMn_2O_5 and to elaborate the phase diagrams of hexagonal ErMnO_3 , YbMnO_3 , TmMnO_3 and HoMnO_3 .

Raman spectroscopy was applied to study rare-earth manganites. Special attention was paid to the effects of substitution with oxygen isotopes and rare-earth elements and to the resonance Raman scattering from relaxor $\text{PbSc}_{0.5}\text{Ta}_{0.5}\text{O}_3$ and $\text{PbSc}_{0.5}\text{Nb}_{0.5}\text{O}_3$. The manifestation of ferroic nanoclusters in relaxors was investigated in several phenomena: the effect of oxygen vacancies, the formation of ferroic clusters and the observation of phonon anomalies in Pb-based relaxors of perovskite type, and the Ba-induced changes in the structure of $\text{PbSc}_{0.5}\text{Ta}_{0.5}\text{O}_3$.

In hexagonal crystals of YbMnO_3 the magnetic susceptibility was measured parallel to the *ab*- and *c*- planes (χ_{ab} and χ_c) at low AC and DC fields.

By means of Raman spectroscopy we followed the transition from electrostatically induced doping to conventional intercalative doping of mats consisting of ropes of carbon nanotubes in an aqueous KCl solution. From a comparative analysis of the Raman spectra it was concluded that at electrochemical potentials above 1 V a significant penetration of chlorine species into the interstitial channels of the nanotube ropes occurs and a chlorine functionalization on the nanotube walls is possible.

PUBLICATIONS:

1. C.R. dela Cruz, B. Lorenz, M.M. Gospodinov, C.W. Chu, *Restoration of ferroelectricity by pressure in multiferroic HoMn_2O_5* , Journal of Magnetism and Magnetic Materials **310** (2007) pp.1185-1186.
2. F. Yen, C. dela Cruz, B. Lorenz, E. Galstyan, Y. Y. Sun, M. Gospodinov, and C.W. Chu, *Magnetic Phase Diagrams of Hexagonal ErMnO_3 , YbMnO_3 , TmMnO_3 and HoMnO_3* , Journal of Materials Research vol. **22**, 8 (2007) pp.2163-2173.
3. Iliev M.N., Hadjiev V.G., Litvinchuk A.P., Yen F., Wang Y.-Q., Sun Y.Y., Jandl S., Laverdiere J., Popov V.N., Gospodinov M.M., *Multiple-order Raman scattering from rare-earth manganites: Oxygen isotope and rare-earth substitution effects*, Phys. Rev. B: Condens. Matter **75**(6) (2007) 064303/1-064303/5.
4. C. R. dela Cruz, B. Lorenz, Y.Y. Sun, Y. Wang, S.Park, S.-W. Cheong, M. M. Gospodinov, and C. W. Chu, *Pressure induced enhancement of ferroelectricity in multiferroic RMn_2O_5 ($R=\text{Tb}, \text{Dy}, \text{Ho}$)*, Physical Review B vol. **76** (2007) pp.174106/1-174106/7.
5. Mihailova B., Gospodinov M., Guettler B., Petrova D., Stosch R., Bismayer U., *Ferroic nanoclusters in relaxors: the effect of oxygen vacancies*, J. of Physics: Condes. Matter **19**(24) (2007) 275205/1-275205/10.
6. Mihailova B., Gospodinov M., Guettler B., Stosch R., Bismayer U., *Ferroic clustering and phonon anomalies in Pb-based perovskite-type relaxors*, J. of Physics: Condes. Matter **19**(27) (2007) 246220/1-246220/10.
7. Mihailova B., Bastjan M., Schuiz B., Rubhausen M., Gospodinov M., Stosch R., Guettler B., Malcherek T., Bismayer U., *Resonance Raman scattering of relaxors $\text{PbSc}_{0.5}\text{Ta}_{0.5}\text{O}_3$ and $\text{PbSc}_{0.5}\text{Nb}_{0.5}\text{O}_3$* , Appl. Phys. Lett. **90**(4) (2007) 042907/1-042907/3.
8. V.M. Skorikov, T.I. Milenov, AV. Egorysheva, P.M. Rafailov, T.D. Dudkina, M.N. Veleva, AY. Vasil, ev and M.M. Gospodinov, *An optical excitation study of Ru, Rh, Re and Os doped $\text{Bi}_{12}\text{SiO}_{20}$ crystals*, physica status solidi (b) Vol. **244**, Issue **9** (2007) pp. 3292-3296.
9. T.I. Milenov, 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 **138**(1) (2007) 35-40.
10. A. Amova-Kostova, M. Veleva, V. Marinova, *Growth of ferroelectric $\text{Pb}_2\text{ScTaO}_6$ single crystals in oxygen and hydrogen atmosphere and investigation of their dielectric*

- properties*, Journal of Optoelectronics and Advanced Materials Vol.9 ISS.2 (2007) (71) pp.268-270.
11. P. Petkova, V. Marinova, M. Veleva, T. Dimov, I. Iliev, *Optical and magneto-optical properties of Bi₄Ge₃O₁₂ doped with aluminium and manganese*, Journal of Optoelectronics and Advanced Materials Vol.9 ISS.2 (2007) (71) pp.278-281.
 12. D. Toncheva, *Growth and electrical properties of doped Bi₄Ge₃O₁₂ single crystals*, Journal of Optoelectronics and Advanced Materials, Vol.9 ISS.2 (2007) (71) pp. 286-288.
 13. T. I. Milenov, V.I. Dimov, and M. M. Gospodinov, *TEM observation of two- dimensional defects in CdTe crystals*, Journal of Optoelectronics and Advanced Materials Vol.9 ISS.2 - 2007 (71) pp. 289-292.
 14. 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 Bi₁₂SiO₂₀ crystals*, Journal of Optoelectronics and Advanced Materials Vol.9 ISS.2 - 2007 (71) pp. 293-295.
 15. P. M. Rafailov, C. Thomsen, U. Dettlaff-Weglikowska, B. Hornbostel and S. Roth, *Raman spectroelectrochemistry on SWNTs at higher doping levels: evidence for a transition to intercalative doping*, physica status solidi (b) Vol. 244, Issue 11 (2007) (pp. 4060-4063).

ONGOING RESEARCH PROJECTS:

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

* F 1712: Growth, Characterization and Investigation of the Physical Properties of Novel Crystals in the Systems Bi-Co(Ni)- Mn(Ru)-O and La-Co(Ni)-Mn(Ru)-O with magnetoelectric and multiferroic behavior.

Financed by the NATO Science for Peace and Security Programmes:

* **CBP.EAP.RIG.982322:** Monitoring Higher Levels of Electrochemical Doping of Carbon Nanostructures

COLLABORATION:

1. Growth and investigation of photorefractive oxide crystals as well as wide band gap semiconductor crystals and layers of the SiN and GaN type – Institute of Common and Inorganic Chemistry, Russian Academy of Sciences, Moscow, Russia.
2. Growth and characterization of oxide crystals for optical application – Research Institute of Solid State Physics and Optics, Budapest, Hungary.
3. Synthesis of multiferroic materials – Insitutute of Material Science – Barcelona, Spain.

DIVISION MATERIAL PHYSICS

LABORATORY

MOLECULAR BEAM EPITAXY and SURFACE ANALYSIS

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

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TOTAL STAFF: 4

RESEARCH SCIENTISTS: 2

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

RESEARCH ACTIVITIES:

1. Creating novel BIOSENSOR SYSTEMS

The most natural and universal approach for identification of nano-sized biological objects (bacterial spores, viruses, macromolecules, molecular complexes etc.) is to immobilize them with respective antibodies on cantilever surface, followed by measuring of the cantilever mass change. Microcantilevers are among the most sensitive sensors for registration of mass changes. An added to the cantilever mass will be registered as a change in deflection, or a shift in its resonance frequency. Thus, the microcantilevers can work as ultrasensitive balances, providing femtogram (10^{-15} g) sensitivity. For the micro cantilever arrays with piezoresistive sensors, (manufactured by Nano Toolshop Ltd, Botevgrad) we developed a strategy for their introducing into production together with three prototype systems.

Real world tasks of security, ecology, food-processing industry etc. require biosensor multi-channel measuring systems. During first phase suitable for the purpose biosensor systems were developed in the Laboratory. These are “Stand – alone intelligent sensor SS-12”, “Multi - channel “spectroscopic type” system SB-11”, and “Development system for cantilever functionalizing DS-32”.

The successful first phase provide the next two phases with sensors and instrumentation sensitive to nano-sized bio-objects, that utilize conformal antigen–antibody reactions.

2. Presenting BIOSENSOR SYSTEMS at International Fair Plovdiv, 2007

“Stand – alone intelligent sensor SS-12“, Multi - channel “spectroscopic type” system SB-11, and “Development system for cantilever functionalizing DS-32” were exhibited at the International Fair Plovdiv, 2007.

Stand – alone intelligent sensor SS-12 (1 to 16 channels) has 4 to 16 cantilevers (in 4 cantilever groups), and provide 0.1 picogram (10^{-13} g) differential sensitivity (between the channels), and 10 picogram (10^{-11} g) absolute sensitivity.

Multi - channel “spectroscopic type” system SB-11 realizes < 1 ppm measuring accuracy and is connected to processing computer trough USB 2.0. SB-11 has a unique sensitivity – 10 femtograms (10^{-14} g) differential sensitivity (between the channels) and 0.25 picograms (2.5×10^{-13} g) absolute sensitivity of mass changes.

Development system for cantilever functionalizing DS-32 is a compact, and inexpensive “virtual” instrument for conducting the whole range of calibration experiments necessary in/for making cantilever sensors selectively responding to a given stimulus (i.e. their functionalization). It excites the cantilevers with 5 ppb precision and measures their responses within 105 dB dynamic range to their thermal noise limits with 0.06 dB resolution.

3. Up to date literature study on InN AND GROUP III NITRIDES FOR SOLAR CELLS

InN and group III nitrides are very promising materials for development of high efficiency photovoltaic solar cells for open space application, due to their superior radiation resistance. In connection with a future technological project, in collaboration with Department of Electrical Engineering, Lakehead University, Canada for development of “Technology for based on InN high efficiency photovoltaic solar cell, designed for open space application” we have studied the recent years publications on “InN and group III nitrides for solar cells”. The selected publications are referred to: a) InN & InGaN, InAlN optical, electrical, and structural properties; b) InN & InGaN, InAlN, and III-V-N alloys growth & characterization; c) GaN, AlN, BN, ScN – properties, growth, characterization; d) Conversion efficiency increasing approaches; e) Photovoltaics.

The study provided the knowledge base for formulation of a novel goal for the mentioned cooperative technological project with Lakehead University and for preparing the project working plan for the technological studies related to the epitaxial growth of InN and group III nitride heterostructures, as well as for the characterization of grown structures and materials.

ONGOING RESEARCH PROJECTS:

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

DIVISION MATERIAL PHYSICS

LABORATORY

BIOCOMPATIBLE MATERIALS

HEAD: Assoc.Prof. Liliana Pramatarova, Ph.D.

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TOTAL STAFF: 3

RESEARCH SCIENTISTS: 2

Assist.Prof. E. Pecheva, Ph.D.

RESEARCH ACTIVITIES:

It is developed universal in vitro system for growth of the layers from functional solutions, imitating blood plasma (SBF, simulated body fluid) on the modified surfaces of the solid substrate with a purpose of obtaining of bone implant coatings.

It is achieved controllable modification of titanium and titanium alloys, stainless steel, silicon, silica glass, polymers, composite layers of hydroxyapatite/detonational nanodiamond (HA/DND) as well as laser treatment. It is established that the modified surfaces induced the growth of bio-like HA.

For the first time it is developed a method for controllable growth of composite layers of HA/DND from supersaturated solution (SBF) and suspension of DND on the various solid surfaces by applying of simultaneous interaction of laser irradiation and substrate immersed in the solution (LLSI, laser-liquid-solid interaction process).

For the first time it is developed the technology for creating of a structure in micro- and nanometer size, typical for nature by a method of LLSI. It is a method for controllable growth of composite layers of HA/DND from supersaturated solution (SBF) and suspension of DND on the various solid surfaces by applying of the simultaneous interaction of the laser irradiation and the substrate immersed in the solution (LLSI, laser-liquid-solid interaction process) as by laser treatment, the micrometer size design is achieved on the substrate surface, immersed in the SBF and in this way nuclear and subsequent growth of nanostructured HA and composite layers Ha/DND is achieved.

For the first time it is investigated the influence of the laser irradiation on the process of HA/DND growth and it is find that the laser enhanced creating of CaP nuclear and subsequent crystal growth of HA/DND layer.

PUBLICATIONS:

1. E. Pecheva, C. Laungu, T. Petrov, L. Pramatarova, Stimulated in vitro bone-like apatite formation by a novel laser processing technique, invited article for Special issue of Chemical Engineering Journal (Materials Synthesis and Processing section): Porous Inorganic Materials for Biomedical Applications, (2007), doi: 10.1016/j.cej.2007.07.096
2. A. Kondyurin, E. Pecheva, L. Pramatarova, Calcium phosphate formation on plasma immersion ion implanted low density polyethylene and polytetrafluorethylene surfaces, Journal of Materials Science: Materials in Medicine, (2007), doi 10.1007/s10856-007-3231-2
3. L. Pramatarova, E. Pecheva, P. Montgomery, D. Dimova-Malinovska, T. Petrov, A. L. Toth, M. Dimitrova, Bioactivity of polycrystalline silicon layers, Journal of Nanoscience and Nanotechnology, 2007, doi: 10.1166/jnn.2007.D163

4. E. Pecheva, L. Pramatarova, G. Altankov, Hydroxyapatite grown on a native extracellular matrix: initial interactions with human fibroblasts, *Langmuir* 23 (18) (2007) pp. 9386-9392
5. E. Pecheva, P. Montgomery, D. Montaner, L. Pramatarova, White light scanning interferometry adapted for large area optical analysis of thick and rough hydroxyapatite layers, *Langmuir* 23 (7) (2007) 3912-3918
6. L. Pramatarova, E. Pecheva, V. Krastev, F. Riesz, Ion implantation modified stainless steel as a substrate for hydroxyapatite deposition. Part I. Surface modification and characterization, *Journal of Materials Science: Materials in Medicine* 18(3) (2007) 435-440
7. L. Pramatarova, E. Pecheva, V. Krastev, Ion implantation modified stainless steel as a substrate for hydroxyapatite deposition. Part II. Biomimetic layer growth and characterization, *Journal of Materials Science: Materials in Medicine* 18(3) (2007) 441-447
8. M. Dimitrova, L. Pramatarova, E. Pecheva, P. Laquerriere, P. Montgomery, A. Petrova, G. Altankov, Osteoblast cells activity on calcium phosphate layers grown on glass by a laser-liquid-solid interaction, *J. of Optoelectronics and Advanced Materials* 9(1) (2007) 240-243
9. F. Riesz, L.D. Pramatarova, E.V. Pecheva, M. Dimitrova, Application of Makyoh (magic-mirror) topography in the research of artificial biomineralization, *Journal of Optoelectronics and Advanced Materials* 9(1) (2007) 201-204
10. 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* 9(1) (2007) 229-232
11. L. Pramatarova, E. Pecheva, S. Stavrev, T. Spasov, P. Montgomery, A. Toth, M. Dimitrova, M. Apostolova, Artificial bones through nanodiamonds, *Journal of Optoelectronics and Advanced Materials* 9(1) (2007) 236-239
12. E. Pecheva, L. Pramatarova, A. Szekeres, T. Nikolova, P. Montgomery, Application of porous SiO_x layer as a template for calcium phosphate growth, *Journal of Optoelectronics and Advanced Materials* 9(1) (2007) 233-235
13. L. Pramatarova, M. Dimitrova, R. Dimitrova, E. Pecheva, T. Spasov, Hydroxyapatite/detonation nanodiamond composites: A novel surface modification to extend implants lifetime, *Functional Materials and Nanotechnologies (FM&NT 2007) IOP Publishing Journal of Physics: Conference Series* 93 (2007) 012049 doi:10.1088/1742-6596/93/1/012049
14. L. Pramatarova, M. Dimitrova, P.C. Montgomery, E. Pecheva, S. Stavrev, M. Apostolova, N. Milinovic, A. Toth, T. Petrov, A. Petrova, Detonation generated nanodiamond reinforced calcium phosphate composites grown through laser-liquid-solid-interaction process, *Proc. ILLA/LTL*, 4-7 October, Smolyan, 2006 Bulgaria, pp. 245-253 (2007)

ONGOING RESEARCH PROJECTS:

1. It is developed the method for solid surface modification as a model for growth of hydroxyapatite, biocompatible material for medical application. The investigation is carried out on the base of NATO project, bilateral projects with Hungarian Academy of Sciences, Latvian Academy of Sciences, Romanian Academy of Sciences, CNRS – France as well as a SME Lightsystem Ltd, Sofia. (Team leader Assoc. Prof. Dr. L. Pramatarova)
2. On the base of bilateral project with InESS, CNRS, France it is developed a method for investigation of the hydroxyapatite layers by adapted interference technique (coherent microscopy, CPM). The developed system is a precised method for measuring the topography, surface topography, optical parameters and roughness of thin and as well as thick layers of bio-like hydroxyapatite material (Team leader Assoc. Prof. Dr. L. Pramatarova)

DIVISION NANOPHYSICS

LABORATORY

PHOTOELECTRICAL AND OPTICAL PHENOMENA IN WIDE BAND GAP SEMICONDUCTORS

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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. Tschauschew, physicist.

RESEARCH ACTIVITIES:

1. DISORDERED MATERIALS - CHALCOGENIDE GLASSES AND THIN FILMS

Optical absorption and photoluminescence (PL) at 1540 nm of Er-doped $(\text{GeS}_2)_{80}(\text{Ga}_2\text{S}_3)_{20}$ glasses have been studied. The emission band is considerably more pronounced at the direct excitation of Er^{3+} ions than via the matrix. A narrowing PL effect on decreasing temperature from 77 to 4.2 K has been observed accompanied by appearance of additional bands at ~ 980 and 820 nm. It has been shown that these glasses are promising materials for telecommunications purposes because of the relatively high lifetime values when compared with other chalcogenides. New $(\text{GeS}_2)_{75}(\text{Ga}_2\text{S}_3)_{25}$ glasses with a larger Ga content have been prepared in order to enhance the photoluminescence efficiency (PLE). Basic thermal parameters have been determined, which are important from a practical point of view. A broadening of the PL band has been observed with increasing Er content. New Er-doped GeSGa-CsBr glasses have also been investigated and the role of CsBr for the improvement of the radiative properties by formation of $[\text{GaS}_{3/2}\text{Br}]^{-1}$ structural units has been specified. The studies are performed in collaboration with colleagues from Czech Republic, Canada, India and South Korea.

Investigation of the dependence of the photostructural changes on the film thicknesses and illumination conditions has been carried out in two compositions from the $\text{Ge}_2\text{S}_3\text{-AsS}_3$ line which have been chosen because they show the highest photoinduced effect. The irreversible photo- and thermoinduced changes in the optical band gap and the volume have been studied films having thickness below 1 μm . Giant irreversible photobleaching (PB) has been obtained in the thinnest (90-100 nm) films and the magnitude of the PB depends weakly on the thickness. New interesting results concerning reversible photodarkening (PD) have also been obtained. The magnitude of the PD depends on the film thickness and the annealing temperature as follows: (1) PD decreases with decreasing thickness. In films with a thickness of ~ 100 nm, the PD converts to the reversible PB effect; (2) PD decreases with decreasing annealing temperature. At low annealing temperatures (called critical temperatures), a conversion of the PD effect to PB has been observed. The critical temperatures also depend on the film thickness. The irreversible photoinduced effect in thin Ge-As-S films has been applied for recording of holographic gratings.

Bulk multicomponent glasses from the Ge-Sb-(S,Te) system were prepared using the conventional melt-quenching method from 5N purity elements. Neutron diffraction (ND) investigations have shown that the specimens grown are fully amorphous. From the ND intensity data the total structure factor $S(Q)$ was calculated after correction and normalization procedures. The total atomic pair correlation function, $g(r)$ was calculated by applying the MCGR simulation method. The optical constants and optical band gap energy of thin films, prepared by thermal vacuum evaporation of the powdered parent glassy material, were evaluated from the spectral ellipsometric data analysis. A compositional dependence of the optical constants has been obtained.

2. NANOSTRUCTURED THIN FILMS

A method for improving the discrimination ability of semiconductor thin-film gas sensors has been proposed in collaboration with scientists from UK. It is based on detection of the amplitude and phase of the film photocurrent response to a modulated light source. The changes in photoconductivity of microcrystalline silicon after exposure to iodine solution vapour have been studied using this method and a reversible change of the density of defect states has been observed. In cadmium selenide films some deviations from the theoretically described behaviour have been observed.

The density of defect states in the upper part of the forbidden gap of thin nanocrystalline CdSe films has been investigated by combined measurements of steady-state photoconductivity and thermally stimulated currents. The electron mobility-lifetime product been determined, as well as the energy position of two kinds of defect states, one of which has been related to interface defects and the second one to defects in the nanocrystal volume. Memory effect has been observed in Al/Si-SiO_x/SiO₂/Al structures annealed at 700 °C or 1000° C, related to charging and discharging of nanoparticles upon applying voltages with different polarity. The studies of MIS structures annealed for 30 and 60 min. at 1000°C (containing silicon nanocrystals) have revealed a change of the flat-band voltage by 7 and 5.5 V respectively at charging with voltages in the range ± 12 V. It has been concluded that although the samples annealed for 60 min have a smaller hysteresis, they are more interesting for practical applications because of both the lower defect density at the interface between the Si wafer and the Si-SiO_x film and the smaller value of the fixed oxide charge.

3. AC ELECTROLUMINESCENCE, ELECTROLUMINESCENT STRUCTURES AND DISPLAYS

Layers from Si-containing polymer having thickness of 0.35 и 0.57 μm were produced and implanted with carbon ions of various doses (1, 2 и 4×10^{17} cm^{-2}). Dose dependences of the film transmission and photoluminescence have been measured. A thickness independent minimum has been observed at a dose of 2×10^{17} cm^{-2} . In connection with a project financed by the Bulgarian Ministry of Education and Science (under the National scientific programme “Innovation enhancement in small and medium enterprises”), photomasks were designed and constructed which are necessary for deposition of the different layers of a seven-segment numerical Electroluminescent (EL) display. EL structures with a ZnO protecting layers were produced showing blue emission. Photoluminescence spectra of the ZnO layer and EL characteristics of the structures have been explored. In connection with a joint project of ISSP and MIIT, Moscow, EL structures showing red emission and containing C₆₀/C₇₀ fullerenes have also been prepared and will be subject of further investigations in both Labs.

Spectral and dose dependences of the diffuse reflection have been obtained for several different polymers (PE, PP, PMMA, PTFE /Teflon/) implanted with Si⁺ or C⁺ ions at doses varying between 1×10^{-13} cm^{-2} and 2×10^{-17} cm^{-2} . It is shown that the characterization

method applied allows determining the concentration of the implanted Si or C atoms that are necessary for the formation of clusters and coagulates. Electrophysical measurements of dielectric losses and electrical conductivity have also been carried out at frequencies 10 - 100 kHz. Optimization of the fullerene concentration in EL structures has been made that ensures a maximum EL brightness.

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2. M. J. Šćepanović, M. Grujić-Brojčin, I. Bineva, D. Nesheva, Z. Aneva, Z. Levi, Z. V. Popović, "Raman study of ZnSe/SiO_x multilayers", *J. Optoelectron. Adv. Mater.* **9**, 178-81 (2007).
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8. I. Bineva, D. Nesheva, Z. Aneva, Z. Levi, "Room temperature photoluminescence from amorphous silicon nanoparticles in SiO_x thin films", *J. Luminescence* **126**, 497-502 (2007).
9. D. Nesheva, N. Nedev, E. Manolov and I. Bineva, "Memory effect in MIS structures with amorphous silicon nanoparticles embedded in ultra thin SiO_x matrix", *J. Phys. Chem. Sol.* **68**, 725-8 (2007).
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12. Z.G. Ivanova, Z. Aneva, R. Ganesan, D. Tonchev, E.S.R. Gopal, K.S.R.K. Rao, T.W. Allen, R.G. DeCorby, S.O. Kasap, "Low-temperature Er³⁺ emission in Ge-S-Ga glasses excited by host absorption", *J. Non-Cryst. Solids* **353**, 1418-21 (2007).
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14. Z.G. Ivanova, E. Cernoskova, Z. Cernosek, "Er-doped Ge-S-Ga glasses: photoluminescence and thermal properties", *J. Phys. Chem. Solids* **68**, 1260-2 (2007).

15. D. Tonchev, K. Koughia, Z.G. Ivanova, S.O. Kasap, "Thermal and optical properties of erbium doped $(\text{GeS}_2)_{75}(\text{Ga}_2\text{S}_3)_{25}$ glasses", J. Optoelectron. Adv. Mater., Vol. **9**, 337-40 (2007).
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20. D. Arsova, K. Beeva, E. Vateva, V. Pamukchieva, K. Beev, S. Sainov, "Giant photoinduced effects in films from the $\text{Ge}_2\text{S}_3\text{-AsS}_3$ system", J. Optoelectron. Adv. Mater. **9**, 3115-8 (2007).
21. E. Vateva, "Giant photo- and thermoinduced effects in chalcogenides" (review paper), J. Optoelectron. Adv. Mater. **9**, 3108-14 (2007).
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28. T. Tsvetkova, S. Balabanov, E. Borisova, L. Avramov, J. Zuk and L. Bischoff, "Optical Properties of Si and C Implanted Polymers", IX International Conference: "Laser and laser – information technologies, Proc. Inter. Conf., October 4-7, 2006, Bulgaria (2007) pp. 201-6.

ONGOING RESEARCH PROJECTS:

Financed by the Bulgarian Academy of Sciences:

1. Physics of semiconductor glasses and thin films: nanostructuring photoinduced phenomena, luminescence.

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

1. Defect states in photoconductors of various dimensionality (F 1306).
2. Photoinduced structural changes in Ge-As(Sb)-S glasses and films (F 1309).
3. Multilayer structures and nanocomposite materials for applications in electronics NSP-4-1. Modul 1: Multilayer structures containing silicon nanoparticles, suitable for fabrication of electronic memories and single electron devices.
4. Construction, development and preparation of digital electroluminescent displays, Д01–202, SME –204/06.

COLLABORATION:

1. Electrical and optical properties of multilayer structures with silicon nanoparticles for electronic applications (jointly financed by DAAD and the Bulgarian Ministry of Education and Science), Carl von Ossietzky University, Oldenburg, Germany.
2. Thermodynamical and optical investigations on chalcogenide glasses, Joint Laboratory of Solid State Chemistry, Pardubice, Czech Republic.
3. Nanostructured semiconductor thin films suitable for application as gas sensors, Institute of Physics, Belgrade, Serbia.
4. Structural and optical properties of multicomponent chalcogenide glasses, Institute of Solid State Physics & Optics, Hungary.
5. Investigation of properties and characteristics of ZnS electroluminophores and making of set-ups of their base“, MIIT (Moscow State University of Railway Engineering), Russia.

DIVISION NANOPHYSICS

LABORATORY

SEMICONDUCTOR HETEROSTRUCTURES

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TOTAL STAFF: 9

RESEARSH SCIENTISTS: 7

Prof. S. Kaschieva, D.Sc.; Assoc.Prof. S. Alexandrova, Ph.D.; Assoc.Prof. P. Danesh, Ph.D.; Assoc.Prof. A. Szekeres, Ph.D.; Assoc.Prof. N. Peev, Ph.D.; E. Kafedjiiska, Research Scientist; T. Nikolova, Ph.D. student; S. Bakalova Ph.D. student

RESEARCH ACTIVITIES:

1. SiO₂ STRUCTURES WITH EMBEDDED Si NANO-CLUSTERS

The structure and surface morphology of porous SiO_x films with embedded Si nano-clusters are investigated. The SiO_x films, deposited on Si substrates under an angle of 75° between the vapour stream direction and the substrate normal were annealed at 950 and 1100°C in argon ambient. This oblique vacuum evaporation aimed to increase the concentration of the luminescence centers in the films. For characterization of these SiO_x films, X-ray diffractometry, XRD, atomic force microscopy, AFM, and infrared, IR, spectroscopy have been applied. The number of silicon nano-clusters, created in SiO_x films is still insufficient for the appearance of additional peaks in the XRD spectra related to crystallised Si particles. The films possess porous and columnar structure visualized on the surface as high tilted pillars surrounded by empty space. From the IR data analysis the estimated film porosity is 50-60 %. In the as-deposited films the tilted under 51° columns are well-seen on the cross-sectional scanning-electron micrographs.

2. DEFECTS IN IRRADIATED Si/SiO₂ STRUCTURES

The mechanical stress produced by 23 MeV electron irradiation in both n- and p-type Si-SiO₂ structures is studied as a function of the dose. Low dose electron irradiation ($2,4 - 4,8 \times 10^{14} \text{ cm}^{-2}$) increases significantly the yield stress for n-type Si-SiO₂ samples, but to a much lesser extent for p-type ones. The nanohardness of irradiated structures is measured using the sclerometry method. Our results show that the nanohardness increases with the dose in the same manner for both studied groups. The values are very close, but for p-type samples are consistently higher. The variations of both the stress and nanohardness are remarkable at low doses. These mechanical properties of the irradiated samples are discussed on the basis of radiation induced defects.

3. CHARACTERIZATION OF PULSED - LASER - DEPOSITED AlN FILMS

Extended analysis of the admittance frequency dependence of MIS structures with pulsed laser deposited AlN films made in the range of 100 Hz - 10 MHz reveals low density of interface states at the AlN/Si interface and deep levels near to this interface with an energy density of order of $10^{12} \text{ cm}^{-2} \text{ eV}^{-1}$. These levels are responsible for the observed frequency dispersion of AC conductance across the Al/AlN/Si structures. The frequency dependence is an indication for hopping mechanism of charge carrier transport. These polycrystalline AlN

films have been characterized also by spectral ellipsometry and photoluminescence spectroscopy. The data analysis is in progress.

4. HYDROGENATED AMORPHOUS SILICON, CHALCOGENIDE AND METAL OXIDE FILMS

Hydrogenated amorphous silicon with high compressive stress and hydrogen concentration as high as the hydrogen solubility limit has been studied. Silicon ion implantation has been used to transform the hydrogen molecules into silicon-bonded hydrogen. It has been concluded that in spite of high hydrogen content in the material the concentration of molecular hydrogen in the studied films is below 1 at. % and it is not the reason for the high internal stress.

The analysis of the spectroscopic ellipsometry data of thermally evaporated $\text{Ge}_x\text{Sb}_{40-x}\text{S}_{50}\text{Te}_{10}$ ($x=10, 20, 27$), and $\text{Ge}_{27}\text{Sb}_{13}\text{S}_{55}\text{Te}_5$ films has shown that the optical energy gap of these films increases from 1.04 to 1.33 eV with the increase of Ge content from 10 to 27 atomic percent. Comprehensive investigations of transmission spectra and AFM data of $\text{Ge}_x\text{Sb}_{40-x}\text{S}_{60}$ thin films have been carried out. It has been established that films are homogeneous at nano- scale. These results have been confirmed by scanning investigation of second harmonic generation over the film surface.

The XRD spectra analysis has shown that during chemical vapour deposition of chromium oxide films some crystallites are already developed in the amorphous oxide matrix. Annealing at 500°C yields a fully crystallized and stoichiometric Cr_2O_3 films. The amorphous substoichiometric oxide films possess smaller optical energy gap, E_{og} , than crystalline stoichiometric Cr_2O_3 films, the E_{og} value of which is 3.32 - 3.38 eV.

PUBLICATIONS:

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2. S.Kaschieva, K.Christova, I.Boradjiev, A.Petrova, J.Koprinarova and S.N.Dmitriev, The role of high-energy electron irradiation induced defects in some mechanical properties of Si- SiO_2 structures, *J. Optoelectronics & Advanced Materials*, **9**, N2, 394-397(2007).
3. P. Danesh, Bl. Pantchev, B. Schmidt¹, and D. Grambole, "Molecular Hydrogen in Amorphous Silicon with High Internal Stress", *Jpn. J. Appl. Phys. vol.46, No 8A, p. 5050- 5052 (2007)*.
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7. E. Valcheva, D. Manova, S. Mändl, S. Alexandrova, J. Lutz, S. Dimitrov, Ion beam synthesis of AlN nanostructured thin films, *J. Optoelectronics & Advanced Materials*, **1**, 166-169 (2007).

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10. K. Gesheva, A. Cziraki, T. Ivanova, A. Szekeres, "Crystallization of APCVD-Grown Molybdenum and Mixed Tungsten/Molybdenum Oxide Films for Electrochromic Application", *Thin Solid Films* **515**, 4609-4613 (2007).
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12. E. Pecheva, L. Pramatarova, A. Szekeres, T. Nikolova, P. Montgomery, "Application of porous SiO_x layer as a template for calcium phosphate growth", *J. Optoelectronics & Advanced Materials*, **9**, 379-381 (2007).
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14. G. Socol, E. Axente, C. Ristoscu, F. Sima, A. Popescu, N. Stefan, I. N. Mihailescu, L. Escoubas, J. Ferreira, S. Bakalova, A. Szekeres, "Enhanced gas sensing of Au nanocluster doped or coated zinc oxide thin films" *J. Appl. Phys.* **102**, 083103, 6 p. (2007).
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16. N. Peev, "Particle collision frequency in the nanoparticles nucleation process. Three dimensional nanoparticles", *Compt. Rend. Acad. Sci. Bulg.* **60(2)**, 121 – 126 (2007).
17. S. Bakalova, A. Szekeres, A. Cziraki, S. Grigorescu, G. Socol, E. Axente, I. N. Mihailescu, "Structure and optical properties of pulsed-laser-deposited AlN thin films for optoelectronic applications", *Proceedings of SPIE -- ROMOPTO 2006: Eighth Conference on Optics, Vol. 6785, ed. V. I. Vlad, 67850H (Aug. 1, 2007)*.
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19. Szekeres, T. Nikolova, I. Lisovskyy, P. Shepeliavyi, G. Yu. Rudko, A. Cziraki, "Study Of SiO_x Films With Embedded Si Nanoparticles By Spectroscopic Ellipsometry And Photoluminescence Spectroscopy", *Nanoscience & Nanotechnology, Vol. 7, eds. E. Balabanova, I. Dragieva, Heron Press, Sofia, pp.123-126 (2007)*.
20. P. Danesh, B. Pantchev, B. Schmidt, Infrared Absorption Strengths of Ion Implanted Hydrogenated Amorphous Silicon, *Thin Solid Films*
21. V. Pamukchieva and A. Szekeres, "Optical properties of $\text{Ge}_x\text{Sb}_{20-x}\text{Te}_{80}$ thin films and their changes by light illumination", *Optical Materials*
22. Szekeres, T. Nikolova, A. Paneva, I. Lisovskyy, P.E. Shepeliavyi, G. Yu. Rudko., "Effect of Si nanoparticles embedded in SiO_x on optical properties of the films studied by spectroscopic ellipsometry and photoluminescence spectroscopy", *Optical Materials*
23. S. Bakalova, A. Szekeres, A. Cziraki S. Grigorescu, G. Socol and I. N. Mihailescu, XRD study of pulsed laser deposited AlN films with nano-sized crystallites", *Proceedings of NATO-Advanced Study Institute, Functionalized Nanoscale Materials, Devices, and Systems for chem.-bio Sensors, Photonics, and Energy Generation and Storage. June 4-15, 2007, Sinaia, Romania*.

ONGOING RESEARCH PROJECTS:

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

COLLABORATION:

1. "Characterization of defects generated by high energy electron irradiation of Si/SiO₂ structures", *with JINR, Dubna, Russia*
2. "Effects of ion implantation on micro- and nano-mechanical properties of amorphous silicon films". *Programme of EU for access to large scale facilities, Rossendorf, Germany*
3. "Effect of preliminary ion implantation on blister formation in LiNbO₃", *Programme of EU for access to large scale facilities, Rossendorf, Germany*
4. "Optimization of properties of nanostructures based on silicon, metal oxides and nitrides for nano-electronic usage", *with "Eotvos L." University, Hungary*
5. "Investigation of nanostructures with doped oxide films for environment usage", *with Institute of Physical Chemistry, RA, Bucharest, Romania*
6. "Surface and interface properties of thin film semiconductor heterostructures: investigation by non-linear optical methods", *with Institute of General Physics, RAN, Moskva, Russia*
7. "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*
8. "Innovative nano-structured and nano-composite media: diluted magnetic semiconductors", *with National Institute for Lasers, Plasma and Radiation Physics, Institute of Atomic Physics, Romanian Academy, Bucharest, Romania*

DIVISION MICRO- AND ACOUSTOELECTRONICS

LABORATORY

PHYSICAL PROBLEMS OF MICROELECTRONICS

HEAD: Assoc.Prof. Stefan Andreev, Ph.D.

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TOTAL STAFF: 20

RESEARCH SCIENTISTS: 14

Prof. E. Atanasova, D.Sc.; Assoc.Prof. L. Popova, Ph.D.; Assoc.Prof. V. Gueorguiev, Ph.D.; Assoc.Prof. G. Beshkov, D.Sc.; Assoc.Prof. S. Georgiev; Ph.D., Assoc.Prof. N. Nedev, Ph.D.; Assoc.Prof. J. Koprinarova, Ph.D.; Assoc.Prof. A. Paskaleva, Ph.D.; Res.Assist. D. Spasov, Ph.D.; Res.Assist. J. Pazov; Res.Assist. E. Manolov; Res.Assist. Ts. Ivanov; Res.Assist. M. Georgieva; L. Petkanov, physicist; E. Gajdarzhieva, physicist; S. Tsvetanov, technologist; K. Kozareva, technologist; L. Stamenov, technologist; V. Grigороva, technologist

RESEARCH ACTIVITIES:

1. HIGH-K DIELECTRICS FOR NANO-ELECTRONICS

Detailed investigations are carried out on the long-term reliability and degradation mechanisms of high-k/Si memory capacitors (5-15 nm Ta₂O₅ on a clean and nitridated silicon surface). It is found that nitridated interface yields much more stable electrical characteristics of the memory capacitors for DRAMs, compared with the clean Si surface. The RTA nitridation is optimal for forming interfaces with controlled parameters. Unified interpretation of the breakdown characteristics of memory capacitors with thin and ultrathin (5-15 nm) pure and Ti-doped Ta₂O₅ is formulated. The parameters of memory capacitors, corresponding to SiO₂ thickness of 1 nm, volume dielectric constant of Ta₂O₅ - 30 and leakage current under 10⁻⁹ A/cm² are optimized. It is found that the electrical degradation in (5-15 nm) Ta₂O₅ is based on two competing mechanisms. A general conclusion is drawn that the degradation mechanisms in high-k dielectrics are different from the known for SiO₂. The results obtained are crucial for understanding degradation mechanisms in high-k dielectrics for nanoelectronics. Original methods for Ta₂O₅ doping with Ti and Hf are proposed. As a result, the electrical degradation could be controlled and substantial improvement of the long term reliability could be obtained. An original method for microwave irradiation of the high-k capacitors is developed and proposed as an alternative of the high temperature annealing processes.

Investigated are the mechanisms of trapping and leakage current enhancement induced by strong electrical stress in MIS structures with Hf- and Zr- silicate as active high-k dielectric. It is found that the SILC- creation mechanism is substantially different from the known for SiO₂.

2. MAGNETORESISTIVE THIN LAYERS AND DEVICES

Several types of magnetoresistive multilayer sensors are developed, including passive and active components with hard magnetic layers of Co or SmCo₅. Extended structure investigations of the thin layers are carried out. The dependence of the coercivity of the hard

magnetic layers on their structure is established. Based on the results obtained appropriate deposition processes are selected for production of thin layers with controlled parameters. Designed and fabricated are structures, containing W passive elements.

3. THIN FILMS FOR THE MICROELECTRONICS

Technology is developed for obtaining of pH-ISFET sensors with Zr-titanate or diamond-like ion-sensitive layers. The pH-ISFET sensors produced with ZrO_2 ion-sensitive layer demonstrate pH-sensitivity in the range of 50-55 mV/pH-dec. This sensitivity depends on the annealing processes and the thickness of the buffer layer of SiO_2 .

Technology is developed for deposition of bio-compatible nanolayers of diamond-like carbon. The technology is dedicated to bio-compatible layers for implantable arterial stents.

Designed and produced are several versions of probe for measuring the electron temperature and electron density of the plasma in hf reactors for microelectronic and nano-processes.

4. RAPID THERMAL ANNEALING (RTA)

The influence of RTA on the properties of the structure a-C:H/c-Si (p-type) is investigated. It is found that after the RTA process hetero-junction SiC-Si is formed on the silicon surface. Results obtained are prospective for the production of photovoltaic structures.

PUBLICATIONS:

1. E. Atanassova, A. Paskaleva, Challenges of Ta_2O_5 as high- k dielectric for nanoscale DRAMs, *Microel. Reliab.* 47, 913-923 (2007), **introductory invited paper**
2. E. Atanassova, D. Spassov, A. Paskaleva, Metal gates and gate-deposition defects in Ta_2O_5 stack capacitors, *Microel. Reliab.* 47, 2088-2093 (2007)
3. E. Atanassova, D. Spassov, A. Paskaleva, Effects of metal gate on the breakdown characteristics and leakage current of Ta_2O_5 stack capacitors, *J. of Optoelect. and Advanced Mater.* 9, No2, 315-318 (2007)
4. A. Paskaleva, D. Spassov, E. Atanassova, Impact of Si substrate nitridation on electrical characteristics of Ta_2O_5 stacks, *J. Phys. D : Appl. Phys.* 40, 6709-6717 (2007)
5. N. Novkovski, E. Atanassova, A. Paskaleva, Stress-induced leakage current in rf sputtered Ta_2O_5 on N-implanted Si, *Appl. Surf. Sci.*, 253, 4396-4403 (2007)
6. N. Novkovski, E. Atanassova, Frequency dependence of the effective series capacitance of metal- $Ta_2O_5/SiO_2 - Si$ structures, *Semicond. Sci. Technol.* 22, 533-536 (2007)
7. A. Paskaleva, M. Lemberger, A. J. Bauer, Stress induced leakage current mechanism in thin Hf-silicate layers, *Appl. Phys. Lett.* 90(4), 042105, (3pp) (2007)
8. M. Lemberger, F. Schon, T. Dirnecker, M. P. M. Jank, L. Frey, H. Ryssel, A. Paskaleva, S. Zurcher, A. J. Bauer, MOCVD of Hf-silicate films obtained from a single-source precursor on Si and Ge for gate-dielectric application, *Chemical Vapor Deposition* 13, 105-111 (2007)
9. A. Paskaleva, M. Lemberger, A. J. Bauer, Polarity asymmetry of stress and charge trapping behaviour of thin Hf- and Zr-silicate layers, *Microel. Reliab.* 47, 2094-2099 (2007)
10. E. Vlajkova, A. Szekeres, S. Georgiev, G. Beshkov, Optical properties of PECVD carbon films on silicon subjected rapid thermal annealing, *J. of Optoelect. and Advanced Mater.* 9, No2, 379-381 (2007)

11. S.S.Georgiev, Optimal distance between current collecting electrodes of the solar cells , Solid State Electronics 51, 376-380 (2007)
12. N.Nedev, E.Manolov, B.Panchev, Ts.Ivanov, R.Durny and V.Nadazdy, Influence of the a-Si:H interfacial-region defects on the quasistatic capacitance of Metal/c-Si/SiO₂/ a-Si:H structures, J. of Optoelectronics and Advanced Mater. 9, No2, 352-354 (2007)
13. N.Nedev, D.Nesheva, E.Manolov, R.Bruggemann, S.Meier, K.Kirilov and Z.Levi, Influence of thermal annealing on the memory effect in MIS structures containing crystalline Si nanoparticles, J. of Optoelectronics and Advanced Mater. 9, No1, 182-185 (2007)
14. D.Nesheva, N.Nedev, E.Manolov, I.Bineva, H.Hofmeister, Memory effect in MIS structures with amorphous silicon nanoparticles embedded in ultra thin SiO_x matrix, J. of Physics and Chemistry of Solids 68, 725-728 (2007)
15. 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, J. of Optoelectronics and Advanced Mater. 9, No1, 294-297 (2007)
16. I.Iordanova, L.Popova, P.Aleksandrova, G.Beshkov, E.Vlakhov, R.Mirchev, B.Blagoev, X-Ray investigation of CeO₂ films , prepared by sputtering on Si substrates, TSF 515, 8087-8091 (2007)
17. P.Dimitrova, S.Andreev, L.Popova, Comparative analysis of the behavior of AMR position sensors at real-life magnetic fields, J. of Optoelectronics and Advanced Mater. 9, No2, 319-322 (2007)
18. E.Atanassova, V.F.Mitin, R.V.Konakova, D.Spassev, Microwave irradiation impact on Ta₂O₅ capacitors with different gates, Semicond.Sci.Technol. (proofs)
19. E.Atanassova, R.V.Konakova, V.F.Mitin, D.Spassev, O.Lytvyn, Microwave irradiation effect on Ti-doped Ta₂O₅ stacks, Recent Patents on Electr.Eng. (proofs)
20. E.Atanassova, A.Paskaleva, N.Novkovski, Effects of the metal gate on the stress-induced traps in Ta₂O₅ / SiO₂ stacks, Microel.Rel. (proofs)
21. E.Atanassova, D.Spassev, A.Paskaleva, M.Georgieva, J.Koprinarova, Electrical characteristics of Ti-doped Ta₂O₅, TSF (proofs)
22. D.Spassev, E.Atanassova, Conducting mechanisms in Ta₂O₅ stack in response to rapid thermal annealing, Microel.Engin. (proofs)
23. N.Novkovski, A.Skeparovski, E.Atanassova, Charge trapping at contact high-work function metal / high-k dielectric, Appl.Phys.Lett. (proofs)
24. A.Paskaleva, M.Tapajna, E.Atanassova, K.Frohlich, A.Vinze, E.Dobrocka, Effect of Ti doping on the Ru/ Ta₂O₅ gate stacks, J.NonCryst.Sol. (proofs)
25. E.Atanassova, N.Stojadinovich, A.Paskaleva, D.Spassev, L.Vracar, M.Georgieva, Constant voltage stress induced current in Ta₂O₅ stacks and its dependence on gate electrode, Microel.Rel. (proofs)
26. D.Nesheva, N.Nedev, Z.Levi, R.Bruggemann, E.Manolov, K.Kirilov and S.Meier, Absorption and transport properties of Si rich oxide layers annealed at various temperatures, Semicond.Sci.Technol.
27. G.Beshkov, D.Gogova, D.Spassev, St.Georgiev, P.Stefanow, Synthesis and Characterization of BN_x Nanolayers prepared by Rapid Thermal Low Pressure Chemical Vapor Deposition, 16th European Conference on Chemical Vapor Deposition – Book of Extended Abstracts, Ed.Chris R.Kleijn, TU Delft, The Niderland 2007

28. N.Nedev, M.Stoycheva, D.Nesheva, E.Manolov, R.Bruggemann, S.Meier, Z.Levi, R.Zlatev, B.Valdez and L.Alvarez, MOS Structures Containing Amorphous Silicon Nanoparticles for Application in Memory Devices, Proc. of the Nanoscience and Technology Institute Conference Nanotech 2007, May 20-24, Santa Clara, Ca,USA, Vol.4, 485-488 (2007)
29. G.Beshkov, D.Spassov, St.Georgiev, P.Stefanov, Properties of BN nanofilms prepared by Low Pressure Rapid Thermal Chemical Vapor Deposition, Proc. of 16th EUROCVI conference – 15-22 Sept.2007, Hague, Netherland
30. V.Yanev, A.Paskaleva, W.Weinreich, M.Lemberger, S.Peterson, M.Kommel, A.J.Bauer, H.Ryssel, Verification of grain boundaries in annealed thin ZrO₂ films by electrical AFM technique, Proc.EMRS Fall Meeting ,17-21 Sept.2007, Warsaw, Poland
31. P.Stefanov, G.Atanasova, E.Manolov, Z.Raicheva, V.Lazarova, Preparation and Characterization of SnO₂ Films for Sensing Applications, 17th International Vacuum Congress (IVC – 17) and 13th International Conference in Surface Science (ICSS – 13), 2-6 July 2007, Stockholm,Sweden
32. G.Atanasova, P.Stefanov, Z.Raicheva, E.Manolov, M.Atanasov, V.Lazarova, XPS Characterization of WO₃ Layers for Gas Sensor Application, 17th International Vacuum Congress (IVC – 17) and 13th International Conference in Surface Science (ICSS – 13), 2-6 July 2007, Stockholm,Sweden
33. G.Atanasova, P.Stefanov, Z.Raicheva, E.Manolov, V.Lazarova, L.Spassov, Ammonia detection using SnO₂ acoustic sensor, Ecomaterials and Processes:Characterization and Metrology,19-21 April 2007, St.Kirik, Plovdiv, Bulgaria
34. G.Beshkov, D.Spassov, V.Krastev, St.Georgiev, P.Stefanov, XPS study of BN nanolayers prepared by Rapid Thermal Annealing Process , Int.Conf. of Vacuum Electron and Ion Technology (VEIT) , Sept.2007,Sozopol, Bulgaria- in press
35. E.D.Atanassova, A.E.Belyaev, R.V.Konakova, P.M.Lytvyn, V.V.Milenin, V.F.Mitin, Effect of active actions on the properties of semiconductor materials and structures, NTC Inst.for Single Crystals, 2007, Kharkov, Ukraina,p.216

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 by 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

DIVISION MICRO- AND ACOUSTOELECTRONICS

LABORATORY

ACOUSTOELECTRONICS

HEAD: Prof. Lozan Spassov, Ph.D., D.Sc., Corresponding member of BAS

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TOTAL STAFF: 14

RESEARCH SCIENTISTS: 8

Assoc.Prof. I. Avramov, Ph.D.; Assoc.Prof. V. Georgieva, Ph.D.; Assoc.Prof. E. Radeva, Ph.D.; R. Velcheva, Ph.D.; Ts. Yordanov, researcher; M. Atanassov, researcher; V. Gadjanova, researcher; Z. Raicheva, chemist; L. Vergov, engineer; J. Lazarov, engineer, I. Yotova, Techn. Ass.; S. Staikov, technician; G. Grigorov, technician.

RESEARCH ACTIVITIES:

In 2007, the scientific and applicable activity of Acoustoelectronics laboratory at ISSP – BAS was focused on creation of new materials, technologies and elements in accordance with the Academy's basic strategic goal-delivery and maintenance of internationally competitive & high scientific quality.

– SEMI ANALYTICAL MODELING OF THERMOSENSITIVE STRIP RESONATORS

The analysis of strip resonators was continued, by caring out new development of the two-dimensional semi-analytical model. The analysis includes the dependence of the vibration mode versus the third co-ordinate, i.e. the length of the strip plate. This way, the model is extended up to three-dimensional. The computer programme was updated, so now it is able to interpret the developed three-dimensional semi-analytical model for strip resonators analysis. An experimental set of thermosensitive strip resonators was released, and the alteration of their dynamic parameters was detected. The obtained results are being processed and will be included in the dissertation of PhD student Julian Lazarov.

– INVESTIGATION OF LONG-TERM AND SHORT-TERM STABILITY OF QUARTZ TEMPERATURE SENSORS

Investigation on long-term stability of quartz crystal temperature sensors at room temperature and at 80°C placed in thermostat was accomplished in the course of two years. The results from the investigations carried out, confirm the high level of the developed technology, providing for the production of precise temperature sensors, which are able to work for decades without additional re-calibration. The data from the investigation is summarized and will be included in an article, which is to be published in the specialized magazine edition - IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control.

– MASS-SENSITIVE QUARTZ RESONATORS

In regards of the above, there have been two modules of work from contract HT3 "Creation of acoustic sensor for detection of noxious contaminations in the environment":

- Module HT3-04 "Designing and creation of sensor elements used in the quartz crystal microbalance".

A mathematical analysis and computer modeling of quartz piezoelement with different electrode configurations was carried out. Based on the obtained results, quartz resonators with electrode diameter of 3, 4 and 5 mm were designed. Quartz resonators on AT – cut with 8mm diameter of the quartz plate and thickness of the Au and Ag electrodes, respectively 55 and 120 nm were released. The influence of the electrode configuration on the dynamic parameters, temperature stability and frequency characteristics of the created structures were also investigated.

The measured dynamic parameters (resonance frequency - 16 MHz, equivalent resistance ranging from 5 to 17 ohms, and quality factor (Q) 36 000 - 65 500) prove their applicability as precise mass-sensitive transducers. The typical spectral characteristics have clearly expressed basic modes. It's been proved that, the bigger the diameter of the metal electrodes, the stronger the aharmonic modes are expressed, which results form the weaker detection of the basic mode's energy.

- Module HT3-03 “Investigation of the sorption properties of metal dioxide layers by the quartz crystal microbalance method”.

Based on meticulously developed principal scheme, an experimental laboratory set for massloading measurements by the quartz crystal microbalance method (QCM) was designed and created in the Acoustoelectronics laboratory – ISSP, BAS. It includes a mechanical part, and a computerized measurement system. The set allows: obtaining gas mixtures with concentrations from 10ppm to 10000ppm; carrying out measurement of the QCM massloading under strictly defined conditions; measuring the frequency change with high accuracy - $\Delta f/f \cdot 10^{-9}$. The set was tested for hermetical sealing, and the functionality of all systems was meticulously checked. The different principle opportunities for work, which the set allows were also examined. Coming up is the assimilation of the set. Outside the module, some preliminary experiments for mass-sensitivity determination of different dielectric layers (LPD-TiO₂, rf-TiO₂, SnO₂) versus ammonium vapors above water solutions were carried out by the QCM method.

The obtained results from the experiments, in compliance with the programmes of both modules - HT3-03 and HT3-04, were reported at five international conferences in Bulgarian and abroad. Two of the reports were printed in proceedings in 2007.

– SYNTHESSES AND STUDY OF PLASMA POLYMERS

The photoluminescence and optical properties of plasma polymers obtained from hexamethyldisiloxane were studied in order to use them as protective layer against electrical breakdown and capsulating layer in electroluminescent display structures. The plasma deposition conditions of polymer layers were optimized for obtaining samples with best parameters – brightness and time of life.

After implantation with carbon ions in polymer layers its photoluminescence, optical and electrical properties were investigated. It is established increase in photoluminescence, decrease in transparency and electrical resistance of implanted samples compared to not implanted.

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

Systematic electrical, noise and temperature studies have verified quartz crystal stability in recently developed at the Acoustoelectronics Laboratory low-voltage STW oscillators that are injection locked to a high-overtone crystal frequency. The studies are performed on a 1,0 GHz STW oscillator operating on a record low 1,25V supply voltage and synchronized with

the 10-th overtone of a 100 MHz quartz crystal comb spectrum oscillator. Experimental results prove that, as a result of injection locking, the STW oscillator improves its temperature stability by a factor of 10, the close-in phase noise suppression is improved by 19 to 24 dB and the oscillator noise floor, determined by the free running STW oscillator, is retained as low as -174 dBc/Hz. This is the lowest noise floor reported with a 1,0 GHz SAW oscillator operating on such a low supply voltage to date. The above improvements result in a r.m.s. jitter in the 220 to 640 fs range over the entire temperature operation range of (0 to 85) deg. C over which the oscillator remains locked to the crystal reference.

The gas sensing characteristics of novel recently developed RSAW sensors using gold electrode structure for operation in highly reactive chemical environments have been studied and analyzed. The sensors are coated with chemically sensitive PCFV polymers at different thicknesses using the electrospray method and are experimentally probed with cooling agent, octan and tetrachloroethylene. Optimum polymer thicknesses for highest gas sensitivity and sensor dynamics are experimentally determined. Comparative studies show that RSAW sensors with gold electrode structures demonstrate up to two times higher gas sensitivity than their counterparts with aluminum electrode structure.

- DEVELOPMENT OF THIN-LAYER TECHNOLOGY FOR HIGH EFFECTIVE REFLECTORS

The design and instrumental equipment of the above are already completed. A series of three different sizes of plastic traffic reflectors was created. Based on Al-Ag-SiO₂, a technology for surface coating was developed, where the achieved reflecting ability ranges from 82% to 93%. The results are allowing a successful replacement of the old metal reflectors with the new ones.

- CREATION OF SOLAR PHOTOVOLTAIC PANELS FOR SPECIAL APPLICATION

A photovoltaic panel applicable in illuminant and independent of energy sources was designed. The technological line is already designed; materials and parts of the equipment are delivered. A photovoltaic panel is created but the project continues in 2008.

- CREATION OF HIGHLY STABLE MAGNET-RESISTIVE SENSORS

There was participation in setting the technological line for production of micro-electron articles, based on Si with pilot products - highly stable magnet-resistive sensors. The vacuum installation in the line is additionally equipped with RF magnetron, which improves its potentials. Pilot technological samples were also created. The project continues in 2008.

PUBLICATIONS:

1. I. D. Avramov, K. Laenge, S. Rupp, B. Rapp and M. Rapp, "Polymer coating behavior of Rayleigh SAW resonators with gold electrode structure for gas sensor applications", in IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control, Vol. 54, No. 1, Jan. 2007, pp. 157-166.
2. V.Georgieva, L.Spassev, D.Spassev, N.Donkov, P.Petkov. "Tantalum pentoxide – based quartz crystal microbalance for NH₃ detection". Journal of Optoelectronics and Advanced Materials Vol. 9, No.2, February 2007, pp. 252-255.
3. L.Spassev, V.Gadjanova, R.Velcheva, B.Dulmet, "Short and Long Term Stability of Resonant Quartz Temperature Sensors", IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control

4. K.M. Kolentsov, L.S. Yourukova, E.I. Radeva, Improved technology for AC HEL display structures – characteristics and application possibilities, *Electrical Engineering and Electronics*, v. 42, 2007 pp. 20-31 (in Bulgarian).
5. Yu. Lazarov, B. Dulmet, L. Spassov, “Calculation of the motional capacitance of thermosensitive quartz resonators in the framework of semi-analytical model” *Comptes Rendus de l'Academie Bulgare de Sciences*, Vol. 60, №5, 2007
6. I. D. Avramov and J. Columbus, “Performance Verification of Injection Locked STW Clocks with BAW Crystal Stability”, *Proc. 2007 Joint Meeting of the European Frequency and Time Forum (EFTF) and the IEEE International Frequency Control Symposium (IEEE-IFCS)*, May 29 to June 1, 2007, Geneva, Switzerland, pp. 771-778.
7. V.L. Georgieva, P.L.Stefchev, P.K.Stefanov, L.S.Spassov, Z.G.Raicheva, K.I.Ivanova, “Liquid Phase Deposition of Thin Titanium Dioxide Films for NH₃ Detection”, 6-th International Conference of the Balkan Physical Union, 22-26 August 2006/ Istanbul-Turkey, *AIP Conference Proceedings*, vol.899, p.732, 2007.
8. S.I.Boiadjiev, V. Lazarova (Georgieva), M.M. Rassovska, “ Sorption Properties of RF Reactive Sputtered TiO_x Thin Films” 6-th International Conference of the Balkan Physical Union, 22-26 August 2006/ Istanbul- Turkey, *AIP Conference Proceedings*, vol. 899, p.765, 2007.
9. B.Dulmet, Yu. Lazarov, L. Spassov, P. Tinguy “Last improvements in the analysis of resonant strip sensors” *Proc. of the 2007 IEEE International Frequency Control Symposium jointly with the 21-th EFTF*, Geneva, Switzerland, (Electron. version) pp.363-368
10. K.Ivanova, P.Stefchev, P.Vitanov, Hr.Dikov, Chr. Trapalis, V. Lazarova (Georgieva), “LPD TiO₂ Coatings on Anodized Aluminum”, *Workshop on Size-Dependent Effects In Materials for Environmental Protection and Energy Application*, May 25-27, 2006 Varna, Bulgaria
11. Genoveva Atanasova, Plamen Stefanov, ZdravkaRaicheva, Emil Manolov, Velichka Lazarova (Georgieva), Lozan Spassov, “Ammonia detection using SnO₂ acoustic Sensor”, *Workshop on Ecomaterials and Processes: Characterization and Metodology*, April 19 – 21,2007, St. Kirik, Plovdiv, Bulgaria
12. Maria Shipochka, Plamen Stefanov, Petko Stefchev, ZdravkaRaicheva, Velichka Lazarova (Georgieva), Lozan Spassov, „XPS Characterization of TiO₂ Layers for Gas Sensor Application”, *Workshop on Ecomaterials and Processes: Characterization and Metodology*, April 19 – 21,2007, St. Kirik, Plovdiv, Bulgaria
13. Genoveva Atanasova, Plamen Stefanov, ZdravkaRaicheva, Emil Manolov, Mitko Atanasov, Velichka Lazarova (Georgieva), “XPS Characterization of WO₃ Layers for Gas Sensor Application”, *NANO HARD 2007 “Development, characterization and Industrial application of nanostructured thin films, hard and superhard coatings”*, May 16, 2007, Velingrad, Bulgaria
14. Plamen Stefanov, Maria Shipochka, Petko Stefchev, ZdravkaRaicheva, Velichka Lazarova (Georgieva), Lozan Spassov, “XPS Characterization of TiO₂ Layers Deposited on Quartz Plates”, *International Vacuum Congress and European Conference of Surface Science*, Sweden, Stockholm 2-6.07.2007
15. P. Stefanov, G. Atanasova, E. Manolov, Z.Raicheva, V. Lazarova (Georgieva), “Preparation and Characterization of SnO₂ Films for Sensing Applications”, *International Vacuum Congress and European Conference of Surface Science*, Sweden, Stockholm 2-6.07.2007
16. H. Vasilev, M. Atanasov, G. Ganchev, “Pellets production energyeffective technology“, *Energy forum* 13.04.2007

RESEARCH PROJECTS:

1. Project financed by Bulgarian Academy of Sciences

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

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

2.1 Digital Electroluminescent Display – Design, Constructional Development and Preparation

2.2 Designing and creation of sensor elements used in the quartz crystal microbalance.

2.3 Investigation of the sorption properties of metal dioxide layers by the quartz crystal microbalance method.

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 Investigation of properties and characteristics of zincsulphide electroluminescentors and making of set-ups of their base.

4.2 Development of mass sensitive quartz resonators for operation at cryogenic temperatures.

4.3 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.

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. “Development of mass sensitive quartz resonators for operation at cryogenic temperatures”. - Joint Institute for Nuclear Research, Dubna, Russia.

2. “Design of an improved Rayleigh surface acoustic wave (RSAW) resonator with gold electrode structure and improved corrosion immunity for sensor applications in highly reactive chemical gas-phase environment”- Research Center Karlsruhe, Germany.

3. “Development of chemical sensors based on a piezoresonant type for hazardous substances in the air”- Russian Academy of Science.

4. “Piezoelectric crystal microsensors at cryogenic temperatures”. - ENSMM – Besançon, France.

DIVISION LOW TEMPERATURE PHYSICS

LABORATORY

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TOTAL STAFF: 17

RESEARCH SCIENTISTS: 16

Prof. V. Kovachev, Ph.D., D.Sc.; Assoc.Prof. V. Lovchinov, Ph.D.; Assoc.Prof. M. Bushev, Ph.D.; Assoc.Prof. E. Vlahov, Ph.D.; Assoc.Prof. B. Terziyska, Ph.D.; Assoc.Prof. D. Dimitrov, Ph.D.; Assoc. Prof. K. Kalaydjiev, Ph.D.; Assoc.Prof. N. Balchev, Ph.D.; Assoc.Prof. E. Nazarova, Ph.D.; Assist.Prof. K. Nenkov; Assist.Prof. A. Stoianova-Ivanova, Ph.D.; Assist. Prof. Y. Radulov; Assist. Prof. S. Terzieva; P. Simeonova, Ph.D, chemist; G. Mihova, chemist; K. Lovchinov, technologist

RESEARCH ACTIVITIES:

1. NEW MATERIALS, STRUCTURES AND MULTIFUNCTIONAL MAGNETIC SYSTEMS

The theory of phase transitions in systems with finite geometry (stripes, films, etc.) and strong anisotropy is developed. Prominent examples are systems with long-range interactions, decaying with the interparticle distance r as $r^{d-\sigma}$ with different exponents σ in corresponding spatial directions, systems with space–“time” anisotropy near a quantum critical point, and systems with Lifshitz points. The simplest consideration is in the framework of the O(N)-vector model in the limit $N \rightarrow \infty$, where the model is exactly solvable.

The structural, magnetic, magnetoelectric, and ferroelectric properties of series of monocrystals of rare-earth manganites with orthorhombic structure, space groups D2h/16/ and D2h/9/ ($\text{Sm}_{0.864}\text{Pb}_{0.136}\text{MnO}_3$, HoMn_2O_5 , $\text{La}_{0.78}\text{Pb}_{0.22}\text{MnO}_3$ monocrystals as well as mixed compounds of $\text{Ho}_x\text{Tb}_{1-x}\text{O}_3$, $\text{HoMn}_x\text{Fe}_{1-x}\text{O}_3$, $\text{Ho}_x\text{Cr}_{1-x}\text{O}_3$, $\text{DyFe}_x\text{Cr}_{1-x}\text{O}_3$) have been investigated in wide temperature range $T = 2 \text{ K} - 800 \text{ K}$ and in magnetic field up to 14 T. The existence of giant magnetoresistance (GMR) for some samples, a giant magnetostriction effect for others and the presence of multiphase ferroelectric states were demonstrated. Various possibilities for practical applications are discussed.

Thin cobaltite films of $\text{NdBaCo}_2\text{O}_{5+x}$ system have been obtained by magnetron sputtering for the first time on monocrystal substrates of strontium lanthanum aluminate SLA (100). The deposition regime has been optimized in order to tune oxygen stoichiometry. Magnetic properties of $\text{NdBaCo}_2\text{O}_{5+x}$ ($x = 0.20 - 0.75$) thin films have been investigated. Magnetotransport properties of polycrystalline samples of the same system $\text{NdBaCo}_2\text{O}_{5+x}$ ($x = 0.50; 0.73$) have been investigated in pulse magnetic fields up to 50 T and in wide temperature range 4K – 300 K.

Nanoparticles of ferrofluids obtained by different ways were investigated. The submitted results concern structures with diameters in the range from 20 to 3000 nm. Time-dependence of their temperature increment is presented. The magnetic heating efficiency (MHE) was calculated. The nanoparticles were coated using β -cyclodextrin and solved in

water in different concentrations. The obtained results show that they are environmentally friendly for applications concerning the human being. These nano-particles were proposed as new contrast agent for liver Magnetic Resonance Imaging (MRI). Our initial experiments demonstrate that liver tissue difference of signals before and after contrasting is sufficient for the detection of focal liver lesions and is potentially usable for their diagnosis.

A spectrophotometric method has been developed for the determination of the oxygen stoichiometry in $\text{YBa}_2\text{Cu}_3\text{O}_y$ superconducting bulk samples. The sensitivity of the method is comparatively high and allows a sample mass about 2 mg to be used.

2. CRYOGENICS, SUPERCONDUCTIVITY AND SUPERCONDUCTING MATERIALS

Thermal properties of ternary chalcogenide glasses, $\text{Ge}_x\text{As}_{40-x}\text{S}_{60}$ with $x = 0 \div 40$ are analysed in wide temperature range. Established low-temperature anomaly behaviour is successfully explained in the frame of Soft Potential Model which assumes an excess in the vibrational density of states $g(\omega)$ and postulates a coexistence of acoustic phonons with quasilocalized low-frequency modes. Interaction of the additional excitations with phonons conditions the observed thermal properties peculiarities of the studied glasses, a maximum C_p/T^3 in the scaled specific heat and a plateau in thermal conductivity at low temperatures.

Special features of the low-temperature specific heat of polytetrafluoroethylene and polychlorotrifluoroethylene have been examined and interpreted in the light of a recently developed Soft Potential Model. An estimate of the excess specific heat over Debye contribution as well as a determination of the contributions to C_p and C_p/T^3 values of these fluoroplasts were provided, too. The established special features are accepted to originate from the additional localized soft modes postulated in the SPM.

Samples with nominal compositions $\text{Ru}_{1-x}\text{Sn}_x\text{Sr}_2\text{Gd}_{1.4}\text{Ce}_{0.6}\text{Cu}_2\text{O}_y$ ($0 \leq x \leq 0.2$) were synthesized and their superconducting and magnetic properties were investigated. It was shown that the Sn-doping enhances the crystal growth in Ru-1222. A maximum in the dependencies of the lattice parameters and T_c on the dopant content x was observed. It was established that small doping levels ($0 < x \leq 0.05$) significantly increase the T_c of the Ru-1222 samples, prepared at the same conditions – from 20 K for the undoped sample to 35 K for the $x=0.03$ one. The $0.1 \leq x \leq 0.2$ samples are not superconducting, i.e. the Sn-doping more rapidly destroys the superconductivity in Ru-1222 than in the conventional superconductors. The initial increase of T_c was associated with an increase of the hole concentration. The decrease of T_c and suppression of SC at higher doping levels may be explained by an enhanced disorder in the system, due to a possible presence of Sn in both Ru and Cu sites. The latter fact could also explain that the onset of the magnetic transition T_{mag} weakly depends on the dopant content.

We fabricate Ag-sheated $\text{Y}_{1-x}\text{Ca}_x\text{Ba}_2\text{Cu}_3\text{O}_{7-\delta}$ ($x=0; 0.3$) tapes and show that overdoped superconducting core gives better result. First: a higher degree of out-of-plane texturing is achieved due to the presence of BaCuO_2 and formation of low melting eutectic. Second: overdoped core provides more carrier concentration and better intergrain transparency and Third: smaller Y diffusion in Ag-sheat takes place ensuring better stoichiometry in the superconducting core. As a result 8 times higher J_c values are obtained for tapes with $\text{Y}_{0.7}\text{Ca}_{0.3}\text{Ba}_2\text{Cu}_3\text{O}_{7-\delta}$ core in spite of the fact that J_c is measured very close to T_c . Releasing of stress between the superconducting core and Ag-sheat with the time leads probably to further J_c improvement. The above results are obtained for the superconducting tapes made by OPIT technology, but in principle they could be applicable for the coated conductors also.

The influence of Ca and Pr substitution on microstructure, phase formation and oxygen content in superconducting $\text{Y}(\text{Ca},\text{Pr})\text{BCO}$ system was investigated. The result was used for preparation of Ag-sheathed superconducting tapes with similar core. It was

established that hot-rolling technology is suitable for making $Y_{0.7}Ca_{0.3}Ba_2Cu_3O_z$ tapes. The results show that hot-rolled tapes with and without Ca-substitution have orthorhombic 1:2:3 structures with no impurity phases. The superconducting core of the $Y_{0.7}Ca_{0.3}Ba_2Cu_3O_z$ tape has a finer grain structure than the $Y_1Ba_2Cu_3O_z$ tape. It was established that the critical current density (J_c) continues to increase with the time, reaching up to 965 A/cm^2 after one year.

Patent № 65265/06.07.2007 “Method and set-up for measurements of ac losses in HTSC tapes at nitrogen temperatures” is defended; authors: B. Terziyska and V. Kovachev

The superconducting phenomenon has been used for dating of lead archaeological finds. Meissner fraction of lead artifacts in superconducting state is used for determination of non corroded metal mass. Knowing the total mass of the sample it is possible to determine the mass of corroded products. The last correlates with the archaeological age of artifacts. This dependence was successfully used for dating of lead pieces found during the excavations in Sofia Amphitheater discovered in 2004.

3. ENVIRONMENTAL PHYSICS RESEARCH

The environmetric studies were concentrated on the assessment of the river water quality (Ropotamo River and Yantra River) as well as on the air quality assessment (aerosols from the Northern Greece). Multivariate statistical models were constructed, which allow the interpretation of the effects of different pollution sources on the pollution parameters values. They assist the better understanding of the reason and the type of pollution in the environmental system in consideration. In this case unexpected pollution sources were detected even for systems considered as unpolluted, e.g. the area of Ropotamo River, where a pollution of the estuary region is established.

A significant novelty in our research is the multivariate statistical interpretation of clinical analysis data for a large group of patients of different age and sex. An original classification of the clinical parameters is achieved, which makes it possible to cluster them into similarity groups and allows an optimization of the schemes of clinical analysis for the aim of prophylaxis.

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2. N. S. Tonchev, An introduction to the Casimir effect in critical phenomena JOAM 9, 11-17, (2007).
3. V. Lovchinov, A. Apostolov, D. Dimitrov, I. Radulov, P. Simeonova, K. Kalaydjiev, PH. Vanderbemden, Magnetic And Transport Properties Investigation of Rare-Earth Compounds With Orthorhombic Structure, JOAM 9, 460-463 (2007).
4. E. Vateva , B. Terziyska, D. Arsova, “Low-temperature specific heat and thermal conductivity of ternary chalcogenide glasses, JOAM 9, 1965–1973 (2007).
5. Pavlina Simeonova and Vasil Simeonov, Multivariate statistical interpretation of laboratory clinical data, Ecol. Chem. Eng.14, 159-170 (2007).
6. Vassil Lovchinov, Andrey Apostolov, Dimitar Dimitrov, Pavlina Simeonova and Konstantin Nenkov, “Magnetotransport properties of $Sm_{0.864}Pb_{0.136}MnO_3$ single crystal”, JOAM 9, 2897-2901 (2007).
7. Pavlina Simeonova, Vasil Lovchinov, Vasil Simeonov, Multivariate Statistical Assessment of the Ropotamo River Water Quality, Journal of Balkan Ecology 10, 197-204 (2007).

8. Pavlina Simeonova, Vasil Lovchinov, Dimitar Dimitrov, Ilia Radulov, Quality assessment of the Yantra River water monitoring data, *Ecol. Chem. Eng.* 14, 693-705 (2007).
9. Pavlina Simeonova, Vasil Lovchinov, Vasil Simeonov, Data Interpretation using Multivariate Statistics for an Aerosol Sample Collection from Northern Greece, *Journal of Balkan Ecology* 3, 99-306 (2007).
10. S. Terzieva, A. Stoyanova-Ivanova, V. Mikli, A. Zahariev, Ch. Angelov, Y. Dimitriev and V. Kovachev, The influence of the partial Ca substitution on the microstructure of YBCO tapes, *JOAM* 9, 453 – 456 (2007).
11. P. Simeonova and V. Simeonov, Chemometrics to Evaluate the Quality of Water Sources for Human Consumption, *Microchim. Acta* 156, 315-320 (2007).
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13. N. Balchev, K. Nenkov, B. Kunev, J. Pirov, G. Mihova, G. Fuchs, “Superconductivity, Magnetism and Magnetoresistance in RuSr₂R_{1.4}Ce_{0.6}Cu₂O_{10-δ} (R=Eu, Sm)”, *Journal of Superconductivity and Novel Magnetism* 20, 333 (2007).
14. N. Balchev, K. Nenkov, G. Mihova, B. Kunev and J. Pirov, “Magnetic and Superconducting Properties of Sn doped Ru-1222”, *Physica C* 467, 174-178 (2007).
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18. A. Stoyanova-Ivanova, S. Terzieva, A. Staneva, V. Mikli, Ch. Angelov, V. Kovachev, The influence of the partial Ca-Pr substitution on the microstructure of Y_{0.96}Pr_{0.04}Ba₂Cu₃O_z and Y_{0.71}Pr_{0.04}Ca_{0.25}Ba₂Cu₃O_z superconducting ceramics, *Journal of the University of Chemical Technology and Metallurgy* 42, 423-426 (2007). N. Balchev, K. Nenkov, G. Mihova, J. Pirov, “Superconducting, Magnetic and Transport Properties of RuSr₂R_{1.4}Ce_{0.6}Cu₂O_{10-δ} (R=Eu, Sm)”, CP899, Eds. S.A.Cetin and I. Hikmet, 2007, AIP, p. 584.
19. B. Terziyska, E. Vateva, D. Arsova, “Low-temperature contributions to the specific heat of Ge_xAs_{40-x}S₆₀ glasses”, CP899, Eds. S.A.Cetin and I. Hikmet, 2007, AIP, p.589.
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21. I. Radulov, V. Lovchinov, D. Dimitrov, A. Apostolov, V. Nizhankovskii, M. Daszkiewicz. Magnetic properties of HoMn₂O₅; CP899, Eds. S.A.Cetin and I. Hikmet, 2007, AIP, p. 627.
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 25. Emil Vlahov, Roumen Kakanakov, Lilyana Kolaklieva, Yordan Marinov, Nikolay Tonchev, "Ni/NiO Nanodispersed Thin Films: Development and Applications", Proc. of Int.Conference NANO HARD 2006 "New Trends in Development of Nanostructured Thin Films, Hard and Superhard Coatings", May 28 –31, 2006, Sozopol, Bulgaria, pp. 59-62.
 26. Emil Vlahov, Roumen Kakanakov, Lilyana Kolaklieva, Nikolay Tonchev, " ALD approach for enhancing sensitivity of porous silicon gas sensors" Proc. of Int. Workshop NANO HARD 2007 "Development, characterization and industrial application of Nanostructured Thin Films, Hard and Superhard Coatings", May 13 -16, 2007, Velingrad, Bulgaria, pp. 79-82.
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 28. D. Dimitrov, I. Radulov, V. Lovchinov, A. Apostolov, Parameters of the Dzyaloshinsky-Moriya type weak ferromagnetism for some perovskite compounds, Anniversary Collection of the University of Sofia, 2007, p.64-71.
 29. V. Lovchinov, A. Apostolov, D. Dimitrov, I. Radulov, Ph. Vanderbemden. Peculiarities in the properties of some rare-earth compounds with orthorhombic structures, Anniversary Collection of the University of Sofia, 2007, p.54-63.
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 32. А. Стоянова-Иванова, С. Терзиева, "Двадесет години от откриването на високотемпературната свръхпроводимост, Високотемпературни свръхпроводими материали", Сборник (доклади) том II, 24 Март 2007г., Пловдив, 2007, стр.50-54.
 33. Ангелина Стоянова-Иванова, Зоя Митрева, Станимира Терзиева, Розина Йорданова, Донка Ангелова, "Изследване влиянието на процеса на валцуване при получаване на високотемпературни свръхпроводими ленти върху свойства им", Сборник (доклади) том II, 24 Март 2007г., Пловдив, 2007, стр.39-44.

ONGOING RESEARCH PROJECTS:

1. Thermal and magnetic properties of HTSC Tapes and magnetic materials, 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. Synthesis of smart materials and superconductors and their characterization, Ss”Cyril and Methodius” University, Skopje, Makedonia.
5. Synthesis and structural investigations of new compounds for application in opto-microelectronics and medicine, Central of Material Research, University of Tallin, Estonia.
6. Investigation of overdoped superconducting 123 System, Institute of Low Temperatures and Structural Research, Polish Academy of Sciences, Wroclaw, Poland.
7. Investigation of fluxoid dynamics in superconducting tapes obtained by OPIT with overdoped superconductor, Univ. Babes Bolyai, Kluj Napoka, Rumania.

INTERNATIONAL COLLABORATION:

1. Universite de Liege, Institute d’Electricite – SUPRATECS, Liege, Belgium.
2. Institute of Physics, Polish Academy of Sciences, Warsaw, 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.
6. Central of Material Research, University of Tallin, Estonia.
7. Univ. Babes Bolyai, Kluj Napoka, Rumania.

DIVISION LOW TEMPERATURE PHYSICS

LABORATORY

CRYOGENIC TECHNOLOGY

HEAD: Assoc.Prof. Borislav Nikolov, Ph.D.

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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:

NEW SUPERCONDUCTIVE MATERIALS

The effect of hole doping, on the transport and magnetic properties of Ca substituted YBCO bulk samples was 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. For this purpose Ag-sheathed $Y_{1-x}Ca_xBa_2Cu_3O_{7-y}$ ($x=0; 0.3$) superconducting tapes were prepared by OPIT method. Their investigations show that overdoped superconducting core gives better result. First: a higher degree of out of plane texturing is achieved due to the presence of $BaCuO_2$ and formation of low melting eutectic. Second: overdoped core provides more carrier concentration and better intergrain transparency and third: smaller Y diffusion in Ag-sheath takes place ensuring better stoichiometry in the superconducting core. As a result 8 times higher J_c values are obtained for tapes with $Y_{0.7}Ca_{0.3}Ba_2Cu_3O_{7.8}$ core in spite of the fact that J_c is measured very close to T_c . Releasing of stress between the superconducting core and Ag-sheath with the time leads probably to further J_c improvement. The above results are obtained for the superconducting tapes made by OPIT technology, but in principle they could be applicable for the coated conductors also. The results are published.

The computerised system for investigations of a resistivity and AC magnet susceptibility of different materials (including high temperature superconductors) was realized and the results were published in JOURNAL OF SUPERCONDUCTIVITY AND NOVEL MAGNETISM.

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: As. prof. Dr. E. Nazarova.

PUBLICATIONS:

1. M.G.Mitev, E.K.Nazarova, E.N.Dimitrov, A.L.Zahariev, J.K.Georgiev, ELECTRONICS ET 2007, Proceedings of the sixteenth international scientific and applied science conference, Sozopol-Bulgaria, 19-21.09.2007, book 3, p.145.

Automated system for investigation of resistance temperature dependence of high temperature superconductors.

2. H.Ignatov, E.Nazarova, A.Zahariev, V.Lazarova, J.Georgiev, A.Stoyanova-Ivanova, S.Terzieva, K.Kliavkov, V.Kovachev, JOURNAL OF SUPERCONDUCTIVITY AND NOVEL MAGNETISM, Journal of Superconductivity and Novel Magnetism, 21 (2008), No1, 69-73.

Deformation effects on the structure and properties of $Y_{1-x}Ca_xBa_2Cu_3O_{7-\delta}$ ($x = 0; 0.3$) tapes produced by OPIT method in the Ag-tube.

DIVISION PHYSICAL OPTICS AND OPTICAL METHODS

LABORATORY

OPTICS AND SPECTROSCOPY

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RESEARCH SCIENTISTS: 29

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RESEARCH ACTIVITIES:

I. PHYSICAL OPTICS. PHOTONICS

- OPTICS AND SPECTROSCOPY OF WAVEGUIDES

Hydrogenated amorphous silicon with high compressive stress and hydrogen concentration as high as the hydrogen solubility limit has been studied. The concentrations of total hydrogen and bonded hydrogen have been determined by nuclear reaction analysis and infrared transmission spectroscopy, respectively. Silicon ion implantation has been used to transform the hydrogen molecules into silicon-bonded hydrogen. It has been concluded that in spite of high hydrogen content in the material the concentration of molecular hydrogen in the studied films is below 1 at. % and is not the reason for the high internal stress.

The quasistatic capacitance voltage dependencies of the M/c-Si/SiO₂/a-Si:H structures are measured using a modification of the standard qs C-V method, which allows reduction of the influence of a-Si:H transient currents. The structures are fabricated by thermal oxidation of n⁺-doped c-Si followed by PECVD deposition of a-Si:H film. It is shown that the change in the qs C-V characteristic of the sample caused by thermal annealing with an applied bias can be explained using the defect-pool model for a-Si:H. Therefore, the information obtained by qs C-V measurements can be used to characterize the defects close to the insulator/semiconductor interface in PECVD a-Si:H.

Silicon and hydrogen ion implantations have been used to affect the absorption of the infrared stretching modes at 2000 cm⁻¹ and 2100 cm⁻¹ in hydrogenated amorphous silicon (a-Si:H). The a-Si:H films have been prepared by plasma enhanced chemical vapor deposition. It has been established that the values of the absorption strengths of stretching modes of the isolated monohydrides, A₂₀₀₀, and clustered hydrogen forms, A₂₁₀₀, are not equal and remain constant for all ion implantation doses. It has been suggested that the absorption strengths do not vary when a post-deposition treatment of samples is associated with the introduction of structural defects in the amorphous silicon network.

A new method has been suggested and developed since 1985 with the aim to help in dating archaeological objects. This specific modern combination of chemical and physical

techniques is denoted as thermally or optically stimulated luminescence dating (TL or OSL dating). Initially the method has been proposed for dating ancient ceramics, but a new modification has been invented for treating ancient stone buildings. The scientific team has to include archaeologists, physicists (optics and spectroscopy), chemists and also specialists in low radioactivity measurements (dosimetric control).

Based on the publications from 1990-2006 an attempt was made to summarize some of the important tendencies in integrated optics as well as the different techniques for activating lithium niobate by doping it with rare earth (lanthanide) ions. 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.

The phase composition of proton exchanged waveguiding layers obtained in LiNbO₃ of main crystallographic orientations under different diffusion parameters was analysed by waveguide mode, IR and Raman spectroscopy or their combinations. The results obtained could be used for estimation of the phase composition and therefore of the optical and electrooptical properties of proton exchanged waveguides in LiNbO₃.

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 results obtained show that co-doping with lithium leads to considerably higher efficiency of the Sm³⁺ luminescence in comparison with samples doped with samarium only. Relatively strong f-f emission was observed in a wide range of wavelengths between 220 and 390 nm. The decay of Sm³⁺ luminescence excited with third harmonic generation pulses of a Nd-YAG laser (335 nm) was influenced to some extent by introduction of Li⁺ ions. On the contrary, the luminescence spectrum did not depend on the presence of lithium.

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.

- FIBER OPTICS

Simple sensor element consisting of a side-polished single-mode fiber and a planar metal oxide waveguide is described. The thin ZnO planar waveguide was produced on the polished fiber surface by pulsed laser deposition at optimized processing parameters. The operation principle of the waveguide structure bases on distributed coupling between the fiber mode and the corresponding mode of the metal oxide planar waveguide and on establishing the spectral behaviour of the channel- dropping filter thus obtained when exposed to a gas. A measurement scheme for “in-situ” control of the film thickness during the deposition process was developed and applied. XRD measurements and SEM were applied to characterize the structure and the surface morphology of the planar waveguide, grown on the quartz substrates. The influence of the processing parameters, such as substrate temperature and oxygen pressure applied during deposition, on the sensitivity to ammonia of the sensing element was investigated.

The numerical evaluation of the spectral position of the resonances of the fiber and the planar waveguide modes showed that change the film refractive index by 0.001 will produce a shift of the channel-dropping filter minimum by 1 nm.

The experimental investigation of the sensing properties of the element were also performed. Spectral changes of 0.03nm for 1.5% butane diluted in N₂ and 1.2nm for pure butane were detected, which corresponds to the refractive index change in ZnO film by 3×10^{-5} and 1.2×10^{-3} for the two concentrations, respectively. The response time and the recovery time of the sensor element are in the range from 3 to 5 s.

Spectral changes of 0.16, 0.27, 0.49, and 1.13 nm for NH₃ concentrations of 500, 1000, 2000, and 5000 ppm, correspondingly were registered.

- HOLOGRAPHIC DIFFRACTION GRATINGS

Resonant diffraction gratings have been developed in order to form femto-second laser pulses. High efficiency, broad-band TE-polarization diffraction over a wavelength range centered at 800 nm is obtained by high index gratings placed on a non-corrugated mirror. First, an all-dielectric compression grating of close to 100% efficiency over a 40 nm wide spectral width suitable for femtosecond laser machining of high average power can be fabricated with sufficient control. Secondly, a compression grating associating a flat metal mirror and a corrugated high index dielectric overlay can be fabricated to match the demands of femtosecond CPA laser down to 20 fs pulse duration. The fabrication technology is difficult; however, the present work has permitted to identify fabrication steps which can lead to a better control and to a major reduction of the fabrication costs. A damage threshold slightly above 1 J/cm² was measured under the incidence of 50 fs T-polarized pulses in both grating types. This result may have a major impact on the whole laser

A 90% input coupler has been developed for exciting integrated optical waveguides. This coupler consists of a resonant diffraction grating, which is fabricated directly onto the waveguide surface.

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 1030nm/13W output under 20W 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.

- MICRO- AND NANO-PHOTONICS "Georgy Zartov"

Stable wideband antireflection coatings for the spectral region 1.06μm have been created technologically. The investigations included the determination of the refractive index dispersion for each layer at different evaporation conditions as well as the structure optimization.

Initial experiments have been performed for the laser mirrors preparation for the UV spectral region, as well as for interference filters for visible region. A laser mirror for the specific needs of the firm "Optics" Panaguriszte has been created.

We continue our theoretical and experimental investigations on polarization properties of Vertical-Cavity Surface-Emitting Lasers (VCSELS). The dependence of the spectral half width of the light generated by a VCSEL on injection current, polarization and temperature are experimentally investigated. New VCSELS with quantum dot active medium are investigated experimentally. Suitable rate equation models are developed which also consider the susceptibility of semiconductor medium with quantum wells and/or quantum dots under anisotropic mechanical strain.

We investigated theoretically and experimentally the stationary regimes in VCSELS with extremely short external resonator. Detailed mapping of polarization behavior is carried out in the plane of injection current external-cavity length using in-home developed rate equation model. Excellent agreement with the same experimental mapping is demonstrated.

In such a way, such system can be successfully used for control and stabilization of light polarization.

The phenomenon of Stochastic resonance, that is the synchronization of system dynamics to internal time scale in the system when adding external noise to the system has been successfully demonstrated in VCSELs subject to optical feedback from two external cavities.

Our experimental and theoretical investigations of orthogonal optical injection in VCSELs (polarization of injected light is linear and orthogonal to the one of the free running VCSEL mode continues. Experimentally and theoretically a new Hopf bifurcation has been discovered which limits the injection locking region below the codimension 2 bifurcation when the saddle-node and the Hopf bifurcation lines cross. Furthermore the interplay with a new Torus bifurcation on the two mode solution and the polarization switching is revealed. Finally, we investigated both theoretically and experimentally the role of the first order mode for switching and injection locking for large positive detuning.

The theoretical investigations on the impact of VCSEL polarization properties on the level of synchronization revealed unexpected improvement of the correlation properties for the case of two mode dynamics.

Photonic crystal VCSELs have been widely investigated theoretically. A detailed mapping of the modal properties depending on the PC parameters is carried out. Improved operation is predicted for bottom-emitting devices. Furthermore, for a first time the impact of the PC hole depth has been analyzed. Polarization stabilization has been numerically predicted when breaking the six-fold symmetry of the PC.

II. OPTICS AND SPECTROSCOPY OF ANISOTROPIC AND NONLINEAR MEDIA

- OPTICS AND SPECTROSCOPY OF THERMOTROPIC LIQUID CRYSTALS

The electroconvection in nematic liquid crystals, which appear before smectic C phase at cooling, was studied. Three detached nematic regions with characteristic electroconvections were detected under temperature variation. The influence of the change of the magnitude and the sign of the electroconductivity anisotropy, as well as the influence of the nematic director location (both driven by the temperature variation), on electroconvection mechanism and the relevant optical patterns were analyzed. An isotropic character of the electroconvection instability initiated by the ‘loss’ of electroconductivity anisotropy below the temperature T^* , dividing the nematic phase in classical and quasi-smectic nematic ranges, and in the vicinity of the nematic-isotropic phase transition was detected. The characteristic for the isotropic electroconvection prewavy pattern was observed for the first time in the nematics with short range smectic C order and dimerized molecules. The competition between the two possible EC mechanisms: the Carr-Helfrich and the ‘isotropic’ one, was discussed.

The surface anchoring in a smectic C liquid crystal, in contrast to that in nematics, has been studied very scantily. We have presented the angular dependence of the surface anchoring energy of the S_C with a temperature independent tilt angle (8OBA) on two surfaces: $SiO_x/ITO/glass$ and a holographic diffraction grating. This dependence was measured using a twist – cell method. The smectic C single local monocrystal rotation, starting at a critical bulk twist, reveals surface anchoring breaking. A model for the bulk twist influence on the smectic C single local monocrystals was suggested.

An optical method for measurement of the bandwidth of the reflection spectral band (expressing the bandgap of the liquid crystal photonic crystal fibers) for chiral nematic liquid crystals, infiltrated in photonic crystal fibers, allowing an effective electrical control of such optical waveguides, is presented. An effective driving of the helix axis alignment at a diversity of electric field magnitudes and frequencies was achieved.

The zenital and azimuthal surface anchorings of liquid crystal mixtures on variety of orientating surfaces were calculated.

- THEORETICAL METHODS IN MOLECULAR PHYSICS

The vibrational spectrum and ground electronic state potential energy surface (PES) of thiophosene (CSCl₂) have been studied quantum mechanically using a completely symmetrized Hamiltonian formalism and vibrational basis set, including all 6 molecular vibrational modes in the calculations. The calculated vibrational frequencies have been compared to the experimentally measured data by other authors. From a good fit achieved between the theoretical and experimental frequencies up to considerably high excess vibrational energies, the harmonic and some anharmonic (cubic and quartic) force constants of the molecular PES have been reliably determined.

We have performed a calculation on the rate constant of intersystem crossing T₁-S₀ in thiophosgene, using a modified golden rule expression and a set of specific symmetrized vibrational coordinates for description of the potential energy surface (PES) and basis vibrational wavefunctions in both electronic states. The results from the present calculation were compared to those obtained previously using a different theoretical approach, as well as to experimentally measured data.

- MULTY-PHOTON PROCESSES. NONLINEAR OPTICS

The nonlinear optical response of highly dipolar media upon two-photon-resonant activation by intense nanosecond laser pulses is studied. The nonlinear contribution to the absorption and refraction of a three-level mixed-parity molecular system is calculated and the effect from the incident laser intensity is estimated. The numerical results indicate that under two-photon resonance conditions the intensity-dependent absorption and refraction of highly dipolar media can be significantly enhanced by the permanent dipole moments of the electronic molecular states coupled by two-photon resonance. From a practical point of view, the enhanced nonlinearity of such media have a potential for various two-photon-induced intensity-dependent nonlinear optical applications.

A general uncorrelated jumps model for the reorientation of anisotropic molecules in anisotropic media is developed. The proposed model is more general than the strong collision one, which can be derived from our approach as a particular case. The theoretical model is compared with other approaches already existing in the literature. The new solutions obtained for the molecular reorientation are quite promising for the investigation of the spinning and tumbling relaxation in anisotropic media. The proposed approach can be generalized taking into account the molecular biaxiality and therefore will be applicable to any anisotropic system with rotational degree of freedom.

Coherent and Squeezed States are widely discussed in literature, but there exist an other class of states (Covariance), minimizing more general inequality [Schrodinger, 1930] than Heisenberg's one. To examine this relation and classify the Covariance, Squeezed and Coherent States, we consider the quantum optical problem of the propagation of electromagnetic waves in an anisotropic waveguide. The squeezed parameter, taking place in both - squeezed and covariance states, is expressed in explicit form through the main parameters of degenerated parametric amplification in an anisotropic waveguide. The expressions for the three independent quantum fluctuations are derived. The presence of nonlinearity is essential for the Covariance that appears in the Schrodinger Uncertainty Relation. Proposal for experimental realization of Covariance States in anisotropic optical waveguides is done.

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

DNA is not the static entity suggested by the famous double helix structure. It shows large fluctuational openings, in which the bases, which contain the genetic code, are temporarily open. Therefore it is an interesting system to study the effect of nonlinearity on the physical properties of a system. A simple model for DNA, at a mesoscopic scale, can be investigated by computer simulation, in the same spirit as the original work of Fermi, Pasta and Ulam. These calculations raise fundamental questions in statistical physics because they show a temporary breaking of equipartition of energy, regions with large amplitude fluctuations being able to coexist with regions where the fluctuations are very small, even when the model is studied in the canonical ensemble. This phenomenon can be related to nonlinear excitations in the model. The ability of the model to describe the actual properties of DNA is discussed by comparing theoretical and experimental results for the probability that base pairs open at a given temperature in specific DNA sequences. These studies give us indications on the proper description of the effect of the sequence in the mesoscopic model.

Telomeres can fold into t-loops that may result from the invasion of the 3' overhang into duplex DNA. Their formation is facilitated in vitro by the telomeric protein TRF2, but very little is known regarding the mechanisms involved. Here we reveal that TRF2 generates positive super coiling and condenses DNA. Using a variety of TRF2 mutants, we demonstrate a strong correlation between this topological activity and the ability to stimulate strand invasion. We also report that these properties require the combination of the TRF-homology (TRFH) domain of TRF2 with either its N- or C-terminal DNA-binding domains. We propose that TRF2 complexes, by constraining DNA around themselves in a right-handed conformation, can induce untwisting of the neighboring DNA, thereby favoring strand invasion. Implications of this topological model in t-loop formation and telomere homeostasis are discussed.

In eukaryotes, base excision repair (BER) is responsible for the repair of oxidatively generated lesions. The mechanism of BER on naked DNA substrates has been studied in detail, but how it operates on chromatin remains unclear. Here we have studied the mechanism of BER by introducing a single 8-oxo-7,8-dihydroguanine (8-oxoG) lesion in the DNA of reconstituted positioned conventional and histone variant H2A.Bbd nucleosomes. We found that 8-oxoguanine DNA glycosylase, apurinic/apyrimidinic endonuclease, and polymerase β activities were strongly reduced in both types of nucleosomes. In conventional nucleosomes SWI/SNF stimulated the processing of 8-oxoG by each one of the three BER repair factors to efficiencies similar to those for naked DNA. Interestingly, SWI/SNF-induced remodeling, but not mobilization of conventional nucleosomes, was required to achieve this effect. A very weak effect of SWI/SNF on the 8-oxoG BER removal in H2A.Bbd histone variant nucleosomes was observed. The possible implications of our data for the understanding of in vivo mechanisms of BER are discussed.

- COLORIMETRY AND ITS APPLICATIONS IN INDUSTRY AND ENVIRONMENT

A programme and a test procedure were elaborated for the use of a miniature USB colorimeter for solid, transparent and semitransparent samples.

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62. M. Kuneva, S. Tonchev, “Phase Formation in Proton-Exchanged Layers in LiNbO_3 ”, *Proceedings of NPS’08 (Nanoscale Phenomena and Structures, February 26 – March 02, 2008, Sofia)*.

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, Department of Photonics, Belgium

2. Forschungszentrum Rossendorf, Institut fuer Ionenstrahlphysik und Materialforschung, Germany.

3. Pluridisciplinary Laboratory Joliot Curie at the Ecole Normale Supérieure, Lyon (CNRS UMR 5161) France, The Institute Albert Bonniot, UJF & INSERM U309, and CEA, Grenoble, France and funded by Ministry of Education and Science BG (K 1402/ 2004), and 6th FP ECC MCRTN “CLUSTOXDNA”.

4. Ecole Normale Supérieure de Lyon, Laboratoire Pluridisciplinaire Joliot-Curie, (CNRS USR 3010) France; UJF, Institute Albert Bonniot, INSERM U309 and CEA-CENG, Grenoble, France

5. Research Institute of Solid State and Optics, Budapest, HAS, Hungary.

TEACHING ACTIVITIES:

1. 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., D.Sc.; Assoc.Prof. A. Zheliaskova, Ph.D.; Assist.Prof. V. Vitkova, Ph.D.; Assist.Prof. R. Marinov, Ph.D.; J. Genova, physicist

RESEARCH ACTIVITIES:

Three projects were developed in the Laboratory “Liquid Crystals” during 2007 on different contracts: one of them with ISSP, one with BAS and one with NSF.

The surface energy of the smectic-A was estimated by two methods: a) from the balance between the electrostatic energy of the smectic-A and the surface energy (an experiment of Le Berre and Hareng) and b) from the balance between the elastic energy of (1/2) confocal domain and the surface energy of the smectic-A (obtained by us). The two methods give comparable results: 0.24 erg/cm^2 versus 0.14 erg/cm^2 , respectively.

The formation of the smectic-A from strongly-deformed nematic with initial hybrid (homeo-planar) orientation was observed. Arrays of confocals, observed for the first time by Marignan-Malet-Parodi, were formed at the glass plate with a homeotropic orientation of the nematic and edge-dislocations were formed at the glass plate with planar orientation of the liquid crystal. The orientation of the smectic-A shows that the smectic-A was formed first in the middle oriented part of the nematic (a higher transition temperature of the nematic-smectic-A phase transition) and then in the surface regions where the nematic was strongly deformed (a lower transition temperature of the nematic – smectic-A phase transition). These observations undoubtedly confirmed the theory of de Gennes for the nematic-smectic-A transition that the temperature of the nematic-smectic-A phase transition decreases when the smectic-A grows from previously strong deformed nematic phase.

It was experimentally proved that the smectic-B phase of the liquid crystal 6O.4 (hexyloxy-benzylidene-butylaniline) is crystalline.

Some elastic constants of the smectic-C phase of the liquid crystal NOBA (n-nonyloxybenzoic acid) ($A_{12} = 16A_{21}$ and $|A_{11}| < 1/8A_{12}$) were estimated on the basis of the conditions for the formation of smectic-C broken focal conics and some well-known data from the literature.

These results are part of successfully defended dissertation for obtaining of the scientific degree: “Doctor of physical sciences”.

The dependence of the mechanical properties (bending elasticity at free flip-flop and stretching elasticity) of lipid bilayer, containing a soluble in the water phase inclusion, on the concentration of the inclusion in the membrane was theoretically determined.

The vibrational spectrum of the chemical compound thiophosgen was studied by means of a developed for this purpose quantum-mechanical model. The calculated vibrational frequencies were compared with the experimental ones, obtained by other

authors. The harmonic and some of the anharmonic force constants of the model were determined from the comparison.

The bending elastic modulus of lipid membranes was measured using the method of thermally induced shape fluctuations. The electroformation was performed using glasses covered by thin aluminum conductive layers. The results were compared to those obtained using ITO covered glasses. The nature of the conductive layer does not influence the measured value.

The electroformation protocol was adapted for formation of lipid vesicles containing rhodamin marker. The bending modulus of membranes containing marker molecules and immersed in water phase containing sucrose was measured.

Preliminary experiments were performed in order to study the dynamics of thermally induced shape fluctuations of quasi-spherical lipid vesicles (as planned in the frames of the research project VK-01-07, funded by ISSP – BAS). An experimental procedure for GUV formation with the synthetic lipid dioleoyl phosphatidylcholine (DOPC) was developed on the basis of the electroformation method. A specially created electroformation cell was used (with plane ITO electrodes). Experimental data (long image sequences of fluctuating GUVs with diameters higher than 20 μm) was accumulated, which will permit the calculation of the bending elasticity of DOPC membranes and also the deduction of the intermonolayer friction coefficient in the bilayer.

The rheology of diluted suspensions of deformable particles (lipid vesicles and erythrocytes) was studied. The viscosity of vesicular and red blood cell suspensions (effective viscosity) was determined experimentally as a function of the viscosity contrast between the internal and external solutions. The volume fraction of vesicles and erythrocytes was measured in each sample in order to obtain the so-called intrinsic viscosity. The experimental data are in excellent agreement with the theoretical results obtained recently in the group of Dynamics of complex fluids and morphogenesis in the Laboratory of Physical Spectrometry (University of Grenoble “Joseph Fourier” and CNRS, Grenoble, France). Thus, the experimental dependence of the intrinsic viscosity of diluted red blood cell suspensions (haematocrit up to 5%) on the viscosity of the external medium was obtained for the first time. The effects of hydrodynamic interactions between the particles on the rheology of red blood cell suspensions at increase of the erythrocyte volume fraction (up to 20%) were studied. The viscosity of diluted vesicular suspensions (vesicle volume fraction, less than 10%) was measured as a function of the viscosity contrast of the solutions inside and outside the vesicle.

PUBLICATIONS:

1. 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. Optoelect. Adv. Mater.* **9**, 435 (2007).
2. V. Vitkova, V. Doltchinkova, M. D. Mitov, and I. Bivas, Membrane bending elasticity of human erythrocyte ghosts, *Journal of Optoelectronics and Advanced Materials*, **9**, 431-434 (2007).
3. Svetoslav Rashev, Isak Bivas, David C. Moule, Large scale vibrational Hamiltonian calculations on thiophosgene, *Chemical Physics Letters*, **438**, 153-156 (2007).
4. J. Genova, A. Zheliaskova, M.D.Mitov, Mono- and disaccharides influence elasticity of lipid membranes, *Journal of Optoelectronics and Advanced Materials*, **9**, 2, (2007) p.427-430.
5. H. Hinov, Electrooptical and Flexoelectrical Properties and Phenomena in Thermotropic Liquid Crystals, D. Sc. Thesis (2007).

DIVISION SOFT MATTER PHYSICS

LABORATORY

BIOMOLECULAR LAYERS

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TOTAL STAFF: **6**
RESEARSH SCIENTISTS: **4**

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

RESEARCH ACTIVITIES:

Flexoelectricity is a biophysical phenomenon that provides a reciprocal relationship between membrane curvature and polarization, thus enabling various membrane structures to function like mechanoreceptors. The processes of mechanotransduction under a pulse excitation in flexoelectric biomembranes, either channel-free or channel-containing are investigated. The process of mechanotransduction in membranes seems to benefit not only from specialized and localized elements like stress-activated channels, but also from the collective properties of the mechanosensitive membranes as a whole. These collective properties evolve from the liquid crystal character of membranes and are best understood in terms of liquid crystal physics. Among them, curvature elasticity and flexoelectricity hold the first places. They ensure an effective and direct way of transformation of mechanical energy of the whole membrane into electrical one and vice versa. In doing so, both the lipid bilayer part of the membrane and the cytoskeleton of a special architecture are vital. The localized protein structures like membrane channels are obviously able to interact with global membrane properties in a striking way that is not fully understood.

The route for obtaining of hydrophobic superparamagnetic particles contrast and tracing agents for magnetic resonance imaging (MRI) has been examined. A shorter synthesis was proposed by integration of the Fe_3O_4 – magnetite obtaining and the surface modification. The nanoparticles were investigated by IR, TEM, XRD and AFM techniques.

A new contrast agent for liver MRI was propose. The effect and the degree of change in the rabbit liver MRI signal by using the experimental contrast substance: superparamagnetic iron oxide (SPIO) nanosized particles entrapped in β -cyclodextrin was studied. The contrast agent prepared by us substantially reduces the MR intensity of liver parenchyma during T_2 magnetic resonance imaging. The shortening of T_2 relaxation time is about 50% with the 80 nm size of the nanoparticles used. Our initial experiments demonstrate that liver tissue difference of signals before and after contrasting is sufficient for the detection of focal liver lesions and is potentially usable for their diagnosis.

PUBLICATIONS:

1. Alexander G. Petrov, Flexoelectricity and mechanotransduction (Invited Review) In: Current Topics in Membranes, vol. 58: Mechanosensitive channels, O.P. Hamill, Ed., Elsevier/Academic Press, pp. 121-150 (2007).

2. S. D'Elia, C. Versace, N. Scaramuzza, Y. Marinov, A. G. Petrov, Pretilted nematic layers of 5CB on PTFE treated glass supports, *Mol. Cryst. Liq. Cryst.* 465, 301-308 (2007).
3. Y. Marinov, G. B. Hadjichristov, A. G. Petrov, Controllable-gradient microscale PDLC electro-optical materials formed by nanosecond laser photopolymerization, *J.Optoelec.Adv. Mat.*, 9, 417 - 419 (2007).
4. A.G. Petrov, Y. Marinov, S. D'Elia, S. Marino, C. Versace, N. Scaramuzza, Dielectric and flexoelectric oscillations in PDLC studied by flexoelectric spectroscopy and laser light diffraction, *J.Optoelec.Adv. Mat.*, 9, 420 - 423 (2007).
5. T. Angelov, D. Radev, G. Ivanov, D. Antonov, A.G. Petrov, Hydrophobic magnetic nanoparticles: synthesis and LB film preparation, *J.Optoelec.Adv. Mat.*, 9, 424 - 426 (2007).
6. M. Petrov, B. Katranchev, H. Naradikian, T. Angelov, K. Panajotov, A. Zheltikov, Electrically tunable chiral nematic liquid crystal photonic crystal fibers, *J.Optoelec.Adv. Mat.*, 9, 446 - 448 (2007).
7. H. P. Hinov, Y. Marinov, An electro-magneto-optical resonance method for determination of the value and sign of the flexoelectric coefficients in nematics, *J.Optoelec.Adv. Mat.*, 9, 435 – 437 (2007).
8. E. Vlahov, B. Blagoev, E. Mateev, L. Neshkov, T. Nurgaliev, L. Iakov, K. Toncheva, Y. Marinov, K. Nenkov, I. Radulov, K. Piotrowski, A. Szewczyk, M. Baran, R. Szymczak, Magnetron sputtering deposition and characterization of GdMnO₃ thin films, *J. Opt. Adv. Mat.*, 9 (2), 456–459 (2007).
9. R. Kalionski, T. Merodiiska, M. Dencheva-Zarkova, L. Todorova, S. Naydenova, V. Lovchinov, Z. Lalchev, I. Nedkov, A.G. Petrov, Magnetic resonance imaging by specially formulated iron oxide nanoparticles, *Compt. rend. Acad. bulg. Sci.* 60, No8, 893-898 (2007).
10. T. Angelov, D. Radev, G. Ivanov, D. Antonov, I. Spirov, T. Ruskov, A.G. Petrov, Hydrophobic magnetic nanoparticles: synthesis and characterization, *Nanoscience& Nanotechnology*, 7, eds. E. Balabanova, I. Dragieva, Heron Press, Sofia, pp. 47-50 (2007).

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".

TEACHING ACTIVITIES:

Alexander G. Petrov - lecture courses on Bioelectronics and Soft Matter Physics for Chemistry Department and Physics Department 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: **9**

RESEARCH SCIENTISTS: **8**

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

RESEARCH ACTIVITIES:

1. ATOMIC STRUCTURE, SPECTRA AND CONSTANTS

Radiative lifetimes of highly lying excited states of Zr II have been determined. The Time Resolved Laser Induced Fluorescence method was used. Most of the data were determined for first time. The obtained results will give possibilities for determination of transition probabilities of the transitions originating from these excited states.

The experiment for determination of cross sections of interaction of resonance and metastable states of ^3He with molecule N_2 was prepared.

2. HOLLOW CATHODE DISCHARGE - PROPERTIES AND APPLICATION

The contribution of different excited Ne I states to the coherent conductance of self alignment ensemble of atoms was estimated by selective optical excitation or deexcitation. It is shown that the coherent conductance can change its sign depend on ionization characteristics of the admixture metal atoms. Nondecreasing, oscillating solutions have been obtained for the equation of equivalent electric chain at random single deviation of working point, including in the case of positive dynamical resistance. More correct approximation of the SRIM software was realized, taking in to account processes in the glow discharge conditions.

3. HOLLOW CATHODE DISCHARGE AS AN ACTIVE LASER MEDIUM

The spontaneous emission of the UV lines 357 nm, 381 nm and violet line 406 nm of the nitrogen molecule is investigated. The discharge is ring shaped in Ar- N_2 and Ne-Ar- N_2 mixtures at our discharge conditions. Stable and homogeneous discharge is obtained in He-Ar- N_2 mixture.

An improved design of the discharge tube is realized to reach stable operation at higher pressures and currents.

4. APPLICATION OF HOLLOW CATHODE DISCHARGE

The studies of elementary processes with H^- participation are reviewed in a hollow cathode discharge and a positive column glow discharge in order to clarify the main processes for H^- formation and destruction. The H^- concentration is estimated by modelling these discharges and it is measured by both photo detachment (optogalvanic) method and an emission method.

The H^- concentration is investigated as a function of the glow discharge type, gas mixture and discharge conditions. At the chosen discharge conditions the concentration of H^- is more than an order of magnitude higher in a hollow cathode glow discharge than in a positive column glow discharge. Besides, the $(Ne+H_2)$ mixture hollow cathode discharge is more favourable for higher H^- concentration than the pure H_2 discharge. The results obtained are important for study the negative ions behavior in the recent technological plasmas.

PUBLICATIONS:

Review article

V. Gencheva, R. Djulgerova, V. Mihailov, T. Dohnalik, Z. Petrovic – “On hydrogen negative ion formation and concentration measurements in hollow cathode discharge and positive column glow discharge”, in “First International Workshop on Nonequilibrium Processes in Plasma Physics and Studies of Environment”, Eds. Z. Petrovic, G. Malovic, M. Tasic, Z. Nikitovic, Journal of Physics: Conference Series **71** (2007) 012009 doi:10.1088/1742-6596/71/1/012009

Articles

1. M. Ortiz, R. Mayo, E. Biémont, P. Quinet, G. Malcheva, K. Blagoev « Radiative parameters for some transitions arising from $3d^94d$ and $3d^84s^2$ electronic configurations in Cu II spectrum” J. Phys. B:Atom, Mol.Opt. Phys. **40**, 167-176(2007)
2. J. Gurell, E. Biémont, K. Blagoev, V. Fivet, P. Lundin, S. Mannervik, L. O. Norlin, P. Quinet, D Rostohar, P. Royen, P. Schef, “Laser-probing measurements and calculation lifetimes of the $5d^2D_{3/2}$ and $5d^2D_{5/2}$ metastable levels in Ba II” Phys. Rev **75** 052506(2007)
3. E. Biémont, K. Blagoev, V. Fivet, G. Malcheva, R. Mayo, M. Ortiz, P. Quinet, Experimental and theoretical transition probabilities in singly ionized gold, Monthly Notices of Royal Astronomical Society - Main Journal, **380**, 1581-1588(2007)
4. В. Полищук, Н. Горбева, Д. Жечев, Г. Тодоров, “ Влияние интерференции атомных состояний на гальванические свойства плазмы газового разряда”, Вестник Санкт Петербургского Университета, сер. Физика, 4, 2007
5. Nely Bundaleska, Zoritsa Tomova, Vasilka Stefleкова and Dimo Zhechev, “*Ion sputtering of cathode surface in a hollow cathode discharge*”, Vacuum 134, 2007 1-4
6. L. Petrov, D. Slavov, A. Gorbenko, V. Stefleкова, V. Polistuk, D. Zhechev, G. Todorov “*Self-induced coherence and conductivity of glow discharge*”, Proc. SPIE, vol. 6604, 660401 (2007).
7. D Slavov, L Petrov, V Arsov, V Stefleкова, A Gorbenko, V Polischuk, D Zhechev, N Mihailov and G Todorov, Magneto-galvanic signals and ionization processes in a neon hollow cathode discharge, J. of Phys. Conference Series (accepted) (**VEIT 07**)
8. E Dimova, A Fioretti, D Comparat, P. Pillet, G Stern – Proceedings of SPIE 6604, 66040M (**2007**)Magnetic or optical molasses loading for a Cs dipole trap, **Conf. reports**
9. G. Malcheva, K. Blagoev, R. Mayo, M. Ortiz, J. Ruiz, H. Nilsson, L. Engstrom, H. Lundberg and S. Svanberg, Experimental radiative lifetimes of highly excited states in Zr I, ASOS 9, P.47, 2007.
10. Jonas Gurell, Emile Biémont, Kiril Blagoev, Vanesa Fivet, Petr Lundin, SvenMannervik, Lars-Oliv Norln, Pas. Quinet, Dnjla Rosohar, Peder Royen and Peter Shifer, Laser Probing Measurements and Calculations of Lifetimes of the $5d^2D_{3/2}$ and $5d^2D_{5/2}$ Metastable Levels in Ba II, ASOS 9,40,2007.
11. M. Ortiz, R. Mayo, É. Biémont, P. Quinet, V. Fivet, G. Malcheva and K. Blagoev, "Transition probabilities for lines originating from 6d and 7s configurations in singly ionized gold", ECAMP 9, Creta, Greece (2007).

12. R.Djulgerova, V. Mihailov, V. Gencheva, M. Todorov, J. Koperski, M. Strojecki, Z. Petrovic - "Plasma instabilities in a hollow cathode discharge demonstrated by the dynamic Ne optogalvanic signals", Proc.5th EU-Japan Joint Symposium on Plasma Processing, Serbia, 2007, 1(1-4).
13. V. Mihailov, R.Djulgerova, V. Gencheva, M. Todorov, J. Koperski, M. Ruszczak, T. Dohnalik, Z. Petrovic – "Argon dynamic optogalvanic signals in 445-467nm spectral range for wavelength calibration", Proc.5th EU-Japan Joint Symposium on Plasma Processing, Serbia, 2007, Po 2(1-4).
14. E. Dimova, Quenching of ^3He excited states ($n>2$) by collisions with neon atoms, ECAMP 9, (2007).
15. Sofikitis Dimitris, G. Stern, A. Fioretti, E. Dimova, D. Comparat and P. Pillet, Routes towards Cs atom BEC via high density dipole trap, ECAMP9.
15. V. Steflekova, E. Dimova and D. Zhechev Self-sustained oscillating mode of operation of a hollow cathode discharge at positive dynamic resistance, ECAMP9(2007).
16. D. Slavov, L. Petrov, V. Arsov, V. Steflekova, A. Gorbenko, V. Polischuk, D. Zhechev, N. Mihailov and G. Todorov *Magneto-Galvanic Signals and Ionization Processes in a Neon Hollow Cathode* Doctoral training course, Brusel, 2007.

TEACHING ACTIVITIES:

PhD student: V. Steflekova, supervisor Prof. D. Zhechev
 Organization of the 10th winter seminar of young scientists

NEW ACTIVITIES:

1. Laser cooling and trapping of atoms – The development of the experimental set-up for laser cooling and trapping of Rb atoms and experiments with cooled atoms is going on.
2. Investigations of traces of elements in archeological artifacts using Laser Induced Breakdown Spectroscopy.

ONGOING RESEARCH PROJECTS:

1. Physics of atoms, molecules and plasma - project in the framework of Bulgarian Academy of Sciences
2. Radiative properties of ionic spectra (supported by Bulgarian National Science Foundation – contract 1516/2005) Experimental investigation of Au II spectrum is in progress.

INTERNATIONAL COLLABORATION:

1. Radiative Constants in Zr I spectrum - Laser Lab in Europe" (RII-CT-2003-506350) - Prof. DSc K. Blagoev
2. International collaboration under the Problem "Laser spectroscopy of low-living isomers" with Laboratory of Nuclear Reactions, Dubna, Russia – Prof. DSc. D. Zhechev
3. "Possibilities of the glow discharge in hollow cathode as a plasma source for obtaining and investigation of new materials and in the metrology", Institute of physics, University of Krakow - Assoc. Prof. DSc R. Dyulgerova
4. Dynamic optogalvanic signals in a hollow cathode glow discharge as a technique for plasma, Institute of Physics of Belgrade, Serbia and Montenegro – Assoc. Prof. DSc R. Dyulgerova

DIVISION LASER, ATOMIC, MOLECULAR AND PLASMA PHYSICS

LABORATORY

METAL VAPOUR LASERS

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TOTAL STAFF: **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:

The research efforts at LabMVLs in 2007 were focused on the following main topics:

1. Theoretical and experimental studies of some elementary processes in the gas discharge plasma (reported in six publication works);
2. Investigation of the quality factor M2 of an oscillator-amplifier CuBr laser system (reported in two publication works);
3. Theoretical and experimental studies of the plasma processes in hollow cathode discharge lasers (reported in five publication works);
4. Development of a packet of control techniques for the states of multidimensional quantum systems with capabilities for essential applications in the quantum information and quantum computers (reported in 15 publication works).

Research projects

Totally 10 projects including:

- Projects supported only by the budget of BAS: 2
- Projects with additional support from the National Science Fund of the Bulgarian Ministry of Education and Science: 3
- Projects with additional support from ministries, institutions and companies in Bulgaria: 2
- Projects under agreements for cooperation between academies and institutes: 2
- Projects-contracts with external consigners incl. state and private companies, from both Bulgaria and abroad: 1

Patents, licenses:

- 5 patents
- patent applications: 2

PhD students:

- 5 PhD students

PUBLICATIONS:

Totally: 37 published in 2007 and 7 accepted for print

Papers published in international journals and proceedings

1. D.N. Astadjov, L.I. Stoychev and N.V. Sabotinov, M2-Factor for MOPA CuBr Laser System, Proc. SPIE Vol. 6604, 66040Z, (2007)
2. D. Astadjov, L. Stoychev and N. Sabotinov, M2 of MOPA CuBr Laser Radiation, Opt Quant Electron 39(2007):603–610; DOI 10.1007/s11082-007-9113-5, (2007)
3. M.Grozeva, D.Mihailova and N.Sabotinov, Dependence of laser power and gain on the cathode length of a sputtering copper ion laser, Journal of Physics: Conference Series, 63012028, (2007)
4. D. Mihailova, M. Grozeva, N. Sabotinov, J. van Dijk, W. Brok, J. van der Mullen , Theoretical and experimental studies of the plasma processes in hollow cathode discharge lasers, 28th ICPG Proceedings, Eds. J. Schmidt, M. Šimek, S. Pekárek, V. Prukner, IPPAS CR, v.v.i. publication, p.533-536, (2007)
5. Annemie Bogaerts, Krassimir A. Temelkov, Nikolay K. Vuchkov and Renaat Gijbels, Calculation of rate constants for asymmetric charge transfer, and their effect on relative sensitivity factors in glow discharge mass spectrometry, Spectrochimica Acta - Part B Atomic Spectroscopy 62 (4), pp. 325-336, IF=3.092, (2007)
6. J T Mouchovski, K A Temelkov, N K Vuchkov and N V Sabotinov, Laser grade CaF2 with controllable properties: growing conditions and structural imperfection, J. Phys. D: Appl. Phys, vol.40, IF=2.0772007, (2007)
7. M. Ilieva, V. Tsakova, N.K. Vuchkov, K.A. Temelkov, N. V. Sabotinov, UV copper ion laser treatment of poly-3,4- ethylenedioxythiophene, Journal of Optoelectr. and Advanced Materials, Vol. 9, No. 2, p. 303 - 306, 2007, IF=1.106, (2007)
8. 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, Proceedings of SPIE - The International Society for Optical Engineering 6604, art. no. 660410, (2007)
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