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*Original Article*

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

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**ABSTRACT**

*Electrode position in different current density was used to prepare nanostructure thin films of NiP. Films deposited with NiP have a texture that shows FCC structure. The structural properties of thin films observed experimentally for different current density were compared. The addition of phosphorus (Co) to nickel thin films will improve their structural and mechanical properties. Electrodeposited NiP films were prepared at various current density of 2,3,4 and 5 mA/cm$^2$. Morphological, structural, and mechanical characterization were performed on them. At 5 mA/cm$^2$, the nickel concentration reached its peak of 79.16wt%. As the current density was raised, the nickel content rose. NiP films were bright and evenly coated. NiP film deposits were also nano scale, with an average crystalline size of about 54 nm.*

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## INTRODUCTION

Electrode position is a simple and flexible approach for precisely controlling the nucleation and growth process in order to obtain catalysts of various purity, form, and morphology. Furthermore, electrode position is a scalable device that is used in a variety of manufacturing areas, making it ideal for large-scale applications [1-4]. Electrode position is a process of altering the surface structure of a substance using an electrochemical system [4-6]. The Ni–P alloy is one of the most researched materials because of its unique properties. I–P films as AMR sensors are widely used to detect weak magnetic fields in recording heads of magnetic data storage devices such as hard disks because of these properties [7-11]. The properties of iron-group metals such as iron and electro-deposited binary alloys have been improved by changing the deposition conditions [12-15]. The electrode position-based synthesis of nano crystalline nickel has gained a lot of attention [16-17]. The nature of crystallites and grain size of films are related to their soft magnetic nature. To boost traditional diamond tools, the grain size, hardness, and tensile strength of pulse electroformed nano crystalline NiP are used [17-19]. The electrodeposition method is widely used in the MEMS, NEMS, communication, optical, and sensor industries. NiP, NiPW, and NiW are the most commonly found magnetic thin film compounds in MEMS and NEMS. NiP thin film electroplating is used to achieve improved structural and mechanical properties, unique optical properties, and increased corrosion resistance [20-23].

## METHODS

Current density of 2,3,4 and 5 mA/cm$^2$ were used to prepare electroplated NiP alloy films. The deposition process took 15 minutes to complete. Copper and stainless steel substrates with dimensions of 1.5 cm x 7.5 cm were used as cathode and anode in this study [21-23]. Phosphorus acid (15 g/l), Nickel sulphate (30 g/l), Ammonium sulphate (40 g/l), Boric acid (10 g/l), and Saccharin (10 g/l) were used to make NiP thin films [23-25]. By adding ammonia solution, the pH of the electrolytic solution was set to 6.0, and the electroplating procedure was carried out with a temperature of 30 ºC. After 15 minutes, the copper or cathode was gently removed from the bath and dried for a few minutes [24-25].

Scanning Electron Microscope was used to describe the surface nature of NiP films. Energy-dispersive X-ray spectroscopy was used to look at the atomic composition of film deposits, and X-ray diffraction was used to look at the crystal structure of the deposits. Vickers Hardness Test was used to determine the micro hardness of the films.

## RESULTS AND DISCUSSION

### *Composition of Nip Films*

The elemental composition of deposits is determined using an energy-dispersive X-ray analyzer (EDAX). EDAX study reveals the weight percentage of P and Ni at various current density in Table 1. According to the findings, films prepared at high current density have a high nickel content. At a current density of 2mA/cm$^2$, the maximum phosphorus content of 42.73wt% was found. The content of phosphorus decreases as the current density rises.

*Table 1: EDAX analysis of thin films*

| S. No | Current density (mA/cm$^2$) | Ni Wt% | P Wt% |
|---|---|---|---|
| 1. | 2 | 57.37 | 42.63 |
| 2 | 3 | 66.04 | 33.96 |
| 3 | 4 | 73.74 | 26.26 |
| 4 | 5 | 79.16 | 20.84 |

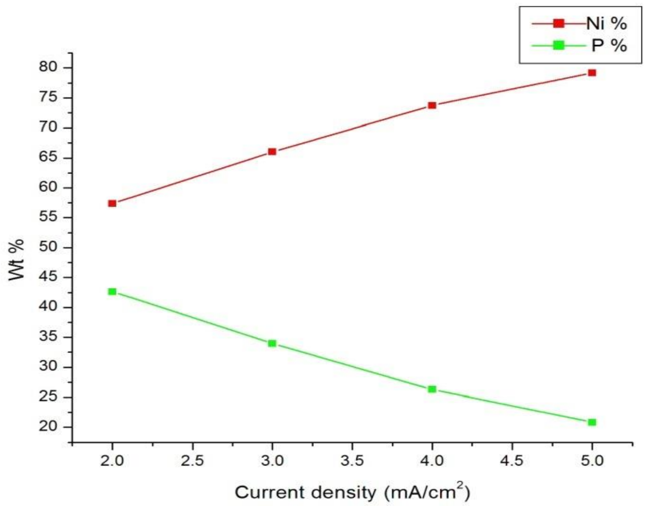


***Figure 1. Variation of weight percentage with different current density***

### ***Morphological Study of Nip Films***

Scanning Electron Microscope (SEM) images of the surface structure of NiP thin films at current density of 2,3,4 and 5 mA/cm2 were analyzed, and the results are shown in Fig 2. On the result, the thin films are bright and uniformly coated. They appear to be crack-free.

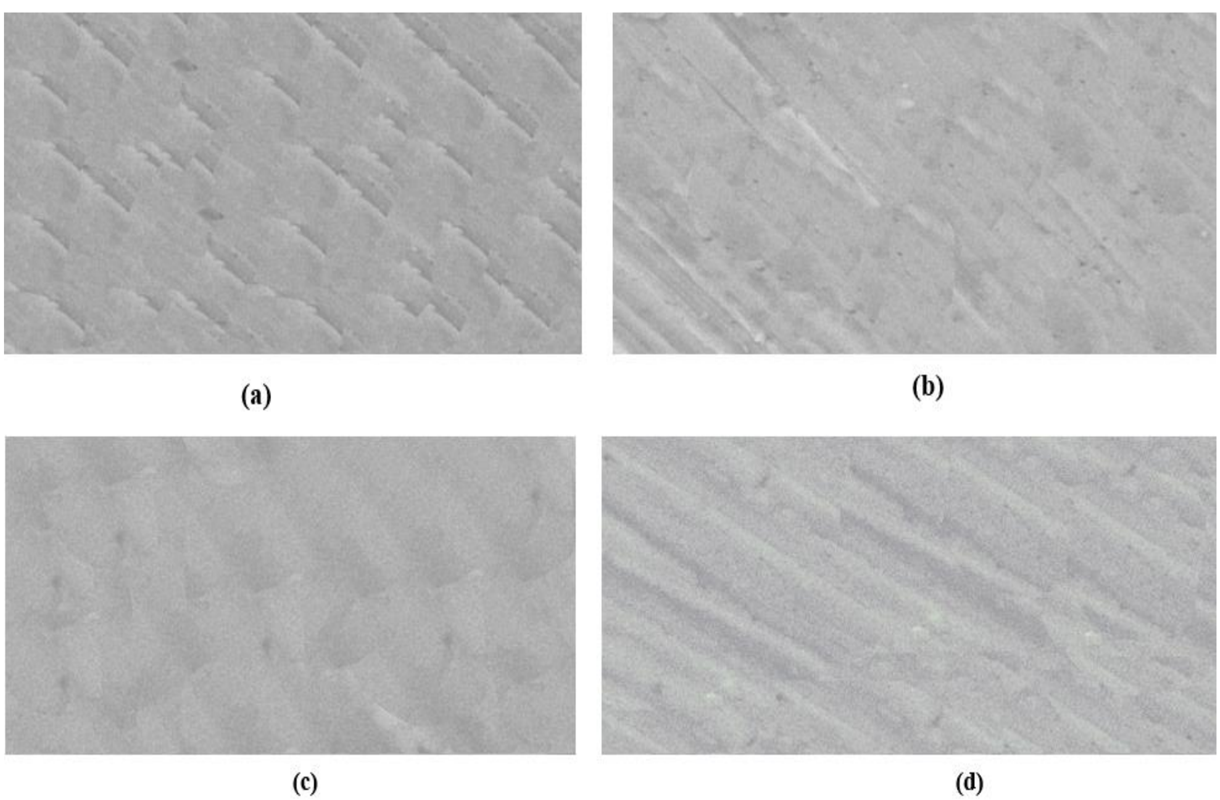


***Figure 2. NiP films –SEM images at (a) 2 (b) 3 (c) 4 (d) 5 mA/cm$^2$***

### *STRUCTURAL ANALYSISOF Nip FILMS*

Powder X-ray diffraction was used to examine the crystal structure of NiP alloy films (XRD). Diffraction patterns of NiP films prepared at various current density are shown in Fig 2. The presence of sharp peaks in the X-ray diffraction pattern indicates that the deposits are crystalline. The XRD patterns of all samples deposited at current density of 2,3,4 and 5 mA/cm$^2$ shows (111), (200), and (211) peaks. In addition, the XRD results show the presence of an FCC form crystal. NiP deposits have particle sizes of 68.43 nm, 56.21 nm, 50.93 nm and 38.67 nm for current density of 2,3,4 and 5 mA/cm$^2$respectively. As a result, increasing the current density reduces the crystal size of thin film deposits.  Also deposits of thin films reveals nano scale and average crystalline size is around 54 nm.

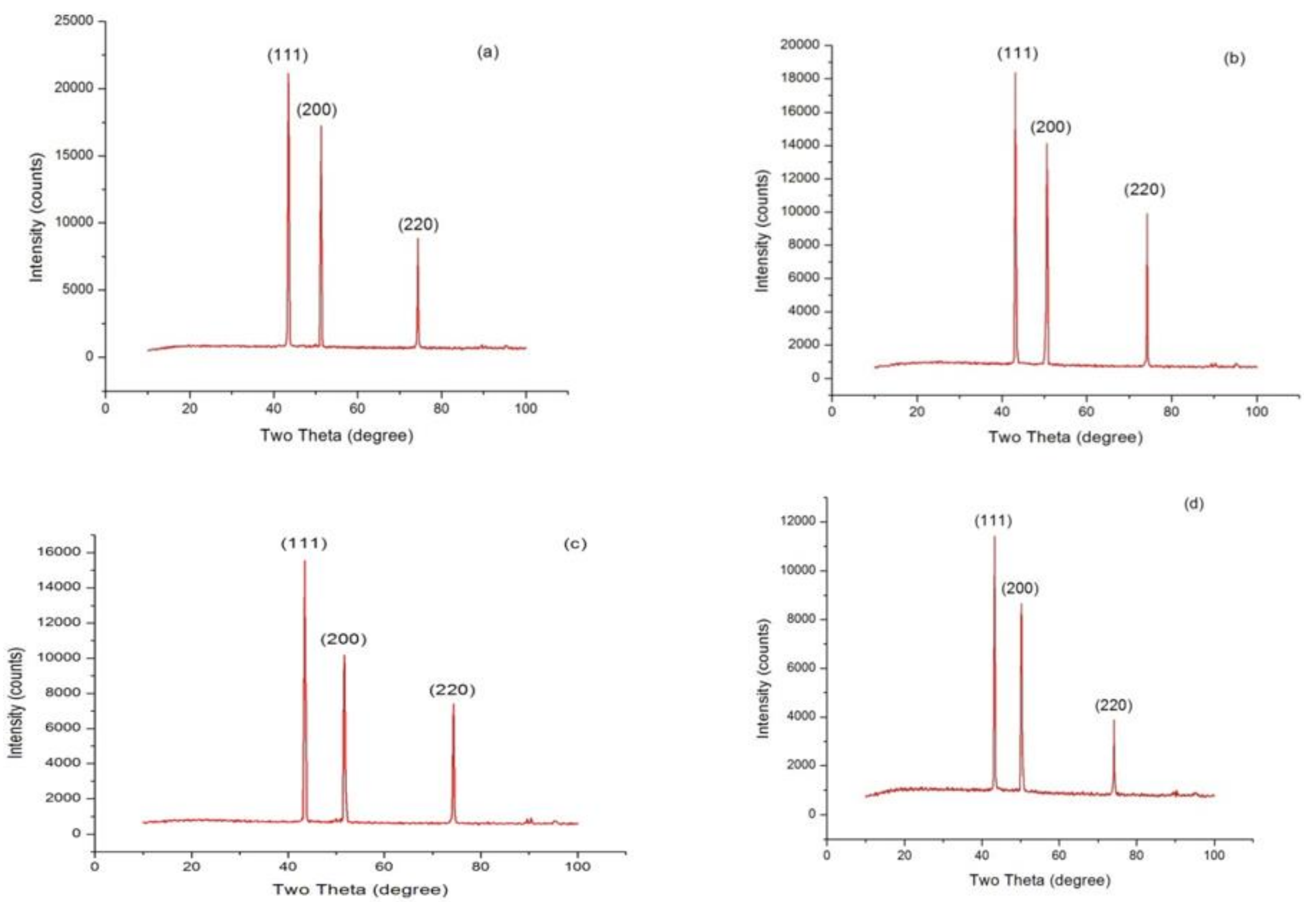


***Figure 3. NiP films-XRD patterns at (a) 2 (b) 3 (c) 4 (d) 5 mA/cm$^2$***

Table 2 shows the crystal dimension of NiP alloy films. If the bath temperature rises, the crystalline size of the deposits reduces owing to the start of crystal orientation. Figure 4 illustrates how crystal size decreases as bath temperature rises.

***Table.2: Structural characteristics of NiPalloy thin films***

| S.No | Current density (mA/cm$^2$) | 2θ (deg) | d (A$^0$) | Particle Size(D) (nm) |
|---|---|---|---|---|
| **1** | 2 | 45.88 | 1.5243 | 68.43 |
| **2** | 3 | 46.05 | 1.7452 | 56.21 |
| **3** | 4 | 44.63 | 1.6354 | 50.93 |
| **4** | 5 | 47.01 | 1.7104 | 38.67 |

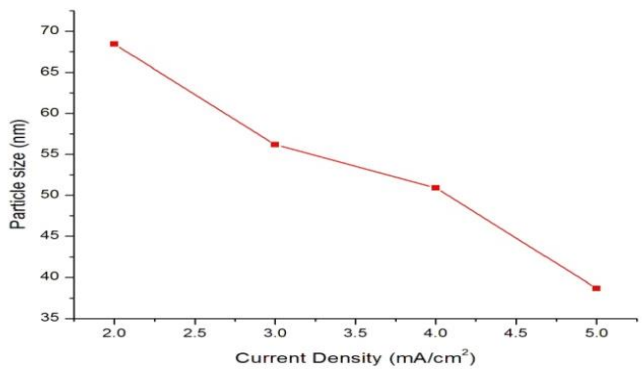


***Figure 4. Variation of crystal size with different current density***

### *Mechanical Properties of Nip Films*

Vickers hardness tester was used to measure the micro hardness of the deposits. Thin films prepared at current density of 2, 3, 4, and 5mA/cm$^2$have hardness values of 93,112, 143 and 175 VHN, respectively. As a result of the lower tension associated with thin films, the micro hardness increases. As the current density rises, micro hardness increases. Figure 5 illustrates how hardness changes as current density rises.

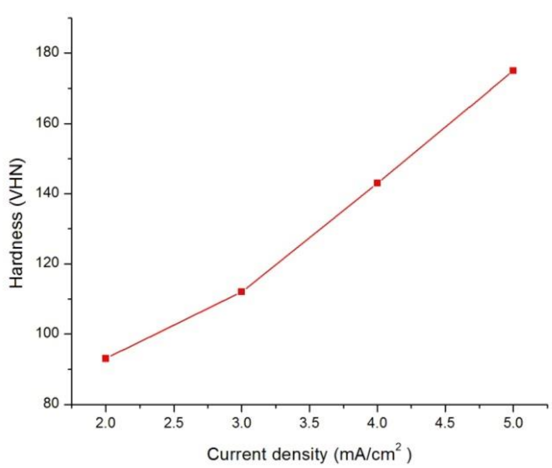


***Figure 5. Variation of micro hardness with different current density***

## CONCLUSION

The NiP alloy thin films were prepared by electrodeposition at varying current density while maintaining a temperature of 30 º C and a pH of 6.0 in the solutions. On the result, the thin films are bright and uniformly coated. The XRD results show that an FCC form crystal exists. If the current density rises, the crystalline size of the deposits decreases due to online crystal orientation. Due to the lower stress associated with thin films, the hardness increases as the current density rises. The particle size decreases from 68.43 nm to 38.67 nm as current density rises from 2 to 5mA/cm$^2$.This is due to the deposits of nano crystalline composition. As nickel is electroplated with phosphorus (P), the mechanical and structural properties improve, and the alloy films can be used in NEMS, MEMS, and memory units.

***Disclosure***. *No competing of interest declared*

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