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Dear Colleagues,

This annual report gives an account of the second year of the second mandate of the Institute Administration in office. With respect to the scientific production the year 2005 was a continuing success for us. The number of papers in prestigious foreign and international journals is markedly increased. In this respect, it is a pleasure to underline and to acknowledge the commitment of our administration and staff to various responsibilities in science and management. Despite persisting economic difficulties it is this devotion of the staff that keeps the Institute going.

Two years ago the Scientific Council of the Institute adopted a new program for financial stabilization of the Institute via financial stabilization of its departments. Thus, the responsibility of heads of departments in this respect is greatly increased. This program proceeds with a variable success. Scientists engaged in nationally and internationally funded projects enjoy a better perspective and recognition of their results. Support by the National Science Fund of the Ministry of Education and Science, Innovation Fund of the Ministry of Economy and Energy, NATO, European Community, is gratefully acknowledged.

The administration also made joint efforts to get external funding for the Institute as a whole. Submitted grant application for scientific infrastructure to the National Council "Scientific Research" aimed at the restructuring of the scientific studies in the Institute around the priority subject of Nanoscience. Regardless the outcome of the application these efforts are going to continue.

Professor A. Derzhanski, Corresponding Member of the Academy, received the sign of honor of the Chemical Faculty of the Moscow State University. Team lead by A.G. Petrov received a 1st prize diploma from to the National Science Fund. Teams lead by N.V. Vitanov, S. Andreev and I. Bivas received Institute diplomas for the best scientific achievements of the year 2005. Medals and diplomas from international meetings and fairs, like the gold medals from East-West-Euro-Intellect exhibition for K. Kolentsov, L. Yourukova, E. Radeva, O. Ivanov, N. Peev and S. Simeonov brought pride and satisfaction not only to their winners, but to the Institute as a whole.

During the year 2005 the Institute of Solid State Physics elected as Honorary Member Professor Elena Vateva. This is our tribute to her great role in founding and establishing the Institute. D. Nesheva, L. Popova, M. Kalitsova, A. Zheliaskova H. Hinov, B. Terziyska, M. Bushev and M. Primatarowa received the George Nadjakov Sign of Honour 2nd degree.

Now we are looking forward to the 110 Anniversary of the birth of Academician George Nadjakov in 2006. The next, 14th edition of our renown International School of Condensed Matter Physics is devoted to him.

Alexander G. Petrov



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The Institute of Solid State Physics "Acad. G. Nadjakov" (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, 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). Co-organizers of the last few schools are the Department of Electronic Materials Engineering, University of Wales (Swansea, U.K.) and other British scientific organizations.

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 Langmuir-Blodgett layer deposition on various substrates for molecular electronics, 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 George 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.

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

SCIENTIFIC COUNCIL

Head: Prof. N. Tonchev, D.Sc.

Deputy Head: Prof. V. Kovachev, D.Sc.

- | | |
|----------------------------------|---|
| 1. Acad. A. G. Petrov, D.Sc. | 7. Prof. K. Blagoev, D.Sc. |
| 2. Acad. N. Sabotinov, D.Sc. | 8. Assoc. Prof. I. Bivas, D.Sc. |
| 3. Prof. M. Petrov, D.Sc. | 9. Assoc. Prof. S. Andreev, Ph.D. |
| 4. Prof. S. Rashev, D.Sc. | 10. Assoc. Prof. S. Aleksandrova, Ph.D. |
| 5. Prof. M. Gospodinov, D.Sc. | 11. Assoc. Prof. D. Nesheva, Ph.D. |
| 6. Prof. N. Vuchkov, D.Sc. | 12. Assoc. Prof. V. Gueorguiev, Ph.D. |
| 13. Assoc. Prof. M. Mitov, Ph.D. | |

THEORETICAL DEPARTMENT

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

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

RESEARCH ACTIVITIES:

Throughout the year, the research activities in the Theoretical department were focused on some modern problems of condensed matter theory, nonlinear phenomena, material science and statistical physics as well as on some interdisciplinary areas as neuron networks and complex correlations in biological systems.

The interaction of soliton solutions of the nonlinear Schroedinger equation with long (compared to the soliton length) segments with modified nonlinear coefficients was investigated. It was shown, that decreased nonlinear coefficients act as potential humps and lead to quasiclassical behavior of the soliton – transmission or reflection, depending on its kinetic energy. Much more interesting is the case of increased nonlinear coefficients, which act as a potential well and yields nonclassical behavior of the soliton. The numerical simulations show, that depending on the initial velocity and the nonlinear coefficient, there exist wide areas of transmission or capture of the soliton inside the segment, as well as an intermediate region of parameters, in which the transmission and capture of the soliton change periodically as a function of the length of the segment. The detailed analysis showed, that this periodicity is due to excitation of shape oscillations of the soliton at the first boundary and their resonant deexcitation at the second boundary. The resonance occurs when the length of the segment is commensurate with the spatial period of the shape oscillations. This is an important novel result in the theory of scattering of solitons from wide defects.

The magnetic phase diagram $h - J$ (where J is the frustration parameter) of two coupled ferromagnetic chains was investigated. It contains two phases with quantized cell magnetic moment $M=1/2$ and $3/2$. The analysis is performed by using spin-wave series and exact numerical diagonalization techniques. The critical behavior at the boundaries of the phases is studied in detail. The phase diagram turns out to be an exact magnetic analog of the diagram of the Hubbard boson model for one-dimensional periodic potential. This is of particular importance, since real systems in which Mott's insulator-superfluid transition can be studied are scarce.

Some simple lattice gas models, consisting of particles that carry a three-component classical spin, and associated with a simple-cubic lattice. Each site can host one particle at most, thus implicitly allowing for hard-core repulsion are investigated. The pair interaction, restricted to nearest neighbors, is ferromagnetic in spin space. We have studied thermodynamic properties and phase diagrams of the models by means of mean-field and two-site cluster treatments, and identified the tricritical points. The case of zero chemical potential has been investigated by grand canonical Monte Carlo simulations, so as to obtain a

quantitative test of the named approximations, as well as a more detailed physical characterization. The mean-field treatment was found to yield only qualitative agreement with simulation results, and the two-site cluster treatment recognizably improved upon it. Extensive simulations point to a second-order transition, whose universality class was found to be the same as its saturated-lattice counterpart.

PUBLICATIONS:

1. M.T. Primatarowa, K.T. Stoychev and R.S. Kamburova, Interaction of Solitons with Extended Nonlinear Defects, *Phys. Rev. E* **72**, 036608 (2005).
2. N.B. Ivanov and J. Richter, Frustrated ferrimagnetic ladder in a magnetic field, ID: 242530.0, MPI für Physik Komplexer Systeme (2005).
3. H. Chamati and S. Romano, "Classical Heisenberg lattice-gas model: Thermodynamic properties and phase diagrams"; *Phys. Rev. B* **72** 64424; (2005).
4. H. Chamati and S. Romano, "Two dimensional lattice gas models with extremely anisotropic interactions"; *Phys. Rev. B* **2**, 64444; (2005).
5. H. Chamati, S. Romano, L.A.S. Mol and A. R. Pereira, "Three dimensional generalized xy models: a Monte Carlo study"; *Europhys. Lett.* **72** (2005) 62-68.
6. H. Chamati, A.Ts. Djankova and N.S. Tonchev; "On the application of the non-extensive statistical mechanics to the black-body radiation"; *Physica A* **360** 297-303 (2006).
7. H. Chamati and N.S. Tonchev, "Generalized Mittag-Leffler functions in the theory of finite-size scaling for systems with strong anisotropy and/or long-range interaction", *J. Phys. A: Math. Gen.* **39** 469-478 (2006).
8. K.Koroutchev and E.Korutcheva, "Conditions for the emergence of spatially asymmetric retrieval states in an attractor neural network", *Central European J. of Physics*, **3** (2005) 409.
9. K.Koroutchev and E.Korutcheva, Bump formations in binary attractor neural networks, *PRE*, in press.
10. M.A. de la Casa, E.Korutcheva, J.M.R.Parrondo and J.de la Rubia, System size resonance in binary attractor neural network, *PRE*, in press.

ONGOING RESEARCH PROJECTS:

1. F1414: Spectra and Nonlinear Dynamics of Low-Energy Elementary Excitations in Quasi-One-Dimensional Systems, Financed by the NSF
2. DFG Project: Grant No 436BUL 113/106

INTERNATIONAL COLLABORATION:

1. Invited visits at the International Centre for Theoretical Physics – Trieste, Italy

LABORATORY

COLLECTIVE PHENOMENA in Condensed Matter

HEAD: **Prof. Dimo I. Uzunov, PhD, DSc**
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TOTAL STAFF: **4**
RESEARCH SCIENTISTS: **2**

Assoc. Prof. D.V. Shopova; Mr. Tsvetomir E. Tsvetkov, MS, post-graduate student (2004-2006); Miss Yana G. Maneva, BS, physicist at a temporal position (Nov 2005 - Apr 2006)

RESEARCH ACTIVITIES

The effect of a ferromagnetic triggering of the spin-triplet superconductivity (**M-trigger effect**) in some metallic compounds (UGe₂, URhGe, ZrZn₂) has been established and described. This new effect makes possible the explanation of coexistence of ferromagnetism and unconventional superconductivity of the f-electrons in the compounds UGe₂ and URhGe, and of the d-electrons in ZrZn₂. The phase diagram of this class of itinerant ferromagnetic compounds has been studied. The similarity of the M-trigger effect to a known phenomenon in improper ferroelectrics has been pointed out.

PAPERS

1. D. V. Shopova, and D. I. Uzunov, Phys. Rev. **B 72** (2005) 024531. "Meissner phases in spin-triplet ferromagnetic superconductors." See also: arXiv.org, cond-mat/0505087, and Preprint IC/2004/124 (ICTP, Trieste).
2. D. I. Uzunov, Preprint IC/2004/123, (ICTP, Trieste). "On the derivation of effective field theories." [See, also, arXiv.org, hep-lat/0412018.]
3. D. V. Shopova, and D. I. Uzunov, Preprint IC/2004/124 (ICTP, Trieste). "Meissner phases in spin-triplet ferromagnetic superconductors." (this article is a preliminary version of [1]).
4. D. V. Shopova, T. E. Tsvetkov, and D. I. Uzunov, Cond. Matter Phys. **8** (2005) 181. "Phenomenological study of spin-triplet ferromagnetic superconductivity." [See also, arXiv.org, cond-mat/0411503.]
5. D. V. Shopova, and D. I. Uzunov, Bulg. J. of Phys. **32** (2005) 81-114. (Invited review article). "Meissner superconductivity in itinerant ferromagnets." [See, also, arXiv.org, cond-mat/0506396.]
6. D. V. Shopova and D. I. Uzunov, in: *Progress in Ferromagnetism Research*, ed. by V. N. Murray, Nova Science Publishers, 2005. (ISBN: 1-59454-469-7). [See also: arXiv.org, cond-mat/04044261, and Preprint MPI-PKS (Dresden): mpi-pks/0404002.] Title: "Phases and phase transitions in spin-triplet ferromagnetic superconductors." (Invited review article).
7. V. G. Ivanov, *Meetings in Physics at Sofia University*, ed. by A. Proykova (Heron Press, 2005). "Effects of constraints on the phase transition to Bose-Einstein condensation."
8. D. I. Uzunov, Journal of BAS, No 4 (2005) 10-18. "Problems of the physics of phase transitions."

9. T. E. Tsvetkov, in: *Meetings in Physics at Sofia University*, vol. 6, ed. by A. Proykova (Heron Press, Sofia, 2005). "A simple model of ferromagnetic superconductivity in unconventional superconductors."
10. T. E. Tsvetkov, *Journal of BAS*, (2005). "Coexistence of uniform superconductivity and ferromagnetism in ferromagnetic superconductors."

CURRENT PROJECTS, GRANTS

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

SEMINARS, LECTURES, CONFERENCE REPORTS

1. 40-hour lecture course on physics of phase transitions [for PhD students of BAS and St. Kl. Ohridski University of Sofia].
2. Seminar talk: D. I. Uzunov, "On the derivation of effective field theories." (MPI-PKS-Dresden, 17th February 2005).
3. Seminar talk: D. I. Uzunov, "Effective field theory of BEC" (MPI-PKS-Dresden, 24th February 2005).
4. Conference talk: T. E. Tsvetkov, *Meeting in Physics at Sofia University*, "Coexistence of spin-triplet superconductivity and ferromagnetism," (14th March 2005).
5. Conference talk (T. E. Tsvetkov) at the Annual Vitosha Meeting of young scientists (Dec, 2005).
6. Conference talk (Y. G. Maneva) at the Annual Vitosha Meeting of young scientists (Dec, 2005).
7. Current seminars at CP Laboratory.

INTERNATIONAL COLLABORATION

1. **Memberships** (D.I.Uzunov): **(a)** The Editorial Board of *J. Phys. Studies* (Lviv, Ukraine), **(b)** The Editorial Board of the *Institute of Physics – IoP* (London, UK), and **(c)** The Board of Advisors of the *American Biographical Institute* (USA).
2. **Collaborative visits**, including seminar talks (D. I. Uzunov): **(a)** 45 days in MPI-PKS (Dresden), and **(b)** 12 days in JINR-Dubna.
3. **Referee reports** (by D. V. Shopova and D. I. Uzunov) for papers submitted to the journals of *IoP* (London).

LABORATORY

ELECTRON-PHONON INTERACTIONS

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

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TOTAL STAFF: **8**

RESEARCH SCIENTISTS: 6

Prof. M. Georgiev, Ph.D., D.Sc.; Assoc.Prof. O. Ivanov, Ph.D.; L. Mihailov, Ph.D.; Z. Dimitrova, Ph.D.; Assist.Prof. G. Kamisheva; M. Kamenova and V. Gergov- technical ass.

RESEARCH ACTIVITIES:

SYMMETRY LOWERING, VIBRONIC EFFECTS AND WAVES IN HIGH-TEMPERATURE SUPERCONDUCTORS AND OTHER CRYSTALS. Bardeen-Christov's quantum-mechanical approach to the transition probabilities for elastic tunneling is expanded upon inelastic-tunneling associated with the absorption of phonons. The deduced reaction rate is in a good agreement with calculations on specific experimental systems.

Explicitly correlated wave functions (WF): relativistic and mass effects of isoelectronic He series. The ground states of helium isoelectronic series for the base nuclides and isotopes of all the elements from He to Xe are analyzed. It was developed a variational procedure that allows solving Schrödinger equation for an unlimited number of parameters, which are actually coefficients in series of trial wave functions along the Hylleraas coordinates degrees. As to study the contribution of the nuclei motion, calculations are performed on number of nuclides having the same number of protons and varying number of neutrons.

MECHANICAL STRESS IN FILM-SUBSTRATE SYSTEMS

From the photoelectron spectra for as-deposited and heat- and photo- treated films of ternary chalcogenide system GeSbS was shown that these treatments affect all the building units, which change depending on Ge content. At small Ge content, favourable conditions are realized as to be revealed V-state of Sb. At high Ge content this ability is strongly decreased, but the opportunity for GeS constituents to be formed is increased, the number of SbS units is decreased and a residium of non-stoichiometric GeS appears.

SURFACE PHOTO-CHARGE EFFECTS (SPCE) AND ITS APPLICATION

We worked on the creation of a chapter in the first in the world encyclopedia of sensors, which will be published by American Scientific Publishers, California. The subject of the chapter is "Sensor applications of field-matter interactions". The content is in 140 handwritten pages.

For a task given by Inergy Automotive Systems (Belgium), we created a laboratory model of a levelmeter for fuels, designed for use in the fuel tanks of cars. A demonstration was conducted and representative of the company signed a report that the device is working according to the requirements. The project was awarded with gold medal on the exhibition of innovations, taken place at the Park-Hotel Moskva, in October 2005.

For a consistent description of SPCE, we are weighing carefully the experimental evidence against the common knowledge of frictional electrification and analyze it on the premise that

photocharging may be the electric face of the structural damage produced at the surface by photodesorption or laser sputtering. Alternative photoelectrification mechanisms are also discussed. In relevance to the photoelectrification mechanisms proposed above, we derive rate equations for the negative-U and STE photoelectrification modes and solve them under conditions close to the experimental ones.

DYNAMIC TRACTION FORCE INTEGRATOR

The project of the system “Optimal distribution of traction force in rolling composition” requires a classical linear problem for optimization along two criteria to be solved, i.e. an matrix with time and distance to be found. This problem is extremely slow for a computer realization, but it is still able to be solved in a reasonable time.

DYNAMICS OF ADAPTING POPULATIONS

Agent model are popular in natural and social sciences and they are used to explain complex behavior of different systems. Main place in agent models is dynamics of competing populations. The interactions between populations are at the basis of development of society. The systematic investigations in this area are present in a book “Population Dynamics and National Security. Risks for National Security of Bulgaria” by N.K.Vitanov, Z.I.Dimitrova and S. Panhev, Acad. Publ. House “M.Drinov” BAS (2005). With the investigation on systems of competing population we participate in the European program COST P10 “Physics of Risk”. The study on the contract MM 1201/02 with the National Science Fund (NSF), “Extracting information from time series” led by Dr. N. Vitanov from the Institute of Mechanics of BAS has won the First Award of the NSF.

HISTORY OF PHYSICS IN BULGARIA

It is studied the following: a) lecturer’s activity in theoretical physics at Sofia Univ. (1921-1944); b) peculiarities in physics teaching at the Central eparchial school, Plovdiv, founded by N. Gerov in 1850; c) CV of acad. E. Nadjakov, of member correspondents A. Christov and D. Stoianov.

PUBLICATIONS

1. M. Georgiev, A. Gochev and J. Singh. A Theory of the Colossal Van der Waals Binding in Soft and Hard Condensed Matter. *Internet Electronic J. of Molecular Design*. 4, 765-785 (2005)
2. Mladen Georgiev, Alexander Gochev. Reaction rate assessment of multiphonon relaxation. *Internet Electronic J. of Molecular Design*. 4, 862-881 (2005)
3. R.K. Debnath, A.G. Fitzgerald, K. Christova, A. Manov. Characterization of heat- and photo- treated GexSb40-xS60 films by X-ray photoelectron spectroscopy. *J. of Optoel. & Adv. Materials* 7, 353-356 (2005)
4. O. Ivanov, R. Dyulgerova and M. Georgiev. Photoinduced electrification of solids: I. Plausible mechanisms. xxx.lanl.gov, Paper ID: cond-mat/0508457 (2005)
5. M. Georgiev, O. Ivanov. Photoinduced electrification of solids: II. Photovoltage transients. xxx.lanl.gov, Paper ID: cond-mat/0508460 (2005)
6. Z. Dimitrova, D. Gogova. On the structure, stress and optical properties of CVD Tungsten oxide films. *Mater.Res.Bulletin* 40, 333 (2005)
7. Z. I. Dimitrova, N. K. Vitanov. Shilnikov chaos in a generalized system for modelling dynamics of competing populations. *Compt. rend. Acad. bulg. sci.* 58(3), 257 (2005)
8. O. Ivanov. Sensor applications of field-matter interactions, *ENCYCLOPEDIA of SENSORS*, Ed. Rudolph Marcus, American Scientific Publishers, California.

9. N.K.Vitanov, Z.I.Dimitrova, S. Panhev. Population Dynamics and National Security. Risks for National Security of Bulgaria, Acad. Publ. House "M.Drinov" BAS (2005).
10. R. L. Pavlov, L. M. Mihailov, L. Pavlov, M. D-Ivanovich, J. Maruani. Mass Effects in the Ground State Energies for the Ground State neutral and 1s Core-Ionized Helium-Like Atoms and Their Isotopes from Helium to Xenon. Progress in Theoretical Chemistry and Physics, Advanced Topics in Theoretical Chemical Physics (2005), in press.
11. N. K. Vitanov, Z. I. Dimitrova, H. Kantz. On the trap of extinction and its elimination. Phys. Lett. A (2005), in press.
12. R. L. Pavlov, L. M. Mihailov, L. Pavlov, M. D-Ivanovich, J. Maruani. Mass Effects in the Ground State Energies for the Ground State neutral and 1s Core-Ionized Helium-Like Atoms and Their Isotopes from Helium to Xenon. X European Workshop on Quantum Systems in Chemistry and Physics, Aug. 2005, Tunis, Carthage.
13. N. K. Vitanov, Z. I. Dimitrova. Influence of extinction, substitution and mutation on the chaotic behavior and evolution in a generalized Volterra model of competing populations. Talk at the Second Annual Meeting COST ACTION P10 "Physics of Risk", Toledo, Spain, 23-26. 04. 2005.
14. Z. I. Dimitrova, N. K. Vitanov, I. P. Jordanov. On the nonlinear dynamics of agent systems: A case of competing populations. Talk at the Xth Jubilee Congress for Theoretical and Applied Mechanics, Varna, Bulgaria, 12-15.09.2005. Journal of Theoretical and Applied Mechanics, in press.
15. O. Ivanov. Level meter for liquids. Exhibition for inventors and innovations. Sofia, 2005. **Golden medal.**
16. G. Kamisheva. Lectures in Mathematical and Theoretical Physics at the University of Sofia by Professor Georgi Ivanov Maneff (1921-1944), in: Prof. G. Manev's Legacy in Contemporary Astronomy, Theoretical and Gravitational Physics. Ed. V. Gerdjikov and M. Tsvetkov, Heron Press Science Series, Sofia, 2005, p. 45-53
17. G. Kamisheva. Peculiarities in physics teaching at the Central eparchial school, Plovdiv. Symp. Physical knowledge in Bulgaria, May 10, 2005, Plovdiv 2005, p. 79-82
18. G. Kamisheva. CV of prof. G. Manev (15.01.1884-15.07.1965). Symp. Physical knowledge in Bulgaria, May10, 2005, Plovdiv 2005, p. 38-44.
19. N.K.Vitanov, Z.I.Dimitrova, S. Panhev. Science (in Bulg.) 15, 13-23 (2005)
20. G. Kamisheva. Physics science (in Bulg.), Sofia, 2005, p. 217-227.
21. G. Kamisheva. Physics science (in Bulg.), Sofia, 2005, p. 314-323.
22. G.Kamisheva Founders of the theoretical physics in BAS, Balkan Conf. 2005, Plovdiv
23. G.Kamisheva. Founders of the experim. physics in BAS, Balkan Conf. 2005, Plovdiv

ONGOING RESEARCH PROJECTS:

1. Contemporary problems of the nuclei theory and other many-electron systems. (NSF)
2. Extracting information from time series. (NSF)
3. Investigations of optogalvanic effect in gas mixture hollow cathode discharge plasma – peculiarities and interpretations. (Inst. Physics, Belgrad, Acad. Sci. Serbia and Montenegro)
4. Analysis of multi – component materials – problems and applications. (Institute of Physics, Belgrad, Academy of Sciences of Serbia and Montenegro)
5. Optimal distribution of traction force in rolling composition. (Bulg. Govern. Railway)
6. History of mathematical and theoretical physics in Sofia University until 1939. (NSF)
7. XPS and structure of amorphous films of GeSbS family. (contract with BAS)
8. Light-induced effects in low-temperature plasma and solid state surface - photoresonant and surface photo-charge effects. (contract with BAS)
9. Correlation properties of non-linear systems. (contract with BAS)

LABORATORY

ELECTRON MICROSCOPY AND ELECTRON DIFFRACTION

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TOTAL STAFF: 4

RESEARCH SCIENTISTS: 3

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

RESEARCH ACTIVITIES:

1. Ion Beam Synthesis of Nanoclusters in Silicon and High Frequency Electromagnetic Field Annealing.

The post-implantation effect of high frequency electromagnetic field (HFEMF) on the microstructure and electrical properties of high fluence Zn^+ , Te^+ or Bi^+ implanted (100) Si was investigated by cross-sectional transmission electron microscopy (XTEM), impedance spectroscopy and four-point probe electrical measurements.

XTEM analyses show an amorphous Si layer (a-Si) at the Si surface for the three types of implanted species. Te^+ and Bi^+ form metallic nanoclusters (NCs) in the a-Si at fluences $\geq 10^{16} \text{ cm}^{-2}$, while no NCs were observed for Zn^+ implantation. Post-implantation treatment with 0.45 MHz HFEMF leads to decreased sheet resistance values only for samples with formed NCs. In the case of Te^+ implantation it was also shown that the real part of the electrical resistivity decreased down to four orders of magnitude after annealing in HFEMF. It is proposed that HFEMF influences the dynamics of nanoclustering by stimulation of spinodal decomposition and rearranging the Te NCs to a percolation system. For the case of Bi^+ - it is assumed that the high frequency stimulates electrical microcurrents through the NCs causing local heating of the NCs boundaries and recrystallization of the surrounding a-Si matrix. The process of percolation in Te^+ implanted Si and crystallization of a-Si in Bi^+ implanted Si influence in different degree reduction of the sheet resistivity under the action of HFEMF.

2. Semiconductor ions implantation in high-k dielectric layers.

The aim of the present study is the synthesis of Ge nanoclusters in Ta_2O_5 layers as an alternative structure to SiO_2 .

Ge^+ ions with energy of 40 keV and fluences of 5×10^{15} , 1×10^{16} and $5 \times 10^{16} \text{ cm}^{-2}$ were implanted in reactive sputtered Ta_2O_5 films at room temperature. The samples were rapid thermal annealed in vacuum at 700°C and 1000°C for 30, 60 and 180s. Structural studies were done by Cross-sectional Transmission Electron Microscopy in diffraction and phase contrast mode. Under optimized conditions (high implantation fluence and annealing temperature) Ge-containing NCs nucleate close to the projected range of the implanted Ge^+ ions. The implanted layer keeps being amorphous at the lower annealing temperature (700°C), while at the higher one (1000°C) crystallization processes start and the Ta_2O_5 matrix becomes orthorhombic. No evidence is obtained for crystallization of NCs independently on the different annealing cycles.

PUBLICATIONS:

1. M. Kalitzova, K. Gesheva, E. Vlahov, Y. Marinov, D. Gogova, T. Ivanova, Ch. Angelov, N. Pashov, G. Zollo, G. Vitali, High frequency electromagnetic field processing of amorphous silicon layers containing nanoclusters produced by implantation of metal ions in Si (100) matrix, Nuclear Instruments and Methods in Physics Research B, 229, 65-72 (2005)
2. M. Kalitzova, A. Peeva, V. Ignatova, O.I. Lebedev, G. Zollo, G. Vitali, Ion beam synthesis of Te and Bi nanoclusters in silicon: The effect of post-implantation high frequency electromagnetic field, Nuclear Instruments and Methods in Physics Research B, 242, 209-213 (2006)
3. A. Peeva, M. Kalitzova, G. Zollo, G. Vitali, G. Beshkov, W. Skorupa, Thermal Behaviour of Nanoclusters in Ge⁺ Ion implanted Ta₂O₅ Layers, 14th International School on Vacuum, Electron and Ion Technologies (VEIT 2005), Varna, 12-16 Sep. 2005

ONGOING RESEARCH PROJECTS:

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

COLLABORATION:

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

LABORATORY

X-RAY DIFFRACTION AND MAGNETIC RESONANCE

HEAD: **Assoc.Prof. Malina Baeva, Ph.D.**
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TOTAL STAFF: **6**
RESEARCH SCIENTISTS: **4**

Assoc. Prof. L. Pramatarova, Ph.D.; Assist. Prof. E. Pecheva, Ph.D.; Assist. Prof. A. Boianova; physicist P. Botev; technician H. Paskovski; Ph.D. student Z. Zenkov

RESEARCH ACTIVITIES:

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

In connection with formulated priorities of BAS the scientific activities of the laboratory is directly connected with the program “Interdisciplinary investigations of the man, living nature and quality of life. This program is directed to the development of: Contemporary medical-biological investigations and their application in development of new diagnostic methods; development of modern technologies for needs of medicine and health care, creation, testing and production of medicaments, healthy full-bodied foods.

1. Natural clinoptilolite – Application for medical purposes. In the rows of bioactive minerals that are used by the human for different purposes the zeolite have leading role as a catalysts, molecular sieves, adsorbents and ion exchangers. A diagnostic method is developed, which includes a stage of organism purification with natural zeolite – clinoptilolite. Bulgarian natural zeolite – clinoptilolite is with high purity and it possesses well-defined catalytic and adsorbing properties in respect to toxic and disintegrated products of the protein purine and lipid metabolism. After per-oral acceptance of clinoptilolite in the acid stomach medium (pH = 1-2) the mineral clinoptilolite is protonised). In these conditions its catalytic and absorption ability is raised repeatedly. Well-shaped auto recreating porous structures are observed- spherulites with one central opening with diameter from nanometers to micrometers. The spherulites are considered as adsorbents, catalysts and molecular sieves in different human liquids. Spherulites as well as isotropic and anisotropic crystals of dendrite and skeleton type are observed by polarization microscope. They are investigated by X-ray analysis with Cu and Co radiation. According to X-ray analysis they are derivates of amidinourea and phosphoric acid. It is supposed that they represent potassium-sodium hydrate of amidinourea and phosphoric acid. These investigations are in initial stage. Future measurements are coming with the aim structural characteristics of spherulites formed in human organism to be specified.

2. X-ray topography of single crystals. The topographic patterns of CdTe, BSO and BGO single crystals are obtained.

3. The technical support of the scientific activity requests updating and starting the large-scale scientific x-ray apparatus DRON-3M. It will give possibility the diffractograms to be obtained of the investigated samples and precise their structural parameters.

PUBLICATIONS:

1. M.Baeva, A.Boianova, N.Izmirova, Z.Mircheva, Porous structures – spherulites with central opening, Proceedings of International Symposium – Catalytic processes on advanced micro- and mesoporous materials, Sept. 2-5, 2005. Nessebar, Bulgaria, p. 63.

2. N.Izmirova, M.Baeva, A.Boianova, Z.Mircheva, Spherulites – a mesomorphous state for diagnostic purpose, Proceedings of International Symposium – Catalytic processes on advanced micro- and mesoporous materials, Sept. 2-5, 2005. Nessebar, Bulgaria, p. 67.

2. DEVELOPMENT OF AN IN-VITRO SYSTEM FOR STUDYING THE PROCESS OF BIOMINERALIZATION

SCIENTIFIC SUBJECT OF THE PROJECT:

The project for development of controllable in-vitro system for growth of hydroxyapatite (HA) layers on solid state substrates with the leader Assoc. Prof. Dr L. Pramatarova is related to national and international important topics, such as Improving Human Potential and Quality of life, Nanostructures and Nanotechnologies of the 6 FP of the EC. The progress in understanding the process of biomineralization, particularly the HA growth, modification of the substrate surfaces as well as the interactions between an implanted in the living body material and different cells, is attained through in-vitro experiments.

SUMMARY of the results for the scientific investigations on contract No L-1213/02 for the period 2002-2205, financed by the National Foundation for Scientific Research at the Ministry of Science and Education.

The results of the project "Formation of an in vitro system for the layer growth from functional solutions on modified substrates", which aims the development of an universal in vitro system for inorganic layer growth from functional solutions on modified substrates as well as the determination of the possibilities of this system for obtaining of coatings on bone implants, are as follows:

- Novel method for controllable growth of hydroxyapatite (HA) from supersaturated solution as is call simulated body fluid (SBF), resembling the human blood plasma on different surfaces has been developed with an application of simultaneous "laser – liquid-solid " interaction (LLSI process) in cooperation with SME "Pulslight" Ltd, Sofia. The influence of the laser radiation on the hydroxyapatite growth has been investigated *for the first time* and it has been found that the irradiation enhance the formation of calcium phosphate nucleation, that further stimulates the faster layer growth of HA. It has been found that the LLSI process results in a synergistic effect on the hydroxiapatite layer formation. A request for a patent of the method was submitted.
- A controlled surface modification has been achieved on stainless steel, titanium, silicon and silica glass with chemically and topographically structured surfaces by subsequent implantation of Ca and P, and of Na ions on the whole surface and through a mask as well as by nanostructuring and by porous and poly- silicon. A modification has also been made with natural ECM proteins that are capable to induce growth of bioresembling HA. For a first time the HA growth is investigated on natural ECM proteins with application of the LLSI process. It has been foud that the precipitated ECM serves as a matrix both for growth and arrangement of the layer.
- The investigation of the biocompatibility by in vitro experiments with fibroblast cells showed that the precipitation of natural organic components like ECM is an effective way to improve the initial interactions between the materials and living cells. It is ascertained that the preliminary coating of the samples with the protein fibronectin improves their interaction with the fibroblasts and it could be used as a positive control

for the efficacy of the cell interaction with the materials, and by this way to contribute to the compatibility of the materials with the tissues in the living organism. It has been shown that the proposed system could be applied for a development of coatings on bone implants.

- On the basis of the project a PhD dissertation on a topic "Modified solid surfaces as a model for hydroxyapatite growth" was successfully defended in May 2005.
- The results from the investigation were used as a basis for participation of the workteam in four 6th FP projects of the EU.
- The results are presented in 12 publications in peer reviewed journals. The results are presented at international conferences and symposia as posters.

PUBLICATIONS:

1. L. Pramatarova, E. Pecheva, R. Presker, A. L. Toth, E. Horvath, H. Reuther, D. Dimova-Malinovska, Behavior of porous silicon under simulated physiological conditions and laser irradiation, Semiconductor nanocrystals, v. 2 (2005), 390-394, Proc. 1st International Workshop on Semiconductor Nanocrystals, SEMINANO2005, 10-12 September 2005, Budapest, Hungary
2. L. Pramatarova, E. Pecheva, D. Nesheva, Z. Aneva, A. L. Toth, E. Horvath, Nanostructured CdSe in SiO_x thin films as model for induction of bone like hydroxyapatite, Semiconductor nanocrystals, v. 2 (2005) 387-390, Proc. 1st International Workshop on Semiconductor Nanocrystals, SEMINANO2005, 10-12 September 2005, Budapest, Hungary
3. L. Pramatarova, E. Pecheva, R. Presker, U. Schwarz, R. Kniep, Natural opal as a model system for studying the process of biomineralization, Solid State Phenomena 106 (2005) 75-78, From nanopowders to functional materials, ed. by R. Piticescu, W. Lojkowski and J. Blizzard
4. L. Pramatarova, E. Pecheva, D. Nesheva, Z. Aneva, A. L. Toth, E. Horvath, F. Riesz, Hydroxyapatite growth on glass/CdSe/SiO_x nanostructures, Solid State Phenomena 106 (2005) 123-126, From nanopowders to functional materials, ed. by R. Piticescu, W. Lojkowski and J. Blizzard
5. L. Pramatarova, E. Pecheva, T. Petrov, R. Presker, M. Stutzmann, Hydroxyapatite kinetic deposition on solid substrates induced by laser-liquid-solid interaction, Proceedings of SPIE 5830 (2005) 419-423
6. L. Pramatarova, E. Pecheva, D. Dimova-Malinovska, R. Presker, M. Stutzmann, U. Schwarz, R. Kniep, A novel laser-liquid-solid interaction process for hydroxyapatite formation on porous silicon, Proceedings of SPIE 5830 (2005) 110-114
7. L. Pramatarova, E. Pecheva, R. Presker, M. Stutzmann, M. Maitz and M. Pham, Patterned surfaces for hydroxyapatite in vitro growth, Journal of Optoelectronics and Advanced Materials 7(1) (2005) 469-472
8. L. Pramatarova, E. Pecheva, R. Presker, M.T. Pham, M.F. Maitz, M. Stutzmann, Hydroxyapatite growth induced by native extra cellular matrix deposition on solid surfaces, European Cells and Materials Journal 9 (2005) 9-12
9. L. Pramatarova, E. Pecheva, Bioactivity of nanostructured surfaces, in Functional Properties of Nanostructured Materials, Eds. R. Kassing, P. Petkov, W. Kulisch, C. Popov, Springer-Verlag, Berlin, 2006 (*accepted for publication*)
10. L. Pramatarova, E. Pecheva, V. Krastev, F. Riesz, Modified by ion implantation stainless steel surface as a substrate for hydroxyapatite deposition. Part I. Surface modification and characterization, Journal of Materials Science: Materials in Medicine, 2006 (*accepted for publication*)
11. L. Pramatarova, E. Pecheva, V. Krastev, F. Riesz, Modified by ion implantation stainless steel surface as a substrate for hydroxyapatite deposition. Part II. Biomimetic layer

growth and characterization, Journal of Materials Science: Materials in Medicine, 2006
(*accepted for publication*)

12. L. Pramatarova, E. Pecheva, R. Presker, Formation of Hierarchically Organized Micro- and Nanometer Scale Surfaces During a Laser-Liquid-Solid-Interaction Process, Plasma Processes and Polymers, 2006 (*accepted for publication*)

INTERNATIONAL COLLABORATION:

- ISSP, BAS and Research Institute for Technical Physics and Materials Science, Hungarian Academy of Sciences, Budapest, project: Physical and chemical processes on the surfaces and thin layers of condensed matter (semiconductors and insulators),
- ISSP, BAS and Institute of Technical Physics, Laboratory of Semiconductor, Riga Technical University, project: Physics Study of laser-liquid-solid interaction (LLSI) in an *in vitro* system for hydroxyapatite growth from simulated body fluid (SBF) on a substrate,
- ISSP, BAS and Institut D'Electronique du Solide et des Systemes (Laboratoire PHASE), Strasbourg, France, project: Advanced analysis of hydroxyapatite layers using adapted scanning interferometry (CPM, Coherence Probe Microscopy) for study of biomineralization.

LABORATORY

LOW TEMPERATURE PHYSICS

HEAD: **Prof. Nikolay Tonchev, Ph.D., D.Sc.**
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TOTAL STAFF: **21**
RESEARCH SCIENTISTS: **17**

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. N. Todorov; Assist.Prof. Chr. Popov; Assist.Prof. M. Kirov; Assist.Prof. M. Baychev; Assist.Prof. A. Stoianova-Ivanova; Y. Radulov, physicist; S. Terzieva, physicist; G. Mihova, chemist; P. Simeonova, chemist; K. Lovchinov, technologist

RESEARCH ACTIVITIES:

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

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

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

The obtaining of the bulk samples of MgB_2 by different way of synthesis was studied. In order to produce MgB_2 in nanophase it was used two step technique for mechanical activation of high temperature synthesis. The current pulse was $30 A/cm^2$.

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

Thermal properties investigation of $Ge_xAs_{40-x}S_{60}$ glasses within 4-300 K is carried out to study the mechanisms controlling scattering and heat transfer processes in these materials. The observed universal low-temperature behaviour of the measured thermal characteristics (thermal conductivity, specific heat and thermal diffusivity) is explained in the frame of Soft Potential Model (SPM), postulating the existance in glasses of additional quasy-localized low-frequency modes over acoustic ones, reflecting a noticeable feature in their vibrational density of state $g(v)/v^2$. A correlation between a degree of fragility of these ternary chalcogenides and compositional dependences of their specific thermal characteristics is established to change stronger at 2D-3D transition and weaker at chemical ordering.

A weighted orthonormal polynomial expansion method (OPEM) is applied for approximation of thermometric characteristics of the Ge film microsensor and Cernox type

temperature sensor in the range of 1.7-300 K. The extended algorithm of OPEM allows mathematical description of $R(T)$ and $T(R)$ functions by usual polynomials, too.

The effect of high-frequency electromagnetic field (HFEMF) on the electrical properties of metal ion beam implanted silicon has been investigated. Silicon wafers, (100) oriented, were implanted with Zn^+ , Te^+ or Bi^+ with energy of 50 keV and doses from 1×10^{15} to $1 \times 10^{17} \text{ cm}^{-2}$. Post-implantation treatment with 0.45 MHz HFEMF leads to decreased sheet resistance values for samples with formed nanoclusters (NCs) only. AC electrical conductivity measurements were used at frequencies in the range of 1 Hz to 100 kHz. A correlation between the NCs evolution (as a function of implantation dose and post-implantation processing) and the samples impedance dependence on these frequencies was found. An explanation based on potential barriers and HFEMF effect on the NCs is given.

2. MAGNETIC AND TRANSPORT PROPERTIES OF MANGANITES

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

The influence of magnetic and electric field on magnetotransport properties of thin films of $La_{1-x}Ca_xMnO_3$ ($x=0.3; 0.51$) deposited on $LaAlO_3$ and STO_3 substrates have been investigated. Compressively strained $La_{0.7}Ca_{0.3}MnO_3$ layers reveal semiconducting behaviour and charge ordered insulating (COI) state which melts to ferromagnetic metallic (FMM) above a certain magnetic field, accompanied by a significant hysteresis. Variable Range Hopping (VRH) mechanism well fits the conductance in zero magnetic field. The change of the slope of VRH dependence and magnetotransport of strained thin films are consistent with the model of inhomogeneous material: coexistence and competition of FMM and COI phases. The nonlinear electronic transport and hysteretic behaviour are driven by a fine balance of competing charge order with strong tendency to localization, FM interactions and strain energy.

On the basis of the free energy expansion, the low-symmetry orbital phases originating from the high-temperature crystal phase with the $Pn\bar{m}n$ (D_{2h}^{16}) symmetry in $Pr_{1-x}Ca_xMnO_3$ ($x=0.3; 0.5$) manganite are investigated. The free order parameter susceptibilities and elastically clamped ones in these phases are calculated.

3. STATISTICAL PHYSICS AND INTERPRETATION OF QUANTUM MECHANICS

Analytical method for studying the finite – size scaling in d-dimensional $O(N)$ systems with strong anisotropy where the correlation length critical exponents depend on the direction are presented. The anisotropic properties involve also the geometry of the systems. Prominent physical examples are systems with long-range interactions, decaying with the interparticle distance with different exponents in corresponding spatial directions, systems with space-“time” anisotropy near a quantum critical point and systems with Lifshitz points.

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

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

4. ENVIRONMENTAL RESEARCH

Environmental research to assess the air, soil and water quality using multivariate statistical methods is performed in order to detect and model pollution sources. Risk management estimation of the air quality in an industrial region (case study city of Kosice, Slovakia) was done as well as a trend study of the monitoring data (1962-2004) of the total B-activity of soil in the vicinity of the Nuclear Research Reactor.

PUBLICATIONS:

1. A. Handstein, U. K. Roessler, B. Idzikowski, N. Kozlova, K. Nenkov, K.-H. Mueller, A. Kreyssig, M. Loewenhaupt, A. Heinemann, A. Hoell, N. Stuesser, Change of magnetoresistivity and magnetic structure of $MnAu_2$ by iron substitution, *Journal of Magnetism and Magnetic Materials* 290-291, 1093-1096 (2005).
2. A. Stoyanova-Ivanova, S. Terzieva, K. Zalamova, Ch. Angelov, A. Zahariev, H. Ignatov and V. Kovachev, "The influence of Pr-Ca substitution on phase formation, microstructure and oxygen content in YBCO bulk samples", *J. Optoelectr. Adv. Mat.*, 7, 431-434 (2005).
3. Angelina Stoyanova-Ivanova, Tsvetanka Krasteva Nedelcheva and Latinka Krumova Vladimirova, "Spectrophotometric determination of oxygen content in calcium substituted RBCO ($R = Eu, Er, Gd$)", *Central European J. Chem.*, 3 (3), 432-440 (2005).
4. B. Terziyska, A. Czopnik, E. Vateva, D. Arsova and R. Czopnik; Low-temperature specific heat of Ge-As-S glasses, *Phil. Mag. Letters*, 85, 145-150 (2005).
5. B. Terziyska, H. Misiorek, E. Vateva, A. Jeżowski, D. Arsova, Low-temperature thermal conductivity of Ge-As-S glasses, *Solid State Communications*— Vol. 134, 349-353 (2005).
6. E. Nazarova, K. Nenkov, A. Angelov, A. Zahariev, Effect of silver addition on the superconducting properties of $LaBa_2Cu_3O_{7-\delta}$ ceramics, *Journal of Optoelectronics and Advanced Materials* 7, 427-430 (2005).
7. E. S. Pisanova and N. S. Tonchev, On the low-symmetry orbital phases in $Pr_{1-x}Ca_xMnO_3$ manganite, *J. Of Optoelectronics and Advanced Materials*, V. 7, No1, p. 435 -438 (2005).
8. E. S. Vlakhov, K. A. Nenkov, T. I. Donchev, E. S. Mateev, R. A. Chakalov, A. Szewczyk, M. Baran, and K. Piotrowski, Coexistence and competition of ferromagnetic and charge ordered phases in strained $La_{1-x}Ca_xMnO_3$ films, *J. of Magn. and Magn. Mat.*, 290-291, 955-958 (2005).
9. E. Vateva, B. Terziyska, H. Misiorek, A. Jeżowski, D. Wlosewicz, D. Arsova, Low-temperature thermal properties of Ge-As-S glasses, *J. Optoelectronics and Advanced Materials*, Vol.7, 357-360 (2005).
10. J. Cwik, K. Nenkov, T. Palewski, G. S. Burkhanov, O. D. Chistyakov, J. Klamut, H. Maedge, Specific heat of the $Sc_xHo_{1-x}Ni_2$ solid solutions, *Journal of Magnetism and Magnetic Materials* 290-291, 651-653 (2005).
11. J. Cwik, T. Palewski, K. Nenkov, G. S. Burkhanov, O. D. Chistyakov, N. Kolchugina, H. Maedge, The effect of substitution of Lu for Ho on some physical properties of $LuxHo_{1-x}Ni_2$ solid solutions, *Physica B* 358, 323-331 (2005).
12. J. Cwik, T. Palewski, K. Nenkov, G.S. Burkhanov, Magnetic, electrical, and thermodynamic properties of the $LaxHo_{1-x}Ni_2$ solid solutions, *J. Alloys and Comp.* 399, 7-13 (2005).

13. J. G. Brankov, N. S. Tonchev, V. A. Zagrebnov, Comment on “Direct equivalence between quantum phase transition phenomena in radiation matter and magnetic systems: Scaling and entanglement” by J. Reslen et al., *Europhys. Lett.*, 72, 151-152 (2005).
14. K. Kalaydjiev, V. Lovchinov, D. Dimitrov, M. Kirov, M. Baychev, Chr. Popov, D. D. Radev, M. Marinov, V. Tumbalev, I. Radev, Ph. Vanderbemden, Superconducting Nanostructured Magnesium Diboride, *J. Optoelectr. Adv. Mat*, 7, 423-426 (2005).
15. L. Shlyk, G. Krabbes, G. Fuchs, K. Nenkov, Flux pinning enhancement in melt-processed $\text{YBa}_2\text{Cu}_3\text{O}_7$ with extended nanodefects, *Applied Physics Letters* 86, 92503/1-3 (2005).
16. L. Shlyk, G. Krabbes, G. Fuchs, K. Nenkov, B. Schuepp, Effects of annealing treatments on the superconducting properties of melt-processed YBCO doped with Ni, *Superconductor Science and Technology* 18, S10-S14, (2005).
17. L. Shlyk, K. Nenkov, G. Krabbes, G. Fuchs, Melt-processed YBCO with Pt or Ce additions: comparison of pinning behavior, *Physica C* 423, 22-28 (2005).
18. M. Kalitzova, K. Gesheva, E. Vlahov, Y. Marinov, D. Gogova, T. Ivanova, C. Angelov, N. Pashov, G. Zollo and G. Vitali, High Frequency Electromagnetic Field Processing of Amorphous Silicon Layers Containing Nanoclusters Produced by Implantation of Metal Ions in Si(100) Matrix, in *Nucl. Instr. Meth. Phys. Res. B* 229, 65–72 (2005).
19. N. Balchev, B. Kunev, J. Pirov, G. Mihova, K. Nenkov, Low temperature magnetoresistance in the Ru-1222 superconductor, *Mater. Letters* 59, 2357-2360 (2005).
20. N. S. Tonchev, Finite-Size Scaling and Long-Range Interactions, *Physics of Particles and Nuclei, Supplement*, V.36, No1, p.82-87 (2005).
21. Nickola S. Todorov, Experimental and Conceptual Implications of Recent Reinterpretation of the Relativistic Quantum, *Hadronic Journal Supplement*, vol. 19, p. 425-490 (2004).
22. Nina B. Bogdanova, B.M. Terziyska, H. Madge “Thermometric characteristics approximation of Ge film temperature microsensor by orthonormal polynomials”—*Review of Scientific Instruments*, v.76, # 11, 116104 (2005).
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24. P. Simeonova, V. Lovchinov, Classification of High Temperature Superconducting YBCO Thin Films by Fuzzy Clustering, *J. Optoelec. Adv. Materials* 7(1) 419-423 (2005).
25. S. Terzieva, A. Stoyanova-Ivanova, K. Zalamova, V. Mikli, Ch. Angelov and V. Kovachev, “Morphology of Y1Ba2Cu3Oz and Y0.7Ca0.3Ba2Cu3Oz Bulk samples depending on Ca substitution”, *J. of Optoelectr. Adv. Mater.*, Vol 7, 477-480 (2005).
26. V. Markovich, E.S. Vlahov, Y. Yuzhelevskii, B. Blagoev, K.A. Nenkov, G. Gorodetsky, Electrical transport and glassy response in strained thin La0.7Ca0.3MnO3 films, *Physical Review B*, 72, 134414/1-8 (2005).
27. A. Стоянова –Иванова, С. Терзиева, V. Mikli, R. Traksmaa и В. Ковачев, “Текстура и структура на горещо валцувани YBCO ленти с калциева (Ca) субституция”, *Списание на БАН*, 5, 1-4 (2005)
28. N. S. Tonchev and V. Kovachev, Low Temperature Physics in the Institute of Solid State Physics of Bulgarian Academy of Sciences, *J. Bulg. Acad. of Sci.* No 4, p.18-23 (2005).
29. D. Dimitrov, A. Apostolov, N. Piperov, Transport and Magnetic Properties of $\text{Pr}_{0.7}\text{Sr}_{0.3}\text{MnO}_3$ Single Crystal and Its Magnetocaloric Ability, *Proceedings of the 1st International Conference on Magnetic Refrigeration at Room Temperature*, Montreux, Switzerland, Sept.27-30, 2005; Editor: Peter W. Egolf, International Institute of Refrigeration, 177, Bd Malesherbes 75017 Paris – France, pp. 149-154.
30. N. S. Tonchev, Finite-size scaling in systems with strong anisotropy: an analytical example, *Communication JINR E17-2005-148*, p. 1-12 (2005).

31. Nina B. Bogdanova, B.M. Terziyska, R. Wawryk "Orthonormal Polynomial Approximation of Thermometric Functions for Cernox-RuO₂ Composition Temperature Sensors", Communication JINR Dubna E11-2005-177, 1-7, (2005).

ONGOING RESEARCH PROJECTS:

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

INTERNATIONAL COLLABORATION:

1. Universite de Liege, Institute d'Electricite – SUPRATECS, Liege, Belgium.
2. Institute of Physics, Polish Academy of Sciences, 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.

LABORATORY

CRYOGENIC TECHNOLOGY

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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, has been investigated. The existence of bulk pinning (established by measurements of third harmonics of ac magnetic susceptibilities) and increasing of critical current density is found for 30% Ca substitution.

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

RESEARCH PROJECTS:

METHODS FOR INCREASING OF CARRIERS, IMPROVING OF WEAK LINKS AND GENERATING OF EFFECTIVE PINNING IN 1-2-3 SUPERCONDUCTING SYSTEMS

BAS budget financial support

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

PUBLICATIONS:

1.A.Stoyanova-Ivanova, S.Terzieva, K. Zalamova, Ch. Angelov, A. Zahariev, H. Ignatov and V. Kovachev, "The influence of Pr-Ca substitution on phase formation, microstructure and oxygen content in YBCO bulk samples", J. of Optoelectr. & Adv. Matter., v.7, N1 (2005) 431-434.

2. E. Nazarova, K. Nenkov, A. Angelov, A. Zahariev, "Effect of Silver Addition on the Superconducting Properties of $LaBa_2Cu_3O_{7-\delta}$ ", J. of Optoelectr. & Adv. Matter., v.7, N1 (2005) 427.

LABORATORY

PHYSICAL PROBLEMS OF MICROELECTRONICS

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RESEARCH ACTIVITIES:

1. HIGH-K DIELECTRICS FOR NANOELECTRONICS

By means of complex electrical (including stress), structural, and optical measurements the conductivity mechanisms of 5-35 nm layers of Ta₂O₅ as a high-k dielectric have been investigated. It has been found that the type of the upper electrode (Al, Au, W, TiN/W) as well as the deposition method affected strongly the parameters of the memorizing planar capacitors. The Au electrode is the most appropriate for use under electrical stress and could guarantee long - term stability of all parameters.

Making use of a rapid thermal nitridation of the Si surface an equivalent oxide thickness of 1 nm for Ta₂O₅ / SiON/ Si system was obtained. But the increased rate of trapping at the interface modifies strongly the dominant conductivity character and has to be taken into account. It has been found that doping the Ta₂O₅ layer with small amounts of Ti could increase the potential abilities of Ta₂O₅ to be used as high-k material.

Oxidation of Ta to Ta₂O₅ was implemented successfully using Nd:YAG laser. The layers produced have good high-k-dielectric parameters. This method could be used for a local oxidation of surface "dots" and formation of different desired configurations.

It is found that the asymmetry of the conductivity mechanism in HfTiSiO layers with different contents of Hf and Ti is a result of two different phenomena (increased trapping rate for the electrons in the layer and formation of a two-layer structure. Both of them originate from the same process – phase separation and formation of HfO₂, TiO₂ and SiO₂ islands. The degree of this phase separation defines the behavior of the islands like electron traps or like a separate interface layer. This result is important for understanding the fundamental relation between the leakage currents and the physical properties of the high-k dielectrics considered as alternative to SiSiO₂ in the nanoelectronics.

Thin high-k layers of Ta₂O₅, Si₃N₄, Al₂O₃ and ZrO₂ are deposited on Si making use of a previously developed and optimized sputtering process. These layers demonstrate high breakdown voltages, low leakage currents and thermal stability and are important for further scaling down of the microelectronic devices.

2. THIN FILMS FOR THE MICROELECTRONICS

It is found that the defects in structures $\text{Al}_2\text{O}_3/\text{SiC}$ and SiO_2/SiC are of different type and with different space and energy distribution. The structures $\text{Al}_2\text{O}_3/\text{p-SiC}$ demonstrate improved electrical characteristics compared to the structures with SiO_2 . The Fowler-Nordheim tunneling of electrons from the metal electrode is found as a predominant conductivity mechanism in the system $\text{Al}_2\text{O}_3/\text{p-SiC}$, while the tunneling of holes from the SiC is predominant in the system $\text{SiO}_2/\text{p-SiC}$. This difference combined with increased defects density results in higher leakage currents in the system $\text{SiO}_2/\text{p-SiC}$.

By means of measuring of the leakage currents and the threshold voltages non- hydrogenated and ion-implantation hydrogenated gate oxides of thin-film transistors are investigated after irradiation by high-energy electrons. A reduction of the trap density and increasing of the density of the positive charge in the oxide are found. Smoothing of the interface and improvement of the quality of the oxide near to the lower interface is observed for the hydrogenated transistors. Non hydrogenated transistors exhibit increasing both of the oxide charge and the interface-states density after irradiation.

Thin-film polysilicon transistors with different rates of the channel doping and hydrogenation are investigated. The threshold voltages and the channel mobility are calculated as a function of the rates of the P doping and the hydrogenation.

By means of a modified C-V technique the influence of the bias-temperature (BT) stress on the profile of the states in the energy gap of hydrogenated amorphous silicon is investigated. It is found that the variations of the distribution after BT correspond to the “defect-pool” model.

3. RAPID THERMAL ANNEALING AS A MICROELECTRONIC TECHNOLOGY PROCESS

Investigations are carried out of the Rapid Thermal Annealing (RTA) as a technology process for synthesis and modification of nanomaterials. Confirmed is experimentally the possibility for obtaining nanolayers of AlN and BN by means of the RTA processes. AES analysis reveals the presence of Al-N bonds after RTA processing. A simultaneous doping of SnO_2 layers with Si, N and C. The XPS analysis yields the distribution profile of the doping elements. The modified this way layers could be applied as active elements of different kinds of sensors.

The system $\text{CeO}_2\text{-Si}$ is investigated by means of X-ray diffraction analysis after RTA processing. The results obtained show that the as grown layers represent a mixture of amorphous and polycrystalline phases in different configurations. At thermal processing with increasing the temperature a transition to a polycrystalline phase is observed. At temperature of 1400°C a decomposition of CeO takes place together with a formation of Si-Ce and Si-Ce-O phases.

The effect of RTA on the properties of the structure a-C:H/c-Si (p-type) is studied. The a-C:H layers are deposited by PE CVD deposition. It is found that after the RTA in the range $800 - 1000^\circ\text{C}$ a heterojunction is formed . RTA at 1200°C for 5 min yields optimal results for the improvement of the electric characteristics of the structure.

4. MAGNETORESISTIVE THIN LAYERS AND DEVICES

The stability of the anisotropic magnetoresistance effect in thin permalloy layers at magnetic fields with strength and configuration equivalent to those used in the industrial automation is investigated. The behaviour of structures with different geometry and electric diagram is

modelled making use of a dedicated energy-distribution program created for the purpose. Several versions of prototypes of magnetic positioning sensors are designed and implemented technologically. Samples are produced by means of a previously developed technology with original elements (magnetization after annealing). It is found that the behaviour of the samples is sufficiently well described and modelled making use of the “single domain” model with appropriate estimation and analysis of the energy minimums and some additional corrections. It is shown that the flipping phenomena do not affect the response of the created prototypes at real working conditions. As a result samples demonstrate very good resolution of the positioning and stable work in a “heavy-duty” environment.

PUBLICATIONS

1. E. Atanassova, A. Paskaleva, N. Novkovski, M. Georgieva, Conduction mechanisms and reliability of thermal Ta₂O₅-Si structures and the effect of the gate electrode, *J. Appl. Phys.*, 97, 094104-1 – 094104-11 (2005)
2. E. Atanassova, G. Tyuliev, A. Paskaleva, D. Spassov, K. Kostov, N₂ annealing effect on thermal Ta₂O₅ layers on Si studied by XPS, *Surf. Sci. Spectra*, 11, 1-25 (2005) (**invited paper**)
3. G. Aygun, E. Atanassova, R. Turan, Tz. Babeva, Reflectance spectra and refractive index of a Nd:YAG laser-oxidized Si surface, *Materials Chemistry and Physics*, 89, (2005) 316-320
4. A. Paskaleva, R.R. Ciechonski, M. Syväjärvi, E. Atanassova, R. Yakimova, Characterization of 4H-SiC MOS structures with Al₂O₃ as Gate Dielectric, *Materials Science Forum*, 483-485, 709-712 (2005)
5. E. Atanassova, R.V. Konakova, V.F. Mitin, J. Koprinarova, O.S. Lytvyn, O.B. Okhrimenko, V.V. Schynkarenko, D. Virovska, Effect of microwave radiation on the properties of Ta₂O₅-Si microstructures, *Microel. Reliab.* 45, 123-135 (2005)
6. Tz. Babeva, E. Atanassova, J. Koprinarova, Optical characteristics of thin rf sputtered Ta₂O₅ layers, *Phys. Stat. Sol. (A)*, 202, 330-336 (2005)
7. N. Novkovski, A. Paskaleva, E. Atanassova, Dielectric properties of rf sputtered Ta₂O₅ on rapid thermally nitrided Si, *Semicond. Sci. Technol.*, 20, 233-238 (2005)
8. P. Ozdag, E. Atanassova, M. Gunes, The effects of oxide thickness on the interface and oxide properties of metal-tantalum pentoxide-Si (MOS) capacitors, *J. Optoelectronics and Advanced Materials*, 7, 293-296 (2005)
9. N. Novkovski, E. Atanassova, Origin of the stress-induced leakage currents in Al-Ta₂O₅/SiO₂-Si structures, *Appl. Phys. Lett.*, 86, 152104-1 – 152104-3 (2005)
10. N. Novkovski, E. Atanassova, Dielectric properties of Ta₂O₅ films grown on silicon substrates plasma nitrided in N₂O, *Appl. Phys. A*, 81, 1191-1195 (2005)
11. A. Paskaleva, R.R. Ciechonski, M. Syväjärvi, E. Atanassova, Electrical behaviour of 4H-SiC metal-oxide-semiconductor structures with Al₂O₃ as Gate dielectric, *J. Appl. Phys.* 97, 124507-1 – 124507-4 (2005)
12. A. Paskaleva, E. Atanassova, M. Georgieva, Charge trapping and conduction mechanisms in Ta₂O₅ on nitrided silicon, *J. Phys. D: Appl. Phys.* 38, 4210-4216 (2005)
13. M. Lemberger, A. Paskaleva, S. Zürcher, A.J. Bauer, L. Frey, H. Ryssel, Electrical Properties of Hafnium Silicate Films Obtained from a Single-Source MOCVD Precursor, *Microel. Reliab.*, 45, 819-822 (2005)
14. A. Paskaleva, A.J. Bauer, M. Lemberger, Conduction mechanisms and an evidence for a phonon-assisted conduction process in thin high-k Hf_xTi_ySi_zO films, *Microel. Reliab.*, 45, 1124-1133 (2005)

15. A. Paskaleva, A.J. Bauer, M. Lemberger, An asymmetry of conduction mechanisms and charge trapping in thin high-k $\text{Hf}_x\text{Ti}_y\text{Si}_z\text{O}$ films, *J. Appl. Phys.*, 98, 053707 (8 pages) (2005)
16. V. Strijkova, D. Dimov, A. Paskaleva, I. Zhivkov, E. Spassova, J. Assa, G. Danev, Electrical properties of a thin layer polyimide matrix, *J. Optoelectronics and Advanced Materials*, 7, 1319-1322 (2005)
17. P. Aleksandrova, V. Gueorguiev, Tz. Ivanov, L. Popova, Characteristics of polysilicon TFTs, hydrogenated by ion implanatation P-Channel Transistors, *Journal of Optoelectronics and Advanced Materials Vol. 7, No. 1, February 2005*, pp. 313 – 316
18. L. Popova, St. Peneva, P. Aleksandrova and G. Beshkov, Structural investigations of RTA boron-doped thin a-Si layers, *Journal of Material Science: Materials in Electronics*, Vol. 16, No 8 pp.489 – 493, 2005
19. R.Djulgerova, V.Mihailov, V.Gencheva, L.Popova, G.Beshkov, Z.Rakocevic, Z.L.Petrovic, Is it possible to use the hollow cathode discharge for depth profiling, *Proc.XXVI ICPIG, Eindhoven, The Netherlands, 18-22 july, (2005)*, 1-4, **invited paper**
20. Wkulich, C.popov, S.Boicheva, G.Beshkov, V.vorlicek, P.N.Gibson, G.georgioev “Investigation of the growth mechanism and structure of nanocrystalline diamond films by rapid thermal annealing”, *Thin Solid Films* 469-470, (2005) 99-104
21. V. Bakardjieva, G.beshkov, P.Vitanov, Z. Alexieva. Effect of the rapid thermal annealing of the properties of mCVD and PECVD Silicon Nitride Thin films“, *Journal of optoelectronics and Advanced Materials*, vol. 7 №1 Febr. 2005, p. 377-380.
22. S.S. Georgiev, G.Beshkov, D.Sueva, E. Manolov, Properties of SiC/ Si Structure prepared by rapid thermal Annealing of amorphous hydrogenated carbon layers deposited on crystalline silicon,” , *Journal of optoelectronics and Advanced Materials Vol. 7 № 1p p Оефил 2005 p зл 373-376л*
23. Ch.Dicov, M.Marinov, H.Maciel, K.Grigorov, I.Nedkov, G, Beshkov,” Properties of Cr and Mo, Films Deposited by RF Sputtering. *Journal of Optoelectronics and Advanced Materials*, vol.7 no.1 Febr. 2005 p. 365-387
24. K.Grigorov , I.Nedkov, G.Beshkov, Ch.Angelov, N.Velchev, “AlN films obtained by broad energy nitrogen ion implantation, and rapid thermal annealing processes.” *Journal of Optoelectronics and Advanced Materials vol.7 no.1 Febr.2005 p,381-384*
25. Ch.Angelov, Bl.Amov, ,A.kimonura, E, Goranova, G.Beshkov, M.Takai,” Depth profiles and crystalization of Mg ions implantation into Si” *Journal of optoelectronics and Advanced materials vol.7 no.1 Febr.2005 p. 465-468*
26. N.Nedev, E..Manolov, Tz. Ivanov, B. Panchev, G.Beshkov, R.Dumy, K.Gmukova, v. Nadazdy “ Density of localized States in Hydrogenated silicon Determined by quasistatic capacitance of metal/aSi₂H/SiO₂/cSi Structure.” *Journal of Optoelectronics and Advanced Materials vol.7 no.1 Febr.2005 p.507-511.*
27. I.P.Litovskyy, V.G.Litovchenko, D.O.Mazunov, S.Kaschieva, J.Koprinarova, S.N.Dimitriev “Infrared spectroscopy study of Si-SiO₂ structures irradiated with high-energy electrons” *J of Optoelectr. and Adv. Mater.* 7(1) (2005), pp.325-328
28. S.Andreev, J.Koprinarova, P.Dimitrova, “Magnetic properties of thin film AMR sensor structures implemented by magnetization after annealing” *J.of Optoelectr. and Adv. Materials*, vol.7 (1) (2005), pp.317-320
29. S.Andreev ,P.Dimitrova, “Anisotropic-magnetoresistance integrated sensors”, *J. of Optoelectr. and Adv. Materials*, vol.7, No1 (2005) 199-206
30. V.Parvanova, S.Andreev,”Microwave properties of the systems $\text{Ba}_{1-x}\text{Sr}_x(\text{Zn}_{1/3}\text{Ta}_{2/3})_{0.94}\text{Ti}_{0.06}$ and $\text{Ba}(\text{Zn}_{1/3}\text{Nb}_{2/3})_{1-x}\text{Zr}_x\text{O}_3$, *J.Materials Sci:Materials in electronics* 16 (2005)249-252
31. A. Paskaleva, E. Atanassova, M. Lemberger, A.J. Bauer, Correlation between defects, leakage currents and conduction mechanisms in thin high-k dielectric layers, (**Invited**

- lecture)** NATO Advance Research Workshop on Defects in High-K dielectrics, St.Petersburg, Russia, 11-14 July, 2005: published in: “Defects in High-K dielectric nano-electronic semiconductor devices”, ed. E. Gusev, Springer, 2006, pp.409-420
32. M. Lemberger, F. Schön, T. Dirnecker, M.P.M. Jank, A. Paskaleva, A.J. Bauer, L. Frey, H. Ryssel, High-k hafnium silicate films on silicon and germanium wafers by MOCVD using a single-source precursor, in: A. Devi, R. Fischer, H. Parala, M. Allendorf, M. Hitchman: Fifteenth European Conference on Chemical Vapor Deposition (EUROCVD-15), Proceedings Volume 2005-09, The Electrochemical Society, Inc., Pennington, NJ, USA, 2005, pp.873-880
 33. A.J. Bauer, A. Paskaleva, M. Lemberger, L. Frey, H. Ryssel, Thin $Hf_xTi_ySi_zO$ films with varying Hf to Ti contents as candidates for high-k dielectrics, presented at Electrochemical Society Conference, Quebec, 15-20 May, 2005; in: “Advanced Gate Stack, Source/Drain, and Channel Engineering for Si-Based CMOS: New Materials, Processes, and Equipment”, (eds.) E.P. Gusev, L.J. Chen, D.-L. Kwong, P.J. Timans, F. Roozeboom, M.C. Öztürk, H. Iwai, Proceedings Volume 2005-05, pp. 125-132, Pennington, NJ, USA, The Electrochemical Society, Inc., ISBN 1-56677-463-2
 34. R.Djulgerova, V.Mihailov, V.Gencheva, L.Popova, G.Beshkov, Z.Rakocevic, Z.Petrovic, Is it possible to use the hollow cathode discharge for depth profiling, Proc.XXVI ICPIG, Eindhoven, The Netherlands, 18-22 July, (2005) ,1-4, invited paper

ONGOING RESEARCH PROJECTS

1. Physics and technology of thin layers for applications in the modern microelectronics.
2. Alternative dielectric layers based on Ta_2O_5 , ($Hf:Ta_2O_5$; $Al:Ta_2O_5$; $Ti:Ta_2O_5$) for 65-70 nm generation integrated memories (supported by NSF).
3. Investigation of the electric and physical properties of thin C layers deposited by CVD techniques (supported by 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. Micro and nanotechnologies for manufacturing implantable devices (supported by the National SMEs Program).
7. High-stability magnetoresistive sensors (supported by the National SMEs Program).

INTERNATIONAL COOPERATION

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

LABORATORY

PHOTOELECTRICAL AND OPTICAL PHENOMENA IN WIDE BAND GAP SEMICONDUCTORS

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RESEARCH ACTIVITIES:

1. DISORDERED MATERIALS - CHALCOGENIDE GLASSES AND THIN FILMS

Photo- and thermally induced changes in the optical band gap and thickness of thin films that belong to 3 lines of the Ge-As-S system were investigated. It has been found that the changes are dependent on the degree of the network rigidity of the parent glasses. The maximal reversible (photodarkening) and irreversible (photobleaching) induced changes have been observed in the range of $Z=2.6-2.7$ where the compositions are supposed to have "stress-rigid" structure. To our knowledge, the obtained photo- and thermally induced changes in $\text{Ge}_{32}\text{As}_5\text{S}_{63}$ (from the $\text{AsS}_3\text{-Ge}_2\text{S}_3$ line) are greater than everything published in the literature. The XPS study has shown that the parameters of the core level Ge^{3p} , As^{3d} , S^{2p} peaks depend not only on the composition, but also on the film's treatments. Photo- and thermally induced changes of the electronic structure have been observed in the EXAFS spectra, as well. This study has confirmed our previous concepts about the nature of the photostructural changes in Ge-As-S films.

Raman scattering spectra of $(\text{GeS}_2)_x(\text{As}_2\text{S}_3)_{1-x}$ glasses were measured over temperatures ranging from 20K to the respective glass transition temperatures (T_g). The low frequency parameters of the Boson peak (BP) have been analyzed in dependence both on the glass composition and the temperature. The dynamics of the structural changes with the temperature has been checked. The monitoring of the BP parameters has confirmed a close correlation between BP and medium range order of the glasses. The method constitutes a reliable technique for detecting T_g values.

Photoluminescence from Ge-S-Ga glasses doped with erbium was measured under direct excitation on the chalcogenide matrix and Er^{3+} -ions. On decreasing measuring temperature from 300 K to 4.2 K, a strong increase has been observed in the intensity of the 1540 nm emission line. The effect of Er doping on the local structure of the glasses has been clarified by Raman spectroscopy measurements. The investigations have been performed in collaboration with scientists from Canada, India, France and Czech Republic.

2. LOW-DIMENSIONAL SYSTEMS

Defect states and recombination processes are investigated in a-SiO_x/nc-CdSe, GeS₂/nc-CdSe multilayer and composite films and CdSe single films, using steady-state and transient photoconductivity and thermally stimulated current measurements. A reduction in mobility-lifetime product observed as layer thickness is reduced is assigned to increased deep

defect density at the nanocrystal surface. At elevated temperatures, the transient current in multilayer films falls below the steady-state dark current. This is explained by the effect of potential barrier profiles on recombination. The density of states distribution obtained is fairly broad in multilayers and composite films while in single layer films it is noticeably peaked. Two defect bands located at 0.55 and 0.7 eV below the conduction band edge have been observed in a-SiO_x/nc-CdSe, samples and CdSe single films. The former has been associated with the nanocrystal bulk and the latter with the CdSe–CdSe interface. In the GeS₂/nc-CdSe samples the 0.7 eV band is missing and a new one peaked at 0.5 eV has been resolved related to defects at the GeS₂-CdSe interface. Exponential ‘tails’ have been observed in the absorption spectra of all samples studied. It has been ascertained that its characteristic energy increases with decreasing nominal thickness of CdSe layers, which indicates that the smaller the CdSe nominal layer thickness the higher the lattice disorder in CdSe nanocrystals.

Thin films of SiO_x having thickness of 0.2 μm and oxygen content $x = 1.5$ or 1.7 were furnace annealed for various times (5-60 min) at 500 and 700°C. In the photoluminescence (PL) spectra measured with the 442 nm line from samples annealed at 500°C for $t \leq 40$ min two distinct PL bands peaked at about 2.3 and 2.5 eV have been revealed. They do not shift appreciably with increasing annealing time. At longer annealing times, a weak third band is resolved centered in the range 2.0-2.1 eV. It exists in the spectra of all samples annealed at 700°C. Both the energy position and intensity of this band depend on the annealing time and temperature. The bands at 2.3 and 2.5 eV have been assigned to radiative recombination via defect states, while the band centered in the 1.9-2.1 eV range is related to recombination in amorphous silicon nanoparticles grown upon annealing.

3. AC ELECTROLUMINESCENCE, ELECTROLUMINESCENT STRUCTURES AND DISPLAYS

AC electroluminescent structures provided with an organic protective layer, have been prepared using a further improved hybrid technology. Dependence of the structure brightness on the applied voltage was investigated on electroluminescent structures showing blue emission and having fullerenes C₆₀/C₈₀ included in the heterogeneous matrix of the emitting layer. Four different fullerene concentrations were added which causes an increase of the brightness of the electroluminescent structures of 5 to 8 times when compared with the structures not containing fullerenes. In order to clarify the reasons for the brightness increase, optical transmission and diffusive light scattering were studied in the visible and near-ultraviolet spectral ranges.

It has been produced an 11-segment electroluminescent display having organic protective layer and showing yellow emission. It was exhibited at XIIIth International Innovation Exhibition “EAST-WEST EURO INTELLECT’ 2005“, held in October 2005 in Sofia. The display was awarded with gold medal.

PUBLICATIONS:

1. D. Nesheva, S. Reynolds, C. Main, Z. Aneva and Z. Levi, Defect states in CdSe nanocrystalline layers, *Phys. Status Solidi (a)*, **202**, 1081 (2005).
2. D. Nesheva, Raman scattering from semiconductor nanoparticles and superlattices, *Journal of Optoelectronics and Advanced Materials*, **7**, 185 (2005).
3. Z. Aneva, D. Nesheva, Recombination of photoexcited carriers in Bi₁₂TiO₂₀ monocrystals, *Journal of Optoelectronics and Advanced Materials*, **7**, 513 (2005).
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5. D. Nesheva, Z. Levi, Z. Aneva, Size effects and lattice disorder in GeS₂/CdSe nanostructures, *Journal of Optoelectronics and Advanced Materials*, **7**, 1837 (2005).

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ONGOING RESEARCH PROJECTS:

Financed by the Bulgarian Academy of Sciences:

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

Financed by the Bulgarian Ministry of Education and Sciences:

1. Photoinduced structural changes in Ge-As(Sb)-S glasses and films (F 1309)
2. Defect states in photoconductors of various dimensionality (F 1306)

COLLABORATION:

1. Nano and micro scale structural transformations in thin films from glassy semiconductors: physical problems and possible applications, Physico-Technical Institute of the Russian Academy of Sciences, St. Petersburg, Russia.
2. Thermodynamical and optical investigations on chalcogenide glasses, Joint Laboratory of Solid State Chemistry, Pardubice, Czech Republic.
3. Raman scattering and photoluminescence from semiconductor nanoparticles, Institute of Physics, Belgrade, Serbia.
4. Structure and photoinduced changes in Ge-As-S glasses and amorphous films, Laboratory of molecule aggregates and inorganic materials, (UMR 5072 CNRS), Montpellier, France & LCTPCM (UMR 5624 CNRS), University of Pau, Pau, France (NATO PST.CLG.980343 Grant).
5. Optoelectronic properties of semiconductor thin films suitable for application as gas sensors (NATO CLG Grant No 980656) Dundee University, Dundee, Scotland, Institute of Photovoltaics, Juelich, Germany.

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RESEARCH ACTIVITIES:

1. STRUCTURES WITH VERY THIN SiO₂ AND SiO_x FILMS

Our research on new generation MOS devices with nano-sized structures proceeds in two directions, namely i) toward improvement of the properties of ultra thin SiO₂ gate dielectric through its growth on hydrogenated Si and ii) toward substitution of the SiO₂ gate with other dielectrics possessing higher dielectric permittivity, such as TiO₂, AlN and SiO_xN_y. For preparation of these films different deposition techniques were applied. The optical and electrical properties of the deposited films were studied by means of IR spectroscopy, spectral ellipsometry, atomic force microscopy and C-V and I-V measurement methods. The results have shown that the interface charge density is in the order of 10¹¹ cm⁻² in the MOS structures with SiO_xN_y films, prepared by plasma-assisted chemical vapor deposition (PACVD), and with AlN films, synthesized by pulsed plasma deposition (PPD), or with sol-gel deposited TiO₂ films doped with La and it is lower than that for MOS structures with classical thermal SiO₂ gate dielectric. The small density of the interface traps (<< 10¹² eV⁻¹cm⁻²) and their considerably flat distribution in the Si band gap are evidence for low structural stress in the interface region. However, in comparison with thermal SiO₂ grown in hydrogenated Si these dielectric films have high conductivity and, thus, low specific resistivity due to more defective structures. That's why our future investigations are focused on optimization of technological conditions for preparation of thin films with significantly higher resistivity.

Thermally evaporated SiO_x films with embedded Si nanoparticles have been studied by means of spectral ellipsometry, X-ray diffractometry and transmission electron microscopy. Comprehensive analysis of the results has shown that during annealing the oxide decomposes into Si and SiO₂ phases. Annealing at 700°C leads to formation of amorphous Si clusters in the oxide matrix, while at 1000°C the Si clusters start to crystallize in randomly distributed and oriented crystallites with averaged size of 3 nm. All the films possess visible photoluminescence (PL). The PL emission from the SiO_x films with embedded amorphous Si nano-clusters is 5-10 times more intense as compared with that from the oxides with embedded Si nanocrystallinities.

2. DEFECTS IN IRRADIATED Si/SiO₂ STRUCTURES

Si-SiO₂ structures were studied by means of infrared transmission spectroscopy in the wave number range 800-1400 cm⁻¹. They were irradiated with 23 MeV electrons at a flux of

about 10^{13} electrons $\text{cm}^{-2} \text{s}^{-1}$ for different durations: 30, 120 and 7200 s. It was demonstrated that as a result of high energy electron irradiation, the main absorption band shifts towards higher wave numbers and the shape of the absorption band is changed. The absorption band peak position shifts monotonically with increasing electron irradiation dose. The shift depends on the oxide type, varying in the range $7\text{-}14 \text{ cm}^{-1}$. This effect is most pronounced for samples with wet oxide. Analysis of the absorption band shape shows that the irradiation changes the contribution of 4 and 6-fold SiO_4 tetrahedral rings into the oxide lattice.

Inter-trap tunnelling is observed in $\text{SiO}_2/(\text{n})\text{Si}$ structures with 60 nm SiO_2 film after 0.8 and 1.6 keV hydrogen implantation with doses from 10^{13} to 10^{15} cm^{-2} . Tunnelling type conduction at 77 and 86 K is observed in Au-Si Schottky diode structures after 0.8 keV hydrogen implantation with a dose of 10^{13} cm^{-2} . This tunnelling type conduction is explained by electron tunnelling via deep levels with interface energy density of $(5\text{-}9.5) \times 10^{12} \text{ cm}^{-2} \text{eV}^{-1}$.

3. HYDROGENATED AMORPHOUS SILICON

The role of hydrogen in hydrogenated amorphous silicon (a-Si:H) has been studied from the viewpoint of its specific contribution to mechanical stress in the films. The experimental results have shown that it is the silicon-bonded hydrogen that essentially affects the stress. The change in hydrogen bonding configuration caused by ion implantation has made it possible to distinguish the major contribution of clustered hydrogen to the value of stress.

18 MeV electron beam-induced degradation of a-Si:H has been studied. The complete recovery of the photoconductivity at the relatively low annealing temperature of 180°C suggests the metastable nature of the created defects. The annealing kinetics obeys the stretched-exponential law which is known to be typical for a-Si:H films underwent the light-induced degradation. Hydrogen collision model has been suggested as a mechanism for the defect creation by the electron irradiation.

A waveguide structure consisting of a side-polished single-mode polarization maintaining fibre and a-Si:H film on top has been applied for “in-situ” control of the a-Si:H deposition process. The changes in the fibre output intensities resulting from the film thickness growing have been measured. The interaction of the fibre mode and TE_0 and TE_1 planar modes of a-Si:H waveguide has been investigated. The applicability of the structure as a high sensitive refract metric sensor element for chemical and biological solutions has been demonstrated.

4. OPTICAL PROPERTIES OF MIXED Mo AND WO_3 FILMS

The structure of CVD Mo and W oxide films deposited on conductive glass and silicon substrates has been studied in dependence of technological conditions. It has been established that, in comparison with films on Si substrate, films grown on conductive glass crystallize to a higher degree. Mixed Mo and W oxide films crystallize in triclinic phase of tungsten oxide lattice, where W atoms partly substituted by Mo atoms.

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12. A. Szekeres, T. Nikolova, A. Paneva, A. Cziraki, Gy. Kovacs, I. Lisovskyy, D. Mazunov, I. Indutnyy, P. Shepeliavyi, "Silicon Clusters In Silicon Monoxide Films", *JOAM 7(3)*, 1383-87, (2005).
13. K. Gesheva, A. Cziraki, T. Ivanova, A. Szekeres, "Structure And Composition Of Thermally Annealed Mo- And W-Based CVD Metal Oxide Thin Films", *Thin Solid Films*, **492**, 322-326, (2005).
14. I. Lisovskyy, V. Litovchenko, D. Mazunov, A. Szekeres, "IR Spectroscopy analysis of structure and composition of Si-O phase in ultrathin (10-15 nm) SiO₂ films", *Ukr. J. Phys.* **50**, 78-83, (2005).
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19. A.Szekeres, T.Nikolova, A.Paneva, A.Cziraki, Gy.J. Kovacs, I. Lisovskyy, D. Mazunov, I. Indutnyy, P. Shepeliavyi, "Silicon Nanoparticles In Thermally Annealed Thin Silicon Monoxide Films", *Mater. Sci.&Engineering B*, *Vol. 124-125*, 504-507, (2005)
20. С. Бакалова, "Елипсометрично изследване на слоеве от AlN, получени чрез импулсно-лазерно отлагане, *Списание на БАН*, (2005) *in press*.
21. S. Simeonov, I. Yurukov, A. Gushterov, E. Kafedjiiska, A. Szekeres, "Trap assisted tunneling in Si/SiO₂ structures", *chapter 4, Thin films and Coatings: New Research ed. B.M.Caruta, Nova Science publishers (2005)*
22. Szekeres, S. Alexandrova, P. Lytvyn, M Kompitsas, "Oxidation of hydrogenated crystalline silicon as an alternative approach for ultrathin SiO₂ growth", *J. Physics: Conference Series 10* 246-250, (2005).

23. Szekeres, A. Paneva, T. Nikolova, I. Lisovsky, D. Mazunov, I. Indutnyy, P. Shepeliavyi, "Effect Of Annealing On SiO_x Films With Embedded Si Nanoparticles", *Nanoscience & Nanotechnology*, Eds. E. Balabanova, I. Dragieva, Heron Press, Sofia, Vol. 5, pp. 40-42, (2005)
24. S.Kaschieva, Ch.Angelov, S.N.Dmitriev, "RBS investigation of ion implanted Si-SiO₂ structures irradiated with 20 MeV electrons", *Plasma processes & polymers*, in press
25. S. Kaschieva, E. Halova, E. Vlaikova, S. Alexandrova, E. Valcheva and S.N.Dmitriev, "Investigation of p-type MOS structure irradiated with 23 MeV electrons", *Plasma processes & polymers*, in press
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27. S. Bakalova, S. Simeonov, E. Kafedjiiska, A. Szekeres, S. Grigorescu, G. Socol, E. Axente, I. Mihailescu, "Electrical Properties of MIS Capacitors with AlN Films Synthesized by Pulsed Laser Deposition", *Plasma Proc.&Polymers*, in press
28. E. Valcheva, S. Alexandrova, S. Dimitrov, H. Lu, W.J. Schaff, Recombination processes with and without momentum conservation in degenerate InN, *Phys. stat. sol. (c)*, in press
29. Т. Т. Николова, "Изследване на SiO_x слоеве с вградени силициеви нанокластери с помощта на спектрална елипсометрия", *Списание на БАН*, 2006, in press
30. Szekeres, T. Nikolova, A. Cziraki, Gy. Kovacs, "I. Lisovsky, I. Indutnyy, P. Shepeliavyi, "Silicon nanoparticles in evaporated silicon oxide films: Effect of annealing", *Proceeding of the Workshop on Nanostructured Thin Films, Plovdiv, Bulgaria, 19-21 October, 2005*

ONGOING RESEARCH PROJECTS:

1. "Structure and defects in micro and nano-sized heterostructures" - Financed by BAS

COLLABORATION:

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

LABORATORY

ACOUSTOELECTRONICS

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RESEARCH ACTIVITIES:

1. DESIGN OF A NEW MINIATURE RESONANT TEMPERATURE SENSOR IN NLC-CUT OF QUARTZ

A new 29.3 MHz miniature resonant sensor made from quartz strip-resonators in NLC-cut is developed in a cooperation with LCEP – ENSMM, Besancon, France. The project is a part of QxSens EU contract from program GROWTH of 5-th FP of EC. The strip-resonator design was chosen for temperature sensing application for two reasons: it fits in much smaller enclosures than common disk resonators operating in trapped energy thickness shear, and it operates at a much higher frequency than flexure bars, which are less stable with respect to most perturbing effects. The smaller volume is expected to significantly improve response time. Nevertheless using strip resonators as sensors in large temperature ranges as a counterpart: it requires the control of the stability of spectrum with respect to temperature since exchanges in the spectrum (activity-dips) would perturb the sensor function. In this view, we performed extensive simulations by Finite Element Analysis to analyze the effect of slow temperature changes on the resonant modes spectrum and determine optimal dimensions of the sensors for a given temperature range. Optimizing the FEA model to ensure that it would simultaneously describe both main and spurious modes was performed with help of a semi-analytical model. This dual approach is required by the large computer resources required by FEA. This modeling effort was accompanied by X-rays topography analysis performed at various temperatures in order to track possible activity-dips indicated by frequency-temperature measurement.

Sensors designed in this framework have yielded excellent electrical parameters and are smaller than quartz resonators previously proposed as temperature sensors. Dimensions of piezoelement are 0.082x2x5mm, Q-factor surpasses 50 000. Temperature sensitivity is near 1000Hz/K making easy the use of the frequency output.

2. INVESTIGATION OF THE LONG-THERM STABILITY, THERMAL RESPONSE TIME AND CALIBRATION OF QUARTZ TEMPERATURE RESONANCE SENSORS (QTS)

Resonator's thermal response time at two constant temperature points, $t = 0^{\circ}C$ and $t = 100^{\circ}C$ was examined. A comparison between the thermal response time for QTS01 (plan

parallel circuit-ppc) type in HC 45/U enclosure and QTS02 (strip-type) in TU 39 enclosure shows that the thermal response time of the QTS02 is better than the QTS01's one. For achieving the ambient temperature with an accuracy of 0.001 °C, 60 seconds are enough.

Frequency stability at temperature of 0 °C within time interval of 150 seconds is better than $3,5 \cdot 10^{-9}$, which permit to register temperature variations of 0.085 mK. The long-term stability within 100 days in storages with temperatures of 25 °C and 80 °C is not exceeded $5 \cdot 10^{-7}$. This ensures the success of the sensor's work within 5 years without additional calibration.

Temperature frequency characteristics (TFC) for QTS sensors can be described by a polynomial of third order in the temperature range from liquid helium temperature to 150 °C. At temperatures above minus 20 °C the TFC has linear character with thermosensitivity C_t of 1100 Hz/°C.

Therefore, we have figured out that the single point calibration methodology of QTS for some applications, where low cost calibrated sensors are necessary. In the temperature interval from minus 20 °C to 110 °C the non-linearity of QTS is the smallest one ($\leq 0,2$ °C). TFC in this range is approximated knowing thermosensitivity and measured frequency at temperature 0 °C. Expanded uncertainty, obtained by multiplying the standard uncertainty by a coverage factor $k=2$, in temperature range from minus 20 °C to 110 °C is estimated as 0,24 °C. This value could be in an order lower if a correction of the non-linearity is taken into account at every defined temperature point.

3. IMPLEMENTATION OF "MULTI-CHANNEL MEASUREMENT AND CONTROL SYSTEM BASED ON RESONANT PIEZOELECTRIC CRYSTAL SENSORS – QxSENS" FOR TECHNOLOGICAL PROCESSES DIRECTION

In close cooperation with the partners from the QxSens project a pilot automatic system for control and measurement of food liohylyzation is developed. The system has been mounted and implemented in the Institute of Cryobiology and food technology. Industrial tests prove proposed characteristics of the quartz temperature sensor (QTS).

4. MASSENSITIVE QUARTZ RESONATORS AS A QUARTZ CRYSTAL MICROBALANCE SENSORS

- Sorption properties of thin Ta₂O₅ films to NH₃ vapor were investigated. Quartz piezoelement with two sides deposited thin Ta₂O₅ is used as Quartz Crystal Microbalance (QCM). The experiments were carried out by measuring the resonant frequency shifts of QCM over aqueous solution of NH₃ with different concentrations from 10ppm to 10000ppm. The obtained results have shown that the layers of Ta₂O₅ deposited by method of electron beam evaporation posses enough sorption ability to NH₃ to be measured by QCM. All measured time-frequency characteristics have shown exponential decrease in time independently of NH₃ concentration and the thickness of the layers. The correlation between the relative changes of resonant frequency and ammonia concentration in all investigated interval was found. The obtained data suggest that QCM coated with Ta₂O₅ could be used as an ammonia sensor element with an estimated low limit of 10ppm NH₃.
- Experiments for registration of nano-masses of contamination of hydrogen, oxygen and nitrogen in helium at cryogenic temperatures were carried out. Quartz resonators mounted in the liquid helium system do the measurements. This work is a collaboration between the ISSP- BAS and the Joint Institute for Nuclear Research – Dubna, Russia. Preliminary investigations show sensor ability for purity estimation of liquid helium.
- The humidity-sensing properties of TiO₂ were measured by a quartz microbalance. A two-layer structure consisting of a plasma polymer sublayer and a humidity sensing titanium

dioxide layer was assembled on a quartz resonator. The upper film deposited by magnetron sputtering was determined to be close to that of the stoichiometric TiO_2 . The results (sensitivity up to 10 Hz /%RH) are promising for the developing sensors for measuring the relative humidity in the air.

- The influence of different kinds (Ag, Au and Al) and thickness of thin metal electrodes on the main equivalent dynamic parameters and amplitude-frequency characteristics of quartz resonators are studied. The best values of equivalent dynamic resistance, R_q (9,09 Ohm) and quality factor, Q (57583) are measured for resonators with Ag-electrodes – 1200 Å. The measured AFCs depend on the electrode thickness, but they remain identical for all metals at the same mass loading. The obtained results show that varying the types of the electrodes - their structure and thickness - the acoustical characteristics of resonators can be improved.

5. RESONANT STRUCTURE OF RSAW AND STW AND THEIR APPLICATIONS

An improved version of a Rayleigh surface acoustic wave (RSAW) based single mode resonator operating at 433 MHz and using a gold electrode structure has been developed. This device is intended for use as a sensor coated with chemosensitive polymer films in highly reactive gaseous environments. Full compatibility with existing SAW based sensor systems for gas analysis, developed by the Research Center Karlsruhe, Germany has been demonstrated.

The phase noise performance of surface transverse wave (STW) based oscillators in the 0,9 to 2,5 GHz frequency range, operating at very low supply voltages in the 1,2 to 3,3V range according to the “boost converter” principle has been systematically investigated. These clock oscillators are intended for direct interfacing next generation CMOS circuitry. It has been shown for the first time that, due to the above nonlinear principle, these low-voltage oscillators feature greatly improved overall phase noise performance compared to their linear counterparts operating at much higher supply voltages, in the 5 to 15V range.

A novel low-noise method for improving the medium and long-term stability of GHz range SAW/STW based oscillators to the stability of low-frequency bulk acoustic wave (BAW) crystal oscillators has been demonstrated. Rather than using noisy PLL circuits, this method implements injection locking of the SAW/STW oscillator to a higher overtone of a crystal controlled comb spectrum oscillator. Within the synchronization bandwidth, which is chosen to be sufficiently high to maintain lock over a desired temperature range, the SAW/STW oscillator adopts the medium and long-term stability of the crystal reference and retains its own very low thermal noise floor. The close-in phase noise up to a few kHz carrier offset is improved and equal to the close-in phase noise of the crystal stabilized comb spectrum overtone

6. APPLICATION OF ADVANCED TECHNOLOGY IN OTHER FIELDS

The polymer layers are synthesized in electroluminescent structures in order to be used as protective coatings. The optimization of the plasma parameters and the thickness of the polymer are done. The increase of the brightness over 10 times, stability to electrical breakdown, the reliability and the period of exploitation were demonstrated. The eleven segment hybrid electroluminescent display with protective silicon containing polymer layer received a gold medal in Exhibition for transfer of intellectual products and selling of goods “East-West Euro Intellect – Way to the 21st Century, 2005, Sofia, Bulgaria.

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2. I. D. Avramov, "A 0-Phase Circuit for QCM-Based Measurements in Highly Viscous Liquid Environments", *IEEE Sensors Journal*, Vol. 5, No. 3, June 2005, pp. 425-432.
3. I. D. Avramov, "Low Voltage Surface Transverse Wave Oscillators for the Next Generation CMOS Technology", *IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control*, vol. 52, No. 8, Aug. 2005, pp 1247-1252.
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7. I. D. Avramov, "Low-voltage, high performance STW clocks with BAW crystal stability", *Proc. IEEE 2005 Int. Freq. Control Symp. and PDA Exhibition*.
8. V.Georgieva, L.Spassev, Ts.Yordanov "The effect of different electrode films of the resonators acoustic parameters"Proc. of the 19th European Frequency and Time Forum – 21-24 March 2005, Besancon, France, (in print)
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RESEARCH PROJECTS:

1. Project financed only by Bulgarian Academy of Sciences

1.1. "Investigation of the structure and physicochemical properties of thin layers based on polymers obtained by plasma for sensor application".

2. Financed by international sources

2.1. Institute of Solid State Physics - Joint Institute of Nuclear Research, Dubna, Russia
"Development of mass sensitive quartz resonators for helium complex of the NUCLOTRON" – first stage

2.2. Development of an improved RSAW resonator, using gold electrode structure, with enhanced suppression of parasitic transverse waveguide modes

2.3. Development and test of new technologies for design, construction and manufacturing of energy effective light bodies.

3. Project financed by 5 FP of European Community

3.1. "Growth Programme of 5 Framework of EU: "Multi – Channel Measurement and Control System Based on Resonant Piezoelectric Crystal Sensors – QxSens".

COLLABORATION:

1. "Development of mass sensitive quartz resonators for helium complex of the NUCLOTRON" - Joint Institute for Nuclear Research, Dubna, Russia
2. "Development of an improved RSAW resonator, using gold electrode structure, with enhanced suppression of parasitic transverse waveguide modes" – Research Center Karlsruhe, Germany

LABORATORY

CRYSTAL GROWTH

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RESEARSH SCIENTISTS: **7**

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Assist.Prof. P.M. Rafailov, Ph.D.; Assist.Prof. L.K. Yankova; Assist.Prof. D.I. Toncheva;
O.B. Mihailov, Technician

RESEARCH ACTIVITIES

The research work of the Laboratory of Crystal Growth was focussed on three 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.

The AC conductivity of undoped and doped with Os, Re, Ru and Rh $\text{Bi}_{12}\text{SiO}_{20}$ (BSO) crystals was investigated in the temperature interval 290- 600 K and the frequency range 10^4 - 10^7 Hz- [1]. The main processes for preparing bulk single crystals and films of photorefractive and piezoelectric $\text{Bi}_{12}\text{MeO}_{20}$ (Me= Group II–VIII elements) sillenite compounds are considered and experimental data are summarized and analyzed. The results of measurements of their main physical properties are also reported- [2]. $\text{Bi}_{12}\text{SiO}_{20}$ doped with Ru as well as $\text{Bi}_4\text{Ge}_3\text{O}_{12}$ doped with V are successfully grown and the optimal crystal growth conditions are established. Absorption spectra are measured and magneto- optical effect is investigated in the visual part of the spectra. Some basic parameters of photo-induced phenomena and photo- refractive properties in these crystals are determined [3,4].

Spatially resolved polarized Raman measurements were performed on a Czochralski grown $\text{Bi}_4\text{Ge}_3\text{O}_{12}$ crystal and observed significant spot-dependent changes in the relative scattering intensity of some A_1 , E and F_2 modes. These experimental findings were explained with presence of two-dimensional structural defects with high concentration and strongly non-uniform distribution in the investigated crystals- [5]. The available information about the macrostructural defects (i.e. two- and three- dimensional defects in sillenite crystals $\text{Bi}_{12}\text{MiO}_{20}$ (M = Ge, Si, Ti)) is summarized and analyzed in ref. [6]. The twinning in cubic crystals with symmetry that belongs to the space groups $\overline{F}43m$ (sphalerite type) and $Fd3m$ (diamond type) is considered as a tilt at $(180\pm\alpha)^\circ$ ($\alpha= 70.53^\circ$) about the $\langle 011 \rangle$ axis- [7]. Crystals of $\text{Hg}(\text{Br}_x \text{I}_{1-x})_2$ are grown and their detection of X- and gamma rays capability is determined- [8].

Crystals of LaMnO_3 (La = Dy, Ho, Er, Tb, Yb, Tm, Lu) as well as of HoMnO_3 , HoMn_2O_5 and TbMn_2O_5 are also growth by high temperature solution growth (HTSG) method. Ferro- magnetic as well as ferro- electric phase transitions of HoMnO_3 crystals in the temperature range 1- 300 K and some other effects at low- temperature are investigated- see refs. [9-11]. The temperature dependence of the dielectric loss and susceptibility (ϵ and $\text{tg}\delta$) at different frequencies are measured in $\text{La}_{1-x}\text{Pb}_x\text{MnO}_3$ ($x = 0.3$) crystals [12,13].

Raman spectra at low temperatures of HoMn_2O_5 and TbMn_2O_5 crystals are measured. Any structural changes in HoMn_2O_5 crystals are not established at phase transition temperatures (about 50K) by Raman spectroscopy- [14].

Nano- scale structure and mechanisms of the formation of diffuse phase transition in relaxor ferro- electric of type $\text{PbB}^{0.5}\text{B}^{0.5}\text{O}_3$ (in $\text{PbSc}_{0.5}\text{Ta}_{0.5}\text{O}_3$ (PST) and $\text{PbSc}_{0.5}\text{Nb}_{0.5}\text{O}_3$ (PNT)) were investigated by polarized Raman spectroscopy and far- infra- red ellipsometry- [15,16]. Crystals of $\text{PbSc}_{0.5}\text{Ta}_{0.5}\text{O}_3$, doped with Sn (PST:Sn), as well as mixed crystals $\text{PbSc}_{0.5}(\text{Ta},\text{Nb})_{0.5}\text{O}_3$ (PSTN) were synthesized for evaluation of the influence of the compositional cation disordering. The dielectric behaviour of these crystals was compared with those of stoichiometric $\text{PbSc}_{0.5}\text{Ta}_{0.5}\text{O}_3$, as well as of annealed crystals of $\text{PbSc}_{0.5}\text{Ta}_{0.5}\text{O}_3$. The dielectric measurements are carried out at 0.01- 1 MHz and 243- 573K. It was established a very serious influence of the doping with Sn on the $\epsilon(T)$ - [17].

Some important properties of carbon nanotubes and fullerenes are measured and carbon and WS_2 nanotubes are investigated by Raman spectroscopy- see refs. [18-20].

Crystals of $\text{Pb}_5\text{GeO}_4(\text{VO}_4)_2$ and $\text{Bi}_2\text{Mo}_3\text{O}_{12}$ were grown by the Czochralski method. The absorption spectra in the infra- red range of the spectra are measured in the temperature interval 9- 400 K. The absorption peak of the vibrational bending modes of the hydroxyl $[\text{OH}]^-$ group is determined at $3561,5 \text{ cm}^{-1}$ in $\text{Pb}_5\text{GeO}_4(\text{VO}_4)_2$ crystals. Two absorption peaks at $3467,4 \text{ cm}^{-3}$ and $3337,4 \text{ cm}^{-3}$ at 9 K and anomalies in the temperature dependence of the vibrational frequencies of the peak at $3337,4 \text{ cm}^{-3}$ are observed in $\text{Bi}_2\text{Mo}_3\text{O}_{12}$ crystals- [21].

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ONGOING RESEARCH PROJECTS

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

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

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

COLLABORATION

1. Growth and investigation of wide band gap semiconductor and oxide crystals and layers including SiN and GaN- Institute of Common and Inorganic Chemistry, Russian Academy of Sciences, Moscow, Russia
2. Growth and magneto- optical investigations of sillenite and manganite crystals- Ioffe Institute of Physics, Russian Academy of Sciences, St. Petersburg, Russia
3. Growth and characterization of oxide crystals for optical applications- Research Institute of Solid State Physics and Optics, Budapest, Hungary
4. Static moments of short- lived exotic nuclei studied via hyperfine interaction on the nuclear spins with crystalline electric field gradients- Instituut voor Kern en Stralingsfysica, Leuven, FWO- Flanders, Belgium

LABORATORY

MOLECULAR BEAM EPITAXY and SURFACE ANALYSIS

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TOTAL STAFF: 4

RESEARCH SCIENTISTS: 2

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

RESEARCH ACTIVITIES:

1.1. “Investigation of the surface reconstruction and the epitaxial crystal growth micro mechanisms self-consistency in vacuum” – BAS Project.

A mechanical construction supporting a scanning head of Scanning Tunneling Microscope was designed. The head is intended for integration in the Ultra High Vacuum System (UHVS) for Molecular Beam Epitaxy (MBE) of ISSP and is supplied with piezo ceramic element BM 527 / $\text{Pb}(\text{Zr}_{0.66}\text{Ti}_{0.34})\text{O}_3$. The necessary electronics was designed as well.

To ensure the combined action of the piezo ceramic element and MBE technology we elaborate technologies for 1). *insitu* re-polarization of BM 527, 2). stabilization (training) of the electromechanical properties of the piezo element.

To provide more precise control over the UHV System background atmosphere and the MBE processes an empirical formula for calculation of absolute electron impact ionization cross sections of atoms was developed. The formula was tested for the atoms available in the background atmosphere of the MBE System. It was found an in - the – error – limits conformity between calculated cross section values and the experimentally obtained cross sections for these atoms.

1.2. “Preliminary estimation and modeling of the feasibility for operation of efficient multi – layer staggered – lineup heterostructures for producing a photocell with energy conversion coefficient close to unity” – BAS Project.

The necessary software for multilayered “staggered” heterostructures modeling was elaborated. Using this software a computer modeling of “staggered” III-V heterostructures containing Ga, In and As, Sb, P, and Bi was performed. The dependence of radiation energy conversion on the composition, i.e. $\text{In}_{1-x}\text{Ga}_x/\text{GaSb}_{1-y}\text{As}_y$, $\text{In}_{1-x}\text{Ga}_x\text{Sb}_{1-y}\text{As}_y/\text{GaSb}$, $\text{In}_{1-x}\text{Ga}_x\text{P}_{1-y}\text{As}_y/\text{GaSb}_k\text{As}_l\text{P}_{1-(k+l)}$, $\text{In}_{1-x}\text{Ga}_x\text{Sb}_{1-y}\text{As}_y/\text{GaSb}_k\text{As}_l\text{Bi}_{1-(k+l)}$ was cleared. Four compositional ranges were distinguished and targeted for more detail investigation. For concrete multilayered heterostructure were specified all conditions of epitaxial growth, i.e. growth rate, growth temperature, intensity of molecular beams etc.

1.3. “Studying human chromosomes structure by analyzing their topography obtained through Scanning Tunnelling Microscopy on ultrathin coating water films” – BAS Project.

The technical characteristics of the recently created Scanning Tunneling Data Logger (STD L) for investigation of topographic structure of soft matter objects covered with ultra-thin water layer were improved in several points. The STD L box was sealed hermetically to

ensure better isolation and stabilization of the internal operating environment. An improvement in the box acoustic opacity and stability was achieved by its weighting and sound isolation. The vibration characteristics of the STDL System (resonance frequencies, damping decrement etc.) were investigated.

Second stage in the development of the software for soft matter objects experiments was realized.

A device for STM tips preparation from various metals and of different structure was assembled. The relevant technique for tips preparation using chemical etching was also worked off.

It was created an updated literature base, which has been used to establish a protocol for Scanning Tunneling Microscopy in ultra-thin water layer of soft matter objects, including human chromosomes.

1.4. Within the range of consulting contract on “Visualization of acoustic waves in piezo materials” we developed “Measuring electric field in piezo materials sonde” and “Method for visualization of acoustic waves in piezo materials”

The realizing the method instrumentation includes coaxial sonde, scanning system, measuring electronics, and computer with software. The inherent of the acoustic wave in excited piezo material alternate electric field induces proportional alternate electric charge into scanning the piezo material sonde, where, in this way, an electric wave originates and propagates. The electric wave enters the measuring electronics, where its root mean square amplitude and phase difference towards the periodic stimulation is measured. The obtained result is registered as amplitude and phase of acoustic wave in every point, so that two-dimensional map is produced which is the needed visualization of the acoustic wave.

ONGOING RESEARCH PROJECTS:

1. Studying human chromosomes structure by analyzing their topography obtained through Scanning Tunneling Microscopy on ultrathin coating water films.

LABORATORY

LIQUID CRYSTALS

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RESEARCH ACTIVITIES:

Three projects have been developed in the Laboratory "Liquid Crystals" during 2005 on different contracts: two of them with BAS and one with NSF.

A theoretical study of the dependence of the mechanical properties of lipid bilayer, containing ionic lipids on their concentration in the membrane was performed. For this purpose the value of the electrolyte dissociation of the charges lipid and the free energy of the system, due to electrostatic interactions were determined. It was shown that at certain conditions the electrostatic interactions lead to phase separation in the flat membrane.

The bending elasticity of lipid membranes with the increase of the alamethicin concentrations in the membrane via analysis of the thermally induced shape fluctuations of quasi-spherical giant vesicles was experimentally and theoretically investigated. Our experimental results prove the strong influence of alamethicin molecules on the bending elasticity of diphytanoyl phosphatidylcholine and dilauroyl phosphatidylcholine membranes even in the range of very low peptide concentrations (less than 10^{-3} mol/mol in the membrane). The results testify to the peripheral orientation of alamethicin molecules at low peptide concentrations in the membrane for both types of lipid bilayers. An upper limit of the concentration of the peptide in the membrane is determined below which the system behaves as an ideal two-dimensional solution and the peptide molecules have a planar orientation in the membrane.

A study of the morphological transformations of giant vesicles, prepared, using spontaneous swelling or electro formation methods from different lipids (steroyl oleoyl phosphatidylcholine, diphytanoyl phosphatidylcholine, palmitoyl oleoyl phosphatidylcholine) in water solution of alamethicine and in the presence of the photoactive substance (potassium ferricyanide) outside the vesicles was performed experimentally. The initial results show a certain repetition of the changes of the form of the liposomes at fixed experimental conditions.

The influence of different sucrose concentrations (0, 100, 200, 300, 400 mM) in the aqueous phase on the bending elasticity modulus, k_c , of a lipid membrane was studied using the analysis of thermally induced shape fluctuations of giant quasispherical vesicles. Stroboscopic illumination was applied to cancel the effect of the camera integration (smearing) and to improve the precision of the measurement (almost two-fold). The experiment confirmed that the sucrose reduces the bending elasticity modulus of the lipid membrane. We established a difference in the values of the bending elasticity modulae,

obtained by thermally induced shape fluctuations method and micropipette technique and this difference depends on the sucrose concentration. It was experimentally shown that SOPC vesicles electroformed in 300 and 400 mM sucrose concentration in the water phase do not show any aging effect after a period of 3 - 9 days after the formation.

The elaboration of the theoretical results, obtained by Romanov and Skljarenko (Zh. Eksp. Teor. Fiz. 112, 1675 (97), 116, 543 (99)) permitted to obtain the exact solution of the differential equations describing the behavior of the flexoelectric domains of Vistin' –Pikin-Bobylev under the simultaneous action of d.c. and a.c. voltages. In this way, the exact threshold characteristics $U_c(U_{ac})$, $q_c(U_{ac})$, $U_c(q_c)$, where U_c is the threshold d.c. voltage showing the appearance of the domains, U_{ac} is the value of the a.c. voltage showing the disappearance of the domains and q_c is the threshold wave number, were obtained. The usefulness of these formulae is two-fold: First, the comparison of the experimental points with appropriate computer calculated threshold curves permitted to obtain four of five material parameters, which are the elastic coefficient of splay k_{11} and bend k_{22} , the modulus $|e_{1z} - e_{3x}|$, where e_{1z} is the flexoelectric coefficient of splay and e_{3x} of bend, the modulus of the dielectric anisotropy $|\Delta\epsilon|$ and the thickness of the liquid crystal cell. In this way the important parameters k_{11} , k_{22} and $|e_{1z} - e_{3x}|$ were obtained for the nematic BMAOB (p-n-butyl-p-methoxyazoxybenzene). Second, the computer simulated threshold curves permitted to point out the optimal working parameters for an arbitrary nematic concerning the flexoelectric domains as a part of a device, working in “a variable grating mode” or an electrically-governed diffraction grating on the basis of the electrically-varying wave spacing of the flexoelectric domains.

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10. H. P. Hinov, “On the gradient flexoelectric effect in nematic thirty years later”, *Bulg. J. Phys.* 31, 55 (2004);
11. J. Genova, V. Vitkova, L. Aladgem, P. Meleard, and M.D. Mitov, “Using stroboscopic illumination to improve the precision of the bending modulus measurement” *Bulg. J. Phys.* 31, 68 (2004);
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16. I. Bivas “Mechanical, electric and rheological properties of lipid membranes”, Synopsis of thesis for awarding the scientific degree DSci (Doctor of Physical sciences)

LABORATORY

BIOMOLECULAR LAYERS

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RESEARSH SCIENTISTS: **6**

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T. Angelov, chemist; M. Dencheva-Zarkova, technologist

RESEARCH ACTIVITIES:

The effects of mercury ions on pure lipid bilayers and bilayers containing ion channels formed by alamethicin have been investigated. It was found that the membrane stability is influenced by Hg^{2+} in a non-monotonic concentration-dependent manner. Mercury ions increase the open probability of alamethicin channels.

Photoisomerization effects of 4-octadecylamino-4'-cyanoazobenzene on mechanical stability of bilayer lipid membranes and human erythrocytes have been investigated. Photoinduced pore formation and shape changes have been observed. The results of this investigation indicate that lipid matrix poration probably also takes place in living cells destruction during photodynamic therapy.

On the base of exact solution describing the flexoelectric domains under the joint action of increasing d.c. and high frequency a.c. voltages the best values of the material constants for nematic liquid crystal have been determined. The employed fitting procedure allows improving of the liquid crystal devices utilizing "a variable grating mode (VGM)" and the quality of the liquid crystal diffraction gratings built on the flexoelectric domains.

For the purpose of the magnetic resonance visualization superparamagnetic particles on the base of ferro-oxide have been synthesized. By means of β -cyclodextrin coating a good particle's biocompatibility was obtained. They have excellent water solubility and extended life-time.

Voltage dependency of the membrane resistance of mammalian outer hair cells (OHC) was investigated. Bell shaped dependency symmetrical around zero volts was found under conditions of blocked potassium, sodium and calcium ion currents. Similar dependency was demonstrated in cultured human embryonic kidney (HEK) cells. Transfection of HEK cells with the OHC specific membrane protein Prestin leads to change of the membrane resistance.

Planar nematic layers of 5CB oriented by "sliding on" nanolayers of PTFE were studied by electrooptic methods. In pre-splayed assembled cells low-frequency flexoelectric oscillations were excited thus the weak nematic anchoring on PTFE was revealed. In some of these samples an unusual modulated domain pattern after prolonged a.c. excitation was observed for the first time.

Temperature and voltage dependence of 1st and 2nd harmonic electrooptic spectra for PDLC films characterized by various droplets size distributions was studied. All spectra demonstrate a peculiar minimum. Voltage dependence of the spectra minimum position was found thus indicating for extra nonlinearity in the electro-optical response. At higher voltages splitting of the minimum was observed.

NOA65/thermoindicator/carbon black was tested by heating and registration of the spectra in the wavelength range 380-780 nm. Colors were calculated in the standard CIE system. The results show an expansion of the maximal optical activity to temperatures lower than those for the pure PDLC.

High temperature formation of polymer-dispersed hydrogen bonded liquid crystals has been studied. Bifocal liquid crystal droplets in the PDLC samples were observed. A mechanism for the possible chiralization in the bifocal droplets is suggested.

Holographic recording techniques are used to form switchable gratings in PDLCs.

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1. Y. Marinov, H. P. Hinov, A. G. Petrov, Longitudinal flexoelectric domains in BMAOB nematic layers under the joint action of DC and AC voltages, *J. Optoelectronics and Advanced Materials*, 7, 277-280 (2005).
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* Vol. **31** of Bulg. J. Phys. has been printed in 2005.

ONGOING RESEARCH PROJECTS:

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

1. Project F-1003/00: “Opto-mechano-electricity in photoactive nano liquid crystal systems”. Completed in 2005. Awarded a **1st degree Diploma** by National Council “Scientific Studies”
2. Project DNP1-03/04: “Lyotropic liquid crystalline nanostructures for the biology and medicine”.

COLLABORATION:

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

TEACHING ACTIVITIES:

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

LABORATORY

OPTICS AND SPECTROSCOPY

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RESEARCH ACTIVITIES:

1. OPTICS AND SPECTROSCOPY OF WAVEGUIDES

Different technological regimes were used for obtaining of proton-exchanged waveguides in ferroelectric crystals of different crystallographic orientation. The phase content of the protonated layers and its depth distribution were analyzed by combined spectroscopic measurements (absorption and reflection IR-spectroscopy, Raman spectroscopy and waveguide mode spectroscopy). The results allow technological control of the optical and electro-optical properties through controlling the phase content of such type waveguides.

Thin layers of indium oxide on quartz substrates were deposited by laser ablation. Their structural and optical properties depending on the oxygen pressure and substrate temperature were studied. Their cubic structure was confirmed by Raman spectra. The layers are 85-92 % transparent in the spectral region 400-2400 nm. The lowest optical losses measured are 9 dB/cm.

Periodically structured waveguiding layers of Y_2O_3 doped with Er and Yb deposited on glass substrate by laser ablation were studied. The period of the structure was 650 nm. The inhomogeneity of the waveguides due to the process peculiarities was evaluated to be about 4.6%, however, it does not affect waveguide propagation. Such waveguides are particularly suitable for laser applications because of the low threshold of generation, higher efficiency of light coupling and easier manipulating.

The influence of hydrogen diffusion on Raman spectra of strongly protonated planar waveguides in X- and Z-cut $LiNbO_3$ was studied. A special attention was paid to the vibrations in the low-frequency range ($30-150\text{ cm}^{-1}$) and their dependence on the scattering geometry was studied. The results were used for examination of the structural changes provoked by the proton exchange.

The role of hydrogen in hydrogenated amorphous silicon (a-Si:H) has been studied from the viewpoint of its specific contribution to mechanical stress in the films. The experimental results have shown that it is the silicon-bonded hydrogen that essentially affects

the stress. The change in hydrogen bonding configuration caused by ion implantation has allowed to distinguish the major contribution of clustered hydrogen to the value of stress.

18 MeV electron beam-induced degradation of a-Si:H has been studied. The complete recovery of the photoconductivity at the relatively low annealing temperature of 180°C suggests the metastable nature of the created defects. The annealing kinetics obeys the stretched-exponential law, which is known to be typical for a-Si:H films underwent the light-induced degradation. Hydrogen collision model has been proposed as a mechanism for the defect creation by the electron irradiation.

A waveguide structure consisting of a side-polished single-mode polarization maintaining fiber and a-Si:H film on top has been applied for “in-situ” control of the a-Si:H deposition process. The changes in the fiber output intensity resulting from the film thickness growing have been measured. The interaction between the fiber mode and the TE₀ and TE₁ planar modes of the a-Si:H waveguide has been investigated. The applicability of the structure as a high sensitive refractometric sensor element for chemical and biological solutions has been demonstrated.

2. FIBER OPTICS

Technological and experimental work for creating of optical fiber sensor elements for gas analysis and detection is accomplished. Optical fiber elements are based on a waveguiding structure which consists of a single mode side-polished optical fiber and a planar waveguide. Different metal oxide layers, prepared by pulsed laser deposition are used as a planar waveguide.

A measuring set for the in-situ control of the deposited layer thickness is created. Samples with layers of ZnO, SnO₂, WO₃, ITO (In₂O₃+ SnO₂) and ITO + PdO₂ are successfully prepared and their spectral and polarization characteristics are measured.

Initial experiments which demonstrate the sensitivity of the made sensor elements to different gas components are carried out.

3. HOLOGRAPHIC DIFFRACTION GRATINGS

An extremely high absolute diffraction efficiency (99.6%) in the -1st order was experimentally demonstrated. The high efficiency is due to the optical resonance with a leaky waveguide mode.

The compressing of a spectral wide laser pulse was achieved using two parallel gratings. The peak power strongly increased, while total energy remained almost unchanged. Unique resonant diffraction gratings have been developed having close to 100% diffraction efficiency in a wide spectral region. That way high power 100 fs pulses could be formed.

A method for polarization control of solid-state Yb:YAG ceramic disk laser was proposed and experimentally demonstrated. It is based on resonant diffraction grating, having constructive interference for TE-polarization. Polarization of 600:1 was achieved.

A new theory was developed for the general case and was applied for two concrete situations. First, for studying of the anomalous high light transmission through sub-wave aperture in a highly conducting metal sheet. Second, for analyzing the enhancement of molecular fluorescence in solvents in the presence of thin metal sheet with numerous sub-wave apertures.

Light transmission through a slab of two-dimensional photonic crystal is known to present forbidden gaps. By a particular choice of the surface cut of the slab it is possible to introduce a narrow band of 100% transmission in the forbidden gap.

A differential theory of light diffraction by an arbitrary object described in spherical coordinates was developed. The object could be of any shape and material – conducting or insulating. The method is particularly simple when applied to rotationally symmetric objects.

A new differential theory is developed for studying mode propagation in microstructured optical fibers with arbitrary cross section. The present method called Fast Fourier Factorization initially applied on gratings is generalized to anisotropic and/or inhomogeneous media described in cylindrical coordinates.

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

We carry out experimental and theoretical investigations of the dynamics of home-made multilayer periodic anisotropic structures. The time behaviour in a self-pulsation regime is investigated and the stability conditions are clarified. The time constants of thermal and photorefractive effects are experimentally determined. We investigate an integrated thermo-optical device based on a ZnSe / MgF₂ multilayer and demonstrate a modulation of the optical reflectance around the band edge.

We continue our theoretical and experimental investigations on polarization properties of Vertical-Cavity Surface-Emitting Lasers (VCSELs). We have developed a variational approach model for a single transverse-mode VCSELs with a shallow etch relief, which is confirmed with more fully vectorial numerical method. Our investigations show that polarisation orientation of emitted light depends on the anisotropy of induced losses. A macroscopic analytical model of dielectric susceptibility of semiconductor medium with quantum wells under anisotropic mechanical stress is developed. It allows calculating of the differential optical gain, enhancement of halfwidth of emitted spectral line and the density of electrical carriers at the transparency point. New VCSELs with quantum dot active medium are investigated experimentally.

We investigated theoretically the change of the form of the pulse packages generated in a scheme of short external cavity feedback when the injection current is changed. We unveil the transition of this regime to the regime of low-frequency fluctuations. Experimental investigations of the impact of light polarization is carried out for the case of VCSELs by using cross-correlation analysis and spectral techniques. We investigate stationary regimes in VCSELs with extremely short external resonator and demonstrate that such system can be used for control and stabilization of light polarization.

We carry out experimental and theoretical investigations of orthogonal optical injection in VCSELs. Experimentally is shown that four-wave-mixing precedes polarization switching which itself is either accompanied or not by injection locking. Cascade of period doubling towards chaos is unveiled, where both polarization modes are excited.

Photonic band gap fibers are theoretically investigated using plane wave approach, including optical anisotropy. This approach is of great interest for developing mechanical sensors on the base of photonic band gap fibers. Polarisation behaviour of photonic band gap fibers, including anisotropic liquid crystal, is theoretically investigated. Admittance approach for calculating modal structure of 3-D photonic band-gap crystals is developed, including perfect antireflection layer at the boundaries.

5. OPTICS AND SPECTROSCOPY OF THERMOTROPIC LIQUID CRYSTALS

An unified model of mechanism of thermal and electroconvective (EC) dendrites in nematics with short range smectic order has been suggested. It has been explained that the dendrites growth is an indication of nonlinear dissipative process driven outside of equilibrium. It was settled that, while the thermal dendrites are indication of the propagation of the low temperature (low symmetric) ordered state in high temperature metastable nematics, then EC dendrites are indication of the invasion of the nonequilibrium convective state in the quiescent state of the nematic media in the presence of electric field. The common feature of the both nonlinear processes is the propagation of the interface (front) between the two states accompanied with hysteresis. The growth of the thermal and EC dendrites is driven by the deviation from the equilibrium, expressed by the dimensionless

parameter, which for thermal dendrites is supercooling of high temperature nematic metastable phase in low temperature phase and for EC dendrites it is the deviation of the threshold voltage. Following the dynamic of the growth for both dendrites, we found that the trend characteristic for the thermal dendrites follows power law and that for the EC dendrites is a nonlinear and could be defined by two-dimensional solution of the diffusion equation, expressing the director orientational diffusion. It was found, that while the driving force in the thermal dendrites is the diffusion of the enthalpy out of the interface at lack of the flow, in the EC dendrites the flow is basic characteristic and the driving force is the splitting of the bulk charge carriers (perpendicular to the applied electric field) in the electroconvective state. It was indicated that the thermal and EC dendrites are indication of one subcritical behavior, which is the base of one bifurcation effect – splitting of the convective and homogeneous state, observed as textural bistability.

The optimal and successfully controlled orientation of the LC system in the basic experimental sample – LC cell, also and in the LC display is the main requirement for investigation of the LC substances. However, due to the competition of too many surface alignment ‘agents’, which provoke forces with short and long range order, frequently anisotropical, the problem with LC orientation control is quite complicated. That problem is optimized by holographic diffraction grating with sinusoidal profile, thus achieving a very good distinguish between the ‘clear’ elastic topographical orientation, according to the model of Berreman, from that provoked by the interface liquid crystal – solid surface physicochemical interactions. In this way could be separated the mechanical part of the erasure activation energy from the rest (polarization - ordoelectrical type and adsorption) parts, which is a contribution to the improvement of the physical mechanism model of this kind of memory.

A suddenly rotation of the single local monocrystals axis has been found by imposing the bulk twist on the LC system, at one critical value of the twist angle. Such surface texture transition we explain as disrupting of the surface anchoring – surface instability. A model of this surface instability, which is based on divergation (critical enhancement) of the surface extrapolation length was suggested. The last one is equivalent to the zero value of the surface anchoring.

It is shown, that the monostable surface anchoring, which is created by the holographic diffraction grating with sine-shaped profile consisted of different amplitude-period sizes, could be disrupted by short electrical pulses. In this way the director exhibit one bistable surface configuration – a texture transition from one monostable to the other twisted on π – optical state.

A method for creation of one polymer dispersed LC (PDLC) at which the closed in the polymer matrix liquid crystal “droplets” are chiral structures with ferroelectrical features has been applied. The dispersed in the polymer liquid crystal droplets, with almost spherical shape, exhibit bifocal (twisted bipolar) texture. That texture expresses the existence of chirality, which is created by the reducing of the symmetry in the LC system included in the polymer matrix. A method for polarization analysis, aiding determination of the direction of chiral axis of bifocal chiral LC droplet has been created.

An optical polarization method for indication and control of the nematic LC alignment infiltrated in photonic bandgap fibers has been suggested. The relation between the transmitted trough LC light intensity and the averaged effective birefringence values, which give us possibility to calculate the effective averaged polar angle θ (the angle between the capillary axis and direction of director in nematic LC) is the base of the method. In this way, it is possible to control the orientation of the nematic director towards to the capillary tube axis. The control of the director orientation allows by analysis of the dielectrical coherence length of the controlling electrical field to find the surface extrapolation length value – a measure of the LC surface anchoring value on the inner capillary surface.

6. THEORETICAL METHODS IN MOLECULAR PHYSICS

We have studied theoretically highly excited vibrational states and force constants, characterizing the ground electronic state potential hypersurface of ammonia and some of its symmetrical isotopomers. Computations have been performed on the ammonia vibrational spectrum, based on a specific molecular quantum mechanical model. The results from the calculations are in good agreement with the experimentally available data.

7. MANYPHOTONIC PROCESSES. NONLINEAR OPTICS

New theoretical approaches for rotational and translational contribution to the elastic incoherent structure factor of neutron scattering in liquid crystal systems are proposed. The mesomorphic structure, molecular biaxiality and orientational order parameters are included in the models. The numerical results are presented, discussed and compared with the existing experimental data.

The structure and properties of SiO layers obtained by CVD techniques are investigated and discussed.

The nonlinear reflection of coherent optical waves in substances with large permanent dipole moments is theoretically considered and discussed. The results indicate that phase-conjugate reflection in modified four-wave mixing $\omega = \omega + \omega - \omega$ is considerably enhanced if proper two-photon resonance at 2ω are achieved in such nonlinear optical media. The effect mainly depends on the difference of the permanent dipole moments of the molecular states involved in relevant nonlinear optical process.

Based on the monitoring data of the National Institute of Meteorology and Hydrology at the Bulgarian Academy of Sciences, the quality of the Iskar River water near by Sofia is analyzed. The form, chemical composition and partially the origin of the contaminants are discussed and compared quantitatively with the existing data of the end of the previous decade. The tendency of decreasing of the contaminants is encouraging.

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

The unusual histone variant mH2A represses p300- and Gal4-VP16-dependent polymerase II transcription (1). The repressive effect of mH2A is observed at the level of initiation but not at elongation of transcription, and mH2A interferes with p300-dependent histone acetylation. The nonhistone region of mH2A is responsible for both the repression of initiation of transcription and the inhibition of histone acetylation. In addition, the presence of this domain of mH2A within the nucleosome is able to block nucleosome remodeling and sliding of the histone octamer to neighbouring DNA segments by the remodelers SWI/SNF and ACF. These data unambiguously identify mH2A as a strong transcriptional repressor and show that the repressive effect of mH2A is realized on at least two different transcription activation chromatin-dependent pathways: histone acetylation and nucleosome remodelling.

We have studied the sample concentration-dependent and external stress-dependent stability of nucleosomal arrays (2). Whereas upon stretching a single chromatin fiber in a solution of very low chromatin concentration the statistical distribution of DNA length released upon nucleosome unfolding shows only one population centered on ~ 25 nm, in nucleosome stabilizing conditions a second population with average length of ~ 50 nm was observed. Upon lowering the chromatin concentration to very low values, first the linker histones are released, followed by the H2A-H2B dimer, whereas the H3-H4 tetramer remains stably attached to DNA even at the lowest concentration studied. This suggests that the 25-nm disruption length is a consequence of the histone H2A-H2B dimer dissociation from the histone octamer. In nucleosome stabilizing conditions, a full ~ 145 bp is constrained in the nucleosome.

The photophysical features of laser-induced DNA photochemistry were generalised in terms of energy-migration mediated biphotonic ionization and hole transport (3). The results are fundamental in understanding the mechanisms of UV laser induced DNA-protein “photofingerprinting” and covalent crosslinking.

Our interdisciplinary research uses an original combination of physical methods: Cryoelectron, and Atomic Force Microscopy, Optical Tweezers, and the new laser fingerprinting and protein-DNA crosslinking techniques together with the state of the art molecular biology methodologies to study a very hot and important biological problem.

The research, carried out in collaboration with Ecole Normale Supérieure de Lyon, The Institute Albert Bonniot and UJF-Grenoble, and CEA, Grenoble, France, are funded by Ministry of Education and Science BG, and 6th FP ECC MCRTN “CLUSTOXDNA”. A PhD student from France has been appointed through the latter grant.

9. COLORIMETRY AND ITS APPLICATIONS IN INDUSTRY AND ENVIRONMENT

We have investigated a set of experiments related to the colorimetric parameters (L^* , a^* , b^* , H , Cab and ΔE_{ab} in color space CIELAB) and their ability to be used for textile samples (experimental samples) exploration. The visual color system NCS (Natural Color System) and its color visual samples were successfully studied by smooth textile samples need for evaluation of small color differences (smaller than 1,0 ΔE_{ab}).

The CIE Publication 167: 2005 “Recommended Practice for Tabulating Spectral Data for use in Colour Computations (ISBN 3 901 906 4 41 X) was edited by Central Bureau of CIE in 2005.

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3. K. Panajotov, R. Kotynski, M. Camarena and H. Thienpont, Modelling of the polarization behavior of elliptical surface relief VCSELs, *Journ. Optl. Quant. Electr.*, **37**, 241-252 (2005).
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13. B. Katranchev, H. Naradikian and M. Petrov, 'The role of hydrogen bonding for initiation of chirality, dendrites and physical gel in nematic with short range smectic C order', *Journal of Optoelectronics and Advanced Materials*, **7**, 273-276 (2005).
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27. C.-M. Doyen, W. An, D. Angelov, V. Bondarenko, F. Mietton, V. M. Studitsky, A. Hamiche, R. G. Roeder, P. Bouvet, S. Dimitrov (2006) Mechanism of Polymerase II transcription repression by the histone variant macroH2A. *Mol. Cell. Biol.*, in press.
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36. M. Arizaleta, M. Valencia, H. J. Unold, R. Michalzik, H. Thienpont, K. Panajotov, Polarization properties of VCSELs under optical feedback from extremely short external cavity: parametrical investigation, *Proc. of PHASE Workshop*, p.41 (Metz 29-30 March 05).
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47. M. Sciamanna, I. Gatara, A. Tabaka, H. Thienpont, K. Panajotov, Optical switching with VCSELs, CLEO/EQEC, Munich, (12-17 June 2005) invited talk.
48. I. Gatara, M. Sciamanna, J. Buesa, H. Thienpont, K. Panajotov, Polarization switching and dynamics induced by optical injection in VCSELs, CLEO/EQEC, Munich, (12-17 June 05).
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53. R. Kotynski, T. Szoplik, K. Panajotov, Photonic band structure of 2D lattices with left-handed materials, 7th International Conference on Transparent Optical Networks, Barcelona, Catalonia, Spain (July 3-7 2005) invited paper.
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57. M. Sciamanna, I. Gatara, J. Buesa, M. Triginer, H. Thienpont, K. Panajotov, Nonlinear polarization dynamics in VCSELs with orthogonal optical injection, Second 'Rio de la Plata' Workshop on "Noise, Chaos and Complexity in Lasers and Nonlinear Optics" in Colonia del Sacramento, Uruguay (5-9 December 2005) invited paper.
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ONGOING RESEARCH PROJECTS:

1. Spectroscopical investigations of materials for new liquid crystal displays- PAS Poland-BAS joint research project (Prof. M. Petrov).
2. Investigation of the role of the light polarization in photonic devices for optical processing of information- Brussels, Belgium-ISSP contract (Assoc. Prof. K.Panayotov).
3. 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).
4. Contract No MRTN-CT-2003-505086 within the EC 6th Framework Programme (FP6) "SELECTIVE FORMATION AND BIOCHEMISTRY OF OXIDATIVE CLUSTERED DNA DAMAGE" (CLUSTOXDNA), contact person Dr. Dimitar Angelov
5. Ion Beam Modification of Polymer Surfaces 12924, MAAE, Assoc. Prof. T.Tsvetkova
6. Nonlinear optical phenomena in periodical and anisotropic structures - National grant for science F-1011 (Assoc. Prof. R. Peeva Ph.D.).
7. Investigation of achiral and with induced chirality thermotropic liquid crystals - National grant for science F-1307 (Prof. M. Petrov, D.Sc.).
8. Relaxation processes in polyatomic molecules - National grant for science F-1415 (Prof. S.Rashev, D.Sc.).
9. DYNAMIC OF DNA-PROTEIN INTERACTION AND MECHANISM OF NUCLEOSOME REMODELING - National grant for science K1402, National Found of Science, Principal investigator Dr. Dimitar Angelov

COLLABORATION:

1. Institute of Low Temperature and Structural Research, Polish Acad. of Sciences, Wroclaw.
2. Free University of Brussels, Department of Photonics, Belgium.
3. Forschungszentrum Rossendorf, Institut fuer Ionenstrahlphysik und Materialforschung.
4. 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".

TEACHING ACTIVITIES:

1. Boyko Katranchev, Ph.D. student - thesis in Liquid crystals field.
2. Dimitar Dimitrov, Ph.D. student - thesis in Colorimetry.
3. Erve Menoni, Ph.D. student - thesis in Biophysics.

LABORATORY

ATOMIC SPECTROSCOPY

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

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TOTAL STAFF: **10**

RESEARCH SCIENTISTS: **8**

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

RESEARCH ACTIVITIES:

1. ATOMIC STRUCTURE, SPECTRA AND CONSTANTS

Radiative lifetimes of 16 odd levels belonging to the $4d^25p$ ($z\ ^2F^{\circ}_{5/2,7/2}$; $y\ ^2D^{\circ}_{3/2,5/2}$; $z\ ^2S^{\circ}_{1/2}$; $z\ ^2G^{\circ}_{9/2}$; $z\ ^2P^{\circ}_{1/2}$; $y\ ^2F^{\circ}_{7/2}$; $y\ ^2G^{\circ}_{7/2}$; $x\ ^2D^{\circ}_{3/2,5/2}$; $x\ ^2F^{\circ}_{7/2}$; $x\ ^2F^{\circ}_{5/2}$) configuration of Zr II have been measured using a time-resolved laser-induced fluorescence technique with a single-step excitation process either from the ground state or from metastable levels belonging to the $4d^25s$ and $4d^3$ configurations. For 12 levels, there were no previous results available. The new experimental results and the lifetime values available in the literature have allowed to test a theoretical HFR model including core-polarization effects and to deduce transition probabilities for 243 transitions of astrophysical interest.

Radiative lifetimes of $4d5p$ excited states of Zr III produced in a laser produced plasma were measured. The ions were populated either in the ground state or in metastable states, and the number of ions is strongly dependent on the application of an external magnetic field, which is shown to be very important when using the time-resolved laser-induced fluorescence technique for lifetime measurements in highly charged ions. The experimental lifetime results fall in the region 1-2 ns with statistical uncertainties less than 7%. The experimental values were compared with multi-configuration Hartree-Fock calculations showing an agreement within 12-20%. The experimental values are systematically higher than the theoretical ones.

The experiment was carried out in Lund Laser Center using time resolved laser induced fluorescence method. The experiment was performed in the framework of EC programme "Improvement of Human Potential – Access to Research Infrastructure RII3-CT-2003-506350."

2. HOLLOW CATHODE DISCHARGE - PROPERTIES AND APPLICATION

The spontaneous coherent conductivity in a negative glow is observed and ascribed to the self-aligned excited states. It is an integral galvanic manifestation of the spontaneous coherence. The fine structure observed allows both contributing coherent states and local weak magnetic field to be identified. In a diffusion approach the space distribution of the sputtered atoms is calculated. The corresponding cross-sections and rate constants of Penning ionization by ArI- and NeI- metastable atoms are also computed.

3. HOLLOW CATHODE DISCHARGE AS AN ACTIVE LASER MEDIUM

The gas mixture Ar-N₂ is studied in order to create a light source in the UV region. The aim is to investigate the possibility of making Hg free discharge lamps and to develop a laser emitting in this spectral region, as well. The main assumption in the kinetics of excitation is that the upper laser level population is due to the excitation transfer from the Ar metastable atom to the N₂ molecule in C³Π_u states. Thus, the selfterminated transitions in UV region with nanosecond laser pulse duration can oscillate with microsecond pulse duration. In the case of spontaneous emission there is a significant improvement in the output emission.

4. APPLICATION OF HOLLOW CATHODE DISCHARGE

The SnO₂ thin film modified with hexamethyldisilazane and developed as a base for solid-state gas sensors production is investigated by depth profile analysis in hollow cathode glow discharge, Auger - and XPS- analyses and completed by AFM analysis. Changes in surface morphology and layer composition are revealed caused by rapid thermal annealing treatment. The results are summarized as a function of treatment time and temperature. The optimal conditions are found for fabrication of such kind gas sensors with high sensitivity and selectivity to definite gases.

The experimental and theoretical investigations of negative hydrogen ions in hollow cathode glow discharge as a function of neon/hydrogen proportion are summarized.

Dynamic optogalvanic signals corresponding to uninvestigated up to now Ne optical transitions are registered in Ne-Ca and Ne-Mn hollow cathode lamps. They are supplement to the Ne optogalvanic atlas and are necessary when optogalvanic spectrum is applied for wavelength calibrations of light sources.

PUBLICATIONS:

1. R. Mayo, M. Ortiz, J. Campos, K. Blagoev, G. Malcheva, "Transition probabilities of some high lying states of CdII", **Physica Scripta**, **72**, 142 - 147 (2005).
2. J. Campos, M. Ortiz, R. Mayo, E. Biémont, P. Quinet, K. Blagoev and G. Malcheva, "Radiative Parameters for some Transitions in Ag II spectrum", **Monthly Notices of Royal Astronomical Society - Main Journal**, **363**, 905-910(2005).
3. E. Biémont, K. Blagoev, J. Campos, R. Mayo, G. Malcheva, M. Ortiz, P. Quinet, "Transition probabilities for lines from 4d⁹6s, 4d⁹5d of AgII spectrum and from 3d⁹4d of CuII lines"**SPIE**, **5830**, p. 221 (2005), Bourgas, Bulgaria.
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10. O. Ivanov, R. Djulgerova and M. Georgiev, Photoinduced electrification of solids. I. Plausible mechanisms, xxx.lanl.gov, Paper ID: cond-mat/0508457 (2005)

TEACHING ACTIVITIES:

PhD students - N. Parvanova and V. Steflekova, supervisor Prof. D. Zhechev
Organization of the 8th winter seminar of young scientists

ONGOING RESEARCH PROJECTS:

1. Micro Hollow Cathode Discharge and applications (supported by Nat Sci Fund, 2003-2006)
Experiment on this light source is in progress.
2. Radiative properties of ionic spectra (supported by Bulgarian National Science Foundation – contract 1516/2005) Experimental investigation of Cu II spectrum is in progress.
3. Photo-induced effects in low temperature plasma and solid state surface: photo-resonant and surface photo-charge effects" project in the framework of BAS.
4. Radiative lifetimes and transition probabilities of excited atomic and ionic states project in the framework of BAS. Cancellation effects in Zn II spectrum will be investigated.
5. Recombination and ionization processes in nonequilibrium low temperature plasma project in the framework of BAS. An experimental study of the UV lasing on the neon ion lines is in progress. Calculations have shown that population inversion on the UV neon ion transitions in the region 330 nm – 370 nm can be created.

INTERNATIONAL COLLABORATION:

1. International collaboration under the Problem "Laser spectroscopy of low-living isomers" with Laboratory of Nuclear Reactions, Dubna, Russia – Prof. DSc. D. Zhechev
2. EU Program COST 529 Efficient Lightning of 21th century – Prof. DSc. K. Blagoev
3. " Investigations of optogalvanic effect in gas mixture hollow cathode discharge plasma – peculiarities and interpretations" - Institute of Physics of Belgrade, Serbia and Montenegro – V. Mihailov (2004-2006)
4. "Analysis of multy-component materials – problems and applications " – Institute of Physics of Belgrade, Serbia and Montenegro – Dr. R.Djulgerova

LABORATORY

METAL VAPOUR LASERS

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

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TOTAL STAFF: **14**

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**
Blagovela G. **Blagoeva**; Georgi D. **Toshev**; Ivan S. **Radkov**

RESEARCH ACTIVITIES

International and national scientific projects

In 2005 the scientific team at the Laboratory of Metal Vapour Lasers worked on totally four research projects, as follows: two international research projects under agreements for cooperation between Academies and Institutes, one project with the National Council for Scientific Research at the Ministry of Education of Bulgaria, and one project with a Bulgarian industrial company.

Scientific activities abroad

In 2005 scientists from the Laboratory of Metal Vapour Lasers visited foreign scientific institutions in pursuance of scientific tasks as follows: for long-term scientific investigations: 1, for giving lectures: 1.

TEACHING ACTIVITIES

PhD students: 3

SCIENTIFIC ACHIEVEMENTS

The scientific investigations carried out in 2005 at the Laboratory of Metal Vapour Lasers were in the next areas: 1) Metal vapour ion lasers; 2) Pulsed self-terminating lasers; 3) Technological applications of the lasers oscillating in the UV and visible spectral regions; and 4) Theoretical studies in the field of coherent optics.

1) Metal vapour ion lasers

A lifetime of 700 hours has been achieved for the discharge tube of an UV Cu⁺ Ne-CuBr laser at periodical replenishment of the Ne buffer gas at an average output power of 500-600 mW. An optical system with a collimator was built which enabled to obtain a laser beam divergence of 0.1 mrad. That enables precise focusing of the UV laser beam in a spot of about 10 micron diameter.

A hollow cathode copper ion laser oscillating in the near infrared spectral region was investigated. The length of the active discharge zone in a longitudinal hollow cathode

discharge was determined. The investigations to obtain UV laser action in thallium ions in a longitudinal pulsed discharge ended with no result.

2) Pulsed self-terminating lasers

The coherent properties of a CuBr amplifier system were investigated. It was shown that the spatial coherence improves highly with reducing the laser beam divergence, as for this purpose an unstable diffraction resonator was used. Ways for manipulating the laser pulse shape by means of an amplifier CuBr laser system were shown.

Investigations on a copper CuBr laser with a cold point of the laser tube for increasing the lifetime of a powerful 40-W laser were continued.

Investigations of a He-Sr recombination laser oscillating at 6.45 microns in the infrared spectral region were completed successfully. In a new laser tube construction a maximum average output power of 12.5 W has been obtained that is the best result for such a laser.

3) Technological applications of the UV and visible lasers created at the Laboratory of Metal Vapour Lasers

Laser-induced modification by the use of UV laser radiation with 248.6 nm wavelength has been performed in a conducting polymer. A significant growth in the electro-crystallization of copper on polymer layers was obtained. The refractivity of polymer layers in the visible and ultraviolet spectral regions was determined. Micronic holes of 10, 20 and 40 microns in size were drilled in glass, polymer and ZnSe.

Structural modifications in the surface layer of copper and aluminum were investigated by the use of visible laser radiation.

4) Theoretical studies in coherent optics

These studies are related with the processing of quantum information. A new technique has been suggested for the controllable creation of quantum superposition of many states and for studying qutrits (three-state systems).

PUBLICATIONS

Papers published in international journals and proceedings

1. D.N.Astadjov, L.I.Stoychev, S.K.Dixit, S.V.Nakhe, and N.V.Sabotinov, High-brightness CuBr MOPA laser with diffraction-limited throughout-pulse emission, IEEE J. Quantum Electronics 41, 8, 1097-1101, (2005).
2. N. K. Vuchkov, K. A. Temelkov, N. V. Sabotinov, Effect of hydrogen on the average output power of the UV Cu⁺ Ne-CuBr laser, IEEE J. of Quantum Electron, vol.41, No1, pp.62-65, (2005).
3. N. K. Vuchkov, K. A. Temelkov, N. V. Sabotinov, UV Cu⁺ Ne-CuBr laser – some problems with the discharge tube resource, Proceed. of SPIE, vol.577, part two, pp. 524-527, (2005).
4. N. K. Vuchkov, K. A. Temelkov, N. V. Sabotinov, A comparative investigation on the output characteristics of the UV Cu⁺ Ne-CuBr laser excited by the Blumlein and IC electrical schemes, Proceed. of SPIE, vol. 5830, pp. 531-535, (2005).
5. K. Beev, K. Temelkov, N. Vuchkov, Tz. Petrova, V. Dragostinova, R. Stoycheva-Topalova, S. Sainov, N. Sabotinov, “Optical properties of Polymer films for Near UV Recording”, J. of Optoelectr. and Advanced Materials, vol.7, No 3, pp.1315-1318, (2005).
6. D. Mihailova, M. Grozeva and N. Sabotinov, Effect of cathode length on the excitation efficiency of sputtering hollow cathode metal vapour laser, Proc. SPIE 5830, 526-530, (2005).
7. E. Kyoseva and N. V. Vitinov, Resonant excitation amidst dephasing: An exact analytic solution, Phys. Rev. A 71, 054102(4), (2005).

8. P. A. Ivanov and N. V. Vitanov, Adiabatic evolution amidst dephasing, Phys. Rev. A 71, 063407(7), (2005).
9. R. Garcia-Fernandez, A. Ekers, L. P. Yatsenko, N. V. Vitanov, and K. Bergmann, Control of population flow in coherently driven quantum ladders, Phys. Rev. Lett. 95, 043001(4), (2005).
10. Z. Kis, N. V. Vitanov, A. Karpati, C. Barthel, and K. Bergmann, Creation of arbitrary coherent superposition states by stimulated Raman adiabatic passage, Phys. Rev. A 72, 033403(10), (2005).
11. G. S. Vasilev and N. V. Vitanov, Coherent excitation of a two-state system by a linearly chirped Gaussian pulse, J. Chem. Phys. 123, 174106(10), (2005).
12. A. A. Rangelov, N.V. Vitanov, L. P. Yatsenko, B. W. Shore, T. Halfmann, and K. Bergmann, Stark-shift-chirped rapid-adiabatic-passage technique among three states, Phys. Rev. A 72, 053403(12) (2005)
13. A. A. Rangelov, J. Piilo, and N. V. Vitanov, Counterintuitive transitions between crossing energy levels, Phys. Rev. A 72, 053404(9), (2005).
14. N. V. Vitanov and B. W. Shore, Quantum transitions driven by missing frequencies, Phys. Rev. A 72, 052507(8), (2005).
15. P.A. Ivanov, N. V. Vitanov, and K. Bergmann, Spontaneous emission in stimulated Raman adiabatic passage, Phys. Rev. A 72, 053412(8), (2005).

Papers accepted for publication in international journals and proceedings

1. K A. Temelkov, N K Vuchkov and N V Sabotinov, Penning ionization cross sections and rate constants, in print in Journal of Physics: Conf. Series.
2. K A Temelkov, N K Vuchkov and N V Sabotinov, Cross sections and rate constants for charge transfer into excited states, in print in Plasma Processes and Polymers.
3. Nikolay K. Vuchkov, "High discharge tube resource of the UV Cu+ Ne-CuBr laser and some applications", обзорна статия като глава от книга "Progress in Laser and Electro-Optics Research", in print in Nova Science Publishers Inc., New York.
4. M.Grozeva, D.Mihailova and N.Sabotinov, Possibilities of UV Laser Oscillation on Aluminum Ion Lines, Journal of Physics: Conference Series
5. E. S. Kioseva and N. V. Vitanov, Coherent pulsed excitation of degenerate multistate systems: Exact analytic solutions, accepted in Phys. Rev. A (2005)
6. P. A. Ivanov and N. V. Vitanov, State reconstruction of a qutrit by a minimal set of discrete measurements, accepted in Opt. Commun. (2005)

Papers published in full size in proceedings of conferences in Bulgaria

1. D. N. Astadjov, L.I.Stoychev and N. V. Sabotinov, Improvement of CuBr Laser Coherence Properties – SPIE Intern. Conf. on Holography, Optical Recording and Processing of Information "Holography 2005", May 2005, Varna
2. D. N. Astadjov, L.I.Stoychev and N. V. Sabotinov, CuBr Laser Pulse Shaping by MOPA System – IV Intern. Symposium on Laser Technologies and Lasers "LTL Plovdiv'2005", Oct.2005, Plovdiv
3. N. P. Denev, D. N. Astadjov and N. V. Sabotinov, Analysis of the Copper Bromide Laser Efficiency - IV Intern. Symposium on Laser Technologies and Lasers "LTL Plovdiv'2005", Oct.2005, Plovdiv
4. N.V.Sabotinov, Development of Copper Vapour Lasers, IV Intern. Symposium on Laser Technologies and Lasers "LTL Plovdiv'2005", Oct.2005, Plovdiv
5. M.Grozeva, D.Mihailova and N.Sabotinov, Sputtering hollow cathode cooper ion laser: optimization of cathodes length, Symposium Proceedings - IV LTL Plovdiv'2005
6. N. Vuchkov, K. Temelkov, M. Ilieva, V. Tsakova, , N. Sabotinov, UV Cu+ Ne-CuBr laser for material Processing, in print in Proc. of LTL, 2005.