ABSTRACT AND REFERENCES

MATERIALS SCIENCE

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INVESTIGATION OF PHYSICAL AND CHEMICAL PROPERTIES AND STRUCTURE OF TRIPOLYPHOSPHATE COATINGS ON ZINC PLATED STEEL (p. 4-8)

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The results of complex studies on the influence of the concentration of aqueous sodium tripolyphosphate solution on the physicochemical properties and structure of the coats on zinc-plated steel are presented. The coats were chemically deposited from 2–14 % aqueous sodium tripolyphosphate (STPP) solutions, heated to 70 °C. It has been established that increasing concentration of aqueous STPP solution leads to an increase of the specific mass and crystallinity of the coats and decrease of protective properties. Metallographic studies have shown that the amorphous structure of the coats deposited from 2 % aqueous STPP solution changes to a structure with large sizes of crystallites for the coats prepared from aqueous STPP solutions with higher concentrations. The results of the X-ray diffraction (XRD) analysis have revealed that the coats with low protective properties, in addition to anhydrous zinc phosphates, also contain hydrated species. By means of raster electron microscopy, it has been established that the coats with the lowest protective properties, prepared from 12–14 % aqueous STPP solutions, are formed as thick, spongy layers with the presence of microcracks. Such structure leads to the accumulation and containment of moisture, which promotes corrosion under atmospheric conditions.

Keywords: composition, coat structure, zinc-plated steel, protective properties, sodium tripolyphosphate, aqueous solution.

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RESEARCH INTO INFLUENCE OF THE ELECTROLYSIS MODES ON THE COMPOSITION OF GALVANIC Fe-Co-Mo COATINGS (p. 9-15)

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We examined the influence of the energy (current density i) and temporal (duration of pulse ton and pause toff, the ratio of ton/toff) parameters of the electrolysis on the composition and morphology of the Fe-Co-Mo coatings. An increase in the pulse duration contributes to the enrichment of alloy with molybdenum in proportion to the increasing current density. At the ratio of pulse/pause ton/toff>1–2, the composition of an alloy changes towards an increase in the content of iron. We demonstrated a tendency of the enrichment of coatings with a high-melting component and a decrease in the content of iron with an increase in the current density. It is shown that with an increase in the current density, the surface of coatings changes from the fine-grained to the globular structure. It was established that at fixed ton/toff, the power yield grows with an increase in the pulse duration over the entire interval of current densities. With an increase in the current density (at ton/toff=const) we observe a reduction in the process efficiency. It was found that the most optimal for obtaining the soft magnetic Fe-Co-Mo coatings is the current amplitude of 3 A/dm2, the duration of pulse 2–5 ms and of pause 10–20 ms. Current at amplitude of 5 A/dm2 is recommended when obtaining materials with the content of a high-melting component larger than 15 at. %. It is shown that the regime of the unipolar pulse current makes it possible to obtain the Fe-Co-Mo coatings with the content of iron of 58–46 at. %, cobalt – 34–43 at. % and molybdenum – 6–17 at. %. The results obtained create prerequisites to control the composition and properties of the Fe-Co-Mo coatings with a wide range of content of the alloy-forming components.

Keywords: current amplitude, pulse mode, Fe-Co-Mo coatings, ternary alloys, citrate electrolyte.

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EXAMINING THE EFFECT OF PHYSICAL FIELDS ON THE ADHESIVE STRENGTH OF PROTECTIVE EPOXY COMPOSITE COATINGS (p. 16-22)

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We examined and substantiated the effect of treating the compositions in the electromagnetic field and with ultrasound on the adhesive strength of epoxy composites that contain highly dispersed particles of ferro-, para- and diamagnetic nature. It was established experimentally that the optimal content of highly dispersed fillers is 6 mass fractions.

The studies conducted confirm the prospects of using the treatment of compositions in physical fields for obtaining epoxy composite protective coatings. The given technology enables to ensure high adhesive strength (60–70 MPa) of bonds between a coating and a metal base, to increase the degree of structuring (G=99.7 %) and to reduce by 65 % internal stresses in coatings. We achieved an increase in the number of physical-chemical bonds between an epoxy polymer binder and the surface of highly dispersed particles by increasing the mobility of segments of macromolecules and improving the interaction between components of the system under the influence of external physical fields.

By using the electron microscopy method, we registered a uniform distribution of ferro- and paramagnetic particles in epoxy composites after treating the compositions in the electromagnetic field. This occurs due to the orientation of the dipole segments of macromolecules in a force field and the uniform distribution of chemical bonds in the structure of epoxy composite.

The received epoxy composite coatings with highly dispersed powders after treating the compositions in the physical field are characterized by defect-free structure. Epoxy composite coatings could be used as wear- and corrosion resistant coatings for parts of machines and mechanisms in automotive and instrument-making industries, as well as in the oil and gas sector. Such parts can operate under conditions of temperature gradient, mechanical stresses, deformations and aggressive impacts.

Keywords: epoxy composition, ultrasonic treatment, electromagnetic field, highly dispersed filler, residual stresses.

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INVESTIGATION OF CHARGE AND DISCHARGE REGIMES OF NANOMODIFIED HEAT-ACCUMULATING MATERIALS (p. 23-29)

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Charge/discharge regimes of nanomodified paraffins have been studied. The nanomodification of paraffin was carried out by using the "Taunit" series nanomaterials with different morphological parameters under ultrasonic treatment. Comparative studies of thermophysical parameters (thermal conductivity and heat capacity) have been conducted for the prepared samples. Under charge/discharge regimes, the effect of "tracking thermal contact" manifests. The thermal conductivity increases to 0.48, 0.42 and 0.36 W/m°C in case of CNM-MD, CNM-M and CNM, relative to the initial thermal conductivity of 0.25 w/m°C. It has been established that the extreme on the thermal dependency graph depends on heat capacity (57, 63 and 72 °C for CNM, CNM-M and CNM-MD correspondingly). Modification of paraffin with carbon nanotubes allows controlling the phase-transition parameters, which allows obtaining a variety of temperature dependencies of heat capacity, thermal conductivity and physical-mechanical characteristics by combining different ratios of the "Taunit" series nanotubes and physical influences such as thermal fields and ultrasound. The heat-accumulating materials prepared in such a way allow achieving optimized operation of the heat accumulator under different temperature regimes.

Keywords: heat accumulator, paraffin, modification, carbon nanotubes, thermal conductivity, heat capacity, charge/discharge.

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DEVELOPMENT OF AN IRON-BASED ALLOY WITH A HIGH DEGREE OF SHAPE RECOVERY (p. 30-37)

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We examined a technological process for receiving an iron-based alloy with a shape memory effect, substantiated the choice of chemical composition of the alloy, and selected thermal treatment modes. Research results into scale resistance revealed at heating the samples in the temperature range of 600–1000 °C, surface oxidation was not observed. In the course of experiment on corrosion resistance of the alloy, we found that the alloy is corrosion resistant and is not inclined to change the weight when exposed to 10 % solution of sulfuric acid. Study into the microstructure confirmed the existence of dispersion hardening in the alloy after the aging regimes.

Diffractogram of the alloy after hardening at a temperature of 1150 °C and cooling in the open air showed a surge that corresponds to γ-Fe, therefore, the content of residual austenite in the alloy is 100 %. Research results demonstrated that the degree of shape recovery of the proposed alloy is 78–97 %. The proposed alloy is plastic enough; it may undergo hot, warm and cold deformation in the open air. We constructed mathematical models of the impact of chemical composition of the alloy on tensile strength of the alloy and the values of a shape memory effect. The iron-based alloy with a shape memory effect can be obtained both under laboratory conditions and on industrial equipment.

Keywords: iron-based alloy, a shape memory effect, mechanical properties, scale resistance, corrosion resistance.

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ELECTROCHROMISM OF $Ni(OH)_2$ FILMS OBTAINED BY CATHODE TEMPLATE METHOD WITH ADDITION OF Al, Zn, Co IONS (p. 38-43)

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The films from mixed solutions of nickel-aluminum, nickel-zinc and nickel-cobalt have been prepared using the cathodic template synthesis with polyvinyl alcohol as a template. The prepared films have been studied by means of X-ray diffraction analysis, cyclic voltamperometry with simultaneous recording of the transparency change. The results have shown that the addition of aluminum and cobalt allows obtaining layered double hydroxides. However, the addition of aluminum leads not only to the formation of layered double hydroxide but also to poisoning of the active material.

In case of deposition from solutions containing cobalt, the obtained films have good electrochemical and electrochromic properties, and also two-stage color transition. The film obtained at a molar ratio of nickel to cobalt of 8:1 possesses the best electrochromic characteristics and coloration degree of 0.8, which is more than for the film obtained from nickel nitrate solution without additives of other metals by 0.2.

Keywords: nickel hydroxide, $Ni(OH)_2$, electrochromism, electrodeposition, cathodic template synthesis, polyvinyl alcohol, layered double hydroxide.

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STUDY OF STRUCTURE INFLUENCE ON WEAR RESISTANCE OF HIERARCHIAL SUPERHYDROPHOBIC COATINGS (p. 44-49)

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Superhydrophobic coatings are a relatively new class of coatings with a variety of applications. But their application is constrained by two main drawbacks. The first is complexity and high cost of production methods. The second is low mechanical resistance of coatings.

The work used a single-stage production method, which is common in the paint and varnish industry. Compositions have been made that contain particles of different dispersity to create a wear-resistant hierarchical structure. Wear resistance was tested by the method of attrition with the flow of silica particles. The state of the coating was then characterized by the angle of wetting with water drops. SEM photographs were taken to study structural changes in the surface after treatment with solid particles.

As a result of the conducted studies, it was established that when using crushed calcite, a densely packed structure forms on

the surface of the coating. It was shown that the contact with abrasive particles destroys hierarchical structures in several stages. Dependence of concentration of the polymer matrix in three-fraction composite coatings on the wetting angle of the superhydrophobic coating and dependence of the wetting angle on filler concentration in the composition were also established. Critical concentration of the polymer matrix in three-fraction composite coatings was established at which the maximum water wetting angle was observed.

Keywords: superhydrophobicity, hierarchical structure, rolling down angle, mechanical stability of superhydrophobic coatings.

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RESEARCH INTO PROTECTIVE PROPERTIES OF ELECTROMAGNETIC SCREENS BASED ON THE METAL-CONTAINING NANOSTRUCTURES (p. 50-56)

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We developed and examined protective properties of the metal polymeric electromagnetic screens. We used metal-containing particles of nano dimensions as a filler in the polymeric matrix. It was established that this provides shielding coefficient of 10 dB at the content of a metal substance of 11–12 %. In this case, reflection coefficients are 0.27–0.30. This is not attainable for the materials based on macro particles. It was found that increasing the dispersion of particles by 2–4 times reduces reflection coefficient by 0.15–0.20. We studied dependence of the electrical-physical properties of material on the content of a metal substance. This allowed us to calculate shielding coefficients and the contribution of protection to them due to the reflection of electromagnetic waves. Micro structural research revealed the uniformity of distribution of metal particles in the body of a polymer matrix. This has provided a possibility to calculate at their low concentrations the required coefficients using the relations for regular metal structures. We have demonstrated experimentally the possibility of fabricating electromagnetic screens of the gradient type in a single layer matrix.

Keywords: electromagnetic screen, metal-containing nanoparticles, shielding coefficient, absorption coefficient, reflection coefficient, electro physical properties.

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MARTENSITE TRANSFORMATIONS IN THE SURFACE LAYER AT GRINDING OF PARTS OF HARDENED STEELS (p. 56-63)

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The mechanism of direct and inverse martensitic transformation in the surface layer of a ground part of hardened steel under the influence of the grinding temperature was investigated. It is shown that the reverse martensitic transformation is carried out during grinding according to the martensite-perlite-austenite scheme. The possibility of high-speed tempering of martensite to perlite is shown, under the action of a contact grinding temperature, which, with a further increase in temperature, turns into austenite, forming an extremely harmful defect in the working surface – quenching burn.

In the present work, it is shown that the quenching burn in the form of austenite is happened by the M–P–A diffusion mechanism. This made it possible to obtain graphical and analytical dependencies, using which it is possible to calculate the Ac1 temperature points of the formation of austenite for virtually any steel grade depending on the content of carbon and alloying elements. The latter circumstance makes it possible to create such grinding conditions (the type of abrasive, the characteristics of the wheel, the use of coolant, treatment regime), at which the austenite formation temperature is not attained and the quenching does not happen.

Thus, as a result of the studies, it is possible to determine safe grinding temperatures for steels of different chemical compositions and treatment regimens that do not cause an increase in the grinding temperature above a certain level.

Keywords: martensite transformation, contact temperature, heating rate, martensite tempering, diffusion rate, austenitization temperature.

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