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ANNEALING EFFECT ON GIANT MAGNETORESISTANCE OF CoCu/Cu MULTILAYER FILMS

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ABSTRACT

The discovery of giant magnetoresistance (GMR) in multilayer and granular system has stimulated world wide research activities, due to its fundamental significance and potential application. Cu/Cu-Co multilayers were prepared by RF sputtering deposition technique. The as-deposited and annealed ($300^{o}C$, 15 minutes) samples were characterised by X-ray diffraction and Atomic Force Microscope. The resistances were measured using a four-point probe method to calculate the GMR effect. The microstructure analysis shows that the formation of <111> FCC Cu texture is dominant and small grain size was formed. X-ray diffraction indicated that the reduction of the correlation length is caused by grain coarsening due to growth of crystallites and grain boundaries after heat treatment. The magnetoresistance of Cu/Cu-Co multilayer has been measured as a function of the stacking layers before and after annealing. The MR ratio increase after the annealing process is carried out, but the MR value change within a small range as the number of the stacking layers increase. This shows that the number of stacking layer doesn't affect the GMR value. The highest GMR value observed is for sample with five stacking layers where 0.61% for as-deposited sample and 0.92% for annealed sample.

INTRODUCTION

Since its discovery, GMR has generated a lot of interest among academic and industrial laboratories due to deep fundamental physics that controls this phenomenon and tremendous technological potential for magnetic recording, storage and sensor industries [1,2]. In 1988, Baibich et al. [3] reported changes in resistance of as much as 50% at low temperatures with applied magnetic field for (Fe/Cr)n multilayer ultrathin films and labelled the "giant magnetoresistance" effect. Doi and co-workers [4] observed that samples with structure Si/[Co/Cu]$_5$/Co(25Å)/ Cu(25Å)/Co(30Å) exhibits as large as 2%/Oe of sensitivity. It is considered that the enhanced sensitivity of the Co/Cu/Co sandwich structure is due to the Co/Cu multilayer with antiferromagnetic coupling used as a pinning layer. Hecker and co-worker [5] discovered that grain growth and texture alteration can improve the GMR properties. In this work, hybrid multilayer CuCo/Co films were fabricated to investigate its magnetoresistance properties for the in-situ and annealing situation.

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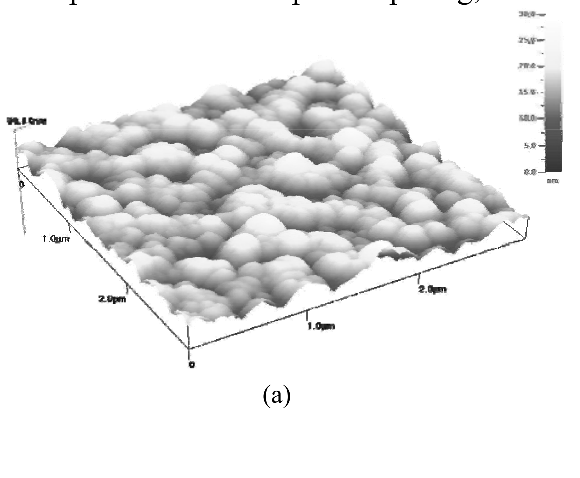
EXPERIMENTAL

Hybrid multilayer CuCo/Co films were fabricated with number of layer of 5,7,9,11,13 using RF magnetron sputtering system onto water-cooled microscope glass. The background pressure was pump to $1x10^{-5}$ mbar and during deposition the pressure was kept in $4x10^{-3}$ mbar with Ar flowing. The temperature of the glass substrate was maintained at 100°C during all the preparation process in order to achieve an initial degree of intermixing between the two non-miscible components as high as possible. The crystal structures of all the specimens were determined by an X-ray diffractometer with Cu $K\alpha$ radiation. Surface morphology was performed using atomic force microscope. The magnetoresistance (MR) measurements were carried out by using a pressure contact type four-point probe technique. After characterized, the samples were annealed at 300^oC for 15 minutes in a tube furnace with constant Argon gas flowing, before performing second time characterization.

RESULT AND DISCUSSION

The AFM images (Figure 1) show that the particle size of Cu layer is quite homogenous which the grain size is ranging from 0.3-0.5µm as its form by single element. Meanwhile for the as-deposited Cu-Co layer, the distribution of the particle size is large, ranging from 0.1-0.7µm. The combination of particles distribution in the Cu-Co layer is consist of non-magnetic and magnetic element which form in varies particle size, either in single element (Cu or Co) form or alloy (Cu and Co) form. Therefore, wide range of particles size distribution is observed.

Figure 2 show the XRD spectrums for as-deposited and annealed Cu film at 300^oC for 15 minutes. The XRD spectrum shows that as-deposited as well as annealed Cu films are polycrystalline which consist of <111>, <200> and <220> textured structure. The position of the Cu diffraction peak shift slight to higher angles from that of pure FCC Cu peak after annealed. This could be due to the impurities from the environment of the furnace that diffuse into the films where alloying might be occurred. Therefore, the mean lattice parameter or interplanar spacing, d of the film is change.



(a)

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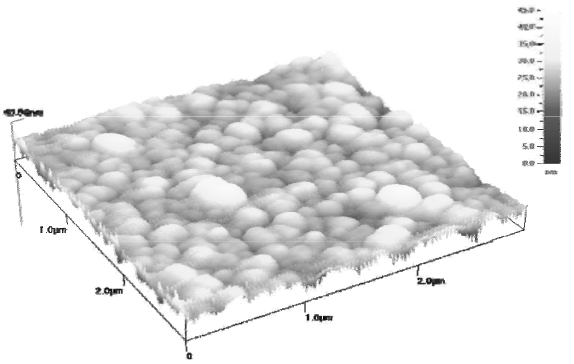

(b)

Figure 1 : AFM image of as-deposited (a) Cu layer and (b) Cu-Co layer

Figure 3 shows the XRD spectrums for as-deposited and annealed CuCo film at 300^{o}C for 15 minutes. The result indicated that both films consist of Cu <111>, <200> and <220> textured structure. There is no clear crystallographic observation of the presence of pure Cobalt in the Cu-Co layer. This is due to the fact that Co FCC <111>, <200> and <220> position is almost overlap with the <111>, <200> and <220> peak of FCC Cu. The composition of Co in the film is small. Therefore, this minor formation of Co FCC <111>, <200> or <220> peak might be overlap by the Cu peak.

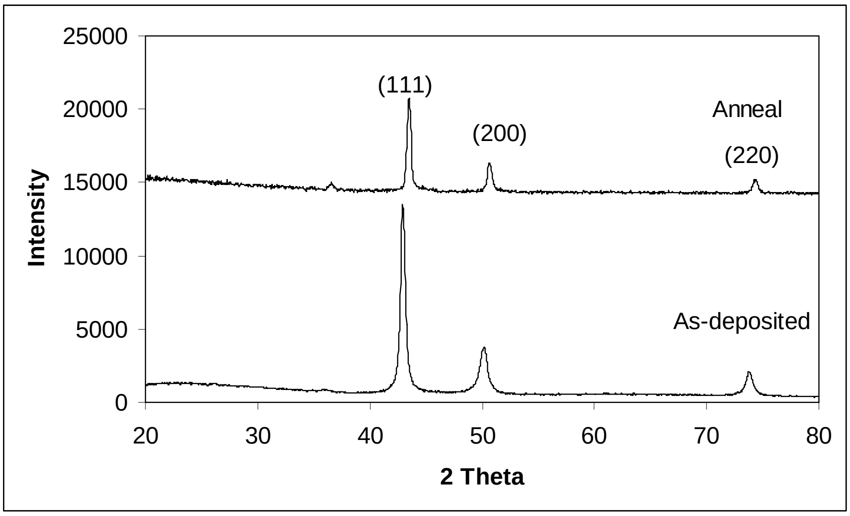

Figure 2 : XRD pattern for as-deposited and annealed Cu film at 300^{o}C for 15 minutes

Figure 4 shows the as-deposited GMR value for various Cu/Cu-Co multilayers. The GMR values for these samples are small (less then -0.65%). The highest value is -0.60% for sample with 5 layer films, follow by -0.56% for 11 layer films, -0.48% for 7 layer films, -0.48% for 13 layer films and -0.46% for 9 layer films. Negative GMR is observed when external magnetic field is applied. This is due to the spin scattering of the conduction electron. Without the external magnetic field, the magnetic moments of

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the granules are randomly oriented and the conduction electrons are highly scattered and responsible to higher resistance. Under an external magnetic field, the randomly oriented magnetic moments of the granules are parallel aligned and the conduction electrons are less scattered. It leads to a reduction of electrical resistance. The %GMR decrease nearly linearly for all samples and its still has not achieved saturation at 1 Tesla. From XRD spectrum, its show that all samples consist of wide range of particles size distribution. Some of these small granules which behaviour as superparamagnetic particles might exist and need higher magnetic field to saturate completely.

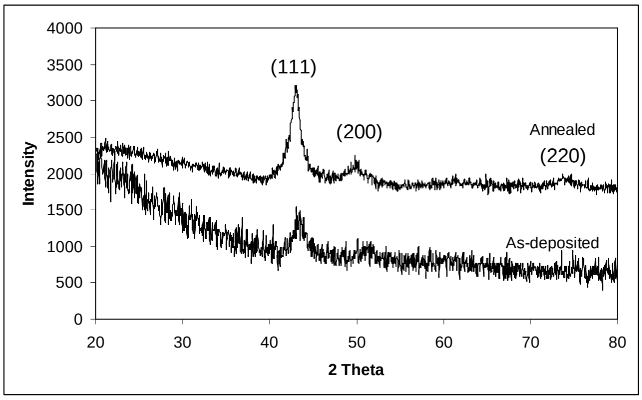

Figure 3 : XRD pattern for as-deposited and annealed CuCo film at 300^{o}C for 15 minutes

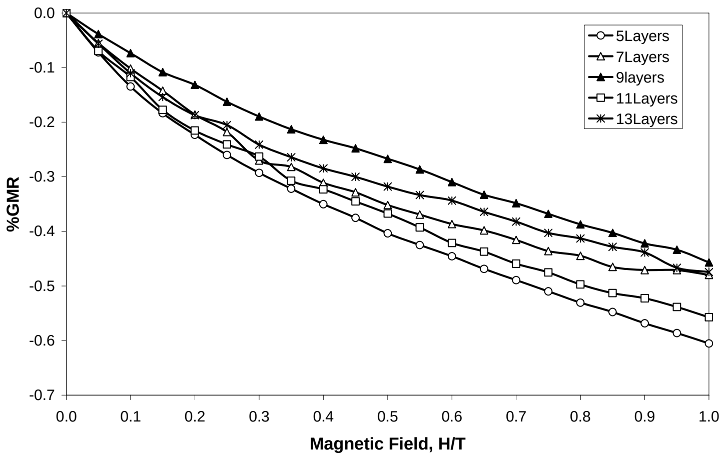

Figure 4: Giant magnetoresistance curve for all the as-deposited multilayer thin films.

Figure 5 shows %GMR curve for all the annealed multilayer thin films. Annealing at 300^{o}C for 15 minutes increased the %GMR ratio as compare to as-deposited samples. Annealing help the films partial recrystalline and and improve homogeneity of magnetic structure due to structural relaxation and residual stress release (Leszek et al., 2000). Beside, heat treatment also enhances some grain growth and hence reduces the number of superparamagnetism granules. Therefore, non-linear curve had been observed and the GMR ratio increases slightly.

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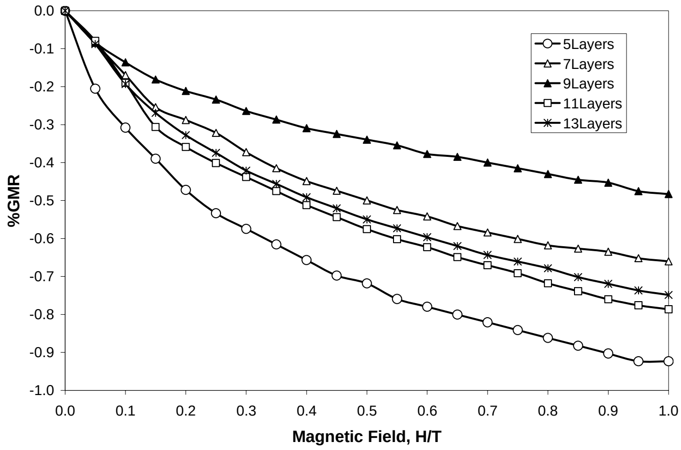

Figure 5: Giant magnetoresistance curve for all the annealed multilayer thin films

Figure 6 illustrate the values of GMR for as-deposited and annealed samples at different layer. The values are oscillating with increasing of the number of samples layers but the variation is not big. This shows that the number of Cu and Cu-Co layer in the sample do not affect much on the GMR values or this small variation (5 to 13 layers) is not sufficient to give a significant influence to the GMR value. The highest GMR value of -0.60% and -0.92% had been obtained for the as-deposited and annealed samples having five alternating magnetic and non-magnetic layers.

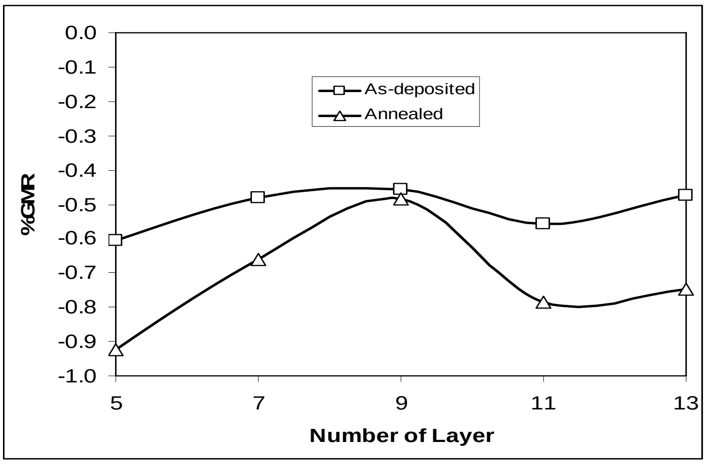

Figure 6: Giant magnetoresistance value of as-deposited and annealed sample at different layer

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CONCLUSION

Hybrid-multilayer metal-granular Cu/Cu-Co films had been successfully fabricated using RF magnetron sputtering system. XRD spectrum pattern show that as-deposited Cu layer consist <111>, <200> and <220> structure. The intensity of the spectrum of Cu layer shows that the texture of <111> is highly established. GMR value for Cu/Cu-Co multilayer sample are quite close with increase of stacking layers but oscillate with the increase of stacking layers. From the intensity and peak width of the XRD spectrum, it shows that annealing process increases the grain size and this lead to the increase of MR ratio. Negative GMR values have been obtained for all samples where resistance of the multilayer films decrease with the applied field. This appearance is due to the alignment of the localized spin along the magnetic field that enhances the conductivity by reducing the scattering of the conduction electron.

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