

Study on the Electroforming Ni-Co-Al₂O₃ Alloy

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ABSTRACT. Electrolytic codeposition technique was adopted in the deposition of Ni-Co-Al₂O₃ coating on the stainless substrate, using nickel alloyed with iron as the binder phase with Al₂O₃ as dispersed particles. The results indicated that the deposit with Al₂O₃ nanoparticles was level and compact; the crystal-planes of the deposit were (111), (220) and (200). The resistivity of deposit was about $30 \mu \Omega \cdot \text{cm}$. when the Co(wt.%) ranged from 10% to 50% in the deposit, the electrodeposit Ni-20%Co-Al₂O₃ has a strong paramagnetism effect with the smallest coercivity of $2.75 \times 10^{-2} \text{ A/m}$. The remanence showed a monotonic decrease with the increasing iron content in deposit. Which proved that the electroformed NiCo-Al₂O₃ alloy has good electromagnetic property and higher corrosion resistance than those of electroforming Ni-Co alloy. It is a promising material in the fabrication of micro sensor.

Introduction

NiCo deposit has a compact structure, bright and smooth surface and was widely used in the production of new materials that required specific mechanical, chemical and/or physical properties[1,2,3]. These alloys also exhibit excellent properties of levelling, high hardness, thermally stable, and fine magnetic properties. Various compositions of Ni-Co alloys such as Permalloy (Ni-20%), Invar alloy (Ni-64%Fe) and high strength Ni-Fe alloy can be used to produce micro sensor, micro actuators and other MEMS device[4,5]. David Flynn compared various microscale magnetic components and described a novel method to manufacture and assemble a Ni-20%Fe microinductor that is based on flipchip bonding[6]. The micro component fabricated with electroforming Ni-Co alloy could be integrated with other materials easily[7,8]. But the corrosion resistance of Ni-Co deposit was lower than that of the electroforming Ni. Al₂O₃ nano particles has been studied as a promising material in corrosion protection. Gajendra Sharma concluded that the Ni-Co-Al₂O₃ composite coating shows substantial improvement in the hardness as compared to pure Ni plating[9]. Electroforming Ni alloys with nano Al₂O₃ has a smaller grain size and finer property than that of the electroforming Ni, moreover, nano Al₂O₃ could improve the corrosion resistance of the deposit considerably[10]. Min-Chieh Choua revealed that adding SiC to the Ni-P alloy matrix substantially reduces the residual stress in the deposit and, therefore, eliminates surface cracking[11].

In the present work, the nickel-iron deposit with nanocomposites Al₂O₃ and its electromagnetic property were investigated. The work will be benefit to the fabrication of many magnetic microactuators with Ni-Co-Al₂O₃ electrodeposits.

Experimental procedure

There are many kinds of solution for Ni-Co deposit. An acid sulphate solution, containing metal sulphates and some brightener, was chosen for this study[4]. The main content of solution and devices using in the experiment was presented as follows:

Main Salts: Nickel Sulphate, Ferrous Sulfate. Buffer Solution and Stabilizer: Boric acid, Citric acid. Anode activators and conductive agent: Sodium Chloride, Sodium Sulphate and some additive, 50nm grain size Al₂O₃ nanoparticles :2-3g/L. When preparing metal salt solutions of different concentrations, the amount of Nickel Sulphate was 250g/l, the amount of iron ion was adjusted by the Ferrous Sulfate additives. The main electroforming parameters: PH value of the solution was less than 2.5, current density was set from 2.5 to 4 A/dm², stirring velocity: 500-700 rpm/min, the solution temperature was ranged from 50 to 60°C, CoSO₄·7H₂O: 3-7g/l, several different process parameters were adopted in the experiment. The composition and range of experimental operating parameters were given in table 1.

Table 1 Operational parameters of Ni-Fe-Al₂O₃ composite

NiSO ₄ ·6H ₂ O	250g/l
NiCl ₂ ·6H ₂ O	30g/l
H ₃ BO ₃	40g/l
CoSO ₄ ·7H ₂ O	3-7g/l
NaSO ₄ ·10H ₂ O	10 g/l
Al ₂ O ₃ particles	2-3g/l
Parameter for equipment setup	
Temperature of bath	55°C
PH	< 2.5
Current density	2.5-4A/dm ²
Plating time	100-300 min
Stirring rate	600 rpm

Results and discussion

The properties of Ni-Co deposit are affected by several factors such as the texture, compositions[12], etc. The main properties of the plating were presented as follows:.

Surface morphology of the plating

The deposit surface morphology was sensitive to the impurity in the solution. Some organic additives were adopted in the experiment to obtain the bright and smooth plating surface. Ni-Co-Al₂O₃ deposit has a more compact structure than that of pure Ni. Fig.1 was the surface morphology SEM photograph of the electrodeposit Ni and Ni-22.27%Co-Al₂O₃. The corrosion test of the deposit was performed subsequently. The corrosion rate of Ni-22.27% Co -Al₂O₃ deposit was 0.17 mg/dm² per hour in 2M HCL solution, which was smaller than that of the electroforming Ni-20% Co (0.23 mg/dm² per hour). The results indicated that the corrosion rate of the deposit be improved significantly with the ad Al₂O₃ particles. The deposition rate is about 5µm-8µm per hour. The electrodeposits showed no curling or buckling after removing from the substrate. Which indicated that internal stresses was relatively low.

Fig. 2 showed the X-ray diffraction of electroforming Ni-Co-Al₂O₃ alloy. The plating has a well

crystal structure. The X-ray diffraction peak were (111),(220) and (200). When the Co content reached to 41%, the highest diffraction peak fall from (111) to (220). Pure Ni has a diffraction peak of (111).The change of the crystalline orientation may be attributed to the cathodic over-voltage and the change of the ion concentration. There are some inhibition material such as H_2 , $Ni(OH)_2$ on the cathode-solution interface. They not only affected the plating morphology and the selective adsorption, but also altered the crystal growth mode.

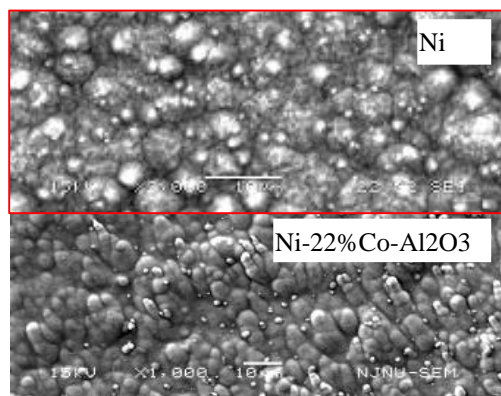


Fig.1. SEM photograph of deposit (Ni, Ni-22% Co -Al₂O₃)

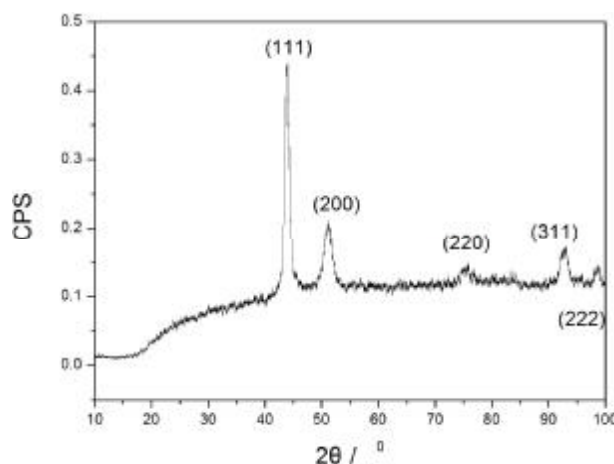


Fig.2. X-ray diffraction of the deposit

Electromagnetic property

To compare the magnetism property with permalloy, the hysteresis loop of Ni-30% Co -Al₂O₃ deposit and permalloy (IJ85) were tested under the same condition. As showed in Fig.3, Ni-30% Co -Al₂O₃ deposit has superparamagnetic characters with magnetic remnant was $0.528 \text{ mA} \cdot \text{m}^2$, coercivity was $2.88 \times 10^{-2} \text{ A/m}$. Moreover Ni-20% Co -Al₂O₃ has a smallest coercivity value of $2.75 \times 10^{-2} \text{ A/m}$, which was less than that of IJ85 permalloy. Saturated Magnetization value of deposit was only 10% of the IJ85 alloy. The remanence and coercivity comparison of the deposit was showed in Fig. 4. Ni-20%Fe-Al₂O₃ deposit has a lowest remanence, and the coercivity show a monotonic decrease with increasing the iron content in deposit. The test data indicate that the deposit has a satisfacted magnetism property. The resistivity of deposit was about $30 \mu \Omega \cdot \text{cm}$, when the iron content ranged from 10% to 50% in the deposit.

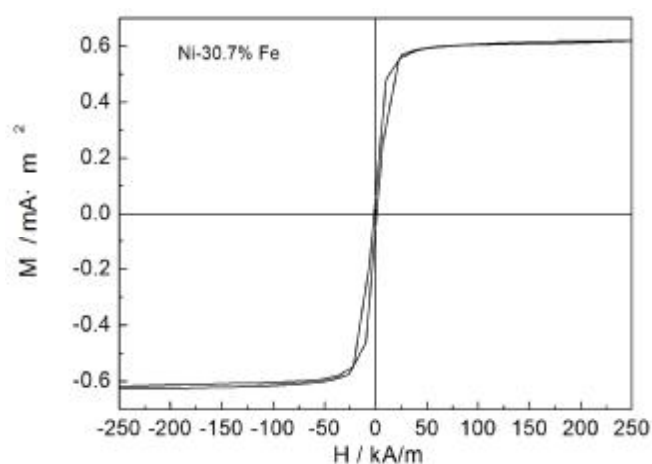


Fig.3. The hysteresis loop of electroforming alloy

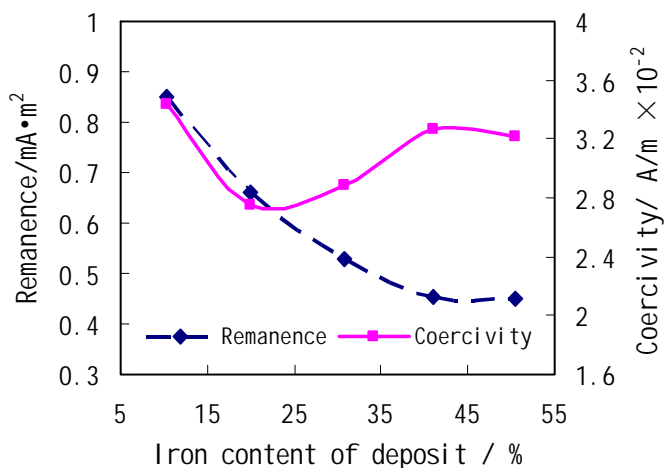


Fig.4. The Co content of deposits against the coercivity and remanence

Conclusions

Ni-Co-Al₂O₃ electrodeposit technology and physical property was discussed in this paper, The hysteresis loop of electroforming alloy and the trend of the iron content in the deposit against the coercivity, remanence were given. From the experiment it can concluded that the Ni-Co-Al₂O₃ electrodeposit has fine electromagnetic property, high corrosion resistance, compact structure, and could be used in MEMS actuator manufacture.

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