INFLUENCE OF CURRENT DENSITY ON THE CHARACTERISTICS OF NI-CR ALLOY COATINGS

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ABSTRACT

In the present study, Ni-Cr alloy coatings were electrodeposited on pretreated Cu substrates, from a citrate bath containing chromium sulfate salt. In order to study the effect of applied current density, Ni-Cr alloy coatings were electrodeposited at 1, 3, 5 and 8 A/dm². The characteristics of the coatings were assessed by X-ray diffraction (XRD) and microhardness tests. The corrosion results were calculated from polarization Tafel lines. XRD analyses of elaborated coatings at different applied current densities indicate the formation of NiCr and Cr_3Ni_2 phases. The co-deposition of chromium in Ni matrix improved the microhardness and the corrosion behavior.

KEYWORDS: Ni-Cr alloy coatings, Microhardness, Co-deposition, Polarization Tafel.

1 INTRODUCTION

Nickel is largely used as based metal in the electroplating process raison of its good resistance to general corrosion [1-3]. In order to improve mechanical and chemical properties of nickel layers, various modifications could be applied, such as alloying with other elements, incorporating composite components [4-5]. The incorporation of these types of particles like Mo, Al, Co, [6-8], hard oxides Al_2O_3, SiO_2, TiO_2 [9-11], carbides like (Cr-C and SiC) [12-13] into Ni-matrix leads to an improvement of its properties such as hardness, wear and corrosion resistance, catalytic properties etc.

Nowadays world, the growing needs of the population and the growing technological innovation are pushing industrial and researchers to move towards so called new generation composites such as ''clean'' technologies in the electroplating industry[14].

Generally, chromium coatings are produced based on conventional hexavalent chromium electrodepositing process, but the severe toxicity of hexavalent chromium has done great harm to environments. Therefore, researches have been carried out to replace conventional hexavalent chromium electrodepositing process by trivalent chromium (Cr(III)) electrodepositing[15-16].

The deposited Ni-Cr alloy coatings are quite attractive materials because of their low electroplating density during their deposition on foreign substrates, good mechanical properties acceptable for application [17-19].

The aim of this work is to investigate the influence of applied current densities on the optical, mechanical and electrochemical properties of Ni-Cr alloy coatings.

2 EXPERIMENTAL

Ni-Cr alloy coatings were prepared using DC current, which is made to circulate between two electrodes immersed in a conductive solution. The DC current flow causes one of the electrodes (nickel sheet) to dissolve and the other electrode (substrate) to be covered by Ni-Cr coatings. The volume of the electrolyte was approximately 200 ml. The cathode is Cu sheets with an exposed surface of 1.15 cm². Prior to deposition the samples were cleaned in alkaline solution to remove oil and greases, then dipped in a dilute acid (10% HCl) to remove the oxide layer and finally washed with distilled water. Components of the electrolyte and electroplating conditions are listed in Table 1. H_3BO_3 was used to keep the pH constant. Tri-sodium citrate ($Na_3C_6H_5O_7.2H_2O$) was used as a complexing agent to forme strong nickel complexes and controls the reduction rate. The anode used in all experiments was pure nickel (99.99%). pH value of the bath was adjusted by addition of the aqueous HCl or NaOH solution.

The morphology of the Ni/Cr alloy coatings was examined by optic microscopy (Microscopy b5p-ics). Structural investigations and phase composition of the coatings were

conducted by XRD method using a Bruker diffractometer (D8 Advance model) with Cu Kα-radiation (1.5406 Å). Microhardness measurements were carried out using microhardness Vickers tester machine (Leco 0.1-100 KGF/ LMV series), under a load of 25 g for 10s. The corresponding final values were determined using an average of 4 measurements.

Potentiodynamic polarization measurements were conducted using a standard three-electrodes cell with the coated samples (1.15 cm2) as a working electrode, Pt as auxiliary electrode and saturated calomel electrode as a reference electrode, all immersed in 0.6M NaCl electrolyte. This cell was connected to Voltalab 20 (PGP201) device working at a scanning rate of 5 mV/s. Corrosion rate (mm/y), corrosion potential Ecorr (mV), and Tafel slopes (mV/s) were calculated using Tafel extrapolation technique provided by Volta Master 4 software.

Table 01: Bath composition and electroplating conditions for Ni-Cr alloy coatings

Bath composition	**Concentration (g/l)**
$NiSO_4.6H_2O$	26
$Cr_2S_3O_{12}.xH_2O$	45
H_3BO_3	18
$Na_3C_6H_5O_7.2H_2O$	80
Na_2SO_4	14
Electrodeposition parameters	
Current density (A/dm2)	1-8
pH	5.12
Temperature (°C)	35
Time(s)	60

3 RESULTS AND DISCUSSION

Thermal shock tests show that electrodeposited composite coatings have an excellent adherence to the substrates.

Figure 1 presents optical images of Ni/Cr samples obtained at different electroplating current densities. Figure 1.a shows an uniform and compact morphology. Whereas, Figure 1.b-c reveal a cracked surface of Ni-Cr coatings increase with increasing of applied current density, these resulting cracks may be attributed to the internal stress caused by the intensification of the hydrogen, through the increase of plating current density.

Figure 2 presents the XRD analyses of elaborated coatings at different applied current densities. Figure 2 indicate the formation of NiCr (Ref. code 00-026-0429), and Cr3Ni2 (Ref. code 00-026-0430), phases. In the range of 1-5 A/dm²; NiCr phase was obtained at 1 A/dm² with preferred orientation (211), corresponding to 2theta=48°. At 8 A/dm², a new peaks of NiCr and Cr_3Ni_2 phases appeared at 2theta= 44°, 74° and 76°, respectively. The preferred orientation (413) was obtained at 2theta=74°, corresponding to Cr3Ni2 phase.

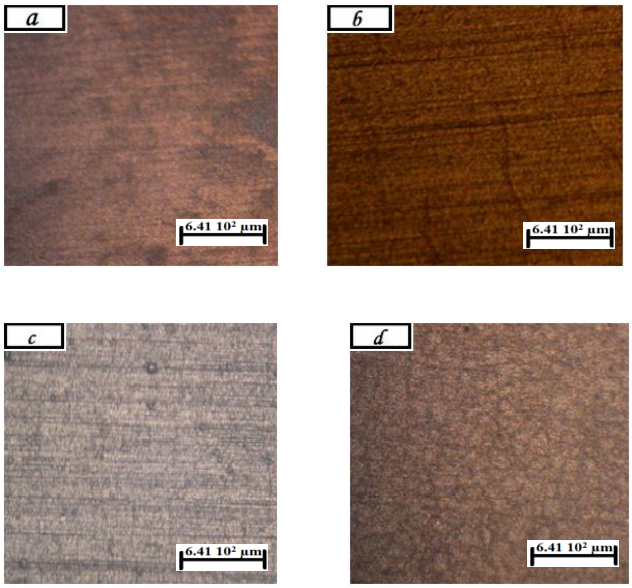

Figure 01: Optic microscopy images of various coatings electrodeposited at a) 1 A/dm², b) 3 A/dm², c) 5 A/dm² and d) 8 A/dm²

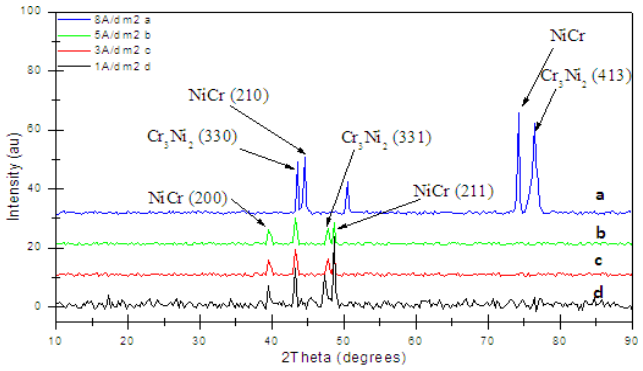

Figure 02: XRD patterns of Ni–Cr samples as a function of applied current densities

Microhardness results of Ni-Cr alloy coatings are shown in Fig.3. These results indicate an enhancement from 250 to 500 Hv by increasing the applied current density from 1 to 8 A/dm2, respectively. This is essentially due to the fact of Cr metal incorporation into Ni matrix [20]. The trend of increasing of chromium content in Ni-Cr alloy coatings as result of increasing the applied current density has been reported by Ching An Huanget et al. [21, 22].

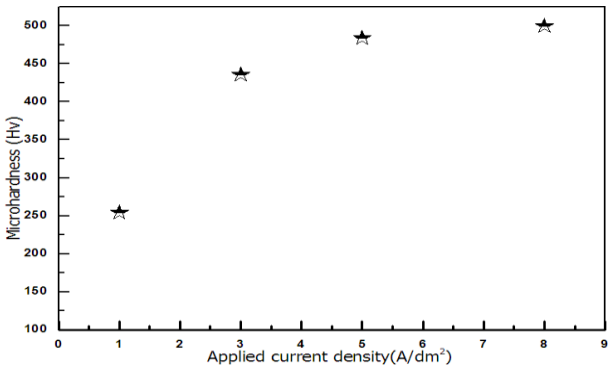

Figure 03: Variation of microhardness as a function of applied current density

The polarization curves for electrodeposited Ni-Cr samples for different plating current densities in a solution of 0.6 M NaCl at 25 °C, are shown in Fig.4, and the corrosion properties are summarized in Table 2. The results showed that the sample with the best corrosion properties is the electrodepositing at 1 A/dm², in according to the lowest negative value of Ecorr (-105.3 mV) , the lowest corrosion current density (0.3228µA/cm²) and the highest polarization resistance (21.460 Kohm/cm²). These results leads us to conclude that the reduce of applied current density improves the electrochemical properties of Ni-Cr alloy coating. These good electrochemical properties can be agreed by the compact morphology of electrodeposited Ni-Cr coatings at 1 A/dm² Fig.1.

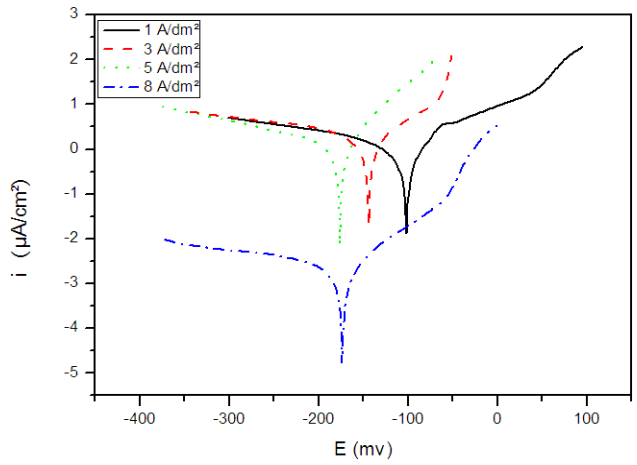

Figure 04: Polarization curves of Ni-Cr alloy coatings fabricated at different current densities in 0.6M NaCl

Table 02: Corrosion properties of electrodeposited Ni-Cr composites at different plating current densities

current density (A/dm²)	E_{corr} (mV)	I_{corr} (µA/cm²)	Rp(Kohm/ cm²)	Corrosion rate (µm/y)
1	-105.3	0.3228	21.460	3.775
3	-147.2	2.0058	11.590	23.46
5	-179.5	1.1696	13.860	13.68
8	-175.9	1.8219	9.260	21.30

4 CONCLUSION

Electrodeposition of Ni–Cr alloy coatings could be carried out using a bath of nickel sulphat, sodium citrate, and chromium sulphate salt. XRD results showed that elaborated coatings indicate the formation of NiCr and Cr_3Ni_2 phases. In addition, at 8 A/dm² there is a new peaks of NiCr and Cr_3Ni_2 phases appeared, in which the preferred orientation (413) is related to Cr_3Ni_2 phase. Hardness results of Ni-Cr samples showed that the increase of current density greatly improve the mechanical properties of these coatings. Polarization test results showed that Ni-Cr sample electrodeposited at 1 A/dm², proved to be the most immune corroded alloy compared to other samples.

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