SOFT, HIGH MOMENT FECONI ALLOYS ELECTRODEPOSITED IN MAGNETIC FIELDS

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Electrodeposited FeCoNi alloy films have been extensively studied in the last few years as they provide large saturation magnetization Ms (up to 2.1 T) while maintaining low coercivities (< 1 Oe). These properties are of importance in the production of advanced recording heads for magnetic recording systems, and are also essential for the development of miniaturized thin films inductors and transformers for high frequency applications.

In these applications the films must provide a reliable magnetic response at low fields, which is usually achieved by inducing a suitable domain structure through electrodeposition in a magnetic field. The actual domain structure is however determined not only by the field-induced anisotropy, but also by an interplay between the magnetocrystalline anisotropy of the alloy (which depends on the film crystal structure) and the stress-induced anisotropy.

We have identified alloy compositions and deposition conditions which yield at the same time soft magnetic properties, high moment, and well-defined uniaxial anisotropy (Fig. 1). Soft magnetic properties are obtained by inducing the growth of films with mixed BCC-FCC phase, which exhibit grain size in the 10 nm range [1]. Pure BCC or FCC films on the contrary show larger grains and higher coercivity.

Soft magnetic properties and uniaxial anisotropy (Fig. 2) are obtained in correspondence of a minimum in the stress-induced anisotropy $K_\sigma = 3/2 \times \lambda_s \times \sigma$ (Fig. 3), λ_s being the saturation magnetostriction and σ the internal stress. These films show also a ferromagnetic resonance frequency near to its theoretical limit $f_{res} = \gamma \times (4\pi M_s \times H_k)^{1/2}$, where H_k is the anisotropy field

Dispersion in the anisotropy must be minimized in order to optimize domain structure and magnetic response while maximizing frequency response, of particular importance in the function of high frequency inductors. This was accomplished by electrodepositing FeCoNi films on sputtered $Fe_{20}Ni_{80}$ (Permalloy) seed layers possessing themselves a uniaxial anisotropy. It was found that the angular dispersion of the anisotropy axis of FeCoNi films on FeNi seeds is lower than on Cu seeds, increasing with film thickness and eventually reaching the values of films grown on Cu seeds. This behavior is attributed in part to the different microstructure of the seeds, and in part to a possible exchange coupling between the growing film and the magnetic seed layer.

The magnetic moment of these alloys is higher than in bulk alloys with the corresponding composition. This unusual behavior was tentatively explained in terms of the growth of a supersaturated BCC solid solution by electrodeposition. The supersaturation could be controlled to a certain extent by pulse plating.

References

[1] X. Liu, G. Zangari, M. Shamsuzzoha, *J. electrochem. Soc.*, to be published (2002).

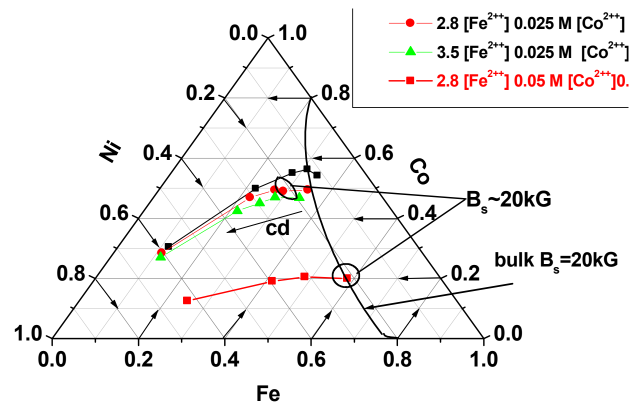

Fig 1. Ternary diagram indicating the variation of alloy composition with concentration of the metal ions in solution and applied current density. Alloy compositions with low coercivity, high magnetic moment and uniaxial anisotropy are indicated with circles.

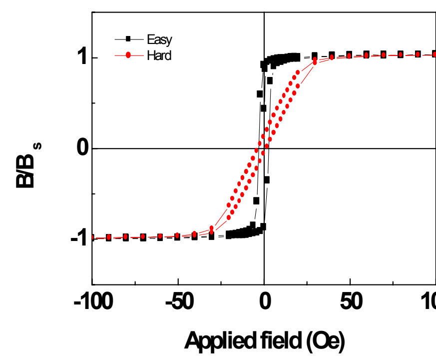

Fig. 2. In-plane hysteresis loops of soft, high moment $Fe_{30}Co_{20}Ni_{50}$ films.

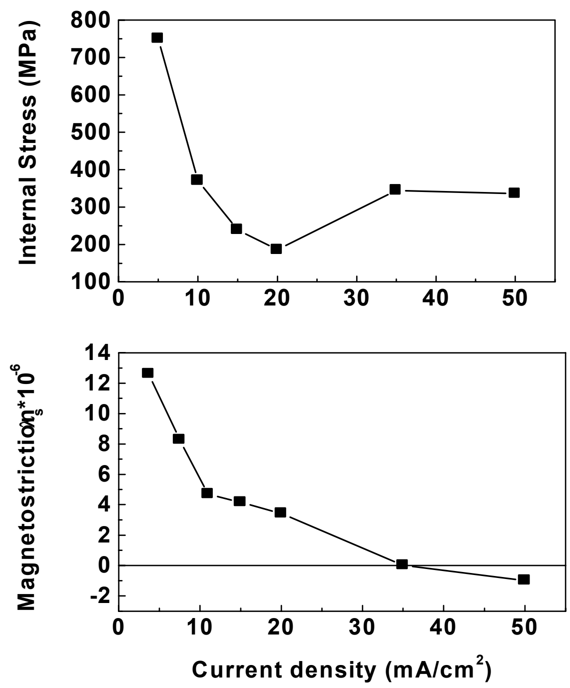

Fig. 3. Internal stresses and saturation magnetostriction λ_s for a series of FeCoNi films grown at increasing current density cd. Soft magnetic properties and uniaxial anisotropy are obtained around 15 mA/cm2, corresponding to a minimum in the product $\lambda_s \times s$, proportional to the stress-induced anisotropy.