Effect of Electrolyte Composition on Magnetic Properties and Structure of Electrodeposited Co-Fe-Ni Alloys

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Soft magnetic films with high saturation magnetization are essential components of write heads in high density magnetic recording systems and are becoming more and more important in the fabrication of miniaturized sensor and actuators. Electrodeposition is the technique of choice because the process of plating through mask allows easy and accurate definition and control of small features.

Most of the current work on electrodeposited Fe-Co-Ni alloys is conducted using electrolytes containing additives to decrease the internal stress. However, the presence of additives can influence the growth of the resulting film, and thus the magnetic properties. In order to better understand the intrinsic properties of the ternary alloy and thus determine the conditions at which best magnetic properties are obtained, we systematically studied the structure and magnetic properties of high purity FeCoNi fabricated from additive-free, sulfate-based electrolytes.

Electrodeposition was carried out from sulfate electrolytes ($[Fe^{2+}]$=0.02-0.05M, $[Co^{2+}]$=0.02-0.05M, $[Ni^{2+}]$=0.1-0.2M and $[H_3BO_3]$=0.4M) with varying pH value = 2.0, 2.8 and 3.5. Ni content in the alloy films increased with pH. XRD studies of the films obtained at pH 2.8 showed the presence of the two phases fcc and bcc. A transition from a bcc to a fcc structure with increasing current density was observed. Films with best soft magnetic properties were obtained when bcc and fcc phases coexist. $Co_{52}Fe_{26}Ni_{22}$ has a B_s=20 kG, H_c=1 Oe, ρ=22 μΩ•cm and saturation magnetostriction was 0.9×10^{-6}. Films obtained at other pH values did not show such a transition and exhibited only fcc structure and lower values of saturation magnetization. This can be explained by an increased incorporation of non-magnetic phases (metal hydrides or hydroxides) in the films.

Film composition is a function of current density cd. For films obtained at pH 2.8, a maximum in Fe content was obtained at an intermediate current density value. Ni content increased with increasing current density. Co content was affected by current density only to a limited extent. Fig. 1-3 show the dependence of alloy composition and structure on metal ion concentration and current density at pH 2.8. In each figure the concentration of two metals is held constant while that of the third metal is changed. It can be seen that increase in the concentration of one metal yields almost parallel lines on the ternary diagram.

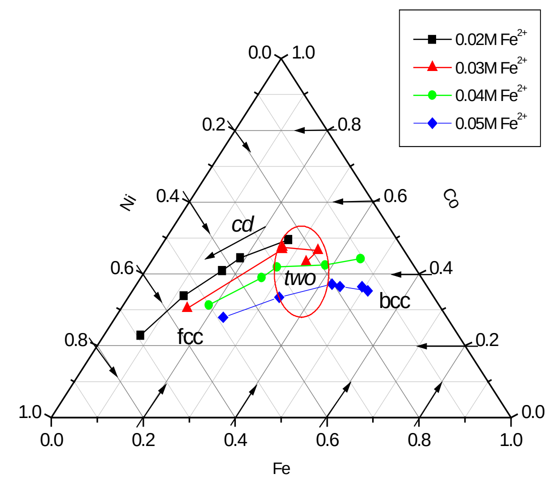

Fig.1 Composition and structure of films as function of $[Fe^{2+}]$, while $[Ni^{2+}]$=0.2M and $[Co^{2+}]$=0.05M (T=25°C, pH=2.8).

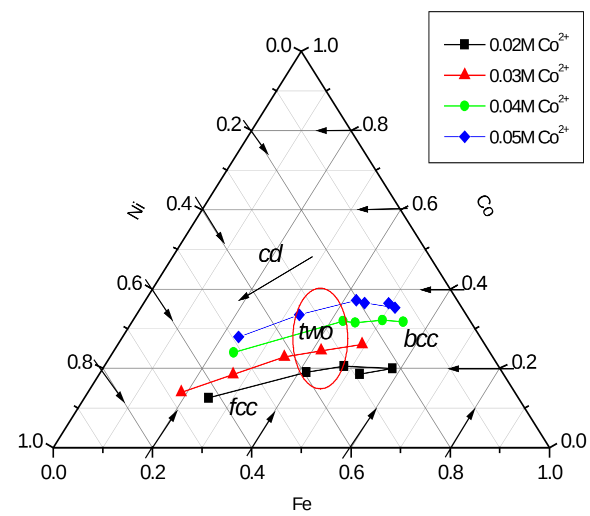

Fig.2 Composition and structure of films as function of $[Co^{2+}]$, while $[Ni^{2+}]$=0.2M and $[Fe^{2+}]$=0.05M (T=25°C, pH=2.8).

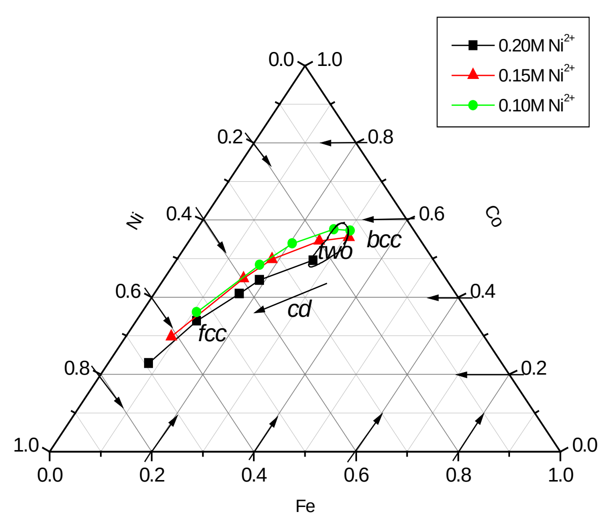

Fig.3 Composition and structure of films as function of $[Ni^{2+}]$, while $[Co^{2+}]$=0.05M and $[Fe^{2+}]$=0.02M (T=25°C, pH=2.8).