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Reciprocating Wear Behavior of Ni–Co Alloys Produced by Pulse Current Electrodeposition

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In the present work, Ni–Co alloy coatings were prepared from a modified Watt type electrolyte by direct current. For this purpose, current density was investigated for optimization to obtain high quality coatings on the steel copper substrates. The depositions were controlled to obtain specific thickness (between 50 and 200 μm). The characterization of the coatings was investigated by scanning electron microscopy and X-ray diffraction facilities. The hardness of the resultant coatings was also measured. The effects of the current density on the tribological properties of Ni–Co coatings were investigated. The results showed that although increasing current density showed increasing coating thickness, the wear resistance of the Ni–Co alloys was decreased due to Co depletion in the deposited layer.

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1. Introduction

Ni–Co alloy coatings have been widely used as recording head materials in computer hard drive industries. The thickness of the magnetic layer used in the micro-electrical mechanical system (MEMS) can vary from a few nanometers to a few millimeters, depending on the applications, and the magnetic thin films must have good adhesion and corrosion resistance and low-stress, and be thermally stable with excellent magnetic properties [1]. Several studies reported that the magnetic properties of Ni–Co alloy was greatly influenced by the composition and phase structure of Ni–Co alloy. Unfortunately, there are very limited studies focused on the friction and wear properties of Ni–Co alloys as a function of their microstructure and composition [2–5], it is essential and feasible to improve the comprehensive properties of Ni–Co alloy applying pulse current and altering current density.

2. Experimental

The plating electrolyte for the electrodeposition of Ni–Co alloys were a Watt-type bath. Figure 1 shows a pulse current source and a schematic representation of the electrodeposition system. The basic composition of the electrolyte and the plating conditions are also shown in Fig. 1. The temperature of the electrolyte during deposition of alloy was controlled at 45 °C (± 2) and the pH was fixed at 4 (± 0.2).

In the electrodeposition experiments, three different pulse currents were studied to obtain optimum conditions for homogeneous microstructures. Plating time was 120 min for each electroplating run. The process steps

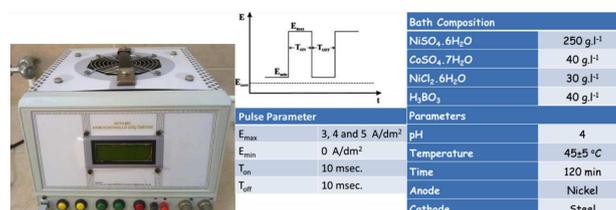


Fig. 1. Pulse power supplier, pulse parameter and coating conditions.

are: (i) polishing of substrate, (ii) preparation of electrolyte, (iii) magnetic stirring for 30 min, (iv) performing electrodeposition for 120 min.

Microstructural investigations were performed by JEOL-JSM 6060LV SEM instrument. The hardness of the coatings was measured by using a Vickers microhardness indenter (Leica VMHT) with a load of 50 g. Wear and friction tests were performed with a reciprocating ball-on disk CSM tribometer at room temperature with a relative humidity of 55–65% under dry sliding conditions. Counterpart was Al₂O₃ ball (\varnothing 10 mm). The system allows measuring friction coefficient by using sensitive transducers. Thus, the tests were performed at a constant applied load of 1.0 N with a sliding speed of 0.05 m/s.

3. Results and discussion

In the electrodeposition process, it was aimed to produce a layer of the Ni–Co alloy. Figure 2 shows the microstructure of the alloys that was produced by using different current applications. The microstructures show that all alloys coating steel substrates by electrodeposition show uniform grain size and shape.

In Fig. 3 energy dispersive spectroscopy (EDS) and X-ray diffraction (XRD) analysis results are given for the

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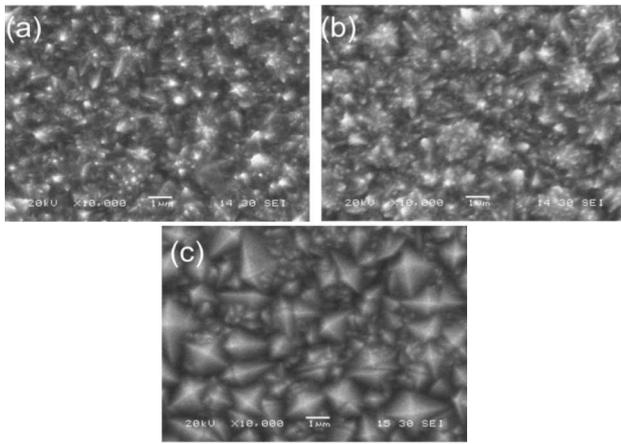


Fig. 2. High magnification surface structure of electrodeposited Ni-Co coatings: (a) 3.0 A/dm², (b) 4.0 A/dm², (c) 5.0 A/dm².

coating obtained at 3.0 A/dm². XRD analysis gives preferential analysis growth in two distinct planes of (α 111) and (α 220) with increasing applied current (E_{\max}).

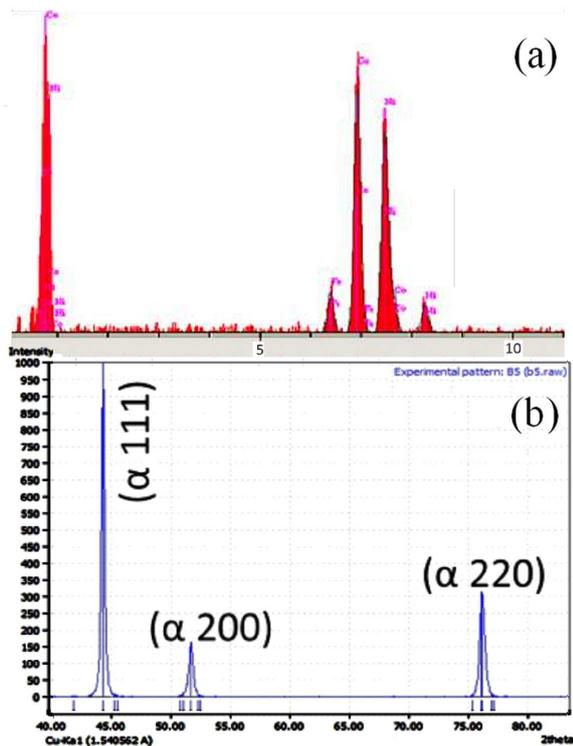


Fig. 3. EDS (a) and XRD (b) analysis of electrodeposited Ni-Co coating at 3.0 A/dm².

The microhardness measurement results are shown in Fig. 4. Microhardness tests confirmed that the hardness of alloys coatings depends on the applied current. The hardness of the alloys decreases with increasing applied current E_{\max} .

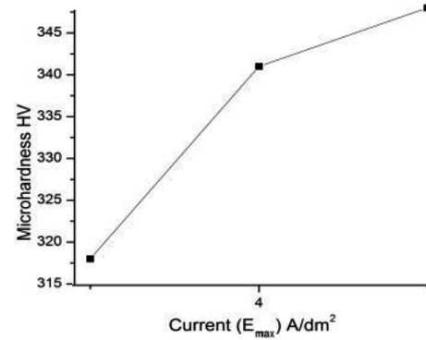


Fig. 4. Microhardness of Ni-Co layer.

When Fig. 5 is seen, it can be observed that in the alloys, a mixed mode of adhesive-abrasive wear occurred for all the conditions. From the low magnification scanning electron microscopy (SEM) micrographs, it can easily be seen that wear tracks to show the highest wear appeared in the sample that was produced at $E_{\max} = 3.0$ A/dm² current. For under 3.0 A/dm² coating the wear track shows identical mechanism, while the sample produced under 4.0 A/dm² exhibits a typical adhesive wear and severe delamination along the sliding direction under the combined stresses of compression and shear. In Fig. 5, heavy plastic deformation is seen with increasing current during deposition. Mainly, the plastic deformation occurs by smearing of the wear debris on the coatings.

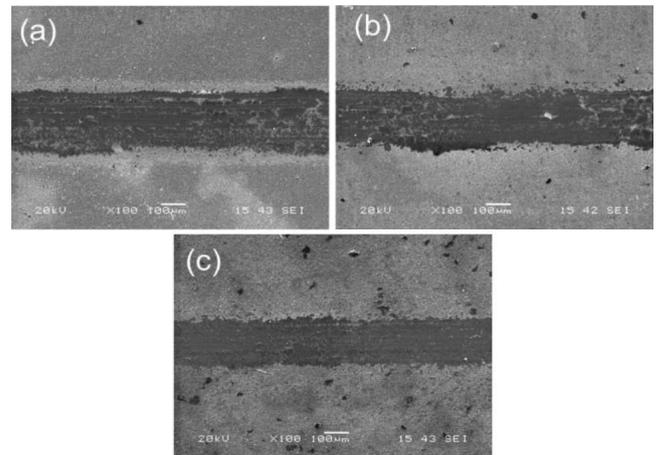


Fig. 5. Low magnification wear tracks of electrodeposited Ni-Co: (a) 3.0 A/dm², (b) 4.0 A/dm², and (c) 5.0 A/dm².

Figure 6 shows the wear rate and friction coefficient values of the alloy that were produced with $E_{\max} 5.0$ A/dm² are the lowest among studied coatings. This is because this current is the optimum value and resulted in decreasing grain size and hardness to provide high wear resistance. Therefore, wear rate and friction coefficient decreases with increasing E_{\max} .

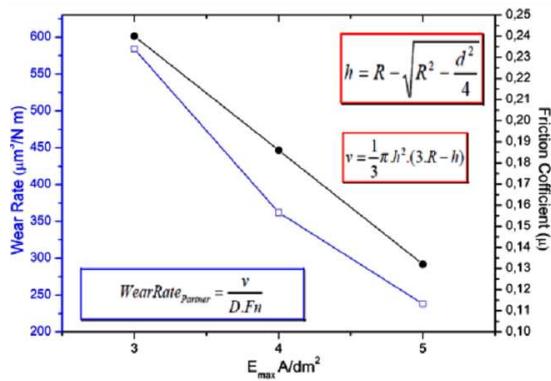


Fig. 6. Effect of current on wear rate and friction coefficient of coatings.

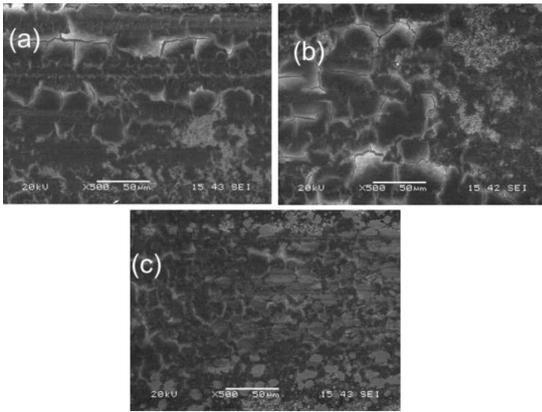


Fig. 7. High magnification worn surfaces of electrodeposited Ni-Co alloys: (a) 3.0 A/dm², (b) 4.0 A/dm², and (c) 5.0 A/dm².

Figure 7 shows four typical SEM morphologies of worn surfaces of the Ni-Co alloys produced with different current densities. Figure 7a shows the worn surface of the Ni-Co deposited layer produced with E_{max} 5 A/dm² cur-

rent. As can be seen in Fig. 7a Ni-Co alloy shows an extensive amount of plastic deformation is occurred. Plastic deformation is seen to cause smearing of the wear debris on the sliding surface coming from the electrodeposited alloy and then plastic deformation occurs when sliding continues. The cracks are evidence that after deformation hardening, delamination type of the material transfer will occur when the current density is increased.

4. Conclusions

1. The Ni-Co layer has been successfully synthesized by a pulse electrodeposition process.
2. All the Ni-Co coatings on copper substrates produced by electrodeposition show uniform distribution of grain size and shape.
3. EDS analysis shows Co ratio in the Ni-Co layer decreases with increasing current density (E_{max}).
4. XRD analysis shows preferential Ni-Co growth in two distinct planes of (α 111) and (α 220) with increasing E_{max} .
5. Wear rate and friction coefficient decrease with increasing E_{max} .
6. The hardness of the Ni-Co alloy obtained by electrodeposition increases with increasing E_{max} .

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