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Magnetization Measurements on Electrodeposited $Cu_{1-x}Co_x$ Alloy Films

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Abstract

The magnetic properties of $Cu_{1-x}Co_x$ alloy films prepared by electrodeposition technique were investigated by Alternating Gradient Force Magnetometer. The magnetization curves of $Cu_{0.94}Co_{0.06}$, $Cu_{0.87}Co_{0.13}$ and $Cu_{0.74}Co_{0.26}$ films were easily saturated while the other $Cu_{1-x}Co_x$ samples with x= 0.17, 0.19 and 0.21 had more inclined magnetization curves. The saturation magnetization value of $Cu_{1-x}Co_x$ film increased with increasing Co content in the film. The minimum values of the ratio of remanence to magnetization and the coercive field were determined in the $Cu_{0.81}Co_{0.19}$ alloy film among the others. The ferromagnetic order in the $Cu_{1-x}Co_x$ films was between 2.5-29%.

Key Words: Electrodeposited alloy, Magnetization curves

1. Introduction

In recent years, one of the most interesting and widely investigated class of materials has been magnetic alloy films. Potential applications in magnetic recording and sensor technologies are the reasons driving attention to these alloy films. These inhomogeneous alloy systems show peculiar magnetic and electrical properties. The CuCo alloys are among the systems under investigation due to their electrical and magnetic properties. Multilayers of Cu and Co elements have been prepared by sputtering [1], molecular beam epitaxy [2], evaporation [3] and electrodeposition techniques [4]. However, CuCo alloy systems have not been investigated as much as Cu/Co multilayer systems although few groups have prepared CuCo alloys by sputtering [5] and electrodeposition [6].

Electrodeposition technique has important advantages due to its deposition control parameters and relative inexpence over other sophisticated techniques. In this study, the $Cu_{1-x}Co_x$ alloy films were prepared by electrodeposition technique and their magnetic properties were investigated by Alternating Gradient Force Magnetometer.

2. Experimental Details

An acidic citrate bath was used to electrodeposit six $Cu_{1-x}Co_x$ alloy films. The deposition was performed with constant current regime. The deposition current was 5 mA/cm^2 at 20^{o}C and pH = 6. The films were deposited onto an Aluminum substrate which was subsequently stripped from the films by using 10% NaOH solution. The compositions of the films were determined to be x = 0.06, 0.13, 0.17, 0.19, 0.21 and 0.26 by using an atomic absorption spectrophotometer. The crystal structures were analyzed by an x-ray (Cu-K_α) diffractometer. Magnetization loop spectra of the samples were taken by an alternating gradient force magnetometer (AGFM, model 2900) at room temperature. The dimensions of the samples used in the magnetization loop experiments were 4mm x 4mm x 2.5x10^{-3}mm and the applied magnetic field was directed parallel to the film plane.

3. Results and Discussion

The actual strength of the magnetic field near and within the sample is modified by a demagnetization effect which depends on the geometry of sample and the relative orientation of the applied field. The required corrections for the demagnetization effect are different in the case of transverse geometry where the applied field is perpendicular to the film plane and in the case of longitudinal geometry where the applied field is parallel to the film plane. A non-negligible demagnetization field is obtained in the transverse geometry while a negligible demagnetization effect occurs in the longitudinal experimental geometry when the strength of external field and the demagnetization effect are incomparable magnitudes. In our magnetization measurements, the external magnetic field was applied parallel to the film plane (the longitudinal geometry). The demagnetization field is therefore negligible and no demagnetization correction was done in our magnetization measurements. The magnetization curves of $Cu_{1-x}Co_x$ were measured by AGFM. Figure 1 shows some examples of magnetization curves of $Cu_{0.94}Co_{0.06}$, $Cu_{0.81}Co_{0.19}$ and $Cu_{0.74}Co_{0.26}$ films.

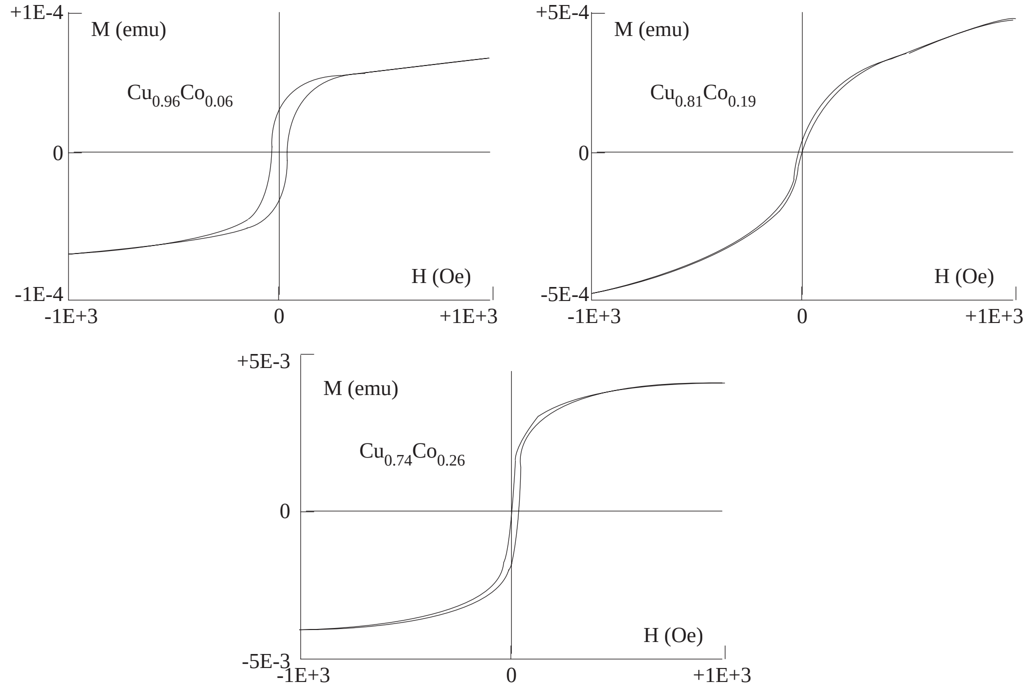

Figure 1. The magnetization curves of $Cu_{0.94}Co_{0.06}$, $Cu_{0.81}Co_{0.19}$ and $Cu_{0.74}Co_{0.26}$ films.

It was observed that the magnetization curves of $Cu_{0.94}Co_{0.06}$, $Cu_{0.87}Co_{0.13}$ and $Cu_{0.74}Co_{0.26}$ films were saturated easily while the other $Cu_{1-x}Co_x$ samples with x= 0.17, 0.19 and 0.21 had more inclined magnetization curves that may be attributed to a more disordered arrangement of Co atoms in these alloys. It was also detected that the saturation magnetization value of $Cu_{1-x}Co_x$ film, which occurred above 1 kOe, increased with increasing Co content in the film.

The variations in coercive field and remanence as a function of Co percentage in the alloy film can be seen in the Figure 2a and b, respectively. Both coercive field and remanence decrease while the Co percentage in the alloy film increases toward the value of x=0.19. But both increase with the increasing Co percentage above x=0.19. The ferromagnetic order of Co atoms in our samples may be determined from the ratio of remanence to magnetization values. The minimum value of the ratio of remanence to magnetization was determined to be ∼0.025 at 10kOe in the $Cu_{0.81}Co_{0.19}$ alloy film while the maximum value of the ratio was ∼0.29 at 10kOe in the $Cu_{0.94}Co_{0.06}$ film. So, it was found that the ferromagnetic order in our $Cu_{1-x}Co_x$ films was between 2.5-29%.

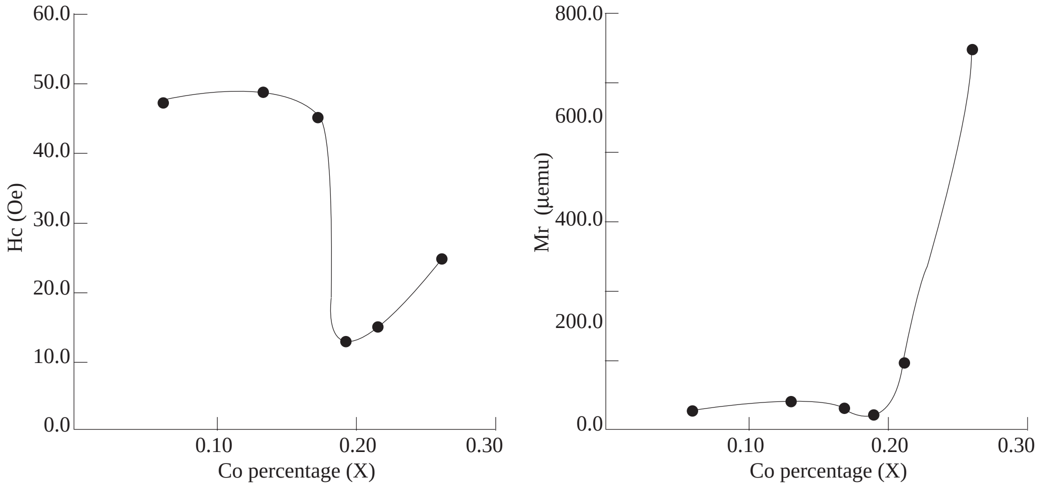

Figure 2. The variations of a) coercive field (Hc) and b) remanence (Mr) of $Cu_{1-x}Co_x$ films with Co percentage (x) in the films. The solid lines were drawn as a guide for the eye.

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