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Effect of Current Density on Properties of Electrodeposited Nickel-Ferrous-Phosphorus Alloy Thin Films

Dr.V.Sujatha[1], Dr.T.Baskar[2], Dr.A.Shaji George[3] , A.S.Hovan George[4]

[1]Principal & Professor, Department of Electronics and Communication Engineering, Shree Sathyam College of Engineering and Technology, Sankari Taluk, Salem District, Tamil Nadu, India.
[2]Professor, Department of Physics, Shree Sathyam College of Engineering and Technology, Sankari Taluk, Salem District, Tamil Nadu, India.
[3]Director, Masters IT Solutions, Chennai, Tamil Nadu, India.
[4]Student, Tbilisi State Medical University, Tbilisi, Georgia.

Abstract - To create NiFeP nanostructured thin films, multiple current densities were maintained in electrodeposition. FCC structure is visible in the texture of NiFeP-deposited films. Experimentally observed thin film structural characteristics for various current densities were compared. The structural and mechanical qualities of nickal thin films will be enhanced by the addition of phosphorus (P). At different current densities of 2, 3, 4, and 5 mA/cm2, electrodeposited NiFeP films were created, and their morphological, structural, and mechanical characteristics were assessed. The nickel concentration peaked at 62.32 wt% at 5 mA/cm2. The nickel content increased as the current density increased. NiFeP films have a brilliant, uniform coating. NiFeP film deposition had average crystal sizes of 69 nm, which were likewise nanoscale.

Keywords: Electrolytic bath, SEM, Crystalline size, VHN, Ni-Co, X-ray diffraction, VHN.

1. INTRODUCTION

Using an electrochemical system, electrodeposition modifies the surface structure of a substance [1-4]. Because of its distinctive features, the Ni-P alloy is one of the materials that is most studied. Because of these characteristics, NiFeP films are frequently utilised as AMR sensors to detect weak magnetic fields in recording heads of magnetic data storage systems like hard discs [5-8]. By altering the deposition circumstances, the characteristics of iron-group metals, such as iron and electrodeposited binary alloys, have been improved [9–12]. There has been a lot of interest in the electrodeposition-based production of nanocrystalline nickel [13–15]. Their soft magnetic character is related to the nature of crystallites and the grain size of films.In the MEMS, NEMS, communication, optical, and sensor industries, the electrodeposition technique is frequently employed. The most prevalent magnetic thin film compounds in MEMS and NEMS are NiFeP, NiFePW, and NiW. Using NiFeP thin film electroplating, it is possible to strengthen corrosion resistance, obtain novel optical characteristics, and improve structural and mechanical qualities [16–19].

2. EXPERIMENTAL PART

Electroplated NiFeP alloy films were prepared using current densities of 2, 3, 4, and 5. It took 15 minutes to conduct the deposition. In this investigation, 1.5 cm x 7.5 cm copper and stainless steel substrates were utilised as the cathode and anode, respectively [5=7]. NiFeP thin films were created using phosphoric acid (15 g/l), nickel sulphate (30 g/l), ferrous sulphate (15 g/l), ammonium sulphate (40 g/l), boric acid (10 g/l), and saccharin (10 g/l). The electrolytic solution's pH was adjusted to 6.0 by adding ammonia solution, and the electroplating process was carried out at a temperature of 30 oC. The copper or cathode was gently withdrawn from the bath after 15 minutes, and it was allowed to dry for a short while [14–18]. The surface characteristics of NiFeP films were described using scanning electron microscopy. X-ray diffraction and energy-dispersive X-ray spectroscopy were employed to examine the crystal structure and atomic make-up of the film deposition, respectively. The micro hardness of the films was assessed using the Vickers Hardness Test.

3. RESULTS AND DISCUSSION

3.1 Composition of NiFeP Films

An energy-dispersive X-ray analyzer is used to determine the elemental composition of deposits (EDAX). Table 1 from the EDAX study shows the weight percentages of P and Ni at various current densities. The results show that films produced at high current densities include a lot of nickel. The greatest phosphorus content of 26.50 wt% was discovered at a current density of 2 mA/cm2. As the current density increases, the phosphorus content drops.

Table -1: EDAX analysis of thin films

S. No	Current density (mA/cm2)	Ni Wt%	Fe Wt%	P Wt%
1	2	42.37	31.13	26.50
2	3	48.08	27.96	23.96
3	4	55.68	24.06	20.26
4	5	62.32	19.84	17.84

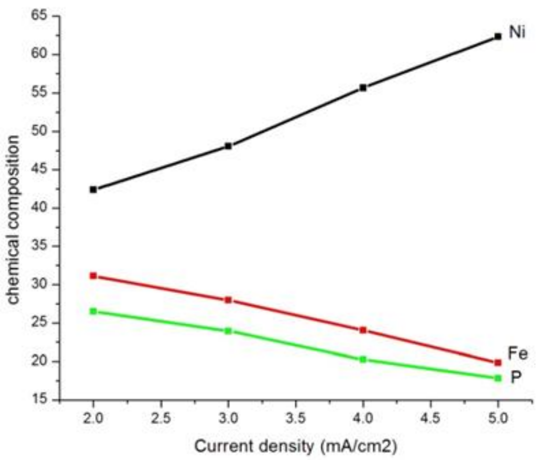
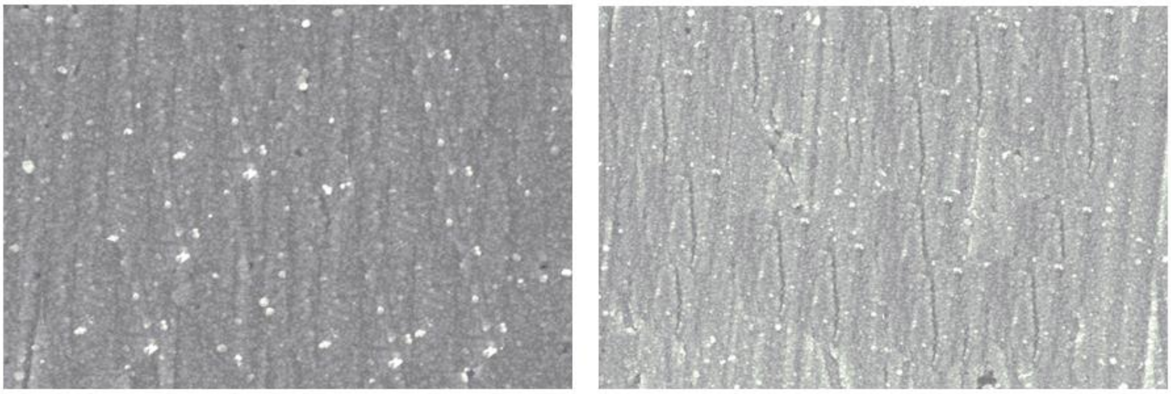


Fig -1: Variation of Weight percentage with different current density

3.2 Morphological Study of NiFeP Films

The surface structure of NiFeP thin films was examined using scanning electron microscopy (SEM) images at current densities of 2, 3, 4, and 5. The results are given in Fig 2. The thin films are brilliant and evenly covered as a result. They don't seem to have any cracks.



(a) (b)

Fig -2:NiFeP films –SEM images at (a) 2 (b) 3

3.3 Structural Analysis of NiFeP Films

Films made of NiFeP alloy were examined using powder X-ray diffraction (XRD). Fig. 2 displays the diffraction patterns of NiFeP films created at varying current densities. The X-ray diffraction pattern shows that the deposits are crystalline because it contains sharp peaks. The (111), (200), and (211) peaks can be seen in the XRD patterns of all samples deposited at current densities of 2, 3, 4, and 5. The XRD data also demonstrate the presence of an FCC form crystal. Hence, a reduction in crystal size occurs in thin film deposits as the current density is increased. Moreover, thin film deposition show nanoscale, with an average crystalline size of 69 nm.

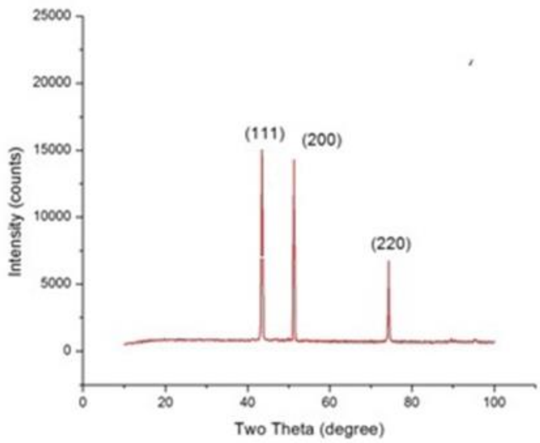


Fig -3:NiFeP films-XRD patterns

Table 2 displays the NiFeP alloy films' crystal dimensions. Due to the beginning of crystal orientation, the deposits' crystalline size decreases as the bath temperature rises. Figure 4 shows how crystal size reduces with increasing bath temperature.

Table -2: Structural characteristics of NiFeP alloy thin films

S.No	Current density (mA/cm2)	2θ (deg)	d (A0)	Particle Size(D) (nm)
1	2	43.80	1.7243	97.09
2	3	42.02	1.6022	75.58
3	4	45.61	1.7610	60.23
4	5	44.82	1.5301	41.67

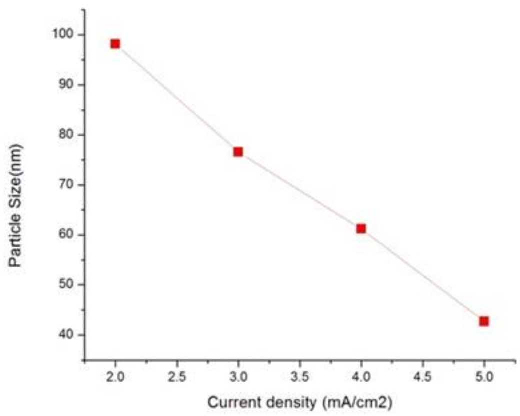


Fig -4:Variation of crystal size with different current density

3.4 Mechanical Properties of NiFeP Films

The microhardness of the deposits was assessed using a Vickers hardness tester. The hardness values of thin films produced at current densities of 2, 3, 4, and 5 mA/cm2 are 112, 134, 162, and 189 VHN, respectively. The micro hardness rises as a result of the thinner tension present in thin films. Micro hardness increases with current density. The hardness changes as current density increases, as shown in Figure 5.

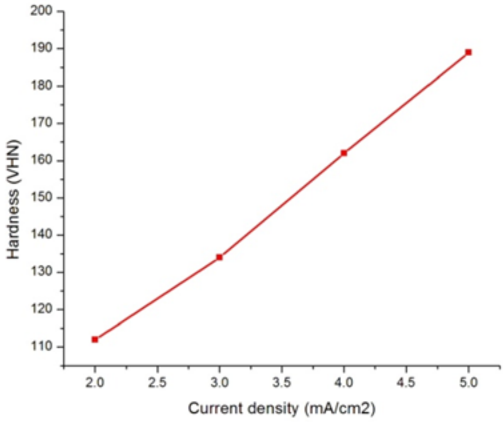


Fig -5:Variation of micro hardness with different current density

4. CONCLUSION

The NiFeP alloy thin films were created by electrodeposition while keeping the solution temperatures at 30 o C and the pH level at 6.0 constant. The thin films are brilliant and evenly covered as a result. The XRD data demonstrate the presence of an FCC form crystal. Due to online crystal orientation, as the current density increases, the deposits' crystalline size shrinks. The hardness grows as the current density does so because thin layers experience less stress. As current density increases from 2 to 5 mA/cm2, the particle size drops from 97.09 to 41.67 nm. This is owing to the presence of nanocrystalline deposits. The mechanical and structural qualities of nickel increase as it is electroplated with phosphorus (P), and the alloy films can be employed in NEMS, MEMS, and memory units.

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