Composition Modulation in Ferromagnetic Layer in Ni-Co(Cu)/Cu Multilayer

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Introduction: Nanostructured multilayers consisting of alternate layers of ferromagnetic and nonmagnetic materials show a special magnetic property called giant magnetoresistance (GMR)[1]. GMR in electrodeposited Ni(Cu)/Cu[2], Co(Cu)/Cu[2,3] and Ni-Co(Cu)/Cu[1] has been reported. In a ternary system like Ni-Co(Cu)/Cu, the electrochemical parameters and compositions of the ferromagnetic layer may have an important role in controlling GMR. Therefore, we have deposited Ni-Co(Cu)/Cu multilayers from a single citrate bath in a flow electrochemical cell by a two-pulse plating method. The composition of the multilayers as well as of the ferromagnetic layer have been controlled by varying electrolyte composition, pH and deposition parameters.

Experimental: For electrodeposition of Ni-Co(Cu)/Cu multilayers, a citrate electrolyte of 0.025 M $CuSO_4.5H_2O$, 0.6 M $NiSO_4.6H_2O$, 0.2 M $CoSO_4.7H_2O$ and 0.265 M $Na_3C_6H_5O_7.2H_2O$, and of pH 6, was chosen as standard. Multilayers of various compositions were made by varying either Ni or Co concentration while keeping the concentration of other magnetic component fixed and by varying other deposition parameters such as high pulse potential, hydrodynamic condition and pH of the electrolyte. Deposition was carried out in a flow cell on a Ti-Au coated silicon disc. All multilayers consisted of 200 bi-layers, where Cu and Ni-Co(Cu) layers were 15 and 30 Å thick, respectively.

Results and Discussion: Figs. 1 & 2 show the overall compositions of multilayers produced by varying Ni and Co concentrations, respectively. Understandably, the amount of the individual component in the multilayer increases with the increase of its concentration in the solution. In both cases, the other two components, which are not varied, decrease. Anomalous co-deposition of Ni and Co is well known. The ratios of Ni and Co in the solution and in multilayer indicate anomalous deposition in the ternary system.

Fig. 3 shows the variation of compositions with high pulse potential. It has been found that both Ni and Co contents increase with the increase of high pulse potential. The Cu content decreases significantly. The decrease of Cu in the multilayer means the lowering of its impurity in the magnetic layer. This is simply because, at higher potentials, the deposition current is high, thereby necessitating a lower deposition time. Since Cu deposits on mass transfer control and is plated for a smaller time period, its content in the deposit is lower.

Fig. 4 shows the variation of composition with pH of the electrolyte. It is found that both Ni and Co contents in the multilayer increase with pH. This is because the current efficiency of Ni and Co are very low at lower pHs. The flow rate, however, has little effect on composition as shown in Fig. 5.

Conclusion: The variation of electrolyte concentration is the most effective way to produce ternary multilayers with controlled composition. Multilayers with less Cu impurity in the ferromagnetic layer can be deposited at higher high pulse potential and from electrolyte of higher pH.

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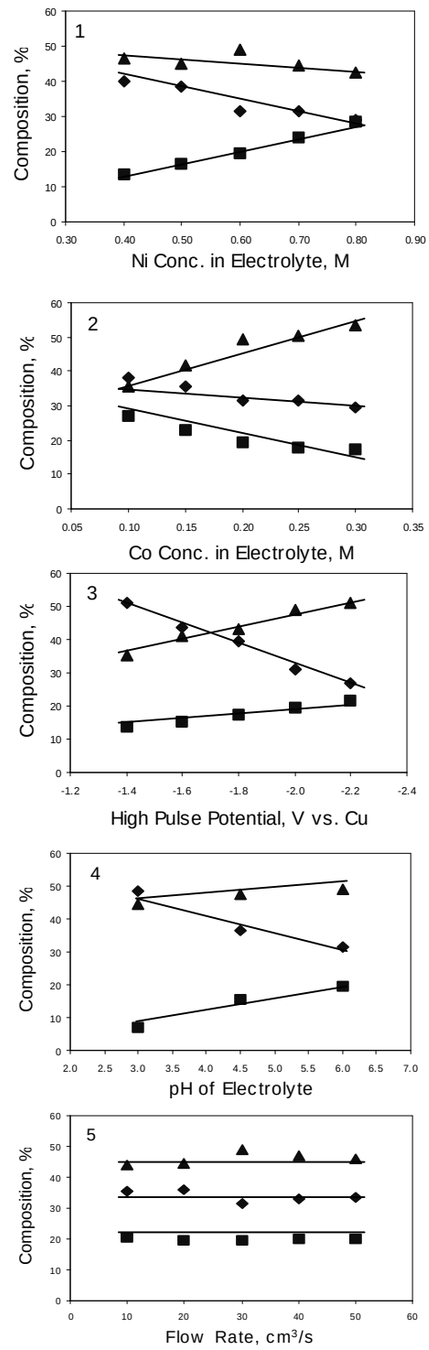

Legends: ◆: %Cu, ■: %Ni, ▲: %Co.
Deposition Parameters (if not variable): Electrolyte: 0.025 M Cu^{+2}, 0.6 M Ni^{+2} and 0.2 M Co^{+2}, pH: 6, high and low pulse potentials: -2 and -0.6 V vs. Cu respectively, flow rate: 30 cm^3s^{-1}.