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Investigation of Structural, Compositional and Magnetic Properties of Copper-Nickel Alloy by Electrodeposition

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ABSTRACT

The arrangement of various metals in a nanoalloy framework enables the alteration of chemical and physical properties. In this study, the structure, surface,composition and magnetic properties of a copper-nickel alloy thin film that was electrodeposited on a stainless steel substrate at -0.9V and 60°C are examined. During the deposition of the bath temperature, chemical elements copper forms first, followed by the formation of a bimetallic copper-nickel alloy. A nickel-rich alloy that effectively resists oxidation covers the underlying copper. It was found that the copper-nickel films revealed a face-centered cubic structure with crystallites oriented along the (1 1 1) plane including crystallite size, micro-strain, dislocation density, and stacking fault probability. Morphological and film composition characteristics revealed that the deposited films were well adherent to the surface of the substrate with microcracks and stoichiometric ratio. The magnetic properties of the deposited films were estimated.

NOMENCLATURE

D	crystallite size (nm)
d	lattice spacing (Å)
M_s	saturation magnetization
Hc	coercivity, (O_e)
	Retentivity, (emu)

1. INTRODUCTION

Electroplating is one technique for producing multi alloys at lower temperatures and potentials for advancements in science and technology. Because they can fulfil a wide range of practical requirements that pure metals cannot, their fields of application have grown significantly. Protective, decorative, and functional applications are among the requirements. Alloy plating is also important in the conservation of valuable and scarce metals. In this case, the electrodeposited alloys typically have a more pleasing colour and appearance than the existing metals and better appearance than the parent metals with smoother, brighter and fine grained. Many of the alloys are best plated in a bright state, either by themselves or in the presence of brightening additives. In some environments, their resistance to chemical attack and corrosion outperforms that of the parent metals [1]. The magnetic material based binary and ternary composite alloys are interest for their very potential application due to their magnetostrictive smart material for actuator, sensor, energy harvesting applications, high density recording and data storage discs [2,3]. This attention is due to the fact that, unlike other super clever material systems, cubic Fe-Ga and Fe-Ga-Al alloy is the first to combine good magnetostrictive and mechanical and physical properties with the ability to be formed and welded into a variety of shapes and configurations [4]. So, these alloys exhibit conductive properties ranging from normal metallic to superconductor like vanadium baesed aloys are mostly used high-field superconductors [5]. It is important to note that the metals with the highest electrical conductivity (e.g., Cu, Au) do not have superconductivity by nature. In this case, the combination of semi-hard magnetic materials demonstrated magnetic properties intermediate between hard and soft magnets, with coercivity values (Hc) ranging between 50 and 1000 Oe. They have relatively high magnetization at saturation (Ms), but medium magnetization at remanence (Mr) and saturation field, so the cost of energy to magnetise the material is much lower than for hard magnets [6]. As a result, they can be easily magnetised and demagnetized to control the value of residual magnetization with magnetic force that is proportional to its thickness for films. From that alloys pure copper is not stable in oxygen-containing electrolytes, particularly in marine environments [7]. So, the nickel is commenly used ferromagnetic and its is used wide range of energy application due to the its corosion resistance. Cu-Ni alloys corrosion resistance is attributed to a protective layer composed primarily of a thin, strongly adherent inner barrier CuO layer that is in contact with a solution via a porous and thick outer Cu(I) hydroxide/oxide layer. Through a solid-state reaction, Ni from the alloy segregates into the CuO barrier layer and incorporates into the cation vacancies, increasing corrosion resistance [8].

2. EXPERIMENTAL

All chemicals used were analytical grade. Nickel chloride hexahydrate (molecular weight:237.69) and copper chloride dihydrate (molecular weight:170.48), ammonium chloride were used to self-decomposition of copper nickel ions from the electrolytic solution [9]. Precursor consists of 0.2 M $CuCl_2$, and 0.06 M $NiCl_2$ and 0.3 M NH_4Cl were used for electrodeposition method, respectively. The electrochemical deposition of Cu-Ni alloys was carried out potentiostatically by employing three electrode system consists of stainless-steel substrates working electrode, Graphite rod as counter electrode whereas Saturated Calomel Electrode (SCE) as reference electrode, respectively. The substrates were cleaned with hydrochloric acid, acetone and double distilled water. Initially, the pH value of the electrolytic bath was found to be 4.0 ± 0.1 Thereafter, the pH value was slightly increased above 5.0 ± 0.1 by the addition of NH_3OH respectively. The electrolytic bath temperature of the electrolytic bath was maintained at 60°C with the input potential -0.9V. the bath temperature 60°C is the rate of release of ions were produced film with well adherence nature to the substrate. The depositd film were going to take further characterization.

3. RESULT AND DISCUSSION

3.1. Structural properties

XRD analysis confirmed the presence of elemental copper-nickel alloys is shown if Figure 1. Alloying is a common practice because metallic bonds allow joining of different types of metals. In this case the copper nickel molarity is exhibited fm3m space group with FCC structure. And also, the prominent peaks (111), (200), (220) and (311) and are exhibited well Cu-Ni alloy formication. XRD analysis confirmed the presence of elemental copper-nickel alloy is shown if the CuKα peak positions for lattice parameter was determined from a plot of lattice parameter versus cos2θ/sinθ [10]. The experimental lattice parameters for copper and nickel were found to be 3.4402 Å These values are in agreement with the lattice parameter for copper nickel alloy (JCPDS no-009-0205). The crystallite size (D), dislocation density (δ) strain (ε) and stacking fault (SF) values are estimated using the following Eq(s). **(**1-4**).**

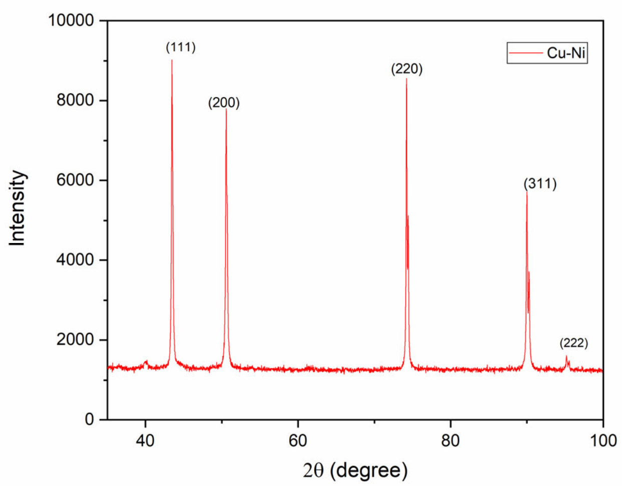

Figure 1. XRD pattern of Cu-Ni alloy thin films deposited on Stainless steel substrate

$$D = \frac{0.9\lambda}{\beta COS\ \theta} \quad (1)$$

$$\delta = \frac{1}{D^2} lines\ /\ m^2 \quad (2)$$

$$\varepsilon = \frac{\beta \cos\theta}{4} \quad (3)$$

$$SF = \left[\frac{2\pi^2}{45(3\tan\theta)^{1/2}}\right]\beta \quad (4)$$

So, the compact surface morphology of material would affect the corrosion rate of the Cu-Ni alloy [11]. According to EDX results of electrodeposited copper-nickel alloy in the atomic percentage are exhibit to the homogeneous mixture and the relative counts are related to the XRD pattern. This phenomenon probably correlated with the FWHM in our xrd analysis. The highest average FWHM is in the Cu-Ni alloy thin film that shows a compact small grain around the big grain. So, that the composition of the alloy deposited at high potential -0.9V is almost similar to the concentration of the metal ions in the electrolyte.

3.2. Surface morphology and film composition

The microscipic analysis of electrodeposited Cu-Ni alloy on stainless steel is was analyzed by Scaning Electron Microscope is shown in Figure 2. It seems that the Cu-Ni alloys has to show aggrigation of uneven with large grains and the compact surface microcracks was clearly indexed on the stainless steel substrate.

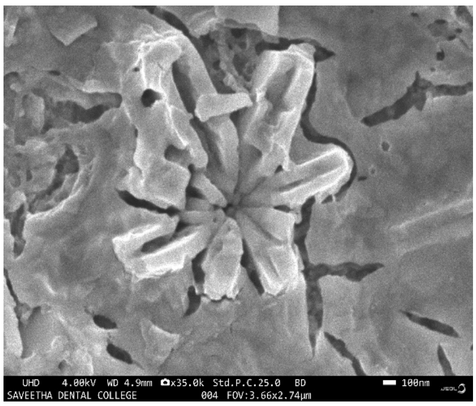

Figure 2. SEM image of electrdeposited Cu-Ni alloy

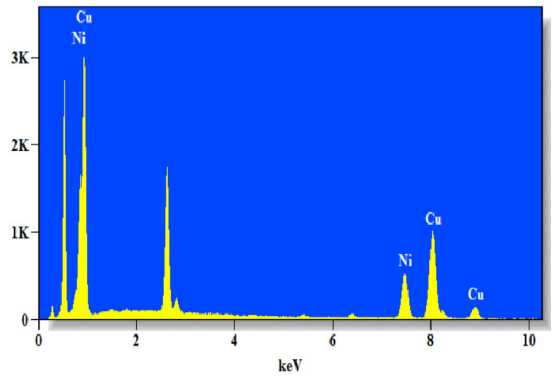

Figure 3. EDX analysis of electrodeposited Cu-Ni alloy

3.3. Magnetic properties

The Magnetic hysteresis (B-H) loop electrodeposited Cu-Ni thin films deposited on SS substrate is shown in Figure 4.

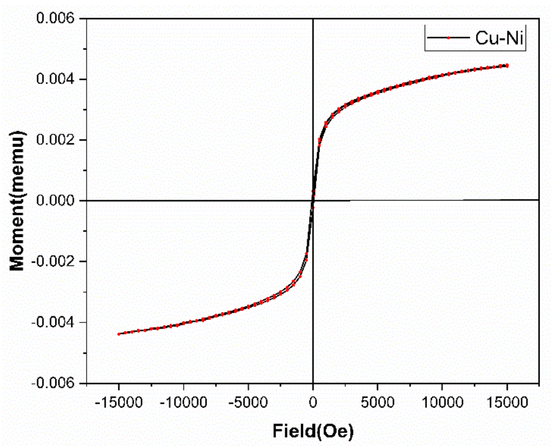

Figure 4. B-H loop of Cu-Ni alloy thin films on stainless

Table 1 The estimated value of structural parameters for electrodeposited Cu-Ni alloy thin films on steel substrate

2 θ (degree)	**β**	**d spacing (Å)**	**Crystallite size (D) (nm)**	**Strain (ε) (x 10^{-3} line^{-2} m^{-4})**	**Dislocation density δ (10^{14}) lines metre^{-2}**	**Stacking fault Probabiity α (10^{-3})**
43.47	0.19	2.0801	46.99	0.0020	4.5288	0.2119
50.57	0.23	1.8034	39.88	0.0021	6.2876	0.4378
74.21	0.2	1.2768	52	0.0011	3.6982	0.0864
90.08	0.26	1.0886	45.15	0.0011	4.9034	0.0427
95.16	0.28	1.0434	43.92	0.0011	5.1841	0.1667

Among the magnetic properties the value of coercivity plays an essential role, since it is well known that the lower value of coercivity focuses the materials for soft magnetic properties [12]. The exhibition of magnetic properties of the deposited films depends upon the structure as well as stoichiometry.Cu-Ni alloy exhibits higher hardness, better adhesion, excellent magnetic properties, high wear and corrosion resistance as well as good stability at room temperature. The magnetic topographies such as saturation magnetization, anisotropy constant, squareness and coercivity depend upon the content of Cu and Ni present in the dceposited films. The value of coercivity and retentivity was found to be 67.11 Oe and 275.64 x 10^{-6}emu respectively.

4. CONCLUSION

The Cu-Ni thin film were successfully deposited on stainless steel substrates by electrodeposition technique. All of the deposited films had face-centered cubic structures that were oriented along the (1 1 1) plane, according to structural analysis. The microstructural parameters such as crystallite size, interplaner atomic distance, microstrain, dislocation density and stacking fault probability are investigated. Morphology showed that the deposited films found to exhibit compact microcracks surface. Compositional analysis revealed that the content of Cu and Ni with atomic percentage of 54.83, 45.17, respectively. The deposited films were found to exhibit soft magnetic properties. The maximum value of saturation magnetization was found to be 4.4216 x 10^{-3}. The value of coercivity was found to be in between 67.117Oe, whereas the value of retentivity and sensitivity was found to be in the range 275. 64 x 10^{-6} emu and -6.1000 emu.

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