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Abstracts & Schedule

ABSTRACTS

AUTOCATALYTIC GROWTH OF WHISKERS ON GAAS(100) BY MBE

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GaAs low-dimensional structures, such as whiskers have attracted more and more intense interest and as objects of basic research and as advanced materials to create devices with new operational capabilities. Greatest interest to the whiskers began with the emergence and development of epitaxial growth techniques. The method of molecular beam epitaxy (MBE) allows one to obtain arrays of whiskers with high crystallographic perfection. Ultra-high vacuum and control the flow, morphology and structure directly in the growth make MBE method an indispensable tool for the study of the formation of whiskers.

In this article, for forming nanostructures was used module of molecular-beam epitaxy A3B5 (SemiTEq), part of the multifunctional ultrahigh vacuum nanotechnology complex NANOFAB NTK-9 (NT-MDT).

In the framework GaAs whiskers have been obtain. Whiskers formed on GaAs (100) substrate by autocatalytic method, by epitaxy growth of gallium arsenide under standard conditions at a substrate temperature 580 °C. Effective thickness of the epitaxial layer was 200 nm.

Investigations by raster electron microscopy (REM) were carried out on electron microscope NOVA NANOLAB. Research of the NWs by methods of REM showed that the NWs are uniformly distributed over the surface of the sample with density of 4×10^{8} cm^{-2}. Length of whiskers is equal 4 – 6 μm. Diameter of the cross section short whisker is 80 – 90 nm, otherwise long is 90 – 100 nm. Aspect ratio was in the range of 40 – 50. The average ratio of the whiskers to the effective thickness of the deposition was 20. Estimates of the rate of growth of whiskers gives the values of 20 – 30 monolayer/s. NWs were oriented under 42-degree angle to the surface, which corresponds to the maximum packing density in the crystallographic direction (111) in bulk material, and it is in good agreement with literature data. All whiskers are focused primarily in the [110] and [1$\bar{1}$0] in the plane of the substrate.

Obtained nanowhiskers open wide range of application in optoelectronic, microelectronic, nanomechanics, and nanobiotechnology. Based on the whiskers can create field-effect transistor and geterobipolar transistor, light-emitting device with low power consumption, various types of sensors, probes for atomic force microscopes, field emission cathodes, tunnel diodes, single electron transistors, single-photon emitters, and so on. Autocatalytic growth of whiskers allows one to avoid unintentional doping of whisker structures by material of catalytic centers and greatly simplifies the technology of their production.

DETERMINATION OF YOUNG'S MODULUS OF GALLIUM ARSENIDE WHISKERS BY ATOMIC FORCE MICROSCOPY

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The class of semiconductor whiskers, in particular gallium arsenide ones, is a promising material for formation of the new instruments and devices of micro- and nanoelectronics, micro- and nanoelectronic technology and provides a wide range for future applications (CMOS-chips, sensors, cathodes, etc.).

The operation of devices based on the whiskers (flexible displays, the atomic force microscopy probes, etc.) is often associated with conditions of high local loads and bending deformations. This fact causes an increased interest in studying the mechanical properties of such structures. Therefore, an urgent task of modern science is the research of the whiskers mechanical properties.

The aim of the work is to determine the Young's modulus of GaAs whiskers by atomic force microscopy (AFM).

A forest of the oriented under angle to the substrate surface GaAs whiskers deposited by the molecular beam epitaxy method on the multifunctional nanotechnology complex NANOFAB NTC-9 ("NT-MDT", Russia) was used as an experimental sample.

The mechanical properties of the sample were studied by using probe nanolaboratory Ntegra ("NT-MDT", Russia) by the AFM force spectroscopy method. A silicon cantilever NSG 20 was used as the probe.

The values of Young's modulus for GaAs whiskers with various geometrical parameters have been determined on the base of the beam theory, according to which the GaAs whisker can be regarded as an elastic beam fixed at one end, and of the experimental dependences obtained by the AFM force spectroscopy method. We have found that the Young's modulus of the GaAs whiskers depends on their geometrical parameters in contrast to the GaAs bulk material. So the Young's modulus of the GaAs whiskers increases from 33.21 GPa to 143.4 GPa at increase of the aspect ratio of whiskers from 10 : 1 to 27 : 1, i.e. in more than 4 times. The observed dependence may be associated with a rise in the ratio of the area of GaAs whisker to its volume and with the increased influence of surface tension.

The results of the work show that the Young's modulus of GaAs whiskers greatly depends on their geometric parameters and is greater than the elasticity of the GaAs bulk material at the aspect ratio of GaAs whisker more than 17 : 1. The obtained data can be used to develop the technological processes of formation of nano- and microelectronics, nano- and microsystem technology structures.

NOVEL NO_2, NH_3, CH_4 GAS SENSOR BASED ON NANOCRYSTALLINE ZNO AND VO_x FILMS

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Multisensory systems based on nanocrystal films of metal oxides provide the selectivity and significantly extend the range of detectable gases. Creation of the systems is challenging to solve a wide range of problems of the gas phase composition determining.

The sensors based on nanocrystalline films of ZnO and VO_x were created and their sensitivity was investigated to NH_3, NO_2 and CH_4.

Formation of nanocrystalline films was carried out on the basis of UHV cluster for nanolocal techniques of multifunctional nanotechnology facility NANOFAB NTF-9 (NT-MDT Co., Russia) using pulsed laser deposition module, scanning probe microscopy, and Auto 500 vacuum coating system (BOC Edwards, UK).

The gas sensor prototypes were created (Fig. 1), and sensitivity of the sensors was investigated (see, e.g. Fig. 2). Relative sensitivity to 10 ppm NO_2 was 400 % at 20 °C, to 10 ppm NH_3 was 200 % at 20 °C, to 50 ppm CH_4 was 150 % at 20 °C.

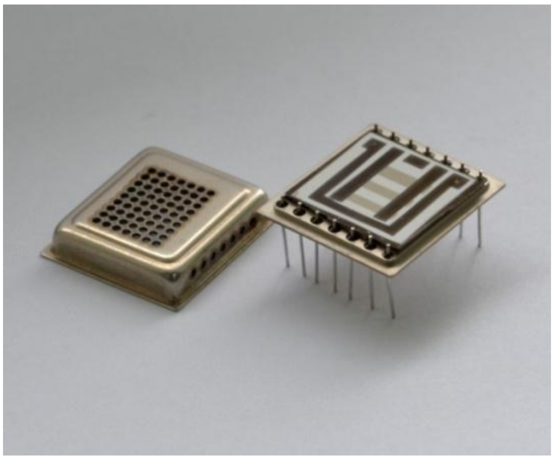

Fig. 1. Gas sensor prototype

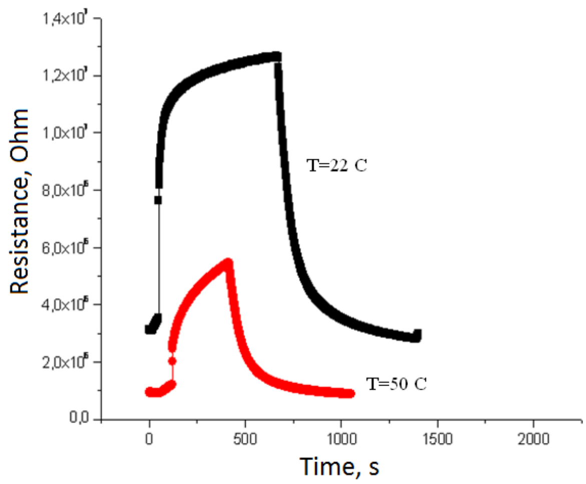

Fig. 2. Sensitivity of the nanocrystalline ZnO film sensor to 10 ppm NO_2 at different working temperatures

The obtained results show prospective of using nanocrystalline ZnO and VO_x films for gas sensor fabrication, and can be used for design and technology development of environmental monitoring and microelectromechanical systems and their elements.

Growth Horizontal-Aligned ZnO Nanowires by Pulsed Laser Deposition

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One of the most important issues of modern science is growth of one-dimensional horizontal-aligned nanostructures. Sometimes these structures grow vertical-aligned, but usually nanostructures grow not oriented. Today, any reports about synthesis of horizontal-aligned ZnO nanowires lack. Therefore developing a technology of synthesis of the horizontal-aligned ZnO nanowires is the actual problem.

Experimental investigation has been made in pulsed laser deposition module of NANOFAB NTF-9 complex (NT-MDT Co., Russia). Surface morphology and texture of nanowires have been analyzed with probe nanolaboratory NTEGRA Vita (NT-MDT Co., Russia) and scanning electron microscope with ionic column Nova Nanolab 600 (FEI Co., Netherlands).

First of all Ni catalytic center for growth nanowires has been formed (Fig.1.). Further horizontal-aligned ZnO nanowires have been grown. Energy density of laser radiation on ZnO target surface was 2 J/cm^2, the laser wavelength was 248 nm, number of pulses was 30000, and pulse duration was 20 ns. Growth occurred in an atmosphere O_2 under pressure 2 Torr. Fig.2 show horizontal-aligned ZnO nanowires.

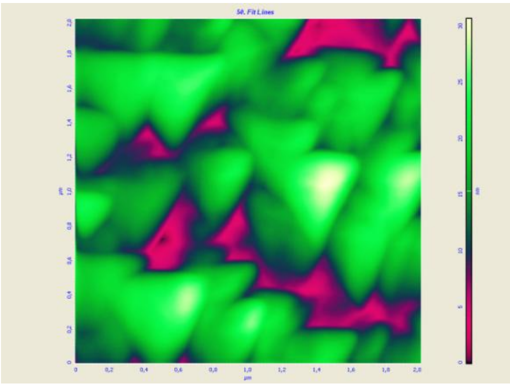

Fig.1. AFM image of Ni catalytic center for growth ZnO nanowires

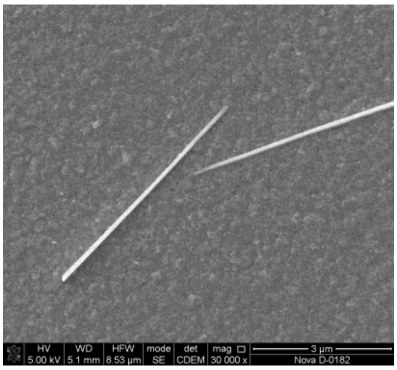

Fig.2. SEM image of horizontal-aligned ZnO nanowires

These nanowires are horizontal-aligned with a length of 5 μm and diameter of 5 nm. So, the technology of growth horizontal-aligned ZnO nanowires has been created.

The obtained results may be used to develop a technology for production of sensitive elements of the sensors, optoelectronic devices, interconnection of integrated circuits, etc.

The Analytical Solution of Axisymmetric Contact Problems for the Coatings of Complicated Structure

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We suggest the new effective method of construction of analytical approximations of kernels' transforms of the dual integral equations of contact problems for inhomogeneous media by the functions of a special kind. On the basis of transforms' approximation of high accuracy, analytical solutions of contact problems for materials with coatings of complicated structure are constructed. The method is dual-sided asymptotically exact and allows receiving the approximated solution of contact problems, effective for coatings of any thickness.

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Theoretical and Experimental Investigations of Cantilever Type Piezoelectric Generators

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Today, the problem of R&D piezoelectric generators (PG) for different applications is not solved in required form due to low energetic effectiveness of PG and small output power existing test samples. One of the most problems is search of optimal parameters of sensitive element (SE) of PG, ensuring maximal output power. In the result of computer and experimental analyses of electric physical parameters of the cantilever type piezoelectric generator, there have been calculated and supported by experiments optimal characteristics of PG with original construction allowing attainment of its output power which has been sufficient for charging accumulators of thin devices of mobile and radio-communication disposed, in first order in hard places for replacement of the accumulators.

In order to search and statement of correlation relationships and connections between electric physical, mechanical and geometrical parameters of the considered PG model and its output electric power into wide ranges of eigen-frequencies of the PG oscillations and impedance of its sensitive element, it has been conducted computer simulation into software Comsol Multiphysics. At the first stage of the study, the modal analysis of the system has been carried out, which calculated eigen-frequencies of first three modes of the bending oscillations of consol beam into plane of the least stiffness. In natural experiments conducted by using original experiment device, it has been stated significant dependence of electrical power, returned by the piezotransducer in electric load, on value of the load.

(a) **(b)** **(c)**

Fig. 1. Cantilever type PG working on bending oscillations: (a) picture without frame cup, (b) collected cantilever module, and (c) sensitive element of PG

The calculation results of optimal impedance of the load for first four eigen-frequencies of the cantilever bending oscillations showed that with growth of the eigen-frequency the magnitude of the optimal impedance of the load decreased very significantly. For example, at oscillations on frequency of first mode (~ 15 Hz) the value of optimal impedance was some units of MOhm; at the same time, the optimal impedance was ~ 500 – 600 kOhm on second mode at frequency of ~ 80 Hz. The calculations showed also that maximum of output electric power of PG with the considered configuration can be reached at the oscillations on third mode of the bending oscillations; in this case in original electric scheme of PG, the electric resistance of load should be of order 180 – 200 kOhm. Figure 1 presents test sample of compact cantilever type PG (the frame sizes are 45 × 30 mm^2) providing maximal output voltage of 5.8 V, and electric power of 0.55 mW. This PG could be applied for autonomic devices of charging accumulators of sensor control system of gas parameters on supply pipes, diagnostics of technical state of high-rise buildings, etc.

The work is executed with financial support of grants of the RFBR No. 10-08-13300-RT_omi, 10-08-00093, 10-08-00136.

MATERIALS FOR LOW-FREQUENCY APPLICATIONS BASED ON THE SYSTEM (NA, K, $CD_{0.5}$)NBO_3

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Ferroelectric materials are widely used in electronic equipment (piezoelectric transmitters, pyroelectric infrared sensors and microwave telecommunication devices). However, the basis of the overwhelming majority of piezoelectric ceramic materials is based on a system of lead zirconate titanate [1]. Released and the group of materials that does not contain lead, based on sodium niobate-lithium, which have unique properties: extremely low dielectric constant (< 100), high speed of sound (V_R ≈ 6 km/s), at a wide range of mechanical quality factor (from a few to thousands units) and low specific weight (< 4.5 g/cm^3). But, despite these properties, these materials have occupied only a narrow segment of piezotechnique, namely applications in microwave technology. The today problem is an extension of areas of possible applications of these materials, up to the use of the devices employed in power modes-piezotransformers, piezoengines, ultrasonic emitters, high-voltage generators, etc., for which are required the materials with high relative dielectric constant and mechanical quality factor at sufficient piezoelectric responses. Solid solutions (SS) of (Na, K) NbO_3 [1] have the closest properties to the target, which are selected as a base. In order to expand the range of properties based on its SS three-component system was constructed.

The objects of the present study were selected multicomponent SS on the basis of ternary system $(1-x-y)NaNbO_3 – xKNbO_3 – yCd_{0.5}NbO_3$, that researched by the seven sections. Synthesis of SS was carried out by solid-state method. Sintering was carried out by the common ceramic technology (solid-phase synthesis without using of hot pressing): $T_{sint.}$ = (1400 – 1510) K (depending on composition) for (1 – 2.5) hours.

The four groups of SS with perspective parameters for practical applications were assigned:
- with $2000 < \varepsilon_{33}^T/\varepsilon_0 < 2250$ for applications in the mid-range;
- with $\varepsilon_{33}^T/\varepsilon_0 < 700$, $K_P \sim 0.40$, $V_1^E > 5.0$ km/s for applications in microwave devices;
- with $\varepsilon_{33}^T/\varepsilon_0 = 500 – 700$, $g_{33} \sim 30$ mV·m/h for use in highly sensitive accelerometers, ultrasonic flaw detectors;
- with $Q_M \approx 1000$, $K_P \approx 0.20$ for applications in devices operating in power mode.

The obtained results are useful when designing devices of piezotechnique for various applications.

This work was financially supported by the Ministry of Education and Science of the Russian Federation, State Ccontract № 16.513.11.3032.

References

[1]. B. Jaffe, W.R. Cook, H. Jaffe. *Piezoelectric Ceramics*. R.A.N. Publishers: Marietta, OH, USA, 1971. 317 p.

THE FORMATION OF A CERAMIC FRAME AND GRAIN STRUCTURE OF PZT SOLID SOLUTIONS

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The use of PZT- based ceramics the basis for which is solid solutions (SS) of the binary $Pb(Ti_xZr_{1-x})O_3$-system in the piezotechnique remains actual up to now. Most of industrial functional ferro-piezoelectric ceramic materials (FPCM) are based on such SS. Taking account of the fact that the properties of such FPCM are mainly, determined by the crystal structure (being formed at T = 873 – 1073 K), microstructure (being formed at T = 1073 – 1373 K, that is, against a background of the already existing structural motive) and the ceramic sintered body, it is advisable to ascertain the dynamics of changing the latter and the size of crystallites over the complete interval of solubility of the system components. This seems to be reasonable from the point of view of establishing a correlation between the phase and grain structures of SS as well as the possibility of governing the ceramic microstructure by varying the ratio of components, that is, the SS position on the phase diagram of the system.

The objects for studying were SS having a composition of the formula $(1-x)PbZrO_3 – xPbTiO_3$ ($0.0 \le x \le 1.0$). In the range $0.0 \le x \le 0.12$, $0.30 \le x \le 0.36$, $0.37 \le x \le 0.42$ and $0.52 \le x \le 0.57$ a concentration step Δx was 0.01; in the range of $0.37 < x \le 0.52$ and $0.60 < x < 0.90$ it was 0.005 and 0.005. The SS samples were prepared according to the conventional ceramic technology (solid-phase synthesis without using hot pressing).

The lower density values are peculiar to the end components of the system, which is connected with their crystallochemical peculiarities (a practical absence of vacancies in the structure and a thermal instability of $PbZrO_3$, and the strong mechanical stresses in $PbTiO_3$ because of a large magnitude and anisotropy of deformation of the crystallites, leading to its self-destruction.

The non-monotonic change in density ($\rho_{meas.}$) with the maxima at certain values of x is related to localization of the vacancy-saturated morphotropic regions (R → Rh, Rh → T) and the region of the diffuse R3c → R3m phase transition inside which there arise the favorable conditions for diffusion and mass transfer in the process of synthesis and sintering.

A spreading $\rho_{meas.}$values of the Rh region is related to the large number of structural rearrangement in this concentration range.

The microstructure of the ceramics of SS is a fairly homogeneous, mosaic and sufficiently close packed isometric crystallites of 3 – 11 μm in section but there is some special features due to the component and phase composition of the objects: (i) the formation of sphere-like structures in the form of clusters "pore-single- (or multi-) layer grain shell", "chains" of extremely small grains fields of abnormal grain growth, etc., and (ii) the non-monotonic change in $\bar{D}$ similar to the $\rho_{meas.}(x)$ relation.

This work was financially supported by the Ministry of Education and Science of the Russian Federation, State Contract № 16.513.11.3032.

RAMAN SCATTERING AND X-RAY DIFFRACTION STUDIES OF MULTILAYERED STRUCTURES AND SUPERLATTICE BASED ON BARIUM-STRONTIUM TITANATE AND BISMUTH FERRITE

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We present experimental results on the multilayer ferroelectric - multiferroic structures $(Bi_{0.98}Nd_{0.02})FeO_3$ (BNFO) - $(Ba_{0.8}Sr_{0.2}TiO_3)$ deposited on a substrate (100) MgO by rf sputtering. Each layer thickness varied from 3 to 100 nm. The heterostructures consisted from 3 to 34 alternating layers. X-ray diffraction patterns of heterostructure contain independent Bragg reflections of each constituting layer if their thickness exceeds 40 nm. When the thickness of each deposited layer was about 3-6 nm satellite peaks on X-ray diffraction patterns were observed, implying formation of perfect superlattice structure.

Raman spectroscopy is an effective method of characterization since the structural changes associated with mechanical stresses, have a great influence on the vibrational spectrum. We discussed the transformation of the lines in polarized Raman spectra related to BNFO and BST, depending on the thickness and number of layers. Thickness of BNFO film was varied from 20 to 160 nm, while thickness of the BST buffer layer was always the same, namely 5 nm. In this case, no remarkable frequency changes in the Raman spectra of these BNFO films were found.

Raman spectra of the 5 thick (60-70 nm) multilayers (5ML) contain all main peaks corresponding BST and BNFO. The E(TO) soft mode exhibits upward shift in the spectra of 5ML heterostructure and is overlapped with the lowest mode of BNFO at about 70 cm^{-1}. Apparently, BST layers are clamped in the 5ML heterostructure and upward shift of the soft mode is induced by the compressive stress imposed by neighboring BNFO layers. Moreover, the soft mode is seen in both VV and VH spectra, while in single *c*-domain BST films on MgO no Raman spectrum is usually observed in VH configuration.

Raman spectrum of superlattice consisting of 20 6-nm-thick layers remarkably differs and contains a dominating band at 705 cm^{-1}. This frequency range is usually associated with the symmetrical stretching mode of BO_6 octahedra in perovskites. We assume that lattice distortions of BNFO layers within superlattice produce significantly different Fe-O bond lengths, that is, necessary to produce the change in the polarizability and measurable intensity of the stretching modes.

NANOTECHNOLOGIES IN LOW-COST SOLAR CELLS

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Scientific breakthroughs in solar energy are needed to achieve planned target of 0.3$/Wp, 4TWp cumulative photovoltaic (PV) production in 2030. Thus, to achieve very high photovoltaic (PV) efficiency with low manufacturing cost for the grid-parity target, four thin film nanotechnologies that were compatible with IC processes, were proposed, including (1) a photovoltaic (PV) material system of Si_xGe_{1-x}-Si-Si_yC_{1-y} with multiple bandgaps to improve the utilization efficiency of broadband solar photons [1]; (2) a very dense array of Si-based quantum-dots to yield enhanced UV-to-NIR opto-electronic response and function as the intermediate layer in tandem structure so as to enhance tunneling junction and carrier separation [2]; (3) nanoparticles with light trapping effect to increase the optical path due to their spectacular scattering and plasmonic effect [3]; and (4) anti-reflective ZnO nanowires with large length-to-diameter aspect ratio and high surface-to-volume ratio to enhance light response [4]. In conclusion, we have demonstrated various nanostructures in achieving low-cost photovoltaic devices.

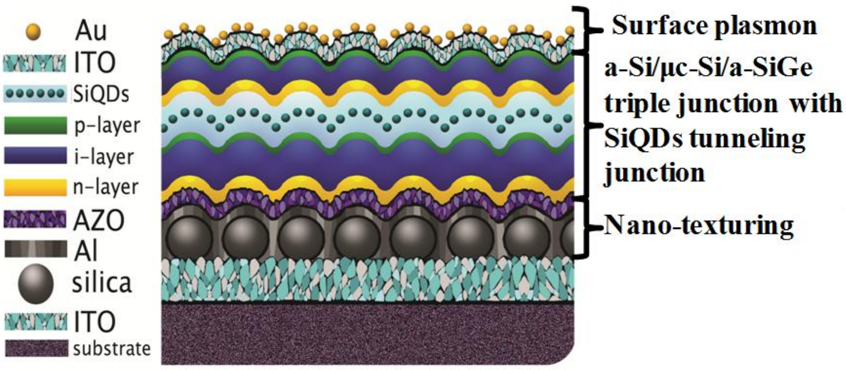

Fig. 1. Schematic diagram showing the cross-sectional structure of third generation Si thin film solar cell

References

[1] Chang-Hong Shen, Jia-Min Shieh*, Jung Y. Huang, Hao-Chung Kuo*, Chih-Wei Hsu, Bau-Tong Dai, Ching-Ting Lee, Ci-Ling Pan, Fu-Liang Yang, Appl. Phys. Lett. **99**, 033510 (2011).

[2] J. Y. Huang, J.-M. Shieh, H.-C. Kuo, C.-L. Pan, Advanced Functional Materials, **19**, 2089–2094 (2009).

[3] Wen-Hsien Huang, Jia-Min Shieh*, Chang-Hong Shen, Jung Y. Huang, Hao-Chung Kuo, Fu-Ming Pan, Chih-Wei Hsu, Bau-Tong Dai, Ching-Ting Lee, Ci-Ling Pan, Fu-Liang Yang, Conference on Laser and Electro Optics 2011, CMCC7, Oral presentation.

[4] Ting-Jen Hsueh*, Siou-Yi Lin, Wen-Yin Weng, Cheng-Liang Hsu, Tsung-Ying Tsai, Bau-Tong Dai, Jia-Min Shieh, Solar Energy Materials and Solar Cells, Vol 98, March 2012, P. 494-498.

Development and Validation of a Neural Network Model for the Gas Sensitive Properties of Ag-containing Polyacrylonitrile Films

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Development of new materials with specific properties is the perspective direction of researches in electronic engineering and technology. In recent years semiconductor gas sensors have found widespread commercial application in gas monitoring. For a prediction of properties the various methods one of which is neural network modeling are used.

Materials which are based on polyacrylonitrile (PAN) with different modifying additives are a basis for creating of effective low-temperature gas sensors. The variation of technological parameters of fabrication the films based on such materials can essentially change their properties.

The neural networks design for prediction of gas-sensing properties of Ag-containing PAN films was carried out. The method of building of neural network model is applied to the analysis of experimental data, by creation of a neural network in the form of double-layer perceptron (Fig.1). Training of a neural network was carried out with use of algorithm of return distribution.

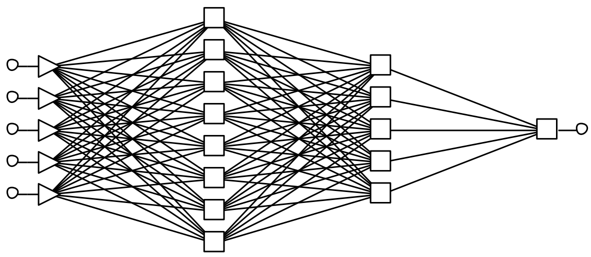

Fig.1. Double-layer perceptron of neural network

Quality of work of an artificial neural network was determined by a root-mean-square error of predicting of values of property on a training sample (s_t), on factor of correlation between predicted and experimental values of property on a training sample of R and a root-mean-square error of a forecast on a control sample of s_v: $s_t = 0.07$; $s_v = 0.11$; $R = 0.927$.

The optimum set of technological parameters for fabricating Ag-containing PAN films with the best values coefficient gas sensitive to NO_2 is established: $\omega(\mathrm{Ag}) = 0.05$ mass. %, $T_{\mathrm{drying}} = 160$ ºC,

t_{drying} = 30 min, $T_{IR\text{-}annealing\ 1\ phase}$ = 200 ºC, $t_{IR\text{-}annealing\ 1\ phase}$ = 2 min, $T_{IR\text{-}annealing\ 2\ phase}$ = 350 ºC, $t_{IR\text{-}annealing\ 2\ phase}$ = 28 min.

NEW APPROACHES TO THE PROBLEM OF INCREASING ACCURACY AND STABILITY OF CRITICAL LOADING OF BURSTING DISCS

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Search of trusty protection frames of the equipment in chemical and a petroleum-refining industry and afterwards in thermal and atomic engineering has resulted to the destroyed shell elements (bursting discs), which are a part of membrane safety devices,. Effectiveness of bursting disks collapse is grounded on an appearance of loss of their stability (buckling) at excess of critical loads.

High sensitivity of critical loads of domed shells to small initial irregularities is known. This factor demands refinement of manufacturing methods of bursting disks for ensuring stability of their critical loads and an exactness of the disk operation under operating conditions.

The new manufacturing methods and trials of dome-shaped membranes with use of the artification methodology have been developed with this aim. The artificial technology provides steered power effects on a forming shell at its manufacture, leading to creation of optimum geometry of a cupola. Artificiation ensures the effective form losses of a stability of the shells, high stability of pressure of wear and feeble sensitivity to stochastic technological irregularities.

The automated computer complex which accompanies a process of manufacture, trial and a nondestructive check of pressure of wear of membranes is developed. An exactness of prediction of the pressure of wear of the diaphragms has been reached to be equal 1 – 3 %, over the range working temperatures 20 – 450 ºC.

The bursting disks made on new production engineering, have transited performance tests of their application at the stand of the A. I. Leipunsky Institute of Physics and Power Engineering. The results of tests of the membranes in regular service conditions have confirmed their correspondence to rigid engineering specifications on an exactness and stabilities of pressure of wear, and also longevity, including under conditions of effect of the sodium heat-transfer agent.

BETA-ANALYSIS

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Within the realization of the program "START" (project 5823) was developed the mockup first of the Russian Derivatograph, which fulfills the method of the synchronous - couplings baro - electro - thermo - acoustical (BETA) analysis of substances and materials, and implements simultaneously the termogravimetry (TG and DTG), termodilatometry (TD and DTD), the differential-thermal analysis

(DTA), electrometric (EM) data and registration of acoustic emission (AE) on the macrosample (till 50), by his barothermocycling in thermostat with the help of adaptive "baro-thermal shocks" in a range from −70 to +835 °C and 0.001 – 1 MPa.

In spite of the fact that systems of TA are created by many leading world firms (DuPont, Perkin Elmer, NETZSCH, etc.), which implement TG and DTG, TD and DTD, DTA, the differential-scanning calorimetric (DSC) analysis, and also special methods: the dynamic mechanical analysis (DMA), the dielectric analysis (DEA), a method of laser flash (LFA), the thermo mechanical analysis (TMA), including synchronous and serially integrated TG-DTG-DSC/DTA-mass spectrometer, TG-DTG-DSC/DTA-infrared Fourier spectrometer, nobody yet did not manage to synchronize dilatometry with thermogravimetry and with simultaneous definition of heat conductivity and DEA, and furthermore on macro-button of a sample, moreover in a wide range of pressure. Due to, from the point-view of thermodynamics, physical chemistry and methods of the thermal analysis, the developed breadboard model of BETA-analyzer offered the novel approach connected with synchronization of thermogravimetry and thermodilatometry at change of pressure. It allows registration of density of a sample and its derivative, i.e. creates new method of TA: the baro-thermal analysis (BTA) or thermobarodensimetry (TBD).

Integration TBD with the method of acoustic emission gives possibility to define on the one complex and on one sample all stages nano-, micro- and macro-destructions, including "firemen the parameters", which till now were defined on different devices (see Table 1), but the some parameters were not defined in general [1, 2].

Table 1. Comparative characteristics of methods and devices of the thermal analysis

	m	ℓ	ρ	λ	C_P	C_V	$T_{пл}$	$T_т$, $Ч_ц$	H	S	σ, ρ	ε	tgσ,φ	μ	a	E_D	E	G	K	ν	$μ_μ$, $λ_λ$	α	β	γ	t_p
TG	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DTA	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DSC	-	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TD	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
DEA	-	-	-	-	-	-	-	-	-	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-
DMA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	-	+	+	-
TMA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	-	-
LFA	-	-	+	+	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
SSA	+	+	-	+	+	-	-	-	+	-	-	+	-	-	+	-	+	+	+	+	+	+	+	+	-
STA	+/-	-/+	-	-	+/-	-/+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SCTBEA	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

References

[1] S. I. Builo, V. V. Belozerov, Yu. V. Prus. Combined Thermogravimetric and Acoustic-Emission Diagnostics of Stages of Thermal Destruction of Substances and Materials // Russ. J. Nondestructive Testing, **44** (3), 212–214 (2008).

[2] S. I. Builo, V. V. Belozerov, S. P. Zinchenko, I. G. Ivanov. Excitation of Acoustic Emission by Laser Radiation for Studies of Structural Alterations in Composites and Polymers // Russ. J. Nondestructive Testing, **44** (9), 615–620 (2008).

RANDOM VIBRATIONS IN THE WEDGE-SHAPED ELASTIC MEDIUM

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The dynamic mixed boundary value problem is considered for the wedge-shaped elastic medium under the antiplane random vibrations, generated by inner finite defect on the polar radius of a wedge. The problem in question is reduced to the boundary integral equation about the jump of unknown stresses at the defect. Solvability problems for the integral equation are studied in the spaces of the fractional smoothness and the method of estimation of its solution is suggested. Earlier such a technique has been applied to the investigation of transient wave propagation in number of papers [1-3] and so on. The main results of present investigation may be used when simulating the acoustic emission by linear defects in the sphenoid elastic media.

References

[1] Shaw R.P. Boundary-integral equation methods applied to transient wave scattering in an inhomogeneous medium // *J. Appl. Mech.*1975. No. 42. P. 147-152.

[2] Berkovich V.N. The transient mixed dynamic problem for heterogeneous wedge-shaped elastic medium // *Ecol. Bull. BSEC*. 2005. No 3. P. 14-20.

[3] Salem M.A., Kamel A.H., Osipov A.V. Electromagnetic fields in the presence of an infinite dielectric wedge // *Proc. R. Soc. A.* 2006. (doi: 10.1098/rspa. 2006.1691).

SURFACE ACOUSTIC WAVES IN THIN FERROELECTRIC FILMS OF BARIUM STRONTIUM TITANATE

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Surface acoustic wave (SAW) devices are widely used in modern acoustoelectronics for creation of resonators, filters, transmission (delay) lines, etc. An obvious trend in the development of communication systems consists in increasing the working frequencies of devices. In the traditional SAW devices an increase in the central frequency is achieved by two methods, which are based on using a sound-guiding substrate with a higher sound velocity and decreasing the characteristic geometric size (gap and electrode width) in the transmitter and receiver interdigital transducer (IDT).

The present work shows that, using a thin barium strontium titanate film in the ferroelectric state as the active element in a SAW device, it possible to double the working frequency on the converter due to the formation of a periodic domain structure in the film, with a period equal to the distance between the centers of the adjacent electrode (i.e., to half of the geometric period of the IDT).

Thin heteroepitaxial films with thickness within 300 – 400 nm were grown on single-crystalline MgO substrates by RF sputtering of stoichiometric targets. Depending on the deposition condition, the film could be formed in the regime of either layer or block epitaxial growth.

Using the method of inverse (exposition) lithography, a transmitter/receiver IDT structure was formed on the sample surface coated with 0.18-mm-thick aluminum film. A polarized state necessary for the required piezo-effect was created by applying a constant polarizing voltage of 50 V to electrodes of IDT. A thin ferroelectric film device with standard electrode structure is capable of effectively exiting the SAW second harmonic. Variation of the external polarizing voltage applied to the electrodes ensures field-controlled electromechanical feedback in the converter.

PHYSICAL, MECHANICAL AND STATISTICAL ASPECTS OF ACOUSTIC EMISSION DIAGNOSTICS

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Experimental data on the fracture physics and mechanics of materials show that deformation and destruction processes occur at the micro-level in the form of discrete collective dynamic processes. The discrete character of these processes is likewise confirmed by the data of acoustic-emission (AE) tests, which testify that, in each collective event of structural damage (motion of a dislocation avalanche, merging of microcracks, etc.), a primary elastic pulse is generated, the emission process of which involves, so-called AE event. Hence, measuring intensity of the stream of AE events (the number per unit time) or their total number in principle makes it possible to perform quantitative study of the damage-accumulation kinetics and diagnostics of early damage stages.

As a result of multimode propagation, reflection, and transformation of the wave mode, damping of high-frequency components, and resonance properties of the receiving equipment, the detected AE signals differ greatly from emitted elastic AE pulses [1]. For example, we have revealed that, in the case of a high-intensity emitted AE-event stream, both false minima in the recorded activity and false maxima in the amplitude distribution of recorded AE pulses may appear. To solve this problem, we are developing methods for reconstructing the true initial AE-event stream parameters inside the material and the process of flaw storage using the recorded AE signals. The first experimental confirmation of the Poisson character of the AE phenomenon was obtained in our investigations in the end of 1970s.

The essence of the reconstruction method we develop can be briefly described as follows. Proceeding from the physical nature of AE, the kinetic concept of strength that utilizes a statistical Poisson's model of an event stream is used to determine a specific form of the distribution function (or density) for a given parameter in the signals that have not yet overlapped. This distribution is then extrapolated to the region where the recorded parameters have been strongly distorted during signal propagation and receiving. In this way, it becomes possible to evaluate the true distributions of AE parameters. Subsequently, the desired characteristics of AE sources (flaws) are calculated on the basis of the information on the reconstructed distribution functions [1]. We discovered, that in the most general case, the intensity of the reconstructed (i.e., emitted inside a material) AE-event stream is accompanied by a local peak in the yield zone, a much lower local peak in the strengthening region, a lower inflection point corresponding to the onset of dispersed accumulation of microscopic discontinuities, and an upper inflection point corresponding to a transition from the dispersed to localized flaw accumulation.

The obtained results make it possible to identify stages of flaw-formation processes on the basis of detection and position of critical points (local extrema and inflection points) of the recorded parameters of the reconstructed AE-event stream [2].

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References

[1] Builo S. I. A Method for Identifying Deformation and Destruction Stages by Location of Critical Points of a Reconstructed Flow of Acoustic-Emission Events // Rus. J. NDT, **44**(8), 517–526 (2008).

[2] Builo S. I. Diagnostics of Deformational and Fracture Stages Based on Integral Parameters of the Flow of Acoustic-Emission Acts // Rus. J. NDT, **40**(8), 552–560 (2004).

EFFICIENT BUILDING MATERIALS FROM INDUSTRIAL WASTERS

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The paper develops technology for efficient use of materials from solid waste coal and fuel industries. The peculiarity of the proposed technical solution is that the process involves the minimum amounts of natural raw materials and the numerous kinds of man-made ones:

♦ *fine concrete* with increased strength, frost resistance, water resistance, high resistance to abrasion and the action of aggressive media. It is intended for the manufacture of paving slabs, curbs, pavement slabs, thin-reinforced products and other building products, as well as for monolithic concrete in hydraulic construction and mine;

♦ *heavy concrete* with compressive strength of class B7.5-B40, high density, frost resistance, weather resistance. It is intended for the manufacture of concrete, concrete products from small sized to large-scale building blocks slabs, panels, massive blocks, etc.;

♦ *light-weight concrete* with compressive strength of class B7.5-B30, resistance to aggressive environments and temperature extremes. This concrete can be considered as a versatile material that can be used in various building structures, such as exterior building walls, ceilings, enlarged structures, bulk items, etc.;

♦ *non-autoclaved cellular concrete* curing compressive strength of class B0.5-B12.5, the average density of D500-D1200, frost resistance and thermal conductivity does not yield to such concrete from the traditional raw materials. Cellular concrete blocks can be manufactured insulation, stones for walls, panels, partitions, floors and other promising applications of such concrete in a monolithic concreting of the construction of cottages;

♦ *maloklinkernoe binder* having an activity of 5 to 60 MPa. Physical and mechanical properties of these binding properties are comparable to traditional Portland cement. A distinctive feature of such binders is high corrosion resistance. Concretes made with these binders can withstand 100-300 cycles of freezing and thawing;

♦ *ceramics* and *refractory materials* with a compressive strength of 10-40 MPa, frost-resistant and acid. Ceramic and refractory materials are used in the production of fine and coarse pottery (ceramic art, front and tiles, shingles, brick, masonry units, fire clay, pottery, sanitary and other products);

♦ *road materials* (gravel, sand, rubble and sand mixture, mineral powder, concrete and asphalt road), which on the properties and quality is not inferior, and for some parameters are even better than the materials traditionally used in road construction;

♦ *insulating covering*, which has the brand strength of 400, 600, bulk weight 600-900 kg/m^3, thermal conductivity of 0.15-0,18 W/m·C°. For heat insulation expanded clay backfill is comparable to, but surpasses it in strength;

♦ *briquettes* (charcoal, wood charcoal, wood). Fuel briquettes are to be easy to transport and use, has low cost, low ash content and sulfur content, capable of burning in thermal plants and small power units.

MOCVD Growth and Characterization of Regularly Patterned Nanorod LED Arrays with Polar and Non-polar InGaN/GaN Quantum Wells

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Regularly patterned nitride nanorod (NR) arrays of uniform geometry are grown with metalorganic chemical vapor deposition (MOCVD) based on the nano-imprint lithography technique. For the application to light-emitting diode (LED), an NR array has the advantages of lower threading dislocation density and hence higher crystal quality, stronger scattering for enhancing light extraction efficiency, lateral strain relaxation for increasing indium incorporation, non-polar and semi-polar InGaN/GaN quantum well (QW) growths for reducing the quantum-confined Stark effect, larger emission volume with sidewall quantum well structures, and fabrication of high-quality GaN template with coalescence overgrowth. In this presentation, several issues on this subject are to be discussed, including the mechanism of improved crystal quality, the simultaneous growth of *c*-plane and *m*-plane InGaN/GaN QW structures, optical characterization and material analysis of the QWs, and NR array LED fabrication.

In more detail, with the nano-imprint lithography and the pulsed growth mode of metalorganic chemical vapor deposition, a regularly-patterned, *c*-axis nitride NR array of quite uniform geometry with simultaneous depositions of top-face, *c*-plane disc-like and sidewall, *m*-plane core-shell InGaN/GaN QW structures is formed. The differences of geometry and composition between these two groups of QW are studied with scanning electron microscopy, cathodoluminescence, and transmission electron microscopy (TEM). In particular, the strain state analysis results in TEM observations provide us with the information about the QW width and composition. It is found that the QW widths are narrower (1-2 nm) and the indium contents (16-21 %) are higher in the sidewall *m*-plane QWs, when compared with the top-face *c*-plane QWs (~5 nm and ~12 %). Also, in the sidewall *m*-plane QWs, the QW width (indium content) decreases (increases) with the height on the sidewall. The observed results can be interpreted with the migration behaviors of the constituent atoms along the NR sidewall from the bottom. The excitation power-dependent PL measurement confirms the non-polar nature of the *m*-plane sidewall QWs.

Development of the Multilayered Structurally Heterogeneous Antifriction Nanomodified Covering

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The main result of the executed research consists in the development of the creation principles for the antifriction multilayered nanostructured covering on a massive metal body which consists of the power skeleton representing a layer with a high roughness at considerable improvement of physic-mechanical characteristics, and an antifriction nanostructured layer from a polymeric composite material. The interpretation of the physical and chemical processes proceeding at adhesive interaction was given due to the application of new analytical methods of a surface studying and the expansion of the possibilities of already known methods. Plasma processing was experimentally applied to modify the polymer surface. Influence of the structurally-active nano-additives (the fillers) on the processes of polymer crystallization and formation of cluster structures at tribo-coupling was investigated. Special elements were found that possess high binding energy with the surface of the iron and at the same time weak solubility in a volume phase of the iron. Such elements, being introduced into an antifriction nanostructured layer, then diffuse in small amounts into steel, forcing out atoms of sulfur and phosphorus from a grain border surfaces and strengthen bonds between iron grains which ultimately contributes to wear resistance of steel. The estimation of energy of a chemical bond in the investigated connections is done in the framework of a cluster model by means of the software package ADF based on DFT approach, application of which for tribology problems and analysis of phenomena occurring on a tribo-coupling surface is new.

In the second part of the present investigation the mathematical and computer models of contact interaction between rigid and deformable indenters and structurally inhomogeneous bodies were developed in order to optimize their strength and functional properties. For investigation of the formulated contact problems, the effective finite element methods and software tools were established. The stages of solving the contact problems with inhomogeneous properties include such processes as development of the finite element model for homogeneous bodies with concentration around supposed contact zone, finite element modifications by redefinition of their material properties according to the law of heterogeneity, creation of the finite element contact pairs and numerical solution of nonlinear contact finite element problem.

Developed methods and software programs were verified by comparison of experimental nanoindentation data for laminated coverings with computation results. The established models permit to take into account the presence of inclusions in the near-surface areas at the boundaries between layers. The analysis of stress concentrations was performed at the boundaries with changes of mechanical properties of the structurally heterogeneous bodies and at singular points associated with the presence of inclusions of other materials. The calculations with different geometric and mechanical characteristics of multi-layer and functionally gradient media were carried out with the use of finite element software for solving strengthening and contact problems with inclusions, defects and delaminations.

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DEVELOPMENT OF CALCULATION METHODS AND DESIGNING OF BINARY SLIDING BEARING

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The calculation methods, the theory and principles of optimal design of new types of binary bearings from the metal-polymer materials of tribological purposes are developed. The ways of modify its surface are developed in order to use polytetrafluoroethylene (PTFE), composed of binary antifriction self-lubricating materials. The modification allows one to significantly improve the adhesion ability of the composite surface. The surface modification is the only possibility to create a strong adhesive joint for low polar polymers such as polyethylene (PE) and PTFE. The methods, based on the joint application of both methods electron spectroscopy for chemical analysis (ESCHA) and infra-red multiple frustrated total internal reflection (IR MIR) spectroscopy, are used to control the quality of the modified surface of the filler.

Application of new methods for studying the surface in the performance of work allows one to evaluate the physical and chemical processes, accompanying the adhesive interaction at the interface of binary metal-fluoroplastic bearings. The surface modification of a number of polymer composite materials is experimentally realized by chemical and physical methods, such as treatment of pickling solutions, radiation modification, treatment in a plasma glow discharge. The advantage of the latter method over the other is shown. The degree of processing parameters influence of the sample surface from PTFE (residual air pressure in the chamber and the processing time) on adhesion work value of PTFE film is explored using the developed procedure of its calculation. Optimization of activation mode is conducted.

Analysis of contact interaction mechanics is also carried out for certain types of widely used binary self-lubricated cylindrical bearings on the basis of two and three dimensional mathematical models. The method of finite-element analysis, realized in the software complex ANSYS, for which the appropriate programs in the language APDL ANSYS are developed, is used for solution the appropriate contact problems. The calculation of contact and effective stresses, the value of the contact zone for various values of mechanical and geometrical parameters of binary bearings are conducted. The analysis of obtained results is showed that there is a local stress concentration on the change material border, lying in the contact zone. Such local stress concentration can lead to the cracks emergence and subsequently to the destruction of the bearing. The increase of the concentration of contact stresses under decreasing sizes of protector inserts is also shown. Herewith the concentration increases under approaching to the ends of butts of piecewise-homogeneous cylindrical layer, simulated the bearing.

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Information Technologies at Diagnostics of Incision in Components of Rod Frame Constructions

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The technical inspection of components of the rod frame constructions conducts with aim to obtain objective data on an actual state of object and the account them in further operation.

At diagnostics, the project model documentation is studied, the designs of separate nodes and components are specified, the damage degree and loading factors investigated, the various external factors of impact on object analyzed.

Diagnostic inspection of an incision is carried out to 3 stages.

The first stage consists in collecting and studying technical documentation, generalization of data on model.

The second stage includes inspection and diagnostics of the incisions of the frame construction based on application of methods of the vibration diagnostics with use of tool and measuring complexes.

The third stage is connected with working out the conclusion on fulfill diagnostics.

During diagnostics, there are applied the specialized devices for measurement of parameters of the construction oscillations. At unit of measuring devices in the control and diagnostic system, allowing one to make multiple parameter measurements, there is a need for preservation, processing and delivery of results of the analysis on the incisions of the construction. For this purpose, it is used the specialized software for control and government by external measuring and retransforming devices by using the portable computer. In the program software of the vibration diagnostics of the construction incisions, there are included various modules on collecting and processing of parametrical signals and also production of analysis of the construction incisions.

Influence of Parasitic Effect between Frequency and Quantum Impedance for Quantum Resonant Materials and Structures

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The variety of impedance of resonant tunneling structure by changing dynamic resistance, series inductance, and dynamic device capacitance is reported to model and analyze the resonant tunneling structure in small signal impedance. The high-frequency impedance model in quantum resonant structure is successfully constructed by combing a parallel *R-C* circuit along with a series *R-L* circuit with parasitic effect. The relationship between quantum impedance and frequency is obtained. Well-defined model corresponding to the quantum effect is implemented. The quantum inductance absolutely influenced the imaginary value of impedance. The positive resistance value of quantum resonant device is influenced by the quantum inductance, as the device current is expressed in thermal ionic effect but not resonant tunneling effect. The quantum inductance absolutely influenced the imaginary value of impedance, because the imaginary value of resonant impedance is the negative resistance effect. As the capacitance value is more than 0.01 pF, the positive quantum impedance will be absolutely influenced by frequency. The quantum impedance is also absolutely influenced by frequency either in large capacitance or small capacitance.

AN MIMO-OFDM UNDERWATER ACOUSTIC MULTIMEDIA COMMUNICATION

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It is present, a transmission scheme based on multi-input multi-output (MIMO) orthogonal frequency-division multiplexing (OFDM) which has been proposed for underwater acoustic multimedia (UWAM) communication. The direct mapping (DM) and space-time block code (STBC) strategies, OFDM, adaptive modulation, and unequal error protection (UEP) was used in the proposed UWAM system. Simulation results show that the proposed scheme not only fulfils the quality of services (QoS) required of a UWAM system, but also achieves maximum transmission bit rates or minimum transmission power.

This research was supported in part by the Russian Foundation for Basic Research Grant No. 10-08-13300-RT_omi and National Science Council of Taiwan under contract NSC 99-2923-E-022-001-MY3.

INVESTIGATION OF INTEGRATED ZNO-BASED ION-SELECTIVE FIELD-EFFECT-TRANSISTOR PH SENSORS

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The field-effect transistor-based sensors have been widely investigated in recent years. The advanced sensors are requested to possess high sensitivity, fast response, ideal stability, and minimized size. Therefore, the ion-selective field-effect transistors (ISFETs), which integrate the sensing material and the field-effect transistors, are the promising structures to minimize the sensor devices and provide the high stability and sensitivity. In general, the mechanisms of many biosensors are established via detecting the variation of the pH value owing to the measured elements catalyzed by the enzyme. Therefore, the pH sensors are regarded as one of the most important devices among various biosensors. The zinc oxide (ZnO) is an ideal material for sensing in view of the favorable stability and biocompatible properties. In addition, the ZnO nanorods were usually utilized to the biosensors due to the large surface-to-volume ratio which can effectively improve the sensing performance [1]. However, the dangling bonds and surface states existed on the surface of sensing film and the nanorods would degrade the performance of the sensors. It's necessary to ameliorate the difficulty by passivating the surface of the sensing film and the nanorods [2].

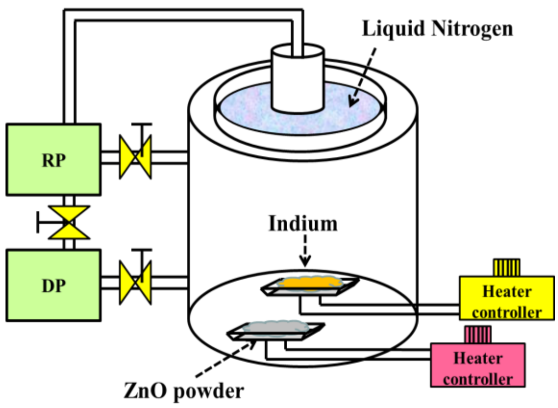

Fig. 1. The Schematic configuration of vapor cooling condensation system

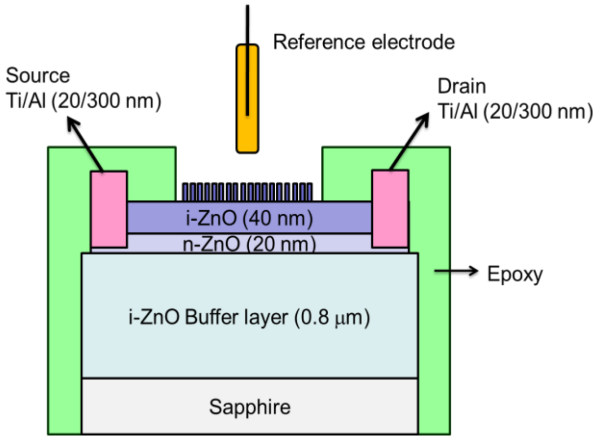

Fig. 2. The schematic configuration of the integrated ZnO ISFET pH sensors

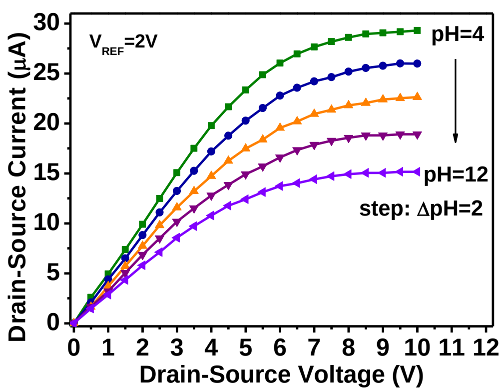

Fig. 3. Drain-source current – drain-source voltage characteristic of ZnO ISFET pH sensor with PEC passivation

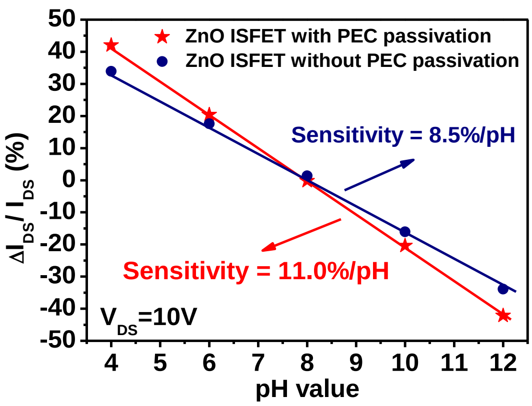

Fig. 4. Current variation ratio as functions of pH value for ZnO ISFET pH sensors

In this work, the unique vapor cooling condensation system was used to fabricate the ZnO-based ISFET pH sensors and the photoelectrochemical (PEC) method was then utilized to improve the sensing performance. The vapor cooling condensation system and the schematic configuration of the ZnO-based ISFET are shown in Figs. 1 and 2, respectively. In the fabrication process of the ZnO-based ISFET, a 0.8 μm-thick *i*-ZnO buffer layer, a 20 nm-thick *n*-ZnO:In channel layer, and a 40 nm-thick *i*-ZnO sensing film were sequentially deposited on the sapphire substrates which were attached to the stainless steel plate cooled by the liquid nitrogen. The aqueous solution growth method was then used to directly grow the

ZnO nanorods with length of 1.25 μm on the gateless region. Finally, the PEC method was used to passivate the surface of the ZnO sensing film and the ZnO nanorods. The measured results of the integrated ZnO-based ISFET pH sensors with PEC passivation revealed the ideal sensing performance as shown in Fig. 3. The drain-source current (I_{DS}) increased with the lower pH value of the detection solution and vice versa. The results represented that the drain-source current of the sensors can be effectively changed corresponding to the varied pH value of the detection solution. The sensitivities of the pH sensors with and without PEC passivation are both shown in Fig. 4. The sensitivity is defined as the slope of the current variation ratio corresponding to the pH value. The calculated sensitivity of the pH sensors with PEC passivation was 11 %/pH compared to the 8.5 %/pH of the pH sensors without PEC passivation. The reason of the obvious sensitivity improvement is that the Fermi level pinning effect induced by the surface states and the dangling bonds was restrained by the passivation via PEC method. In conclusion, the integrated ZnO-based ISFETs pH sensors with PEC passivation function demonstrated the favorable sensing performance and was expected to further develop and realize in the biomedical or chemical sensing applications.

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References

[1] Y. S. Chiu, C. T. Lee // *J. Electrochem. Soc.* **158**, J.282 (2011).

[2] C. T. Lee, Y. S. Chiu, S. C. Ho, Y. J. Lee // *Sensors* **11**, 4648 (2011).

RAPID ANNEALING OF PZT THICK FILMS ON STAINLESS STEEL SUBSTRATES USING CO_2 LASER PROCESSING

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In this study, lead zirconate titanate (PZT) ferroelectric thick films prepared by a modified sol-gel method have been made using CO_2 laser low temperature annealing on a stainless steel SUS 430 substrate. Firstly, the PZT powders were synthesized using a sol-gel process and annealed at 550 °C, after which possessed an average particle size of about 194 nm. Then the PZT precursor and powder were mixed to form a slurry and spin-coated on a lanthanum-strontium-molybdate (LSMO) coated-SUS 430 substrate by a modified sol-gel method. The subsequent sandwich structure is PZT(5 – 15 μm)/ LSMO/SUS 430. As the thickness of the PZT layer increasing to 15 μm, the reflection of CO_2 laser resulted from the SUS 430 substrate can be reduced so that not only the CO_2 laser energy can be absorbed effectively by the PZT films but also the sintering ability of the PZT films can markedly be promoted at a low temperature annealing of 880 °C. Scanning electron microscopic observations show that the microstructures of the PZT thick films are dense and uniform. The remnant polarization P_r value was enhanced to ≈ 22 μC/cm^2 due to improved crystallinity of the PZT thick films. In addition, it is estimated that the penetration depth of PZT thick film is about 36.5 μm for CO_2 laser by measuring a reflection power from the specimens.

INFLUENCE OF DISLOCATIONS AND DISCLINATIONS ON NONLINEAR DEFORMATION OF THIN-FILM MATERIALS

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Thin-film materials and carbon nanostructures have unique physical properties that are directly related to their exotic geometry. It was experimentally found that graphene, for example, is always corrugated and covered by ripples that may have intrinsic character (caused by topological defects like dislocations and disclinations) or be induced by a roughness of substrate. We propose a nonlinear elastic shell theory of Kirchhoff-Love type which takes into account both isolated and continuously distributed dislocations and disclinations. In contrast to the usual shell theory the strain compatibility conditions are replaced by the so-called incompatibility equations of the first and second order containing densities of defects. We present some exact solutions to a number of practically important problems, e.g. buckling of a nonlinearly elastic membrane due to a given density of disclinations, torsion and bending of a cylindrical nanotube with distributed dislocations, inflation of a fullerene containing dislocations and disclinations.

RECENT ADVANCEMENTS TO ENABLE ECO-LED TECHNOLOGY

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Gallium nitride materials have attracted considerable interest in the development of light-emitting diodes (LEDs) for solid-state lighting application. The critical point in pushing for the commercialized white-LED in lighting market is to develop a cost-effective fabrication process. To obtain a better performance and longer lifetime for GaN-based LEDs, the LED structures grown on sapphire have to be transferred to other substrates with better thermal and electrical properties by any lift-off techniques where laser lift-off (LLO) is the most prevalent one at present. However, LLO tends to cause defects generated by the high energy laser irradiation onto the interface between GaN and sapphire. Recently, chemical lift-off (CLO) technique has attracted much attention because the LEDs have not experienced any physical and thermal shock during a detaching process and the vertical LED which has a similar device performance to that of the LLO method has been fabricated. There are several sacrificial materials such as CrN, ZnO, Ga_2O_3 and Si-doped n-GaN layer that have been reported. In our studies, an incredible progress in enhancing the yield and separation time for CLO process has been made. These strongly suggest that the CLO technique will show an important impact on the sapphire substrate recycling (i.e. eco-LED) in a near future.

ON RESTORING OF THE INHOMOGENEOUS COMPLIANCE MODULE IN PIEZOELECTRIC ROD

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Development of methods for determining the properties of structural elements is one of the main line of development in modern solid mechanics. The work of many diagnostic devices and sensors is based on the piezoelectric phenomenon, which describes a model of classical linear theory of electrodynamics. The inverse problem of restoring inhomogeneous laws of the electroelastic body characteristics is presented. The weak formulation is developed, on which the operator equations can be constructed relating the unknown and the given functions. The problem of reconstruction of the inhomogeneous compliance module for longitudinally polarized electroelastic rod is considered.

The solution of the direct problem of longitudinal vibrations of an inhomogeneous rod is reduced to a Fredholm equation of the second kind. The inverse problem of reconstruction of the heterogeneous module compliance is investigated by known amplitude-frequency characteristic of the end of the rod. The iterative process is constructed at each step of which corrections are detected as the solution of a Fredholm integral equation of the first kind. Numerical solution of this equation is constructed using Tikhonov regularizing method with automatic selection of the regularization parameter. The results of computational experiments on the restoring of monotonic and non-monotonic changes in the laws of the module compliance are presented.

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GROWTH OF $In_xGa_{1-x}As$ AND GE EPITAXIAL LAYERS ON SI SUBSTRATE FOR POST CMOS APPLICATION

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Recently, the semiconductor industry community faces challenges from the continued reduction of device feature size for silicon devices. Meanwhile, the III-V compound semiconductor materials such as InSb, $In_xGa_{1-x}As$ attract a lot of attentions for post CMOS applications For example, InAs has an electron mobility of 30000 $cm^2V^{-1}s^{-1}$. High-speed devices such as quantum-well field-effect transistors (QWFETs) made from these III-V materials have demonstrated very low gate delay time. Meanwhile, for the post

CMOS applications, Ge is considered as a good candidate for p-channel material because of its high hole mobility (1,900 $cm^2V^{-1}s^{-1}$). The Ge epitaxial film grown on GaAs is of immense interest due to the lattice mismatch is practically zero (~ 0.08 %) which ensures large critical thickness and low dislocation density, strain-free Ge epitaxial film. In the study, growth of InAs on Si is demonstrated using "interface blocking" technique with SiGe layers as buffer layer. And the growth of high quality Ge film on GaAs is demonstrated using ultra high vacuum chemical vapor deposition (UHVCVD). Both Ge film grown on GaAs and InAs film grown on Si substrate demonstrate high crystallinity and good surface morphology as observed by XRD and AFM. Furthermore, the fabrication process and electrical characteristics of Ge/GaAs and InGaAs/InP MOSCAP are discussed in the study. The developed epitaxial materials and device fabrication technologies including InAs on Si, Ge on GaAs are useful for III-V and Ge integration on Si substrate for next generation of high speed low power CMOS as well as for RF/digital mixed signal circuit applications in the future.

INFLUENCE OF MECHANICAL ACTIVATION ON THE SYNTHESIS AND PROPERTIES OF THE SOLID SOLUTION BASED ON LEAD ZIRCONATE-TITANATE AND LITHIUM NIOBATE

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The influence of mechanical activation on the synthesis and properties of solid solutions based on lead zirconate-titanate and lithium niobate, which can be used as piezomaterials and piezoelements to manufacture measuring devices, was investigated. The initial components for synthesis of lead zirconate-titanate were lead oxides (orthorhombic and tetragonal PbO, Pb_3O, PbO_2), titanium oxides (TiO_2 as rutile and anatase and TiO), monoclinic zirconium oxide ZrO_2 and metals (titanium and zirconium). The initial reagents for synthesis lithium niobate were Li_2CO_3 and Nb_2O_5 powders. Copper oxide was used as the alloying additive. Mechanical activation was carried out in the planetary-centrifugal mill AGO-2 (Russia).

The results of the examination of specific surface and electron microscopic studies of the powders, both initial and subjected to mechanical activation, are presented. The initial powders contain the particles of splintered shape with sharp edges. In the activated powders, along with the destruction of the particles of the initial reagents and the formation of smaller particles of round shape, the agglomerates of particles having round shapes without keen edges were also observed, which simplifies powder compaction.

The sintering processes were investigated by means of X-ray powder analysis. The final formation of lead zirconate-titanate structure occurs at the annealing of samples in the temperature range from 1000 up to 1100°C depending on the initial components. The formation of nanodispersed structure with the grain size 10 – 40 nm was demonstrated by X-ray diffraction and TEM. It was shown that lithium niobate of the compound was complete at 500°C, which is lower by 300°C than the temperature in the conventional technique. The end of the synthesis at 500°C was confirmed by the data on weight losses. For sintering at 500°C, weight loss was about 13 %, and under further heating it did not exceed of 1.5%. Thus, the time of high-temperature processing, in comparison with the classical technology, was in six times shorter.

Plots of density changes for the samples depending on activation time and annealing temperature are presented. It was established that the density of the samples is at a minimum at 500°C and the maximum value (4.5 g/cm^3) is reached at 960°C, which is lower by more than 150°C than that for non-activated powders.

The lattice parameters, the sizes of blocks of coherent dispersion and their distortion, as well as the density and weight losses depending on annealing conditions were calculated.

The results of electron microscopic studies of the surface of sintered samples are presented.

STRUCTURAL AND ELECTRICAL PROPERTIES OF DILUTE NITRIDE GAASSBN

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GaAsSbN can be lattice-matched to GaAs and with a tunable energy gap ranging from 1.42 to 0.8eV, which makes it a promising material for multi-junction solar cells and optoelectronic devices. Its narrow energy gap is due to the tiny amounts of N and Sb incorporated in the host GaAs. The electronegativity values of these two atoms are very different from that of As atom, leading to localized energy states embedded in the GaAs energy bands. The anti-crossing between the localized states and the bands results in the narrow energy gap. A band anti-crossing model, considering the repulsive effects has well explained the energy gap reduction in GaAsSbN. In this manner, the local environments of N and Sb, resulting from specific growth conditions, are very crucial to the energy gap of the dilute nitride. Several reports suggested N pairing in the as-grown GaAsN and GaAsSbN and the dissociation of the pairs in the following thermal treatment. In this paper, we report on the short range configuration of N atoms in GaAsSbN. The alloys were grown on GaAs using gas-source molecular-beam epitaxy. N source was from a RF plasma cell. N K-edge X-ray absorption near-edge spectroscopy (XANES) and Sb K-edge extended X-ray fine structure (EXAFS) were measured on the samples in National Synchrotron Radiation Research Center, Taiwan. The results were then compared with simulation curves for GaAsSbN supercells with different short range arrangements. The lattice structures of the supercells were calculated using valence force field (VFF) model. FEFF9 code was used to simulate the XANES curves. After comparing the experimental and simulation XANES curves, we found that GaAsSbN grown with atomic-N rich source contains N pairs surrounded by Sb atoms. The GaSb bond lengths obtained from EXAFS are also close those determined from EXAFS. Details of the measurement of EXAFS and XANES as well as the structure of the supercells will be presented.

Cathodoluminescence Study of β-Ga_2O_3 Epilayers Grown by MOCVD

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Monoclinic-structured gallium oxide (β-Ga_2O_3) is a meta-stable, wide band gap semiconductor oxide which shows a high stability under harsh mechanical, chemical, and thermal conditions. β-Ga_2O_3 is a promising material for next generation of optoelectronic devices for its high potential in optical bandgap engineering by different impurity doping.

In this research we developed a method to synthesis single crystal β-Ga_2O_3 using MOCVD technique for the first time. MOCVD grown β-Ga_2O_3 epilayers, is essential for the mass production. β-Ga_2O_3 is known for its high oxygen vacancies which influence its optical performance. Here we reduced oxygen vacancies by annealing epilayers in atmosphere. To investigate local optical properties of β-Ga_2O_3 epilayers cathodoluminescence (CL) is employed which is a technique based on electron-induced optical emission (Fig. 1). Applying electron beam at low voltage enables it to probe the optical behavior of β-Ga_2O_3 epilayers at the surface.

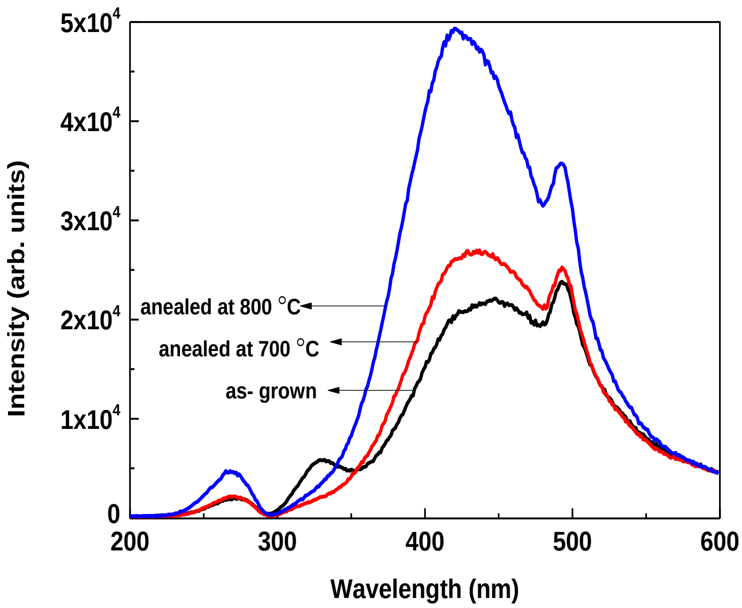

Fig. 1. Room-temperature CL spectra of MOCVD grown β-Ga_2O_3 epilayers

Peaks centered at (270 nm) is attributed to the bandgap of β-Ga_2O_3. A clear peak in ultra-violet region which is clear for the as-grown epilayer, probably is related to the oxygen vacancies. This peak tends to vanish for epilayers after annealing. Annealing at atmosphere provides enough energy for oxygen molecules to get diffused inside β-Ga_2O_3 epilayers. A broad peak in blue-green region is attributed to transfer of donors (electrons in the form of oxygen vacancies) to acceptors (holes in the forms of gallium vacancies and/or a gallium–oxygen vacancies pairs). Blue shift in this broad peak after annealing may be related to compressive stress related to the diffused oxygen inside β-Ga_2O_3 epilayers. Peak in the red region is the same for all epilayers before and after annealing. We attribute it to the surface states arising from oxygen adsorption.

System Function of Magnetoelectronic Devices

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The development of modern electronics is moving towards the introduction of new physical principles in the design of circuits. One of the most promising for the application of physical phenomena is the spin and magnetostatic waves. The need for miniaturization of devices, magnetic electronics leads the developer to analyze the behavior of a complex problem in an inhomogeneous magnetoactive media field. This is especially important in the calculation of spin-wave electronics devices.

As an example of a magnetoactive medium is considered heterostructure AsIn of microconverter of magnetic field into a voltage, which is regarded as a four-pole. To calculate the system function we use the Green's functions method. A relation for the output voltage of microconverter in the linear approximation received in the form of a convolution of distribution of the magnetic field $\mathbf{B}(\mathbf{r})$ with the system function of a magnetoactive medium $\mathbf{W}(\mathbf{r})$:

$$u_H(\mathbf{r}) = \frac{i}{en}\int_D \mathbf{B}(\mathbf{r}')\mathbf{W}(\mathbf{r}-\mathbf{r}')d^3r', \text{ where } \mathbf{W}(\mathbf{r}) = \lim_{i\to 0}\frac{[\mathbf{j}_1(\mathbf{r})\times\mathbf{j}_2(\mathbf{r})]}{i^2}.$$

Here $\mathbf{j}_1(\mathbf{r})$ is a current density, when the current i passed through the contacts 1 and 3, and $\mathbf{j}_2(\mathbf{r})$ by passing current through the contacts 2 and 4 of converter, e is the electron charge, n is the concentration of carriers.

We perform experimental verification of the relations of reciprocity of magnetoactive medium in an inhomogeneous field and measuring the distortion of magnetic field distribution caused by the reduction of the instrumental function of the converter. The experimental setup is a group of parallel thin (90 mm) wires and switching current system, controlled from a PC. The voltage measured at the converter with analog-digital unit of the Hall magnetometer, developed at the SEC "Radiophysics."

It is shown, that the reciprocity relations, which Onsager proved for the uniform field, for a magnetoactive medium in an inhomogeneous field are satisfied with an error less than 1%. Difference between experimental and calculated distortion of distribution of magnetic field is about 3% in terms of standard deviation. Consistency of experimental and theoretical data for measurements of the inhomogeneous magnetic field distribution confirms the possibility of using the proposed method of analysis of magnetically active media in the design of magnetic electronics devices and galvanomagnetic converters.

QUASI-LINEAR CONDUCTIVITY OF NON-LINEAR PLASMA-LIKE MEDIA

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The development of modern electronics industry assumes using of new physical phenomena, such as magnetic and spin waves in a magnetoactive medium, which may be regarded as plasma. Designing devices based on these phenomena are required to take into account the nonlinearity of the medium. Usually for this purpose the series of Voltaire are used, which contains complex tensor function of many variables that cannot be calculated or measured with the required accuracy. Much more accurately you can solve this problem using a quasi-linear conductivity.

Charge transport processes in plasma-like media in the relaxation approximation are described by the kinetic Boltzmann equation. In steady state, homogeneous and isotropic case, the solution of the kinetic equation can be represented as a functional series:

$$f_1 = f^{(1)} + f^{(2)} + f^{(3)} + \dots ,$$

where f_1 is the non-equilibrium distribution function, $f^{(1)}$ is the function, linear by electric field E, function $f^{(2)}$ is the proportional to E^2, function $f^{(3)}$ is the proportional to E^3, and expressions for these functions:

$$\begin{cases} f^{(1)} = -\mu(B^2)\left\{\mathbf{E} + \frac{\mu}{c}[\mathbf{E}\times\mathbf{B}]\right\}\mathbf{p}\frac{df_0}{d\mathrm{E}}, \\ f^{(2)} = \mu(B^2)\left(\frac{df_0}{dW} + \frac{p^2}{m^*}\frac{d^2 f_0}{dW^2}\right)q\tau E^2, \\ f^{(3)} = -q\tau\mu^2(B^2)E^2\left(3\frac{d^2 f_0}{dW^2} + \frac{p^2}{m^*}\frac{d^3 f_0}{dW^3}\right)\left\{\mathbf{E} + \frac{\mu}{c}[\mathbf{B}\times\mathbf{E}]\right\}\mathbf{p}, \end{cases}$$

where $\mu(B^2) = \frac{\mu}{1+(\mu B/c)^2}$, $\mu = \frac{q\tau}{m^*}$ is the charge carrier mobility, m^* is the effective mass, f_0 is the equilibrium distribution function, q is the electrical charge, τ is the relaxation time.

Full current in plasma-like medium equals:

$$\mathbf{j}(t,\mathbf{r}) = q\int \mathbf{v} f_1(t,\mathbf{r},\mathbf{p})d^3p = \sigma(E^2,B^2)\left\{\mathbf{E} + \frac{\mu}{c}[\mathbf{E}\times\mathbf{B}]\right\},$$

where, taking into account the quadratic nonlinearity, quasi-linear conductivity $\sigma(E^2,B^2)$ has the form:

$$\sigma(E^2,B^2) = 3q\mu(B^2)\left(1 - 3\frac{q\tau\mu(B^2)E^2}{\theta}\right)(2\pi m^*\theta)^{\frac{3}{2}} .$$

In that way, for calculating the response of the nonlinear magneto-plasma-like medium on the external impact, you can use just one function. Obviously, the quasi-linear conductivity satisfies the Onsager reciprocal relations.

Analysis of Magnetic Microtopology

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The technological characteristics of quality, such as the absence of unacceptable defects, compliance with the physical and mechanical properties and structure of the base material and coating, etc. are the important criteria for high quality machine parts, tools, instruments. The priority in the field of nondestructive methods of control is the creation of computer diagnostic systems, providing a classification of defects in the process of automated control. The parameters of defects can be determined by fitting the parameters of a mathematical model describing the scattering of the field defect. The increase information content of measurements is required for determination of the defect parameters, that is, substantial increase as the number of measurement points, and the number of values defined at each point. In cases where it is important to know not only the approximate total amount of defects, but also to determine their number, there is a problem resolution of defects, which can be solved by having the most accurate information about microtopology field.

The film Hall sensor is best to apply for the micromagnetic tomography. It is usually assumed that such a sensor measures the mean integral of the square sensor value of the magnetic induction. The results of the work show that the spatial resolution of Hall sensor on the order of magnitude less than the most sensitive element, that is 0.1 mm, and it may be relatively easy improved considerably. Systematic errors of the Hall sensor, due to residual voltage, displacement of meter, as well as the magnetic field of the control current sensor are also eliminated by using a special algorithm for measurement. The tests of the tensor components of the magnetic stray field of the hidden natural defects in the steel rods with a sensor, consisting of three inverters Hall ПХЭ602117А with a slope of conversion of about 800 μV/mT, produced by LLC "Sensor", were performed. Transmitters were located in a brass sleeve around the circumference of the rod under angle of 120° relatively to each other. The signal from each sensor was proportional to the magnetic field component normal to the surface of the rod and processed by the measurement module, which was built by the scheme of precision magnetometer. The data from the modules in a digital form entered to the digital processing unit that performed synchronous operation of the modules and data transfered to PC for further processing.

Through an accurate analysis it has been possible to detect defects with the characteristic size less than 0.015 mm. The coincidence of the results of the tensor magnetic microtopology of natural defects with the results of metallographic control confirms the validity of the method.

Growth of Semi-Polar GaN/InGaN on V-Grooved 7°-off (100) Si Substrates by Metal-Organic Chemical Vapor Deposition

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GaN-based semiconductors have been used widely for optical and electronic devices. Although extensively used for GaN epitaxy, sapphire substrate is limited by its small wafer size and low thermal conductivity compared to Si. The growth of high quality GaN-based devices on Si substrates has therefore attracted a great deal of interests. Due to the compatibility of crystal symmetry, most of the works to date are done on (111) Si substrates and result in (0001) GaN, a polar crystallographic plane, on which InGaN/GaN quantum wells have high polarization fields. For optical devices, such as light-emitting diodes (LEDs), non-polar and semi-polar GaN planes are desirable as they exhibit lower spontaneous polarization field than the polar (0001) GaN and performance in both luminescence efficiency and wavelength variation of the devices are expected to be better. For this purpose, semi-polar GaN on 7°-off (001) Si substrates is proposed.

In this talk, we will demonstrate the growth of crack-free semi-polar (1-101) GaN and (1-101) InGaN/GaN MQWs on V-grooved 7°-off (001) Si substrates. Excitation-power dependent and time-resolved photoluminescence measurements confirm that the internal electric field is reduced and the luminescence efficiency is increased for the (1-101) InGaN/GaN MQWs compared to the (0001) InGaN/GaN MQW on (111) Si. Detailed growth issues, structural properties, and optical properties assessed by scanning electron microscopy, transmission electron microscopy, atomic force microscopy, cathodoluminescence, photoluminescence, Raman scattering as well as X-ray diffraction will be discussed.

PHYSICS AND MECHANICS OF NEW MATERIALS IN SOUTHERN SCIENTIFIC CENTER OF RAS

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We presents an overview of the results obtained in the Southern Scientific Center of the Russian Academy of Sciences in the study of physics and mechanics of new materials, and development of methods for their synthesis, as well as the development of thin-film technology.

The new technological methods for creating the high perfection nanoscale ferroelectric heterostructures allow us to fabricate the ferroelectric structures with a thickness from 6 up to 1000 nm.

The newly developed multilayered ferroelectric heterostructures with the properties of the superstructure use fundamentally different substances, not only in composition but also with a different type of symmetry of the unit cell. The superstructure is a twenty pairs of alternating layers of $(Ba,Sr)TiO_3$ – $BiFeO_3$ with a thickness of each layer from 2 nm up to 6 nm.

As the most promising materials for power electronics the large-scale high-quality single crystals of 6H-SiC (silicon carbide) with a thickness over 30 mm were developed.

The technology for synthesis of epitaxial films 3s-SiC/Si of cubic silicon carbide on a silicon substrate is developed. This method is based on a preliminary covering of a buffer layer on the surface of a silicon wafer with thickness of 10 – 20 nm, next by the synthesis of silicon carbide films. The use of the buffer layer excludes the large distortions of lattices for SiC and Si, thus allows one to obtain a high-quality oriented single-crystal film of silicon carbide.

By using the techniques of gradient epitaxy and ion-beam deposition the nanoheterostructures with an array of quantum dots of compounds A^3B^5 and Ge/Si are obtained.

New technology for manufacturing of luminophores with submicron particle sizes is developed and distributed for the use in electronics, lighting products and light-transforming materials.

We reported also the new red glow photo-luminophor, which converts UV light into the red. On its basis, the polyethylene film for greenhouses and hothouses is created, which transform the part of ultraviolet radiation into the visible red-orange light, providing a significant bio-stimulation effect on the cultivated plants.

RESEARCH OF THE OPPORTUNITY TO USE OF MISM STRUCTURES FOR COOLING OF LIGHT-EMITTING DIODES

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As one of the reasons for the degradation of light-emitting diodes (LED) is that they overheat, in order to decrease this effect it is proposed to use cooling devices. The basis of the cooling device is the structures of the metal-insulator-semiconductor-metal (MISM structure) such as the field-effect transistor. MISM structure is a capacitor that is charged through the bottom electrode and the resistor connected in series to a voltage U_0, and discharged through the near-surface charge (through connected together drain and source) and through the same resistor to a voltage U. The magnitude and polarity of the voltage on the capacitor is chosen so that the concentration of electrons in it would be much greater than in the bulk semiconductor, resulting in the disappearance of the barrier layer between the near-surface charge and metal, contacting with it. The electrons in the near-surface charge at a high concentration of electrons are in a degenerate state, which does not characteristic of the presence of barrier layers in metal-semiconductor contact. When charging through the bottom electrode, the electrons pass from metal to semiconductor, overcoming the potential barrier is equal to the U_k.

This can be done only by the most energetic or "hot" electrons. Therefore, in contact with excess there are less energetic or "cold" electrons, and it is cooled, as they are, coming to a thermodynamic equilibrium with the lattice of the metal, taking away from its energy (Peltier effect). In this case the absorbed heat energy (i.e. kinetic energy) is converted into potential energy of a charged capacitor. The discharge through the near-surface charge of the heat released in the contact is much less than the absorbed by the bottom electrode, contacting with the substrate, since the Peltier coefficient in contact of the metal with the near-surface charge is much less because of high electron density and the capacitor is cooled during charging and discharging.

Thus, the proposed structure will only be cooled, i.e., will not have a hot side, in contrast to existing refrigeration and absorbed heat is converted into electrical energy, thus reducing the energy consumption of cooling devices. Moreover, MISM structures are produced by the integrated-circuit technology and will be good agreed with LED matrices.

IDENTIFICATION OF STIFFNESS PARAMETERS OF NON-LINEAR ELASTIC REINFORCED BEAM

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A lot of research has been devoted to the problems of nondestructive testing of the load-bearing units made of reinforced materials. However, so far the problem of authentic determination of physical and mechanical properties of the multiphase material components is still unsolved. Direct measurement of the integral stiffness of particular elements of the structure without violation of its integrity is mostly impossible. As a consequence, indirect estimates appear to be of great importance for non-destructive testing, based on mathematical models of full-scale tests of diagnosed objects.

We propose a method of identifying stiffness parameters of reinforced concrete beams according to full-scale experiment data on the basis of interpretation of non-destructive testing using their mathematical model. It is assumed that the beam during operation has experienced a fire impact, which resulted in the thermal destruction of the surface layers - the upper and/or bottom. The task of identification is to determine the thickness of damaged layers.

The following tasks have been stated and solved: (i) the model of the static deformation of structures with variable stiffness parameters for calculating state variables under given conditions has been developed, (ii) the approximation of the response function with physical and mechanical variables of the material which determine the rigidity of the structure to improve the calculation efficiency has been constructed, (iii) the algorithm for computing the point and interval estimates of required stiffness parameters according to full-scale tests has been developed, (iv) the computer identification programs have been worked out.

Low-Temperature CO Gas Sensors Based on Cobalt-Containing Polyacrylonitrile

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The development of gas sensors to monitor toxic and combustible gases is actual due to it concerns about environmental pollution. In recent years conductive films of polyconjugated polymers have been studied intensively. That kind of organic polymer can find widespread commercial application in gas monitoring as a gas-sensitive layer in semiconductor gas sensors. Polyacrylonitrile (PAN) is the organic polymer, which linear form represents dielectric, after heat treatment gains semi-conductor nature of conductivity thanks to structural transformation of a polymeric chain. Therefore thin-film polymer films based on cobalt-containing IR-pyrolyzed PAN are perspective materials for low-temperature gas sensors for carbon monoxide (CO).

Gas-sensitive layer of sensor represents a film of a semiconductor nanocomposite material, which consists of PAN and the dopant (Co content by weight: 0.25%, 0.5%, 0.75%, 1%), formed on a dielectric substrate. The method of formation of gas-sensitive material is pyrolysis with the influence of incoherent infrared radiation. IR-annealed films of PAN/Co was carried out at a low vacuum ($8 \cdot 10^{-2}$ mm Hg. Cent.) in two stages. The films were processed at 250 – 300 °C of the IR-annealing for 15 – 20 minutes at the first stage, and at 350 °C of the IR-annealing for 2 minutes at the second stage.

To study the gas-sensing properties of a material of the received cobalt-containing PAN films was measured their resistance on teraommetre E6-13A. Sensitivity of the films was estimated by means of the sensitivity coefficient S, which is calculated as $S = (R_g - R_0)/R_0$, when $R_g > R_0$, where R_0 is the value of the film resistance in air, R_g is the value of the film resistance in the atmosphere of detected gas.

As a result of the carried out researches, it is established that materials which are based on the films of PAN/Co with rather high degree of resistance ($10^9 - 10^{11}$ Ohm) possess sensitivity to CO

(S = 0.44 – 0.58) at working low temperatures (18 – 25 °C) and the concentration of detected gas being in an interval of 250 – 400 ppm.

Advantages of the films based on cobalt-containing PAN are that they react to gas reducer (CO) at working room temperature, unlike the majority of known inorganic gas sensing materials that allows creating non-heater sensors of carbon monoxide.

EFFECT OF $CaTiO_3$ ADDITION ON PHYSICAL AND ELECTRICAL PROPERTIES OF $Na_{0.52}K_{0.48}NbO_3$ LEAD-FREE PIEZOELECTRIC CERAMICS

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$(K_{0.5}Na_{0.5})NbO_3$ (KNN) is considered to be one of the most promising candidates for lead-free piezoelectric ceramics because of its very high Curie temperature (420 °C) and large electromechanical coupling factors (k_p ~ 0.36). For the purpose of further improving its properties, various amounts of $CaTiO_3$ (CT) (0 – 7 mol%) were added into $(Na_{0.5}K_{0.5})NbO_3$ ceramics by using the conventional mixed oxide method in this study. The doped ceramics were characterized by X-ray diffraction analysis, scanning electron microscopy, X-ray photoelectron and Raman spectroscopy to study their composition and microstructure. The dielectric, piezoelectric and ferroelectric properties were also measured.

Correlated with the changes of the crystal structure, phase transition, defect and electric properties with the composition variation, relationship among microstructures, physical and electric properties were studied in the present work. Experimental results showed that the addition of $CaTiO_3$ is very effective in preventing the deliquescence and in improving the density and electric properties of the ceramics. The important results are summarized as the followings: First, $(1-x)$ $(Na_{0.5}K_{0.5})NbO_3 – xCaTiO_3$ solid solution system can be successfully synthesized and the relative density of sintered bulks of each composition can achieve 95% or higher. At the doping amount of (x = 0.03), the ceramics with grain size of about 1 μm have the best domain switch-ability. The leakage and X-ray photoelectron spectroscopy (XPS) results indicate that addition of $CaTiO_3$ is very effective in preventing the deliquescence and to decrease the overall electrical conductivity, but it can increase oxygen ion conductivity. The best remnant polarization of (P_r = 21 μC/cm^2) can be achieved for the ceramics with x = 0.03. The transformation of normal ferroelectric characteristics to relaxor-like ferroelectric ones is found for the ceramics in the composition range ($0.03 \le x \le 0.05$). The experimental results can demonstrate the relation of the MPB composition, electron-negativity and tolerance factor t value, consequently, providing a method for designing new piezoelectric materials. Second, the phase transformation is found to be changed with composition. For composition with x = 0.03 the orthorhombic-tetragonal phase transition appears to be near room temperature. This material corresponds to morphotropic phase boundary between orthorhombic and tetragonal ferroelectric phases and thus exhibits the optimum properties: d_{33} = 117 pC/N, k_p = 0.39, P_r = 21 μC/cm^2, and T_C = 333 °C.

New Decisions in Hydroacoustics and Acoustics Made by Innovational-Educational Center "New Materials" of SFU

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1. The technologies of obtaining new materials including lead-free piezoactive ones and products on their base have been developed. These technologies include the whole innovational cycle from the fundamental research and final-element computer modeling to optimization and manufacturing of new generation receivers and emitters. A new method for such production has been developed and can be applied to solve the similar Customer's tasks.

2. Piezoceramics with very high sensitivity in frequency band from units to hundred thousands of Hz. It allowed one to create a new type of highly effective broad-band hydrophones (Fig.1), receiving hydroacoustic elements, vibro-receivers, etc. Thus, on the base of new vibro-receivers there have been created contact-bone microphones that are able to register speech by human head bone tissue vibration which allows one to lead the conversation on the background of any outward noise. Contact microphones can also be applied as sensors in search devices designed to detect living people under the blockages. They can also register heart functioning as well as other acoustic signals of survivors through concrete and reinforcement. In this aspect they surpass the abilities of existing analogues and dogs.

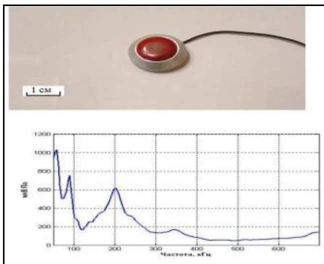

Fig. 1.
A new type hydrophone and its sensitivity characteristics

Fig.2
Protection of the beaches against the sharks

3. Multielement highly effective hydroacoustic emitters including those with 55 – 120 kHz work band have been developed. These emitters in combination with new type receivers may become the base for water area security system including, for instance, protection of beaches against sharks (Fig. 2).

4. New type of acoustic emitters including mini-sirens of advanced power with high specific acoustic efficiency characteristics (mass, volume and energy consummation) have been developed.

5. For the first time the acting model "Light from vibration" was created on the base of electric energy piezogeneration from the vibration source with 35 Hz frequency and the other product developments.

Simulation and Experimental Testing of Piezocomposites with Regular Structure

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Piezocomposites with a regular structure, due to the high acoustic impact, low-transverse piezoelectric and acoustic impedance, and a number of other specific characteristics are to be perspective as ultrasonic emitters for destructive testing, devices of medical ultrasound diagnostics and other applications. The properties of this class of composites depend on the nature of their piezoelectric and organic phases, technology, and a variety of dimensional characteristics. Due to the statement of "opportunities" and optimization of the properties of these piezocomposites is rather complicated for the experimental study of multi-factor problem, which, despite the great interest to these materials and their practical importance, is far from solution.

We have carried out a study which combined and mutually complemented by mathematical modeling and experimental testing composites of piezoelectric and organic phases with a regular structure, corresponding to 1-3 and 1-3-2 connectivity. Here we have solved the following problems: (i) developed a parametric finite-element mathematical model of this class piezocomposites for software ANSYS, (ii) developed technology that allowed one to process new two-phase piezocomposites with a regular structure (Fig. 1) and tested methods to optimize their properties by the complementary mathematical modeling and experimental testing, (iii) discovered the influence on the properties of composites with the 1-3 and 1-3-2 connectivity of the piezoelectric nature and organic phases, as well as the dimensional characteristics of their structural components, including the effect of the cross-section of the piezoelectric elements into size range from 0.1 to 1.0 mm.

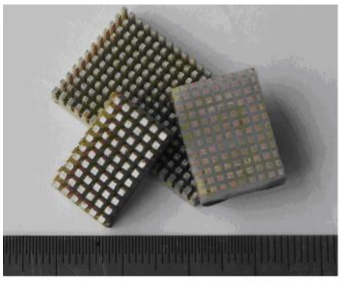

Fig. 1. Piezocomposites with a regular structure

As a result, a general picture of changes in the resonance frequency and acoustic activity piezocomposites of this class has been stated in dependence on the size and complex technological factors.

This work was partially supported by RFBR (grant numbers 10-08-01296-a, 10-01-00194-a, 10-08-00093-a, 10-08-13300-RT_omi, 12-08-91165-NNSF_A).

On the Reconstruction of the Properties of the Non-homogeneous Poroelastic Media

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At present time the investigations in the field of poroelastic media have taken on special significance. This is due to increasing interest in new materials such as porous piezoceramics, porous structures in living organisms (bone tissue) and moist grounds. Note that simulation of the bone tissue requires the model consisting of two phases at the least; most often such medium contains two phases. The various processes of fluid filtration in the ground under nonstationary loads, in addition to deformations and sediment, can be successfully described by porosity models. We note two models of poroelastic medium – when the latter includes fluid and gaseous phases.

Nowadays, the Biot model is one of the most popular models used for description of poroelastic media. At that, the basic unknown quantities are the displacement vectors of solid and fluid phases. Many scientists dealt with the problems of the vibrations of poroelastic media including heterogeneities of canonical forms. Sufficient number of numerical results has been received for different poroelastic media. The explicit integral approximations of the wave fields in porous media for problems with simple geometry of layer and half-space types were obtained earlier in researches by V. M. Seymov, A. N. Trofimchuk, O. A. Savitskiy, Jian-Fei Lu, Dong-Sheng Jeng, Yuanqiang Cai and others.

At the same time, there is also a second model which is popular enough and contains fewer variables; the unknown quantities are the components of the displacement vector of solid phase and the pressure in pores. In the limits of the model described in the present paper the general formulation of the problem of steady-state vibration of the three-dimensional poroelastic body is considered. The weak formulation of the problem and the functional of Hamilton type are given; from the stationary condition of the latter the equations and the boundary conditions of porosity can be derived. By means of adding corresponding hypotheses and simplification of the functional the particular formulations of direct problems for poroelastic non-homogeneous rods and layer-like structures are obtained. The direct problems solutions are calculated using the shooting method.

The inverse problems on the identification of the elastic material modules of rod and layer are formulated. For solving the inverse problems the acoustical method and reduction to the iterative process is used. As additional information the data on the displacement field at the boundary part in the set of oscillation frequencies is considered. On the basis of the reciprocity principle the operator equations which bind together the given and unknown characteristics of the problem are formulated. Each iteration of the process of solving the inverse problem consists of solving the direct problem and the integral Fredholm equation of the first kind.

The results of the reconstruction of the elastic modules for problems on the longitudinal vibration of the column and vibration of the poroelastic layer are presented.

The present work is done with the support of Russian Foundation for Basic Research "Development of new methods for identification of localized and dispersed heterogeneousness in solid bodies" (Project Code 10-01-00194-a) and Federal Target Program "Scientific and Research-and-Educational *Staff of Innovative Russia" on 2009 - 2013 years (State Contract No. P596).*

THE USE OF HALF-WAVELENGTH MATCHING LAYERS TO FORM THE OPTIMAL PULSE RESPONSE OF IMMERSION ULTRASONIC TRANSDUCERS

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For high precision ultrasonic measurements in non-destructive testing, medical diagnostics and other ultrasonic applications, immersion ultrasonic transducers with a specific impulse response combining a short-pulse response with high efficiency and low reverberation noise are needed. The fabrication of such transducers involves a number of technological problems such as the deposition of multiple quarter-wavelength matching layers, the development and application of effective dampers, or the use of advanced composite piezomaterials. All of this leads to a significant increase in the cost and complexity of the manufacture of such transducers. However, there are a number of applications that do not require maintaining a low level of reverberation noise. In particular, for some applications in thickness gauging it might be sufficient that the amplitude of the second “half-wave” of the ultrasonic pulse exceed the remaining “half-waves” of the same polarity on 6 dB only. This allows one to use instead of multiple quarter-wavelength matching layers a "locking" half-wavelength matching layer, which can transmit to immersion medium relatively free two of first “half-waves” of an ultrasonic pulse emitted by piezoelement of ultrasonic transducer, but prevents the passage of all subsequent “half-waves”. The use of such a layer can significantly simplify the transducer design by reducing the number of matching layers and a twofold increase in the thickness of the remaining half-wavelength matching layer that is extremely important for high frequency transducers. This, in turn, can significantly (up to 2 times or more) reduce the cost of ultrasonic transducer manufacture. For the new design concept realization the experimental samples of ultrasonic immersion transducers with a half-wavelength matching layers were developed and tested. For comparison the reference ultrasonic transducers of the same design but with quarter wavelength matching layers were also fabricated. The center frequency for all of ultrasonic transducers was equal to 5 MHz. The comparison showed that the coefficient of double conversion for transducer with a quarter-wavelength layer is on 30% higher than for half-wavelength one. The duration of the ultrasonic pulses at 6 dB, 20 dB and 30 dB levels for the half- and quarter-wavelength transducers were measured as 0.1 ms and 0.3 ms, 0.9 and 0.6 ms and 1.2 and 0.8 ms, respectively. Thus, the ultrasonic transducers with a half-wavelength matching layer are inferior in all respects except for the key property: the duration of the ultrasonic pulse at the level of 6 dB that determines the measurement accuracy. On this parameter the half-wavelength transducer surpasses a quarter wavelength analog in 3 times. This feature allows creating technological and efficient pulsed immersion ultrasonic transducers with a half-wavelength matching layer.

EFFECT OF THERMODYNAMIC PREHISTORY ON THE EVOLUTION OF DIELECTRIC SPECTRA OF BISMUTH FERRITE

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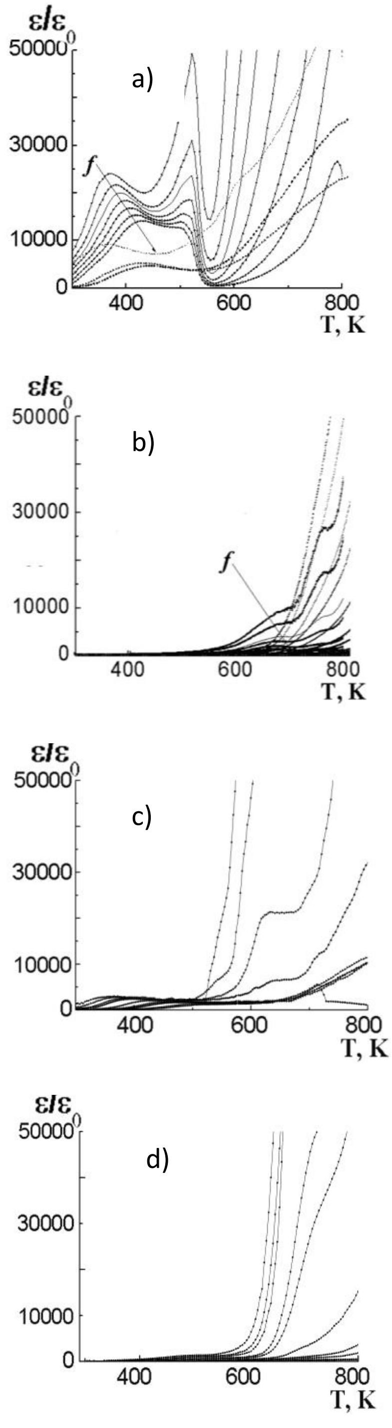

Multiferroics is the large group of functional materials that combine ferroelectric, ferromagnetic and ferroelastic behavior. One of the most intensively studied multiferroic bismuth ferrite is ($BiFeO_3$), which has antiferromagnetic (T_N = 643 K) and ferroelectric (T_C = 1103 K) properties over a wide temperature range. But its practical application prevent the structural and thermodynamic instability caused by the border situation in the perovskite family, as well as the proximity of the sintering temperature and thein congruent melting, which leads to difficult to exclude impurities, and as a consequence, high electrical conductivity. In addition, for this compound is characterized by the critical instability of the dielectric properties at temperatures close to room temperature.

This work is aimed at eliminating the above-mentioned negative factors.

Figure 1a shows the temperature dependence of the relative permittivity $\varepsilon/\varepsilon_0$ $BiFeO_3$, resulting in the traditional way (by the usual ceramic technology, OCT). Using the method of mechanical activation of precursors, we were able to move the low-temperature peaks in the region of higher temperatures (Fig. lb), however, exclude the inherent $BiFeO_3$, the impurity was not possible. Application of the combined method, "hardening" (heating to 800 ºC (Fig. 1c), 850ºC (Fig. 1d) and quenching to room temperature) and mechanical activation allowed us to completely eliminate impurities from the high iron content ($Bi_2Fe_4O_9$) and to reduce the impurity content, enriched with bismuth ($Bi_{36}Fe_2O_{57}$). Thus, It has been established the effect of thermodynamic history (conditions for obtaining $BiFeO_3$) on its dielectric properties.

Fig. 1. Temperature dependence of $\varepsilon/\varepsilon_0$ for ceramic $BiFeO_3$, obtained by OCT (a), using mechanical activation (b) and the combined method (c, d)

This work was financially supported by the Ministry of Education and Science, State Contract No. 16.513.11.3032.

Cu_2ZnSnS_4 Solar Cell Material Prepared by Spin-Coating Metal Chloride Precursors and Treated with Post-Synthesizing and Annealing

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Cu_2ZnSnS_4 (CZTS) thin films applied for solar cells were prepared by sol-gel spin-coated method. The as-coated films were treated with post-synthesizing and annealing processes. CZTS precursors were prepared by using solutions of copper (II) chloride, zinc (II) chloride, tin (IV) chloride, and thiourea. The post-annealing process was found to have a great influence on the properties of CZTS films. Less other than CZTS phases of SnS and SnS_2 are observed in the as-annealed CZTS films. The precursors were prepared using the close stoichiometry ratio of $CuCl_2 : ZnCl_2 : SnCl_4 : CH_4N_2S = 4 : 1 : 1 : 8$, where $SnCl_4$ is of 1 mol/l. The SEM images show uniform surface morphology of as obtained CZTS films. In this work, the CZTS with an average absorption coefficient, and optical energy gap of over 10^4 cm^{-1} and ~ 1.5 eV, respectively, is obtained, and has the crystallinity with a cupper-poor composition.

Novel Optical Means for Measurement of Displacements of the Control Object Surfaces at State Diagnostics of Materials and Goods

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Today, one of the most perspective scientific directions for solution of practical problems of the goods state diagnostics and experimental studies of damage processes in novel materials is the development and use of high-precise measurers of the control object surface displacements based on implementation of laser interferometers. This allows one to increase significantly accuracy and informative of analysis of the elastic wave fields at ultrasound defectoscopy, state diagnostics of goods by acoustic-emission method, etc.

The main directions of improving themselves laser interferometers for solution above-mentioned problems are connected with development of new optic schemes of the interferometers, creation of new techniques of registration and handling information obtained from interference pictures, modernization of sources and receivers of the optical radiation and also extension their possibilities that allows one to account for continuously various influencing factors with simultaneous fulfillment of correction and introduction of corrections into measurement results in real time scale.

Here, the theoretical and experimental studies of functional characteristics of the perspective optical interference measurer of displacement are conducted which allow ones formulate a set of actual directions for its improvement. There are grounded the novel methods of measuring displacements of control object surface, technical and technological solutions ensuring quality of measurement results and extending functional possibilities of the considered measurer of displacements. New results of theoretical and experimental supporting are obtained for these technical and technological solutions.

The proposed means have been successively applied in studies of damage formation into high-temperature superconductive tapes, and in development of technique for quality control during processing.

The proposed technical solutions and computer programs have been patented in Russia and successively used in solution of actual scientific and industrial problems. They have been presented at several international exhibitions and awarded by gold medals.

The proposed measuring means could be successively applied in the process of high-accuracy measurements of small linear and angle displacements of the control object surfaces at conduction test investigations of prospective constructions and estimation of their state, at the study of acoustic-emission processes and material damage in solids, at investigation of wave processes in layered constructions and constructions from anisotropic materials.

This study, in partially has been supported financially by Russian Foundation for Basic Research (Grant No. 10-08-00136).

VIBRO-STABLE OPTICAL MEASURER OF DISPLACEMENTS FOR MOBILE DIAGNOSTIC SYSTEMS

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Today, a significant shortage of known measurers of displacements, based on use of interference methods and applied to registration of small displacements of the control objects in state diagnostics of construction materials and goods, is a low accuracy of measurement results. It is caused by that what during measurements there are external non-stationary and, as rule accidental excitations (vibrations of technological test equipment? Influence of various nature, etc.). They transfer on a control surface from the base with stated on its control object and cause its additional displacements. This leads to insertion of accidental errors in the measurement results diminishing their accuracy. Therefore, a solution of the problem on compensation above-mentioned excitations is very actual one, especially for high-precise optical measuring means in complex of mobile diagnostic systems.

It has been developed perspective method of compensation of the external influencing loadings which realized in construction of known optical measurer of small displacements, extended its functional possibilities and provided account for influence of external excitation during measurements.

In order to confirm a principle possibility of realization of the proposed method and conduction its experimental ground, the experimental device has been designed and manufactured. Preliminary tests have been carried out and their analysis allows one to conclude on the possibility to realize the proposed method and solve the problem stated.

The proposed method could be extended on interference measurements in a whole and its application also allows one to increase a precise of the measurements. The proposed technical solution has been patented in Russia and presented at XIV Moscow International Salon of Inventions and Innovative Technologies “Archemedes-2011” where awarded by gold medal.

The proposed measurer can be successively applied in the process of high-accuracy measurements of small linear and angle displacements of control object surfaces at conduction of experimental studies of the perspective constructions and estimation of their state, at study acoustic-emission processes and damage in solids, at investigation of wave processes in layered constructions and constructions from anisotropic materials.

This study, in partially has been supported financially by Russian Foundation for Basic Research (Grant No. 10-08-00136).

Some Approaches to Finite Element Analysis of Piezoelectric Devices with Gyration Effects and Temperature Fields

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In the present work new models and numerical methods for dynamic behaviors of piezoelectric devices with rotation and temperature effects are presented. The special finite element techniques and computer programs are used for analyses of piezoelectric vibratory gyroscopes, piezoelectric transformers and biomedical ultrasound devices.

For piezoelectric vibratory gyroscopes, working on "energy trapped" effects, we introduce the small parameter [1, 2]. This parameter is the ratio between rotation frequency and principal resonance frequency. For modeling the work of such piezoelectric gyroscope we use the solution expansion in series with this small parameter. In first phase we solve the eigenvalue problems and the harmonic problem close to resonance frequency. Obtained mechanical displacements are stored in the nodes of finite element mesh for utilization in the next step. In the second phase we solve the problem with axial rotation and relative displacement in the resonance frequency. These Coriolis' forces are considered as nodal body forces. Developed methods are applied in the special program modules for finite element package ANSYS. The new piezoelectric finite elements with Coriolis' forces and axial rotation are built. In the results the optimization calculations for investigated new effective piezoelectric vibratory gyroscopes are realized.

For analysis of piezoelectric transformers and smart-devices with temperature effects we consider thermo-piezoelectric problems. In classical coupled system of thermo-piezoelectric equations the damping components are added. The finite element formulation of coupled thermo-piezoelectric problems in general case and in the case of partial relatedness is obtained.

Using additional macros in finite element package ANSYS it is possible to solve practically important problem about dissipative initial heating of piezoelectric devices under harmonic vibration. In particular, having solved in ANSYS the harmonic piezoelectric problem by standard way one can find the displacement field. Using this field we calculate averaged dissipative function. This dissipative function is further considered as additional thermal source in heat flow problem, which is solved in ANSYS. Note, that with the dependence of the modules of a piezoelectric body on the temperature, it is possible to determine new piezoelectric moduli for the changed temperature from the oscillation period, and to solve the harmonic piezoelectric problem again, and then to solve the problem on the dissipative heating. In the result we receive the iterative computing process described dissipative heating.

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References

[1] Nasedkin A.V. Some finite element methods and algorithms for solving acousto-piezoelectric problems / Piezoceramic Materials and Devices. Ed. I. A. Parinov. Nova Science Publishers, N.-Y., 2010. P. 177-218.

[2] Nasedkin A. Some approaches to finite element modeling of piezoelectric vibratory gyroscopes and multilayer transformers // IMF-ISAF-2009. 12th International Meeting on Ferroelectricity and 18th IEEE International Symposium on Applications of Ferroelectrics. Abstract CD. August 23-27, 2009, Xi'an, China. Abstract JO-012.

MULTISCALE COMPUTER SIMULATION OF PIEZOELECTRIC DEVICES WITH ELEMENTS FROM POROUS PIEZOCERAMICS

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Porous piezoceramic materials have received considerable attention due to their application in ultrasonic transducers, hydrophones and other piezoelectric devices. Porous piezoceramics have ultra-high volume piezosensitivity, broadened operating frequency range and lower impedance comparing to the dense ceramics, giving a better acoustic agreement between piezoelectric and acoustic media. On the other hand, its thickness piezoelectric module remains almost the same as for the dense ceramics.

The methodology of the computer modeling consists in the following steps. At microlevel, to calculate the effective moduli of 3-0 and 3-3 porous piezocomposites, we use an approach based on the effective moduli methods, and by the finite element (FE) modeling of representative volumes [1, 2]. FE models of high-porous ceramics assuming the heterogeneity of the polarization vector for a variety of piezoelectric finite elements were developed.

For the numerical determination of the effective moduli the sets of the static piezoelectric problems were solved with boundary conditions, which guarantee the constant values of electric displacements, strains, stresses and electric fields for homogeneous material. The finite element computations were implemented using the computation package ANSYS, and specially developed computer programs were written in macro-language APDL ANSYS. At that, the generation of the range of the representative volumes structures was carried out using separate C++ programs, developed by Remizov V., with the subsequent transfer of solid and finite element models to ANSYS. The effective moduli for different types of porous piezoceramics were calculated. A comparison of these basic characteristics for porous piezocomposites with the experimental data, obtained at the Research Institute of Physics, (Southern Federal University), was presented and discussed. On the macrolevel we investigate 1-3 piezocomposite (piezoelectric generator), hydro-acoustic projectors made of solid ceramics with intermediate non-piezoelectric layers and piezoelectric emitter from porous piezoceramics without such layers. From the FE solutions of static and dynamic problems we conclude a good efficiency of high porous piezoceramics for quasistatic and low-frequency applications in piezoelectric energy harvesters, as its piezo-sensitivity rapidly increases at the porosity growth. We also justify the preference of porous ceramics for different hydro-acoustic ultrasonic applications.

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References

[1] Nasedkin A. V., Shevtsova M. S. Improved finite element approaches for modeling of porous piezocomposite materials with different connectivity / Ferroelectrics and Superconductors: Properties and Applications. Ed. I. A. Parinov. Nova Science Publishers, N.-Y., 2011. Ch.7. P.231-254.

[2] Domashenkina T. V., Nasedkin A. V., Remizov V. V., Shevtsova M. S. Finite element modeling of porous piezocomposite materials with different connectivity and applications for analysis of ultrasonic transducers // Proc. 7th GRACM Int. Congress on Comput. Mechanics, Athens, Greece, June 30 – July 2, 2011. CD. Paper 141. 10 p.

MULTI-SECTIONAL SUPERCONDUCTING MAGNETIC ENERGY STORAGE (SMES) FOR RAILWAY TRACTION APPLICATIONS

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Because of non stationary graphics of power consumption railway traction applications such as electric power supply system and autonomous locomotives with electric power transmission are the technical branches for those energy storage devices usage is a question of the time and cost only. SMES is one of the best-fit candidates. The goal is recuperation to SMES braking power of locomotive's traction motors. In SMES this energy can be stored for a time. And, while the power from railway substation or traction generator is insufficient for traction force realization or auxiliary needs, it is possible to use stored in SMES power for additional or only supply of locomotives.

We developed a scheme for SMES integration to traction electric power supply system or autonomous rail locomotive electric power transmission. This scheme is based on DC-DC converter technology. The converter can be used not only with DC-DC electric systems but with AC-DC (in presence of input rectifier) or with AC-AC (in presence of input rectifier and output autonomous inverter) electric systems.

Most effective and flexible functioning this scheme can be achieved by sectionalizing SMES. There are variants: number of SMES devices parallel junction or sectionalized coil in the only SMES. Technical decision with multi-sectional SMES permits to organize several power supply channels with separate or mutual-dependent control. For example, it is possible to charge one section of SMES from energy source, discharge the second section to the load and keep the third in a mode of current storage. But synchronization of SMES sections work is possible, too. Some modes of multi-sectional SMES are simulated by computer model.

Phase Composition and Piezodielectric Response of Solid Solutions of a Multicomponent System with a Different Nature of the Ferroelectric Behavior

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Possible applications of ferroelectric ceramic materials in the devices affected by the external factors provide the ground for this study, which aims at examining the properties of active materials under cyclic temperatures, electrical and mechanical stresses, and so on. Furthermore, recently, in developing new high-performance piezoelectric materials attempts have been made to move from two- and three-component systems to multicomponent ones, with the main tendency being driven in the direction of choosing relaxor materials as their basis. Such a choice is called for the ability of relaxors to possess giant dielectric and piezoelectric responses that are usually realized in statistical mixtures and piezocomposites characterized by the excessive complexity of the preparation. The ability to combine such characteristics within the scope of one mono-system using a simplified technology without a great number of components, has predetermined the development of a new multicomponent system of solid solutions (SS) based on two well-known, practically important, and extensively used binary $PbTiO_3$ – $PbZrO_3$ (PZT) and $PbNb_{2/3}Mg_{1/3}O_3$ – $PbTiO_3$ (PMN–PT) systems, which form the basis of virtually all known ferro-, piezoelectric, and electrostrictive materials. The present study is devoted to a detailed investigation of crystal structure, dispersion, piezoelectric and elastic properties of perovskite multicomponent SS showing the different nature of the ferroelectric behavior, and on selection of promising compounds for further development with an emphasis on practical applications.

The system has been studied with five sections situated in the Gibbs triangular along the isotherms (axis), one of them represented the binary PZT system, and another one – the PMN-PT system. These sections corresponded to $PbNb_{2/3}Mg_{1/3}O_3$ and $PbZrO_3$ contents of 5 and 10 mol.% respectively, and constant $PbNb_{2/3}Mg_{1/3}O_3$ and $PbZrO_3$ proportions.

Several groups of materials have been chosen from the variety of available solid-solution compositions. Their properties conformed to those in regular ferroelectrics, ferroelectrics with diffuse phase transition, and relaxor ferroelectrics. And, finally, the best compounds have been chosen (selected) to satisfy the aim of the present investigation. Values of dielectric $P(E)$ and electromechanical $\xi_3(E)$ hysteresis have been calculated from the measurements which were performed in the strong bias fields. Information on the evolution of the dielectric spectra and parameters of diffuseness with the compositional changes is also presented. Correlations in the parameters behavior of the solid solutions studied have been identified as well the relations between those and defect subsystem changes in the variation of composition have been emphasized.

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DIELECTRIC RETARDATION AND RELAXATION IN $PB_{1/2}NB_{1/2}O_3$ CERAMICS

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Lead ferroniobate $PbFe_{1/2}Nb_{1/2}O_3$ (PFN) is a multiferroic in which the electric and magnetic orders coexist [1, 2]. Earlier, when studying the PFN ceramics, we detected an anomalous behavior of the relative permittivity and dielectric loss in the vicinity of the Néel (T_N = – (100 …130) °C) and Curie (T_C ~ 98 °C) temperatures [3]. The aim of this work is to state the regularities of forming the dielectric properties of the PFN ceramics in the temperature range 20 … 400 °C based on detailed studying the dielectric spectra in the frequency range 1… 10^5 Hz.

For a linear medium, it is accepted to distinguish the dielectric retardation and dielectric relaxation. This difference is due to the specific features of the behavior of the complex dielectric permittivity $\varepsilon = \varepsilon' - i\varepsilon''$ under the action of voltage (retardation) and complex electric modulus $M = 1/\varepsilon$ under the action of charge (relaxation) [4, 5]. The ratio of the average retardation and relaxation time constants is represented as $\tau_\varepsilon / \tau_M = \varepsilon_s/\varepsilon_\infty$, where ε_s and ε_∞ are the static dielectric permittivity and high-frequency dielectric permittivity, respectively. This relation is strictly valid only for Debye dielectrics, semiconductors and ferrites.

However, for non-Debye dielectric materials, the aforementioned relation can appear incorrect and, therefore, is to be checked. With this aim we have studied a single-component material with the rectangular distribution function $f(\tau)$ of the relaxation times, $f(\tau) = h$ = const within the interval $\tau_1 \le \tau \le \tau_2$ and $f(\tau) = 0$ at $\tau < \tau_1$ and $\tau > \tau_2$ (here, $f(\tau)d\tau$ is the probability that the relaxation time is in the interval from τ to $\tau + d\tau$) [3]. A relaxation oscillator in such a material can be described at a microscopic level by the model of a deep potential well with two equilibrium positions divided by a potential barrier (so-called the Fröhlich oscillator [4]).

The results of our treatment of experimental data [3] for $\varepsilon_s = 42 \cdot 10^3$, $\varepsilon_\infty = 3 \cdot 10^3$, $\tau_1 = 0$, $\tau_2 = 7.5 \cdot 10^{-5}$ s at temperature T = 250 °C have shown that $\omega_r^\varepsilon \approx (\tau_1 + \tau_2)/2 \approx 0.264 \cdot 10^5 << \omega_r^M \approx 8.9 \cdot 10^5$ rad/s. The non-Debye character of dielectric spectra consists in the large distinction between the dielectric retardation (ω_r^ε) and dielectric relaxation (ω_r^M) frequencies.

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References

[1] G. A. Smolenskii, I. E. Chupis // *Sov. Phys. - Usp*. **25** (7), 475 (1982).

[2] H. Schmid // *J. Phys.: Condens. Matter* **20**, 434201 (2008).

[3] A. V. Pavlenko, A. V. Turik, L. A. Reznitchenko, L. A. Shilkina, G. M. Konstantinov // *Phys. Sol. State* **53**, 1872 (2011).

[4] H. Fröhlich. *Theory of Dielectrics* (Clarendon, Oxford, 1958).

[5] J. Jäckle, R. Richert // *Phys. Rev.* E **77**, 031201 (2008).

DIELECTRIC, PIEZOELECTRIC AND MÖSSBAUER STUDIES OF PEROVSKITE MULTIFERROICS AND SOLID SOLUTIONS ON THEIR BASE

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Multiferroic perovskite oxides exhibiting both ferroelectric or antiferroelectric and antiferromagnetic phase transitions are promising candidates for various applications. One of the promising ways of designing new single-phase multiferroic materials is adjusting the temperatures of both ferroelectric and magnetic phase transitions by ion substitutions in the host compound to obtain the maximal magnetoelectric coupling. The scope of the present work is the study of both ferroelectric and magnetic phase transitions and their dependence on composition as well as on sintering conditions in $Pb(Fe_{1/2}Nb_{1/2})O_3$ (PFN), $Pb(Fe_{1/2}Ta_{1/2})O_3$ (PFT) and some solid solutions based on PFN, PFT and $BiFeO_3$. The mean temperature T_N of the antiferromagnetic phase transition was determined from the anomaly in the temperature dependence of the doublet relative intensity η in the ^{57}Fe Mössbauer spectra [1].

T_N values of PFN and PFT were found to depend on the sintering temperature. This dependence may be attributed to the changes of the degree of compositional ordering of Fe and Nb (Ta) cations. Piezoelectric and dielectric studies revealed anomalies of permittivity and piezoelectric coefficients at cryogenic temperatures which seem to correspond to the magnetic phase transitions.

It is generally believed that in all perovskite ABO_3 multiferroics magnetic and ferroelectric subsystems are independent. Magnetic properties are provided by *B*-site (e.g. $Mn^{3+}$and Fe^{3+}) cations while ferroelectric properties are provided by the *A*-site cations having the so-called dangling bonds (Bi^{3+} and Pb^{2+}). In contrast to this assumption not only *B*-site but also *A*-site ion substitutions have been found to effect greatly the T_N values of PFN and PFT. Both these substitutions lead to lowering of T_N. However above a certain compositional threshold fast lowering of T_N stops and a new magnetic state with comparatively high (~ 50 K) transition temperature becomes stable in a rather wide compositional range. The results obtained are explained using the models of magnetic super-exchange involving Pb^{2+} cations and next-nearest Fe^{3+} neighbors.

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References

[1] I. P. Raevski, S. P. Kubrin, S. I. Raevskaya, V. V. Stashenko, D. A. Sarychev, M. A. Malitskaya, M. A. Seredkina, V. G. Smotrakov, I. N. Zakharchenko, V. V. Eremkin // *Ferroelectrics*, **373**, 121 (2008).

FIELD-INDUCED ENHANCEMENT OF PYROELECTRIC AND PIEZOELECTRIC RESPONSE OF DISORDERED FERROELECTRICS

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Temperature and bias field dependences of the dielectric permittivity ε, piezoelectric coefficients d_{31} and d_{33} and dynamic pyroelectric coefficient γ have been studied for single crystals and ceramics of both lead-containing and lead-free disordered ferroelectrics and relaxors: (1–x)$Pb(Mg_{1/3}Nb_{2/3})O_3$ – $x$$PbTiO_3$ (PMN-PT), (1–x)$Pb(Fe_{1/2}Nb_{1/2})O_3$ – $x$$PbTiO_3$ (PFN-PT), $Ba_{1-x}Sr_xNb_2O_6$, multicomponent PZT-based soft piezoelectric ceramics PCR-7M, some $BaTiO_3$-based solid solutions.

For relaxor ferroelectric compositions at zero field, the maxima in the temperature dependences of both piezoelectric and pyroelectric coefficients are observed in the vicinity of the Fogel-Vulcher temperature but, at even small but finite bias fields, these maxima shift to the position of the supposed critical point (which is in the vicinity of the permittivity maximum temperature T_m) and grow in magnitude. The magnitude of both $d(T)$ and $\gamma(T)$ maxima increases up to the field strength corresponding to the critical point at the E-T phase diagram (it can be roughly estimated from the minimum or inflection in the $T_m(E)$ dependence) and decreases at higher fields. Dramatic enhancement of the pyroelectric response under finite bias fields in the vicinity of T_m was also observed for PMN-0.33PT and PFN-xPT ceramics as well as for some other compositions which do not exhibit relaxor behavior. For these materials dependences of the maximal γ values on field strength saturate approximately at the E values corresponding to the inflection at the $T_m(E)$ curve.

Thus application of the biasing fields driving the system towards the critical point crucially enhances the piezoelectric and pyroelectric responses of single crystals and ceramics of disordered ferroelectics and substantially increases their working temperature limit. These data support a quasicritical behavior of piezoelectric and pyroelectric coefficients at the critical point [1, 2].

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References

[1] S. I. Raevskaya, A. S. Emelyanov, F. I. Savenko, M. S. Panchelyuga, I. P. Raevski, S. A. Prosandeev, E. V. Colla, H. Chen, S. G. Lu, R. Blinc, Z. Kutnjak, P. Gemeiner, B. Dkhil, L. S. Kamzina // *Phys.Rev.* B **76**, 11580R (2007).

[2] S. I. Raevskaya, Yu. N. Zakharov, A..G. Lutokhin, A. S. Emelyanov, I. P. Raevski, M. S. Panchelyuga, V. V. Titov, S. A. Prosandeev // *Appl. Phys. Lett.* **93**, 042903 (2008).

NANOPARTICLES TRANSPORT IN CERAMIC MATRIXES: A NOVEL APPROACH FOR CERAMIC MATRIX COMPOSITE FABRICATION

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Nanoparticles are perfect building blocks offering a wide variety of compositions, structures and properties, ideally suited to designing functional nanomaterials and nanodevices. Nanoparticles can be embedded in various matrixes; however, a major technological problem is spontaneous aggregation of nanoparticles which, as a result, lose their unique properties. Recently polymer nano- and microgranules filled with nanoparticles (magnetic, metal, oxides etc.) start widely used as a delivery means of nanosubstances in medical, biotechnology and chemical applications. Very recently, there was a tendency to fix (immobilize) particles on the surface of spherical polymeric microgranules. Such composite micro-nano-systems offer a number of significant advantages. When fixed to a surface or embedded in microgranules, nanoparticles loose their tendency to readily aggregate but retain their reactivity and, for the most part, their physical properties. Besides, microgranules are easier to manipulate then nanoparticles. Microgranules, coated or filled with nanoparticles can be used to produce “homogeneous” disperse systems, such as sols and aerosols, and fabricate films, coatings or bulk materials.

A novel approaches for fabrication of nano- and microporous piezoceramics as well as c*eramic matrix* piezocomposites (CMC’s) are proposed in this work. The technique is based on nanoparticles transport in ceramic matrixes using polymer nanogranules, coated or filled by a various chemicals, as a porosifiers at standard ceramics fabrication process. Resulting CMC’s are composed by super-lattices of closed pores filled or coated by nanoparticles of metals, oxides, ferromagnetics etc., embedded in piezoceramic matrix. Pilot samples of nano and microporous ceramics and CMC’s were fabricated using different piezoceramics compositions as a ceramic matrix. Two types of polymer microgranules were used for a nanoparticles transport: polystyrene microgranules filled by magnetite nanoparticles and polytetrafluoroethylene microgranules coated by metal nanoparticles. Parent microgranules and nanoparticles as well as resulting CMS’s were examined using transmission and scanning electron microscopy (TEM and SEM). New family of nano- and microporous piezoceramics and CMC’s are characterized by a unique spectrum of the electrophysical properties unachievable for standard PZT ceramic compositions and fabrication methods, including combination of piezoelectric, magnetic and electrets properties, giant dielectric relaxation, giant piezoelectric and electrocaloric effects, as well as a possibility of controllable changes of the main properties within a wide range.

DEVELOPMENT OF NEW PIEZO- AND PYROELECTRIC MATERIALS AND TRANSDUCERS DESIGNS FOR ENERGY HARVESTING DEVICES

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Energy recovery from wasted or unused power has been a topic of discussion in recent times. Unused power exists in various forms such as industrial machines, human activity, vehicles, structures and environment sources. Piezoelectric and pyroelectric transducers materials can be used as a means of transforming ambient influences into electrical energy that can then be stored and used to power other devices. However, the energy produced by these transducers materials is in many cases far too small to directly power an electrical device. Therefore, much of the research into power harvesting has focused on development of a more effective materials, transducers as well as methods of accumulating the energy. Piezoelectric converters are prominent choice for mechanical to electric energy conversion because in general the energy density is three times higher as compared to electrostatic and electromagnetics. The efficiency of the piezoelectric conversion process in resonance condition is dependent upon the coupling coefficient and mechanical quality factor of the piezoelectric. In the off-resonance condition, the product ($d \cdot g$) is directly related to the energy density. The analysis shows that the piezoceramic and pyroelectric materials properties have been a limiting factor in transducer efficiency. The modifications of these properties along with the development of new transducers designs will yield dramatic improvements in performance and efficiency of energy harvesting devices.

In this paper a comprehensive review and critical comparison of different piezoelectric materials and devices designs for energy harvesting applications were presented. Several types of hot-pressed and conventionally sintered PZT piezoceramics, porous PZT piezoceramics, and multilayer PZT/PZT ceramic piezocomposites with diverse ferroelectric “hardness” were fabricated, optimized and tested. Systematical experimental results comprising electric impedance and capacitance measurements, cyclic loading at different load resistances, frequencies, and mechanical stresses for various types of piezoelements were presented. Empirical criteria of piezoelectric materials efficiency for energy harvesting devices were discussed. Various types of energy harvesting piezoelement and transducer designs including multilayer stacks, cantilevers, flex-tensional elements, and shear-mode elements and stacks were developed and tested. Original design concept for energy harvesting devices with higher overall efficiency, stability, life-time and low self-cost, based on both new materials (piezoelectric, pyroelectric and electret ceramics and composites) and new physical principles (giant field-induced piezoelectric and pyroelectric responses, multimode vibrations and complex deformations) were offered.

PHENOMENOLOGICAL THEORY OF ASYMMETRIC SUPERLATTICES $BaTiO_3/BaZrO_3$

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Phenomenological theory of ferroelectric thin films is the powerful way to investigate and predict their properties. In addition phenomenological approach is fairly simple method (in comparison with *ab initio* calculations) and so this approach is a very useful theoretical instrument for strain engineering. We expand this approach to study ferroelectric superlattices $BaTiO_3/BaZrO_3$ (BT/BZ).

We analyzed possible phase states in BT/BZ superlattices as function of relative thicknesses of dielectric ($BaZrO_3$) and ferroelectric ($BaTiO_3$) alternating layers. Topology of phase diagrams (u_m, T) of superlattices is similar to one of simple BT films [1, 2] but transition lines exhibit substantial shift, as it was predicted earlier [3]. Thus, at volume fraction of BZ being equal 30% only one polar phase remains stable in BT/BZ superlattices. The main reason of such shift is the electrostatic interaction of alternating layers while the contribution of elastic energy is negligible. This conclusion is obvious when compare coefficients at second order polarization term in thermodynamic function expansion:

Term	BT film	BT/BZ superlattice
P_3^2	$a_1 - \dfrac{2Q_{12}}{s_{11}+s_{12}}u_m$	$a_1 - \dfrac{2Q_{12}}{s_{11}+s_{12}}(u_m - A)$

where

$$A = \frac{(s_{11}+s_{12})(1-\varphi^{BT})b_1}{2Q_{12}(b_1\varepsilon_0+\varphi^{BT})}, \qquad b_1 = \frac{1}{2(\varepsilon-1)\varepsilon_0}$$

Here s_{ij} and Q_{ij} are the elastic compliances and electrostrictive coeffitients of BT respectively, ε is the dielectric response of BZ, and φ^{BT} is the volume fraction of BT layers. Coefficient a_1 is a phenomenological constant of bulk BT at second order polarization terms. It is worth to note that coefficients at another polarization terms are not renormalized. Term A causes the shift of *c*-*p* phase transition line (*p* means “paraelectric phase”).

References

[1] N. A. Pertsev, A. G. Zembilgotov, A. K. Tagantsev // *Phys. Rev. Lett.* **80**, 1988 (1998).

[2] V. B. Shirokov, Y. I. Yuzyuk, B. Dkhil, V. V. Lemanov // *Phys. Rev. B* **79**, 144118 (2009).

[3] F. A. Urtiev, V. G. Kukhar, N. A. Pertsev // *Appl. Phys. Lett*. **90**, 252910 (2007).

Modeling and Optimal Design of Power High Stroke Piezoelectric Actuators for Rotorcraft Applications

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Because of helicopter is a source of external noise, cabin noise and intensive vibrations due to complex features of their dynamic nature, the problem of active vibration preventing and suppression attracts attention of the many engineers and scientific investigators last three decades. This paper considers the means for reduction of vibrations caused by the non-symmetrical and unsteady rotor aerodynamics. The main helicopter rotor is the major source of noise and vibrations, especially in fast forward and descent flight. Historically such technologies for advanced rotor control have been proposed, namely: Higher Harmonic Control (HHC), which provides the controlled oscillation of the swashplate, next the Individual Blade Control (IBC), where each blade is controlled individually by action of power hydraulic actuator which changes the blade's pitch angle. The most advanced and perspective approaches are the Active Trailing Edge (ATE) or Active Flap (AFC) control. According to AFC concept the small flap which placed on the distance close to 0.7 of the blade radius, can deflect upwards or downwards, and due to these changes the blade can change the aerodynamic properties.

Very effective and structurally simple solution for driving whole blade or active flap is the use of power piezoelectric devices. Despite the inherent ability to create of very high forces, all piezoelectric actuators have some drawbacks, among which an incapability to produce enough large displacement, and bad withstanding a tensile stress. These limitations forced to invent some structures for the stroke amplification and complicate the successfully use the piezoelectric actuators for the rotor vibration control.

We present the modeling and approach to the optimal design for the two known piezoelectric actuators concepts: piezoelectric stack with polymeric composite shell and so-called Diamond actuators for its use in AFC structure. For IBC we propose the model of new stand-alone piezoelectric-hydraulic dual stroke actuator, which provide the same action on two opposite directions without formation of cavities in a hydraulic cylinder.

MATERIAL PARAMETERS OF THE (BA, SR)TIO$_3$ SOLID SOLUTIONS

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A phenomenological thermodynamic potential of $Ba_xSr_{1-x}TiO_3$ (BST) solid solutions was recently proposed [1, 2], where the interaction of the order parameters of constituents was introduced through the account of elastic strain due to misfit of the lattice parameters of the end members. Using this approach we found the dependence of material constants (elastic compliances, piezoelectric modules, pyroelectric coefficient) of the BST solid solution at room temperature in the whole concentration range.

All material constants exhibit peculiarities in the vicinity of the first order phase transition at the Ba concentration x = 0.72. Pyroelectric coefficient at this phase transition increases by almost two orders of magnitude. Absolute values of d_{33} and d_{13} piezoelectric moduli, having different signs, significantly increase. Piezoelectric modulus d_{15} undergoes a weak stepwise drop, without significant change in the ferroelectric region.

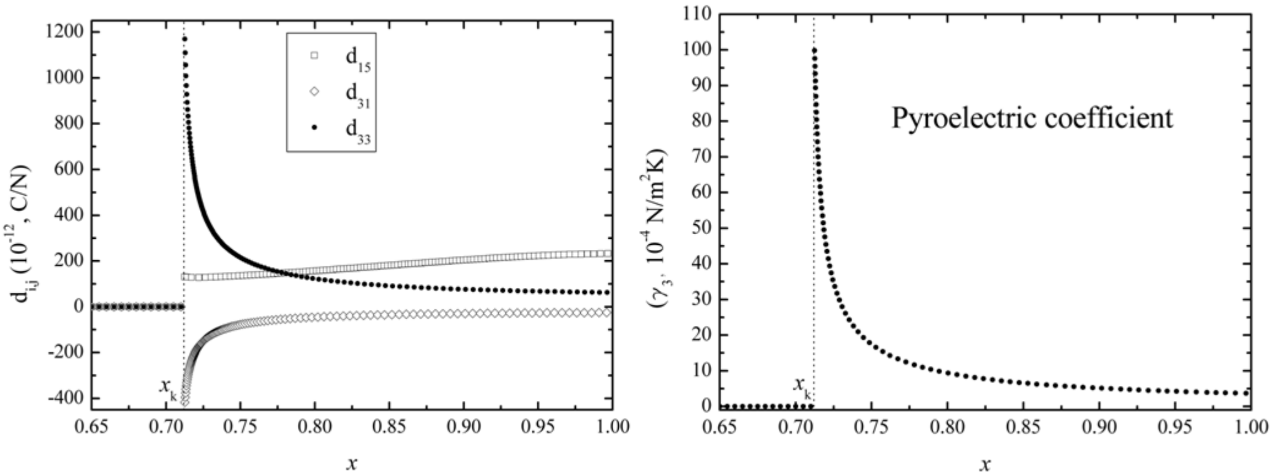

Fig. 1. Concentration dependence of the piezoelectric moduli (left) and pyroelectric coefficient (right) of the BST solid solution at room temperature

References

[1] V. B. Shirokov, V. I. Torgashev, A. A. Bakirov, V. V. Lemanov // *Phys. Rev. B.* **73**, 104116 (2006).

[2] V. B. Shirokov, Yu. I. Yuzyuk, B. Dkhil, V. V. Lemanov // *Phys. Rev. B* **79**, 144118 (2009).

Research of Conditional Viscosity of Thermally Activated Water

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The problem of biological activation of water was still investigated by the methods which are not meeting requirements of unity of measurements; there is no uniform point of view on communication of klasterny structure of water and concentration of the gases dissolved in water with its physical and biological properties. The analysis which has been carried out by methods of quantum chemistry and chemical kinetics showed that biochemical properties of water are correlated with its kinematic viscosity.

Necessary accuracy of measurements provides by viscometer which has a special construction with use of filtering membranes of brand MFAS-B with the size of a pore 0.05 microns, as calibration liquid the distilled water was used. Researches of conditional viscosity of the distilled and spring water subjected to thermal activation in various modes confirm that activation of water changes its structure. Thermal activation of water is carried out in the heat-resistant flask which throat is densely connected to the return refrigerator. The exit from the refrigerator is closed by the ground-in stopper for an exception of removal of gases from volume of activated water. It is proved that thermally activated water is capable to keep the lowered viscosity $\eta = 0.48 \pm 0.02$ °E during 30 minutes, and viscosity of the activated water is influenced by structural changes in a structure of the water, instead of its decontamination. Repeated activation of spring water leads to even bigger reduction of conditional viscosity. The exit to constant level of viscosity $\eta = 0.49 \pm 0.02$ °E after the third thermal activation is characteristic.

Temperature dependence of viscosity of water is well studied the activated water can attribute equivalent temperature. The conditional viscosity of spring water corresponds to conditional temperature 60 °C after triple thermal activation. By a Van Goff's rule the increase in temperature reactionary on the 10 °C is accompanied by increase in speed of reaction in 3 – 4 times. Thus, in thermally activated water acceleration of biochemical reactions almost in 100 times that allows one to explain its increased biological activity is possible.

The studied way of thermal activation natural, for example spring water, provides preservation of its salt and gas structure, allows one to assume that the using of such water will favorably influence to an organism and whole health of the person and to be recommend its use in sports medicine, pharmacology, rehabilitation therapy, in office coolers.

Fabrication of Highly Sensitive ZnO Based Humidity Sensor Through Low Cost Method

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Humidity control is an important issue in everyday life and across several industries. In the present study, new zinc oxide plate based humidity were synthesized and tested. When compared with conventional thin film based humidity sensor, nanoplate based humidity sensor exhibit greater sensitivity and faster response. Such enhancement in sensor performances originates from the high specific surface area offered by the ZnO nanoplate.

ABSORPTION AND EMISSION SPECTRA OF UHF ELECTRODYNAMIC SYSTEM "MICROSTRIP LINE – PIEZOELECTRIC SAMPLE"

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At studying the influence of one-dimensional mechanical stress σ on the dielectric constant $\varepsilon = \varepsilon' - i\,\varepsilon''$ of barium titanate monocrystals at ultrahigh frequencies (UHF) non-monotonic dependencies of $\varepsilon'(\sigma)$ with $\varepsilon' < 0$ region at concomitant high values of ε'' have been found [1]. High values of ε" indicates the high dielectric losses typical for UHF dielectric dispersion which appear at re-polarization of polydomain ferroelectrics at alternative voltages. Absorption of UHF electromagnetic energy in different ferroelectrics was observed by different authors. Negative values of ε' at high energy losses indicates a possibility of ferroelectrics to adsorb as well as to emit at appropriate conditions UHF electromagnetic energy. In this work a direct experiment on detection of electromagnetic emission by ferroelectrics was conducted. In the experiment three frequency-sweep generators overlapping 3 – 12 GHz frequency range as well as VSWR and attenuation indicators loaded by small wide-band microstrip line working in running wave regime were used. Disk shaped experimental piezoceramic samples (diameter of 10 mm, thickness of 0.8 mm) were placed on the surface of the microstrip line in the vicinity of the central conductor. For measurements of the electric and magnetic fields intensity receiving antennas in the form of loop- and pin-shaped vibrators were placed above the experimental samples. Digital voltmeter was connected to the antennas via UHF diode. The measurements were made in low electromagnetic fields; therefore diode volt-ampere characteristic was quadratic. Thus, square root of constant component of voltage measured by digital voltmeter U was in proportion to the normal component of magnetic (H^*) or electric (E^*) fields intensity. Receiving antenna was placed on the distance 0.5 mm above the microstrip line. Main type of the wave in the microstrip line was close to T-type (quasi T-wave) and related electromagnetic field was concentrated mainly in the substrate. Electromagnetic energy above the microstrip line at absence of the ferroelectric sample was not detected. Piezoceramic materials of PCR-type were chosen as the objects of the study. Measured spectra show high energy absorption peaks (≥ 40 dB) located usually in the frequency ranges 4 – 5 GHz and 8 – 10 GHz. As was shown experimentally the electrodynamic system "microstrip line – piezoelectric sample" have emitted an electromagnetic field in all measured frequency range with the energy maximum in the range 4 – 6 GHz. Measured values of $H^* = (U_H)^{0.5}$ and $E^*=(U_E)^{0.5}$ for PCR-1 piezoceramics reach the maximal values equal to 45×10^{-3} $(B)^{0.5}$ and 30×10^{-3} $(B)^{0.5}$, respectively.

References

[1] A. V. Turik, E. N. Sidorenko, N. B. Shevchenko, V. F. Zhestkov, B. F. Prokuryakov // *Izv. AN SSSR*, *Ser. Phys*, **39**, 850 (1975) (in Russian).

On Use of Generalized Method of Scalarization of the Dynamic Elastic Fields in Transverse Isotropic Media

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Implementation of generalized method of scalarization [1] for study of tensor elastic fields in layered constructions including the layers from transverse-isotropic materials is possible in coordinate system with frame having at transformation one invariant vector coinciding with the material symmetry axis. By this, there are considered the cases when this vector coincides with normal to boundary between layers or be tangential to the boundary [2].

Generalization on random case of disposition of the material symmetry axis in relation to unit is reduced to the following. Originally, the components of tensors of displacements and stress, relatively frame, are to be into coordinate system with the valid frame. Then, knowing all components of the tensor fields into given coordinate system, it is possible to find normal and tangential components of displacements and stresses corresponding to plane area laying on boundary by means transition to the coordinate system connected with the boundary between layers. These components then are used to satisfy boundary conditions of the problem.

Moreover, in the case of multi-layer cylindrical construction with external layers from transverse isotropic materials, the axes of which can be no coinciding in direction with the construction axis, it may be applied the method based on “straightening” relatively thin external layers [3]. It is used the fact that with decreasing relative thickness, the layer straights and transforms in limit to plate when could be implied the scalirization method, but fields in cylindrical layer and plate at definite conditions weakly differ one of other. In order to determine these conditions, the movement equations written in cylindrical coordinates are presented as sum of two arts, where all parameters using at covariant differentiation the Christoffel symbols are disposed in second part. Then, we define the conditions at which this part of the sum may be considered as neglected compared to with first part.

From physical viewpoint, these conditions correspond to small thickness of layer and small wave length in radial direction compared to radius of median surface of the layer. This method allows one to obtain approximate solution of the wave problem in which construction of exact solution by means of the scalarization method is impossible.

The proposed approach has been successively used in process of a priori and posteriori analysis of diagnostic results of the state and study of wave processes in layered constructions and construction from anisotropic materials in different areas of engineering.

References

[1] Sizov V. P. On scalirization of dynamic elastic fields in transverse-isotropic media // *Izvestia RAN. Mekhanika Tverdogo Tela*. 1988. No. 5. P. 55-58.

[2] Sizov V. P., Miroshnichenko I. P. *Excitation of Elastic Waves in Layered Anisotropic Cconstructions*. LAP LAMBERT Academic Publishing. 2012. - 270 p.

[3] Petrov A. M., Sizov V. P. Dynamic behavior of anysotropic multi-layer cylindrical constructions // *Izvestia RAN. Mekhanika Tverdogo Tela*. 2000. No. 3. P. 34-39.

IDENTIFICATION OF THE HETEROGENEOUS PROPERTIES OF PIEZOELECTRIC MATERIALS BASED ON GENETIC ALGORITHMS AND FINITE ELEMENT METHOD IN ACELAN

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A number of piezoelectric transducers of complex geometry and complex topology of the electrode coatings have non-uniform polarization. This type of heterogeneity may arise from the operation when exposed to strong mechanical, electrical and temperature fields. Highly technological design and monitoring of such devices involves the definition of non-uniform properties and selection of the optimal structure. For this purpose, in finite element package ACELAN, special modules for the solution of direct problems of piezoelectric devices, elements which have heterogeneous, both mechanical and electrical properties are developed. In the developed module, the heterogeneous properties can be defined by two ways: as an analytic function in the various classes of functions - polynomial, exponential, etc., or on the basis of discrete information about their values in a set of points, such as the nodes of a certain finite element mesh, that proposes their interpolation on the used division. To identify the heterogeneous properties, a previously developed genetic algorithm is applied for software implementation of which the interface is carried out with moduli developed in ACELAN. The paper provides examples of solutions of direct and inverse problems for elastic and electroelastic bodies loaded on the acoustic media.

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FEM MODELING OF PIEZOELECTRIC TRANSDUCER FOR ENERGY STORAGE DEVICES

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Development of energy storage device is relevant theoretical and technical problems of the present time. One type of such devices can be created through the use of piezoelectric transducers of energy, subjected to external vibrations or repeated time-dependent mechanical loading. In this case, the problem of optimal design of such devices arises in sense of getting the most electric power.

In this paper the three-layer piezoelectric transducer with a cylindrical piezoceramic element is described. The main working regime of the transducer is thickness oscillations arising due to the harmonic vibrations of its foundation. The construction is modeled by using the finite element packages ANSYS and ACELAN. The modal and harmonic analyses of the transducer are performed when one of the electrodes of the piezoelectric element is connected to an electrical circuit with energy storage devices.

On the basis of the calculations, rational geometric characteristics of the device and the physical properties of the active element (for instance, materials for the piezocomposites) are selected.

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DETERMINATION OF ANISOTROPIC ELASTIC PROPERTIES OF COMPOSITES BASED ON A COMBINATION OF ANALYTICAL AND FINITE ELEMENT SOLUTIONS AND THE GENETIC ALGORITHM

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In this paper we propose a method for determining the elastic properties of anisotropic composite materials in the case when, due to the technological features of these parts, it is not possible to prepare samples for testing of certain standards. Such a situation arises, for example, when testing polymer composite spars helicopter blades. The developed method is based on the production of a series of thin samples (plates) which represent slices in different planes of symmetry. In the first step of the algorithm, based on the analytical and numerical solutions of static problems and problems of natural vibrations of the plates some elastic moduli are determined which associated with the deformation of the studied plates.

In the second step of the algorithm, there are considered the problems of modal analysis for three-dimensional samples, which solved using the finite element method. Based on the solution of direct problems and genetic algorithm, the elastic moduli are determined which were not considered in the first stage of the problem.

A notable feature of this method is that, the solved by analytically and numerically boundary value problems of deformation of the samples from anisotropic material is easily reproduced in the experiment; it defines the practical sound of the method. The numerical experiments have shown high efficiency of the proposed method.

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IDENTIFICATION OF DEFECTS IN THE COATINGS FROM FUNCTIONALLY GRADIENT MATERIALS

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In this paper we propose a method for reconstruction of defects in functionally graded materials (FGM), in which the problem is reduced to the inverse geometric problems of elasticity theory. The method is based on the application of the principle of reciprocity for the damaged and intact bodies. To do this, some trial solutions are chosen for the body of the FGM, which are the analytical solutions for certain classes of inhomogeneous material properties. As additional information to solve the inverse problem, the measured displacement field on the free surface of the body is used. In the case of small defects, and defects such as cracks with non-interacting faces parallel to the layer surface, we construct analytical formulas for the determination of the vertical coordinate (the layer thickness) of the defect.

When the interaction of crack faces is taken into account and at the prolonged effects of vibration on the object, the defect is modeled by an internal heat source and the problem is reduced to the inverse heat conduction problem for an inhomogeneous body. In this case, additional information to solve the inverse problem is a portrait of the body temperature. Similar to the first case, the use of the reciprocity principle and test analytical solutions allows one to get the formulae for the coordinates of internal points of the "crack – source".

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PIEZOELECTRIC CHARACTERISTICS OF LEAD-FREE CERAMIC SYSTEM $(Na_{1-x}Li_x)NbO_3$ MODIFIED BY MnO_2 IN THE POWER MODE

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Because of significant toxicity of lead compounds in recent years has increased the intensity of the search for alternative materials. The prerequisites for such efforts were the formation of a new legislative framework [DIRECTIVE 2002/95/EC., Of. J. Euro. Union. 37, 19 (2003).]. Lead-free piezoelectric ceramics have been studied intensively in recent years, but their properties were studied in the power mode is not enough. This paper investigates the influence of MnO_2 additives on the behavior of piezoelectric characteristics of ceramics based on $(Na_{1-x}Li_x)NbO_3$ in high electric fields.

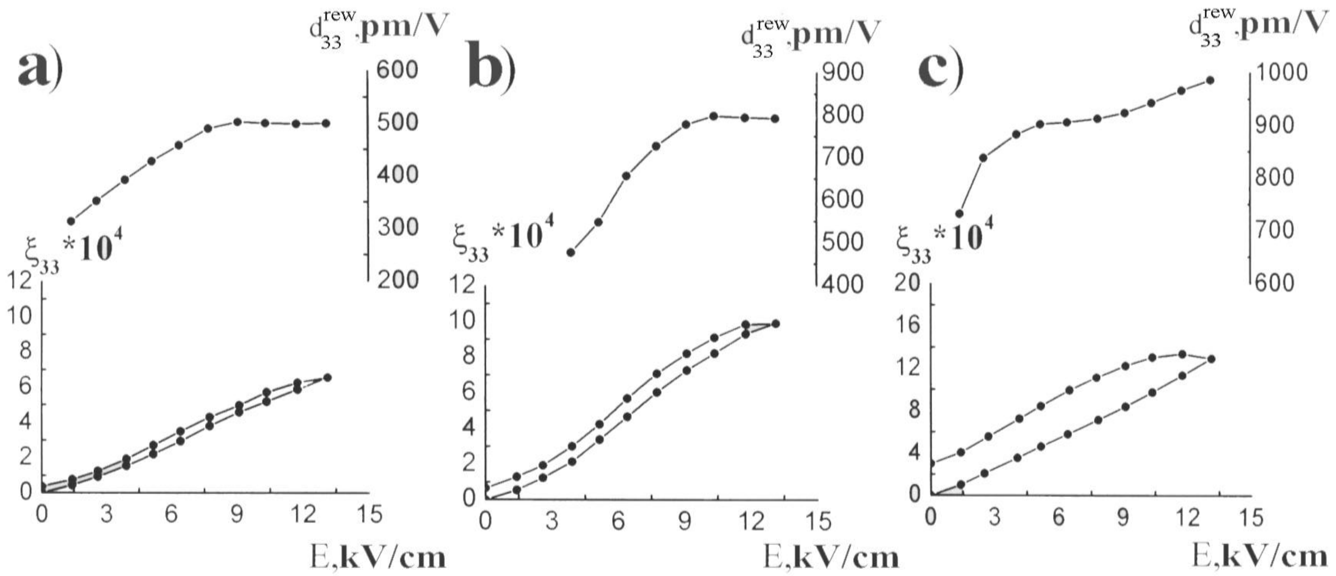

Fig. 1. Dependences of the reverse piezoelectric and electromechanical hysteresis loops of half-cycles of the amplitude on the *dc* electric field *E* of modified MnO_2 ceramics: (a) 1% by weight MnO_2; (b) 2% by weight MnO_2; (c) 3% by weight MnO_2

The figure shows the dependences of the inverse piezoelectric and electromechanical hysteresis loops of half-cycles of the amplitude on the *dc* electric field *E*, which are characteristic for samples with relatively low conductivity and high dielectric strength. As can be seen from the figure, these plots were similar in their behavior, and similar to those observed in hard ferroelectric materials. However, it is noticeable that the introduction of manganese oxide reduces coercive field. It probably indicates a decrease in hardness of ferroelectric ceramics in the modification by manganese. High values (reverse piezoelectric modulus) d_{33}^{rew} of the studied ceramics make them promising basis for developing a new generation of environmentally friendly high-voltage electro-mechanical transducers.

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FEATURES OF ELECTROMECHANICAL PROPERTIES OF CERAMICS BASED ON RELAXOR FERROELECTRICS FOR USE IN MEMS

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Microelectromechanical systems (MEMS) are the devices that combine microelectronic and micromechanical components. Based on MEMS can be realized by a variety of devices: actuators, chemical reactors, sensors, transducers, and biomedical devices [1 and references therein]. Since the characteristic dimensions of the MEMS does not exceed 100 μm, special attention is paid the miniaturization of their components, in particular, micromechanical ones. One of the candidates for use as electromechanical transducers in MEMS can serve piezoelectrics. It is known that the solid solutions, based on ferroelectric relaxors (Pb $(Mg_{1/3}Nb_{2/3})O_3$ (PMN) and Pb $(Zn_{1/3}Nb_{2/3})O_3$ (PZN)) and $PbTiO_3$ (PT), located near the morphotropic phase boundary, have the piezoelectric coefficients, and record electromechanical coupling constants [2]. In addition, these high-performance materials under electric field (E) undergo an irreversible phase transition, which affects the character of the manifestation of electro-mechanical properties [3]. Thus, several studies [4, 5] reported the principal differences between the curves of dependencies of deformation (ξ) crystal PMN-30PT, PZN-8PT on the electric field applied in the bipolar and monopolar modes. The aim of this study was to identify characteristics of the formation of electromechanical properties of multicomponent ceramic systems based on PMN, PZN, Pb $(Ni_{1/3}Nb_{2/3})O_3$ (PNN) and PT with different modes of application of an electric field.

Ceramic system PMN-PNN-PZN-xPT with $x = 0.25 - 0.40$ obtained by solid-phase synthesis with elements of columbite method. A specially designed stand was used to measure ξ induced by E applied to the specimen.

It is found that, in the ceramics with low content of PT (0.25), the curves $\xi(E)$, obtained as in bipolar and unipolar mode with, characterized almost no hysteresis and the higher values of ξ with unipolar E. For heterophase solid solutions (with PT = 0.3), it characterized by maximum values of ξ close in both modes and a more pronounced hysteresis. In ceramics with PT > 0.35, the hysteresis increases and the maximum values of ξ are observed in the bipolar mode. These features are associated with the evolution of the dominant contributions to $\xi(E)$, from electrostrictive to piezoelectric state with increasing content of the PT.

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References

[1] S. M. Spearing // *Acta Mater*. **48**, 179 (2000).
[2] S.-E. Park, T.R. Shrout // *J. Appl. Phys*. **82**, 804 (1997).
[3] F. Bai, N. Wang, J. Li, et al. // *J. Appl. Phys*. **96**, 1620 (2004).
[4] D. Viehland, J. Li // *J. Appl. Phys*. **92**, 7690 (2002).
[5] D. Viehland // *J. Appl. Phys*. **88**, 4794 (2000).

HETEROPHASE STATES IN PEROVSKITE-TYPE FERROELECTRIC SOLID SOLUTIONS: FROM DOMAIN TYPES TO PHASE CONTENTS

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Ferroelectric solid solutions (FESS) with the perovskite-type structure have been important objects for basic research of interrelations in the dependency triangle of ‘composition – structure – properties’. In these materials, various heterophase states [1] are observed in certain molar-concentration, temperature and electric-field ranges. Recent studies [1] of $Pb(Zr_{1-x}Ti_x)O_3$, $(1-x)Pb(Mg_{1/3}Nb_{2/3})O_3 - xPbTiO_3$ and $(1 - x)Pb(Zn_{1/3}Nb_{2/3})TiO_3 - xPbTiO_3$ show that the heterophase states therein are of interest due to the presence of intermediate phases close to the morphotropic phase boundary (MPB). These phases influence the physical properties, heterophase states and stress-relief conditions in the FESS. The present study develops concepts [1] on several domain types in the stress relief at the phase coexistence.

Examples of the phase coexistence in the FESS near the MPB are discussed to show the role of elastic matching of the phases and specific domain types therein.

(i) Features of the phase coexistence in $(Bi_{1-x}Pb_x)FeO_3$ single crystals ($0 \le x \le 0.10$) with a significantly distorted perovskite unit cell are studied. An evolution of heterophase structures and different stress-relief scenarios in the presence of several domain (twin) types in the ferroelectric $R3c$ phase are analysed. The results are systematised using the diagrams relating the domain (twin) types and phase boundaries [2]. Unit-cell parameters are refined [2] for the $R3c$ phase at $x = 0.10$ after the examination of stress-relief conditions at the phase coexistence $Pm\bar{3}m - R3c$.

(ii) The role of elastic matching of the $P4mm$ and Cm phases is considered in $(1 - x)Pb(Fe_{1/2}Nb_{1/2})O_3 - xPbTiO_3$ ($0.05 \le x \le 0.08$) to interpret the volume content of the coexisting phases. The studied phase coexistence under conditions for the complete stress relief is related to elastic matching of the single-domain Cm phase and the $P4mm$ phase split into two types of 90° domains [3].

(iii) Conditions for the complete stress relief are examined in the heterophase states $P4mm - P4mm$ and $P4mm - Cc$ to interpret temperature variations of the phase content [4, 5] in $(1 - x)BiFeO_3 - xPbTiO_3$ near the MPB ($0.27 \le x \le 0.31$). The key role of the 90° domains of the low-temperature $P4mm$ phase in the stress relief is emphasised.

Good agreement between the calculated and experimental data (e.g., from Refs. [4] and [5]) suggests that the concepts on the minimum number of domain types forming the heterophase structure under due conditions for the stress relief can be applied to interpret the phase content in the FESS and related materials near the MPB.

References

[1] V. Yu. Topolov, *Heterogeneous Ferroelectric Solid Solutions. Phases and Domain States*. Springer, Berlin, Heidelberg (2012).

[2] V. Yu. Topolov // *Phys. Solid State* **54**, 478 (2012).

[3] V. Yu. Topolov // *Mater. Lett*. **66**, 57 (2012).

[4] S. Bhattacharjee, K. Taji, C. Moriyoshi et al. // *Phys. Rev. B* **84**, 104116 (2011).

[5] S. Bhattacharjee, D. Pandey // *J. Appl. Phys*. **110**, 084105 (2011).

PIEZOELECTRIC ANISOTROPY IN TWO-COMPONENT COMPOSITES BASED ON FERROELECTRIC CERAMICS

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Modern composites based on ferroelectrics show an important ability to convert mechanical energy into electric energy and vice versa. Among the effective physical properties of these composites, the piezoelectric properties play the key role [1] and promote many transducer, sensor, acoustic, and other applications. An anisotropy of the piezoelectric properties influences the effectiveness of the composites and their potential applications. The aim of the present work is to study physical and microgeometric factors that influence the piezoelectric anisotropy and predetermine features of the piezoelectric response of the composites based on ferroelectrics. The analysis of the effective electromechanical properties and anisotropy factors is carried out for ferroelectric ceramic (FC)/polymer and FC/clay composites with 1–3 and 0–3 connectivity patterns. To predict the effective properties in these composites, the finite element method [1] and the effective field method [1, 2] are used, and some results obtained using these methods are compared. Of particular interest are data on the volume-fraction and aspect-ratio dependences of the following anisotropy factors: $\zeta_{d3j} = d_{33}^*/d_{31}^*$ that is related to the piezoelectric coefficients of the composite d_{3j}^*, $\zeta_{k3j} = k_{33}^*/k_{31}^*$ and $\zeta_{kt-p} = k_t^*/k_p^*$ which characterise links between electromechanical coupling factors of the composite. Among the perovskite-type FC compositions, ZTS-19 (the PZT-type composition) was chosen. For this FC, three full sets of room-temperature electromechanical constants related to different technological conditions of processing are known. Results of the present study include the generalization of data on the two-component composites with the variable anisotropy of their piezoelectric properties and electromechanical coupling factors.

Examples of the large anisotropy $| \zeta_{k3j} | >> 1$ and $| \zeta_{kt-p} | >> 1$ at the moderate anisotropy of d_{3j}^* are discussed in the context of the transducer performance and improving the hydrostatic piezoelectric response of the studied composites. A comparison of the calculated effective parameters and anisotropy factors with some experimental values is carried out. The results of the present study can be taken into account for the manufacture and design of the novel anisotropic composites based on FCs.

References

[1] V. Yu. Topolov, P. Bisegna // *J. Electroceram*. **25**, 26 (2010).

[2] V. Yu. Topolov, C. R. Bowen, *Electromechanical Properties in Composites Based on Ferroelectrics*. Springer, London (2009).

ORIENTATION EFFECTS IMPROVING THE HYDROSTATIC PIEZOELECTRIC RESPONSE IN NOVEL 2–2 COMPOSITES BASED ON RELAXOR-FERROELECTRIC SINGLE CRYSTALS

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In the last decades, many attempts have been made to manufacture high-performance piezo-active composites based on single crystals (SCs) of relaxor-ferroelectric solid solutions, such as $(1 - x)Pb(Mg_{1/3}Nb_{2/3})O_3 - xPbTiO_3$ (PMN–xPT) and $(1 - x)Pb(Zn_{1/3}Nb_{2/3})O_3 - xPbTiO_3$ with compositions near the morphotropic phase boundary. These SCs with domain-engineered structures exhibit outstanding electromechanical properties and can be poled on various crystallographic directions. The aim of the present study is to analyze interconnections between the electromechanical properties of the SC component (either single-domain or polydomain) and the 2–2 (laminar) parallel-connected composite with the periodical arrangement of layers. To predict a full set of effective electromechanical constants of the 2–2 composite at appointed orientations of the main crystallographic axes in the SC layers, we use the matrix method [1]. The orientation of the remanent polarization vector in the ferroelectric polymer layers can be also varied. The effect of the orientation of the main crystallographic axes of SCs on the effective piezoelectric coefficients is studied in the 2–2 composites based on PMN–*x*PT SCs with different piezoelectric properties. Some interrelations between the piezoelectric coefficients are revealed in connection with the effect of the electromechanical properties of the SC component on the hydrostatic piezoelectric response of the 2–2 composite.

It is shown how the aforementioned orientation effects improve the hydrostatic parameters [1, 2] of the 2–2 composite in the presence of the SC component poled along one of the following crystallographic directions: [111], [011] or [001]. Among the hydrostatic parameters, of particular interest are piezoelectric coefficients d_h*, e_h* and g_h*, squared figure of merit d_h*g_h*, and electromechanical coupling factor k_h* [1]. Extreme points of the hydrostatic parameters found for the 2–2 PMN–*x*PT SC/polymer composites [1, 2] enable us to choose the SC components (i.e., SC cuts with a specific orientation of the main crystallographic axes) that are preferential for hydrostatic applications. In addition, the role of the auxetic polymer component in improving the hydrostatic parameters of the composite is discussed. In general, the studied 2–2 composites are of interest for piezotechnical applications, as elements of sensors, hydrophones, acoustic antennae, etc.

References

[1] V. Yu. Topolov, A. V. Krivoruchko //*Smart Mater. Struct.* **18**, 065011 (2009).

[2] V. Yu. Topolov, A. V. Krivoruchko, C. R. Bowen, A. A. Panich // *Ferroelectrics* **400**, 410 (2010).

Numerical Modeling of the Energy Spectrum of InAs/GaAs Quantum Dots

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InAs/GaAs quantum dots (QD) are widely used in infrared lasers and photodetectors. At present, the technological parameters in the manufacture of heterostructures with quantum dots are selected experimentally because theoretically calculated parameters are poorly correlated with the experimentally obtained. Therefore the development of modeling techniques and programs is actual problems in the theory of nanoscale heterostructures.

The goal of this study was to carry out qualitative and quantitative analysis of the multiplicity of the electron energy spectrum as a function of InAs/GaAs QD form and size. Moreover, were determine the number and relative position of all energy levels arising from the motion of an electron in the pyramidal shaped QD as a function of the base size and height.

The first stage included the joint solution Schrödinger and Poisson equations for a superlattice with InAs QD layers using finite differences on a uniform grid in supposing a stationary process in time and a parabolic dispersion of electrons [1].

The second stage applied an analytical model for solving Schrödinger equation for a QD presented in the form of a cylinder using quasi-cylindrical coordinate system constructing method developed in [2] which allows one to produce a complete separation of variables.

The above procedure was used in the calculation of the energy spectrum of a pyramidal InAs/GaAs QD with base size a = 14 nm and height h = 2.4 nm. Simulation was carried out at temperatures 300 K and 77 K for its own electrons and holes in the absence of an external applied voltage. It was found that the ground state of electrons is located at 373 meV at 77 K and 116 meV at 300 K below the bottom of the conduction band in GaAs, and the hole ground state is located near 134 meV at 77 K and 123 meV at 300 K above the valence band in GaAs. The broadening of the electron ground state amounts to 72 meV at 300 K, and it is 37 meV at 300K for hole ground state. The values obtained are in good agreement with experimental data given in [3].

References

[1] E. A. Ryndin. *The Methods for Solving Mathematical Physics Problems* (Taganrog, Rostov Reg., Russia, Publishing House «TSURE», 2003).

[2] G. G. Zegrya, O. V. Konstantinov, A. V. Matveentsev // *Semicond. Sci. Technol.*, **37**(3), 334 (2003).

[3] T. Steiner. *Semiconductor Nanostructures for Optoelectronics Application* (Norwood, MA, USA, Artech House Inc., 2004).

Analytical Solution of the Contact Problem for the Graded Coatings of Non-Deformable Foundation Taking into Account the Independent Changes, as the Elastic Modulus and Poisson's Ratio

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The contact problems for the layer or wedge covered the non-deformable foundation are investigated for the case when elastic properties of the coating are arbitrary continuously differentiable functions of its thickness. Effective numerical method was obtained by using bilateral asymptotical method described in papers of S. M. Aizikovich, V. M. Alexandrov, et al. [1, 2]. The special idea of this method is to present the kernel transform for the dual integral equations with the function of special form convenient for the obtaining the solution in analytical form. This method permits to obtain the problem solution for the wide class of the heterogeneity laws. Particularly, the case when the elastic modulus and Poisson's ratio vary arbitrarily with the normal direction to the contact surface. The analytical expression for the contact stresses is obtained for the integral equation with the kernel of special form constructed numerically with presupposed accuracy. The separate effect of arbitrarily variation of the elastic modulus and Poisson's ratio is examined for functionally graded coatings with complicated structure.

References

[1] Aizikovich S. M., Alexandrov V. M., Kalker J. J., Krenev L. I., Trubchik I. S. // *Int. J. of Solids and Structures*, **39**(10), 2745–2772, (2002).

[2] Trubchik I. S., Aizikovich S. M., Alexandrov V. M. // *Operator Theory: Advances and Applications*, **191**, 3–17 (2009).

Dielectric Retardation and Relaxation in Non-Debye Ferrites

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To the best of our knowledge from literature data, for a linear medium it is necessary to distinguish dielectric retardation and relaxation. This difference is due to the specific features of the behavior of the complex dielectric permittivity $\varepsilon = \varepsilon' - i\varepsilon''$ under the action of voltage (retardation) and complex electric modulus $M = 1/\varepsilon$ under the action of charge (relaxation) [1]. The ratio of the average retardation and relaxation time constants $\tau_\varepsilon/\tau_M = \varepsilon_s/\varepsilon_\infty$, where ε_s and ε_∞ are the static and high-frequency dielectric permittivities, respectively. This relation is strictly carried out only for Debye dielectrics, semiconductors and ferrites.

However for non-Debye materials the aforementioned relation can appear incorrect and demands check. With this aim we have investigated the single-component material with the rectangular distribution function $f(\tau)$ of the relaxation times, $f(\tau) = h = \text{const}$ within the interval $\tau_1 \le \tau \le \tau_2$ and $f(\tau) = 0$ at $\tau < \tau_1$ and $\tau > \tau_2$ ($f(\tau)d\tau$ is the probability that the relaxation time falls into the interval from τ to $\tau + d\tau$) [2]. A relaxation oscillator in such material can be described at a microscopic level by the model of a deep potential well with two equilibrium positions (the Fröhlich oscillator [3]).

According to [3], the real and imaginary parts of the dielectric constant ε of the dielectric without interaction between the relaxation oscillators in the case of a linear superposition of the contributions from different groups depend on $f(\tau)$, ε_s, ε_∞ and the frequency ω as follow:

$$\varepsilon' = \varepsilon_\infty + (\varepsilon_s - \varepsilon_\infty)\frac{h}{\omega}(\mathrm{arctg}\,\omega\tau_2 - \mathrm{arctg}\,\omega\tau_1), \quad \varepsilon'' = (\varepsilon_s - \varepsilon_\infty)\frac{h}{2\omega}\ln\frac{1+\omega^2\tau_2^2}{1+\omega^2\tau_1^2}. \tag{1}$$

The results of calculations according to Eq. (1) for $\varepsilon_s = 10^4$, $\varepsilon_\infty = 100$, $\tau_1 = 10^{-4}$ s, $\tau_2 = 10^4$ s have shown that $\omega_r^\varepsilon \approx (\tau_1 + \tau_2)/2 \approx 2\cdot10^{-4} << \omega_r^M \approx 7\cdot10^{-2}$ rad/s. Hence, the relaxation frequency is greater than the retardation one by over two orders of magnitude.

Moreover, experimental data [4] for the cobalt ferrite $CoFe_2O_4$ thick films that consist of two grades of $CoFe_2O_4$ particles with different sizes, have been used for our calculations. And in this case non-Debye character of dielectric spectra consists in the large distinction between dielectric retardation (ω_r^ε) and dielectric relaxation (ω_r^M) frequencies.

References

[1] J. Jäckle, R. Richert // *Phys. Rev.* E **77**, 031201 (2008).

[2] A. V. Turik, A. S. Bogatin, E. V. Andreev // *Phys. Sol. State* **53**, 2421 (2011).

[3] H. Fröhlich. *Theory of Dielectrics* (Clarendon, Oxford, 1958).

[4] W. Chen, W. Zhu, O. K. Tan, X. F. Chen // *J. Appl. Phys*. **108**, 034101 (2010).

Properties Identification of the Inhomogeneous Electroelastic Medium

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The technique for properties identification of electroelastic inhomogeneous on a thickness medium of rectangular form is presented. Oscillations in the rectangular region are excited by a potential difference on the electrodes placed on the upper and lower boundary lines or a mechanical loading on upper boundary of the region.

The stated inverse coefficient problem is solved by using additional information on the mechanical and electric characteristics measured on upper boundary of the region.

The developed approach is based on preliminary information obtained for simpler boundary value problems concerning average magnitudes of mechanical displacement and a potential which are divided relatively unknown functions and are one-dimensional. Each of the obtained inverse problems solved with application of iterative process on each step of which integral equations of Fredholm of the first and second kinds for definition of corrections of the unknown functions taking into account initial approximations are decided.

As a result of application of the given technique, it is possible to determine three characteristics of the electroelastic medium, namely two elastic modules and piezomodule.

Computational experiments on identification of the inhomogeneous elastic and piezoelectric modules are carried out. Numerical results point the stable convergence of the scheme of initial approximations to re-built functions (with an error is no more than 8 %), that confirm the effectiveness of the proposed approach.

Effect of 3D-Metal Oxide Phase Formation on the $BiFeO_3$

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$BiFeO_3$ because to the high values of the temperature of the ferroelectric (FE) (T_c = 1083 K) and magnetic (T_N ~ 643 K) ordering is considered to be a convenient target for a magnetoelectric materials. However, its magnetoelectric properties are relatively small. This is because of the peculiarities of the magnetic and crystal structures, and with a large difference in temperature between the magnetic and ferroelectric phase transition. In addition, it was found that the $BiFeO_3$ is not thermodynamically stable at temperatures required for the synthesis of solid-phase method. Despite numerous attempts to synthesize thermally stable powder was not possible, suitable for the sintering of dense ceramics. For example, to stabilize the bismuth ferrite can be the addition of modifiers. This paper concerns the influence of oxides of 3D transition metals on the formation of bismuth ferrite.

All samples were obtained by using solid-phase oxides of Bi_2O_3, MnO_2, CoO, NiO, CuO, ZnO qualifications not lower than "analytical grade". The temperature was adjusted in the range of synthesis $T_{sint.}$ = (750 – 830) °C, endurance of 10 hours.

Fig. 1 shows the relative intensities of the X-ray peaks corresponding to the content of impurity phases. It is seen that the impurity content drops sharply in the temperature range (780 – 800) ^{0}C, and again increases with $T \geq 800$ °C. With further increase in T (T = 830 °C), introduction of a number of modifiers (MnO_2, CoO and NiO) again leads to a decrease in the amount of impurities, especially rapidly with decreasing impurity content, enriched with bismuth. Observed, can probably testify to the introduction at $T \geq 800$ °C these elements in the B-sublattice structure of $BiFeO_3$. It is noticeable that the modification of CuO and ZnO total impurity content is much higher, and with increasing temperature up to $T \geq 830$ °C amount of impurity phases is increased. The observed clearly says about the impossibility of embedding of these cations in the structure of $BiFeO_3$.

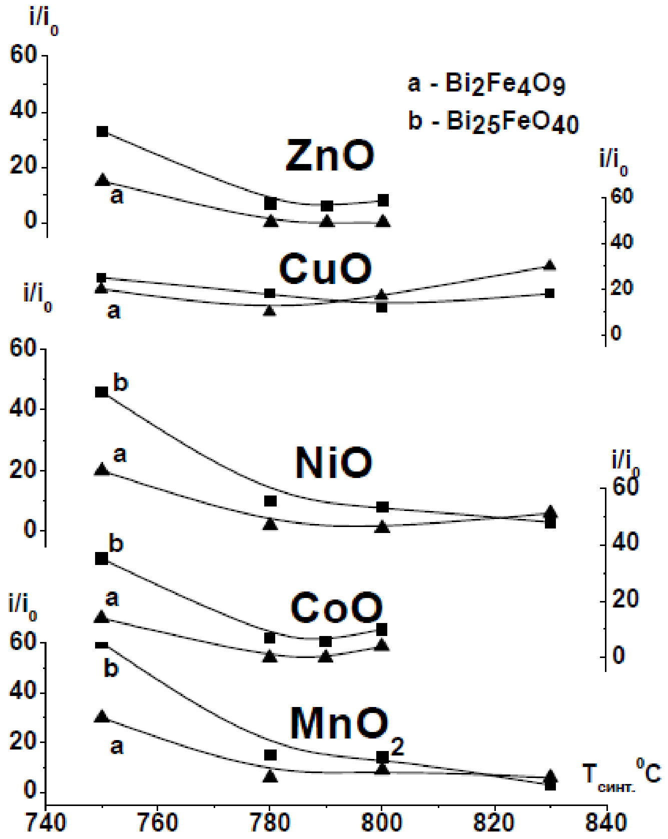

Fig. 1. The relative intensities of the X-ray peaks corresponding to the content of impurity phases

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NOVEL OXIDATION METHOD FOR ALGAN/GAN HIGH ELECTRON MOBILITY TRANSISTORS: SURFACE PASSIVATION AND GATE DIELECTRIC APPLICATIONS

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This work demonstrates a novel oxidation method for AlGaN/GaN high electron mobility transistors (HEMTs) by H_2O_2 treatment. The oxidation process is operated under atmospheric pressure and room temperature circumstance without using any vacuum facilities. After H_2O_2 treatment, about 13 nm AlOx (ε_r = 9.2) was formed upon AlGaN. The proposed oxidation process is used for passivation and MOS applications in AlGaN/GaN HEMT. The performances of both devices are superior to conventional HEMTs, including maximum drain-source current density ($I_{DS,max}$), the peak value of extrinsic transconductance ($g_{m,max}$), gate voltage swing (GVS), gate-drain breakdown/turn-on voltage (BV_{GD}/V_{on}), lower discrepancy between DC mode and pulse mode in oxide-passivated HEMT and MOS-HEMT. The proposed novel oxidation method reveals merits of simple and cost-effective, which are promising to fit the technique into GaN monolithic microwave integrated circuit (GaN-MMIC) fabrications.

THE STUDY OF TECHNOLOGY TRANSFER TO ADVANCED COUNTRIES

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Along with gradual exhaustion of earth energy and increasingly serious environmental pollution, worldwide countries proactively seek for the replacement energy with pollution free, high safety and low cost. After energy crisis in 1970 era, all industries face the problems of energy and production value. However the energy consuming industry starts to be actively involved in the international market, while the other industries face the challenges to improve the manufacturing process and reduce the pollution that triggers another revolutionary mania for manufacturing industry at the same time.

In the development of Taiwan, the small & medium enterprises are always focused on product R&D manufacturing, yet they rarely concern R&D and operational activities of replacement energy so that Taiwan small & medium enterprises should emphasize the development direction and operational strategy in the replacement energy. This issue has been concerned for many years in the foreign countries. To effectively achieve the inter-use between resources and technology, the technology transfer and intellectual property management experiences become the considering focus of enterprise.

From development process, Taiwan technology industry has relied on technology transfer from advanced countries, including Europe, America and Japan and is in line with abilities of Taiwan's production, assembly and OEM to accomplish the prosperity of Taiwan electronics industry in the past. Along with technology transfer and proactive effort put into R&D, Taiwan technology industry is able to create new technical ability and exports Taiwan technology and patent to Japan, Europe and America.

For Taiwan's technical level, Taiwan should take what kind of method to conduct technical cooperation, including agent, strategic alliance, selling, lease, technology transfer, merger & acquisition (M&A) and commercial exchange, with advanced countries so that Taiwan can widely disseminate the technology without hurting its own interests and bringing about the maximum benefit.

This research is focused on "Epoch Energy Technology Corp., Ltd." that the only technology company in Taiwan converts hydrogen and oxygen into energy and develops the replacement energy without causing environmental pollution. The theorem that water electrolysis can produce hydrogen and oxygen has been discovered for long time. Hydrogen is a very good energy while oxygen has the function of combustion supporting that is common sense for junior high school students. Since this technology was not mature at that time, this theorem has not been put into commercialization and practice in daily life. However the research target completely changes the situation and has successfully developed EPOCH Oxy-Hydrogen Generator, meanwhile Yu Chuan uses Taiwan R&D technology to propose the technology transfer to advanced countries.

NEW DOMAIN REQUIRED FOR THE MODERN ENGINEERING EDUCATION: SCIENCE, TECHNOLOGY AND SOCIETY (STS)

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More than one quarter undergraduate students are in engineering related departments. In addition, engineering related companies use more social resources than that ratio. Most of the social conflicts come from using and manipulating materials. There are great value discrepancies between different societies. In this modern democratic society, we expect public participants carry this responsibility. Unfortunately, public participants and experts speak their own languages in science and sociology.

When we look back to the curriculum of our engineering higher education, it reflects less in teaching students with multi-visions. This is however clearly required by the USA Accreditation Board on Engineering and Technology. An engineering education must teach students with global, economics, environmental, and sociology views. Present Taiwan engineering higher education does not include these social judgments, humanistic thinking philosophy in curriculum. Teachers wander in multi-discipline teaching. Division in education results in discrepancies between engineering and social society.

We have conducted several projects from the Ministry of Education. From the previous Science, Technology, and Society (STS) experiences, we plan to add STS concepts into engineering education. The present project is pioneer and important in that we are experienced and wish to share the STS concepts to engineering education. Engineering students will benefit a lot from STS experts. It is hoped that engineering students will have multi-vision in the upcoming challenging world.

A Preliminary Study on Porous Pt-TiO$_2$/Ti and C-TiO$_2$/Ti Electrodes for Electrochemical Prevention of Bio-Fouling with Simultaneously Drag Reduction

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This study investigated porous Pt-TiO$_2$/Ti and C(carbon)-TiO$_2$/Ti electrodes that were activated electrochemically to evolve hydrogen and oxygen gases in sea water for potential applications in bio-fouling prevention and simultaneous drag reduction of sea going ships. The porous Pt-TiO$_2$/Ti and C-TiO$_2$/Ti electrodes were fabricated by two steps, as follows: porous TiO$_2$/Ti plates were first prepared on pure titanium plates by a micro-arc oxidation technique using a micro-arc oxidation technique in the electrolyte solution containing Na_2WO_4 (15 g L^{-1}), $NaOH_3$ (2 g L^{-1}), and NaF (2 g L^{-1}) solutions. Pt and C thin layers were subsequently deposited on the porous TiO$_2$/Ti samples using a DC magnetron sputtering technique. The electric power provided an adequate DC bias to the Pt-TiO$_2$/Ti cathodes and C-TiO$_2$/Ti anodes, where hydrogen and oxygen microbubbles were electrolytically evolved in sea water. Our preliminary tests revealed that no attachment organisms were found on the porous electrodes at an applied DC bias of 2.0 V and 1.7 mA, an energy consumption rate of approximately 1.2 Wm^{-2}, after 30 days of field sea water tests. By contrast, organisms, mainly hydroids and barnacles, attached and grew on the electrode and its fixture, which was applied without a DC bias (i.e., attachment of organisms can be prevented). Furthermore, the porous electrodes continuously yielded a gas production rate of 33.4 $Lh^{-1}m^{-2}$ by electrolysis of sea water at an energy consumption rate of approximately 48 Wm^{-2}. It is attributable to considerably rough and network-structured porous Pt-TiO$_2$/Ti and C-TiO$_2$/Ti electrodes with low resistivity, rendering more reactive sites for electrolytic reactions for gas evolution in sea water. The microbubbles could be distributed evenly over the submerged surface, providing a higher local void ratio close to the hull surface and maximizing the drag reduction effect. Along with its excellent tribological properties, the proposed electrodes can be potentially realized for electrochemical prevention of bio-fouling with simultaneously drag reduction of ship of which submerged surface is covered mostly with the electrode plates.

BROADBAND CHROMIUM-DOPED FIBER AMPLIFIERS FOR NEXT-GENERATION FIBER TRANSMISSION SYSTEMS

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The commercially available erbium-doped fiber amplifiers (EDFAs) play a key role in providing the enabling technology for high-speed and long-distance optical communication systems in the last decades. The EDFAs can boost the amplitude of optical pulses in the spectral regime around 1550 nm without converting the optical pulses to electrical signals. However, current fiber amplifiers cover only a relatively small portion of the spectrum of the low-loss fibers. For example, the commercial EDFA gain bandwidth is limited primarily to the C-band between 1530 and 1565 nm, the L-band between 1565 to 1625 nm, and the S-band between 1450 to1520 nm, giving a total usable spectral bands of 140 nm. The other types of amplifiers, such as the thulium-doped and praseodymium-doped amplifiers provide gain from 1450-1520 and 1260-1360 nm bands, respectively. These usable bandwidths are less than the entire transmission window of newly developed fibers in many of today's optical networks. The transmission bandwidths of newly developed fibers can be as large as 300 nm from 1300 to 1600 nm of the low loss silica fibers. Therefore, it is strongly desirable to develop a single broadband fiber amplifier with gain bandwidth covering the entire spectral range from 1300 to 1600 nm for further increasing the transmission capacity of the wavelength-division multiplexing (WDM) systems.

In this study, we present the experimental breakthrough of a broadband chromium doped fiber amplifier (CDFA) for next-generation fiber transmission systems. A net gain of 1.2 dB, a 40 Gb/s data transmission, and a fiber-to-the home (FTTH) transmission with a 40 Gbit/s of 1550 nm and 10 Gbit/s of 1300 nm signals for broadband CDFA were successfully demonstrated. The demonstration of net gain, good system performance, and potential of broadband FTTH application may open up the possibility for utilizing the new CDFAs as ultra-broadband fiber optical amplifiers to cover the entire bandwidth (1300 to 1600 nm) of low-loss silica fibers. The technology breakthrough achieved in our experimental investigation is a major step toward the broadband CDFAs that could one day replace currently commercial EDFAs to further increase the transmission capacity of the WDM system for the next-generation fiber transmission systems.

DILUTE NITRIDE MATERIAL GROWN BY MOVPE AND ITS APPLICATIONS IN OPTOELECTRONICS

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In this investigation, the III-N-V alloys and their applications on optoelectronic devices have been grown by metal organic vapor phase epitaxy (MOVPE). In recent years, InGaAsN has attracted much attention. It has been demonstrated that incorporating a small amount of nitrogen into the InGaAs–GaAs system leads to a reduction in both band-gap energy and lattice mismatch. By carefully controlling the composition ratios, one should be able to achieve InGaAsN epitaxial layers lattice-matched to GaAs substrates and absorbing in 1.0 – 1.3 μm region. Therefore, InGaAsN is a potentially useful material which could serve as the absorbing layers of photodetectors or solar cells prepared on GaAs substrates for optical application. Previously, it has been reported that one can reduce dark current and enhance responsivity of PDs operating at 850 nm by introducing modulation-doped heterostructures into these devices. It has been shown that these improvements were related to the formation of two-dimensional electron gas (2DEG) at AlGaAs–(In)GaAs interfaces so that one could achieve a larger effective Schottky barrier height. Similar phenomena should also occur in AlGaAs–InGaAsN modulation-doped heterostructures systems as high electron mobility transistor application. On the other hand, InGaAsN also has the potential for high-efficiency tandem solar cells which have been investigated for application in terrestrial high-concentration solar systems and as a power source for satellites. However, GaInP/GaAs tandem cells are limited by the current generated in the bottom GaAs junction. The highest conversion efficiencies of any two-terminal photovoltaic device have been given by multi-junction III-V solar cells, such as GaInP/GaAs/Ge triple-junction cells. It is also an ideal candidate for next-generation multi-junction solar cell applications. $In_xGa_{1-x}N_yAs_{1-y}$ can be grown lattice-matched to GaAs (when $x \sim 3y$), with a band-gap of between 1 and 1.4 eV. Thus, solar cells with an InGaNAs absorption layer and band-gap energies as low as 1 eV have been fabricated. There is a tendency to insert InGaNAs in the four-junctions of GaInP/GaAs/GaInNAs/Ge solar cell structures. However, higher efficiencies have been prevented by the poor electronic quality of InGaAsN. Low electron mobility and short minority carrier lifetime have resulted in short minority carrier diffusion lengths. And the electrical-optoelectronic performance would get improved via *ex-situ* thermal annealing. Therefore, the unique material characteristics of the InGaAsN would lead to many potential applications in optical-electrical devices.

THE PROCESS OF SILICON BASED RESONANT TUNNELING DIODES AND ITS APPLICATION FOR UNDERWATER ACOUSTIC MULTIMEDIA COMMUNICATION

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A structure of the microwave components is the $Al/SiO_2/n\text{-}Si/SiO_2/n\text{-}Si/Al$ hetero-structure designed and fabricated with DC/RF sputter deposition system. In this paper, we demonstrate that quantum well structure of silicon material is deposited at room temperature. NDR effects are directly observed when voltage peak and conductance peak appears at the same voltage positions in the I-V

characteristics. The effect of barrier thickness on the peak-to-valley current ratio, peak voltage J_p and peak is studied. From experiment, we get the best double-barrier thickness of 0.6 μm, J_p = 184nA/cm^2, and J_v = 110nA/cm^2, and an associated PVCR =1.67, which are suitable for low power microwave device applications. Compared with past papers, our research has lots of advantage over them. PVCR of our designed structure is lower, Si based material is cheap, the process can be practiced at room temperature, and size of device is small. In addition, the result demonstrates the designed device can consume low power, switch fast, and be produced easily.

THE FABRICATION OF HYDROPHONE BASED ON EPITAXIAL PZT FILM FOR ACOUSTIC DEVICE APPLICATIONS

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This paper presents the design, fabrication, and characterization of a center-supported circular diaphragm sensor with figure of merit is described. By using circular diaphragm which can make the sensing leaf more flexible to have larger deformation resulted by sound pressure. The proto-type hydrophones of the electrical impedance and receiving sensitivity of the hydrophones in water were evaluated in the frequency range 10 – 200 kHz. The finite element model results were compared with the experimental results. The deposited PZT thin film micro electro-mechanical systems (MEMS) fabrication processes were used to fabricate the acoustic devices. We report the preparation of epitaxial multi-layer structures that are suitable for sensor fabrication on Si substrates, and we evaluate the sensitivity of these ultrasonic sensors to provide details of the first reported use of epitaxial PZT films on Pt/SiO_2/Si structures. The frequency is governed by the dimensions and the layering materials of the diaphragm and can be controlled independent of layer thickness offering more design flexibility and control over the frequency. The sharp resonance peaks observed for the typical hydrophone were broadened to a large extent for porous piezocomposite hydrophones due to weaker coupling of the structure. The highest levels of transmission sensitivity and receiving sensitivity, which can be obtained, are 70 dB and – 65 dB, respectively. The acoustic device has better performance when poled PZT thin film is used.

This research was supported in part by the Russian Foundation for Basic Research Grant No. 10-08-13300-RT_omi and National Science Council of Taiwan under contract NSC 99-2923-E-022-001-MY3.

MODELING AND OPTIMIZATION OF MEMS-BASED ACOUSTIC SENSOR FOR UNDERWATER APPLICATIONS

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This research presents some results of finite element (FE) analysis performed for membrane-type piezoceramic transducer for underwater acoustics applications at water deep up to 200 meters. We investigate the miniaturized membrane-type sensor with perforated holes in the active PZT membrane, intermediate, and protective plates. In this investigation an influence of the polyimide plate viscous damping, the membranes dimensions and the relative area of the perforated holes on the sensitivity frequency response of the MEMS devices was studied for the broadening the operating frequency band. A possibility of optimize these key parameter using the genetic algorithm working with the device's finite element model was demonstrated.
This research was supported in part by the Russian Foundation for Basic Research Grant No. 10-08-13300-RT_omi and National Science Council of Taiwan under contract NSC 99-2923-E-022-001-MY3.

TOOTHED GEARS ON BASE OF CURVATURE CONTACT EFFECTS

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Cardinal improvement of traditional gearings [1, 2] and creation of original gearing systems [3] are based on the revealed fundamental effects of curvature of contact for elastic bodies. The effects of curvature of contact are the effects of much greater (in comparison with classical solutions of Hertz and

Block) influence of curvature of elastic bodies on levels of a pressure stress and temperature in their contact [1, 2]. New gears have best qualities on bending, scoring and contact strength, noise level, structural flexibility (up to the realization of highly loaded narrow gears without axial efforts with small number of teeth z_1 up to $z_1 = 1$), etc.

References

[1] Zhuravlev G. A. About Influence of Hydrodynamic Factors to Choice of a Pressure Angle // Proceedings of International Conference on Mechanical Transmissions and Mechanisms (MTM'97), July 1st – 4th, 1997, Tianjin, China, p. 554-558.

[2] Zhuravlev G. A. Conditions of Teeth Tribocontact and Ways of Improving Gear Pairs // *Journal of Friction and Wear*, Allerton Press, Vol. 20, № 2, 1999, p. 57-69.

[3] Zhuravlev G. A. Gear Drive // Europatent № 1908992, 05.05.2010 // USA Patent № US 8,061,229 B2, Nov. 22, 2011 // Japan Patent № 4838307, Oct. 7, 2011 // China Patent № ZL 200580050187.5, June 8, 2011.

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Schedule

3 June 2012 (Sunday)

***Arrival of Taiwanese delegation in Rostov-on-Don* 11:35, 13:30 and 15:30**

Accommodation of Taiwanese participants of PMNM-2012 in hotel "Nikolaevsky" and Grand-Hotel "AMAKS"

***Registration of Russian participants of PMNM-2012 in Vorovich Mechanics and Applied Mathematics Research Institute* 14:00 – 18:00**

4 June 2012 (Monday) South Scientific Center of Russian Academy of Science

OPENING CEREMONY 9:30

***Greetings of the Head of SSC RAS, Academician of RAS* G. G. Matishov 9:30 - 9:40**

Greetings of PMNM-2012 Co-Chairmen:

I. A. Parinov 9:40 - 9:50

Shun-Hsyung Chang 9:50 - 10:00

***Greetings of Vice-Rector of the Southern Federal University* E. K. Aidarkin 10:00 - 10:10**

***Greetings of Director of the Vorovich Mechanics and Applied Mathematics Research Institute, Southern Federal University* F. A. Surkov 10:10 - 10:20**

***Greetings of Director of the Engineering and Applied Science Department, National Science Council* Ching-Ting Lee, 10:20 - 10:25**

***Greetings of Professor of the National Kaohsiung Marine University* Chi-Tsan Lin 10:25 - 10:30**

***Plenary Report (PR-1):* Kalinchuk V. V., Shevtsov S. N.** Physics and Mechanics of New Materials in Southern Scientific Center of RAS **10:30 - 10:50** (the report duration is 15 min + questions and discussion during 5 min)

Plenary Report (PR-2):* Dong-Sing Wuu, *President of the Da-Yeh University Recent Advancements to Enable ECO-LED Technology **10:50 - 11:10** (the report duration is 15 min + questions and discussion during 5 min)

Plenary Report (PR-3):* Yan-Kuin Su, *President of the Kun Shan University Dilute Nitride Material Grown by MOVPE and Its Applications in Optoelectronics **11:10 - 11:30** (the report duration is 15 min + questions and discussion during 5 min)

***Coffee-Break* 11:30 - 12:00**

United Oral Session (Chairman – Prof. V. Yu. Topolov):

“Physics and Mechanics of New Materials“ (PM1) 12:00 - 13:30 (the report duration is 15 min + questions and discussion during 5 min)

(P-1) ***V. Yu. Topolov*** Heterophase States in Perovskite-Type Ferroelectric Solid Solutions: From Domain Types to Phase Contents **12:00 - 12:20**
(M-1) ***A. O. Vatulyan, I. V. Bogachev, O. V. Yavruyan*** Properties Identification of the Inhomogeneous Electroelastic Medium **12:20 - 12:40**
(P-2) ***A. V. Pavlenko, A. V. Turik, L. A. Reznitchenko*** Dielectric Retardation and Relaxation in $PbFe_{1/2}Nb_{1/2}O_3$ Ceramics **12:40 - 13:00**
(M-2) ***T. G. Lupeiko, D. V. Nasonova, A. N. Soloviev*** Simulation and Experimental Testing of Piezocomposites with Regular Structure **13:00 - 13:20**

Dinner **14:00 - 15:00**

Visit of Taiwanese delegation in Southern Federal University (1 group) **15:30 - 18:00**

Visit of Taiwanese delegation in Museum ***of*** Fine ***Art (2 group)*** **15:30 - 18:00**

Excursion on Rostov-on-Don **18:00 - 20:30**

5 June 2012 (Tuesday) Department of Mathematics, Mechanics and Computer Sciences, Southern Federal University

Greetings of Dean of the Department of Mathematics, Mechanics and Computer Sciences, SFU M. I. Karyakin **9:30 - 9:40**

Oral Sessions:

“Processing Techniques of New Materials” (T1) 9:40 - 11:00 (the report duration is 15 min + questions and discussion during 5 min) ***(Chairman – Prof. Min Yen Yeh)***

(T-1) ***Min Yen Yeh, Yu-Fong Huang, Cheng-Liang Huang, Dong-Sing Wuu*** Cu_2ZnSnS_4 Solar Cell Material Prepared by Spin-Coating Metal Chloride Precursors and Treated with Post-Synthesizing and Annealing **9:40 – 10:00**
(T-2) ***Bau-Tong Dai, Jia-Min Shieh, Chang-Hong Shen, Ting-Jen Hsueh, Wen-Hsien Huang, Fu-Liang Yang*** Nanotechnologies in Low-cost Solar Cells **10:00 - 10:20**
(T-3) ***A. A. Gusev, E. G. Avvakumov, V. P. Isupov*** Influence of Mechanical Activation on the Synthesis and Properties of the Solid Solution Based on Lead Zirconate-Titanate and Lithium Niobate **10:20 - 10:40**
(T-4) ***Andrey N. Rybyanets, Anastasia A. Naumenko*** Nanoparticles Transport in Ceramic Matrixes: A Novel Approach for Ceramic Matrix Composite Fabrication **10:40 - 11:00**

“Mechanics of New Materials (M2) 9:40 - 11:00 (the report duration is 15 min + questions and discussion during 5 min) ***(Chairman – Prof. S. M. Aizikovich)***

(M-3) ***Sergey Aizikovich, Leonid Krenev, Igor Fedotov, Sergey Volkov, Andrey Vasiliev*** The Analytical Solution of Axisymmetric Contact Problems for the Coatings of Complicated Structure **9:40 – 10:00**
(M-4) ***Irina S. Trubchik*** Analytical Solution of the Contact Problem for the Graded Coatings of Non-Deformable Foundation Taking into Account the Independent Changes, as the Elastic Modulus and Poisson’s Ratio **10:00 - 10:20**

(M-5) ***S. Derezin*, L. Zubov** Influence of Dislocations and Disclinations on Nonlinear Deformation of Thin-Film Materials **10:20 - 10:40**
(M-6) ***S. I. Builo*** Physical, Mechanical and Statistical Aspects of Acoustic Emission Diagnostics **10:40 - 11:00**

***Coffee-Break* 11:00 - 11:30**

Oral Sessions:

"Physics of New Materials" (P2) 11:30 - 13:00 (the report duration is 15 min + questions and discussion during 5 min) ***(Chairman – Prof. Chi-Tsan Lin)***

(P-3) ***Hao-Hsiung Lin, Chian-Lin Chiou, Yan-Ting Lin, Ta-Chun Ma, Jian-Sheng Wu, Zhe-Chuang Feng*** Structural and Electrical Properties of Dilute Nitride GaAsSbN **11:30 - 11:50**
(P-4) ***R. H. Horng, D. S. Wuu, P. Ravadga*** Cathodoluminescence Study of β-Ga_2O_3 Epilayers Grown by MOCVD **11:50 – 12:10**
(P-5) ***M. V. Talanov, L.A. Reznitchenko*** Features of Electromechanical Properties of Ceramics Based on Relaxor Ferroelectrics for Use in MEMS **12:10 – 12:30**
(P-6) ***I. P. Raevski, A. G. Lutokhin, C. C. Chou, S. I. Raevskaya, A. F. Semenchev, Yu. N. Zakharov, D. V. Suzdalev, E. M. Panchenko, V. V. Titov, A. S. Emelyanov*** Field-Induced Enhancement of Pyroelectric and Piezoelectric Response of Disordered Ferroelectrics **12:30 – 12:50**

"Applications of New Materials" (A1) 11:30 - 13:00 (the report duration is 15 min + questions and discussion during 5 min) ***(Chairman – Prof. A. N. Rybyanets)***

(A-1) ***A. N. Rybyanets, Y. N. Zakharov, I. P. Raevskii, V. A. Akopyan, E. V. Rozhkov, I. A. Parinov*** Development of New Piezo- and Pyroelectric Materials and Transducers Designs for Energy Harvesting Devices **11:30 - 11:50**
(A-2) ***Sergey Shevtsov, Michail Flek, Igor Zhilyaev*** Modeling and Optimal Design of Power High Stroke Piezoelectric Actuators for Rotorcraft Applications **11:50 - 12:10**
(A-3) ***Yuang-Tung Cheng, Jiun-Chen Liou, Kuo-Chang Hou, Shun-Hsyung Chang, David. R. C. Chu, I. A. Parinov, Chih-Chin Yang, Ian Y.Y. Bu, S. N. Shevtsov, M. S. Shevtsova, I. V. Zhilyaev*** The Fabrication of Hydrophone Based on Epitaxial PZT Film for Acoustic Devices Application **12:10 – 12:30**
(A-4) ***V. N. Noskov, M. Yu. Pustovetov*** Multi-Sectional Superconducting Magnetic Energy Storage (SMES) For Railway Traction Applications **12:30 – 12:50**

Posters* 9:30 - 13:00** ***(Co-Chairmen – Prof. S. N. Shevtsov and Prof. Chen-Ching Chi)

***Dinner* 13:30 - 14:30**

***Visit of Taiwanese delegation in Rostov State Transport University (1 group)* 15:00 - 17:30**

***River walk on Don (2 group)* 15:00 - 17:30**

BANQUET 18:00 - 20:30

6 June 2012 (Wednesday) The Main Building of Southern Federal University

Oral Sessions:

"Processing Techniques of New Materials" (T2) 9:30 - 11:00 (the report duration is 15 min + questions and discussion during 5 min) ***(Chairman – Prof. I. P. Raevski)***

(T-5) ***I. P. Raevski, S. P. Kubrin, A. V. Blazhevich, C. C. Chou, I. N. Zakharchenko, V. V. Titov, D. A. Sarychev, S. I. Raevskaya, M. A.Malitskaya, E. I. Sitalo*** Dielectric, Piezoelectric and Mössbauer Studies of Perovskite Multiferroics and Solid Solutions on Their Base **9:30 - 9:50**
(T-6) ***Che-Hao Liao, Wen-Ming Chang, Yu-Feng Yao, Chih-Yen Chen, Horng-Shyang Chen, Hao-Tsung Chen, Shao-Ying Ting, Dong-Ming Yeh, Chieh Hsieh, Yean-Woei Kiang, Chih-Chung Yang*** MOCVD Growth and Characterization of Regularly Patterned Nanorod LED Arrays with Polar and Non-polar InGaN/GaN Quantum Wells **9:50 - 10:10**
(T-7) ***Jen-Inn Chyi, Hsueh-Hsing Liu, Hsien-Yu Lin*** Growth of Semi-Polar GaN/InGaN on V-Grooved 7°-off (100) Si Substrates by Metal-Organic Chemical Vapor Deposition **10:10 - 10:30**
(T-8) ***Edward Yi Chang, Shih Hsuan Tang, Chia Hua Chang, Chien I Kuo, Hai Dang Trinh, Yung Hsuan Su*** Growth of $In_xGa_{1-x}As$ and Ge epitaxial layers on Si Substrate for Post CMOS Application **10:30 - 10:50**

"Applications of New Materials" (A2) 9:30 - 11:00 (the report duration is 15 min + questions and discussion during 5 min) ***(Chairman – Prof. A. V. Nasedkin)***

(A-5) ***A. V. Nasedkin*** Some Approaches to Finite Element Analysis of Piezoelectric Devices with Gyration Effects and Temperature Fields **9:30 - 9:50**
(A-6) ***A. V. Nasedkin, M. S. Shevtsova*** Multiscale Computer Simulation of Piezoelectric Devices with Elements from Porous Piezoceramics **9:50 - 10:10**
(A-7) ***V. K. Ignatjev, A. A. Orlov*** System Function of Magnetoelectronic Devices **10:10 - 10:30**
(A-8) ***G. A. Zhuravlev*** Toothed Gears on Base of Curvature Contact Effects **10:30 - 10:50**

Coffee-Break **11:00 - 11:30**

Oral Sessions:

"Physics of New Materials" (P3) 11:30 - 12:30 (the report duration is 15 min + questions and discussion during 5 min) ***(Chairman – Prof. V. B. Shirokov)***

(P-7) ***V. B. Shirokov, Yu. I. Yuzyuk, V. V. Kalinchuk, V. V. Lemanov*** Material Parameters of the (Ba, Sr)TiO_3 Solid Solutions **11:30 – 11:50**
(P-8) ***A. S. Anokhin, Yu. I. Golovko, V. M. Mukhortov, Yu. I. Yuzyuk*** Raman Scattering and X-Ray Diffraction Studies of Multilayered Structures and Superlattice Based on Barium-Strontium Titanate and Bismuth Ferrite **11:50 – 12:10**
(P-9) ***P. M. Shmakov*** Research of Conditional Viscosity of Thermally Activated Water **12:10 – 12:30**

"Applications of New Materials" (A3) 11:30 - 12:30 (the report duration is 15 min + questions and discussion during 5 min) ***(Chairman – Prof. W.-C. Hsu)***

(A-9) ***Wei-Chou Hsu, Han-Yin Liu, Bo-Yi Chou, Ying-Nan Lai, Ching-Sung Lee, Chiu-Sheng Ho*** Novel Oxidation Method for AlGaN/GaN High Electron Mobility Transistors: Surface Passivation and Gate Dielectric Applications **11:30 – 11:50**
(A-10) ***Ching-Ting Lee, Ying-Shuo Chiu, Shu-Ching Ho, Yao-Jung Lee*** Investigation of Integrated ZnO-Based Ion-Selective Field-Effect-Transistor pH Sensors **11:50 – 12:10**
(A-11) ***Wood-Hi Cheng, Hidenori Taga, Sheng-Lung Huang, Yi-Jen Chiu, Pi Ling Huang, Yi-Chung Huang*** Broadband Chromium-Doped Fiber Amplifiers for Next-Generation Fiber Transmission Systems **12:10 - 12:30**

CLOSING CEREMONY 12:40 - 13:10

Dinner **13:30 - 14:30**

Visit of Taiwanese delegation in International Department of Rostov City Administration (1 group) **15:00 - 17:00**

Visit of Taiwanese delegation in Museum of Local Lore (2 group) **15:00 - 17:00**

Departure of Prof. W.-C. Hsu group to Moscow **19:00 - 21:00**

7 June 2012 (Thursday)

Excursion in Helicopter Museum of Rostvertol **9:30 - 11:00**

Departure of Prof. S.-H. Chang group to Moscow **11:00 - 13:00**

Poster Session 5 June 2012 (Tuesday) 9:30 - 13:00

(Co-Chairmen – Prof. S. N. Shevtsov and Prof. Chen-Ching Chi)

(PO-1) ***A. O. Ageev, A. V. Rukomoykin, M. S. Solodovnik*** Autocatalytic Growth of Whiskers on GaAs(100) by MBE

(PO-2) ***A. O. Ageev, V. A. Smirnov, M. V. Rubashkina, M. S. Solodovnik*** Determination of Young's Modulus of Gallium Arsenide Whiskers by Atomic Force Microscopy

(PO-3) ***O. A. Ageev, E. Yu. Gusev, E. G. Zamburg*** Novel NO_2, NH_3, CH_4 gas sensor based on nanocrystalline ZnO and VO_x Films

(PO-4) ***O. A. Ageev, E. G. Zamburg, D. E. Vakulov, Z. E. Vakulov*** Growth Horizontal-Aligned ZnO Nanowires by Pulsed Laser Deposition

(PO-5) ***V. A. Akopyan, Yu. N. Zaharov, I. A. Parinov, E. V. Rozhkov, S. N. Shevtsov*** Theoretical and Experimental Investigations of Cantilever Type Piezoelectric Generators

(PO-6) ***K. P. Andrushin, I. N. Andrushina, S. I. Dudkina, L. A. Reznichenko*** Materials for Low-Frequency Applications Based on the System (Na, K, $Cd_{0.5}$)NbO_3

(PO-7) ***I. N. Andrushina, K. P. Andrushin, L. A. Shilkina, V. A. Aleshin, L. A. Reznichenko*** The Formation of a Ceramic Frame and Grain Structure of PZT Solid Solutions

(PO-8) ***T. A. Bednaya, T. V. Semenistaya*** Development and Validation of a Neural Network Model for the Gas Sensitive Properties of Ag-containing Polyacrylonitrile Films

(PO-9) ***N. V. Belikov, Y. M. Zanimonets, V. V. Pavlov, A. M. Kakurin, A. S. Yudin*** New Approaches to the Problem of Increasing Accuracy and Stability of Critical Loading of Bursting Discs

(PO-10) ***V. V. Belozerov, S. I. Bosyj, S. I. Builo, J. V. Prus*** BETA-Analysis

(PO-11) ***V. N. Berkovich*** Random Vibrations in the Wedge-Shaped Elastic Medium

(PO-12) ***S. V. Biryukov, S. I. Masychev*** Surface Acoustic Waves in Thin Ferroelectric Films of Barium Strontium Titanate

(PO-13) ***N. I. Buravchuk, O. V. Guryanova*** Efficient Building Materials from Industrial Wasters

(PO-14) ***M. I. Chebakov, S. A. Danilchenko, I. V. Kolesnikov, Yu. F. Migal, N. A. Myasnikova, A. V. Nasedkin*** Development of the Multilayered Structurally Heterogeneous Antifriction Nanomodified Covering

(PO-15) ***M. I. Chebakov, P. G. Ivanochkin, E. M. Kolosova, N. A. Myasnikova*** Development of Calculation Methods and Designing of Binary Sliding Bearing

(PO-16) ***A. V. Cherpakov*** Information Technologies at Diagnostics of Incision in Components of Rod Frame Constructions

(PO-17) ***Chih Chin Yang, Chong Yan Chen, Jenny Chih-Yu Lee, Ming Lung Hsieh, Shau Jie Shia, Shun Hsyung Chang, Ian Yi-Yu Bu*** Influence of Parasitic Effect between Frequency and Quantum Impedance for Quantum Resonant Materials and Structures

(PO-18) ***Chin-Feng Lin, Shun-Hsyung Chang, Chia-Chang Lee, Wen-Chin Wu, Wei-Hua Chen, Kao-Hung Chang, Jenny Chih-Yu Lee, Ivan A. Parinov*** An MIMO-OFDM Underwater Acoustic Multimedia Communication

(PO-19) ***C. C. Chou, Y. C. Liu, I. P. Raevski, V. V. Titov, S. I. Raevskaya, H. H. Chen*** Rapid Annealing of PZT Thick Films on Stainless Steel Substrates Using CO_2 Laser Processing

(PO-20) ***V. V. Dudarev*** On Restoring of the Inhomogeneous Compliance Module in Piezoelectric Rod

(PO-21) ***V. K. Ignatjev, S. V. Perchenko*** Quasi-linear Conductivity of Non-linear Plasma-Like Media

(PO-22) ***V. K. Ignatjev, D. A. Stankevich*** Analysis of Magnetic Microtopology

(PO-23) ***G. Y. Karapetian, V. G. Dneprovski*** Research of the Opportunity to Use of MISM Structures for Cooling of Light-Emitting Diodes

(PO-24) ***O. K. Kaznacheyeva*** Identification of Stiffness Parameters of Non-Linear Elastic Reinforced Beam

(PO-25) ***S. P. Konovalenko, T. V. Semenistaya*** Low-Temperature CO Gas Sensors Based on Cobalt-Containing Polyacrylonitrile

(PO-26) ***Y. S. Lin, C. C. Chou, I. P. Raevski, V. V. Titov, S. I. Raevskaya, H. H. Chen*** Effect of $CaTiO_3$ Addition on Physical and Electrical Properties of $Na_{0.52}K_{0.48}NbO_3$ Lead-Free Piezoelectric Ceramics

(PO-27) ***T. G. Lupeiko*** New Decisions in Hydroacoustics and Acoustics Made by Innovational-Educational Center "New Materials" of SFU

(PO-28) ***A. A. Lyapin, R. D. Nedin, P. S. Uglich, A. O. Vatulyan*** On the Reconstruction of the Properties of the Non-homogeneous Poroelastic Media

(PO-29) ***D. I. Makariev*** The Use of Half-Wavelength Matching Layers to Form the Optimal Pulse Response of IMMERSION Ultrasonic Transducers

(PO-30) ***A. I. Miller, I. A. Verbenko, L. A. Reznitchenko, A. A Gusev*** Effect of Thermodynamic Prehistory on the Evolution of Dielectric Spectra of Bismuth Ferrite

(PO-31) ***I. P. Miroshnichenko, I. A. Parinov, E. V. Rozhkov, V. P. Sizov*** Novel Optical Means for Measurement of Displacements of the Control Object Surfaces at State Diagnostics of Materials and Goods

(PO-32) ***I. P. Miroshnichenko, V. A. Sorokin, V. A. Shevtsov*** Vibro-Stable Optical Measurer of Displacements for Mobile Diagnostic Systems

(PO-33) ***A. A. Pavelko, L. A. Shilkina, S. I. Dudkina, Ju. I. Jurasov, L. A. Reznichenko*** Phase Composition and Piezodielectric Response of Solid Solutions of a Multicomponent System with a Different Nature of the Ferroelectric Behavior

(PO-34) ***R. A. Shakhovoy, V. B. Shirokov, Y. I. Yuzyuk*** Phenomenological Theory of Asymmetric Superlattices $BaTiO_3/BaZrO_3$

(PO-35) ***Shun-Hsyung Chang, Chih-Chin Yang, Ian Y. Y. Bu*** Fabrication of Highly Sensitive ZnO Based Humidity Sensor Through Low Cost Method

(PO-36) ***E. N. Sidorenko, I. I. Natkhin, A. N. Rybyanets*** Absorption and Emission Spectra of UHF Electrodynamic System "Microstrip Line – Piezoelectric Sample"

(PO-37) ***V. P. Sizov, I. P. Miroshnichenko*** On Use of Generalized Method of Scalarization of the Dynamic Elastic Fields in Transverse Isotropic Media

(PO-38) ***A. N. Soloviev, I. V. Baranov, P. A. Oganesyan, A. S. Skaliukh*** Identification of the Heterogeneous Properties of Piezoelectric Materials Based on Genetic Algorithms and Finite Element Method in ACELAN

(PO-39) ***A. N. Soloviev, T. G. Lupeiko, L.V. Duong*** FEM Modeling of Piezoelectric Transducer for Energy Storage Devices

(PO-40) ***A. N. Soloviev, M. U. Shevtzov, Shun-Hsyung Chang, Jr-Ping Wang, Jiing-Kae Wu*** Determination of Anisotropic Elastic Properties of Composites Based on a Combination of Analytical and Finite Element Solutions and the Genetic Algorithm

(PO-41) ***A. N. Soloviev, A. S. Spogakin, Jiing-Kae Wu, Ping-Chen Wu, Chih-Chin Yang*** Identification of Defects in the Coatings from Functionally Gradient Materials

(PO-42) ***Kh. A. Sudykov, A. G. Abubakarov, I. A. Verbenko, K. P. Andrushin, L.A. Reznichenko*** Piezoelectric Characteristics of Lead-Free Ceramic System $(Na_{1-x}Li_x)NbO_3$ Modified by MnO_2 in the Power Mode

(PO-43) ***V. Yu. Topolov, P. Bisegna, S. E. Filippov, A. A. Vorontsov*** Piezoelectric Anisotropy in Two-Component Composites Based on Ferroelectric Ceramics

(PO-44) ***V. Yu. Topolov, C. R. Bowen, A. V. Krivoruchko*** Orientation Effects Improving the Hydrostatic Piezoelectric Response in Novel 2–2 Composites Based on Relaxor-Ferroelectric Single Crystals

(PO-45) ***D. G. Trayzhon*** Numerical Modeling of the Energy Spectrum of InAs/GaAs Quantum Dots

(PO-46) ***A. V. Turik*** Dielectric Retardation and Relaxation in Non-Debye Ferrites

(PO-47) **I.** ***A. Verbenko, Kh. A. Sudykov, L. A. Shilkina, A. G. Abubakarov, L. A. Reznichenko*** Effect of 3D-Metal Oxide Phase Formation on the $BiFeO_3$

(PO-48) ***Wen-chang Lin, Ying-fang Huang*** The Study of Technology Transfer to Advanced Countries

(PO-49) ***Wenling Hong, Chitsan Lin, J. P. Wang*** New Domain Required for the Modern Engineering Education: Science, Technology and Society (STS)

(PO-50) ***Wen-Ling Hong, Kee-Rong Wu, Jr-Ping Wang, Chung-Wei Yeh, Juinn-Bing Tan, Jiing-Kae Wu*** A Preliminary Study on Porous Pt-TiO_2/Ti and C-TiO_2/Ti Electrodes for Electrochemical Prevention of Bio-Fouling with Simultaneously Drag Reduction

(PO-51) ***Yuang-Tung Cheng, Jiun-Chen Liou, Kuo-Chang Hou, David. R. C. Chu, Ping-Chen Wu, Shun-Hsyung Chang*** The Process of Silicon Based Resonant Tunneling Diodes and its Application for Underwater Acoustic Multimedia Communication

(PO-52) ***I. Zhilyaev, M. Shevtsova, I. Parinov, S.-H. Chang, J. C.-Y. Lee, P.-C. Wu, C.-F. Lin, D.-S. Wuu*** Modeling and Optimization of MEMS-Based Acoustic Sensor for Underwater Applications


Norway
Oslo
Sweden
Stockholm
Finland
Helsinki
Tallinn
Riga
Estonia
Lithuania
Latvia
St Petersburg
Vilnius
Novgorod
Minsk
Vologda
Belarus
Rostov
Yaroslavl
Kiev
Moscow
Vladimir
Suzdal
Ukraine
Rostov-Don
Black Sea
Sochi
Caucasus Mountains
Volgograd
Astrakhan
Georgia
Grozny
Tbilisi
Caspian Sea
Murmansk
Arkhangelsk
Arctic Ocean
Ural Mountains
Yekaterinburg
Astana
Kazhakstan
Russia
Siberia
Altay Mountains
Irkutsk
Lake Baikal
Ulaan Baatar
Mongolia
China
Yakutsk
Khabarovsk
Vladivostok
China
Beijing
Pacific Ocean
Kamchatka Peninsula
Sakhalin Island
Hokkaido
Japan
Tokyo