ABSTRACT AND REFERENCES
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DEVELOPMENT OF ELECTRICARC PSEUDOALLOY COATINGS FOR THE STRENGTHENING OF COPPER WALLS OF MOLDS (p. 6-14)

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On the basis of the requirements for protective coatings of molds, the materials of pseudoalloys were determined for applying coatings from two wires. One of the wires is copper, which provides maintaining a sufficient thermal conductivity of the layer, and the second one consists of a material, which provides wear resistance of a coating. As the second wire, the wires NiCr, Mo, Ti and a flux-cored wire were used, consisting of a steel sheath and a filler – FeB powder. Based on the calculation data on the thermal conductivity of coatings, taking into account the coefficients of heat transfer, the estimation of the influence of these coatings on the thermal processes in the mold (temperature of the wall surface, intensity of heat removal from the wall) was performed. Applying electric-arc spraying, the pseudoalloy coatings with a uniform distribution of components were produced, one of which is copper with a hardness of 1,320–1,460 MPa, and the second one is the strengthening component NiCr, with a hardness of 2,440 MPa; Mo, with a hardness of 5,350 MPa; Ti, with a hardness of 7,540 MPa; FeB, with a hardness of 7,050 MPa.

As a result of measurements of the coefficient of thermal expansion of coatings, it was found that the coating Cu-NiCr is the closest to the coefficient of thermal expansion of copper. Then it is followed by Cu-FCW (FeB), Cu-Ti and Cu-Mo. The abrasive wear resistance of pseudoalloy coatings at a room temperature exceeds pure copper 1.4–2.3 times. The tests of pseudoalloy coatings for resistance to wear during heating to 350 °C showed that the wear resistance of Cu-NiCr and Cu-FCW (FeB) coatings exceeds the resistance of pure copper 4.5 and 22 times, respectively. The hot hardness of the coating Cu-NiCr in the range of 20–400 °C exceeds the hardness of pure copper 3 times.

Keywords: mold wall, electric-arc spraying, pseudoalloy coating, heat flux.

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STUDYING THE EFFECT OF THE COMBINED TECHNOLOGY ON DURABILITY OF THE SHAFTTYPE PARTS (p. 14-22)

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Restoration of shaft parts with extending their service life is an important reserve of development and growth of repair efficiency. Improvement of wear resistance and durability of parts of agricultural machinery is a priority trend in the present-day machine building. For this purpose, analysis was carried out and the process of electro-contact strengthening of sprayed wear resistant coatings on shaft parts was considered.

Experimental studies of physical and mechanical properties of wear resistant coatings obtained by the combined technology have been carried out. Dependence of the bond strength, porosity of the sprayed wear resistant coatings on current and pressure of the electro-contact strengthening process was established. With an increase in strengthening pressure up to 30–40 MPa and current up to 14–16 kA, there was an increase in the bond strength of the sprayed coating up to 180...220 MPa and a decrease in porosity to 2...5 %.

Wear resistance of the coatings obtained by the combined technology in the range of the studied loads and speeds was higher than that of the coatings obtained separately by classical technologies of flame and electric arc spraying. The highest wear resistance indicators were found in the coating of FMI-2 material applied by the combined technology.

Fatigue strength tests of the strengthened parts have shown that the coatings obtained by the combined technology increased the fatigue limit of the parts recovered by spraying by 20 %, and that of the parts without coatings by 50 %.

A comparative estimation of physical-mechanical and operational properties of the coatings obtained by electric arc and flame spraying and the combined technology was made. It was established that the use of electro-contact strengthening of the sprayed wear resistant coatings at a pressure of 20...40 MPa, current strength of 11...16 kA, duration of current pulses and pauses of 0.02...0.04 s significantly increased their physical and mechanical properties and performance.

Keywords: sprayed coatings, porosity, bond strength, wear resistance, electro-contact strengthening, durability, endurance, combined technology, recovery.

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DEVELOPMENT OF MACHINE LEARNING METHOD OF TITANIUM ALLOY PROPERTIES IDENTIFICATION IN ADDITIVE TECHNOLOGIES (p. 23-31)

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Based on the experimentally established data on the parameters of microstructure, elemental and fractional composition of titanium alloy powders, four classes of their conformity (a material with excellent properties, optimal properties, possible defects in the material and defective material) as source raw materials for the additive technologies are identified. The basic characteristics of the material, which determine its belonging to a certain class, are established. Training and test samples based on 20 features that characterize each of the four classes of titanium alloy powders for the implementation of machine learning procedures were built. The developed method for identification of the class of material, based on the use of the second-order Kolmogorov-Gabor polynomial and the Random Forest algorithm, is described. An experimental comparison of the developed method work results with existing methods: Random Forest, Logistic Regression, and Support Vectors Machines based on the accuracy of their work in the training and application modes was made. The visualization of the results of all the investigated methods was given.

The developed supervised learning method allows constructing models for processing a large number of each input vector characteristics. In this case, the Random Forest algorithm provides satisfactory generalization properties while retaining the advantages of an additional increase of the accuracy based on the Kolmogorov-Gabor polynomial.

The main advantages of the developed method, in particular, regarding the additional increase of the accuracy of the classification task solution, are experimentally determined. The developed method allows increasing the modeling accuracy by 34.38, 33.34 and 3.13 % compared with the methods: Support Vectors Machine, Logistic Regression, and Random Forest respectively.

The obtained results allow one to considerably reduce financial and time expenses during the manufacture of products by additive technologies methods. The use of artificial intelligence tools can reduce the complexity and energy efficiency of experiments to determine the optimum characteristics of powder materials.

Keywords: titanium alloy powders, microstructure, morphology, granulometric composition, additive technologies, artificial intelligence methods.

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INFLUENCE OF ULTRASOUND AND TEMPLATE ON THE PROPERTIES OF NICKEL HYDROXIDE AS AN ACTIVE SUBSTANCE OF SUPERCAPACITORS (p. 32-39)

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Nickel hydroxide is widely used as an active materials of supercapacitors. The most active are $Ni(OH)_2$ (α+β) samples with layered structure synthesized in a slit-diaphragm electrolyzer. The study on the influence of template synthesis and ultrasound treatment on the characteristics of the samples was conducted. The synthesis of nickel hydroxide samples in the presence of polyvinyl alcohol as a template and the use of ultrasound treatment of the $Ni(OH)_2$ suspension directly after formation was carried out. The synthesized samples of nickel hydroxide were studied by means X-ray diffraction analysis, scanning electron microscopy, and BET nitrogen adsorption-desorption. Electrochemical characteristics were evaluated by means of galvanostatic charge-discharge cycling in the supercapacitor regime. Comparative analysis of the $Ni(OH)_2$ sample has revealed both negative and positive effect of the template and ultrasound. The use of PVA as a template and ultrasound treatment resulted in a significant decrease in specific surface area (to 6 m^2/g) and an increase of the average pore diameter (to 1181 Å). Application of the template and ultrasound decreases crystallinity and increases the content of α-form, which results in the increased capacity of the samples. The maximum value of 233 F/g is achieved at a current density of 40 mA/cm^2 obtained from the combined effect of the template and ultrasound. Under these conditions, the specific capacity of the sample prepared without the template and ultrasound is 76 F/g. However, with an increase of current density to 120 mA/cm^2, the capacity of this sample increases to 303 F/g. At the same time, for samples synthesized with the template and ultrasound, a decrease of capacity is observed at higher current densities, which is related to difficulties in the breakdown of agglomerated particles. In case of the introduced template, this is explained by the binding effect of the remaining PVA and in case of ultrasound treatment – particle condensation. Based on the results of the comparative analysis, it is recommended to replace the template with a more easily removable one and also conduct an electrochemical synthesis of $Ni(OH)_2$ in SDE directly in the ultrasound field and increase the power of the emitter.

Keywords: nickel hydroxide, specific capacity, supercapacitor, ultrasound treatment, template synthesis, polyvinyl alcohol.

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STUDYING THE EFFECT OF CONCENTRATION FACTORS ON THE PROCESS OF CHEMICAL METALLIZATION OF POWDERED POLYVINYLCHLORIDE (p. 40-47)

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Influence of concentration of components of chemical metallization solutions on the process of copper reduction on activated polyvinylchloride surface has been studied. It has been established that changes in concentrations of copper sulfate, trilon B and formaldehyde can effectively influence the metallization process. It was shown that the loss of stability of chemical metallization solutions and formation of colloidal solutions makes it is impossible to obtain a metallized polymeric material since copper reduction occurs in the solution volume. Copper reduction in the solution volume occurs because of presence of insoluble colloidal particles of copper hydroxide which are centers of nucleation of copper reduction. At such centers, copper reduction occurs as a result of reaction with formaldehyde and is accompanied by high volumes of hydrogen evolvement. It has been established that the formation of copper coating on an activated polymer surface occurs only with the use of true chemical metallization solutions. The main factor determining stability of chemical metallization solutions is complexing. It was shown that trilon B concentration under 40 mmol/l is not sufficient to bind all Cu^{2+} ions in a complex which prevents formation of insoluble copper hydroxide in an alkaline medium. The growth of trilon B concentration above 53 mmol/l results in reduction of a portion of copper in a form of hydroxide and formation of true solutions. It has been established that concentration of copper sulfate and alkali exerts the main influence on the mechanism of copper reduction in the case of true solutions. The growth of pH of chemical metallization solutions above 12 brings about an increase in the portion of copper that is reduced by the exchange reaction with zinc.

Keywords: concentration of solutions, optimization, metal-polymer composites, functional composites, polyvinylchloride, chemical reduction, metal fillers.

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FORMING THE LOWPOROUS LAYERS OF INDIUM PHOSPHIDE WITH THE PREDEFINED QUALITY LEVEL (p. 48-55)

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The morphological quality criterion was developed to have a possibility of formation of nanostructured layers on semiconductor surface with adjustable properties. The layers of low-porous indium phosphide with mesoporous structure were obtained. The porous layers were formed by the method of electrochemical etching in the solution of hydrochloric acid at constant current density. According to the developed criterion, the quality of synthesized por-InP samples was analyzed. This will make it possible to manufacture the structures with porous layers on the surface on an industrial scale. The presented criterion can be applied to other modes of treatment of indium phosphide or to other semiconductors. This will make it possible to treat it as a universal morphological criterion of quality of porous structures. The correlation between morphological properties of porous structures on the surface of indium phosphide and etching conditions was established. To do this, porous structures, which were formed in the interval of etching time from 10 to 20 min at different concentration of acid in the electrolyte, were analyzed. As a result, it

was established that the shape of the pores of nanostructured layers on the surface of semiconductors depends not only on parameters of a crystal, but also on etching conditions, specifically, on etching time and electrolyte composition. The application of saturated electrolytes leads to formation of massive groove-shaped pores – elongated ellipses. The obtained correlations are useful from the practical point of view, as they make it possible to approach reasonably determining the modes of electrochemical treatment of semiconductors.

In addition, it opens up new prospects in the construction of the model of self-organization of a porous structure on the surface of semiconductors. The technique of calculating basic statistical characteristics of the series of distribution of pores by dimensions, specifically, the variation span, dispersion, mean deviation, coefficients of variation and asymmetry was presented. This makes it possible to evaluate in detail the morphological indicators of porous structures and to progress in understanding the mechanisms behind the pore formation on the surface of semiconductors during electrochemical treatment.

Keywords: Indium phosphide, electrochemical etching, morphological indicators, porous semiconductors, quality criterion.

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ACTIVATION OF THE NICKEL FOAM AS A CURRENT COLLECTOR FOR APPLICATION IN SUPERCAPACITORS (p. 56-62)

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Nickel foam is widely used as a current collector and as a major component of the faradic electrode in supercapacitors. Activation of nickel foam would allow increasing the capacity of the nickel hydroxide electrode or preparing high-speed electrodes without additional active material. Multiple (1–20 times) short-term (5 min) treatment in a 1 M solution of HCl, H_3BO_3 or $H_2C_2O_4$ has been proposed. The possibilities of activation of commercial nickel foam samples manufactured by "Novoment-Perm" (Russian Federation) and "Linyi Gelon LIB Co Ltd" (China) have been studied. Activated and non-activated nickel foam samples have been studied by means of X-ray diffraction analysis and scanning electron microscopy, electrochemical characteristics were determined by means of cyclic voltamperometry and galvanostatic charge-discharge cycling in the supercapacitor regime. The comparative analysis of nickel foam samples from Chinese and Russain manufacturers has revealed very low reactivity and low susceptibility to activation of nickel foam from Chinese manufacturer. An assumption has been made that low reactivity is because the sample is composed of Ni-P or Ni-B alloy. The maximum specific capacity of 0.084 F/cm^2 has been obtained after 20 treatments in HCl solutions. The activation mechanism is the increase in the specific surface area of nickel. However, this value is sig-

nificantly lower than that of non-activated nickel foam from Russian manufacturer (0.333 F/cm^2). It has been discovered that the nickel foam sample from Russian manufacturer can be easily activated. The maximum activation effect is achieved when treated with oxalic acid: specific capacities are 1.213 F/cm^2 (one treatment), 6.578 F/cm^2 (five treatments) and 20.003 F/cm^2 (twenty treatments). The activation mechanism is the formation of nickel oxalate on the surface of nickel foam. The results of the comparative analysis have revealed the effectiveness of activation of the nickel foam sample from Russian manufacturer by multiple short-term treatment with oxalic acid. It has been concluded that activation of the nickel foam sample from Chinese manufacturer by multiple short-term treatment in solutions of hydrochloric, boric and oxalic acids is ineffective. Activation of nickel foam from Chinese manufacturer requires the development of a different method.

Keywords: nickel foam, specific capacity, supercapacitor, etching, oxalic acid, hydrochloric acid, current collector.

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