MAGNETO-OPTICAL KERR ROTATION SPECTRA IN SPUTTERED GRANULAR Co-Au ALLOY FILMS


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Abstract: We prepared Co-Au granular alloy films with compositions ranging from 5 to 38at.% Co on glass substrates by a sputtering method and measured their magneto-resistance and magneto-optical Kerr rotation (ΦK) spectra at RT. As a result, it is found that 20at.% and 28at.%Co-Au films show a large peak at about 3.4eV and small peaks due to the plasma enhancement by the Au matrix at about 2.5eV, respectively. By annealing, the shape of the ΦK spectra became to similar to each other in all the films; namely, two ΦK peaks appeared at about 2.0eV and 3.4eV. Thus, ΦK spectra is quite different from those of Co ultra-thin films and bulk Co.

KEYWORDS: Co-Au granular alloy films, Sputtering, Magnetoresistance, Kerr rotation spectra, Kerr ellipticity spectra

I. INTRODUCTION

Much attention has been focused on metallic multilayer films, because they have novel potential for a magneto-optical recording media and magnetic sensors. Recently, a giant magneto-resistance(GMR) effect has been found in metallic granular alloys in which magnetic ultra fine particles are embedded in a non-magnetic matrix[1],[2]. By an analogy from the layered structures[3][4], it is expected that the GMR of this kind of films is also due to the interfacial spin dependent electron scattering at boundaries between magnetic particles and the matrix. In layered structures, two main theories based on an extended RKKY model and a formation of quantum well states(QWS) have been proposed to explain the exchange coupling between two magnetic layers through a non-magnetic metal layer[5][6].

In 1992, we have reported on a new magneto-optical Kerr effect due to a formation of QWS in Fe ultra thin films[7]. If it is possible to confine the electrons in a granular particle, a similar magneto-optical transition should be expected in granular alloy systems. In this paper, we report on the magnetic and magneto-optical properties of granular Co-Au alloys.

II. EXPERIMENT

All the Co-Au granular alloy films were prepared on glass substrates by a sputtering method. A part of the samples was annealed at various temperatures up to 500°C in a vacuum chamber in order to grow Co fine particles. The structures were analyzed by an X-ray diffractometer (XRD). The GMR was measured in a four-terminal geometry with in-plane current. A magnetic field (up to 15 kOe) was applied parallel to the current. Magneto-optical polar Kerr rotation (ΦK) and Kerr ellipticity (ηK) spectra were measured with a Kerr rotation spectrometer (Jasco J-2500) from 200 to 800nm (6.2-1.55eV) in 12kOe at room temperature. The incident angle of light was 10 degree normal to the film surface.

III. RESULTS AND DISCUSSION

III-1. Structure and GMR measurements

Figure 1 shows the XRD patterns of 20at.%Co-Au alloy films. Here, the upper (A) was for the as-sputtered and the lower (B) was for the sample annealed at 300°C for 30minutes. From the figure, it is found that the both films
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have a Au[111] texture normal to the film surface. And the diffraction peak due to Co particles grows slightly after the annealing. We could not distinguish whether the Co precipitates crystallized in fcc or in hcp structures, however, from the transmission electron microscopic experiments on the quenched sample of 10at.%Co-Au alloy, it is found that the Co precipitates have a fcc structure and have a disk shape with a typical length of 20nm parallel to Au(100) matrix keeping coherency[8].

Tables 1 and 2 show the GMR ratio of the Co-Au alloy films. The GMR ratio of all samples (except for sample of 38at.%Co-Au alloy) increases in all samples by the annealing step at 300°C for 30minutes. This is thought to be due to a growth of the Co particle. In 20at.%Co-Au alloy, the GMR ratio increases by the annealing at 300°C, but it begins to decrease after the higher temperature annealing (see Tab.2). Similar phenomena were observed in magneto-optical Kerr spectra as shown later.

III-2 Magneto-Optical Properties

Figure 2 shows the $\Phi_K$ hysteresis loops of as-deposited (as-sputtered) Co-Au alloy films. These loops were measured at 500nm. As clear in the figure, the 5at.%Co-Au film seems to be paramagnetic. The other films are ferromagnetic and their hysteresis loops almost saturate in 12kOe. This suggests that the Co particles in Au matrix are large enough to behave as a ferromagnet.

Figure 3 shows the $\Phi_K$ hysteresis loops of the annealed Co-Au alloy films measured at 500nm. In the figure, 5at.%Co-Au alloy film changes to a ferromagnet with low saturation magnetization by annealing. The saturation $\Phi_K$ values of 20at.% and 28at.%Co-Au alloys become larger than that of the as-deposited. This suggests that the Co particles grow by the annealing step. The 38at.%Co-Au alloy film's does not change by annealing.

In Fig.4, $\Phi_K$ spectra in the as-deposited Co-Au alloy films are shown. 20at.% and 28at.%Co-Au films show a large peak at about 3.4eV and small peaks at about 2.5eV and 5.5eV, respectively. Although the small peak at about 2.5eV is much smaller than that of Co ultra thin
In order to make clear the difference in $\Phi_K$ spectra between Co-Au alloy and Co bulk and Co film on Au, it is thought to be come from the plasma enhancement due to the Au matrix. The $\Phi_K$ spectrum of 38at.% Co-Au alloy is very different from that of the others. In Fig. 5, the $\eta_K$ spectra in the as-deposited Co-Au alloy films are shown for a information. In these cases, almost same stories are told.

Figure 6 shows $\Phi_K$ spectra of the Co-Au alloys annealed at 300°C for 30 min. In 20 and 28at.% Co-Au alloy films, the $\Phi_K$ peaks at about 3.4eV grew, but the peak at about 5.5eV diminishes by annealing. And they become similar to each other by annealing.

Figure 7 shows the annealing temperature dependence of $\Phi_K$ spectra in 20at.% Co-Au alloy films. We can see a small peak due to the plasma enhancement and a relatively large peak around 3.4eV in the three films which are the as-deposited, annealed at 200°C and 300°C. Plasma enhancement peak disappears by an annealing at 400°C but appears at 500°C again. The $\Phi_K$ spectrum annealed at 500°C seems to be similar to that of Co(15Å)/Au(10Å) multilayer reported by Atkinson et al[9]. A peak at 3.4eV grows with annealing until at 300°C, and then decreases by annealing more than 400°C. This behavior seems to correspond to that of GMR measurements. From these annealing effect on the magneto-optical spectra, it is expected to say that the $\Phi_K$ peaks at about 3.4 and 5.5eV may be due to a higher order quantum size effect in Co particles. As to the phenomena, a more detailed research is necessary in future.
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1.5 2 3 4 5 6
Photon Energy [eV]

Fig. 7 Annealing temperature dependence of the $\Phi_K$ spectrum in 20 at.% Co-Au alloy films.

1.5 2 3 4 5 5.5
Photon Energy [eV]

Fig. 8 The $\Phi_K$ spectra of fcc(111) Co ultra thin films. For an information, the $\Phi_K$ spectrum of hcp(0001) bulk Co was shown in lower part.

Thus, in this study, we could not clarify thoroughly the quantum size effect on M.O. properties which was expected before the experiments, because Co precipitates were disk shape with relatively a large size. However, it is found that all the spectra measured are quite different from those of Co ultra-thin films and bulk Co. Namely, there are two $\Phi_K$ peaks at 3.4 and 5.5 eV in 20 and 28 at.% Co-Au alloys and the peak at 5.5 eV diminishes by annealing. These spectra seem to be difficult to explain by a similar argument analogous to thin-film system. In near future, it is necessary to calculate the spectra by using a model proposed by Abe et al[10].

IV. CONCLUSION

In order to investigate the magneto-optical properties due to magnetic fine particle system, we prepared Co-Au granular alloy by a sputtering method and measured the magnetic and magneto-optical properties. It is found that $\Phi_K$ of the as-deposited films changes considerably by annealing. The magneto-optical properties of both the as-deposited films and the annealed films are quite different from those of Co ultra-thin film and Co bulk. It seems to be difficult to explain the magneto-optical properties by a similar argument analogous to ultra-thin film system.

References