

Summaries of All Articles

V. V. Alzoba, A. Yu. Kuazin, Yu. V. Larionov, A. V. Rakov, P. A. Todua, M. N. Fillippov

Analysis of the probe characteristics-conditioned methodical error of object's geometric parameters measurements in SEM by the probe defocusing method

The methodological error of object's geometrical parameters measurement using the SEM electron probe defocusing method is estimated. This error is caused by the dependence of the measurement result on the parameters of the probe. It is shown that this error can be reduced by choosing the optimal parameters of the probe, in which the actual measurement conditions best correspond to the requirements of the theoretical model. As a result, the value of the methodical error is reduced to the level random error of measurements (5–10 nm).

Key words: scanning electron microscope (SEM), defocusing method.

A. S. Baturin, A. A. Kuzin, A. S. Leychenko, D. V. Negrov, P. A. Starikov

Localized synthesis method for highly oriented carbon nanotubes in vacuum microelectronics application

The problem of area-selective highly oriented carbon nanotube plasma enhanced chemical vapor deposition synthesis is studied. Nanotube array characteristics dependences on growth parameters are analyzed. Local field emission characteristics are studied. Functioning of a field emission diode with synthesized nanotubes is analyzed.

Key words: carbon nanomaterials, nanotubes, field emission, chemical vapor deposition, directed growth, nickel catalyzer, field emission probing, planar cathode.

D. S. Bodunov, M. A. Danilova, V. A. Kalnov, A. Y. Kuzin, V. B. Mityukhlyayev, A. A. Orlikovsky, A. V. Rakov, P. A. Todua, M. N. Fillippov

Experimental studies of the electron ray defocusing method in nanosize objects geometric parameters measurements in the low voltage mode of a scanning electron microscope

We measure the linear sizes of a nanorelief element with trapezoid profile using a scanning electron microscope (SEM) working at accelerating voltage 800 V by the electron ray defocusing method. It is shown that a signal in the secondary electrons can be represented as a piecewise linear function with characteristic break points. It is found that the distance between the extrema and points of the beginning of signal increase depends linearly on the effective diameter, a SEM electron ray. The extrapolation of the straight lines on $=0$ allows us to determine the values of the sizes of the upper and lower bases of the above nanorelief element and the mean value of the projection of the side wall of the element.

T. M. Borisova, R. A. Kastro

Study of dielectric properties of thin aluminium oxide layers grown by atomic layer deposition

Dielectric properties of MIS-structures based on aluminium oxide layers obtained by atomic layer deposition (ALD) are experimentally investigated for the first time. The value of dielectric parameters for Al_2O_3 layers of two thicknesses is determined. It is found that the dielectric relaxation in studied structures is defined by the contribution of dipole and interfacial polarization. The temperature and frequency dependence of conductivity indicates the existence of thermally activated hopping mechanism of charge transport with activation energy $\Delta E = (0,15-0,30 \pm 0,01) \text{ eV}$.

Key words: MIS-structure, Al_2O_3 , polarization, dielectric parameters.

A. L. Vasiliev, V. P. Gavrilenko, M. V. Kovalchuk, V. B. Mityukhlyayev, Y. V. Ozerin, A. V. Rakov, V. V. Roddatis, P. A. Todua, M. N. Filippov

Transmission electron microscope calibration by relief structures cross-sections

We propose a new type of reference material as a magnification standard of a transmission electron microscope (TEM) and a scanning transmission electron microscope. The reference material represents a thin cross-section of a silicon relief structure with certified sizes of its elements. It is fabricated using ion milling. This reference material can be used for high microscope magnifications (by direct observation of the lattice), as well as for moderate magnifications (about 30000 times).

Key words: electron microscopy, magnification standard, relief structures.

A. V. Golovanov, V. S. Bormashov, A. P. Volkov, S. A. Tarelkin, B. S. Gennad'evich, V. D. Blank

Reactive ion etching of the synthetic diamond surface

The reactive ion etching of a synthetic polycrystalline diamond film and synthetic monocrystalline diamonds in plasmas based on Ar, O₂, their mixtures, and SF₆ is performed. In plasmas based on Ar/O₂ mixture and SF₆ etching the rates of 6 nm/min and 70 nm/min respectively are achieved. The selectivities for aluminum are respectively 10 and 4. Etching in Ar/O₂ based plasma leads to smoothing the polycrystalline diamond film and monocrystalline diamond surfaces. Etching in SF₆ based plasma leads to an increase in the roughness of the monocrystalline diamond surface and the erosion of the aluminum mask.

Key words: reactive ion etching, synthetic monocrystalline diamond, polycrystalline diamond film, postmechanical polishing, atomic force microscopy, electron microscopy.

I. V. Ekhmenina, E. P. Sheshin

Investigation of the influence of various factors on the cathodoluminescence efficiency for creating a competitive field-emission light source

This paper describes the main factors determining the efficiency of phosphors lamps based on field emission as a whole. These include the conditions of phosphors excitation by an electron beam, the chemical composition of phosphors, and the features of the processes of luminescent screens manufacture.

Key words: field emission, phosphor, radiation, efficiency, lamp.

S. V. Zaharchenko, A. S. Baturin

Approach to an approximate solution to the multifrequency acoustooptic interaction problem

An approximate solution to the system of classical coupled-wave equations that governs acoustooptic diffraction with multiple acoustic waves at different frequencies is developed.

Key words: multifrequency acoustooptic diffraction, coupled-wave equations, Bragg mode, acoustooptics.

A. A. Kolesnikov, Y. E. Lozovik

Graphene photonic crystal

A novel type of photonic crystal formed by embedding a periodic array of constituent stacks of alternating graphene and dielectric discs into a background dielectric medium is proposed. The photonic band structure and transmittance of this photonic crystal are calculated. The graphene-based photonic crystals can be used effectively as frequency filters and waveguides for the far infrared region of electromagnetic spectrum. Due to the substantial suppression of absorption of low-frequency radiation in doped graphene the damping and the skin effect in the photonic crystal are also suppressed. The advantages of the graphene-based photonic crystal are discussed. Key words: grapheme, photonic crystal, FDTD, band structure.

Key words: grapheme, photonic crystal, FDTD, band structure.

I. G. Lyakhov, A. A. Kuzmin, A. S. Ilin, M. A. Ermakova, K. V. Bulakh

Investigation of magnetron sputtering regimes of titanium thin films for cryogenic detectors

We report the investigation of titanium thin films obtained in various regimes of magnetron sputtering on a silicon substrate by means of electrical measurements at $T = 300$ K and 77 K, atomic force microscopy (AFM) and X-ray diffractometry (XRD). It is shown how the residual resistivity of the films (and the critical superconducting transition temperature T_c) depends on the parameters of deposition. The data is compared with measurements on the AFM and XRD.

Key words: superconducting bolometers, transition edge sensors, superconducting titanium thin films, express method for estimating the critical temperature, X-ray diffractometry.

N.N. Mikheev, Stepovich M.A., Todua P.A., Filippov M.N., Shirokova E.V.

Estimation of an absorption correction factor in electron probe microanalysis

The estimation method of an absorption correction factor with the new $\varphi(\rho z)$ -function for electron probe microanalysis is proposed.

Key words: electron probe microanalysis, absorption correction factor, $\varphi(\rho z)$ -function.

A. A. Petrov, R. H. Amirov, E. V. Korostylev, I. S. Samoylov

Cathode erosion in the negative corona discharge

A negative corona discharge is investigated in a Trichel pulse and a pulseless mode in the point-to-plane electrode configuration. Cathodes made of copper, graphite, tungsten, aluminum and silver are used. Stable, unstable, and stochastic regimes of Trichel pulses are found. The formation of erosion craters with typical size 40–100 nm is found on the cathode surface. This process is explained in terms of electro-explosive mechanism. The partial redeposition of erosion products is found for copper and silver in nanocrystalline form on the cathode surface.

Key words: corona discharge, Trichel pulses, cathode erosion, redeposition, nanocrystals.

K. I. Agladze, V. V. Lebedev, M. R. Trunin

On Biophysics Excitable Systems Laboratory in MIPT

We discuss the development strategy for experimental biophysics lab excitable systems research and the education center «Bionanofizika» organized by MIPT after the first megagrant contest. The results of two years work of the laboratory demonstrate the achievement of the main megagrant goal – the modern biophysical laboratory equipped with the latest technology in MIPT. A brief introduction to the series of laboratory articles published in the current issue of the journal «Proceedings of MIPT» is given.

Key words: Peter and Paul Fortress, stem cells, tissue engineering, incredible, photokontrol.

K. V. Barskov, I. S. Erofeev, K. I. Agladze

Effect of AzoTAB on phototaxis in *Planaria torva*

This paper is devoted to the effect of an azobenzol derivative with photocontrolable structure (AzoTAB) on the motion of flatworms *Planaria torva*. Trans-AzoTAB efficiently inhibits ion channels in excitable cell membrane, neurons and cardiomyocytes, while cis-AzoTAB does not. In the current research we study how the presence of AzoTAB isomers controls the simplest behaviour of pluricellular organisms with the rudiments of differentiated nervous system like planaria. We also study the trajectories of planaria which are illuminated with visible and UV light in the medium with AzoTAB of various concentrations. In addition, we measure the velocities of planaria positive and negative phototaxis in the media containing AzoTAB isomers. We demonstrate that the inhibitory effect of the AzoTAB on planaria motion under the UV light is reversible.

Key words: AzoTAB, *Planaria torva*, photocontrol, phototaxis.

O. V. Galaydych, I. S. Erofeev, K. I. Agladze

Optical mapping of excitation waves in the light-sensitive immortalised cell line of cardiomyocytes

This paper demonstrates the investigation of the properties of spiral waves that occur in the immortalised excitable cell line HL-1 transfected with light-sensitive ion channel ChR2-YFP. Due to light-induced modulation of excitability, we succeed in demonstrating the induced shift of the spiral wave core and its wave front discontinuity with subsequent formation of two more spiral waves. Besides, cell culture electrode stimulation demonstrates spiral wave displacement to the boundary by circular excitation higher frequency waves. Also, this method demonstrates the circular waves fronts discontinuity on the homogeneous area of a culture monolayer at frequencies higher than the critical one.

Key words: optical mapping, spiral waves, cell culture, channelrhodopsin-2.

I. I. Goryanin, V. Y. Kotova, E. D. Krasnopeeva, P. A. Chubukov, V. P. Balabanov, S. F. Chalkin, T. Y. Shatrov, G. B. Zavilgelsky, I. V. Manukhov

Genotoxic action of the 1,1-dimethylhydrazine determined by alkylating compounds appearing in the result of oxidation and hydrogen peroxide.

Mechanisms of 1,1-dimethylhydrazine (unsymmetrical dimethylhydrazine (UDMH)) toxic action on living systems on the example of a bacterial cell with lux genes-based biosensors are studied. In the present work, hybrid plasmids with bacterial luciferase reporter genes luxCDABE controlled by the stress-inducible promoters are constructed. Cells of *Escherichia coli* containing these hybrid plasmids are called lux biosensors. Using the obtained lux biosensors that specifically detect oxidative stress, DNA and protein damage, it is shown that PkatG, PcolD (or PrecA) and PalkA are the main promoters induced in response to the UDMH action on the bacterial cells. The activation of PkatG, PcolD promoters in the presence of UDMH is triggered by hydrogen peroxide formed from the reduction of atmospheric oxygen. We demonstrate that the induction of the lux -biosensor *E. coli* MG1655(pAlkA-lux) starts with the appearance of products of incomplete oxidation of UDMH (particularly N-Nitrosodimethylamine), which are strong mutagens similar, in a degree of genotoxicity, to nitrosourea and N-Methyl-N'-nitro-N-nitrosoguanidine.

Key words: biosensor, plasmid, luciferase, promoter, UDMH.

S. R. Ismayilova, K. A. Motovilov, L. S. Yaguzhinsky, K. I. Agladze

Interaction between mitochondrial oxidative phosphorylation chain and a cationic derivative of azobenzene with photocontrollable structure

AzoTAB is a derivative of azobenzene containing tetraalkylammoniumcation. This compound can be used as an agent for photocontrol of cardiac cells excitability. Since the use of the substance is very perspective for a wide class of applications related to excitable cell cultures, we are interested in the study of the action of AzoTAB on the respiration chain of mitochondria, because the maintenance of normal homeostasis of excitable cells systems is directly connected with their energy state. It is demonstrated that trans-AzoTAB is an inhibitor of the mitochondrial respiratory chain which blocks both dehydrogenases- complex I and complex II. The affinity of trans-AzoTAB to NADHdehydrogenase is greater than the affinity to succinate dehydrogenase. This result completely corresponds to the theoretical preliminary expectations made in previous studies. The degree of respiration inhibition by trans-AzoTAB depends on which of dehydrogenases is the main electron supplier of the chain. But there is no difference between uncoupled and phosphorylating respirations. This is the evidence that trans-AzoTAB under experimental conditions (concentration 50-500 mkM) does not affect ATP-synthase activity. Also, it is demonstrated that cis-AzoTAB does not inhibit the respiratory chain. It increases uncoupled respiration (not phosphorylating) for both of substrates. We may interpret this phenomenon in two ways. First, cis-AzoTAB may be able to increase the lateral transfer of membrane bound protons which directly take part in the ATP synthesis by complex V. Second, the presence of cis-AzoTAB may cause mitochondrial swelling, which also leads to an increase in respiration rate in the third state.

Key words: AzoTAB, mitochondrial respiratory chain, NADH-dehydrogenase, succinate dehydrogenase, mitochondria.

T. N. Murugova, O. I. Ivankov, N. K. Ossina, A. K. Islamov, A. I. Kuklin, K. I. Agladze

Small angle neutron scattering study of micelle formation by azobenzene trimethylammonium bromide

The micelles formation by light sensitive surfactant azobenzenetrimethylammoniumbromide (AzoTAB) is studied by small angle neutron scattering. The concentration and temperature effects on AzoTABmicellization are investigated. The influence of UV irradiation is observed as well.

Key words: small angle scattering, micelle formation, AzoTAB.

L. V. Selina, K. A. Motovilov, L. S. Yaguzhinsky, K. I. Agladze

Restoring of primary cultures contractile activity of rat cardiomyocytes suppressed by mitochondrial inhibitors NADH-dehydrogenase under the influence of hydrophilic quinones

In this study, we first demonstrate by an optical mapping technique that the contractile activity of primal neonatal cardiac cell culture, blocked by inhibitors of respiratory complex I rotenone and piericidine, can be regenerated by duroquinone and menadione (vitamin K3). It is known that NAD(P)H:oxidoreductase type I (NQO1,DT-diaphorase) belongs to that kind of enzymes which can be overexpressed under toxic impact. Until 2000, however, it was believed that in cardiomyocytes, due to the nature of their energetics, the active expression of NQO1 does not take place. We first show here that the path of electron transfer in the respiratory chain activated by NQO1, among other things, can be used to maintain the contractile activity of cardiomyocytes.

Key words: primary culture of cardiomyocytes, inhibitors of mitochondrial respiratory chain, optical mapping, rotenone, piericidin, durohinon, NQO1.

A. S. Teplenin, L. V. Eroshenko, I. S. Erofeev, K. I. Agladze

Usage of polymer nanofibers for investigation of immortalized cells structural anisotropy

HL-1 cells are immortalized adult atrial myocytes which beat spontaneously and express the main cardiac-specific proteins. The current cells transfected with photosensible ion channels, channelrodopsin, are stimulated with 480 nm laser. In this work, HL-1 cells are cultured on a nanofibrous substrate, which allows us to control the morphology of myocytes and anisotropy of excitation wave propagation. Using the optical mapping technique, we study the behaviour, characteristics and interactions of spiral waves in created anisotropic media.

Key words: optical mapping, cell culture, nanofibrous substrate, channelrodopsin-2, spiral waves.

S. A. Belan, S. S. Vergeles, P. E. Vorobev

The hybrid plasmonic waveguide

The hybrid plasmonic waveguide consists of a high-permittivity dielectric nanofiber embedded in a low-permittivity dielectric near a metal surface. This architecture is considered as one of the most perspective candidates for long-range subwavelength guiding. The dispersion relation of the fundamental mode of hybrid waveguide is obtained analytically within the quasi-electrostatic approximation. For the first time, to our knowledge, the infinite set of linear algebraic equations for solving the eigenmodes problem in such geometry in general is explicitly written. The numerical solution based on this approach is obtained and discussed. Our qualitative analysis and numerical results reveal advantages of the special waveguide design when dielectric constant of the cylinder is greater than the absolute value of the dielectric constant of the metal.

Key words: subwavelength guiding, plasmonic waveguide.

Y. Y. Broslavets, M. A. Georgieva, A. A. Fomitchev

Features of ultrashort pulse generation in a ring mode-locked YAG:Cr⁴⁺ laser

We simulate femtosecond pulse formation in the laser cavity taking into account the material dispersion, frequency self-modulation on the Kerr-type nonlinearity, loss modulation in the system, including a Kerr lens and an aperture. Kerr-lens mode locking is achieved in a ring bidirectional YAG:Cr⁴⁺ laser with broadband amplification line. We determine the optimum dispersion value for pulse duration minimization and study the problem of application of the ring Kerr-lens mode-locked laser for rotation sensing.

Key words: solid-state ring laser, mode locking, femtosecond pulses, broadband media, laser gyro.

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V. N. Yufa*

Crater formation in multicomponent polycrystalline targets under the action of a high-power laser

The formation of craters in multicomponent polycrystalline (andesite) targets and aluminium under the action of a high-power laser pulse with intensity 10^{12} – 10^{13} W/cm² and wavelength 1,054 μ m is studied experimentally on Nd laser facility Saturn. For aluminum, the craters parameters conform satisfactorily to theoretical estimates based on the model of transformation of laser energy into shock wave energy in the ablation process on the target surface in the hydrodynamic interaction regime. For andesite targets, the calculated value is twice larger than the experimental one, which could be explained by andesite targets porosity.

Key words: laser simulation of shock process, plasma torch, shock wave, laser ablation, hypervelocity micrometeorite impact.