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Wear resistance of nanocrystalline composite NI-B coatings

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Abstract

The nanocrystalline composite electrochemical coatings prepared with nickel matrix and boron particles were investigated. Nickel plating bath of low nickel ion concentration (0.76 mol/dm^3) with brightening organic compound, surfactants and dispersed boron particles content was used for coatings electrodeposition. Boron particles content was determined gravimetrically. The dependence of boron content in composite Ni-B coatings on the concentration and kind of the organic additives was investigated. The coatings structure was established using TEM. The microhardness of the deposited layers was measured by Vickers' method at the load of 0.01 and 0.05 kg. The wear experiments of Ni-B coatings were made without lubrication using the technique based on measuring system comprising a flat surface and a ball. On the basis of measurements of wear traces diameter, the wear depth was calculated and assumed as a measure of wear resistance. Tribological properties were investigated using the disc-block measuring system. Friction tests were made on Amsler A-135 machine.

The obtained results suggest that the organic compounds used in the experiments had a significant effect on the increase of boron content in coating and the development of nanostructure of nickel matrix.

Keywords: Electrodeposition; Nickel; Composite; Boron

1. Introduction

Fast development of contemporary technique is possible due to the progress in machine and equipment parts manufacturing based on new technologies. They determine the operating properties of products and related possibilities of application of selected technology to the given product. One of the main objectives of electrodeposition of metal coatings on machine and construction parts is to improve the operating properties of products subjected to external hazards. Technologies for the deposition of composite electrochemical coatings (CEC) have been recognized in the past decade as having the potential to produce coatings with unique properties.

The electrodeposition technique can be used for the production of composite layers with nickel matrix [1–3]. Nanocrystalline electroplated nickel coatings have better and mostly improved properties as compared with those of conventional coarse-crystalline coatings. These include better strength or microhardness, enhanced diffusivity, reduced modulus of elasticity, higher electrical resistivity, increased specific heat, higher thermal expansion coefficient, superior soft magnetic properties, better adhesion, higher corrosion and wear resistance. Nanonickel maintains it's thermal stability up to the temperature of 573 K [4]. Nanonickel can be used for decorative and protective coatings deposition, as well for plating on the machine parts working in the conditions of wear hazard, high unit pressures and corrosion hazard.

The leading area in which composite materials are used is the transportation industry. Other fields of potential application of electrochemical coatings include agricultural machinery and equipment, medical materials, sports and recreation equipment, and high-temperature instruments used in electronics.

Deposition of good quality composite layer, often with properties inaccessible up to now, consists not only on suitable choice of layer components, but also on the creation

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of proper structure of composite material. Achievement of determined structure depends in great part on the applied technological methods and conditions.

Medeliene et al. [5] investigated microstructure, corrosion resistance, as well as mechanical and physical properties of Ni-B coatings deposited from electrolyte saccharine containing. Non-metallic inclusions on the surface effect both corrosion behaviour of coating and its mechanical and physical properties.

Electroplated Ni-B coatings of improved wear resistance were described by Epik et al. [6].

Skrobotovskaja et al. [7] deposited Ni coatings with amorphous boron from Watts type bath. They investigated the dependence of boron content in the coating on its content in the bath, coating microhardness and structure, as well boron content in the coating using gravimetric method.

Ni-B alloys were deposited from amidosulfonate bath with an addition of $Na_2B_{10}H_{10}$ by Zvyagintseva et al. [8]. Obtained coatings were characterized by fine-crystalline structure and smoother surface than nickel coatings. Modifications of boron content (0.2 to 1.5%) in coating and variations of deposition conditions make possible to obtain wide range of functional properties of coatings. One of possible applications of Ni-B coatings is the substitution of noble metals (Au, Ag, Pd and theirs alloys) in the production of semiconductors and printed-circuits boards. Ni-B layers have an excellent solderability.

The objective of presented investigations was to obtain the electroplated Ni-B composite coatings and to define the effect of bath composition and boron content on coating properties (wear resistance and microhardness).

2. Materials and experimental methodology

The electrodeposition experiments of composite Ni-B coatings were carried-out using a low-concentration Watts nickel plating electrolyte (NS) of following composition:

130 g/dm^3 $NiSO_4 \cdot 7H_2O$, 70 g/dm^3 $NiCl_2 \cdot 6H_2O$, 45 g/dm^3 H_3BO_3. As an organic compound was used: KRN (solution of organic compound protected by patent) starting addition-agent of concentration 20 cm^3/dm^3. Amorphous boron of Sigma production in concentration of 2 g/dm^3 was used as the dispersion particles. The following surface-active compounds were used in the experiments: alkylsulfosuccinate ASB (1-octanesulfonic acid sodium salt) of ZA Kedzierzyn production, cationic silyl surfactant SK ([3-(Triethoxysilyl)propyl]-trimethylammonium chloride) of Aldrich production, cationic high-fluorine surfactant WFK1 ([3-[[(Heptadecafluorooctyl)sulfonyl]amino]-propyl]trimethylammonium iodide) of Aldrich production. These surfactants were used to prepare boron dispersion in nickel plating bath. Electroplating process was realized at current density of 4 A/dm^2, at temperature of 318 K and pH = 3.8 during 1800 s, with mechanical stirring.

Dispersed phase content in the coating was determined gravimetrically with coating dissolution in hydrochloric acid diluted by 1:1 with water. Microscopic observations of nickel foils were made by the use of transmission electron microscope (TEM). Foil specimens for TEM examinations were prepared by pulse electrolytic thinning.

Coatings microhardness was measured by Vickers' method with Hanneman microhardness tester at the load of 0.01 and 0.05 kg. Wear resistance was tested using the flat surface - ball measuring system. Tested specimens were submitted to wear process by dry sliding friction with a ball of 30 mm diameter at an angle of 35°. The ball pressure at contact point was 0.6 N and the friction path - 8000 turns. On the basis of wear traces and the measurements of their diameter, the wear depth was calculated and assumed as a measure of wear resistance.

Tribological properties were investigated using the disc-block measuring system. Friction tests were made on Amsler A-135 machine by choose of the following parameters: rotational speed of disc counter-specimen, $n = 200$ rpm., average friction velocity, $v = 0.42$ m/s, loading of friction system, P = 25 daN, friction time, $t = 10800$ s, lubrication medium, Lux 10, wear measurement: microscopic measure of linear wear accuracy 5 μm, in interval times-1800 s.

3. Results

The dependence of boron particles content in composite Ni-B coating on the concentration and kind of organic additives is presented in Fig. 1. TEM images of three composite Ni-B coatings are shown in Figs. 2–4. Figs. 5 and 6 show the measurement results of microhardness of Ni-B coatings under load of 0.01 and 0.05 kg. Measurement results of wear resistance are presented in Fig. 7. The dependence of linear wear of composite Ni-B coatings on the friction time (wear with lubrication) is given in Fig. 8. The test results of friction coefficient with lubrication of composite Ni-B coatings is illustrated in Fig. 9.

4. Discussion of the results

Organic compounds used as the additives for nickel plating baths exerted a significant influence on boron content built-in the coating (Fig. 1). The use in the low concentration plating bath of KRN starting agent led to a significant decrease of boron content in the composite coating. Introduction of boron dispersion with surface-active compound ABS into KRN containing bath intensified this tendency, although an increase of ABS concentration caused a slight growth of boron content in the coating. WFK1 surfactant applied in the concentration of 0.04 mM for preparation of boron dispersion stimulated the building-in of boron in comparison with plating bath without surfactant, but that boron content was lower than in case