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GMR Properties of Co-Noble Metal Films

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In both eutectic (Co-Ag and Co-Au) and isomorphous (Co-Pt and Co-Pt) systems, the magnetoresistance (MR) was measured of alloyed and multilayered films fabricated by dual-source RF magnetron sputtering. The measurement was carried out by a DC two-point method at room temperature in magnetic fields applied parallel to the DC current. In the eutectic systems, the alloyed and the multilayered films exhibited giant magnetoresistance (GMR) before and after annealing. In the isomorphous systems, on the other hand, the alloyed films showed GMR before annealing, whereas the multilayered films showed AMR after annealing.

Keyword: Co/Noble Metal Films, GMR

1. INTRODUCTION

Magnetoresistance (MR) is a phenomenon that electric resistance of a material changes when the magnetic field is added to the material. It is observed in ferromagnetic alloys, which have spontaneous magnetization such as Ni-Fe and Co-Ni alloys. This is called the anisotropic magnetoresistance (AMR). As for the AMR, electric resistance rises when the direction of the current is the direction of the magnetization and a parallel, and electric resistance lowers vertically.

Giant magnetoresistance (GMR) arises from the spin-dependent scattering of conduction electrons at an interface between non-ferromagnetic and ferromagnetic matters [1]. Materials exhibiting GMR are classed into two types: multilayer and granular systems. The former consists of ferromagnetic layers separated with a non-ferromagnetic layer, and the latter has a structure in which ferromagnetic clusters are dispersed in a non-magnetic matrix [2,3].

In such systems, the granular-type GMR may be controlled, if a multilayered structure showing GMR becomes a granular one through annealing. From this assumption, we examined the MR of multilayered and alloyed films in some Co-noble metal systems before and after annealing. We used the eutectic Co-Ag and Co-Au systems and the isomorphous Co-Pd and Co-Pt systems, since such a difference in the alloy system would greatly influence the GMR properties.

2. EXPERIMENTAL

The multilayered and alloyed films of Co-Ag, Co-Au, Co-Pd and Co-Pt were fabricated by using dual-source RF magnetron sputtering and rotating glass substrates. The content of Co in the suputtered films was determined by electron probe microanalysis. The films were heated at a rate of 280 K/min under a vacuum of 1×10^{-4} Pa for annealing at 373-873 K for 10 min in the

Co-Ag films, at 573 K for 48 h in the Co-Au films, and 673 K for 48 h in the Co-Pd and Co-Pt films. For the Co-Pt films were also annealed for 72 h.

The MR loop was measured by a DC two-point method at room temperature, in magnetic fields up to 1.03 MA/m applied parallel to the measuring current. The MR ratio was defined by $d\rho=(\rho_0-\rho_s)/\rho_s x100$, where ρ_0 and ρ_s are the electrical resistance without a field and with the maximum field, respectively.

3. RESULTS AND DISCUSSION

3.1 Co-Ag Alloyed Film and Co/Ag Multilayered Film

As shown in Figure 1, the as-sputtered alloyed film exhibited a maximum MR ratio of 8.7% for 36.4 at% Co. The MR ratio decreased as the Co content exceeded this value, and it also decreased with increasing annealing temperature. The decrease in the MR ratio can be attributed to an increase in the size of Co clusters.

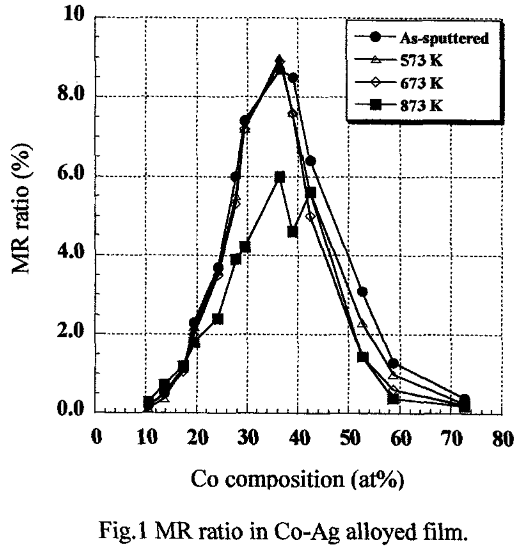

Fig.1 MR ratio in Co-Ag alloyed film.

As shown in Figure 2, the MR ratio in the Co/Ag multilayered films decreased with annealing, when the thickness of Ag layer was 3.6 nm. This is due to the breakdown of the multilayered structure. When the Ag layer was thicker than 3.6 nm, however, the MR ratio increased with annealing. This is an indication that Co atoms in the broken layers formed clusters, which resulted in the granular-type GMR.

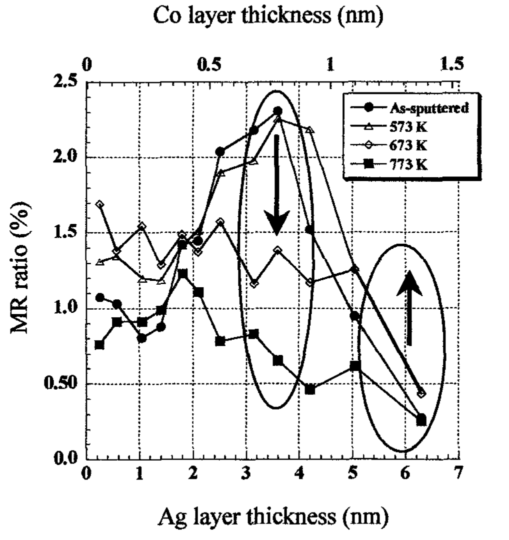

Fig.2 MR ratio in Co/Ag multilayered film.

3.2 Co-Au Alloyed Film and Co/Au Multilayered Film

As shown in Figure 3, the as-sputtered film exhibited a maximum MR ratio of 1.7% for 25.8 at% Co. The MR ratio was decreased to 0.2% by annealing. Such behavior is the same in the Co-Ag alloyed film and can also be attributed to an increase in the size of Co clusters.

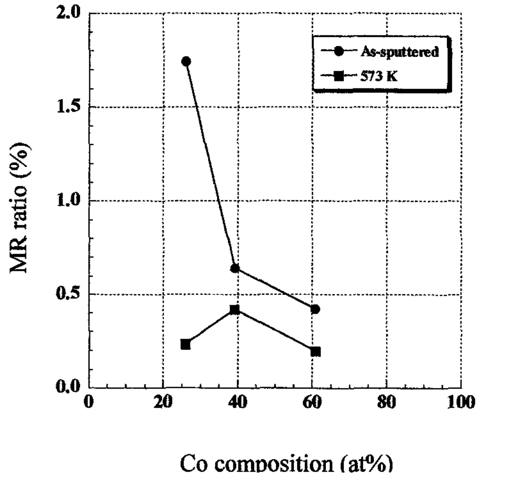

Fig.3 MR ratio in Co-Au alloyed film.

In the Co-Au alloyed films containing 39.2 and 60.9 at% Co, annealing caused little change in the MR ratio.

3.3 Co-Pd Alloyed Film and Co/Pd Multilayered Film

Figure 4 shows the MR loops before and after annealing for a layer thickness of 5.0 nm. In the Co/Pd multilayered films, the GMR-type loop appearing in the as-sputtered film became the AMR-type one after annealing. The result was the same in the Co-Pd alloyed films. For the Co-Pd alloyed films, however, the formation of Co clusters can be excluded, because Co and Pd can mix. A possible explanation for the GMR-type loop is that Co-rich zones may exist in the as-sputtered film and work as Co clusters. Annealing may break down such zones, leading to the AMR-type behavior that appears generally in ferromagnetic materials.

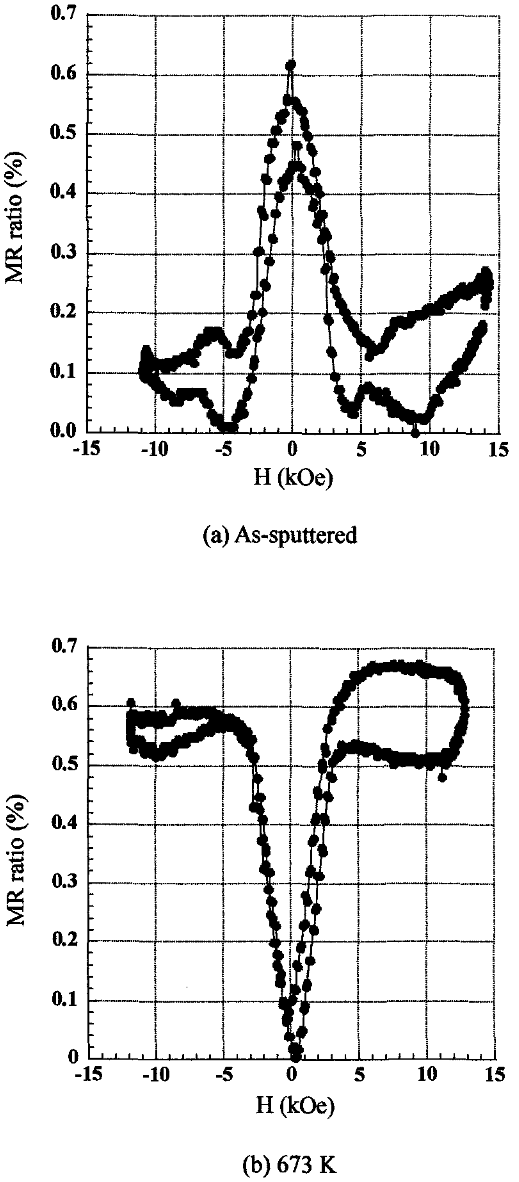

Fig.4 MR loops of 5.0 nmCo/5.0 nmPd Multilayered film.

3.4 Co-Pt Alloyed Film and Co/Pt Multilayered Film

The Co-Pt alloyed films and the Co/Pt multilayered films showed the GMR-type loop before annealing, and the MR loop of the films also became the AMR-type after annealing. This result is thus the same as that of the Co-Pd system, and so should be the relating structural change. Figure 5 is an illustration of such a structural change in the alloyed film of an isomorphous system. As noted above, Co-rich zones surrounded by the dotted circles may work as Co-clusters before annealing. The zones may break down by annealing, thereby resulting in the AMR-type behavior.

4. CONCLUSION

In the multilayered films of the eutectic Co-Ag and Co-Au systems, annealing breaks down the layered structure, leading to a change in GMR from a multilayered type to a granular one. In the alloyed films of these systems, the results indicate that annealing increases the size of Co clusters and decreases the MR ratio.

In both multilayered and alloyed films of isomorphous Co-Pd and Co-Pt systems, the MR loop is the GMR-type before annealing, whereas it becomes the AMR-type after annealing. In the alloyed films, the formation of the Co cluster can be ruled out because the systems are isomorphous. It is very likely that Co-rich zones exist in the as-spattered films and contribute to the appearance of GMR. Annealing may break down such zones, resulting in a homogeneous solid solution, and accordingly leads to the AMR-type behavior, which are generally observed in ferromagnetic materials.

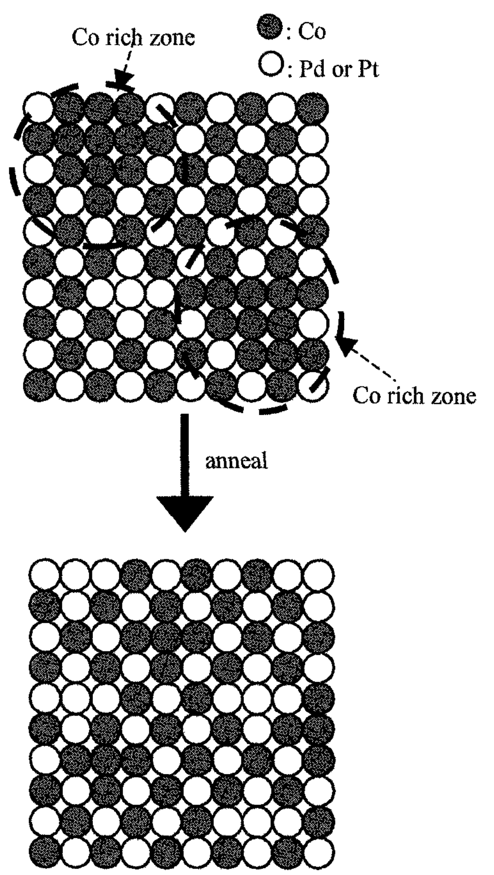

Fig.5 The change of the internal condition of the alloy of a eutectic system.

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