ABSTRACT AND REFERENCES

MATERIALS SCIENCE

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OPTIMIZING PERFORMANCE OF LITHIUMION BATTERY BY NANOSILICON ADDITION MIXED IN $LI_4TI_5O_{12}$ ANODE MADE USING MECHANOCHEMICAL-HYDROTHERMAL METHOD (p. 6-12)

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Lithium Titanate ($Li_4Ti_5O_{12}$ or LTO) is one of the best candidates to replace graphite as anode material in the lithium-ion battery (LIB), due to unwanted solid electrolyte interphase (SEI) layer formation that consumes Li^+ ion and reduces LIB performance and may cause thermal run-away. The ability of LTO to avoid SEI formation and undergo zero-strain during intercalation makes LTO has excellent safety during application. However, the spinel lithium titanate has the low theoretical capacity and poor electronic conductivity. This less conductivity brings limitation to its application. The sol-gel method and combining the LTO with Si that possesses a high theoretical capacity are the key factor to overcome the LTO disadvantages. To attain its high power, safety factor and low-cost fabrication properties, hydrothermal-mechanochemical treatment were used in sol-gel synthesis method in order to outgrowth ($Li_4Ti_5O_{12}$) nanostructure. Then, the 5 %, 10 %, and 15 % weight ratio percentage of silicon nano-particle were added into electrode composite in order to enhance the capacity of lithium titanate anode. All samples were characterized using XRD, SEM and TEM. The active anode material LTO/Si nano was coated and prepared into coin cell battery. The assembled coin half-cell used lithium metal foil as the counter electrode. The battery performance was tested using electrochemical impedance spectroscopy (EIS), cyclic voltammetry (CV) and charge-discharge (CD).

The XRD results showed that the obtained compounds of lithium titanate ($Li_4Ti_5O_{12}$) crystalline spinel and the impurities of TiO_2 rutile. The SEM micrograph results showed almost uniform morphological structures as agglomerates in most of the samples. While, the TEM image of Si nano had a crystalline phase with the particle size less than 100 mm. However, the presence of unwanted SiO_x layer was not clearly observed. Addition of Si-nanoparticle could increase the specific capacity to above the LTO theoretical capacity, however, the formation of SiO_x insulating layer is predicted to be the main hindrance that reduces the effectiveness of addition of Si nanoparticle to the present LTO compound. The hydrothermal treatment of the sample could enhance the performance of nano-composite LTO/Si anode. Based on CD results, the obtained LTO/Si compound possesses the discharge capability up to 12 C.

The CV and CD results showed the optimum percentage of 10 % wt. Si and best capacity of the sample was obtained at 229.72 mAh/g

Keywords: $Li_4Ti_5O_{12}$ /LTO anode, silicon, half-cell battery, battery capacity, sol-gel, nanoparticle, TiO_2

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COMPARATIVE TESTS OF CONTACT ELEMENTS AT CURRENT COLLECTORS IN ORDER TO COMPREHENSIVELY ASSESS THEIR OPERATIONAL PERFORMANCE (p. 13-21)

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We have studied the interaction between contact elements in the pantographs of electric transport under operation at the sections of railroads powered by direct and alternating current. In contrast to known techniques for bench tests, we investigated the mechanism of current collection and wear resistance at the new testing installation over a minimally narrow region of the sliding contact, simulating the phenomenon of a pantograph “cut”. This installation can be used both industrially when manufacturing new contact elements and under laboratory setting when studying wear resistance.

The experimental research confirmed that the wear intensity of contact elements at pantographs depends on current load over a contact area, the magnitude of contact pressure, the area of a contact surface, and motion speed. We have practically proven a possibility to maintain a reliable contact connection in the sliding contact under extreme operating conditions when using a reliable contact material for the current collector pads.

It has been proposed to use the powder composition BrIG based on bronze, iron, and graphite, for making contact elements for pantographs that could provide for reliable contact when interacting with the contact wire. Application of new and high-quality contact materials affects the tribology and stability of interaction between plates and the contact wire.

Owing to our study, a possibility has been established to manufacture a reliable contact element BrIG, which would prolong the time of interaction in the contact pair “pantograph at electric transport – contact network”.

The practical significance of this research relates to the proven efficiency of utilizing the new contact material BrIG for electric railroad transport network, in trolley buses and trams.

Thus, one can argue about the possibility to prolong the time of operation for the contact pair “pad in a pantograph at electric transport – contact network” by applying the new contact material BrIG.

Keywords: pantograph pads, current collector inserts, contact material, contacts wear, contact plate, electric vehicles.

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STUDYING FIBERREINFORCED CONCRETE FOR CASTING HOUSING PARTS OF PUMPS (p. 22-27)

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Many enterprises of the mining and metallurgical industry use pumps transferring aggressive liquids and slurries containing abrasive particles. For the manufacture of pump housings, taking into account their operating conditions, expensive alloy steels with increased wall thickness are used.

As a result of the study, the analysis of possible materials for the manufacture of fiber-reinforced concrete with the required strength characteristics was carried out. The selection of the optimum ratio of the components, providing, on the one hand, cost minimization of fiber-reinforced concrete and, on the other hand, rational technology for the manufacture of housing parts of fiber-reinforced concrete without additional machining, was carried out.

It was found that the specified conditions are met to the greatest extent by the mixes containing crushed rubble, quartz sand and ground quartz as aggregate, anchor steel fiber, as well as resin and hardener.

Theoretical and experimental studies showed that the aggregate must meet the following requirements: it must be three-component by particle size distribution, and the particle size of each component must differ by an order of magnitude from the previous one. This allows obtaining dense mixes by filling voids in large fractions with smaller particles.

As a result of laboratory studies, it was found that the compressive strength of such hardened mixes is 230...240 MPa.

It was found experimentally that the optimum fiber additive (steel anchor) should be within 3...5 % by weight.

The results of the study allow carrying out calculations of the parameters of pump housing parts with reduced wall thickness, lower weight, and also developing a technology for casting such parts with a high degree of readiness for use.

Keywords: fiber-reinforced concrete, fiber, housing parts, wear-resistant material, composite materials, strength characteristic, filling polymer.

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ELECTRIC HEATERS BASED ON NANOMODIFIED PARAFFIN WITH SELFINSTALLING HEAT CONTACT FOR ANTIICING SYSTEMS OF AEROSPACE CRAFTS (p. 28-34)

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Improved effectiveness of ice protection systems of aerospace crafts can be achieved with the development of more effective heaters. Self-regulating electric heaters based on positive or negative temperature coefficient have achieved the highest demand. Development of heaters with such properties involves various matrixes based on cement, glass frit, asphalt mastic, and polymers. Conductivity in such matrixes is governed by metallic or carbon filler. Carbon nanostructures possess the greatest effectiveness. The synthesis method of carbon nanostructures and composites to which they are introduced, the basic properties of resulting electric heaters are determined. To study the effectiveness of electric heaters, a non-contact method of temperature field measurement was used. CNT were synthesized using the Ni/MgO catalytic system, using the thermal decomposition method. CNT morphology was studied using the field emission electron microscope Hitachi H-800. During the investigation, it was found that for the electric heater based on paraffin modified with CNT, the basic specific power was 800±10 % W/m^2 at an ambient temperature of +10 °C. When the temperature was lowered to −40 °C, specific power increased to 1,600±20 % W/m^2. Dynamic change of power at different temperatures indicated the presence of a self-regulating effect. Thermal images of the heat contact have revealed that heat radiation stabilizes at 56 °C. The developed heaters can operate at a voltage up to 200 V and possess rational electrophysical and functional parameters, which allow for effective operation in ice protection systems for aircrafts.

Keywords: electric heater, carbon nanotubes, self-regulation, heat exchange, paraffin, self-installing heat contact

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SPECIFIC FEATURES OF DEFECT FORMATION IN THE NSI <P> SINGLE CRYSTALS AT ELECTRON IRRADIATION (p. 35-42)

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Based on measurements of infrared Fourier spectroscopy, Hall effect, and the tensor Hall-effect, we have established the nature, and determined the concentration, of the main types of radiation defects in the single crystals n-Si <P>, irradiated by different fluxes of electrons with an energy of 12 MeV. It is shown that for the examined silicon single crystals at electronic irradiation, it is quite effective to form a new type of radiation defects belonging to the VO_iP complexes (A-center, modified with an additive of phosphorus). Based on the solutions to electroneutrality equation, we have derived dependences of activation energy for the deep level $E_1=E_C-0{,}107$ eV, which belongs to the VO_iP complex, on uniaxial pressure along the crystallographic directions [100] and [111]. By using a method of least squares, we have constructed approximation polynomials for calculating these dependences. At orientation of the deformation axis along the crystallographic direction [100], the deep level $E_1=E_C-0.107$ eV will be decomposed into two components with a different activation energy. This explains the nonlinear dependences of activation energy of the deep level $E_1=E_C-0.107$ eV on the uniaxial pressure P≤0.4 GPa. For pressures P>0.4 GPa, the decomposition of this deep level is significant and one can assume that the deep level of the VO_iP complex will interact only with two minima in the silicon conduction zone while a change in the magnitude of activation energy would be linear for deformation. For the case of uniaxial pressure P≤0.4 GPa along the crystallographic direction [111] a change in the activation energy for the VO_iP complex is described by a quadratic dependence. Accordingly, the offset in the deep level $E_1=E_C-0.107$ eV for a given case is also a quadratic function for deformation. Different dependences of activation energy of the VO_iP complex on the orientation of a deformation axis relative to different crystallographic directions may indicate the anisotropic characteristics of this defect. The established features in defect formation for the n-Si <P> single crystals, irradiated by electrons, could be applied when designing various instruments for functional electronics based on these single crystals.

Keywords: silicon single crystals, infrared Fourier spectroscopy, Hall effect, uniaxial pressure, radiation defects, deep energy levels.

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DEVELOPMENT OF THE COMPOSITE MATERIAL AND COATINGS BASED ON NIOBIUM CARBIDE (p. 43-49)

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We investigated the structure of composites based on the system NbC with a copper bond, obtained by impregnating the porous carbide skeletons with a metallic melt in a vacuum. In order to receive a porous skeleton, the powder of NbC, the average size of ~1 μm, was mixed on a 5 % solution of rubber in gasoline. After drying, the mixture was ground at a sieve into granules, which were pressed into briquettes of dimensions 55×30×10 mm. To ensure the intensification of the process, as well as wetting, impregnation was carried out at a temperature of 1,400 °C. The result was the obtained material with a fine-grained two-phase structure.

The microstructure was investigated using a method of scanning electron microscopy (SEM), the chemical composition – applying a method for energy dispersion analysis (EDS).

The hardness was measured by Rockwell (scale C), the fracture toughness – by the indirect Evans-Charles method.

The composite's structure consists of rounded grains of NbC, which form a continuous skeleton, and the layers of copper bonding. The average size of grains and the intragrain layers of bonding is 1.8 μm and 1.1 μm, respectively.

An analysis of the interaction zone between NbC and Cu via EDS method revealed the presence of a 0.5 μm thick zone of diffusion, resulting from the redistribution of Nb and Cu by limited solubility. The presence of the diffusion zone makes it possible to provide a solid interphase bonding and, accordingly, the high level of mechanical properties. The hardness and fracture toughness of the obtained material are 40 HRC and 24 MPa×m$^{1/2}$, respectively.

Given the phase composition and properties of the developed composite, it is recommended to apply it as an alternative for composites of the system WC–Cu in the form of a monolithic material or coatings. A coating was applied using the method of electric-spark doping, using the manual installation MP-EL2. The coating's thickness is 30 μm, microhardness is ~500 MPa, and the friction coefficient against steel without lubrication is 0.04.

The designed materials are recommended for use in friction pairs in the form of a monolithic material, or anti-friction coatings.

Keywords: ceramic-metallic materials, matrix-reinforced structure, tribotechnical characteristics, electric-spark doping, anti-friction coatings.

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XRAY DIAGNOSTICS OF THE STRUCTURE OF NEARSURFACE LAYERS OF IONIMPLANTED MONOCRYSTALLINE MATERIALS (p. 50-57)

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A method for obtaining information on the distribution of the parameters of a crystalline structure in the thickness of a near-surface ion-implanted layer, types and characteristics of radiation defects (size, concentration, etc.) has been developed. The influence of the main diffraction parameters on the rocking curve was established, which made it possible to develop an algorithm for the approximation of the theoretically calculated rocking curves to the experimental ones. It is shown that at small doses of implantation, the value of the extinction coefficient μ_{ds} influences most significantly on the intensity of the rocking curves outside the additional oscillatory structure, and the value of the static Debye-Waller factor E influences most significantly on the intensity of the last oscillations of the additional oscillatory structure that correspond to the maximum deformation. To characterize a defective system, it is necessary to analyze the diffuse component using a part of the rocking curve, which is located behind an additional oscillatory structure and in which the contribution of the coherent component is minimal. The method is tested in the analysis of boron-implanted iron-yttrium garnet films. The presented approach provides an opportunity to obtain much of information about the structure of the ion-implanted layer, since it uses the statistical dynamic theory of X-ray scattering, which takes into account the defects of the crystalline structure of any type and size. Also, this approach makes it possible to use all the information contained in the rocking curves and to assess the degree of uniqueness of the specified parameters.

Keywords: strain profile, X-ray diffraction, ion implantation, defects of structure, statistical dynamic theory of X-ray scattering.

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