MAGNETIC PROPERTIES OF Co-Ni-Mg-N CYLINDRICAL FILMS PREPARED BY MAGNETIC ELECTROPLATING

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The magnetic field induced changes in the microstructure and magnetic properties of thin cylindrical Co-Ni-Mg-N films were studied in this work. The long-term objective of the study is to develop a low-cost method for tailoring the magnetic properties of thin magnetic cylindrical films with controlled magnetic properties, in a view to apply them in fabrication of magnetic sensors.

Thin electrolytic cylindrical Co-Ni-Mg-N films (1500 nm) were plated on Cu wire substrates using a procedure presented in our previous works [1-3]. The composition of the bath was $CoSO_4.7H_2O$, $NiSO_4.7H_2O$, $NiCl_2.6H_2O$, $MgSO_4.7H_2O$, NaCl, $Na_2SO_4.10H_2O$, H_3BO_3, $NaNO_3$, sodium laurylsulphate $C_{12}H_{25}NaO_4S$ and sodium saccharin $NaC_7H_4O_3NS.2H_2O$. The work electrolysis parameters (temperature, pH, and current density) were maintained constant for all experiments.

A cylindrical nickel anode was mounted in a specially designed stage that could fit into the cylindrical barrels of glass, containing the solutions. The cathode was a cylindrical Cu wire (0.25 mm diameter and 120 mm length) mounted on the anode axis.

Three sets of samples were prepared in this study, as follows. The samples labeled (a) were electrodeposited without an external imposed magnetic field. The magnetic field (1.3 kA/m) was applied in two configurations: parallel to the wire axis for samples labeled (b) and circular (c). The parallel field was obtained by insertion of the electrolytic cell in a current-carrying solenoid. A circular magnetic field due to a direct current carrying Cu cathode wire was used in the case of samples labeled (c). The composition of the films was investigated by EDAX analyses. The crystal structure of the films was determined by X-ray diffraction. Morphology of the samples was investigated by scanning electron microscopy (SEM).

It was found that the surface morphology of the films (shape and size of the crystallites) is changed by the action of magnetic field. The XRD analysis indicated that magnetic field influences also the structure of the cylindrical films prepared by magnetic electroplating. Our samples are polycrystalline, constituted from a Ni-Co solid solution with a structure, as follows: h.c.p. Co-Ni for the case (a), f.c.c. Co-Ni in the case of (b) samples and they consist in a mixture of the two phases f.c.c. and h.c.p for (c) films.

Magnetic measurements were performed by an induction method, in a longitudinal magnetic field parallel to the wire axis, at room temperature, using a digital scope HM 305 interfaced to computer. The curves representing the derivative of magnetization with respect to time (dM/dt) versus time are recorded with sinusoidal-field excitations (at a frequency of 50 *Hz).*

As an example, dM/dt vs. t curves are shown in figure 1 for three typical samples (in the cases a, b, and c) for a measuring magnetic field of 57,312 kA/m. The notation of the signals in figure 1 is: C1 - (dM/dt) versus t curves, C2 - H versus t curves, C3 - integrated curves of C1 (a branch of the hysteresis cycle).

The peak in dM/dt vs. t curves will appear at a field H_m that corresponds to the pinning strength by which the domain walls (whose movements contribute in the peak) are anchored to the local microstructural pinning centres. The differences in the shape and value of dM/dt for different films reflect the magnetic susceptibility changes as a result of magnetic field applied in electroplating. The peak in dM/dt vs. t curves appears at a field H_m having the following values for samples in figure 1: 11.9kA/m (a), 27.1 kA/m (b) and 19.5 kA/m (c). The samples (b) deposited in a magnetic field parallel to the wire axis are the hardest magnetically from this series of samples.

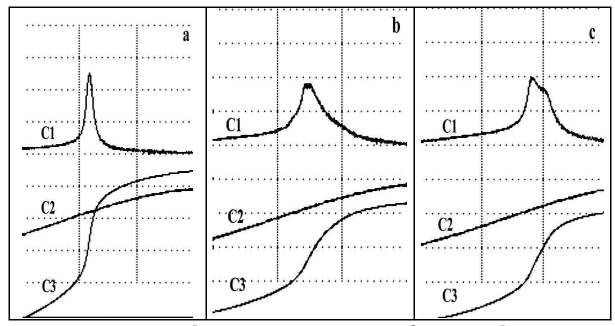

Fig. 1. Magnetic characteristic curves for samples electrodeposited a) without magnetic field, b) in H parallel to the wire axis and c) in circular magnetic field. C1 - (dM/dt) versus t curves, C2 - H versus t curves, C3 - integral of C1. Scalation: C1, C2 = 0.5V/div, C3 = 0.2V/div (a), 0.5V/div (b, c), t = 2.00ms/div.

The small changes in the shape of (dM/dt) vs. H loops reflect the changes in magnetization processes and in the switching properties of films produced in the presence of a magnetic field during the electrodeposition. The coupled action of a magnetic field and of an electric field on the electrodeposition of a metal is a very complex one. This coupled action influences the growth of the cathodic film by electrodeposition. Application of a magnetic field results in changes of mass transport of the ionic species in the electrolyte and therefore, the thickness and concentration of the diffusion layers are modified. The concentration gradient at the interface cathode-solution is the main deposition parameter controlling the morphology of the deposit.

The relationships between nucleation rate, microstructure, preferred orientation, internal stress, magnetic anisotropy and magnetic properties of Co-Ni-Mg-N cylindrical films are very complex one, and the results of these experiments could be important to control magnetic properties of thin magnetic films in a view to apply them in fabrication of magnetic sensors.

The essential result in this research is a direct experimental demonstration of the combined effect of imposed magnetic and electric fields on magnetic properties and structure of Co-Ni-Mg-N alloy films. The magnetic characteristics, the crystallographic structure and the morphology of electrodeposited Co-Ni-Mg-N cylindrical films were found to depend on the direction of the applied magnetic field (in the same working conditions).

REFERENCES

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