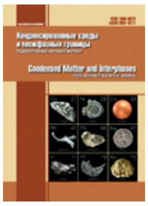

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Аннотации на английском языке

Original articles

Research article

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TiO_2 thin-film dielectric properties are impacted by annealing

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Abstract

Purpose: This study investigates the structural, morphological, and dielectric properties of TiO_2 thin films deposited using the Spray Pyrolysis Deposition (SPD) process and annealed at various temperatures.
Experimental: X-ray diffraction (XRD) analysis confirms the absence of an amorphous phase at 300 °C, while the anatase and rutile phases emerge at 400 °C, 500 °C, and 600 °C, with crystallite sizes increasing from 10.62 to 17.35 nm. Scanning electron microscopy (SEM) reveals a consistent grain growth trend, with grain sizes exceeding XRD estimates. Energy-dispersive X-ray (EDAX) spectroscopy confirms a stoichiometric Ti:O ratio and uniform nanoparticle distribution. The dielectric properties of Pt/TiO_2/Si MOS capacitors were analyzed, demonstrating improved electrical stability with annealing. Conductance studies indicate a reduction in defect states, enhanced crystallinity, and stable dielectric behavior at higher frequencies. The hysteresis loop analysis reveals decreased losses at 600 °C due to minimized trapped charges and broken bonds. Impedance spectroscopy highlights capacitive behavior, with relaxation peaks at 400 °C, 500 °C, and 600°C, while conductance measurements indicate thermal activation of charge carriers.
Conclusions: These findings suggest that TiO_2 thin films exhibit promising dielectric properties for potential applications in Si-based MOS capacitors and VLSI technology.

Keywords: Loss tangent, Angular frequency, Conductance, Series resistance, Impedance
Acknowledgement: The Indian Nano electronics User's Programme, Centre for Nano Science and Engineering (CeNSE), IISc, Bangalore, is gratefully acknowledged by the authors.
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Research article

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Synthesis and study of graphene oxide obtained from waste transparent polythene bags using Modified Hummers method

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Abstract

Purpose: Plastic industry has seen explosive growth in previous decades over the world. Every sphere of day to day life revolves around plastic products. The used plastic gets accumulated on the Earth s surface and serves as a contaminant causing soil, land and water pollution. Waste plastic needs proper management and elimination from the biotic layer of the ecosystem. Most potent solution is conversion of plastic waste into a functional carbon material. Present work concentrates on upcycling of waste plastic into economically crucial material that is graphene oxide. The waste polythene bags were successfully converted to graphitic carbon which in turn serves as the base for the synthesis of graphene oxide using modified Hummers method.
Experimental: The analysis was made by studying the FTIR spectra, SEM images and XRD graphs. The FTIR confirms the presence of hydroxyl and carbonyl groups along with carbon carbon interaction. Surface morphology shows the porous and layered structure with an average particle size of 2.74 µm. X ray diffractogram illustrates the crystal structure of the graphene oxide and interlayer spacing.
Conclusions: With the characterisation results, the synthesis of graphene oxide from plastic waste was verified.

Keywords: Polythene bags, Carbon material, Graphene oxide, Modified Hummers method, Environment protection
Acknowledgement: We are highly grateful for the support provided by the principal of our institution Christ Church College, Kanpur. We would also like to extend our gratitude to IIT Kanpur for providing the analysis facilities.
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Research article
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Crystallographic classification of special grain boundaries

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Abstact

Object of research: Special grain boundaries in centrosymmetric crystals.
The aim of this work is to classify special grain boundaries in centrosymmetric crystals of all syngonies based on the symmetric properties of plane lattices that are the crystallographic planes of these crystals.
Conclusions: It is shown that the set of geometric parameters identifying special boundaries consists of elements of the symmetry of the plane formed by coinciding atoms that preserve the atomic structure of this plane. Possible misorientations of contacting crystals are found depending on the symmetry of the crystallographic plane for different crystallographic syngonies.

Keywords: Lattice of matching nodes, Interfaces, Crystal, Special grain boundaries
Funding: The work was carried out with the financial support of the Russian Science Foundation project No. 24-12-20010.
For citation: Darinsky B. M., Efanova N. D., Prizhimov A. S., Surkova A. A. Crystallographic classification of special intercrystalline boundaries. *Condensed Matter and Interphases*. 2025;27(3): 363–367. https://doi.org/10.17308/kcmf.2025.27/13012

Research article
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Kinetics of electrocrystallization of copper from an acid sulfate solution in the presence of N-methylpolyvinylpyridine-methylsulfate

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Abstract

Purpose: In this work, kinetic patterns are established and the main parameters of heterogeneous nucleation and growth of a new phase during electrocrystallization of copper during cathodic deposition from an acid sulfate solution in the presence of *N*-methyl polyvinylpyridine-methyl sulfate of various molar masses are estimated. The polymer under study is quaternized polyvinylpyridine derivatives and is a promising organic additive for use in the technology of electrochemical void-free filling of through holes (through silicon vias) of silicon wafers used in microelectronics in the manufacture of microcircuits.
Experimental: Using scanning electron microscopy, it was found that the use of *N*-methyl polyvinylpyridine-methyl sulfate additive leads to a noticeable decrease in the size of crystallites and blurring of grain boundaries, however, it can contribute to the localized formation of globular formations (if the molecular weight of the polymer is relatively small) or the formation of a layered structure (in the case of high-molecular derivatives). The introduction of a quaternized polymer into a copper plating solution significantly inhibits the electrodeposition process, which includes the stages of irreversible charge transfer and diffusion-controlled electrocrystallization.
Conclusions: It has been found that the activation process of heterogeneous nucleation sites in the presence of a polymer additive is instantaneous regardless of the molar mass. At the same time, as it increases, the density of active nucleation centers decreases significantly.

Keywords: Copper, Electrodeposition, Nucleation, Kinetics, Polyvinylpyridine, Quaternized derivatives
Funding: The study received financial support from the Ministry of Science and Higher Education of the Russian Federation within the framework of State Contract with universities regarding scientific research in 2025–2027, project No. FZGU-2025-0001.
Acknowledgements: The SEM studies were performed on the equipment of the Center for the Collective Use of Scientific Equipment of Voronezh State University.
For citation: Ilina E. A., Kozaderov O. A., Sotskaya N. V., Vandyshev D. Yu., Polikarchuk V. A., Shikhaliev Kh. S. Kinetics of copper electrocrystallization from an acid sulfate solution in the presence of *N*-methyl polyvinylpyridine-methyl sulfate. *Condensed Matter and Interphases*. 2025;27(3): 368–379. https://doi.org/10.17308/kcmf.2025.27/13013

Research article
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Ternary molybdate $K_5Cu_{0.5}Hf_{1.5}(MoO_4)_6$: synthesis, structure, thermal expansion and ionic conductivity

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Abstract

Objective: A novel ternary molybdate, $K_5Cu_{0.5}Hf_{1.5}(MoO_4)_6$, was synthesized using solid-state ceramic method. The sequence of chemical transformations involved in its formation was determined, revealing that the compound undergoes incongruent melting at 634 °C.
Experimental: The crystal structure was refined using the Rietveld method, revealing a trigonal structure (space group $R\bar{3}c$) with unit cell parameters $a = 10.5617(2)$ Å; $c = 37.5017(7)$ Å; $V = 3622.9(1)$ Å^3, $R_{wp} = 3.78$. Attenuated total reflection Fourier-transform infrared (ATR-FTIR) spectroscopy confirmed the presence of isolated MoO_4 tetrahedra. The electrical conductivity of the title compound reached $7.5 \cdot 10^{-4}$ S/cm at 550°C, with an activation energy $E_a = 0.9$ eV. Thermal deformations were investigated by high temperature powder X-ray diffraction (HT-XRD) over the temperature range of 30–500 °C.
Results: $K_5Cu_{0.5}Hf_{1.5}(MoO_4)_6$ was classified as a high thermal expansion material ($\alpha_V = 45 \cdot 10^{-6}$ °C^{-1} at 500 °C), and exhibited low anisotropy. Combined results from electrochemical impedance spectroscopy (EIS) and HT-XRD indicated that the endothermic peak observed at 479 °C in the differential scanning calorimetry (DSC) curve corresponded to a first-order phase transition.

Keywords: Potassium; copper; Hafnium; Ternary molybdate; Synthesis; Crystal structure; Thermal expansion; Ionic conductivity
Funding: This research was conducted within the framework of the state assignment to Baikal Institute of Nature Management SB RAS (No. 0273-2021-0008) and was supported by the Russian Science Foundation (project No. 23-29-00327).
Acknowledgments: The studies involving XRD, thermal analysis, ATR-FTIR, HT-XRD, and conductivity measurements were performed using the resources of the Research Equipment Sharing Center of BINM SB RAS.

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Research article
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Dielectric and piezoelectric properties of ceramic material based on modified lead zirconate titanate

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Abstract

Purpose: A new high-entropy ferroelectric material $0.9Pb_{0.95}Sr_{0.05}(Zr_{0.52}Ti_{0.48})O_3$-$0.05Pb(Zn_{1/3}Nb_{2/3})O_3$-$0.05Pb(Mn_{1/3}Sb_{2/3})O_3$ was synthesized. At room temperature, it has a tetragonal perovskite-like crystal lattice and is characterized by a high electromechanical quality factor.
Experimental: The dielectric properties was studied in the temperature range of 20 – 500 °C at frequencies of 0.5 – 500 kHz. A noticeable decrease in the temperature of the ferroelectric phase transition (T_m) in comparison with the base composition $Pb_{0.95}Sr_{0.05}(Zr_{0.52}Ti_{0.48})O_3$ and its diffusion were revealed.
Conclusions: Analysis of experimental data suggests that the material under study is an “intermediate link” between conventional and relaxor ferroelectrics.

Keywords: High-entropy ferroelectrics, Electromechanical quality factor, Permittivity, Diffuse phase transition, Dielectric relaxation
Funding: This work was funded by Russian Science Foundation according to the research project No. 24-22-20054.
For citation: Korotkov L. N., Tolstykh N. A., Popov I. I., Bocharov A. I., Kashirin M. A. Dielectric and piezoelectric properties of ceramic material based on modified lead zirconate titanate. *Condensed Matter and Interphases*. 2025;27(3): 391–397. https://doi.org/10.17308/kcmf.2025.27/13015

Research article
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Mechanical Properties of Li-Nb-O System Films

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Abstract

Objective: To quantitatively assess the hardness, elasticity, and plasticity, and to determine the influence of structure and substructure on these parameters in Li-Nb-O system films.
Experimental: Li-Nb-O system films with a thickness of ~0.8 μm were grown on non-heated substrates (oxidized single-crystal silicon wafers (SiO_2 layer ~0.4 μm), single-crystal lithium niobate with (0001) orientation) by ion beam sputtering of a lithium niobate target. Thermal annealing of Li-Nb-O films on substrates was performed in air for 10 min (until complete crystallization) at temperatures of 550, 650, 700, 750, 800, and 850 °C. The heterostructures (film/substrate) were cooled with the furnace. The phase composition of the films was investigated by X-ray diffraction (XRD) and selected area electron diffraction (SAED). The substructure was studied by transmission electron microscopy (TEM) and high-resolution TEM (HRTEM, Tecnai G2 30ST) of cross-sectional specimens prepared by ion milling using a Quanta 3D setup. The surface morphology was investigated by scanning electron microscopy (SEM, Teskan Mira) in the topological contrast mode and atomic force microscopy (AFM, Solver47). Mechanical properties – hardness (H) and Young's modulus (E) – were determined from nanoindentation (NI, NanoHardness Tester CSM Instruments) measurements using a Berkovich diamond indenter under the following conditions: maximum load 10 mN, loading rate 10 mN/min, and unloading rate 15 mN/min.
Results: It was found that thermal annealing in an oxygen-containing atmosphere at 750°C induces crystallization of quasi-amorphous Li-Nb-O films and the synthesis of single-phase LN films with lattice parameters closest to those of stoichiometric single-crystal LN. The most probable mechanisms of irreversible deformation in LN films are: brittle fracture, plastic deformation of crystallites, and grain boundary sliding. LN films synthesized at 650-750°C are most susceptible to brittle fracture. Brittle fracture occurs due to the buildup of macrostresses in the films, resulting from different coefficients of thermal expansion (CTE) of the film and the substrate. The fracture toughness of the films increases significantly when using a substrate with a CTE close to that of the film. The hardness of nano- and microcrystalline LN films is always higher than the hardness of quasi-amorphous Li-Nb-O system films. The decrease in the hardness of films synthesized at high annealing temperatures is due to a decrease in the concentration of point defects and an increase in the size of the crystallites.

Keywords: Thin film, Lithium niobate, Thermal annealing, Crystallization, Structure, Surface morphology, Nanoindentation, Hardness, Cracking
Funding: The study was financially supported by the Russian Science Foundation as part of scientific project No. 24-22-20046.
***Acknowledgments*:** Scanning electron microscopy studies were performed using equipment at the Basic Scientific and Educational Center "Physics and Technology of Thermoelectric Phenomena" of Voronezh State Technical University.
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Research article
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Synthesis of 2-alkyl-5-phenyl-4,5,6,7-tetrahydro-[1,2,4]triazolo[1,5-a]pyrimidin-7-ol derivatives from vegetable oils and their efficiency as inhibitors of hydrochloric acid corrosion of steel

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Abstract

Purpose: The study suggests a new method of synthesis of 2-alkyl-5-phenyl-4,5,6,7-tetrahydro-[1,2,4]triazolo[1,5-a]pyrimidin-7-ol derivatives from vegetable oils (sunflower, palm, and coconut oil).

Experimental: The novelty of the method is based on the use of renewable raw materials, i.e. vegetable oils. It is also a *one-pot* synthesis method, which involves oil hydrolysis, interaction of the resulting *in situ* fatty acids with aminoguanidine bicarbonate and the subsequent alkaline cyclization to a mixture of 3-alkyl-5-amino-1H-1,2,4-triazoles whose composition is further identified by means of HPLC/MS. During the second stage of the synthesis, the obtained triazole mixtures undergo a two-stage condensation with cinnamaldehyde in the presence of an amphoteric surfactant, resulting in the desired 2-alkyl-5-phenyl-4,5,6,7-tetrahydro-[1,2,4]triazolo[1,5-a]pyrimidin-7-ols of sunflower, palm, and coconut oils. The anti-corrosion properties of the synthesized triazolopyrimidinols were studied with regard to ST-3 steel in 24% HCl using direct (GOST 9.905-82, GOST 9.907-83) and electrochemical (potentiodynamic polarization, Mansfeld method) methods. All derivatives exhibited high anticorrosive activity at concentrations of 1-2 g/l. The most effective were coconut oil derivatives: the protection degree (Z) reached 92.6% (1 g/l) and 98.0% (2 g/l) according to mass loss measurements, and 97.2–97.4% according to polarization measurements (i_{cor} decreased to 0.026-0.028 mA/cm² as compared to 6.8 mA/cm² in the control experiment).

Conclusions: The study demonstrated that the high efficiency of coconut oil derivative mixture is associated with the high content of medium-chain fatty acid derivatives (C10-C14, of which ~50% are lauric acid residues) in its composition. The obtained compounds are promising environmentally friendly inhibitors of acid corrosion that can be used in the oil industry.

Keywords: Corrosion of metals, steel, Hydrochloric acid, Corrosion inhibitors, Heterocyclic compounds, Vegetable oils, Aminotriazoles, Tetrahydrotriazolopyrimidinols, Physicochemical research methods

Funding: The study was supported by Russian Science Foundation (project No. 24-23-00457, https://rscf.ru/ project/24-23-00457/).

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Research article
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Refinement of the calculation of the efficiency of a chemical generator

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Abstract

Aim of the article: Analitical calculations and preliminary estimates of efficiency of a chemical generators are of great importance for analysis of conversion chemical energy into electrical one, the base which was consist transformation of heterogeneous chemical energy of formation hydrogen molecules into energy of electronic excitation on the surface of catalyst-semiconductors. However in the works cited by the calculation of probability excitation of chemo-electrons (high-energy electrons in conduction band) is not taken into account of the phonon's channel of the chemical energy accommodation. Such consideration would be by disdain of interaction excited electron with lattice, but in condition of the scattering chemical reaction energy inevitably was shifted of the equilibrium position of oscillators, leading to emission and absorption of phonons. Therefor the technique of the calculation must take into account as electrons as phonons channels of the accomodation. Aim of given work is derivation of the theoretical formula for efficiency of chemo-generator with provision for thermo-stimuleted transition of electrons to conduction band, with the subsequent analysis of particular cases.

Theoretical part: The influence of local thermal oscillations of crystal were inducted the effect of chemical reaction energy of formation hydrogen molecules on the "catalyst" surface, on velocity generation of the high-energy electrons was theoretical investigated. The formulas for efficiency of generator, clarifying the corresponding formulas from the other works was obtained. It is indicated on an impotant part of thermo-stimuleted transitions of an electrons to the conduction band of the semiconductor at room temperatures.

Conclusions: The results obtained may be useful by qualitatively analysis of the accommodation mechanisms of a chemical energy in the context of problem of conversion a chemical energy to electrical one.

Keywords: Surface of catalyst, Accommodation, Phonon's channel, Frank-Condon's energy, Schottky's barrier, Efficiency of chemo-generator

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Research article
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Photoluminescent properties of porous silicon nanoparticles: synthesis, characterization, and cellular imaging

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Abstract

Purpose: This study investigates the stability of photoluminescent (PL) properties of microporous silicon nanoparticles (μpSi-NPs) synthesized by electrochemical etching of monocrystalline silicon followed by lyophilization.

Experimental: Structural analysis revealed a highly porous architecture with < 2-nm pores and silicon nanocrystals (nc-Si) with an average size of 3–5 nm. Fourier-transform infrared spectroscopy confirmed the presence of Si-O-Si bonds, indicating surface oxidation of nc-Si. PL studies demonstrated a broad emission band peaking at 685 nm, attributed to exciton recombination in nc-Si. After 5 months of storage, the PL peak shifted to 655 nm, reflecting oxidation-induced size reduction of nc-Si. Raman spectra showed a 1.5 cm^{-1} shift of the Si phonon peak along with spectral broadening, evidencing phonon confinement and partial amorphization. XANES analysis further confirmed increased suboxide content and structural disorder.

Conclusions: Biological experiments demonstrated the biocompatibility of μpSi-NPs and retention of their PL activity, highlighting their potential for biomedical applications such as bioimaging and biosensing.

Keywords: Porous silicon, Lyophilization, Photoluminescence, XANES, Raman scattering, Bioimaging

Funding: This work was supported by Russian Science Foundation grant No. 24-15-00137 (https://rscf.ru/project/24-15-00137/) for nanoparticle synthesis and structural characterization Lomonosov Moscow State University grant No. 23-SCH06-19 for cellular imaging studies, BASIS Foundation grant No. 23-2-2-18-1 for optical properties investigation.

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Research article
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Study of photoluminescence kinetics in bulk GaPN and GaPNAs layers on silicon substrates grown by molecular beam epitaxy

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Abstract

Objective: The aim of this work is to study bulk GaPN and GaPNAs layers grown by molecular beam epitaxy on silicon substrates. The optical properties of the heterostructures were investigated using photoluminescence. The technique of time-resolved photoluminescence (or photoluminescence kinetics) was employed to evaluate the carrier lifetime in bulk GaPN and GaPNAs layers.

Experimental: An investigation of the influence of the buffer layer on the heterostructure characteristics was conducted. The photoluminescence intensity in the bulk GaPN layer was found to be virtually identical for heterostructures employing either a buffer layer grown by Migration-Enhanced Epitaxy (MEE-GaP buffer) or a GaP buffer layer grown with a gradual temperature ramp from 450 to 600 °C.

Conclusion: It was shown that the lifetime of minority carriers in the bulk GaPN layer grown on a silicon substrate is determined to a greater extent by defects introduced during the nitrogen incorporation into the GaP lattice, rather than by defects caused by growth on silicon substrate.

Keywords: Dilute nitrides, GaPN(As), Photoluminescence, Silicon substrate

Funding: The study was supported by the Russian Science Foundation No. 23-79-00032 (https://rscf.ru/project/23-79-00032/). The optical investigation of time-resolved photoluminescence was conducted on a unique setup “Complex optoelectronic unit of the National Research University Higher School of Economics - St. Petersburg”.

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Research article
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Research on the influence of the powder stoichiometry of $(Ag_xCu_{1-x})_{0.7}GaSe_2$ on the phase composition, structure, and lifetime of photogenerated charge carriers

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Abstract

Purpose: This work presents a series of $(Ag_xCu_{1-x})_{0.7}GaSe_2$ ($0 \le x \le 1$) powders synthesized via a solid-state reaction using the presynthesized ternary compounds $Cu_{0.7}GaSe_{2,}$ $Ag_{0.7}GaSe_2$ and $Ag_{0.7}GaSe_2$.

Experimental: A combination of X-ray diffraction (XRD) and Raman spectroscopy was used to establish that the solid solution region in this system is narrow and lies within the range of $0.8 \le x < 1$.

Conclusions: An investigation of low-temperature luminescence spectra and microwave photoconductivity decay kinetics revealed that single-phase samples exhibit increased lifetimes of photogenerated charge carriers. This is attributed to the replacement of deep charge carrier traps, such as selenium vacancies V_{Se}, with shallower cationic copper vacancies associated with V_{Cu} and V_{Se}-V_{Cu}.

Keywords: Chalcopyrite powders, Copper quaternary compounds, Photoactive cathodes, Hydrogen generation

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Research article
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Double borate $NaScB_2O_5$: synthesis, thermal stability, ionic conductivity, IR spectroscopy, and electronic structure

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Abstract

Purpose: The double sodium scandium borate, $NaScB_2O_5$, whose crystal structure was solved by Backer and Held in 2001, remains a poorly explored object. The crystal structure has wide channels that may suggest ionic conduction of sodium ions. Based on this, the aim of the study was to investigate the ionic conductivity of this object, as well as to study its thermal behavior, measure the IR spectrum and calculate the electronic structure by quantum chemical method.

Experimental: The synthesis of sodium scandium double borate, $NaScB_2O_5$, was achieved using a solid-state reaction method. $NaScB_2O_5$ was explored by using thermal analysis, IR spectroscopy, ionic conductivity, theoretical estimates of activation energy, ion transport pathways, and Ab initio calculations of electronic structure.

Conclusions: Rietveld method was engaged: monoclinic symmetry (sp. gr. $P2_1/c$), a = 7.2460(2) Å, b = 9.7887(3) Å, c = 5.9289(2) Å, β = 71.318(1)°, Z = 4, V = 398.37(2) Å^3, R_{wp} = 2.81, GOF = 1.64. $NaScB_2O_5$ borate is characterized by incongruent melting at 1090 °C. Ab initio calculated IR spectrum of $NaScB_2O_5$, exhibited a high degree of consistency with the experimentally obtained IR spectrum. The calculated energy barrier for oxygen ion migration, determined to be 0.998 eV, exhibits a reasonable degree of agreement with the experimentally determined activation energy of 0.9 eV. The title compound exhibits an ionic conductivity of $0.6\cdot10^{-3}$ S/cm at 1023 K. The band gap was about 6.83 eV.

Keywords: Sodium scandium borate; Solid-phase synthesis; Thermal analysis; IR spectroscopy; Electrical conductivity

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Research article
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Coupled phenomena of concentration polarization in systems with anion-exchange membranes before and after their participation in electrodialysis of tartrate-containing solutions

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Abstract

Objective: Homogeneous anion-exchange membrane ASE and heterogeneous anion-exchange membrane MA-41P were investigated in 20±1 mM $Na_xH_{(2-x)}T$ solutions with pH 2.5 and 9.0, where T represents the acid residue of tartaric acid. Optical images and contact angles of membrane surfaces, as well as their current-voltage curves and pH of desalinated solutions, were measured before and after using ASE and MA-41P in electrodialysis.

Experimental results: It was established that in alkaline solution, the patterns of concentration polarization development do not differ from those well-known for strong electrolytes. In acidic solution, the ability of tartrates to participate in protonation-deprotonation reactions causes a 4–5 fold increase in the empirical limiting current compared to the theoretical limiting current calculated within the convective-diffusion model. The mechanisms of tartrate transfer through anion-exchange membranes are considered when the desalinated solution mainly contains tartaric acid molecules.

Conclusions: It is shown that long-term operation (about 50 hours) under intensive current regimes leads to the appearance of numerous caverns on the ASE surface and to an increase in the proportion of ion-exchange material on the MA-41P surface. The surfaces of both membranes become more hydrophobic. Analysis of current-voltage curves suggests that electrochemical degradation of the ASE surface and specific interactions of tartrates with weakly basic fixed groups of both membranes lead to reduced proton generation and affect the development of electroconvection.

Keywords: Electrodialysis, Tartrates, Anion-exchange membranes, Current-voltage curves, Limiting current, Electroconvection, Catalytic water dissociation

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Short communication

Short communication

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The influence of fullerene C_{60} on the thermal stability of polyvinyl chloride

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Abstract

Purpose: Polyvinyl chloride (PVC) is one of the most widely used industrial polymers, yet its practical application is limited by its low thermal and thermo-oxidative stability. The degradation of PVC is accompanied by the elimination of HCl and the formation of isolated and conjugated double bonds, which leads to polymer aging and deterioration of material properties. Despite the availability of numerous fundamental studies devoted to the degradation and stabilization of PVC, the mechanism of its decomposition remains under discussion, with radical, ionic, and combined pathways being considered. Therefore, the search for efficient stabilizers is still largely empirical. The aim of this work was to reveal the features of thermal and thermo-oxidative degradation of rigid and plasticized PVC in the presence of fullerene C_{60}.

Experimental: The objects of study included industrial PVC grade S-7059M, fullerene C_{60}, phenolic antioxidants (diphenylolpropane, ionol), and ester plasticizers (dioctyl phthalate, dioctyl sebacate). Thermal and thermo-oxidative dehydrochlorination was carried out at 175 °C in a bubbling-type reactor under nitrogen or oxygen flow. Stabilizing effects were evaluated by the rate of HCl release, thermal stability time (according to GOST 14041-91), and melt flow index measurements. It was shown that fullerene C_{60} significantly inhibits PVC dehydrochlorination, reducing the rate of HCl release by more than twofold. The maximum effect is achieved at a content of 0.1 mmol per mol of PVC. In plasticized PVC systems, fullerene demonstrated high antioxidative activity, comparable to or exceeding that of industrial phenolic antioxidants. An «echo-stabilization» effect was observed, attributed to the inhibition of ester plasticizer oxidation.

Conclusions: Thus, fullerene C_{60} can be considered a promising stabilizer for PVC, effectively retarding its thermal and thermo-oxidative degradation. The revealed regularities confirm the predominant role of the radical mechanism in PVC dehydrochlorination and highlight the potential of fullerene for extending the service life of PVC materials.

Keywords: Polyvinyl chloride, Fullerene C_{60}, Polymer dehydrochlorination, Ester plasticizers, Phenolic antioxidants

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Short communication

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Infrared synchrotron nanovisualization of a biomimetic layer composed of trimethyldihydroquinoline and nanocrystalline hydroxyapatite

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Abstract

Objective of the article: This study presents the findings of research on a biomimetic organomineral layer composed of trimethyl-dihydroquinoline, which was polymerized in the presence of nanocrystalline carbonate-substituted non-stoichiometric hydroxyapatite (n-cHAp).

Experimental part: The morphological features of the biomimetic layer were visualized using synchrotron infrared near-field spectroscopy.

Conclusions: It has been demonstrated that the biomimetic layer formed on the surface of dental enamel exhibits a morphological structure characterized by a uniformly distributed and densely packed composite film of poly(2,2,4-trimethyl-1,2-dihydroquinoline-6,7-diol) and n-cHAp. The resulting dental coating, which is based on polydihydroquinoline and nanocrystalline hydroxyapatite, possesses a Vickers hardness coefficient comparable to that of healthy enamel.

Keywords: Trimethyl-dihydroquinoline, Biomimetic layer, Dental enamel, Near-field infrared spectroscopy, Synchrotron radiation

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Synchrotron XANES studies of epitaxial tin-silicon solid solutions nanolayers

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Abstract

Purpose: Functional tin and silicon-based materials and thin-film structures based on them are promising objects for microelectronics devices. An important issue for the study and subsequent application of such materials and structures is the properties control under formation technological regimes variations.

Experimental: The specificity of the local atomic surrounding and the features of the electronic structure of tin-silicon solid solutions have been studied by X-ray absorption near edge structure spectroscopy using synchrotron radiation. Nanolayer structures of tin-silicon solid solutions on buffer silicon nanolayers were formed using molecular beam epitaxy.

Conclusions: The possibility of forming an epitaxial tin-silicon solid solution in the concentration range significantly exceeding the known solubility limits of Sn in Si is shown. The rearrangement of the local density of the electronic states of tin and silicon indicates the formation of solid solutions with tin concentrations of 2, 8, and 15 at. %.

Keywords: Tin, Silicon, Tin and silicon oxides, Electronic structure, Density of states, Local atomic surrounding, Composition, Epitaxial solid solutions, X-ray absorption near edge structure, Synchrotron investigations

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90 years of the scientific school of solid state physics at Voronezh State University: from solid state physics to nanophysics (Scientific and historical essay)

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