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Effect of Different Concentration of Boron on Properties of Electroplated Nickel-ferrous-boron Alloy Thin Films

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Abstract - Electroplating was used to create magnetic alloy thin films of NiFeB at varied boron concentrations. NiFeB deposited films have an orientation that favours the FCC phase. Thin films with soft magnetic properties that were experimentally observed for various boron concentrations were compared. Boron (B) can improve the mechanical and structural qualities of nickel thin films. At various boron concentrations (10, 20, 30 and 40 g/l), electrodeposited NiFeB films were created and then subjected to morphological, structural, and mechanical characterisation study. At 40 g/l boron concentration, the minimum nickel level was 47.64 weight percent. Bright and evenly coated NiFeB films were present on the surface. Moreover, the NiFeB film deposition were nanoscale, with an average crystalline size of about 55 nm. High boron concentration-prepared thin films showed high levels of hardness. NiFeB had a microhardness of 153 VHN at a boron concentration of 40 g/l.

Keywords: VHN, SEM, VSM, Ni-B, Electroplating, electrolytic bath, crystalline size, X-ray diffraction.

1. INTRODUCTION

The adaptability and performance of existing MEMS would be enhanced by the effective application of sensing, storage, and transduction capabilities made possible by nickel ferrous boron alloy sheets [1-4]. Many physical and chemical techniques, including thermal breakdown, co-precipitation, spray pyrolysis, and electro deposition, can be used to create NiFeB alloy thin films. The electrochemical process of electro deposition is an established technique used to change the surface structure. Transformers, inductors, magnetic amplifiers, magnetic shields, and memory storage devices all use NiFeB alloy thin films because they have the best soft magnetic characteristics [5–9]. When producing copper nickel alloys, NiFeB is occasionally used as a deoxidizer [10–14]. NiFeB films have a low resistivity compared to other materials, which causes eddy current loss when utilised in practical microwave applications. The nature of the films' crystallites and their grain size are related to their soft magnetic properties[15–18]. Low particle size, high hardness, readily attained and controllable anisotropy with tiny field, high resistivity, and good thermal stability in a tolerable temperature range are all desirable characteristics of the films[19–21]. As a result, electroplating NiFe alloy has been the focus of several efforts to integrate magnet arrays into MEMS devices. NiFeB thin film is electroplated to produce increased structural and hardness characteristics .

2. EXPERIMENTAL PART

The NiFeB alloy electroplated films were created for boron concentrations of 10, 20, 30, and 40 g/l. The deposition process took 15 minutes to complete. In this study, 1.5 cm x 7.5 cm copper and stainless steel substrates served as the cathode and anode, respectively [13–15]. The electrolytic solution containing nickel sulphate (30 g/l), ferrous sulphate (10 g/l), boron (10,20,30, and 40 g/l), ammonium sulphate (40 g/l), boric acid (10 g/l), and citric acid (10 g/l) was used to generate the NiFeB thin films [16–20]. By combining ammonia solution with the electrolytic solution, the pH value was fixed at 6.0, and the electroplating process was conducted at a current density of 2 mA/cm2. After 15 minutes, the copper or cathode was taken out of the bath with great care and left to dry out for a brief period. [4–7]. Using a scanning electron microscope, the surface characteristics of NiFeB films were identified. Energy-dispersive X-ray spectroscopy was used to evaluate the crystal structure of the deposits and their elemental composition in films [8–12]. The Vickers Hardness Test was conducted to measure the microhardness of films.

3. RESULTS AND DISCUSSION

3.1 Composition of NiFeB Films

EDAX spectrum analysis was used to determine the chemical composition of the electroplated thin sheets. Table 1 displays the EDAX data for thin films. According to the EDAX results, nickel content is less prevalent in thin films made at higher boron concentrations. The concentration of boron that yields the maximum nickel level, 59.31 weight percent, is 10 g/l. According to the EDAX data, nickel content reduces as boron concentration rises.

Table -1: EDAX analysis of thin films

S. No	Boron Concentration(g/l)	Nickel Wt%	Ferrous	Boron Wt%
1	10	59.31	23.92	16.77
2	20	55.65	25.03	19.32
3	30	48.63	26.72	24.65
4	40	47.64	23.30	29.06

3.2 Morphological study of NiFeB Films

Scanning Electron Microscope [SEM] pictures were used to analyse the surface structure of NiFeB thin films with boron concentrations of 10, 20, 30, and 40 g/l. These images are presented in Fig. 1. Bright and evenly covered on the surface, the thin films are. They appear to be crack-free.

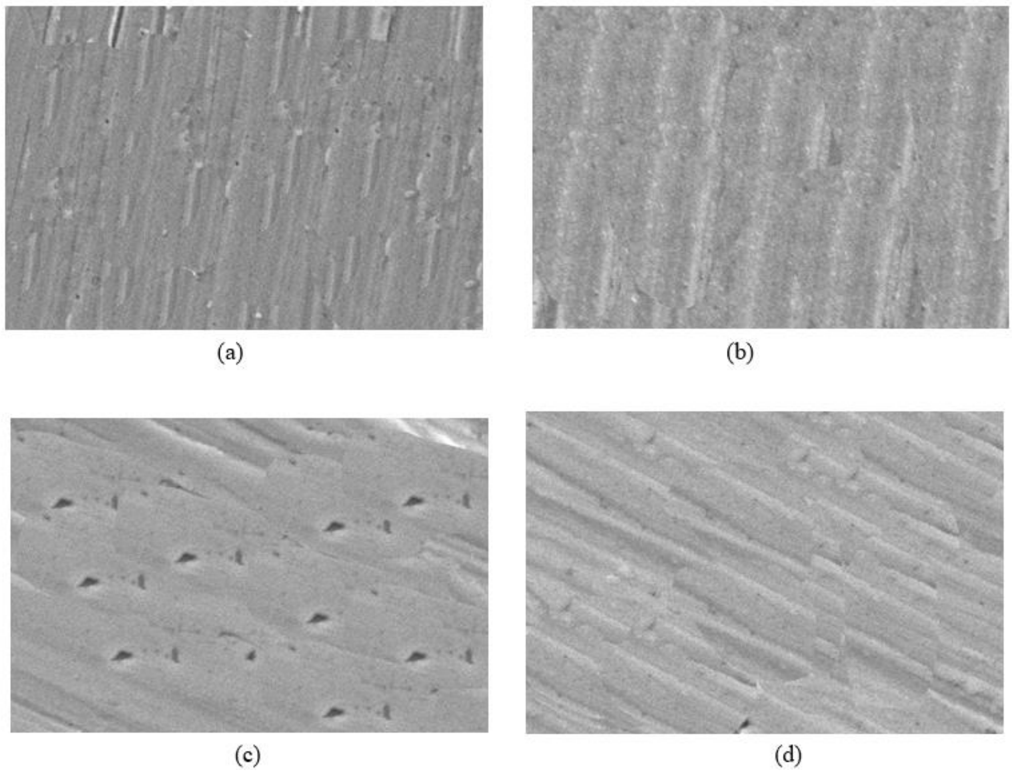

Fig -1: NiFeB films –SEM images with different concentration of Boron (a) 10 (b) 20 (c) 30 (d) 40 g/l

3.3 Structural Analysis of NiFeB Films

By using powder X-ray diffraction, the crystal structure of NiFeB alloy films was investigated (XRD). The diffraction patterns of NiFeB films made with various boron concentrations are shown in Fig. 2. Sharp peaks that appear in the X-ray diffraction pattern show that the deposits are crystalline. All samples that were deposited with varying amounts of boron have XRD patterns that are indicative of the (111), (200), and (220). Moreover, the XRD results show that FCC type crystals exist. For boron concentrations of 10, 20, 30, and 40g/l, respectively, the particle diameters of NiFeB deposits are 85.37 nm, 60.04 nm, 43.15 nm, and 31.25 nm. Hence, it can be said that a thin film deposit's crystal size reduces as concentration increases.

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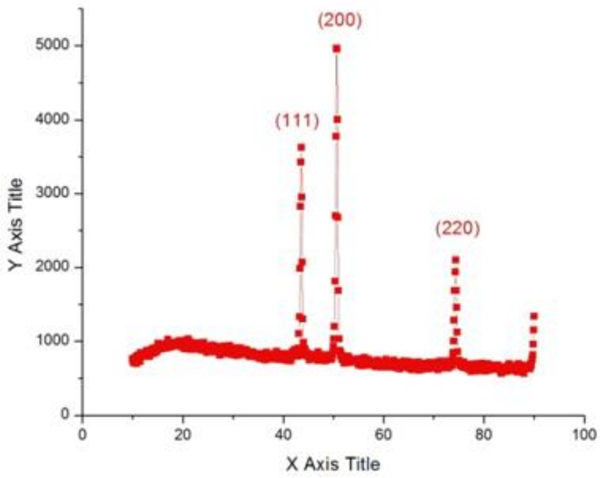

Fig -2: NiFeB films- XRD patterns with different concentration of Boron

Table 2 displays the NiFeB alloy films' crystal sizes. Due to crystal beginning orientation and rising boron content, deposits' crystalline size reduces. Figure 3 demonstrates that as boron increases, crystal size decreases.

Table -2: Structural characteristics of NiFeB alloy thin films

S.No	**Boron Concentration(g/l)**	**2θ (deg)**	**d (A⁰)**	**Particle Size(D) (nm)**
1	10	45.65	1.9001	85.37
2	20	49.04	1.8230	60.04
3	30	47.37	1.8503	43.15
4	40	44.04	1.6582	31.25

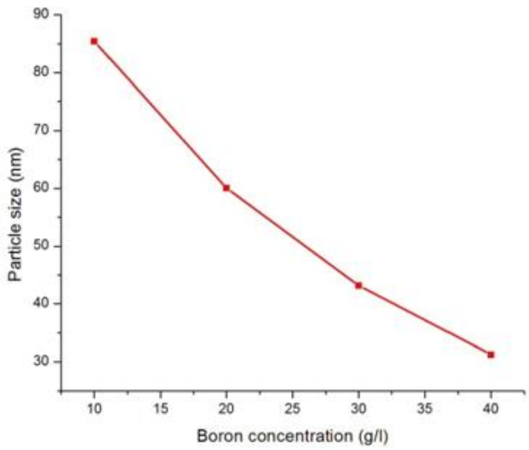

Fig -3: Variation of crystal size with different concentration of boron

3.4 Mechanical Properties of NiFeB Films

Vickers hardness tester was used to measure the micro hardness of the deposits. Thin films made for boron concentrations of 10, 20, 30, and 40 g/l have corresponding hardness values of 82, 104, 112, and 153 VHN. Thus, hardness testing demonstrates that increasing boron content results in a rise in micro hardness because thin coatings are linked with less stress. The fluctuation in hardness with increasing boron content is shown in Fig. 4.

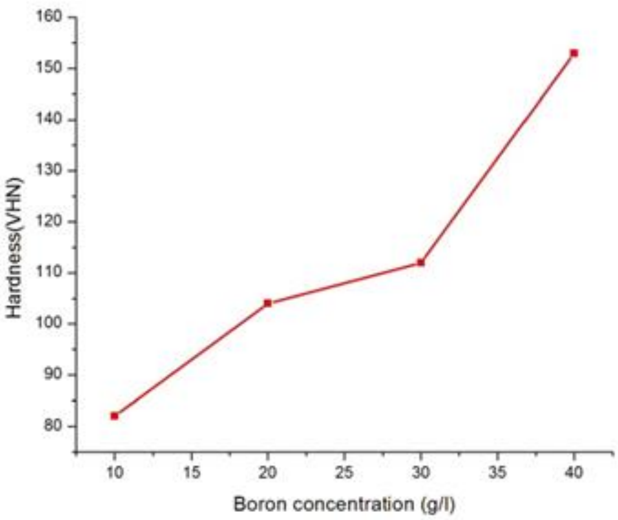

Fig -4: Variation of micro hardness with different concentration of boron

4. CONCLUSION

The NiFeB alloy thin films were made by electro deposition while maintaining a current density of 3 mA/cm2 and a pH of 6.0 in the solution. Bright and evenly covered on the surface, the thin films are. The XRD results demonstrate the presence of crystals of the FCC type. Due to the crystal's onset orientation and rising boron concentration, deposits' crystalline size decreases. Because thin films are subject to less stress, hardness rises as boron (B) concentration does. The crystal size reduces from 85.37 nm to 31.25 nm when boron content is varied by 10, 20, 30, and 40 g/l. This is a result of deposits' nanocrystalline structure. Nickel's mechanical and structural qualities can be improved by adding boron (B) when electroplating, and films made from this alloy can be used in MEMS and memory technology.

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