Bulgarian Academy of Sciences

GEORGI NADJAKOV INSTITUTE
OF SOLID STATE PHYSICS

ANNUAL RESEARCH REPORT
2017

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Foreword

During 2017 the Institute organized the following events: Open Day in the framework of the initiative "BAS Presents its Institutes", 3 exhibitions, 25th anniversary of the creation of the Laboratory “Biomolecular Layers” and 20th Winter Seminar "Interdisciplinary Physics" of doctoral students and young scientists from the Bulgarian Academy of Sciences.

On the occasion of the 45th anniversary of the Institute of Solid State Physics - BAS within the framework of the Academic Seminar "Current Problems of Science" at the Bulgarian Academy of Sciences a series of lectures on "Metal Vapor Lasers and Bulgarian Contribution to Their Development in World Science and Practice" were held. In the three consecutive lectures Acad. Sabotinov presented Bulgarian achievements of major significance in the field of lasers and laser technologies and their realization as innovations in Bulgaria and abroad.

In 2017 the project BG05M2OP001-1.001-0008, funded by the Operational Programme “Science and Education for Smart Growth” financed by the Ministry of Education, Youth and Science and co-financed by the European Union through European structural and investment funds started its realization. The purpose of the project is to build a new type of National Center of Excellence for Mechatronics and clean technologies. ISSP is a one of the basic partners in this project.

In 2017 the project 312804 “Device For Large Scale Fog Decontamination“– COUNTERFOG, financed under the ,,Security” programme was successfully finalized.

ISSP hosts a reintegration grant COPQE (Composite Pulses for Quantum Engineering) in the framework of the Horizon 2020 European programme.

During 2017 started the organization of the Jubilee 20th edition of the traditional International School on Condensed Matter Physics devoted to “Physics and Applications of Advanced and Multifunctional Materials”. The event will be held from 3rd to 7th September 2018 in Varna, Bulgaria.

The total number of publications of ISSP during 2017 is 148, 136 among them printed and 12 at press. 69 papers have been published in high impact journals indexed in ISI web of knowledge and SCOPUS. In 2017 six monographs were published with authors from ISSP; four of them with international scope and two with national coverage. The total number of citations in 2017 exceeds 1336. ISSP currently holds 10 BG patents and 16 applications for patents are in procedure, 5 of which are filed in 2017.

At the end of 2016 a patent "Metal-insulator-silicone structures containing silicone nanocrystals" was approved. The patent was nominated for the best Bulgarian patent in 2017 in the category "Chemistry and Biotechnology".

At the end of 2017 a patent "Method and ionisation detector for analysis of impurities in gases" was approved.

The scientific teams, led by Assoc. Prof. Ognyan Ivanov and Assoc. Prof. Peter Rafailov were awarded the prize for major scientific achievements for the year 2017 in ISSP.

Hassan Chamati

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

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

EQUIPMENT, METHODS AND TECHNOLOGIES

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

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

HISTORICAL REFERENCE: *ISSP at BAS is created by a Decree No 362 / October16, 1972, of the Ministry Council of Bulgaria. This Decree splits the existing Institute of Physics with Atomic Scientific Experimental Center (IP with ASEC) at BAS, founded by Academician G. Nadjakov in 1946, into ISSP and INRNE (Institute of Nuclear Research and Nuclear Energy), starting January 1, 1973. Since February 16, 1982 the Institute of Solid State Physics is named after Academician Georgi Nadjakov. The first Director (1973-1991) of the Institute of Solid State Physics was Academician Milko Borissov. The second Director (1991-1999) was Professor Nikolay Kirov. The third Director (1999-2015) of the Institute of Solid State Physics was Academician Alexander G. Petrov.*

ORGANIZATION OF THE INSTITUTE OF SOLID STATE PHISICS

DIRECTORATE

Director:	Prof. H. Chamati, D.Sc.
Deputy Director:	Prof. A. Paskaleva, D.Sc.
Scientific Secretary:	Assoc. Prof. J. Genova, Ph.D.

DEPARTMENTS

Theory	Head: Prof. H. Chamati, D.Sc.
Functional Materials and Nanostructures	Head: Prof. A. Paskaleva, D.Sc.
Nanophysics	Head: Prof. D. Nesheva, D.Sc.
Physical Optics and Optical Methods	Head: Assoc. Prof. T. Tenev, Ph.D.
Soft Matter Physics	Head: Prof. I. Bivas, D. Sc.
Laser, Atomic, Molecular and Plasma Physics	Head: Assoc. Prof. V. Mihaylov, Ph.D.
Innovation Department:	Head: Assoc. Prof. D. Spassov, Ph.D.
Education Department:	Head: Prof. A. Paskaleva, D.Sc.
Center for Investigation of the Physical Properties of Materials, Surfaces and Structures:	

SCIENTIFIC COUNCIL

Chairman: Prof. D. Nesheva, D.Sc.
Deputy Chairman: Prof. I. Bivas, D.Sc.
Secretary: Assoc. Prof. E. Dimova, Ph.D.

1. Acad. A. G. Petrov, D.Sc.
2. Prof. K. Blagoev, D.Sc.
3. Prof. H. Chamati, D.Sc.
4. Assoc. Prof. A. Paskaleva, D.Sc.
5. Assoc. Prof. V. Vitkova, Ph.D.
6. Assoc. Prof. J. Genova, Ph.D.
7. Assoc. Prof. M. Grozeva, Ph.D.
9. Assoc. Prof. O. Ivanov, Ph.D.
10. Assoc. Prof. V. Mihailov, Ph.D.
11. Assoc. Prof. E. Nazarova, Ph.D.
12. Assoc. Prof. G. Popkirov, Ph.D.
13. Assoc. Prof. M. Primatarowa, Ph.D.
14. Assoc. Prof. P. Rafailov, Ph.D.
15. Assoc. Prof. T. Tenev, Ph.D.
16. S. Varbev (young scientists' representative)

LABORATORY

ELECTROMAGNETIC SENSORS

HEAD: **Assoc. Prof. Ognyan Ivanov, Ph.D.**
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TOTAL STAFF: **5**
RESEARCH SCIENTISTS: **2**
ASSOC. MEMBERS: **1**

Assist. Prof. L. Mihailov, Ph.D.; P. Todorov, Ph.D. student – Mechanical engineer; V. Altunova, B.Sc. student – Laboratory technical assistant

Associated member: Assoc. Prof. Katya Hristova, Ph.D.

RESEARCH ACTIVITIES:

In 2017, studies of the solid surface – two-phase fluid interaction were conducted. On the basis of the results obtained, sensors for two-phase fluids were developed and series of devices were created, which have been designed to cooperate with systems for elimination of consequences of terrorist attacks with weapons for mass destruction, industrial accidents, disasters, etc. These systems have been designed to improve European security.

Properties of matter under extreme conditions, namely in neutron stars, were investigated. Electrons are expected to form an ideal Fermi gas. The composition and the equation of state of such systems were shown to be significantly affected by Landau quantisation of the electron motion. The internal structure of the outer crust of a magnetized neutron star was investigated using sing the latest experimental nuclear mass measurements supplemented with a microscopic nuclear mass model. General approximate analytical formulas for the nuclear quantities and the depths of the different crustal layers were presented.

A link between the energy characteristics of the ground state of helium-like ions and the isotope characteristics of the nucleus of the system was established. High-precision calculations of the electron ground state energies of such ions require to take into account the effects associated with nuclear characteristics and electron correlations. Results for 3833 existing isotopes in the whole range of nuclear charge were discussed. Staggering analysis for the ground state energy dependence on Z and N helped establish the electron characteristic dependence on the nuclear magic numbers. A revolutionary idea of Extra Dimensions on the Energy Characteristics of Heliumoid Electron-Nuclear Systems was proposed.

AWARDS:

First place in the competition *Most Significant Applied Science Achievement 2017* at the Institute of Solid State Physics, Bulgarian Academy of Science for the development of *SPCE sensor with a liquid layer for detection of contamination in fog*.

PUBLICATIONS:

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2. Ivanov O., Mitova I., Pérez-Díaz J. L., Yordanova A., Measurements of speed and diameters of droplets of fogs with devices, operating on the basis of the Surface photo-charge effect, *Proceedings of the First International Scientific Conference on Security "CONFSEC 2017*", 2, 2017, ISSN (Print): 2603-2945, ISSN (Online): 2603-2953, 173-175

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5. Ivanov O., Karatodorov S., Pérez Díaz J. L., Novel Electromagnetic Sensor for Contaminations in Fog Based on the Laser-induced Charge Effect, *Proceedings of IEEE SENSORS 2017*, CFP17SE, IEEE, 2017, ISBN: 978-1-5386-4056-2, 1509-1511

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10. Gelkov M., Ivanov O., Pulis V., Pérez-Díaz J. L., Small-scale infrared fog detector, *Proceedings of the First International Scientific Conference on Security "CONFSEC 2017*", 2, 2017, ISSN (Print): 2603-2945, ISSN (Online) 2603-2953, 162-164

11. Gelkov M., Ivanov O., Pulis V., Pérez-Díaz J. L., Small-scale infrared fog detector, *Security & Future*, 2, 2017, ISSN: 2535-0668, 86-88

12. Gelkov M., Pulis V., Ivanov O., Pérez-Díaz J. L., Stanchev T., Yordanova A., Todorov P., An apparatus for recording of extremes in electrical signals - FDI-1, *Proceedings of The First*

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13. Gelkov M., Pulis V., Ivanov O., Pérez-Díaz J. L., Stanchev T., Yordanova A., Todorov P., An apparatus for recording of extremes in electrical signals - FDI-1. *Security & Future*, 3, 2017, ISSN: 2535-0668, 117-120

14. Gonevski N., Ivanov O., Todorov P., Pulis V., Pérez Díaz J. L., Device for fog density control, *Innovations*, 1, 2017, ISSN (Print): 1314-8907, ISSN (Online): 2534-8469, 21-24

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16. Pashev K., Ivanov O., Pulis V., Todorov P., Pérez-Díaz J. L., Device for fog density control with multiple reflections of the beam. *Proceedings of the First International Scientific Conference on Security "CONFSEC 2017"*, 2, 2017, ISSN (Print): 2603-2945, ISSN (Online): 2603-2953, 159-161

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PATENTS:

- *A method for determining the threshold ablation of solid materials,* Ognyan Ivanov, Valentin Mihailov, Stefan Karatodorov, José Luis Pérez-Díaz, application № 112446 / 24.01.2017 of the Patent Office of the republic of Bulgaria.

- *Contactless detection of phase transition in liquid crystal state by means of laser induced surface photo charge effect through measurement of one electrical signal,* Ognyan Ivanov, Haritun Naradikian, José Luis Pérez-Díaz, application № 112488 / 13.04.2017 of the Patent Office of the republic of Bulgaria.

- *Detecting the presence of impurities in the composition of fogs and aerosols through measuring the electrical signal induced by surface photo charge effect,* Ognyan Ivanov, José Luis Pérez-Díaz, application № 112588 / 29.09.17 of the Patent Office of the republic of Bulgaria.

- *Optimization of the cleaning properties of fog by means of a sensor operating on the basis of laser-induced photo-charge effect by measuring electrical signals*, Ognyan Ivanov, Petar Todorov, José Luis Pérez-Díaz, application № 112601 / 20.10.2017 of the Patent Office of the republic of Bulgaria

- *Contactless evaluation of the number and diameter of fog droplets by gravitational separation and measurement of electrical signals,* Ognyan Ivanov, Petar Todorov, José Luis Pérez-Díaz, application № 112602 / 20.10.2017 of the Patent Office of the republic of Bulgaria

ONGOING RESEARCH PROJECTS:

European project: *Device For Large Scale Fog Decontamination* (COUNTERFOG) – FP7, Programme *Security*, Project Number - 312804

INTERNATIONAL COLLABORATION:

Within the project *COUNTERFOG* we have worked together with nine European partners. We have joint publications, in which our team has a leading role.

During the year we also worked together with a colleague from *NUARI – Norwich University Applied Research Institutes, USA*, on investigations of fluids.

In 2017 we worked successfully in the field of astrophysics with colleagues from *Institut d'Astronomie et d'Astrophysique,* Brussels, *Grand Accélérateur National d'Ions Lourds,* France, and *Département de Physique, Université de Montréal*, Montréal.

We also worked on a study of helium-like ions with colleagues from *Center for Molecular Modelling, Ghent University,* Belgium, and *Laboratoire de Chimie Physique,* Paris.

We also have joint publications with all of them.

THEORY

LABORATORY

THEORY GROUP

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ASSOC. MEMBERS: **1**

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Assoc. Prof. Z. Dimitrova, Ph.D.; Assoc. Prof. R. Kamburova, Ph.D.;
Assist. Prof. A. Donkov, Ph.D.; Assist. Prof. J. Boradjiev, Ph.D.;
Assist. Prof. S. Varbev, Ph.D.; Assist. Prof. M. Georgiev;
Physicist H. Tonchev, Ph.D.; Physicist E. Popov, Ph.D.; Physicist K. Gaminchev
Associated members: Assoc. Prof. M. Primatarowa, Ph.D.

RESEARCH ACTIVITIES:

A short overview of the theoretical and experimental works on the polymer-colloid mixtures is given. The behaviour of a dilute solution of linear and ring polymers in confined geometries like slit of two parallel walls or in the solution of mesoscopic colloidal particles of big size with different adsorbing or repelling properties with respect to polymers is discussed. Besides, we consider the massive field theory approach in fixed space dimensions $d = 3$ for the investigation of the interaction between long flexible polymers and mesoscopic colloidal particles of big size and for the calculation of the correspondent depletion interaction potentials and the depletion forces between confining walls. The presented results indicate the interesting and nontrivial behavior of linear and ring polymers in confined geometries and give possibility better to understand the complexity of physical effects arising from confinement and chain topology which plays a significant role in the shaping of individual chromosomes and the process of their segregation, especially for elongated bacterial cells. The possibility of using linear and ring polymers for production of new types of nano- and micro-electromechanical devices is analyzed.

The study of quantum spin systems defined on Kagome lattices is a hot topic in the field of quantum magnetism. Using 1/S expansions and the coupled cluster method, we analyze the quantum phase diagram and the low-lying states of a spin model of this class containing two types of spin variables ($S=\frac{1}{2}$ and 1) and two types of exchange bonds. We show that at a classical level the system exhibits a ferrimagnetic and a canted phase, the last one been characterized by a line of zero modes in the Brillouin zone. The quantum fluctuations lift the classical degeneracy of the ground state and change the position of the quantum phase transition. For a one dimensional Kagome stripe – a spin chain, which is a cut-out from the aforementioned Kagome lattice – keeping the two types of spin variables and the two values of the spin exchange interactions, the classical phase diagram has been found and the study of the one-magnon excited states is in progress.

We study phenomenologically on the basis of two bilinearly coupled Heisenberg models the phase diagram of some ferrimagnetic substances. Calculations are performed with

the help of Landau energy obtained through applying the Hubbard-Stratonovich transformation to the initial microscopic Heisenberg Hamiltonian. The phase transitions within the model are of second order with the emergence of a compensation point at lower temperatures for some values of parameters of the system. The main phase is a two-sublattice collinear ferrimagnet but also a metastable non-collinear phase is present within the exchange approximation presented. The numerical results give a detailed description of temperature dependence of magnetization on the strength of intersublattice interaction and the difference between the effective exchanges of two ferromagnetically ordered sublattices.

The propagation of soliton excitations in a system of two inhomogenous ferromagnetic chains coupled through the interaction between opposite lying spins is studied. The chains of N spins are described by the Heisenberg model in nearest neighbour approximation with on-site anisotropy and external magnetic field. Three different type localized defects are investigated. Evolutionary equations for this system are derived after consistently applying quasiclassical and continuum approximations. Localized bound soliton-defect solutions are obtained analytically for linear and nonlinear point defects and their stability is studied numerically. The influence of the anisotropy on the stability of the localized solutions is studied. It was found that single peak bound soliton-defect solution, corresponding to an attractive point defect is stable for different anisotropy values, while bound soliton- repulsive defect solution (double peak) is unstable and easily destroyed.

The study of the Jaynes-Cummings Hamiltonian applied to a finite system of spin-1/2 spins has been continued. This is a Hamiltonian, which models the interaction of the quantized electromagnetic field of a laser beam with a particular arrangement of atoms, quantum dots, and so on, subjected to the laser beam's action. The additional spin exchange interaction has been considered in various forms: isotropic, anisotropic, between the nearest, as well as for the further neighbours, and has been applied to open and periodic geometries of a one dimensional spin system. The time dependence of the magnetization and the evolution of the spin system as a whole, as well as the Rabi oscillations of the individual spins has been obtained numerically. The results show the dependence on the explicit form of the initial state of the system. For the analytical results algorithms from computer algebra systems has been used, and for the numerics, packages for numerical simulation of quantum spin systems, such as ALPS and QuSpin, has been utilized.

The synchronization of chaotic units connected through time-delayed fluctuating interactions is studied. Focusing on small-world networks of Bernoulli and Logistic units with a fixed chiral backbone, we compare the synchronization properties of static and fluctuating networks in the regime of large delays. We find that random network switching may enhance the stability of synchronized states. Synchronization appears to be maximally stable when fluctuations are much faster than the time-delay, whereas it disappears for very slow fluctuations. For fluctuation time scales of the order of the time-delay, we report a resynchronizing effect in finite-size networks. Moreover, we observe characteristic oscillations in all regimes, with a periodicity related to the time-delay, as the system approaches or drifts away from the synchronized state.

The modified method of simplest equation is applied to two tasks: (1) Find solutions of nonlinear partial differential equations that contain monomials of even and odd grade with respect to participating derivatives, when the simplest equation has the form $f\xi^2=n^2(f^2-f^{(2n+2)/n})$. With this simplest equation solitary wave solutions can be obtained. As particular cases a version of the modified the Korteweg–deVries equation and the classic version of the Boussinesq-type equation are solved; (2) Solving the modified Korteweg–deVries equation derived to the case of motion of the arterial wall (a displacement from the initial position) under the pressure. The obtained solutions are based on the simple equation of Abel and are of

the type of traveling wave which shape depends on the characteristics of the wall.

Barkhausen effect in ferromagnetic materials provides an excellent area for investigating scaling phenomena found in disordered systems exhibiting crackling noise. The critical dynamics is characterized by random pulses or avalanches with scale-invariant properties, power-law distributions, and universal features. However, the traditional Barkhausen avalanches statistics may not be sufficient to fully characterize the complex temporal correlation of the magnetic domain walls dynamics. Here we focus on the multifractal scenario to quantify the temporal scaling characteristics of Barkhausen avalanches in polycrystalline and amorphous ferromagnetic films with thicknesses from 50 to 1000 nm. We show that the multifractal properties are dependent on film thickness, although they seem to be insensitive to the structural character of the materials. Moreover, we observe for the first time the vanishing of the multifractality in the domain walls dynamics. As the thickness is reduced, the multifractal behavior gives place to a monofractal one over the entire range of time scales. This reorganization in the temporal scaling characteristics of Barkhausen avalanches is understood as a universal restructuring associated to the dimensional crossover, from three- to two-dimensional magnetization dynamics.

Entropy measures are widely applied to quantify the complexity of dynamical systems in diverse fields. However, the practical application of entropy methods is challenging, due to the variety of entropy measures and estimators and the complexity of real-world time series, including nonstationarities and long-range correlations (LRC). We conduct a systematic study on the performance, bias, and limitations of three basic measures (entropy, conditional entropy, information storage) and three traditionally used estimators (linear, kernel, nearest-neighbor). We investigate the dependence of entropy measures on estimator- and process-specific parameters, and we show the effects of three types of nonstationarities due to artifacts (trends, spikes, local variance change) in simulations of stochastic autoregressive processes. We also analyze the impact of LRC on the theoretical and estimated values of entropy measures. Finally, we apply entropy methods on heart rate variability data from subjects in different physiological states and clinical conditions. We find that entropy measures can only differentiate changes of specific types in cardiac dynamics and that appropriate preprocessing is vital for correct estimation and interpretation. Demonstrating the limitations of entropy methods and shedding light on how to mitigate bias and provide correct interpretations of results, this work can serve as a comprehensive reference for the application of entropy methods and the evaluation of existing studies.

We have calculated the W-loop contribution to the amplitude of the decay $H \to Z+\gamma$ in two different methods: 1) in the R_ξ -gauge using dimensional regularization (DimReg), and 2) in the unitary gauge through the dispersion method. Using the dispersion method we have followed two approaches: i) without subtraction and ii) with subtraction, the subtraction constant being determined adopting the Goldstone boson equivalence theorem (GBET) at the limit $M_W \to 0$. The results of the calculations in R_ξ-gauge with DimReg and the dispersion method with the GBET completely coincide, which shows that DimReg is compatible with the dispersion method obeying the GBET.

Optimization techniques of the simulation codes for numerical calculations via Molecular Dynamics are developed for pure iron. A high-pressure phase diagram is built over a wide range of temperatures. Elastic constants, sound velocities and radial (pair) distribution functions for hexagonal iron at extreme conditions of temperature and pressure are obtained and compared to *ab-initio* molecular dynamics at temperature 0K and available experimental data.

PUBLICATIONS:

1. **1. Boradjiev, I.**, Christova, E., Eberl, H.. Dispersion theoretic calculation of the H→Z+γ amplitude. ArXiv:1711.07298, (2017) ISSN:2331-8422
2. **Gaminchev, KG**. Thermal and structural properties of iron at high pressure by molecular dynamics. arXiv:1702.04909 (2017) ISSN:2331-8422
3. **Georgiev, M**, **Chamati, H**. Spin multiplole moments as collective quantum phenomena. Journal of Physics: Conference Series, 794, Institute of Physics, 2017, ISSN:1742-6596, DOI:10.1088/1742-6596/794/1/012026, 012026.
4. **Varbev, S. K.**, **Primatarowa, M. T.**, **Kamburova, R. S.**. Soliton dynamics in two coupled ferromagnetic chains. Journal of Physics: Conference Series, 794, Institute of Physics, 2017, ISSN:1742-6596, DOI:https://doi.org/10.1088/1742-6596/794/1/012027,
5. dos Santos Lima, G. Z., Corso, G., Correa, M. A., Sommer, R. L., **Ivanov, P. Ch.**, Bohn, F.. Universal temporal characteristics and vanishing of multifractality in Barkhausen avalanches. PHYSICAL REVIEW E, 96, 2, 2017, ISSN:2470-0045, DOI:10.1103/PhysRevE.96.022159, 022159.
6. Jimenez Martin M., Rodríguez-Laguna J., D'Huys O., de la Rubia J., **Korutcheva E.**. Synchronization of fluctuating delay-coupled chaotic networks. Phys. Rev. E, 95, APS, 2017, ISSN:2470-0045, DOI:10.1103/PhysRevE.95.052210, 052210
7. Nikolova E., Jordanov I.P., **Dimitrova Z.I.**, Vitanov N.K.. Evolution of nonlinear waves in a blood-filled artery with an aneurysm. AIP Conference Proceedings, 1895, 1, AIP, 2017, ISBN:978-0-7354-1579-9, ISSN:0094243X, DOI:10.1063/1.5007391, 070002-1-070002-8.
8. Usatenko, Z, Kuterba, P, **Chamati, H**, Halun, J. Investigation of ring polymers in confined geometries. Journal of Physics: Conference Series, 794, Institute of Physics, 2017, ISSN:1742-6596, DOI:10.1088/1742-6596/794/1/012002, 012002.
9. Usatenko, Z, Kuterba, P, **Chamati, H**, Romeis, D. Linear and ring polymers in confined geometries. Eur. Phys. J. - Special Topics, 226, Springer, 2017, ISSN:1951-6355, DOI:10.1140/epjst/e2016-60335-0, 651.
10. Vitanov, N. K., **Dimitrova, Z. I.**, Ivanova, T. I.. On solitary wave solutions of a class of nonlinear partial differential equations based on the fnction 1/coshn(αx+βt). Applied Mathematics and Computation, 315, Elsevier, 2017, ISSN:0096-3003, DOI:10.1016/j.amc.2017.07.064, 372-380.
11. Xiong, Wanting, Faes, Luca, **Ivanov, Plamen Ch.**. Entropy measures, entropy estimators, and their performance in quantifying complex dynamics: Effects of artifacts, nonstationarity, and long-range correlations. PHYSICAL REVIEW E, 95, 6, 2017, ISSN:2470-0045, DOI:10.1103/PhysRevE.95.062114, 062114.

ONGOING RESEARCH PROJECTS:

- Quantum effects in low-dimensional and nanostructured magnetic systems
- Phases and excited states of highly frustrated magnetic systems
- Liquid crystal approach for model lipid membrane functions optimization by nanoparticles insertion
- Synthesis and theoretical studies of graphene nanostructures
- Investigation of the interaction of magnetic solitons with quantum bits

INTERNATIONAL COLLABORATION:

University of Bielefeld, Germany

JINR Dubna, Russia

TEACHING ACTIVITIES:

Latex Basics

Computer modeling of complex systems

DEPARTMENT FUNCTIONAL MATERIALS AND NANOSTRUCTURES

LABORATORY

PHYSICS OF MATERIALS AND LOW TEMPERATURES

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

TOTAL STAFF: **15**
RESEARCH SCIENTISTS: **10**
*HONORARY MEMBERS:***1**
ASSOC. MEMBERS: **1**

Assoc. Prof. E.K. Nazarova, D.Sc.; Assoc. Prof. D.Z. Dimitrov, Ph.D.; Assoc. Prof. P.K. Sveshtarov, Ph.D.; Assoc. Prof. B.S. Blagoev, Ph.D.; Assist. Prof. K.M. Buchkov, Ph.D.; Assist. Prof. L. K. Yankova; V.T. Tomov, Ph.D.;S. Boyadjiev, Ph.D.; V. B. Mehandjiev, M.Sc.; S. Petrov, B.Sc., M. Valkovski, B.Sc.; Technicians: O. Mihailov, L. Nikova, S. Simeonov, P. Zashev

Honorary member: Prof. N.S. Tonchev, D.Sc.
Associated member: Prof. M.M. Gospodinov, D.Sc.

RESEARCH ACTIVITIES:

- *Growth and characterization of crystals and thin layers with optical, X-ray, electron-microscopic and other methods*

The magnetocaloric effect in single-crystalline RMn_2O_5 (R = Ho, Tb) was investigated using magnetic and Raman measurements. It was established that the major factor influencing the magnetocaloric properties of RMn_2O_5 is the size of rare earth ion. It influences the spin ordering, the magnetic anisotropy and the strength of the rotational magnetocaloric effect in RMn_2O_5.

Large $LuVO_4$ single crystals were successfully obtained by high-temperature solution method. The structure details of these crystals were determined by X-ray crystallographic analysis and Raman spectroscopy. The crystal displays higher than +0.2 birefringence in a large energy interval. Polarized Raman measurements revealed the correct assignment of 11 of its 12 first-order Raman active phonons.

Using atomic layer deposition (ALD), thin layers of TiN_2 and TiO_2 were deposited on nanofibres of TiO_2 and ZnO, respectively, to investigate the interaction between the oxides in the core material and the coating. The photocatalytic properties of the objects thus obtained and the prospects for their use as gas sensors have been studied.

- *Carbon-nanostructure research*

Mono- and multilayer graphene films were obtained by chemical vapor deposition (CVD) on copper foil. Some of these films were transferred onto insulating substrates. The samples thus obtained were characterized by Raman spectroscopy. A detailed Raman mapping was also carried out.

- *High-temperature superconductors*

Magnetron sputtering and magnetic characterization of thin layers of superconducting YBCO layer on iron oxide Fe_2O_3 were performed. Superconductivity and ferromagnetism are phenomena that are difficult to coexist. On contacting a superconducting (Sc) with a ferromagnetic (Frm) material, diffusion of spin-oriented particles into the superconductor and

of Cooper pairs into the ferromagnetic begins which leads to simultaneous destruction of the ordering parameters in the two materials near the interface. Obtaining of nanosized sandwich Sc/Frm structures is a great challenge for nanotechnology.

The effect of fluctuation superconductivity is investigated by measuring the resistance as a function of temperature for the iron-based superconductor FeSe0.5Te0.5 for various current and magnetic field values. In both cases, the results indicate the presence of three areas with 1D, 2D and 3D superconductivity with a significant reduction of the critical temperature. Following important parameters are determined: the interaction between the layers in the structure and the spacing between them, the coherence length, the anisotropy, the Ginsburg number. The existence of 1D conductivity and the large value of the Ginsburg number indicate existence of unconventional superconductivity in this compound.

A series of magnetic measurements were carried out on pure and silver-doped FeSe specimens. The magnetic moment behavior as a function of temperature, magnetic field and time was analyzed as well as the critical current and the pinning features which are most important from a practical point of view. It is found that a FeSe sample with an addition of 6 wt% Ag has the highest critical current. The nature of the collective pinning and movement of the vortices, as well as the elastic and plastic properties of the vortex matter are analyzed in detail.

AWARDS:

The work reported in Publications 4 and 5 in the following list was chosen by the Scientific Council of the Institute of Solid State Physics as the best research and development achievement of the Institute for the year 2017.

PUBLICATIONS:

1. Boyadjiev, S. I., Georgieva, V., Stefan, N., Stan, G. E., Mihailescu, N., Visan, A., Mihailescu, I. N., Besleaga, C., Szilagyi, I. M.. Characterization of PLD grown WO3 thin films for gas sensing. Applied Surface Science, 417, Elsevier, 2017, ISSN:0169-4332, DOI:10.1016/j.apsusc.2017.03.212, 218-223. SJR:0.951, ISI IF:3.387

2. Boyadjiev, S. I., Keri, O., Bardos, P., Firkala, T., Gaber, F., Nagy, Z. K., Baji, Z., Takacs, M., Szilagyi, I. M.. TiO2/ZnO and ZnO/TiO2 core/shell nanofibers prepared by electrospinning and atomic layer deposition for photocatalysis and gas sensing. Applied Surface Science, 424, 2, Elsevier, 2017, ISSN:0169-4332, DOI:10.1016/j.apsusc.2017.03.030, 190-197. SJR:0.951, ISI IF:3.387

3. Boyadjiev, S. I., Stefan, N., Szilágyi, I. M., Mihailescu, N., Visan, A., Mihailescu, I. N., Stan, G. E., Besleaga, C., Iliev, M. T., Gesheva, K. A.. Characterization of MAPLE deposited WO3 thin films for electrochromic applications. Journal of Physics: Conference Series, 780, IOP Publishing, 2017, ISSN:1742-6588, DOI:10.1088/1742-6596/780/1/012013, 012013. SJR:0.24

4. Dimitrov, D. Z., Rafailov, P. M., Chen, Y. F., Lee, C. S., Todorov, R., Juang, J. Y.. Growth and characterization of LuVO4 single crystals. Journal of Crystal Growth, 473, Elsevier, 2017, 34. ISI IF:1.751

5. Dimitrov, D., Rafailov, P., Marinova, V., Babeva, T., Goovaerts, E., Chen, Y. F., Lee, C. S., Juang, J. Y.. Structural and optical properties of LuVO4 single crystals. Journal of Physics: Conf. Series, 794, IOP Publishing, 2017, 012029. SJR:0.24

6. Marinov Y.G, Vlakhov,T, Blagoev B, Luka G, Krajewski T, Guziewicz E, Vlakhov ES. Characterization of ZnO Nanolayers by complex Impedance Spectroscopy. 40th

International Spring Seminar on Electronics Technology (ISSE), IEEE, 2017, ISSN:2161-2536, DOI:10.1109/ISSE.2017.8000970

7. Marinov Y.G, Vlakhov,T, Alexandrova M, Slavov S, Lakov L, Toncheva K, Vlakhov ES. INVESTIGATION OF IONIC CONDUCTIVE CERAMICS Bi12TiO20 BY COMPLEX IMPEDANCE SPECTROSCOPY. научни известия на нтсм, 1(216), proceedings „NDT days 2017", 2017, ISSN:1310-3946

8. Petrov, M; Katranchev, B; Rafailov, P. The unique physical properties of the hydrogen bonded in dimers liquid crystals. Journal of Physics: Conf. Series, 780, 2017, DOI:10.1088/1742-6596/780/1/012010, SJR:0.26

9. Sveshtarov, P. Carbon Nanotubes: A Review. Bulgarian Journal of Physics, 44, Heron Press Ltd., 2017, 109-132

10. Balli, M, Mansouri, S, Jandl, S, Fournier, P, Dimitrov, D. Z.. Analysis of the anisotropic magnetocaloric effect in RMn2O5 single crystals. Magnetochemistry, 3, 4, 2017

11. Egorysheva, A. V., Milenov, T. I., Rafailov, P. M., Gaitko, O. M., Avdeev, G. V., Dudkina, T. D.. Optical and Vibrational Spectra of Bi1.8Fe1.2(1 – x)Ga1.2xSbO7 Solid Solutions with Pyrochlore-Type Structure. Russian Journal of Inorganic Chemistry, 62, 7, Pleiades Publishing, Ltd., 2017, 960. ISI IF:0.787

12. Galluzzi A., Polichetti M., Buchkov K., Nazarova E., Mancusi D., Pace S.. Critical current and flux dynamics in Ag-doped FeSe superconductor. Supercond. Sci. Technol., 30, 2, IOP Science, 2017, DOI:https://doi.org/10.1088/1361-6668/30/2/025013, 025013. ISI IF:2.878

13. Nurgaliev, T., Blagoev, B., Buchkov, B., Mateev, E., Gajda, G., Nedkov, I., Kovacheva, K., Slavov, K., Starbova, K., Starbov, N, Nankovski, M.. Magnetron sputtering of Fe-oxides on the top of HTS YBCO films. Journal of Magnetism and Magnetic Materials, 429, Elsevier, 2017, DOI:https://doi.org/10.1016/j.jmmm.2017.01.019, 138-141. SJR:0.71, ISI IF:2.63

14. Sedky A., Nazarova E., Nenkov K., Buchkov K.. A comparative Study between Electro and Magneto Excess Conductivities in FeTeSe Superconductors. J. Supercond. Nov. Magn., 30, 10, Springer US, 2017, DOI:https://doi.org/10.1007/s10948-017-4096-3, 2751-2762. ISI IF:1.18

ONGOING RESEARCH PROJECTS:

- National Scientific Research Fund: Projects DFNI-T02/26 and DH08/9;

- Projects funded under the Academy's bilateral agreements and in the framework of institute-to-institute cooperation: with National Ciao Tung University – Taiwan and Institute for Structure Studies and Low Temperatures, Wroclaw, Poland;

- COST Action "Functional oxide nanolayers and nanolaminates deposited by the ALD method"

INTERNATIONAL COLLABORATION:

- JINR – Dubna, Russia;

- National Ciao Tung University, Hsinchu, Taiwan

DEPARTMENT FUNCTIONAL MATERIALS AND NANOSTRUCTURES

LABORATORY

PHYSICAL PROBLEMS OF MICROELECTRONICS

HEAD: **Assoc. Prof. D. Spassov, Ph.D.**
tel:029795731; e-mail: d.spassov@issp.bas.bg

TOTAL STAFF: **9**
RESEARCH SCIENTISTS: **4**
ASSOC. MEMBERS: **0**

Prof. D.Sc. A. Paskaleva, Assoc. Prof. Ph.D. D. Spassov, Assoc. Prof. Ph.D. E. Manolov, Senior Res. Assist. PhD. Ts. Ivanov, physicist E.Gajdarzhieva, eng. V. Stanoev, technologist S. Tsvetanov, technologist M. Stoicheva, technologist Ch. Petkanov

RESEARCH ACTIVITIES:

The research activities of the Laboratory are focused on nanoelectronics and cover the following topics:

- investigation of thin and ultra-thin dielectrics (incl. high-k dielectrics for advanced dynamic and non-volatile memories), semiconductor and metal layers of interest for future nanoelectronic devices.
- development of solid state sensors based on the silicon and the thin-film microelectronics (gas- sensitive layers for sensor devices; mono- and polycrystalline silicon, anisotropic and hard ferromagnetic layers).
- development and optimization of the technology for deposition of the layers investigated.
- development of new microelectronic structures and devices (incl. memory and sensor structures).

Electrical and dielectric characteristics of nanolaminated HfO_2/Al_2O_3 stacks deposited by atomic layer deposition (ALD) with different thicknesses of Al_2O_3 and HfO_2 sublayers and various repetitions of HfO_2/Al_2O_3 bilayer blocks have been studied in terms of their possible implementation in future non-volatile memory applications. The effect of thermal treatments in oxidizing and inert ambient has also been evaluated. It is established that two processes define the charge buildup in stacks: a trapping of electrons or holes injected into the layers from Si substrates depending on the polarity of the applied bias (this process determines the achievable “memory window”), and generation of positive charge at high electric fields (a parasitic process leading to eventual breakdown of the dielectric). The domination of one of these processes is found to depend on the stack’s composition and the type of annealing ambient. The stress-induced positive charge generation is most intensive in the as-grown samples. Post deposition annealing in O_2 leads to appearance of initial positive oxide charge (i.e. positively charge defects), while the treatment in nitrogen containing ambient has an opposite effect – generation of initial negative oxide charge (negatively charged defects). It is demonstrated that the negative charge originates from introduction of Al_2O_3 in the stacks and its formation is thermally stimulated. The results indicate that from application point of view oxygen annealing is the most favorable treatment to enhance charge trapping and retention characteristics of the stacks. Multilayered HfO_2/Al_2O_3 stacks have a potential for implementation as charge trapping layer in non-volatile memory devices and their charge

storage ability could be tailored and enhanced by optimization of stack parameters as well as annealing processes.

The charge trapping and the charge generation in $Al/ZrO_2/Al_2O_3/ZrO_2$-SiO_2-Si metal-dielectric-semiconductor structures, obtained by reactive sputtering, have been studied in order to clarify the observed instabilities in the hysteresis of the capacitance-voltage characteristics. It is established that apart from the standard electron and hole trapping, at lower negative bases a formation of positive charge occurs due to electron emission from preexisting defect sites, related to the initial oxide charge in the dielectric layers. To obtain maximal "memory windows" in these high-*k* stacks an additional blocking layer at gate interface is necessary to suppress the deleterious electron injection form the gate during the memory erase step.

Negative bias threshold voltage inevitability (NBTI) of commercial power p-channel VDMOSFETS (type IRF9520) has been investigated under constant and pulsed gate biases. It is found that at given temperature the pulsed voltage stress results in smaller variation of the threshold voltage. The threshold voltage instabilities depend on pulse frequency and the ratio of the pulse width to the time distance between pulses. A model based on electrical equivalent circuit for predicting the threshold voltage instability under arbitrary stress conditions is proposed.

Main conduction mechanisms observed in high-*k* dielectrics have been reviewed. The influence of various factors – the type of high-k dielectric and its thickness; the doping with a certain element; the type of metal electrode as well as the measurement conditions (bias, polarity and temperature), on the leakage currents and dominant conduction mechanisms have been considered. Practical hints how to consider different conduction mechanisms and to differentiate between them are given. An approach to assess important trap parameters from investigation of dominant conduction mechanisms is presented.

PUBLICATIONS:

1. M. Rommel, A. Paskaleva, Investigation of high-k dielectric stacks by C-AFM: advantages, limitations and possible applications, *Conductive Atomic Force Microscopy: Application in nanomaterials*, ed. M. Lanza, Chapter 4, Wiley VCH, 2017.
2. A. Paskaleva, D. Spassov, P. Terziyska, Electric, dielectric and optical properties of Ga_2O_3 grown by metal organic chemical vapour deposition, *J. Phys. Conf. Series*, 794 (2017) 012017.
3. D. Spassov, A. Paskaleva, K. Fröhlich, Tz. Ivanov, Effect of oxygen concentration and metal electrode on the resistive switching in MIM capacitors with transition metal oxides, *J. Phys. Conf. Series*, 794 (2017) 012016.
4. A. Paskaleva, D Spassov, D. Dankovic, Conduction mechanisms in high-*k* dielectric stacks as a tool to study electrically active defects, *Facta Universitatis, Series: Electronics and Energetics*, vol. 30, No 4 (2017) 511-548.
5. A. Skeparovski, D Spassov, A Paskaleva, N Novkovski, A Case study of C-V hysteresis instability in metal-high-k-oxide-silicon devices with $ZrO_2/Al_2O_3/ZrO_2$ stack as a charge trapping layer, *Proc. of 30th IEEE International conference on Microelectronics (MIEL'2017)*, Nis, Serbia, 9-11.Oct. 2017, p. 79.
6. V. Davidović, A. Paskaleva, D. Spassov, E. Guziewicz, T. Krajewski, S. Golubović, S. Djorić-Veljković, I. Manić, D. Danković, N. Stojadinović, Electrical and charge trapping properties of HfO_2/Al_2O_3 multilayer dielectric stacks, *Proc. of 30th IEEE International conference on Microelectronics (MIEL'2017)*, Nis, Serbia, 9-11.Oct. 2017, p.143.
7. D. Danković, I. Manić, N. Stojadinović, Z. Prijić, S. Djorić-Veljković, V. Davidović, A. Prijić, A. Paskaleva, D. Spassov, S. Golubović, Modelling of threshold voltage shift

in pulsed NBT stressed p-channel power VDMOSFETs, *Proc. of 30th IEEE International conference on Microelectronics (MIEL'2017)*, Nis, Serbia, 9-11.Oct. 2017, p.147.

8. Davidovic, A. Paskaleva, D. Spassov, E. Guziewicz, T. Krajewski, S. Golubovic, S. Djoric-Veljkovic, I. Manic, D. Dankovic, N. Stojadinovic, I.spitivanje višeslojnih HfO_2/Al_2O_3 struktura za memorijske komponente, *Proc. of ETRAN 2017 Conf.* Kladovo, Serbia, 05-08 Juna 2017, ISBN 978-86-7466-692-0, p. MO1.1.1-4.

9. D. Nesheva, B. Pantchev, N. Nedev, B. Valdez, V, Dzhurkov, R. Nedev, E. Manolov, Resistive switching behavior of SiOx layers with Si nanoparticles. *J. Phys. Conf. Series*, 794 (2017) 012018.
Citstions: 88

ONGOING RESEARCH PROJECTS:

Financed by the Bulgarian Ministry of Education and Science:

1. Atomic layer deposition of dielectric nanolayers on two-dimensional materials as active components for multifunctional devices.

Financed by the Bulgarian Academy of Sciences:

1. Reliability aspects and radiation hardness of HfO_2-based multilayer stacks for non-volatile flash memories.

2. Al_2O_3/HfO_2 multilayer high-k dielectric stacks for charge trapping flash memories.

INTERNATIONAL COLLABORATION:

1. Fraunhofer Inst. of Integrated Systems and Device Technology, Erlangen, Germany.

2. Institute of Electronic Engineering, Slovak Academy of Sci., Bratislava, Slovakia.

3. Insitute of Physics, St.St. Cyril and Methodius Universty, Skopie, Macedonia.

4. University of Nish, Serbia.

5. Institute of Physics, Polish Academy of Sci. Warsaw, Poland.

6. Universidad Autonoma de Baja California, Mexicale, Mexico.

DEPARTMENT FUNCTIONAL MATERIALS AND NANOSTRUCTURES

LABORATORY

ACOUSTOELECTRONICS

HEAD: **Assoc. Prof. Ekaterina Radeva**
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TOTAL STAFF: **9**
RESEARCH SCIENTISTS: 4
ASSOC. MEMBERS: 1

Prof. Ivan Avramov., Assoc. Prof. Ekaterina Radeva, Senior Res.Assist. Karekin D. Esmeryan Ph.D., Julian Lazarov Ph.D., Res. Assist. Natali Dimitrova, eng. Lazar Vergov, eng. Plamen Petkov, Stefan Staykov, technician, Vladimir Kabakchiev, technician
Associated members: Cor. Mem. Lozan Spassov; Assoc. Prof. V. Georgieva

RESEARCH ACTIVITIES:

Resonant Structures Using Rayleigh Surface Acoustic Waves (RSAW), Bulk Acoustic Waves (BAW) and Surface Transverse Waves (STW). Applications to Sensors

The mass sensitivity of Rayleigh surface acoustic waves (RSAW) two-port resonators (TPR) has been studied to provide and discuss experimental data on these devices as an alternative to the widely used low-frequency quartz crystal microbalance (QCM). The RSAW devices are intended for se as sensors for thickness measurements and characterization of extremely thin dielectric layers - in the sub nm to a few tens of nm range where a QCM does not provide sufficient sensitivity. The calibration process of the RSAW mass sensors has been performed in a chemical vapor deposition (CVD) reactor with precisely controlled coatings of Parylene C – a polymer with known density that is deposited onto the TPR surface at room temperature in the absence of strong electromagnetic fields. In this process, sufficiently thick Parylene C films in the 50 to 400 nm range have been used to allow precise thickness measurements with a traditional QCM. Given the fact that the RSAW TPR mass frequency dependence is linear, at very thin films - in the 0 to 50 nm range, the latter has been reconstructed down to 0 thickness (mass) using linear extrapolation. In that thickness range, where the QCM does not work, the RSAW TPR has been found to provide very stable, well behaved and reproducible operation. This mass sensitive device demonstrates more than 4000 times higher relative sensitivity and up to 180 times lower detection limit than a classical 5 MHz QCM.

Synthesis and study of plasma polymers and composites

Silicon and conventional polymer composite layers on glass were produced by plasma polymerization from hexamethyldisiloxane and silver nanoparticles. SEM studies demonstrated the incorporation of silver nanoparticles into the polymer matrix, enabling the synthesis of layers of desired composition and properties.

An efficient PECVD method was developed to modify nanofiltration and ultrafiltration membranes to improve their permeability and rejection. The depositions were made using two different plasma systems: plasma chamber unit B 30.2 (precursor pentane, hexamethyldisiloxane, perfluorhexane) and PECVD system “Oxford Nanofab Plasmalab System 100” (precursor methane-argon and acetylene-argon). More than 100 different samples

were modified: nanofiltration membranes (PEEK) and ultrafiltration membranes (PAN and Ultem). Structural and chemical characterisations of the deposited nano-thick functional layers were implemented through SEM imaging, ATR-FTIR, EDX, XPS, AFM and contact angle measurements, which proved the methods' feasibility and properties of the plasma-polymerised coatings. By using an 8-position cross-flow filtering system, membrane filtration performance was evaluated in terms of permeate flux and rejection characteristics and with styrene oligomers of different molecular weights as markers.

Superhydrophobic coatings and the use of QCM to evaluate their anticoagulant and antimicrobial properties

An artful method for preliminary *in-situ* assessment of the anti-biofouling potential of various functional superhydrophobic coatings was developed. The method is based on the idea that any superhydrophobic coating deposited on the surface of a piezoresonance sensor (quartz crystal microbalance) diminishes its sensor signal in liquids as a result of the trapped air within the surface protrusions. The air film creates a strong reflection boundary at the solid-liquid interface and reduces the oscillation energy transferred to and dissipated by the liquid. However, the surface attachment of biomass, for example bacteria, will extend the actual solid fraction in contact with the liquid and will increase the solid-liquid interfacial energy. This will immediately increase the amount of transferred acoustic energy, hence, will amplify the sensor signal. Thus, the real-time observation of attenuated or amplified response of the superhydrophobic sensor is considered as an accurate measure for the lack or presence of biofouling. We also report on novel findings about the formation mechanism of graphite-like and diamond-like supported nanostructures in low temperature laminar diffusion flames, related with kinetically driven graphite-to-diamond transformation rather than a thermodynamically induced phase transition. Based on this, an opportunity for the fabrication of superhydrophobic carbon soot coatings with controllable degree of oxidation was found - a key factor determining the alterations in their physicochemical properties (thickness, porosity, wettability) upon interactions with alcohols with different alkyl chain length.

AWARDS:

The paper:

1. I. D. Avramov and U. Stahl, "On the Mass Sensitivity of Rayleigh Surface Acoustic Wave (RSAW) Resonators", 40-th Int. Spring Seminar on Electronics Technology (ISSE 2017), IEEE Explore, August 8, 2017, ISSN 2161-2536, DOI 10.1109/ISSE2017.80001982

won the 2-nd place in the contest of the Institute of Solid State Physics for best application oriented scientific paper for 2017

PUBLICATIONS:

1. I. D. Avramov and U. Stahl, "On the Mass Sensitivity of Rayleigh Surface Acoustic Wave (RSAW) Resonators", 40-th Int. Spring Seminar on Electronics Technology (ISSE 2017), IEEE Explore, August 8, 2017, ISSN 2161-2536, DOI 10.1109/ISSE2017.80001982
2. Esmeryan K. D., Castano C. E., Abolghasemibizaki M., Mohammadi R. "An artful method for in-situ assessment of the anti-biofouling potential of various functional

coatings using a quartz crystal microbalance". Sensors and Actuators B Chemical, 243 (2017), 910-918. DOI:http://dx.doi.org/10.1016/j.snb.2016.12.073
3. Esmeryan K. D., Castano C. E., Bressler A. H., Abolghasemibizaki M., Fergusson C. P., Roberts A., Mohammadi R.. Kinetically driven graphite-like to diamond-like carbon transformation in low temperature laminar diffusion flames. Diamond and Related Materials, 75 (2017) 58-68. DOI:http://dx.doi.org/10.1016/j.diamond.2017.01.014,
4. Esmeryan K. D., Castano C. E., Mohammadi R.. Interactions of superhydrophobic carbon soot coatings with short alkyl chain alcohols and fluorocarbon solutions. Colloids and Surfaces A: Physicochemical and Engineering Aspects, 529 (2017) 715-724. DOI:https://doi.org/10.1016/j.colsurfa.2017.06.067,

ONGOING RESEARCH PROJECTS:

Joint Research Project between the Institute of Solid State Physics and the Research Center Karlsruhe, Germany for the Development of SAW Resonators Using Gold Electrode Structure for Sensor Applications.

INTERNATIONAL COLLABORATION:

Research center Karlsruhe, Germany

Chemical Engineering and Chemical Technology, Imperial College London,England

DEPARTMENT NANOPHYSICS

LABORATORY
PHOTOELECTRICAL AND OPTICAL PHENOMENA IN WIDE BAND GAP SEMICONDUCTORS

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

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

Assoc. Prof. Z. Levi, Ph.D.; Assoc. Prof. I. Bineva, Ph.D.; Assoc. Prof. T. Vasileva, Ph.D.; Assoc. Prof. P. Terziyska, Ph.D.; Assist. V. Dzhurkov, Assist. R. Dzhurkova, Technologist E. Zaharincheva;

Honorary members: Prof. E. Vateva, D.Sc; Assoc. Prof. K. Kolentsov;
Associated members: Prof. S. Kaschieva, D.Sc; Prof. S. Alexandrova, D.Sc; Assoc.Prof. S. Balabanov, Ph.D.; Assoc.Prof. S. Simeonov, Ph.D.; Assoc.Prof. A. Szekeres, Ph.D.; Assoc.Prof. D. Arsova, Ph.D.; Assoc.Prof. Z. Ivanova, Ph.D.; Assoc.Prof. N. Peev, Ph.D.

RESEARCH ACTIVITIES:

Frequency assisted thermal evaporation in vacuum was used for deposition of two series of films from sublimating crystalline lead telluride with thicknesses of 40 and 100 nm. In this preparation technique audible input frequencies in the range 50-10 000 Hz were applied on the substrate during the film deposition. The films were investigated by atomic force microscopy (AFM), scanning electron microscopy (SEM), X-ray diffraction (XRD) and spectroscopic ellipsometry (SE). Lattice relaxation and micro deformations removal, as well as significant densification of the films have been observed for all frequencies but the applied vibrations didn't cause distinct changes in the morphology of the 40 nm thick films. For the 100 nm films the surface morphology depends distinctly on the applied frequency. Nanoplates, typical for PbTe, were observed with average thickness of 20 nm, width of 80 nm and variable height in the range 107 - 164 nm depending on the frequency of the applied vibrations. The observed changes in the root mean square (rms) roughness followed the frequency dependence established for Se and Te films. However in the Se and Te films a distinct folding of the surface was seen resembling the nodes and anti-nodes of a standing wave, while in the PbTe films the influence of the applied vibrations was mainly on the height of the specific nanoformations. These investigations were carried out in implementation of the contract DFNP-160/13.05.16 from the Program for career development of young scientists of the Bulgarian Academy of Sciences as well as a project from the bilateral cooperation agreement between ISSP-BAS and IMT-Bucharest.

Two types of ZnO thin films have been deposited by sol-gel method on c-Si substrates covered with 300 nm thick silicon dioxide film. Monoethanolamine and diethanolamine were used as complexing agents. A part of the films was annealed for 60 min in air at 400°C. AFM investigations of as-deposited films revealed a morphology which is typical for amorphous thin films. In the annealed films nanocrystals with size of 20-30 nm and relatively low

rms ~ 2.5 nm were observed. SE measurements showed that the thermal treatment reduces significantly the thickness of as-deposited films. Annealed films were irradiated with nanosecond laser pulses with wavelength 1064 nm and 4 power densities in the range 5-100 mW/cm^2. The irradiation caused a small reduction of the films' porosity and increase of the refractive index. Photographs, taken by means of an optical microscope, revealed that in the microscale the annealed but not irradiated films have an island-type (dendritic) structure. It changes in result of the laser irradiation and at high enough power the structure of the films becomes homogenous.

Raman scattering studies of as-deposited and annealed at 450ºC thin films from TiO_2 nanotubes with different inner diameter and wall thickness were carried out. The samples, which are promising for sensor and other applications were prepared in the Autonomous University, South California, Mexico by anodization of Ti6Al4V alloy plates. The Raman results showed that before annealing the nanotubes are amorphous. After annealing both anatase and rutile crystal phases were observed together with some deviation from the stoichiometry (lack of oxygen). It has been concluded that the doping and/or the changes in the nanotube size have influence on the temperature of appearance of the anatase phase.

The effect of irradiation with high energy (20 MeV) electrons at two different fluences (7.2×10^{14} and 1.44×10^{15} $el.cm^{-2}$) on the optical properties and phase composition of 200 nm thick homogenous SiO_x thin films (x = 1.3,) on crystalline Si substrates and a-Si-SiO_x, composite films has been studied. The composite films were prepared by thermal annealing of homogenous SiO_x films at 700°C, which causes phase separation and growth of amorphous silicon nanoparticles. The thickness and optical constants (n, k, α) were determined by SE measurements. The oscillator model of Cody-Lorentz was used for the homogenous films while for the composite films the effective medium model of Bruggeman was applied. It was found that the SiO_x films are optically homogenous and the electron irradiation leads to formation of very small a-Si nanoclusters homogenously distributed in the oxide matrix. The electron irradiation of the a-Si-SiO_x composite films leads to changes in optical parameters related to a decrease of nanoparticles' size. This assumption was confirmed by FTIR transmission results.

SE studies of vatious thin films (AlN, Al_2O_3, ZnO, high frequency sputtered TiO_2, CoO, Fe_2O_3, thermal SiO_2) deposited on different substrates (Si, glass, Al_2O_3) were performed using Woollam M2000D spectroscopic ellipsometer in reflection mode. For some transparent samples like ZnO films deposited on transparent substrates (PEN, PET, Polycarbonate) the intensities of the transmitted light were also measured. The change of the optical band gap of ZnO films deposited by ALD at different temperatures (100-200ºC) was studied. It has been found that the increase of the deposition temperature causes an absorption edge shift from 3.27 to 3.34 eV which was explained with self-compensation and existence of Moss-Burstein effect. In collaboration with colleagues from Hungary measurements on samples with phase transitions in the temperature interval 20ºC - 400 ºC have been started.

The influence of the Si substrate temperature (450 and 800°C) and laser pulse frequency
(3, 10 and 40 Hz) on the structure, morphology and optical properties of nanostructured AlN thin films synthesized by laser ablation was further investigated. Transmission electron microscopy studies showed that AlN films with different crystal structure could be synthesized

at relatively low temperature (450°C) only by changing the frequency of laser pulses. The measured FTIR reflection spectra displayed wide absorption band in the region 1000-500 cm^{-1} which is characteristic for h-AlN crystals. The optical constants determined by SE measurements showed strong dependence on the deposition conditions and are typical for the respective AlN structures.

The studies of the structure and the optical properties of $Ge_xSb_{40-x}Se_{60}$ (x = 15, 20, 25, 27, 32 и 35) chalcogenide thin films deposited on quartz substrates by thermal evaporation in vacuum of glasses with the respective composition have been continued. The basic chemical bonds ($GeSe_2$, Sb-Se) in the films with particular composition were determined by Raman scattering measurements in the range 100-500 cm^{-1}. SE measurements were carried out in a wide range of wavelengths (193 nm to 33 μm) and optical constants (n, k, ε) of the films were determined. The analysis of the ellipsometric data in the range 300 to 4000 cm^{-1} revealed the existence of impurity (Ge-O, Se-H, OH) as well as defect (Ge-Ge, Sb-Sb) bonds. The presence of these bonds was also confirmed from the vibrational peaks observed in the FTIR transmission spectra registered in the same wavelength range.

PUBLICATIONS

1. Bineva I., Pejova B., Mihailov V., Dinescu A., Danila M., Karatodorov S., Structural and morphological characterization of ternary nanocrystalline Cu-In-S thin films prepared by laser ablation, Journal of Physics: Conference Series, 794, 012019-6pp, 2017.

2. Hristova-Vasileva T., Bineva I., Dinescu A., Danila M., Arsova D., As_2Se_3 thin films deposited by frequency assisted thermal evaporation – morphology and structure, Journal of Physics: Conference Series, 794, 012015-6pp, 2017.

3. Nesheva, D., Pantchev, B., Nedev, N., Valdez, B., Dzhurkov, V., Nedev, R., Manolov, E.. Resistive switching behavior of SiO_x layers with Si nanoparticles, Journal of Physics: Conference Series, 794, 012018-8pp, 2017.

4. Antonova K., Duta L., Szekeres A., Stan G.E., Mihailescu I. N., Anastasescu M., Stroescu H., Gartner M., Influence of laser pulse frequency on the microstructure of aluminum nitride thin films synthesized by pulsed laser deposition, Applied Surface Science, 394, 197-204, 2017.

5. Berova, M., Sandulov, M., Tsvetkova, T., Szekeres, A., Terziyska, P., Kitova, S., Boettger, R., Bischoff, L., Optical contrast formation in ta-C films by ion implantation, Revue Roumanie de Chimie, 62, 10, 2017.

6. Paskaleva, A., Spassov, D., Terziyska, P., Electric, dielectric and optical properties of Ga2O3 grown by metal organic chemical vapour deposition, Journal of Physics: Conference Series, 794, 012017-6pp, 2017.

7. Bachvarova-Nedelcheva, A., Iordanova, R., Gegova, R., Dimitriev, Y., Crystallization of gels in the binary TiO2–MnOm (MnOm= TeO2, SeO2, B2O3, ZnO) systems, Bulg. Chem. Commun, 49, Special Issue A, 110-118, 2017.

8. Butcher, K. S. A., Terziyska, P. T., Gergova, R., Georgiev, V., Binsted, P. W., Skerget, S.. DC voltage fields generated by RF plasmas and their influence on film growth morphology through static attraction to metal wetting layers: Beyond ion bombardment effects, Journal of Applied Physics, 121, 013301, 2017.

9. Fogarassy, Zs., Petrik, P., Duta, L., Stan, G., Mihailescu, I.N., Anastasescu, M., Gartner, M., Antonova, K., Szekeres, A., TEM and AFM Studies of AlN films synthesized by Pulsed Laser Deposition, Applied Physics A, 123 (12), 2017.

10. Krajewski, T. A., Terziyska, P., Luka, G., Lusakowska, E., Jakiela, R., Vlakhov, E. S., Guziewicz, E., Diversity of contributions leading to the nominally n-type behavior of ZnO films obtained by low temperature Atomic Layer Deposition, Journal of Alloys and Compounds, 727, 902-911, 2017.

PATENTS

1. Bulgarian Patent Office, Patent Application: 111032/15.09.2011, Patent No: 66556/30.11.2016. Pretender: ISSP-BAS

Inventors: Nedev N., Manolov E., Nesheva D., Krezhov K., Curiel M., Nedev R., Valdez B.
Invention: Metal-Insulator-Semiconductor structures for detectors of ionizing radiation, containing silicon nanocrystals, and method for their production.

2. Bulgarian Patent Office, Patent Application: 109759/01.12.2006, Patent No: 65971/09.09.2010. Pretender: ISSP-BAS

Inventors: Nesheva D., Nedev N, Manolov E., Brüggemann R., Meier S., Levi Z., Bineva I.
Invention: Metal-Insulator-Silicon structures, containing silicon nanoparticles, and method for their production.

INTERNAL RESEARCH PROJECTS

Financed by the Bulgarian Academy of Sciences:

1. Preparation and properties of nanostructured and amorphous chalcogenide, oxide and nitride semiconductors and structures for applications in optoelectronics and sensors.
2. Frequency assisted thermal evaporation in vacuum – a perspective method for thin films topography change - DFNP 160/13.05.2016, BAS.

Financed by the Bulgarian Ministry of Education and Science:

1. Characterization of new chalcogenide materials by atomic force microscopy, Contract DMU 03-91/12.2011.

INTERNATIONAL COLLABORATION PROJECTS

1. Investigation of the interaction of high energy electrons with SiO_x and nc(a)-Si-SiO_x thin films, Center for Solid State Physics and New Materials, Belgrade, Serbia.
2. Studies of different transparent conductive oxide (TCO) thin films for solar energy and optoelectronics applications, Institute of Physical Chemistry, Bucharest, Romania.
3. Structural and optical properties of new semiconductor materials and structures for advanced opto- and nanoelectronics applications, Centre for energy research, Hungarian Academy of Sciences.

4. Morphological and structural investigations of nanostructured and amorphous semiconductor films for application in microelectronics and sensorics, National Institute for Research and Development in Microtechnology, IMT Bucharest, Romania.

DEPARTMENT SOFT MATTER PHYSICS

LABORATORY

LIQUID CRYSTALS

HEAD: **Assoc. Prof. Victoria Vitkova, Ph.D.**
tel: 979 5796; e-mail: victoria@issp.bas.bg

TOTAL STAFF: **5**
RESEARCH SCIENTISTS: **3**
ASSOC. MEMBERS: **1**

Prof. I. Bivas, Ph.D., D.Sc., Assoc. Prof. J. Genova, Ph.D.;
Eng. D. Mitkova, PhD student; Eng. Z. Slavkova (part-time)
Associated member: Assoc. Prof. A. Zheliaskova, Ph. D.

RESEARCH ACTIVITIES:

Theoretical description of the shape fluctuations of nearly spherical lipid vesicle was carried out. The extreme cases when the stretching elasticity of the vesicle membrane tends to zero and to infinity were considered. The first limit gave the well-known result of Milner and Safran for a tension free membrane. After taking the second limit, the membrane becomes not stretchable, but the membrane tension rests finite. By means of numerical calculations it was shown that the mean-field-approximation, used in the theoretical treatment of the fluctuating vesicle, is a very good approximation.

The specific electrical capacitance of model lipid membranes was measured by analysing the deformation of 'giant' unilamellar lipid vesicles in alternating electric field at varied frequency. The specific capacitance of palmitoyl-oleoyl phosphatidylcholine membranes in sugar-free aqueous solutions of sodium chloride is obtained. The reported value of 0.50 ± 0.02 $\mu F/cm^2$ is lower than the values reported in the literature so far. This finding is in good agreement with the membrane capacitance found in the literature for the same lipid composition in sugar-containing aqueous solutions taking into account the sugar-induced membrane thinning effect. With regard to the previous data for the membrane capacitance from experiments with black lipid membranes, our result is consistent with the expected impact of the coupling of the membrane tension to its thickness.

One of the primary roles of cholesterol in the biological cell is to modulate the physical, in particular optical, properties of the bilayer phospholipid membrane. Furthermore, the effect of cholesterol on lipid bilayers is strongly dependent on the concentration, and as a result it can easily adapt to changes of the cell's temperature. Incorporation of cholesterol in membranes induces diverse changes in the bilayer properties, including alteration of the bilayer thickness and changes in lipid order.

By means of the scanning electron microscopy method, a series of images of the surface and the profile of thin lipid layers containing respectively 0, 10, 30 and 50 weight percent of cholesterol were made. For this purpose, the synthetic lipid 1-stearoyl-2-oleoyl-sn-glycerol-3-phosphocoline (SOPC) was used. The layers were applied onto silicate glass by the spin-coating technique. The low magnification images show homogeneous uniform structures for all concentrations tested. Using high magnification of the studied samples irregularities of the studied layers, namely clustering of material with an increase in the content of cholesterol in the membrane were observed. The profile images of the lipid layer show an ideally arranged

layered structure in the pure lipid pattern that is gradually disturbed by the increase in cholesterol in the system.

We have applied the typical structural methods involving Fourier transform infrared (FT-IR) and polarization micro-Raman spectroscopies, aiming to discover the specific physical characteristics of the lipid SOPC membrane in presence of 0, 10, 30 и 50 weight percent of cholesterol in it. The analysis of the far FT-IR spectra (below 100 cm-1) indicated that hydrogen bonds exist between the hydroxyl group of cholesterol and the phosphate head group of phospholipid. Besides the trivial H-O hydrogen bond, we were able to detect the complex hydrogen bonds involving C and N elements in the complex bilayer membrane. The analysis of the ratio of the area of ratio of the intensity of the bound to the free carbonyl conformations allowed to assess the interaction strength and the amount of possible hydrogen bonds. The results obtained show the presence of competition of cholesterol and water in the realization of hydrogen bonds with the phospholipid residues depending on the level of hydration of the system.

AWARDS:

III Award for “Best oral presentation” of the VI National student scientific conference on physics and engineering technologies, received by Denitsa Mitkova for the oral presentation: "Lipid membranes containing Archaeolipids", Denitsa Mitkova and Victoria Vitkova.

PUBLICATIONS:

1. Vitkova, V., D. Mitkova, K. Antonova. Capacitance of lipid bilayers in sugar-free aqueous solutions. 70, 10, Compt. rend. Acad. bulg. Sci., 2017, ISSN:2367-5535, 1355-1362. ISI IF:0.251
2. Genova J., Dencheva-Zarkova, M.. Interaction of elaiophylin with model bilayer membrane. IOP Science, 794, Journal of Physics: Conference Series, 2017, ISSN:1742-6596, DOI:10.1088, 012031. SJR:0.022
3. Bivas, I., N.S. Tonchev, Membrane Stretching Elasticity of Lipid Vesicle and Thermal Shape Fluctuations. arXiv, Cite as: arXiv:1712.09911 [cond-mat.soft], Cornell University Library, 2017
4. Slavkova, Z., Genova, G., Shirokikh, S., Koroleva, M.. Significance of investigating properties of membranes with incorporated nanoparticles for drug delivery applications. Proc. Int. Conference "Chemical technology of functional Nanomaterials", Moscow, Russia, 2017, 16

ONGOING RESEARCH PROJECTS:

Research Project “The deformability as a key feature of biomembranes and the influence of biologically relevant substances on it – experimental studies on model systems” (National Science Fund, Bulgaria – Grant DMU03-80/2011), coordinator Assoc. Prof. Dr. V. Vitkova

Research Project “Mechanical and electrical properties of model lipid membranes in the presence of biologically active substances” (National Science Fund, Bulgaria – Grant DN08-7/13.12.2016), coordinator Assoc. Prof. Dr. V. Vitkova

Research Project “Liquid crystal approach for model lipid membrane functions optimization by nanoparticles insertion” (National Science Fund, Bulgaria – Grant DN08-2/13.12.2016), coordinator Assoc. Prof. Dr. J.Genova

Research Project “A mechanistic approach to revealing the molecular mechanism of how oxidized lipids alter the 2D and 3D lipid organization in model membranes” National Science Fund, Bulgaria – Grant DN18-15/15.12.2017), Coordinator, principal investigator: Professor Dr Galya Staneva, IBPBME-BAS;
Coordinator from ISSP-BAS /partner organization/: Assoc. Prof. Dr Victoria Vitkova

Research Project “Impact of oxidized lipids on rafts as sorting and signaling platforms of cells. Biomimetic systems: smart tool to reveal lipid-lipid and lipid-protein interactions”
DPTS/France 01-4/09.05.2017) coordinator: Professor Dr Galya Staneva, IBPBME-BAS and Professor Dr Miglena Angelova, University Paris VI: Pierre and Marie Curie and Paris VII: Didrot; ISSP members of the research team: Assoc. Prof. Dr Victoria Vitkova and Denitsa Mitkova, PhD student.

Research Project “Modeling of molecular mechanisms in oxidative stress: effect of palmitoyl-oxo-valeroyl phosphatidylcholine on the membrane organization“ coordinator: Assist. Prof. Dr. Rusina Hazarosova (National Science Fund, Bulgaria, „Young Researchers – 2017”) with a member of the research team from ISSP-BAS Denitsa Mitkova – PhD student.

Research Project “Preparation and characterization of biomimetic archeolipid nanostructures“ (“Program for Supporting of Young Scientists and PhD Students at the Bulgarian Academy of Sciences - 2017” Grant DFNP-17-22/24.07.2017), coordinator: Denitsa Mitkova – PhD student and scientific consultant Assoc. Prof. Dr Victoria Vitkova.

Bilateral Research Project /ISSP – BAS and Wallonie Bruxelles International – Belgium/: “Etude des propriétés mécaniques par holographie digitale”, coordinator Assoc. Prof. Dr. Victoria Vitkova

INTERNATIONAL COLLABORATION:

BELGIUM: Dr Christophe MINETTI, Université libre de Bruxelles

FRANCE: Prof. Miglena Angelova, University Paris VI: Pierre and Marie Curie and Paris VII: Didrot; Dr Thomas PODGORSKI, Laboratoire Interdisciplinaire de Physique, UMR 5588 (CNRS – Université Grenoble-Alpes)

GERMANY: Dr. habil. PD Rumiana DIMOVA, Max Planck Institute of Colloids and Interfaces, Science Park Golm

RUSSIA: Prof. Yury Ermakov, Dr Oleg Batishchev, Frumkin Institute of Physical Chemistry and Electrochemistry, Russian Academy of Sciences

SLOVENIA: Prof. Ales Iglic, Dr. Samo Penic, Faculty of Electrical Engineering, University of Ljubljana, Ljubljana, Slovenia

TEACHING ACTIVITIES:

Ph.D. student Denitsa Mitkova Brankova; Supervisor Assoc. Prof. V. Vitkova

Student Internship „Lipid vesicles – a physical model of biomembranes“ (2-16 May 2017), , B.Sc. student Ralitsa Velitchkova, Sofia University “St Kliment Ohridski”, Faculty of Biology (ID 10484), specialty: Molecular biology; Supervisor: Assoc. Prof. Dr V. Vitkova.

DEPARTMENT SOFT MATTER PHYSICS

LABORATORY

BIOMOLECULAR LAYERS

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

TOTAL STAFF: **11**
RESEARSCH SCIENTISTS: **3**
EMERITUS MEMBER: **1**

Assoc. Prof. Dr. Angelina K.Stoyanova-Ivanova; Assist. Prof. L. Todorova;
Assist. Peter A. Lilov; Chem. Eng. M. Dencheva-Zarkova; Chem. Todor E. Vlahov;
Part-time members: Physicist, Ph.D. Stanimira D. Terzieva;
Chem. Eng. Ph.D. Ivana Ilievska; Techn. Fellow Alexander Y. Vasev;
Techn. Fellow Violeta P. Petrova
Emeritus member: Academician Alexander G. Petrov

RESEARCH ACTIVITIES:

In 2017, science activity of BML laboratory involved investigations on electrical and electro-optical properties of nematic liquid crystals nanocomposites, superconductive ceramics, polymer electrolytes and piezoelectric thin layers by electro-optical, impedance spectroscopy etc. methods. The research group within the Laboratory "Biomolecular layers" conducted research on multifunctional materials and materials for medicine.

Structural and dielectric properties of a composite material prepared from polyethylene oxide (PEO) and polyvinylpyrrolidone (PVP) solid polymeric electrolytes doped with Sodium (meta) periodate ($NaIO_4$) salt was studied by complex impedance spectroscopy. The effect of $NaIO_4$ complexity on the dielectric response was analyzed in the frequency range 0.1 Hz – 1 MHz. The complex of PEO / PVP mixture with 10 wt.% NaIO4 salt showed the highest conductivity at room temperature of 1.56 x 10-7 S / cm.

We studied thin films (25 μm-thick) of nanomaterials composed from 3 wt.% aerosil nanospheres and the room-temperature nematic liquid crystal 4-n-heptyl cyanobiphenyl (7CB). The inclusion of 3 wt.% of the photoactive liquid crystal 4-(4'-ethoxyphenylazo)phenyl hexanoate (EPH) in the aerosil/7CB nanostructured nematics make them photoresponsive. The films had alignment layers from rubbed polyimide (PI). Our study is concentrated on the inspection of the PI-role for the photo-stimulated electro-optical properties of the considered EPH-doped aerosil/7CB nanocomposite films.

Heat-activated Ni-Ti and Cu-Ni-Ti orthodontic brackets were studied by the methods of: XDR, SEM, EDS DSC and LIPS. The results showed that Ni and Ti are the main elements in the composition of the brackets under study. During medical treatment nickel quantity variations on the investigated nickel-titanium orthodontic brackets surface were monitored. As a result, the optimal stay without qualitative changes of the examined brackets in the mouth was proposed.

Superconducting ceramics Y-Ba-Cu-O (YBCO) and Bi-Sr-Ca-Cu-O (BSCCO) are prepared in order to be use as an additive in the active mass of the electrode for Ni-Zn rechargeable batteries. Electrochemical tests show that Ni-Zn cells modified by YBCO and BSCCO superconductive ceramics in the electrode mass of the zinc electrode show increasing

of the specific capacity and superior capacity stability over large number of charge-discharge cycles. The results show that BSCCO ceramics are more suitable for Ni-Zn batteries.

PUBLICATIONS

1. G B Hadjichristov, Y G Marinov, A G Petrov and S K Prasad, Photoresponsive azodoped aerosil/7CB nematic nanocomposites: the effect from concentration of the azobenzene photoactive agent, J. Phys: Conf. Series **794** (2017) 012037 doi:10.1088/1742-6596/794/1/012037Y
2. G Marinov, M P Marinov, G B Hadjichristov, A G Petrov, S K Prasad, L Marino and N Scaramuzza, Dielectric study of azo-doped aerosil/7CB nematic nanocomposite upon UV light, IOP Conf. Series: Journal of Physics: Conf. Series **780** (2017) 012009, doi:10.1088/1742-6596/780/1/012009
3. Y G Marinov, G B Hadjichristov, A G Petrov, H K Koduru, L Marino and N Scaramuzza, Dielectric and electrical behaviours of polymeric (PEO/PVP):NaIO4 composite for solid electrolytes, IOP Conf. Series: Journal of Physics: Conf. Series **794** (2017) 012020, doi:10.1088/1742-6596/794/1/012020
4. H.K. Koduru, L. Marino, F. Scarpelli, A.G. Petrov, Y.G. Marinov, G.B. Hadjichristov, M.T. Iliev, N. Scaramuzza, Structural and dielectric properties of NaIO4 e Complexed PEO/PVP blended solid polymer electrolytes, Current Applied Physics **17**, issue 11 (2017) 1518-1531, IF 1.971, doi:10.1016/j.cap.2017.07.012
5. G. B. Hadjichristov, Y. G. Marinov, Photoresponsive azo-doped Aerosil/7CB nematic liquid-crystalline nanocomposite films: the role of polyimide alignment layers of the films, IOP Conf. Series: Journal of Physics: Conf. Series **780** (2017) 012008, doi:10.1088/1742-6596/780/1/012008
6. H K Koduru, K K Kondamareddy, M T Iliev, Y G Marinov, G B Hadjichristov, D Karashanova and N Scaramuzza, Synergetic effect of TiO2 nano filler additives on conductivity and dielectric properties of PEO/PVP nanocomposite electrolytes for electrochemical cell applications, IOP Conf. Series: Journal of Physics: Conf. Series **780** (2017) 012006, doi:10.1088/1742-6596/780/1/012006.
7. G Exner, Y Marinov and E Perez, Investigation of the structure and thermal behaviour of polymer liquid crystal / single wall carbon nanotubes nanocomposite, IOP Conf. Series: Journal of Physics: Conf. Series 780 (2017) 012011, doi:10.1088/1742-6596/780/1/012011
8. Yordan Marinov, Todor Vlakhov, Mihaela Alexandrova, Stanislav Slavov, Luben Lakov, Krasimira Toncheva, Emil Vlakhov, INVESTIGATION OF IONIC CONDUCTIVE CERAMICS Bi12TiO20 BY COMPLEX IMPEDANCE SPECTROSCOPY, Year XXV, Number **1** (216), June 2017, proceedings „NDT days 2017"/ „Дни на безразрушителния контрол 2017", ISSN 1310-3946
9. Yordan Marinov, Todor Vlakhov, Blagoy Blagoev, Grzegorz Luka, Tomasz Krajewski, Elzbieta Guziewicz, and Emil Vlakhov, Characterization of ZnO Nanolayers by complex Impedance Spectroscopy, 978-1-5386-0582-0/17 ©2017 IEEE, 2017, 40th International Spring Seminar on Electronics Technology (ISSE).
10. Structural and morphological characterization of heat-activated nickel-titanium archwires", I. Ilievska, V. Petrov, L. Andreeva, D. Kovacheva, A. Zaleski, M. Drozd, E. Bukowska, V. Mikli, A. Stoyanova-Ivanova, Bulgarian Chemical Communications, Volume 49, Special Issue A (pp. 33–39) 2017, (IF 0.238).
11. Valeri Petrov, Ivana Ilievska, Laura Andreeva, Valdek Mikli, Andrzej Zaleski, Angelina Stoyanova-Ivanova.Studying the Effects of Autoclaving Process on Orthodontic Archwires" MedInform Journal, doi:10.18044/Medinform, 201741.559, issue 1 (2017).

12. Приложение на физичните методи за изследване в ортодонтската практика“, Обществено дентално здраве- постижения, предизвикателска, перспективи, Петров В, Андреева Л., Стоянова-Иванова А, Илиевска Ив., Георгиева М. (19.11.2016 г.) стр. 86-99, София.
13. Приложение на физичните методи за изследване на TiNb дъги в ортодонтската практика”, Обществено дентално здраве - постижения, предизвикателска, перспективи, В. Петрунов, А.Стоянова-Иванова, И. Илиевска (19.11.2016) стр. 77-85, София.

CITATIONS FOR 2017

29

ONGOING RESEARCH PROJECTS

1. Project financed by the Ministry of Education and Science, National Science Fund of Bulgaria DFNI-TO2/18: “Nanostructured liquid crystals for tunable photonic devices” (2015-2018)

2. Projects, additionally financed by contracts with Ministry of Education and Science:
Indo-Bulgarian intergovernmental programme, contract DNTS/ India 1/04, NSF, “Investigations of Photostimulation Effects in Nano-Structured Liquid Crystals”.

3. Bilateral Scientific Exchange, Estonia 2015-2017: ISSP and Tallin University of Technology - Estonia, Prof. Valdek Mikli: „Synthesis and structural investigations of nanomaterials“

ANNIVERSARIES:

Celebration of 25 years Anniversary of “Biomolecular layers” laboratory.

TEACHING ACTIVITIES

Assoc. Prof. Dr. Angelina Koleva Stoyanova-Ivanova is a PhD supervisor of Ivana Ilievska, appointed on 01/09/2015г. in ISSP.

Assoc. Prof. Dr. Angelina Koleva Stoyanova-Ivanova – The Erasmus Programme lecture courses: 15 hours.

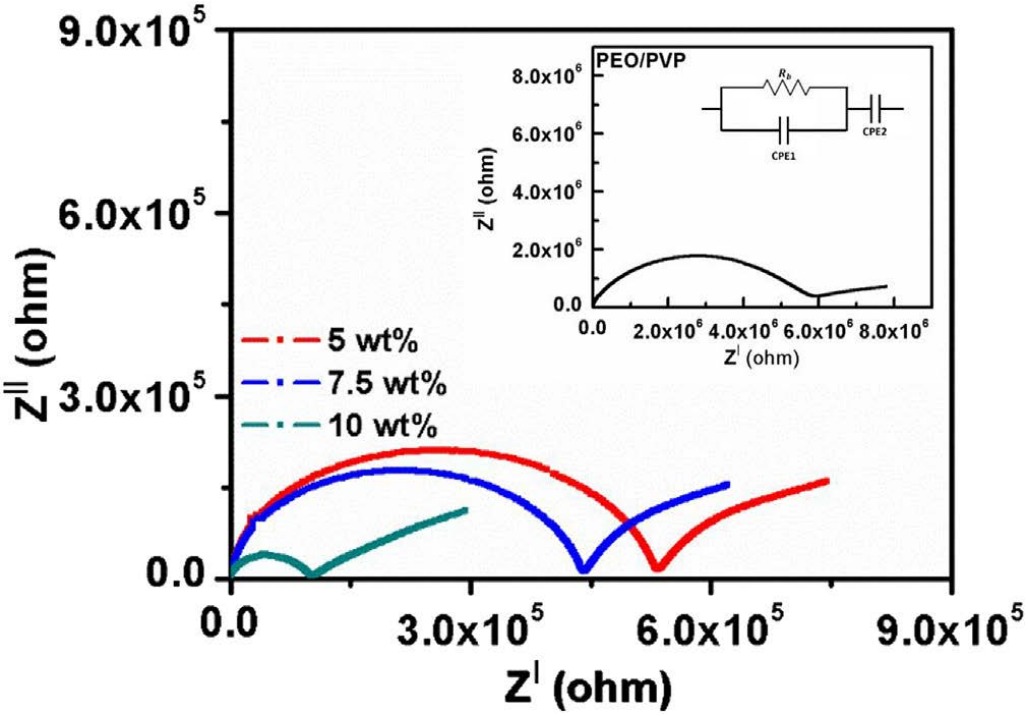

Fig. 1. The Nyquist plots for complexes of PEO/PVP blends with different weight percentages of NaIO4 salt concentrations. Inset: The Nyquist plot for the PEO/PVP blend and equivalent circuit diagram. PEO/PVP blend electrolyte complexed with 10 wt% of NaIO4 salt has demonstrated higher room temperature conductivity of 1.56×10^{-7} S/cm which is two orders of magnitude higher than PEO/PVP.

DEPARTMENT PHYSICAL OPTICS AND OPTICAL METHODS

LABORATORY

OPTICS AND SPECTROSCOPY

HEAD: **Assoc. Prof. T. Tenev, Ph.D.**
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TOTAL STAFF: **19**
RESEARCH SCIENTISTS: **14**
ASSOC. MEMBERS: **4**

Prof. K. Panayotov D.Sc.; Assoc. Prof. L. Tsonev, Ph.D.; Assoc. Prof. A. Andreev, Ph.D.; Assoc. Prof. S. Tonchev, Ph.D.; Assoc. Prof. A. Angelov, Ph.D.; Assoc. Prof. G. Hadjihristov, Ph.D.; Assoc Prof. K. Antonova, Ph.D.; Assoc. Prof. B. Zafirova, Ph.D.; Assoc. Prof. M. Kuneva, Ph.D; Assoct. Prof. B. Katranchev, Ph.D.; Assoc. Prof. E. Karakoleva, Ph.D.; Assist. Prof. H. Naradikian Ph.D.; Assist. Prof. I. Milushev, Ph.D.; Physicist M. Sandulov; Physicist E. Stoyanova; Physicist M. Molerova; Technologist Y.Velkova; Technician Y. Sarafov.

Associated members: Prof. M. Petrov, D.Sc.; Prof. S. Rashev, D.Sc.; Assoc. Prof. T. Tsvetkova, Ph.D.; Assoc. Prof. R. Peeva, Ph.D.;

RESEARCH ACTIVITIES:

The dimerization of aromatic carboxylic acids, is the base of the structure formation of hydrogen bonded in dimers liquid crystals (HBDLCs) that exhibit non-conventional mesomorphism. The structural units of these LCs are amphiphilic-type molecules, which after suitable functionalization, induce supramolecular complexes, nanocomposites based on HBDLCs. The liquid crystalline character of the nanocomposites strongly dependent on intermolecular hydrogen bonds between symmetric, where the H-donors and H acceptors are contained in similar and non-symmetric HBDLCs, where the H-donors and H acceptors are contained in unlike molecules. The strength and non-covalent character of the hydrogen bonds provides both sufficient HBDLCs complex stability and bonding flexibility with a possibility to design and drive the supramolecular geometry. We investigated a series of nanocomposites produced by mixture of HBDLC (p-n-alkyloxybenzoic acid - nOBA), serving as matrices, with non-mesogenic (single walled carbon nanotubes - SWCNTs, hydroxypiridine – HOPY) and mesogenic (cholesteryl benzoate - ChB) nano-particles in various shapes and sizes. A set of new chiral ferroelectric phases were found in the nanocomposites, otherwise do not appearing in the pristine achiral HBDLCs materials. A molecular model of an unique low-temperature ferroelectric smectic phase C based on the molecular dimer ring symmetry reduction (bent dimer formation) towards to the lowest triclinic one is presented for both symmetric and nonsymmetric supramolecular LC complexes.

Diamond-like carbon (DLC) and amorphous carbon films are very promising type of semiconductor materials. Depending on the hybridization sp^2/sp^3 ratio, the material's band gap varies between 0.8 and 3 eV. Moreover carbon films possess different interesting for practice properties: comparable to the Silicon, Diamond like structure has 22-time better thermal conductivity etc. Here we present one type of implementation of such type nanostructure. That is one attempt for orientation of dimeric LC by using of pre-deposited DLC layer with different ratio of sp^2/sp^3 hybridized carbon content. It could be expected a pronounced $\pi 1$-$\pi 2$ interaction between s and p orbital levels on the surface and the dimeric ring of LC. We present

comparison of surface anchoring strengths of both orientation inter-surfaces DLC/dimeric LC and single wall carbon nanotubes (SWCNT)/dimeric LC. The mechanism of interaction of dimeric LC and activated surfaces with DLC or SWCNT will be discussed. In both cases we have π-π interaction, which in combination with hydrogen bonding, typical for the dimeric LCs, influence the LC alignment. The Raman spectroscopy data evidenced the presence of charge transfer between contacting hexagonal rings of DLC and the C = O groups of the LC molecules.

The influence of the static electric field on the orientation of the nematic liquid crystal (NLC) director in the side-electrode cell, is numerically modeled. For the purpose, two-dimensional model of Fréedericksz effect was used. The numerical solutions of two-dimensional parabolic partial differential equation were obtained by finite-difference methods. The Fréedericksz transition threshold for the central part of the cell filled with NLC pentylcyanobiphenyl (5CB), as well as the dependencies of the distribution of the NLC director orientation patterns on the electric field intensity and location, were obtained. The results from the theoretical modeling were compared to the experiment. For the case of 5CB layer with a thickness of 100 μm, the calculations were confirmed by the experimental data obtained by means of polarizing optical microscopy, as well as by macroscopic nonlinear-optical effect, namely electric-field-induced optical second-harmonic generation upon strong (3 kV) static electric field, by applying the corresponding optical & spectroscopy methods.

The effect of single layer graphene (SLG) on the alignment of the room-temperature NLC 5CB was studied. In this case, the SLG nanostructure can interact with the LC benzene rings through π–π stacking. SLG films (growth method: CVD synthesis) on copper substrates (18 μm-thick foils) were examined. LC cells of thickness 50 μm were assembled from these layered structures and glass slides coated with conducting ITO nanolayers overcoated with a polyimide alignment layer. The SLG imposes a planar orientation on the nematic. This alignment effect was elucidated in details by polarizing optical microscopy, combined with complex impedance spectroscopy. By analysis of dielectric spectra we obtained information about the orientation of the SLG-nanostructured films of NLC, that is useful for their practical application, e.g. in NLC electro-optic displays and related devices.

Tree-component photoactive nematic nanocomposites were studied in view of their practical application for photo-controllable electro-optics. Such photoresponsive nanomaterials were produced from nano-filled nematic by doping with photoactive azobenzene liquid crystal 4-(4'-ethoxyphenylazo)phenyl hexanoate (EPH) at concentration of 3 wt.%. The photo-insensitive host nanocomposite material (the filled nematic) was a gel formed from the nematic 4-n-heptyl cyanobiphenyl (7CB) and 3 wt.% of silica nanospheres (hydrophilic Aerosil 300) of size ca. 7 nm. Dielectric spectroscopy was applied to determine the UV-light-produced effect in EPH-doped aerosil/7CB upon continuous *trans*-to-*cis* photoisomerization of EPH molecules by varying the UV light intensity. The effect from UV illumination on the dielectric permittivity (ε) of the studied photoresponsive Aerosil/7CB/EPH nematic nanocomposite was theoretical modeled and analyzed at a room temperature in the frequency range 0.5 Hz – 200 kHz. It was found, that by UV light (and by increase of its intensity) both real and imaginary parts of ε increase, that is related to the corresponding UV-light-induced increase of the electric dipole moment of EPH molecules. The examined Aerosil/7CB/EPH films have alignment layers of polyimide (PI-2555). Further our investigation was focused on the role of these layers for the photo-stimulated electro-optical properties of Aerosil/7CB/EPH nanocomposite films. The observed photo-induced effect was also analyzed as depending on the concentration of the photoactive agent EPH. The results of these studies are useful for the practical applications of nematic nanomaterials in photo-controllable electro-optical devices.

New stable nanocomposite and complexed materials - solid polymer electrolytes (SPEs) were characterized by optical spectroscopy (transmittance/absorption in the UV-vis-

nearIR range, FTIR, Raman spectroscopy and other techniques). The SPEs were fabricated as polymer blends based on the polymers poly(ethylene oxide)(PEO) and polyvinylpyrrolidone (PVP), by use of additives such as inorganic ionic salt $NaIO_4$ compound, as well as TiO_2 nanoparticles. Thin solid films (as thick as ~ 100 μm) of such complexes and nanocomposites were produced by conventional solution cast technique. The PEO network was modified by addition of PVP in order to enhance the electrolyte properties of the complexed/doped polymer blends. Besides by optical spectra, the produced SPEs were characterized also by X-ray diffraction (XRD) analysis, transmission electron microscopy (TEM) and scanning electron microscopy (SEM). These microstructural analytic methods prove the polymer-salt complex formation, and reveal that the addition of $NaIO_4$ (and TiO_2, too) leads to an increase of both the homogeneity and the relative content of the amorphous phase of the material, that is of great importance for its function as SPE. The electrical and dielectric properties, as well as the ionic dynamics of the fabricated SPEs were investigated by complex electric impedance spectroscopy in the frequency range 0.1 Hz – 1 MHz as a function of dopants concentration, in the temperature range 20 – 60 °C. The obtained data, behaviors and characteristics were related to the corresponding both microstructural morphology and optical properties of the examined films of SPEs. The analysis of corresponding spectra of dielectric response reveals that the increase of the concentration of the ionic compound $NaIO_4$ increases the ionic conductance and mobility of Na^+-ions, and improves the dielectric properties of the (PEO/PVP)-$NaIO_4$ salt-polymer complex. As compared to the host polymeric matrix (PEO itself or the PEO-PVP blend system), a distinctly enhanced electrical and dielectric response (an increase of the values of both direct-current and alternating-current electrical conductance of the studied SPEs, as well as an increase in the value of their dielectric constant), were found. For instance, an enhancement of the bulk electrical conductivity by two orders of magnitude was present by the three-component system (PEO-PVP):$NaIO_4$, when the polymers were mixed in a weight ratio 70 % PEO : 30 % PVP, and the concentration of the $NaIO_4$ compound complexed with the PEO-PVP matrix was 10 wt.%. Another important result: a further increase of ionic conductivity can be achieved by addition of TiO_2 nanoparticles to the same SPEs. For example, a conductivity enhancement by a factor of 60 can be achieved for TiO_2-(PEO/PVP)-$NaIO_4$ nanocomposite SPEs with 3 wt.% TiO_2 nanoparticles. The results (experiment and theoretical modeling) obtained from our comprehensive studies suggest the potential of the synthesized complex materials for use in polymer electronics and electric applications such as SPEs and electrochemical cells. An important advantage of the considered flexible polymeric complexes and composites (nanocomposites) is the possibility their electric and dielectric properties to be relatively easily optimized by compositional and/or structural modifications, namely by varying the fillers and their content. The results would be useful also for the optimizing the synthesis of SPEs based on Na^+-ions and PEO/PVP-matrices for rechargeable mini-batteries and other practical applications.

The occurrence of new liquid crystals like textures in water suspensions of chitin particles was obtained. Biphasic systems of chitin tactoids (drops of nematic phase) floating in an isotropic phase, were under investigation. It was shown experimentally and by numerical simulations that the application of an electric field to nematic tactoids induces a transition from the common spindle-like shape with a bipolar director field to a cigar-like shape with an almost uniform director field. The drops extend in the direction of the field to reach aspect ratios of over ten which is a consequence of the low elasticity and strong anchoring at the interface of the chitin tactoids and environment. From a practical point of view, subjecting tactoids to shear flow has been shown to improve the optical properties of liquid crystal films by enhancing the alignment of the particles.

A series of test deposits of multi-layer optical structures from substances with a high (TiO_2), medium ($Al2O_3$) and low (SiO_2) refractive index on colorless optical glasses (BK7, SF56, SF11, H-ZF13 with refractive indices between 1.5 and 1.85, microscope slides of

various manufacturers and Si plates. The layers are obtained under different technological conditions by electron beam evaporation and ion beam assist with Ar, O_2, or mixtire of both ions. Optimal technological conditions were selected for the process to obtain layers with the required characteristics (refractive index, density, strength, adhesion, etc.). Selected deposition conditions of thin layers with these characteristics have been used in multilayered structures for the visible spectral region and different functional coatings are realized: antireflective coatings, dielectric mirrors, cut-off filters, single and twin narrow-band filters.

We proposed a model for the oscillation of a single-frequency feedback semiconductor laser based on a ring fibre interferometer and showed that at a certain level of feedback, the generation frequency is locked by the transmission peak of the fibre interferometer. The effect is accompanied by the narrowing of the spectral line and the reduction of noises. The model is capable of describing the main features of the experimentally measured laser outputs such as laser line narrowing, spectral shape of generated radiation, mode-hoping instabilities and makes possible exploring the key physical mechanisms responsible for the laser operation stability.

We demonstrated experimentally that a chaotic polarization dynamics can be obtained in quantum-well VCSELs by introducing anisotropic strain in the laser cavity. The simplicity of the approach, based on low-cost and easily available components including off-the-shelf VCSELs, paves the way to the wide spread use of solitary VCSELs for chaos-based applications.

We reported experimental and theoretical results of bistable polarization switching (PS) in a single transverse mode 1550nm VCSEL subject to parallel optical injection, namely bistability induced by power variation of the master laser and a new state of simultaneous injection locking (IL) of the parallel polarization mode and excitation of the orthogonal polarization mode, IL+PS. A simple nonlinear dependence between the power of both linear polarizations and the frequency detuning is found. We showed that VCSELs with more than a 35 dB polarization mode suppression ratio can have rich nonlinear dynamics in both linear polarizations, including periodic and chaotic behaviors appearing simultaneously in both polarization modes.

We theoretically investigated a weakly birefringent all-fiber cavity subject to linearly polarized optical injection and showed that, for a wide range of parameters, there is a coexistence between a homogeneous steady state and two different types of temporal vector cavity solitons with different polarization state and peak intensity. We construct their bifurcation diagram and show that they are connected through a saddle-node bifurcation.

We demonstrate a way to generate two-dimensional rogue waves in two types of broad area nonlinear optical systems subject to time-delayed feedback: in the generic Lugiato-Lefever model and in the model of a broad-area surface-emitting laser with saturable absorber. We show that for moderate input intensities it is possible to generate drifting cavity solitons with an asymmetric radiation emitted from the soliton tails. For Lugiato-Lefever model we also identified a route to spatiotemporal chaos through an extended quasiperiodicity and estimated the Kaplan-Yorke dimension that provides a measure of the strange attractor complexity. For a wide-aperture surface-emitting laser with a saturable absorber section subjected to time-delayed feedback we used bifurcation analysis, direct numerical simulations, and numerical path-continuation methods and identified the possible bifurcations and map them in a plane of feedback parameters. We showed that for both the homogeneous and localized stationary lasing solutions in one spatial dimension, the time-delayed feedback induces complex spatiotemporal dynamics, in particular a period doubling route to chaos, quasiperiodic oscillations, and multistability of the stationary solutions.

We studied the feasibility of generating photon pairs in a resonant Vertical-Cavity Surface-Emitting Laser (VCSEL) as a result of a third-order non-linear, four wave mixing interaction. We focus on degenerate four wave mixing in the spontaneous regime where two

pump photons are annihilated to create a pair of signal and idler photons. Using the methods of quantum optics, we calculate the two-photon production rate, the spectrum of the generated photons, and the signal-idler cross-correlations. We highlight how the dispersion of the medium in the VCSEL cavity (a regular GaAs configuration) significantly diminishes the two-photon production rate. Based on our results, we enumerate the characteristics of a VCSEL that would be suitable for photon pair generation.

By the development of the application of the Galerkin method for calculating of photonic crystal fibers (PCFs) theoretical expressions are obtained for the elements of the matrix of the eigenvalue, i. e. for solving of the problem for calculating of

- the Bragg PCFs, which consist of concentric annular dielectric layers with different refractive indices for using them as gas sensors
- the PCFs, consisting of a host medium with holes located in it. The surface of the holes is covered by concentric layers with different refractive indices in order to enhance the sensitivity of the fibers when using them as chemical sensors.

The work on construction and manufacturing of the chamber for gas-sensing measurements is completed. The chamber is necessary in making and researching of the fiber-optical gas sensors.

The application of the surface photo-charge effect (SPCE) for control of fluids is described in a book chapter. The analytical method based on the SPCE provides great potential by combining optical probing of the sample with electrical detection of the generated signal. It represents a universal testing method since a signal is generated by all types of fluids, is very sensitive to any change in fluid properties and thus sensors for various parameters of interest could be built, as well as ones for control of different processes. The SPCE-based sensors can be used for on-line and/or in-situ control as well. The SPCE has the great potential to complement the already known and used methods for control of fluids. Some examples are given of using the method for milk quality control, fuel octane number monitoring, liquid identification, detection of impurities, liquid level control. The main advantages of the SPCE-based detection include high accuracy, contactless measurement, rapidness, universality, low cost, instantaneous results, and possibilities of rapid field measurements in real time, with no need of complex equipment or qualified personnel, low dimensions of the sensors.

In Volume II of the three-volume series “The quantitative history of the University of Sofia 1888-1939, as documented in the biobibliographies of its lecturers, Vol. 2” (in Bulgarian) quantitative historical data are consecutively represented, to further the study announced in Vol. I - on the unique Almanac of the University of Sofia published in 1940. The data on place of birth and places of higher education are complemented with new biographical details: secondary education, promotion in European universities, specializations, scientific and organizational activities. Data on foreign lecturers is added. Basic and summarized data on countries, universities and Bulgarian students graduated from them who later became lecturers in the University of Sofia are presented in tables.

Archaeological sites that are beyond the scope of the professional archaeological guild and have not yet been fully explored are analyzed. The need and usefulness of luminescent dating for megalithic and other antique cultural sites in Bulgaria is argued.

A new perspective on the study of the megaliths in Bulgaria is proposed, namely: the continuity between the prehistoric megaliths and other pagan sanctuaries on the one hand and objects worshiped in the Christian age on the other.

On both topics articles are published in specialized publications, papers are presented to specialized scientific forums and efforts have been made to popularize the possibility for luminescence dating which has the potential to resolve a number of unclear archaeological problems.

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37. Raddo T. R., **Panajotov K.**, Borges B.-H. V., Virte M.. Strain induced polarization chaos in a solitary VCSEL. Scientific Reports, 7, 14032, Nature, 2017, DOI:10.1038/s41598-017-14436-3, 1-7. ISI IF:4.259
38. Tlidi M., **Panajotov K.**. Two-dimensional dissipative rogue waves due to time-delayed feedback in cavity nonlinear optics. Chaos, 27, 013119, 2017, DOI:10.1063/1.4974852, 1-5. ISI IF:2.283
39. Христов Д., **Кънева М.**. Количествената история на Софийския университет „Св. Климент Охридски" 1888-1939, записана в биобиблиографиите на неговите преподаватели, т. II., 168 стр., Изд. Фараго, 2017, ISBN: 978-619-206-050-3

CITATIONS FOR 2017:
130

ONGOING RESEARCH PROJECTS:

Financed by the Bulgarian Academy of Sciences:

"Optics, electroptics and spectroscopy of new materials, surfaces, thin layers, liquid specimens and fiber optics", 2018/20, budjet subsidy from the Bulgarian Academy of Sciences (BAS)

Financed by the Bulgarian Ministry of Education and Science:

Grant application for NSF support for science 2017:
Methods for phase composition analysys of proton-exchanged waveguide layers in lithium niobate and lithium tantalate, H18-17 (Assoc. Prof. M. Kuneva - coordinator)

Approved project (NSF support for periodicals 2018-2019, **The World of Physics**) НП06/24 (Assoc. Prof. M. Kuneva - team member).

Participation in three-year (2016-2018) project "Liquid crystal approach for model lipid membrane functions optimization by nanoparticles insertion" (FNI-DH08-2) head: Assoc. prof. J. Genova, ISSP-BAS (Assoc. Prof. B. Katranchev and Assoc. Prof. G. Hadjihristov – team members)

Participation in three-year (2016-2018) project “Mechanical and electrical properties of model lipid membranes in the presence of biologically active substances” (FNI-ДН08-7) head: Assoc. prof. V. Vitkova, ISSP-BAS (Assoc. Prof. K. Antonova – team member)

TEACHING ACTIVITIES:

Prof. K. Panayotov - Supervisor:

PhD Thesis: **Etienne Averlant,** “Localized structures in surface emitting lasers: vectorial character and delay-induced motion”, November, 2017.

Post Doc: 2;

PhD stidents: 2.

Assoc. Prof. A. Angelov - Supervisor:

MSc Thesis: **E. Stoyanova**, “Sagnac interferometer and description of quantum noises in interferometers“, March 2017 (in Bulgarian).

Assoc. Prof. M. Kuneva:

5.1. 32 hours laboratory exercises in physics, bachelor program, Technical University, summer term, 2017

5.2. 38 hours seminar exercises in physics, bachelor program, Technical University, summer term, 2017

DEPARTMENT - LASER, ATOMIC, MOLECULAR AND PLASMA PHYSICS

LABORATORY

ATOMIC SPECTROSCOPY

HEAD: **Assoc. Prof. Valentin Mihailov, Ph.D.**
tel: 979 5740; e-mail: valentin@issp.bas.bg

TOTAL STAFF: **9**
RESEARCH SCIENTISTS: **8**
ASSOC. MEMBERS: **1**

Prof. Kiril Blagoev, D.Sc.; Assoc. Prof. Emilia Dimova, Ph.D.; Assoc. Prof. Galina Malcheva, Ph.D.; Assoc. Prof. Margarita Stefanova, Ph.D.; Assoc. Prof. Boian Torosov, Ph.D.; Assist. Prof. Vasilka Steflekova, Ph.D.; Assist. Prof. Hristina Hristova, Ph.D.; Ph.D student Vani Tankova

Associated members: Assoc. Prof. Petko Pramatarov, Ph.D.

RESEARCH ACTIVITIES:

During the year, Atomic spectroscopy laboratory has been working in the field of analytical atomic spectroscopy and archaeometry achieving information about the elemental composition of different archaeological objects. Research on the development of a miniaturized analytical detector for the determination of gas pollutants by the electron impact spectroscopy method has continued. The developed detector is protected by a patent that has been issued this year. The work on measuring radiative lifetimes data for highly excited levels in Ni II using a laser-induced fluorescence method has been completed. The results obtained with colleagues from "MVL lab." and the University of Plzeň - Czech Republic for application of FeS layers deposited by laser ablation are summarized and published. In the area of quantum optics, we continued the work on composite pulses theory and the creation of broadband frequency conversion techniques.

A quantitative elemental analysis of bronze objects from Baley necropolis and from Malko Tranovo, as well as objects from the collection of the National Archaeological Institute with Museum at BAS, were performed by laser-induced plasma spectroscopy (LIBS) method within the framework of the BAS project: "Thracians - genesis and development of ethnic, cultural identities and heritage of antiquity". The analytical information obtained from the LIBS spectra was necessary for the qualitative determination of the elements in the material used for the production of the studied objects. There were traces of gold in some of the objects of M. Tranovo and antimony in some of the objects from the collection of NAIM. The evaluation of the tin and lead concentration in a part of the samples was performed after generating calibration curves for a set of four standard samples with a wide range of tin and lead concentrations and a similar matrix composition. The results of the qualitative and quantitative analysis offered some insights into production process of the investigated archaeological objects and their origin. A qualitative analysis of plaster from the tombs in Sveshtari and Shishmantsi was carried out too. The results are compared with data obtained by other methods -XRF, SEM.

Study on the development of a miniature analytical detector for the determination of gas pollutions at high gas pressure by the impact electron spectroscopy method has been continued.

A calibration of the energy scale at medium and high gas pressures was performed. It was found that using additives of 0.05% to about 3% of Ar or Kr to the gas mixture under investigation, the characteristic Ar and Kr maxima in the electron distribution function can be used as energy benchmarks to determine the type of contamination. The use of the plasma potential as an energy marker, especially at high pressures, was not accurate due to the uncertainty in determining the impedance of the sensor circuit at the plasma potential. Studies were conducted to determine the absolute concentration of the analytical component in terms of the areas below the characteristic maxima in the energy distribution function of electrons and the known concentration of the additives of Ar or Kr.

The work on measuring the radiative data for highly excited levels in Ni II was completed using a laser-induced fluorescence method. Two-photon excitation of ions obtained by laser ablation was used to populate the levels. The theoretical calculations of the radiative lifetimes of the measured levels and the transition probability from these levels were performed using the Hartree-Fock pseudo-relativistic method, taking into account the effects of polarization from the nucleus. A new set of transition and oscillation probabilities was obtained for the 477 Ni II transition from astrophysical interest in the spectral range 194-520 nm.

We continued the work on composite-pulse theory. New series of composite pulses, which allow for a more flexible selection of the total pulse area were presented. We derived an analytical solution of the quantum model of a two-state system interacting with an external coherent field, where the Hamiltonian is pseudo-Hermitian. The non-Hermitian generalization of the famous Landau-Zener model was described in details, but similar generalizations can easily be derived for other analytical models. Analytical solutions were shown to have a non-Hermitian dynamical invariant that replaces the condition of preserving the total probability in the Hermitian case. Physical implementations were proposed in waveguides and in non-linear frequency conversion.

The possibility of realizing the Jaynes-Cummings-Hubbard (JCH) one-dimensional model in a waveguide system was explored. From the collected literature review it was visible that attempts to realize the JCH model are based primarily on systems containing quantum objects such as atoms. On the other hand, waveguides successfully simulate a quantum system with two energy levels. Consequently, it is possible to make a quantum-optical analogue of the JCH model combining several such devices (a suitably selected combination of waveguide couplers). Besides being able to study such systems, the realization of this model is relevant to areas such as quantum computing and can be applied in logical elements.

A way to achieve efficient and robust second harmonic generation has been investigated. The proposed technique resembles adiabatic population transfer in a two-state quantum system with crossing energies. If the phase mismatching changes slowly due to the temperature gradient in the crystal and makes the phase match occur for second harmonic generation then the energy is converted adiabatically to the second harmonic. As an adiabatic technique, the presented second harmonic generation scheme is robust to variations in the parameters of the crystal as well as of the input light, crystal length, input intensity, wavelength and angle of incidence.

PUBLICATIONS:

1. H. Hartman, L. Engström, H. Lundberg, H. Nilsson, P. Quinet, V. Fivet, P. Palmeri, G. Malcheva, and K. Blagoev, Radiative data for highly excited 3d84d levels in Ni II

from laboratory measurements and atomic calculations *Astronomy&Astrophysics* vol. 600, A108 (2017)

2. G. Malcheva, K. Blagoev, M. Grozeva, V. Tankova, V. Steflekova, S. Alexandrov, T. Hristova, G. Ivanov, G. Nekhrizov,Qualitative and quantitative laser-induced breakdown spectroscopy analysis of archaeological metal artefacts; *Proceedings of SPIE*, Vol. 10226 (2017)

3. B. T. Torosov and N. V. Vitanov, Pseudo-Hermitian Landau-Zener-Stückelberg-Majorana model *Phys. Rev.* A 96, 013845 (2017)

4. Kudryavtsev, A. I. Saifutdinov, M. S. Stefanova, P. M. Pramatarov, and S. S. Sysoev, Measurement of plasma parameters in He microdischarge by means of additional sensor electrode *Physics of Plasmas* 24, 054507 1-5 (2017)

5. Bineva I., Pejova B., Mihailov V., Dinescu A., Danila M., Karatodorov S., Structural and morphological characterization of ternary nanocrystalline Cu-In-S thin films prepared by laser ablation. *Journal of Physics: Conference Series*, 794, 1, IOP Science, 2017, ISSN:1742-6596

6. T. Krenek, S. Karatodorov, R. Medlna, V. Mihailov, J. Savkova. Pulsed Nd:YAG deposition of nanostructured FeS 1-x containing meta-stable phases. *IOP Conference Series: Materials Science and Engineering*, 175, 1, IOP Publishing, 2017

7. T. Krenek, R. Medlna, S. Karatodorov, V. Mihailov, M. Pola, A. H. Reshak. FormationofmetastablephasesofferroussulfideviapulsedNd:YAGlaserdeposition: Experimentalandtheoreticalstudy. *Journal of Alloys and Compounds*, 2014, 723, Elsevier, 2017

Thracian antiquity: technological and genetic research, history and intangible heritage. V. Nikolov (Ed.), Collectionin honor of the 75th of Peter Mandjoukov. Sofia, 2017,

8. T. Hristova, G. Ivanov, Tz. Dobrovolsca, I. Krustev, G. Avdeev, B. Rangelov, K. Kostov, G. Atanasova, K. Kalchevska, V. Tankova, K. Blagoev, G. Malcheva, M. Grozeva, V. Steflekova, R. Stoianova. The tin – mystery of the bronze objects from necropolis at Balei, Vidin,

9. V. Tankova, K. Blagoev, G. Malcheva , L. Leshtakov. Exploration of bronze archeological artifacts from the late Bronze Age and the Early Iron Age with Laser Induced Plasma (LIBS),

10. M. Tonkova, P. Penkova, I. Krustev, Tz. Dobrovolsca, B. Rangelov, K. Kalchevska, G. MalchevaV. Tankova, R. Stoianova. Technological characteristics of metal objects from the Thracian sanctuary at MalkoTranovo, Chirpansko: archeology and archeometry

11. V. Steflekova.Self-induced optogalvanic effect in a segmented hollow cathode discharge.*Journal of Physics: Conference Series* (JPCS), IOP Publishing, accepted 2017

PATENTS

Applicant: ISSP – BAS

Inventors: P. M. Pramatarov, M. S. Stefanova, Kudryavtsev, A. I.

Invention: “Methodandionizationdetectorforanalysisofimpuritiesingases”

Patent № 66623, Int. Cl. G 01 N 27/62 (2006.01)

ONGOING RESEARCH PROJECTS:

- Atomic and Plasma Physics (funded by the budget subsidy of BAS),
- Thracians - genesis and development of ethnic, cultural identities and heritage of antiquity (private donation to BAS),
- Composite pulses in quantum engineering, Marie Curie reintegration grant (Horizon 2020 and COST),
- New plasma source for elemental spectral analysis of solid materials - laser ablation in hollow cathode discharge, joint project with MVL lab. (Program of BAS to support young scientists),
- Non-Hermitian Hamiltonian approach to quantum control (Program of BAS to support young scientists),
- Adiabatic control and quantum-optical analogues – new techniques (Program of BAS to support young scientists),
- Composite and adiabatic methods for control in quantum and optical technology. (National Science Fund).

INTERNATIONAL COLLABORATION:

- ✓ Faculty of Physics, Jagiellonian University, Krakow, Poland,
- ✓ Faculty of Physics, University of Belgrade, Serbia,
- ✓ ITMO University, Saint Petersburg, Russia,
- ✓ French National Centre for Scientific Research CNRS, Institut de physique.

TEACHING ACTIVITIES:

In 2017 one PhD student (Vani Tankova) was working in the Laboratory under the supervision of prof. K. Blagoev**.**

DEPARTMENT - LASER, ATOMIC, MOLECULAR AND PLASMA PHYSICS

LABORATORY

METAL VAPOUR LASERS

HEAD: **Assoc. Prof. Todor Petrov, Ph.D.**
tel: 979 5748; e-mail: petrovts@gmail.com

TOTAL STAFF: **18**
RESEARCH SCIENTISTS: **16**
HONORARY MEMBERS: **1**
ASSOC. MEMBERS: **1**

Assoc. Prof. Dimo Astadjov, Ph.D.; Assoc. Prof. Krassimir Temelkov, Ph.D.; Assoc. Prof. Peter Zahariev, Ph.D.; Assist. Prof. Krassimir Dimitrov; Assist. Prof. Lubomir Stoychev, Ph.D.; Assist. Prof. Ognian Sabotinov, Ph.D.; Assist. Prof. Stefka Slaveeva, Ph.D.; Assist. Prof. Stefan Karatodorov, Ph.D; Physicist Viktoria Atanasova, Ph.D; Physicist Danka Iordanova; Physicist Yu. I. Fedchenko, Ph.D. student; Physicist Blagovela Blagoeva; Physicist Kaloyan Zlatanov
Associated members: Assoc. Prof. Margarita Grozeva, Ph.D.;
Honorary members: Prof. Nikola Sabotinov, D.Sc., member of BAS

RESEARCH ACTIVITIES:

During 2017 the research of prototyping of new lasers “active medium -tubes" for the metal vapor laser is continued. The new power supply for a high-power copper bromide vapor laser has been developoed. Interactions of femtosecond laser pulses with matter, including non-linear processes in the filaments of air and YAG crystalline matrix, precious metal ions and surface treatment of materials are investigated. Laser cleaning of different materials is done by using the existing laser sources in the institute.

The experiments were carried out on laser cleaning of paper samples from various dirt and stains commonly encountered in the restoration practice (inks, rust and soot). As sources were used the following lasers: Q-switched Nd:YAG laser generating pulses with duration 8 ns, wavelength 1064 nm and 532 nm and pulse repetition frequency 1 Hz and 10 Hz, with a maximum pulse energy at the IR wavelength 500 mJ and at the green one - 60 mJ; a copper bromide vapour laser (CuBrVL) generating light at a wavelength 510.6 nm and a pulse duration 30 ns, with repetition rate 20 kHz and average output power 6 W; Ti:Sapphire femtosecond laser with a pulse duration of 35 fs, 1 kHz pulse repetition frequency, and a wavelength tunability in the range 240-2600 nm. The results were compared with chemical and mechanical methods using different chemicals and rubbers with various abrasion and were evaluated by digital microscopy and additionally by a restorer. It has been found that the cleaning efficiency of the CuBrVL system is comparable and in some cases better than the Nd:YAG laser. CuBrVL is suitable for effective cleaning of soot stains and ballpoint pen on paper, but in some cases, as paper stained with printing ink and rust, proper cleaning is not achieved due to the nature of the materials. In the case of cleaning with the femtosecond laser system, optimal working regime is not achieved due to the nature of the materials.

Experiments have been carried out to produce laser-induced periodic surface structuring with the aid of femtosecond laser radiation. The materials used are platinum, gold, nickel, zinc, steel, teflon. Various operating parameters, including translation stage (0.5-5 mm / s), wavelength (240, 560, 720, 800, 900 nm), applied energy of laser radiation (1- 12 μJ). The processed samples were analyzed with a scanning electron microscope. A laser treatment of dopped glasses with nobel metal ions was performed by means of femtosecond laser pulses. The experiments were performed on dopped glass with nanoparticles of gold and silver. Samples with varying concentrations of gold nanoparticles of 1, 5 and 10% were used, silver ion samples were at 5% concentration. The operating parameters were in ranges respectively - number of pulses - from 4x103 to 6x103; energies - from 20 to 40 μJ. These operating parameters were applied for different wavelengths - 266, 355, 532, 800 and 1064 nm. The analysis of the studied materials shows that the effect of the laser radiation depends mainly on the energy in the pulse, respectively, for each wavelength

Temporal and radial distribution of electron temperature $T_e(r, t)$ is determined in DUV Cu^+ Ne-H_2-CuBr laser. For that purpose, the parameters of the nonstationary heat conduction equation for electrons, namely thermal conductivity and specific heat capacity of the electron gas (at Maxwell-Boltzmann electron energy distribution function), are determined and 2D(r, t) numerical model is developed, in order to solve the equation.

Using the new simple method, proposed during the last year, and the well-known, but far-too complex, Wassiljewa equation, empirically derived in the beginning of the last century, thermal conductivities of various 2- and 3-component gas mixtures are comparatively calculated under gas-discharge conditions, which are optimal for laser oscillation at Cu^+ and Sr spectral lines in nanosecond pulsed longitudinal discharge. It is obtained that the discrepancy in thermal conductivity values retains constant at the transition from 2- to 3- component mixtures. Moreover, the new method proves to be more applicable, since it could be used at molecules presence, also rendering an account of their dissociation.

The monograph “High-end state-of-art copper bromide vapor lasers: optical, electric and thermal properties” written by Assoc. Prof. Dimo Astadjov, has been published.

PUBLICATIONS:

1. N. Nedyalkov, N. E. Stankova, M. E. Koleva, R. Nikov, **M. Grozeva, E. Iordanova, G. Yankov,** L. Aleksandrov, R. Iordanova, D. Karashanova, ″Optical properties modification of gold doped glass induced by nanosecond laser radiation and annealing″ , Optical Materials, accepted 2017.
2. **E. Iordanova, G. Yankov** and K. Garasz, “Surface Modification of Different Materials by fs-Laser Irradiation”, Bulg. J. Phys. vol.**44** no.2 (2017), pp. 133-144.
3. N Nedyalkov, N E Stankova, M E Koleva, R Nikov, P. Atanasov, **M Grozeva, E Iordanova, G Yankov,** L Aleksandrov, R Iordanova, D Karashanova, ”Optical properties modification induced by laser radiation in noble metal doped glasses” Presented at VEIT 2017, submitted to J. Phys. Conference Series, 2017.
4. **D. N. Astadjov**, High-End State-of-Art Copper Bromide Vapor Lasers: Optical, Electric and Thermal Properties. ArXiv e-publication

https://arxiv.org/abs/1712.02422, Cornell University Library, Ithaca, NY, US, 2017, 135

5. Todor Hikov, Emilia Pecheva, Paul Montgomery, Frederic Antoni, Audrey Leong-Hoi, **Todor Petrov**, „Precise femtosecond laser ablation of dental hard tissue: preliminary investigation on adequate laser parameters", Journal of Physics: Conference Series, **v. 794**, number 1.
6. T Krenek, R Medlna, **S Karatodorov**, V Mihailov, M Pola, A.H.Reshak **, "**Formation of metastable phases of ferrous sulfide via pulsed Nd:YAG laser deposition: Experimental and theoretical study", Journal of Alloys and Compounds, 2014, 723 (2017): 689-697.
7. T Krenek, **S Karatodorov**, R Medln, V Mihailov, J Savkova, "Pulsed Nd:YAG deposition of nanostructured FeS 1-x containing meta-stable phases." 2017 IOP Conf. Ser.: Mater. Sci. Eng. 175 012022
8. I Bineva, B Pejova, V Mihailov, A. Dinescu, M Danila, **S Karatodorov** Structural and morphological characterization of ternary nanocrystalline Cu-In-S thin films prepared by laser ablation.,Journal of Physics Conference Series 794(1):012019
9. O. Ivanov, **S. Karatodorov**, J. L. Pérez Díaz Novel Electromagnetic Sensor for Contaminations in Fog Based on the Laser-induced Charge Effect Proceedings of IEEE SENSORS 2017 978-1-5090-1012-7/17
10. Tankova, V, Blagoev, K, **Grozeva, M,** Malcheva, G, Steflekova, V, Alexandrov, S, Hristova, T, Ivanov, G, Nekhrizov, G. Qualitative and quantitative laser-induced breakdown spectroscopy analysis of archaeological metal artefacts. Proceedings of SPIE - The International Society for Optical Engineering, 2017, ISSN:0277786X, SJR:0.216
11. **Temelkov, K. A., Slaveeva, S. I., Fedchenko,** Yu. I.. Determination of gas-discharge plasma parameters in powerful metal halide vapor lasers. Proc. of SPIE, 10226, 2017, ISSN:0277–786X, SJR:0.2
12. **Victoria Atanassova, Ivan Kostadinov, Margarita Grozeva.** Laser Cleaning of Different Surfaces by Copper Bromide Vapour Laser: Application for Cultural Heritage Preservation. Comptes Rendus de L'Academie Bulgare des Sciences, 70, 8, 2017, ISSN:2367–5535, SJR:0.207, ISI IF:0.251
13. **Victoria Atanassova, Ivan Kostadinov, Peter Zahariev, Margarita Grozeva**, Ilko Miloushev. Laser Cleaning of Graffiti on Stone. Proc. SPIE 10226, 19th International Conference and School on Quantum Electronics: Laser Physics and Applications, 2017, DOI:10.1117/12.2262668, SJR:0.216
14. **Koelman PMJ,** Yordanova D.**, Musavi S. Tadayon, Graef WAAD, Mihailova D., Dijk J.. Uncertainty analysis of a reduced CO2 global model. 2017**
15. Nikolov, A. S., Balchev, I. I., Nedyalkov, N. N., **Kostadinov, I. K.,** Karashanova, D. B., Atanasova, G. B.. Influence of the laser pulse repetition rate and scanning speed on the morphology of Ag nanostructures fabricated by pulsed laser ablation of solid target in water.. Applied Physics A, 123, 11, Springer, 2017, 719. ISI IF:1.455
16. T Krenek, **S Karatodorov**, R Medlna, V Mihailov, J Savkova. Pulsed Nd:YAG deposition of nanostructured FeS 1-x containing meta-stable phases.. IOP Conference Series: Materials Science and Engineering, 175, 1, IOP Publishing, 2017, ISSN:1757-899X, DOI:http://sci-hub.tw/10.1088/1757-899X/175/1/012022.
17. T Krenek, R Medlna, **S Karatodorov**, V Mihailov, M Pola, A.H.Reshak. Formation of metastable phases of ferrous sulfide via pulsed Nd:YAG laser deposition: Experimental and theoretical study. Journal of Alloys and Compounds, 2014, 723, Elsevier, 2017, DOI:http://sci-hub.tw/10.1016/j.jallcom.2017.06.229, 689-697. ISI IF:3.113

18. Солдатов А.Н., Полунин Ю.П., **Костадинов И.К.**, Шумейко А.С., Васильева А.В., Лоева Я.А.. Оптимизация процесса абляции костной ткани в среднем ИК-диапазоне при низкой частоте повторения импульсов. Лазерно-информационные технологии в медицине, биологии, геоэкологии и транспорте – 2017 : тр. XXV Междунар. конф. г. Новоросийск, 4-9 сент.2017г., Новоросийск: Изд-во РИО ГМУ имени адмиралаФ.Ф.Ушакова, 2017. С.61, 2017, 61
19. Таня Христова, Георги Иваанов, Цветина Доброволска, Иван Кръстев, Георги Авдеев, Богдан Рангелов, Красимир Костов, Геновева Атанасова, Камелия Калчевска, Вани Танкова, Кирил Благоев, Галина Малчева,**Маргарита Грозева**,Василка Стефлекова, Радостина Стоянова. Калаят – загадката в бронзовите предмети от некропола при Балей, Видинско. Тракийската древност: технологични и генетични изследвания, история и нематериално наследство. Сборник в чест на 75-годишнината на Петър Манджуков. София, 2017

PATENTS:

Maintained patents:

1. Laser tube for strontium infrared laser with strontium halide vapours	N.K.Vuchkov, K.A.Temelkov, N.V.Sabotinov
2. Тръба за кухокатоден лазер с разпрашване на катода	M. Grozeva, D. Mihailova, N.V.Sabotinov
3. Газов лазер с пари на халогениди на медта	N.V.Sabotinov, K. Dimitrov
4. Laser tube for ultraviolet copper laser	N.K.Vuchkov, K.A.Temelkov, P. Zahariev, N.V.Sabotinov
5. Ultraviolet copper laser	N.K.Vuchkov, K.A.Temelkov, N.V.Sabotinov
6. Three-component glassy matrices prossessing variable nonlinear optical properties	T. Petrov, B. Shivachev, Hitoki Yoneda

Patents in procedure:

1. “Method of atmospheric electricity extraction” (No. 112379 13.09.2016)	D. Astadjov, I. Angelov, M. Gospodinov
2. Method and system for deposition of micro- and nanoparticles on transparent substrate	K. Dimitrov

ONGOING RESEARCH PROJECTS:

- Laser induced formation of three-dimensional structures of nanoparticles and study of their optical properties, (funded by NFS №.H08/25 01.09.2016).
- Lasers and Laser Assisted Annealing of nanostructures (WG 5) – part of "Research and Innovation Capacity Strengthening of ISSP-BAS in Multifunctional Nanostructures" (INERA/FP7-REGPOT-2012-2013-1).
- Lasers, laser technologies and applications (funded by the budget subsidy of BAS).
- Femtosecond laser applications (under the Academy's bilateral agreements with IFFM, Gdansk, PAS, Poland).
- Ultrafast laser applications in material processing and characterization (under the Academy's bilateral agreements with National Institute for Lasers Plasma and Radiation Physics, RAS, Romania).
- Laser induced fluorescence analysis for cultural heritage investigation and preservation (funded by NFS MDU 03/79 2012).

INTERNATIONAL COLLABORATION:

The **METAL VAPOUR LASERS,** has international collaborations with:

- ✓ Institute of Fluid-flow Machinery - Polish Academy of Sciences, Gdansk, Poland;
- ✓ Institute for Laser Science – UEC, Chofu-shi, Tokyo, Japan;
- ✓ TU/e, Eindhoven, The Netherlands
- ✓ National Research Tomsk Polytechnic University, Tomsk, Russian Federation
- ✓ National Institute for Lasers Plasma and Radiation Physics, RAS, Romania

TEACHING ACTIVITIES:

Assist. Prof. Ognian Sabotinov is organizing series of introductory courses for medical doctors for work with laser systems.

In 2017 three PhD students were working in the Laboratory under thr supervision of assoc.prof. M.Grozeva and one PhD student was supervised by assoc.prof. K. Temelkov**.**

The young scientists of the Laboratory participated in the traditional XIX Winter Seminar of PhD Students and Young Scientist, as well as in a number of training workshops organised in the frame of INERA project.

Assoc. Prof. Todor Petrov reads lectures on a topic "Ultrafast laser processing" in Technical University – Sofia.

Assoc. Prof. Dr. K. Temelkov gave an invited lecture at 19th Winter Seminar of PhD Students and Young Scientists, December, Koprivshtitsa, Bulgaria, 2017.

MUSEUM
HISTORY OF PHYSICS IN BULGARIA
CURATOR: **Assoc. Prof. Dr. Ganka Kamisheva**
Tel. +359 2 979 58 31, E-mail: gkamish@issp.bas.bg
TOTAL STAFF **1**
RESEARCH SCIENTIST **1**

SCIENTIFIC RESULTS:

Nestor Markov and his role for education on physics and mathematics in Bulgarian schools [1] and for creation Bulgarian physical terminology in the 19th century are investigated documentary in 2017 [2].

Scientific results of Prof. Dr. Elisabeth Kara-Mihailova in experimental centers for radioactive research of Vienna and Cambridge in the first half of the 20th century are analyzed. The hypothesis for her discovery in 1927 is introduced [3].

A hypothesis was made, that creativity needs of positive emotional atmosphere to be productive. When democracy replaced dictatorship in Bulgaria, scientists have fallen into a hostile emotional environment. Historical reason about that is confrontation between three ancient cultures touching each other on the Balkans. Every one has its own language, religion and alphabet. On the other hand, we have emotional nature, which is reflected on the Bulgarian language. An elementary example for that is a form of personal address. It expresses the emotional attitude of the speaker. Personal address may be positive or negative, but never neutral. When we have positive attitude towards someone, we say, “Ganke, Dimanke (Dimanche), Petrunke”. When the attitude is negative, the address sounds otherwise: “Gano, Dimano, Petruno”. Achievement a favorable emotional atmosphere would be possible if there is rules about community relations [4].

During the year 2017, documents about School on condensed matter physics and Jordan Kasabov have been used in the Museum. Georgi Nadjakov’s exhibition was visited by V. Vitkov, D. Georgiev, Lubomir, Delyan and R. O'Shea. Ten donations were received from Dr. Stoyko Neov (INRNE), Assoc. Prof. Dr. Nina Bogdanova (INRNE), Dr. Malina Baeva, Prof. Elena Nazarova (ISSP), Prof. Kiril Blagoev, Maria Mladenova, Prof. Svetoslav Markov, Prof. Stilian Kalitzin, Alexander Karastoyanov, and Iskren Azmanov. Proceedings of the Third Congress of Physics historical section was published in electronic and hard copy.

PUBLICATIONS:

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2. Г. Камишева, Ролята на Нестор Марков за създаването на българска физическа терминология. – Нестор Марков и неговият принос в лексикографията и образованието, доклади от Юбилейна научна сесия по случай 180 години от рождението на Нестор Марков, съставител Диана Благоева (2017) 63-76.
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