NON-STATIONARY ELECTROLYSIS FOR NICKEL NANOCOMPOSITE PLATING

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I. INTRODUCTION

The results of studies of the electrochemical processes of the formation of nanostructured thin-film nickel-based coatings modified with ultradispersed carbon aggregates under conditions of non-stationary electrolysis are generalized.

The inclusion of dispersed materials in the metal matrix during the formation of composite electrochemical coatings (CEC) makes it possible to increase the physicomechanical, functional and protective properties of coatings. An increase in the level of dispersion of the hardening phase and the use of nanoparticles for modifying metal coatings contributes to a decrease in the porosity and roughness of precipitates, an increase in the uniformity of the distribution of particles, the hardness and wear resistance of the coatings due to dispersion hardening and the stability of the electrolyte-suspension, in which the dispersed phase practically does not sediment.

The effect of the dispersed phase, parameters of non-stationary electrolysis and ultrasonic (US) on the electrodeposition process and the properties of nanocomposite nickel coatings has been investigated.

II. RESULTS AND DISCUSSION

Electrodeposition of nickel-based CEC was carried out in Watts sulphate electrolyte modified with ultradispersed carbon aggregates: ultradispersed diamond (UDD), fullerenes (C60), nanotubes (CNT) at a constant and periodic current with a frequency of 0.1-1000 Hz when exposed to ultrasonic (US) frequency 35 kHz and intensity 0.2-1.5 W/cm^2. Ultrasound has been used both to disperse and deagglomerate particles in a plating bath and to improve the incorporation of well-dispersed and evenly distributed particles into a metal matrix.

It was found that the introduction of 0.1-10 g/L UDD and fullerenes into the nickel-plating electrolyte leads to the co-precipitation of nanoparticles with nickel with the formation of composite coatings with a dispersed phase content of 0.01-1.2 wt. % (Figure 1), which depends on its concentration in the electrolyte, the nature of the electrolyte, cathode current density, ultrasound intensity, and periodic current parameters. The large specific surface area of nanoparticles ensures their high absorption capacity, which facilitates the introduction of particles into the sediment and has a significant effect on the kinetics of deposition of nickel coatings, their structure and properties.

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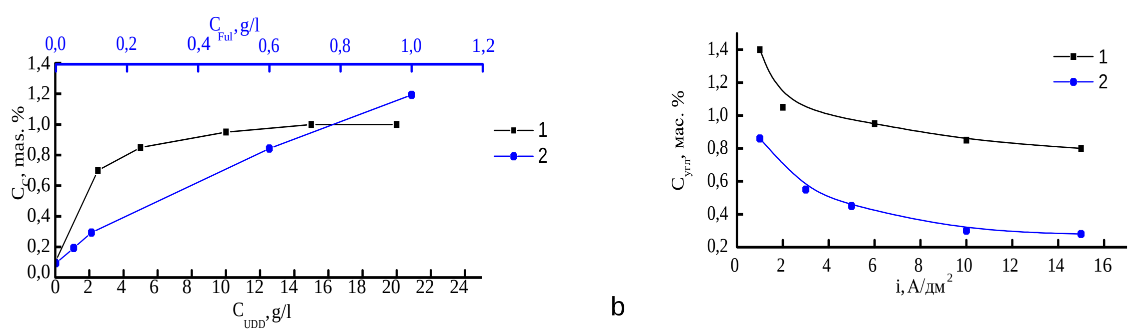


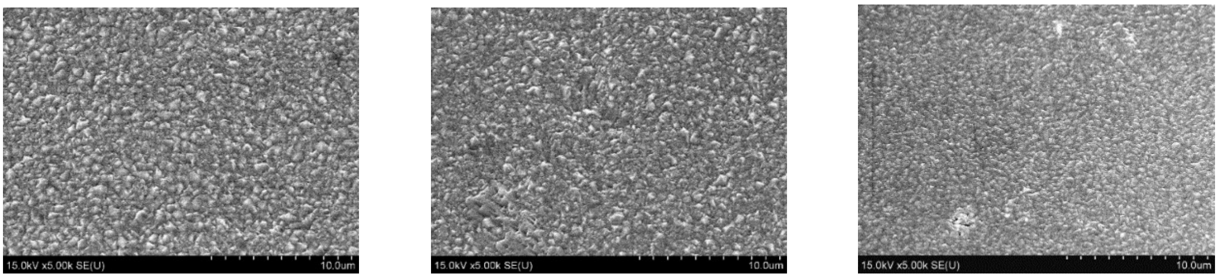
Figure 1. Dependence of the carbon content in the CEC of nickel-UDD (1) and nickel-fullerenes (2) on the concentration of the dispersed phase in the electrolyte (a) and current density (b)

The introduction of 0.01-0.1 g/l CNT into the electrolyte, previously ground and treated in a mixture of acids during high-power ultrasonic treatment, makes it possible to obtain composite coatings with a carbon content of 1-3 vol. % or 0.1-0.3 wt. %.

Dispersed phase nanoparticles, concentrating along the grain boundaries and preventing their growth, refine the CEC structure. Due to the adsorption of particles on nickel nuclei, the active nucleation centers are blocked, the growth rate of the latter decreases and, accordingly, nuclei appear on less active centers, i.e. the number of active centers increases and, as a consequence, the number of new nuclei increases.

A promising way, allowing a wide range of effects on the structure and physical properties of the resulting coatings, is the use of non-stationary electrolysis. The use of a periodic current of various shapes and parameters for electrolysis makes it possible to change the composition, structure and properties of the coatings in the desired direction within a relatively wide range, and it is easy to control the quality of deposited precipitates.

The use of a pulsed current makes it possible to obtain smoother fine-crystalline deposits with an isotropic developed microrelief, which can be explained by a high instantaneous current density and the nucleation of a large number of crystals, the growth of which is limited by the duration of the current pulse, with their subsequent passivation during a pause [1]. This creates conditions for the formation of nuclei at a new location on the cathode surface. Thus, a uniform grain size and fine-crystalline structure of coatings is formed, which depends on the parameters of the periodic current (Figure 2, DC – direct current, IC – impulse current, RC – reverse current).



DC IC RC

Figure 2. Influence of the current shape on the microstructure of nickel-CNT nanocomposites

The introduction of nanoparticles into the electrolyte makes it possible to significantly increase the microhardness (by 11-50%) due to a decrease in the grain size and precipitation hardening and wear resistance (by a factor of 1.05-3), to reduce the coefficient of friction of coatings without deteriorating their electrophysical and operational properties (Figure 3). Deposition under ultrasound increase the microhardness, wear and corrosion resistance CEC (Figure 4).

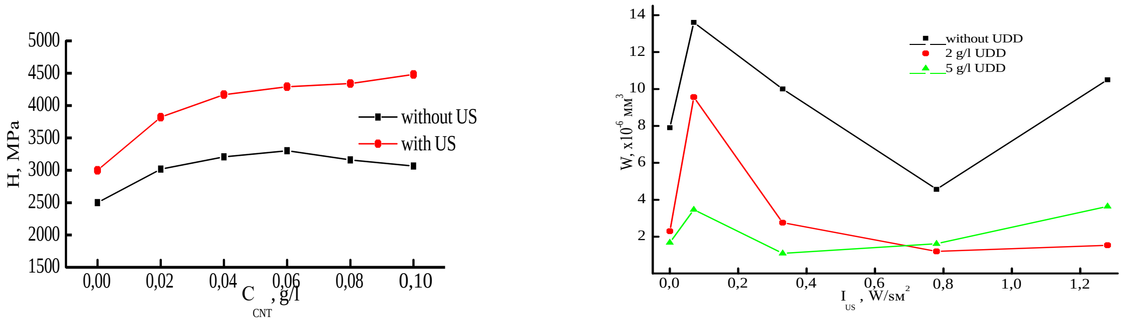


Figure 3. Influence of the dispersed phase concentration and ultrasound on the microhardness and wear resistance of the CEC

Depending on the parameters of the pulsed current, the microhardness of nanocomposite coatings increases to 3700-7000 MPa, wear resistance - by 1.5-3 times, the porosity of the coatings and the corrosion rate are significantly reduced (by 1.2-4 times).

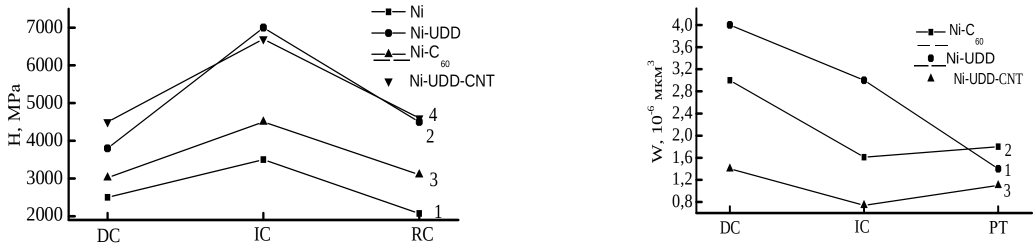


Figure 4. Influence shape current on the microhardness and wear resistance of the CEC, i_{av}=5 A/dm^2

III. CONCLUSIONS

As a result of the studies carried out, it was found that the inclusion of a dispersed phase in the thin-film structures of nanoparticles, the variation of the parameters of the pulsed current and the intensity of ultrasound can significantly increase the operational properties of nickel coatings.

REFERENCES

[1] Kushner, L.K. Nanocomposite nickel plating under non-stationary electrolysis / L.K. Kushner, I.I. Kuzmar, Khmyl, N.V. Dezkunov // Nanoscience and Technology: An International Journal. Special Issue: Fullerenes and Nanostructures in Condensed Matter, Vol. 10, Issue 4, 2019. – P. 355-363.