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MORPHOLOGY OF NICKEL MATRIX COMPOSITE COATINGS WITH NANO- SILICON DISPERSION PHASE

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ABSTRACT

In this paper is presented the morphology of nickel metal layers, nickel matrix composite and particles dispersed phase, obtained by electrodeposition on steel base, using nickel sulphate as electrolyte. Nickel anodes used were of 99.9% purity. Experimental investigations were carried out at the temperature of 293 K and various current densities for 1h, with different stirring rates of electrolyte and silicon powder concentrations. The coatings were deposited on a carbon steel substrate which was kept vertically in the solution.

The inclusion of silicon particles about 50 nm led to significant hardening of nickel composite matrix.

KEYWORDS: nickel, silicon, nano, composite coatings, electrodeposition, microhardness

1. Introduction

In recent years there has been an increasing interest in the field of advanced materials in developing composite coatings obtained by electrodeposition. The necessity for coatings with improved resistance to aggressive environments is high, as a result of a growing consumption for safe service life of industrial objects [1, 2].

Composite coatings are used in various fields, from high-tech industries such as electronic components and computers, to more traditional industries such as general mechanics and automobiles, paper mills, textiles and food industries. During the last decades, the main work carried out in this field is aimed almost entirely to the production of wear and corrosion-resistant coatings, self-lubricating systems and dispersion-strengthened coatings [3–6].

With the increasing availability of nano-particles, the interest of the low-cost and low-temperature composite electroplating is continuously growing, and the major challenge is the achievement of high codeposition rates and homogenous distribution of the particles in the metallic matrix. A recent review on the electrodeposition of metal matrix composite coatings containing nano-particles can be found in literature [7].

The production of composite coatings can be achieved through electrochemical deposition of the matrix material from a solution containing suspended particles such as: oxides, carbides, nitrides, metal powder. The usual dimensions of particles in such applications are in the range of micrometers.

The objective of the present experimental work is the extension of these researches when nano-silicon powder (mean diameter of 50 nm) is codeposited. The inclusion of nanosized particles can give an increased microhardness [8]. Many operating parameters influence the quantity of incorporated particles, including current density, bath agitation and electrolyte composition. High incorporation rates of the dispersed particles have been achieved using a high nanoparticle concentration in the electrolyte solution and smaller sized nanoparticles. It was proved that the uniform dispersion of the codeposited particles leads to the improvement of the mechanical, tribological, anti- corrosion and anti-oxidation properties of the coatings [9, 10].

2. Experimental procedure

Two types of samples were prepared. Samples coated with pure nickel coating and samples coated with Ni–Si coating. Ni coating was deposited at a current density of 2A/dm^2, while Ni–Si composite coatings were deposited at current densities of 2A/dm^2 and 3A/dm^2. The process of deposition was carried out at the temperature of 293 K and the stirring rate was of 500 rpm. The layers were deposited on a carbon steel substrate.

The Ni - Si coatings were electrodeposited from a suspension of Si nanoparticles (50 nm) in nickel sulphate electrolyte. Suspensions were prepared by adding 10 g/L of Si nanoparticles and they were stirred for 1 h before the deposition. The substrate was steel and the anode pure nickel.

The study of the surface morphology, microhardness measurements were carried out for the characterization of the composite coatings of this work.

The investigation of morphological appearance of coatings was performed with an optical microscope Olympus BX 51M.

The measurements of the Vickers microhardness of pure nickel and Ni-Si composite deposits were performed on their surface by using a 20 g load for a period of 10 s and the corresponding final values were determined as the average of 3 measurements.

3. Results and discussion

3.1. Morphology

In Fig. 1 is presented the macrostructure of metallic support, without nickel coating. A macrography of a pure nickel coating obtained by eletrolitic deposition is shown in Fig. 2 while Ni - Si coatings are shown in Fig. 3 and Fig. 4. Both coatings were electrodeposited at a current density of 2 A/dm^{2}. As it can be observed in Fig. 3 (dark field and bright field illumination), the composite coatings are more compact than the pure one. As a consequence better mechanical and anticorrosive properties of the composite coating should be expected. The surface appearance of metal deposition (Ni) reveals a uniform and compact layer without pores or other defects, which faithfully follows the steel support

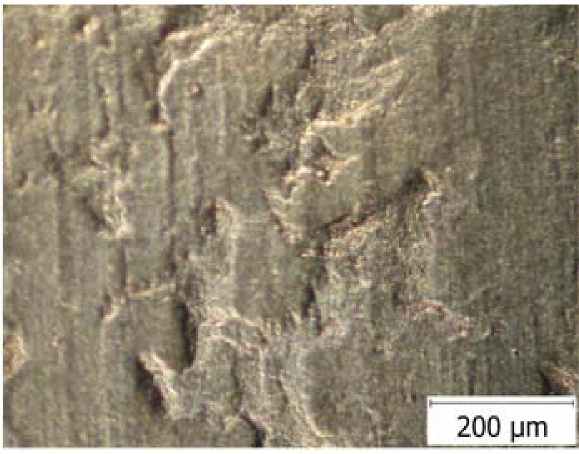


Fig. 1 *Metallic support - without Ni coating (X200).*

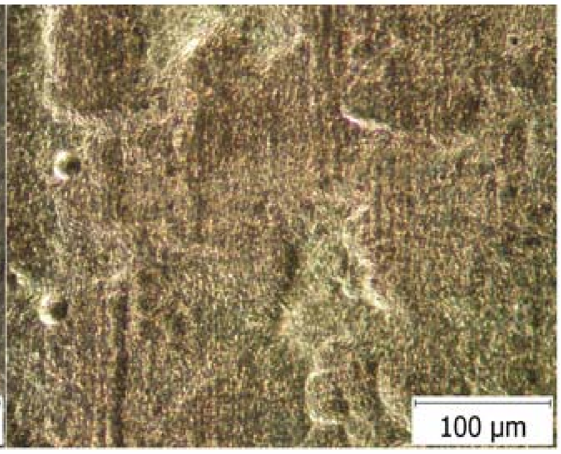
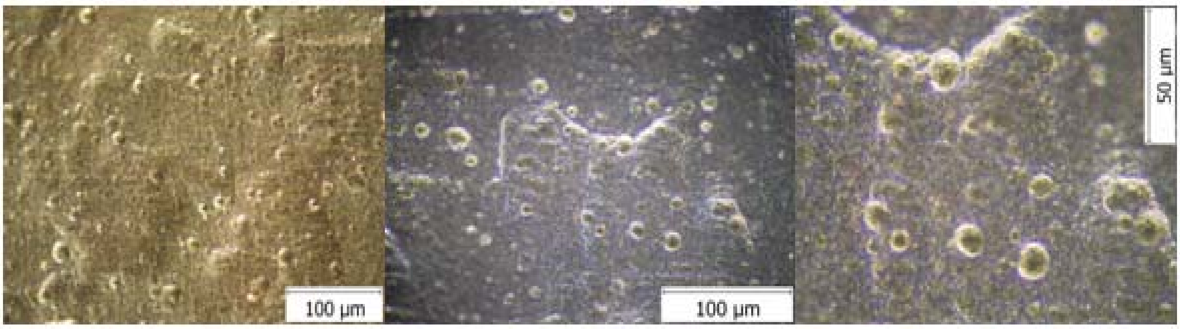


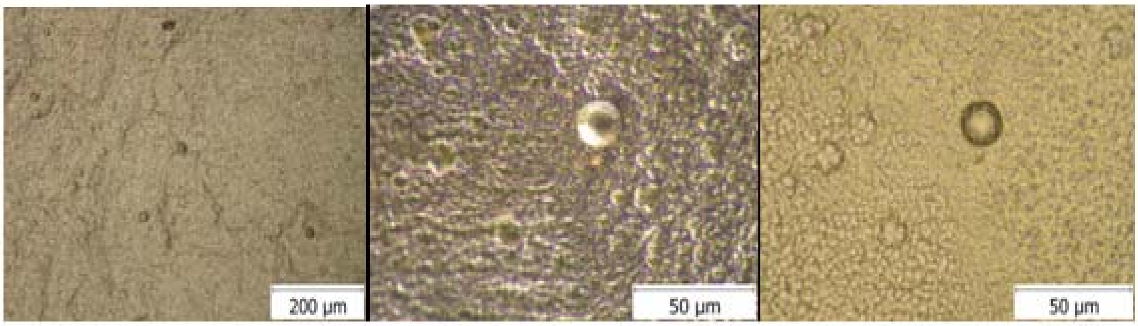
Fig. 2*. Ni coating, 2A/dm^{2}, 500 rpm (X400).*

In figure 3 is presented the macrostructure of Ni-Si coatings (10 g/L Si 50 nm) for operating conditions: current density – 2A/dm^{2}, time – 60 min, stirring rate – 500rpm.



a) b) c)

Fig. 3. *Macrostructure of Ni-Si coating (10g/L Si 50 nm), 2A/dm^{2}, 60 min, 500rpm: a) X400 dark field illumination, b) X500 dark field; c) X1000 dark field.*



a) b) c)

***Fig. 4**. Macrostructure of Ni-Si coating (10g/L Si 50 nm), 3A/dm^2, 60 min, 500rpm: a) X200 dark field illumination, b) X1000 dark field; c) X1000 bright field.*

In Figure 4 is presented the macrostructure of Ni-Si coatings (10 g/ L Si nm) for operating conditions: current density – 3A/dm^2, time – 60 min, stirring rate – 500 rpm.

3.2. Mechanical properties

Vickers microhardness measurements were performed on pure nickel and on Ni - Si coatings. Microhardness measurements were carried out using a Vickers microhardness tester, applying 20 g load for 10 s time.

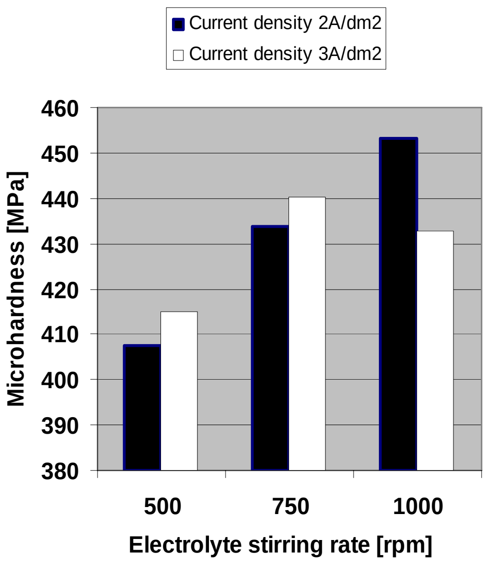


***Fig. 5.** Microhardness as a function of electrolyte stirring rate (10 g/L Si 50nm).*

The mean value of Vickers microhardness of pure nickel coatings has been found of about 300 MPa while the microhardness of composite coatings is about 505 MPa.

This result shows that the codeposition of Si nanoparticles ameliorates the mechanical properties by a 70% microhardness increase.

Fig. 5 and 6 depict the microhardness of the nanocomposite coatings prepared as a function of electrolyte stirring rate.

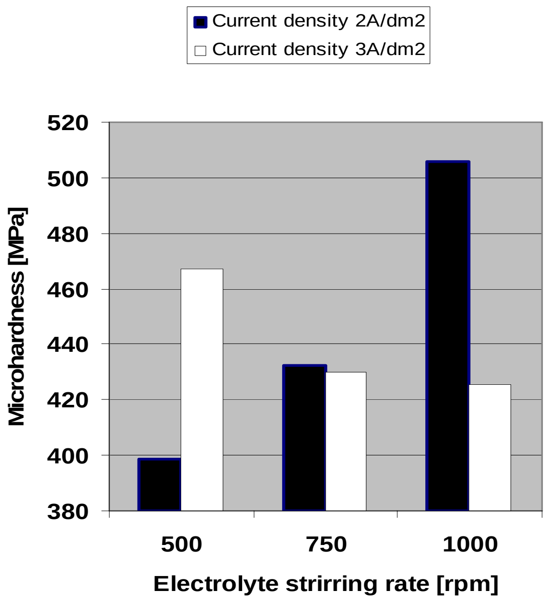


***Fig. 6.** Microhardness as a function of electrolyte stirring rate (20 g/L Si 50nm).*

Sillicon particles dispersion led to hardening of nickel matrix, so the nickel metallic coating had a mean value of 300 MPa comparing to the value of 505 MPa, the microhardnees for Ni-Si composite coating (2A/dm^2, 1000 rpm, 1h, dispersion phase 20g / L Si (50nm)).

The amelioration of the mechanical properties of the composite coating results in a 70% increase of the coating microhardness.

4. Conclusions

The experimental results led to the identification of electrodeposition parameters that provide a very good adhesion to metallic support, the metal layers are compact without pores or other defects, almost flat, with relatively constant thickness.

Significant increase in composite coatings hardness versus nickel coatings certifies that nano-sillicon particles were included and their presence induces a strong hardening in the metal matrix.

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