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ORIGINAL PAPER

A Comparative Study on Microstructures, Magnetic Features and Morphologies of Ternary Fe–Co–Ni Alloy Thin Films Electrochemically Fabricated at Different Deposition Potentials

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Abstract

Electrochemically fabricated ternary Fe–Co–Ni alloy thin films with different chemical compositions were obtained at different deposition potentials. An increase in the deposition potential increased the Ni content while it decreased the Co and Fe contents in the film structure. An anomalous co-deposition behaviour was also studied and the anomalous order of co-deposition was found to be Fe–Ni > Co–Ni > Fe–Co irrespective of deposition potential. Structural characterizations confirmed the presence of single face-centred cubic (fcc) phase structure with [111] preferred crystallographic orientation for all films. The size of the crystallites and the texture degree increased with increasing applied deposition potential. Smaller globular particles occurred on the surface structure of the film fabricated at higher deposition potentials compared to those grown at lower deposition potentials. A decrement detected in the coercive field with increasing applied deposition potential was related to the variations occurred in the chemical composition and the particle size.

Keywords Ternary Fe–Co–Ni thin films · Morphologies · Magnetic features · Texture degree · Anomalous co-deposition · Applied deposition potential

1 Introduction

Ternary alloy thin films composed of Fe, Co and Ni ferromagnetic metals with low coercive field, high permeability, and high saturation magnetization values have an application potential in many areas such as computer read/write heads and microelectromechanical systems (MEMS) [1–8]. Apart from these areas, they also possess a widespread marketing potential in different areas such as transformers, high-frequency inductors and micromagnetic sensors because of their good microwave, corrosion and thermal stability features [2, 4, 9].

In order to produce the magnetic alloy thin films with desired magnetic, microstructural and morphological features for technological and industrial applications, different fabrication techniques have been developed. As one of the most preferred techniques, electrochemical deposition and/or electrodeposition technique provides the simplicity, cost efficiency, versatility and relatively fast deposition rates to fabricate magnetic thin films with relatively high saturation magnetization and low coercive field values at ambient temperature and pressure [3, 5–7, 10]. It was reported that the ternary Co–Ni–Fe alloy thin films electrochemically fabricated from electrolyte solutions without sulphur-containing organic additives such as saccharin and thiourea exhibited relatively high saturation magnetization (2–2.1 T) and low coercive field (less than 160 A/m) [11, 12]. It is well known that the additives influence the structural, morphological and magnetic properties of electrochemically grown alloy thin films [1, 2, 5, 13]. Apart from the influence of additives, the properties of alloy thin films fabricated by electrochemical deposition technique are strongly affected by the electrolyte solution properties (relative concentrations of metals, pH, temperature, bath type); film thickness; substrate type

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increment in the size of crystallites and strength of the $< 111 >$ out of plane texture. A decrement in the lattice constant was revealed due to change of film composition. The size of the larger globular particles formed on the film surfaces decreased considerably with increasing deposition potential. The larger globular particles consisted of smaller rounded shaped particles with sizes ranging from 40 to 100 nm. The average and the RMS surface roughness values were found to be in the range between 11.7 and 16.8 nm and 15 and 21.7 nm, respectively, and the film electrochemically deposited at the highest deposition potential had slightly lower surface roughness values. A decrease in the coercive field from 84 to 38 Oe was also detected when the deposition potential was increased from -1.2 to -1.6 V vs. SCE, which was ascribed to an increase in the Ni content (a decrease in the Co content) and/or a decrease in the particle size. Consequently, ternary Fe–Co–Ni alloy thin films electrochemically fabricated at higher deposition potentials exhibited stronger $< 111 >$ out of plane texture, higher Ni content, lower Co and Fe contents with less anomalous co-deposition behaviour, smaller particle size, lower surface roughness and softer magnetic feature than those of fabricated at lower deposition potentials.

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