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Review

Review article

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Modern scientific and practical approaches to the production of substrates from semiconductor compounds A^3B^5 . Review

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Abstract

Modern electronic and optical engineering uses A^3B^5 single-crystal semiconductor materials (GaAs, GaSb, InAs, InSb, and InP) as substrates for epitaxial growth. These materials are obtained in the form of massive single-crystal ingots. Therefore, technologies for processing of these A^3B^5 wafers are developed to produce the substrates for epitaxial growth. The miniaturization of modern systems and devices demands the high quality of the substrates surface. One of the main criteria is a low surface roughness (R_a) (of about 0.5 nm). To meet this requirement, it is necessary to elaborate the existing methods of surface treatment.

The review analyses the current approaches to the treatment of the surface of semiconductor wafers of A^3B^5 single-crystal materials. It considers the specifics of wafers machining followed by their polishing. The article also presents an analysis of the polishing methods. It reveals that at the moment the chemical-mechanical polishing of A^3B^5 wafers is the most commonly used method. The review presents the main parameters of this process and systematizes the existing theoretical approaches. The analysis determined the key tendencies in the development of chemical-mechanical polishing of semiconductor A^3B^5 wafers aimed at increasing the quality of wafers. The article also analyses the latest studies regarding the methods of chemical polishing as an alternative to chemical-mechanical polishing. The next section focuses on surface passivation methods used upon obtaining wafers with a low roughness. Passivation is performed to reduce the reactivity of the surface and stabilize surface states of wafers.

A classification of passivation methods is suggested based on the obtained chemical composition of the surface, when the passivation layers are created using oxidation, sulfidizing, or nitriding. Another classification is based on the method of creating passivating coatings and includes wet chemical methods and physico-chemical methods.

Keywords: Semiconductor plates, A^3B^5 materials, Machining, Polishing, Chemical mechanical polishing, Surface passivation

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Review article

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Features of the corrosion of coatings based on zinc alloys: oxidation products and the selective dissolution of zinc.

Review

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Abstract

The literature review analyses and systematizes the results of corrosion studies of widely used anti-corrosion zinc coatings based on various binary systems Zn-Al, Zn-Mg, Zn-Fe, Zn-Ni, Zn-Co. The patterns of corrosion, the role of selective dissolution and corrosion products in increasing the corrosion resistance of coatings in neutral chloride-containing environments have been studied. The analysis shows that the corrosion rate depends on the chemical and phase composition of zinc coatings, which is due to differences in the corrosion behavior of the phase components of the alloys. Selective dissolution has an ambiguous effect on the corrosion resistance of coatings. On the one hand, the process of selective dissolution of zinc can be accompanied by the formation of corrosion cracks, which reduces the corrosion resistance of the coating. On the other hand, a rough surface enriched with an electropositive alloying component is formed. As a result, roughness stimulates the deposition of a denser and more compact layer of corrosion products, which reduces the access of oxygen and other electrolyte components to the coating's surface. Under certain conditions, a film of corrosion products can provide additional resistance to the corrosion process due to low electrical conductivity. With the uniform dissolution of coatings, both the co-precipitation of complex compounds of zinc and alloying metals and the doping of the product layer with oxides or hydroxides of alloying metals occur. This also results in increased compactness and reduced electrical conductivity, which increases the corrosion resistance of the coatings. The purpose of the article: an overview of the results of studies of corrosion of zinc coatings, physical and chemical features of the formation and composition of the layer of corrosion products, the influence of corrosion products and selective dissolution on the corrosion resistance of coatings.



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A review of the results of studies relating to the corrosion of zinc coatings was carried out, taking into account the formation of a protective layer of corrosion products and the selective dissolution of zinc. The corrosion of zinc coatings is influenced by the structure and phase composition of the coatings, the selective dissolution of zinc, as well as the nature of the layer of corrosion products. The corrosion resistance of zinc coatings increases if a compact layer of corrosion products with low electrical conductivity is formed. The selective dissolution of zinc can have a positive effect on its protective ability due to the formation of a rough surface, which promotes the deposition of a denser layer of corrosion products. In the case of the uniform dissolution of zinc alloy coatings, alloying metals are able to integrate into the structure of zinc corrosion products, which makes the layer more compact and leads to a decrease in its electrical conductivity, significantly increasing the corrosion resistance of the coatings.

Keywords: Zinc coatings, Corrosion, Selective dissolution, Simoncolleite, Hydrozincite

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Review article

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Prospects of membrane catalysis in hydrogen energetics. Mini review

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Abstract

Hydrogen energetics is undoubtedly highly relevant today as it not only allows solving the issue of energy production from a renewable water source but can also prevent the formation of greenhouse gases. They say that any new idea is a well forgotten old one. The paper is dedicated to an excellent but still unimplemented work of Sainte-Claire Deville who managed to obtain hydrogen from water vapor using membrane technology. He used a clay pipe as a membrane which selectively permeated hydrogen. This process occurred with heating up to 950 °C. Sainte-Claire Deville managed to obtain only a mixture of hydrogen and oxygen in a ratio of 4:1 and then to clean the product from oxygen using chemical reactions.

Modern membrane catalysts based on palladium or its alloys are selectively permeable only for hydrogen. This means that the membrane catalysis method with palladium membranes could allow to realize of thermal water disassociation more effectively and solve the issues of hydrogen energetics using only renewable raw materials.

The history of hydrogen discovery and methods of its production was also studied in this review. Different methods of energy production were analyzed, including mineral resources, wind turbines, solar panels, hydroenergetics, electrolysis, and nuclear power, and a forecast was presented based on them. The review should be considered as an invitation to further discussions regarding this highly relevant and important topic.

Keywords: Energy, Hydrogen, Ecology, Economy, Sustainable development, Membranes, Palladium, Catalysis, Water vapor

For citation: Shaposhnik V. A. Prospects of membrane catalysis in hydrogen energetics. Mini-review. *Condensed Matter and Interphases*. 2024;26(1): 37–44. <https://doi.org/10.17308/kcmf.2024.26/11807>

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Original articles

Research article

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Synthesis and luminescent properties of PbS/SiO₂ core-shell quantum dots

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Abstract

The research focuses on the development of techniques for creating core-shell structures, based on colloidal PbS quantum dots (PbS QDs) and establishing the influence of the dielectric SiO₂ shell on the luminescent properties of PbS QDs. The objects of the study were PbS QDs with an average size of 3.0±0.5 nm, passivated with thioglycolic acid (TGA) and PbS/SiO₂ QDs, based on them with an average size of 6.0±0.5 nm. When we passivated the PbS QD interfaces with thioglycolic acid molecules, there were two luminescence peaks at 1100 nm and at 1260 nm. It was found that increasing the temperature of the colloidal mixture to 60 °C provides an increase in the intensity of the long-wave peak. An analysis of the luminescence excitation spectra of both bands and the Stokes shift showed that the band at 1100 nm is associated with the radiative annihilation of an exciton, while the band at 1260 nm is due to recombination at trap levels. The formation of PbS/SiO₂ QDs suppresses trap state luminescence, indicating the localization of luminescence centers predominantly at QD interfaces. The exciton luminescence at 1100 nm becomes more intensive.

Keywords: Lead sulfide quantum dots, Core-shell structures, SiO₂ shell, Luminescence spectra, Excitation spectra

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Acknowledgements: The results of transmission electron microscopy using a Libra 120 microscope were obtained with the help of the equipment of the Centre for Collective Use of Voronezh State University.

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Research article

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Isolation of partial coupled processes of anodic oxidation of OH⁻ ion on gold using a combination of a graph-kinetic analysis method and linear voltammetry data

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Abstract

The presence of several interconnected electrochemical processes occurring on the surface of an electrode, strictly speaking, does not allow the use of the principle of independent reactions. Often, partial reactions of a complex multi-stage electrochemical process are coupled both through common intermediates and through the competitive adsorption of electroactive species. The presence of conjugation leads either to a change in the potential at which the corresponding electrochemical process becomes possible or to a change in the rate of partial processes. The latter is called kinetic coupling. This does not allow the simple calculation of the rate of each partial reaction as the difference between the current density of the target and background processes. The method of kinetic diagrams can be used to establish the kinetic patterns of such processes. This study shows that this method is applicable not only for the analysis of coupled electrochemical processes of various types, but can also be used in obtaining partial currents of the stages of a separate complex electrode reaction occurring in a background solution. As an example, options for the kinetic modelling of the total voltammogram of the anodic process on an Au electrode in an aqueous alkaline medium in the mode of linear potential change are considered.

The stationary degrees of covering of the gold surface with various surface-active forms of oxygen are calculated depending on the electrode potential. It was established that the change in concentration of OH⁻ ions mainly affects the region of their adsorption potentials. A detailed analysis of stationary partial anodic processes in the Au|OH⁻, H₂O system was carried out and the shape of the general stationary voltammogram was determined by calculation. The latter is in qualitative agreement with the experimental polarization dependence.

It was shown that the type of calculated polarization dependence is determined by the degree of reversibility of individual stages and the rate of their occurrence. The performed analysis is necessary not only for the detailed scheme of the background anodic reaction on gold in an alkaline solution, but also for the subsequent kinetic description of the electrooxidation process of organic substances on a gold electrode.

Keywords: Electrode processes, Conjugation, Graphic-kinetic analysis, Adsorption, Voltammetry

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Research article

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Simple synthesis of floating Fe₂O₃/Luffa catalysts for the photo-Fenton degradation of methyl orange at near neutral pH

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Abstract

Although widely used in the textile industry, methyl orange is considered one of the most toxic dyes, which have negative impacts on the aquatic environment and needs to be removed from water bodies. Hence, the present paper reports the synthesis of new floating photo-Fenton catalysts based on the immobilization of Fe₂O₃ nanoparticles on the surface of Luffa sponges for the oxalate-induced-degradation of methyl orange. The floating catalytic sponges were prepared through a simple precipitation method followed by a reflux heating process and then characterized by field emission scanning electron microscopy, X-ray diffraction, atomic absorption spectrometry, and nitrogen adsorption-desorption experiments. According to the experimental results, methyl orange was effectively degraded over our floating catalytic sponges under light illumination at near neutral pH. The catalytic activity was also found to be enhanced with the increase in crystallinity of Fe₂O₃ nanoparticles, which can be achieved by the reflux heating. Besides, owing to the floating feature, these sponges are easily separated from the solution, thereby not forming a secondary source of pollution for water.

Keywords: Photo-Fenton catalyst; Floating material; Fe₂O₃; Luffa; Crystallinity

Funding: The research is funded by University of Science, VNU-HCM under grant number U2022-11.

For citation: Le T. Q. N., Ly T. Q. T., Nguyen A. T., Nguyen Q. Th., Tsai D.-H., Le T. Kh. Simple synthesis of floating Fe₂O₃/Luffa catalysts for the photo-Fenton degradation of methyl orange at near neutral pH. *Condensed Matter and Interphases*. 2024;26(1): 68–77. <https://doi.org/10.17308/kcmf.2024.26/11813>

Research article

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Microstructural and hydrophilic properties of polyethylene terephthalate glycol polymer samples with different 3D printing patterns

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Abstract

The aim of the work is to study the influence of the 3-D printing process with the Hercules Original printer by sequentially applying polymer layers using the FDM (Fused Deposition Modeling) method on the microstructural and hydrophilic properties of polyethylene terephthalate glycol (PETG) samples with different printing patterns. X-ray phase analysis revealed the presence of a greater ordering of amorphous PETG polymer chains in printed samples, which occurs during thermal and mechanical impact on the initial filamentous sample during 3D printing. This manifests itself in the increase of relative intensity for the main diffraction peak of the amorphous PETG polymer by an order of magnitude for all of the samples with five different print patterns. At the same time, IR spectroscopy data revealed the preservation of all intrastructural chemical bonds of the polymer both in the original thread and in printed samples. Close contact angles of about $\theta \approx 50^\circ$ for all printed samples, which is much smaller than the right angle $\theta = 90^\circ$, show that the surfaces of all five printed PETG samples with different patterns are hydrophilic.

Keywords: Polyethylene terephthalate-glycol PETG, Model drawings 3D printing, X-ray amorphous phase, Ordering of polymer chains, IR spectra, Intrastructural chemical bonds of the polymer, Hydrophilic surface

Funding: The research was carried out with the support of the Ministry of Education and Science of the Russian Federation partly within the framework of the state task for universities in the field of scientific activity, project No. FZGU-2023-006, and Agreement No. 075-15-2021-1351 in parts of the XRD research.

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Research article

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An investigation of the electronic structure and optoelectronic properties of 4-((2-hydroxy-3-methoxybenzylidene)amino)-N-(thiazol-2-yl) benzene sulfonamide

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Abstract

Molecules of 4-((2-hydroxy-3-methoxybenzylidene)amino)-N-(thiazol-2-yl)benzene sulfonamide were investigated at varying concentrations in dimethyl sulfoxide (DMSO). Different temperatures were employed to assess bandgap energies, Tauc plots, refractive indices, optical and electrical properties, and dielectric constants. The refractive index was determined through a straightforward model based on energy gap data and subsequently compared to experimental values. For the examination of the materials' optical properties, reflection and reflection loss at plasma frequencies were considered as they play a crucial role. Density functional theory (DFT) with a 6-311G++ (d, p) basis set and Becke's three-parameter hybrid (B3LYP) level of theory were utilized through Gaussian software to conduct the studies. Chemical reactivity and selectivity parameters, including HOMO-LUMO, global hardness, softness, electronegativity, electrophilicity, nucleophilicity, chemical potential, bandgap energy, and electron affinity, were computed. Becke's three-parameter hybrid exchange-correlation functional (B3LYP) level was employed for optimizing the geometry of the title molecule.

Keywords: Optoelectronic, UV-visible spectroscopy, HOMO-LUMO, DFT

For citation: Mamand D. M., Aziz D. M., Qadr H. M. An investigation of the electronic structure and optoelectronic properties of 4-((2-hydroxy-3-methoxybenzylidene) amino)-N-(thiazol-2-yl) benzene sulfonamide. *Condensed Matter and Interphases*. 2024;26(1): 88–103. <https://doi.org/10.17308/kcmf.2024.26/11811>

Research article

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Electrophysical properties of composite materials based on graphene oxide and polyaniline

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Abstract

The Hall method was used to study the electrical characteristics of composite materials based on polyaniline (PANI), graphene oxide (GO), and manganese. A comparison of these characteristics of GO-PANI and GO-PANI-Mn composite systems with GO and PANI monomaterials was carried out.

It was demonstrated that the electrical conductivity of composites was significantly higher than that of monomaterials and was determined by the charge carrier mobility.

Based on UV-visible and IR spectroscopy data, it was shown that the optical band gap (E_g) of the GO-PANI composite increased with the addition of metal, but decreased compared to PANI; the shift of characteristic vibrations to lower frequencies indicated a covalent interaction of the GO-PANI composite with manganese cations.

Keywords: Composite materials, Polyaniline, Graphene oxide, Specific conductivity, Band gap

Funding: The study was supported by the Russian Science Foundation grant No. 23-22-00459 at the Southern Federal University.

For citation: Myasoedova T. N., Nedoedkova O. V., Yalovega G. E. Electrophysical properties of composite materials based on graphene oxide and polyaniline. *Condensed Matter and Interphases*. 2024;26(1): 104–110. <https://doi.org/10.17308/kcmf.2024.26/11812>

Research article

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Spontaneous photomagnetoelectric effect in ferromagnetic GaMnAs epitaxial layers

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Abstract

Spontaneous photomagnetoelectric effect in ferromagnetic GaMnAs epitaxial layers has been investigated. The goal of this work is to study the temperature dependence of the spontaneous PME effect, determined along [110] and [1 $\bar{1}$ 0] crystal axes. GaMnAs layers with Mn concentration of 2.9 atomic percent studied in this paper were grown by low-temperature molecular beam epitaxy on semi-insulating GaAs (001) substrate. It was shown that below Curie temperature in the illuminated GaMnAs epilayers a transverse voltage (photo-EMF) was observed. This photo-EMF is associated with the photomagnetoelectric effect resulting from the separation the photogenerated carriers by the intrinsic magnetic field of the semiconductor matrix in ferromagnetic state. The temperature dependence of intrinsic photomagnetoelectric effect in GaMnAs epilayer was determined along [110] and [1 $\bar{1}$ 0] crystallographic axes. It was found that the photo-EMF measured along [110] crystal axis exhibits a maximum at temperatures of 35–40 K, while the photo-EMF measured along [1 $\bar{1}$ 0] axis increases monotonically with temperature decay. It was shown that the non-monotonous temperature dependence of the photomagnetoelectric effect along [110] axis can arise due to the reorientation of the easy axis of the sample with decreasing temperature.

Keywords: GaMnAs, Photomagnetoelectric effect, Molecular beam epitaxy, Ferromagnetic ordering, Curie temperature, Photoconductivity

Funding: the study was financially supported by the Agency of Innovative Development under the Ministry of Higher Education, Science and Innovation of the Republic of Uzbekistan, project No. FZ-2020092435.

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Research article

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Electrochemical activity of electroless Ni-P coatings in the hydrogen evolution reaction

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Abstract

The purpose of this study was investigation of the electrochemical activity of Ni-P coatings, differing in phosphorus content and structure, in the hydrogen evolution reaction (HER) and the identification of the reasons for their high activity in the reaction being studied.

The coatings were deposited from an electroless nickel plating solution, the phosphorus content in the coatings (from 4.8 to 8.0 wt. %) varied by changing the pH of the solution. It was found that during cathodic polarization in 0.5 M H₂SO₄ additional surface activation occurs as a result of dissolution of the surface layer of the coating, removal of phosphorus from the surface layer, and development of the electrode surface. Of all the coatings studied coatings containing 4.8% phosphorus were most susceptible to cathodic activation. Coatings with a phosphorus content of 8.0% were least susceptible to cathodic activation.

The similar electrochemical activity of the studied coatings (taking into account the roughness factor) in HER indicates that, as a result of cathodic polarization, the composition of the thin surface layer on which the cathodic reaction occurs is approximately the same, regardless of the initial phosphorus content.

Keywords: Electroless Ni-P coating, Electrochemical activity, Hydrogen evolution reaction, Roughness factor, Electrode capacitance

Acknowledgements: The study was supported by the Perm Scientific and Educational Centre “RATIONAL SUBSOIL USE”, 2023.

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Research article

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Study of the thermal conductivity of natural carbonates

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Abstract

The thermal conductivity of natural monoliths of calcite, dolomite marble, and limestone from various deposits was measured using the absolute stationary method of longitudinal heat flow in the temperature range of 50–300 K and the dynamic method in the range of 323–573 K. A majority of calcite marbles were inferior in thermal conductivity to dolomite marbles. At room temperature, the thermal conductivity coefficients of all studied samples were lower $k = 5$ W/(m K).

The obtained data were compared with the literature data. The diversity of experimental data from different authors on the thermal conductivity of carbonates is associated with qualitative differences in the samples studied.

Keywords: Minerals, Marble, Calcite, Dolomite, Limestone, Siderite, Thermal conductivity, Phonon-defect scattering, Temperature dependence

Funding: The study was carried out using the scientific equipment of the Centre for Collective Use of Bryansk State University and the Centre for Collective Use of the Prokhorov General Physics Institute of the Russian Academy of Sciences.

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Research article

<https://doi.org/10.17308/kcmf.2024.26/11817>**Electrochemical impedance of porous tantalum solids: modeling of frequency response****A. V. Syugaev, V. E. Porsev**¹*Udmurt Federal Research Centre of the Ural Branch of the Russian Academy of Sciences**34 Tatyana Baramzina str., Izhevsk 426067, Russian Federation***Abstract**

The paper proposes a new approach to the analysis of electrochemical impedance spectra of porous tantalum bodies, which involves modeling the frequency response via an equivalent circuit that takes into account the pore hierarchy. It was shown that the proposed circuit describes well the experimental data and allows characterization of the porous structure, including the contribution of different types of pores to the total capacitance of the porous body, characteristic relaxation times, and activation frequencies for different type pores. Two types of samples were analyzed: a porous tantalum body obtained by sintering Ta powder and a porous tantalum body covered with a Ta₂O₅ dielectric layer. Modeling showed a significant redistribution of contributions from pores of different types into the total capacitance after the formation of Ta₂O₅ due to the preferential isolation of the smallest pores and/or those difficult to access. The results of modeling of the frequency response of the analyzed samples agree well with the scanning electron microscopy data. The proposed approach has the potential to be advantageous for the technology of tantalum capacitors.

Keywords: Electrochemical impedance, Porous structure, Modeling

Funding: The studies were carried out using the equipment of the Center for Shared Use “Center for Physical and Physico-Chemical Methods of Analysis, Study of the Properties and Characteristics of Surfaces, Nanostructures, Materials, and Products” of the Udmurt Federal Research Centre of the Ural Branch of the Russian Academy of Sciences within the framework of the state assignment of the Ministry of Science and Higher Education of the Russian Federation (state registration No. FUUE-2024-0011).

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Research article

<https://doi.org/10.17308/kcmf.2024.26/11818>**Composition and structure of tungsten antimony acid****P. V. Timushkov¹, V. A. Burmistrov¹, M. N. Ulyanov¹, V. N. Semenov²**¹*Chelyabinsk State University,**70b ul. Molodogvardeytsev, Chelyabinsk 45402, Russian Federation*²*Voronezh State University,**1 Universitetskaya pl., Voronezh 394018, Russian Federation***Abstract**

Tungsten antimony acids (TAA) with the composition H_(2-x)Sb_(x)W_xO₆·nH₂O (0 < x ≤ 1.45; 0 < n ≤ 2.0) have been synthesized by hydrolysis of antimony trichloride pre-oxidized with nitric acid in the presence of varying amounts of Na₂WO₄. To obtain TAA protonated forms, the samples were kept in a 96% solution of sulphuric acid, the precipitate was washed until reaction became neutral and dried in air. The amount of tungsten, antimony, and silver ions in TAA was determined using energy dispersive analysis. Changes in structural parameters upon doping of AA with tungsten ions were studied using a Bruker D8 ADVANCE X-ray diffractometer (CuK_{α1}-radiation). The number of oxonium ions in TAA was determined by the substitution of these ions by silver ions in equivalent amounts (Ag⁺-TAA forms).

All obtained TAA samples and Ag⁺ TAA forms had a pyrochlore-type structure, space group symmetry *Fd3m*. Refinement of the arrangement of atoms in the structure using the Rietveld method showed that tungsten ions replace antimony ions and are statistically located in 16c, oxygen anions in 48f, and oxonium ions and water molecules in 16d and 8b positions, respectively.

When tungsten ions were introduced into samples, the structural parameters of the resulting phases changed. There was a decrease in the unit cell parameter and the distance between antimony ions and oxygen anions, while an increase in the distance between oxonium ions and oxygen anions located in 48f positions was observed. This allowed the removal of a proton from oxonium molecules and its transport via a system of hydrogen bonds formed by water molecules.

Keywords: Solid electrolytes of antimony oxide, Tungsten oxides, Antimony acid, Pyrochlore type structure

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Research article

<https://doi.org/10.17308/kcmf.2024.26/11897>**Electronic structure and composition of tin oxide thin epitaxial and magnetron layers according to synchrotron XANES studies****O. A. Chuvenkova¹, N. I. Boikov¹, S. V. Ryabtsev¹, E. V. Parinova¹, R. G. Chumakov², A. M. Lebedev², D. Smirnov³, A. Makarova⁴, S. S. Titova¹, K. A. Fateev¹, S. Yu. Turishchev¹**¹Voronezh State University,

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Abstract

The materials of the tin-oxygen system and thin-film structures based on them are modern and actual for the creation of a wide range of electronic devices, for example, resistive gas sensors of high sensitivity and short response time with low energy consumption and high manufacturability. An important direction in the study of such materials and structures is the control of properties with variations in technological formation regimes. Information on the composition, local atomic and electronic structure of thin layers of the tin-oxygen system with varying approaches to their production is in demand.

The work is devoted to the study of the electronic structure of thin layers of tin oxides obtained by modern methods of molecular beam epitaxy and magnetron sputtering. A study of the local partial density of electronic states in the conduction band by X-ray absorption near edge structure spectroscopy of tin and oxygen has been carried out. The data were obtained using high-intensity synchrotron radiation, which allows varying the monochromatized radiation quantum energy without loss in intensity, that is necessary to obtain high-resolution X-ray spectral data.

It is shown that the composition, local atomic surrounding, electronic spectrum and their features depend on the technology of formation and storage conditions of the studied structures. Synchrotron X-ray spectroscopy data show the presence of intermediate oxides of the tin-oxygen system in the studied materials after prolonged storage in laboratory conditions. The data obtained indicate the possibility of controlled variation in the composition, local atomic surrounding and electronic spectrum of thin-film structures of tin oxides of small thickness. The results of the work can be used in the formation and subsequent modification of thin and ultrathin layers of tin oxides by magnetron sputtering and molecular beam epitaxy, as well as in their further application as active layers of microelectronics devices.

Keywords: Tin and its oxides, Electronic structure, Density of states, Local atomic surrounding, Composition, Epitaxial nanolayers, Magnetron nanolayers, X-ray absorption near edge structure, Synchrotron investigations

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Research article

<https://doi.org/10.17308/kcmf.2024.26/11819>**Photoluminescent porous silicon nanowires as contrast agents for bioimaging****M. G. Shatskaia¹, D. A. Nazarovskaia¹, K. A. Gonchar¹, Ya. V. Lomovskaya^{1,2}, I. I. Tsiniiaikin¹, O. A. Shalygina¹, A. A. Kudryavtsev^{1,2,3}, L. A. Osminkina^{1,3}**¹Lomonosov Moscow State University,

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Abstract

Porous silicon nanowires (pSi NWs) have attracted considerable interest due to their unique structural, optical properties and biocompatibility. The most common method for their top-down synthesis is metal-assisted chemical etching (MACE) of crystalline silicon (c-Si) wafers using silver nanoparticles as a catalyst. However, the replacement of silver with bioinert gold nanoparticles (Au NPs) markedly improves the efficiency of pSi NWs in biomedical applications. The present study demonstrates the fabrication of porous pSi NWs arrays using Au NPs as the catalyst in MACE of c-Si wafers with a resistivity of 1–5 mOhm-cm. Using scanning electron microscopy (SEM), the formation of arrays of porous nanowires with a diameter of 50 nm that consist of small silicon nanocrystals (nc-Si) and pores was observed. Raman spectroscopy analysis determined the size of nc-Si is about 4 nm. The pSi NWs exhibit effective photoluminescence (PL) with a peak in the red spectrum, which is attributed to the quantum confinement effect occurred in small 4 nm nc-Si. In addition, the pSi NWs exhibit low toxicity towards MCF-7 cancer cells, and their PL characteristics allow them to be used as contrast agents for bioimaging.

Keywords: Porous silicon nanowires, Photoluminescence, Raman spectroscopy, Contrast agents, Bioimaging

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