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Magnetic Properties of Multiple-Structure Multilayered Co/Noble Metal Films

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Co/noble metal films have new functions such as perpendicular magnetization and giant magneto resistance (GMR). Multiple-structure multilayered Co/noble films (MSM Co/noble films) were fabricated in order to improve the magnetic properties of Co/noble metal films further. Co/noble metal films and MSM Co/noble metal films were fabricated by a dual-source RF magnetron sputtering onto the rotating glass and polyimide substrates. We analyzed their structures by X-ray diffraction and magnetic properties. Compared with Co/Pd films, the increases in saturated magnetizations and coercive forces are observed in MSM films. Moreover, they show perpendicular anisotropic and multistage loops. The reason why the hysteresis loops become multistage loops is due to there is large coercive force difference between the lowest Co/Pd layer and the upper Co/Pd layer. This difference in coercive forces is due to the groundwork effect. As a result of the GMR measurement, a comparatively big GMR value of 6.5% was obtained.

1. INTRODUCTION

Co/noble metal films have new functions such as perpendicular magnetization and GMR, and the applications to high density magnetic recording medium in the next generation are expected. Though Co/noble metal films have the magnetic properties that the conventional materials do not contain, they have also remained on improving points. Then, MSM Co/noble films were fabricated in order to improve the magnetic properties of Co/noble metal films further.[1] [2]

In this paper, the relationships between periodic structure and magnetic properties (hysteresis loops and magneto-resistant (MR) effects) of Co/Pd films and MSM Co/Pd films are reported. The annealing effects of Co/Pd films and MSM Co/Pd films are also reported.

2. EXPERIMENTAL

Co/Pd films and MSM Co/Pd films were fabricated by a dual-source RF magnetron sputtering onto the rotating glass and polyimide substrates at ambient temperature. The preliminary exhaustion pressure was 1 $\times 10^{-4}$Pa. Ar was used for the sputtering gas, and the Ar gas pressure was 0.40-0.43 Pa. The shutter attached for the each target controlled the each layer thickness of films. Table I shows the layered structure of Co/Pd films and MSM Co/Pd films. In table I MSM-3 is Co/Pd films and the others are MSM Co/Pd films.

The hysteresis loops were measured with VSM under 5kOe, and the structure analyses were carried out by XRD. Using the Cu target. XRD was measured by the scanning field 2θ of 1.3-15 deg (low angle region) and 30-50 deg (high angle region).

The MR effects 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 $\Delta\rho=(\rho_0-\rho_s)/\rho_s\times100$, where ρ_0 and ρ_s are the electrical resistance without a field and with the maximum field, respectively.

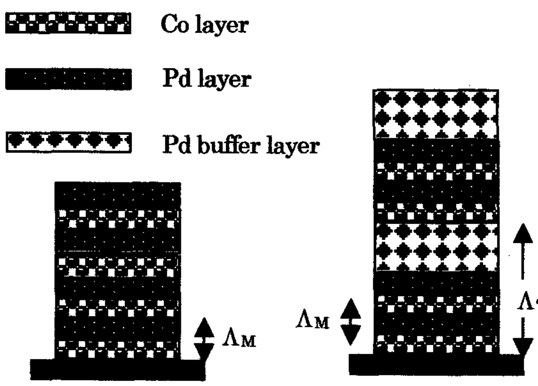
Table I. Layered structure of sample films.

Sample	Layered Structure/ Å [(Co/Pd)n/Pd]m
MSM-1	$[(3.85/8.64)_{20}/250]_2$
MSM-2	$[(3.85/8.64)_{20}/250]_4$
MSM-3	$(3.85/8.64)_{20}$
MSM-4	$[(3.85/8.64)_{20}/0]$~ $[(3.85/8.64)_{20}/1000]$

3. RESULTS AND DISCUSSION

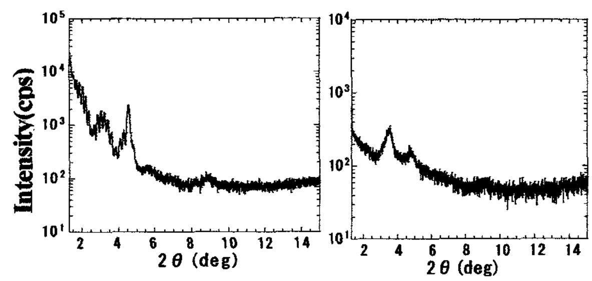
3-1 Structure of MSM Co/Pd films

MSM Co/Pd films have more complicated than Co/Pd films. Figure 1 shows the periodic structures of Co/Pd films and MSM Co/Pd films. For Co/Pd films, the periodic thickness Λ_M consists of a Co layer and a Pd layer. MSM Co/Pd films have two sorts of periodic thickness. One is Λ_M and the other is Λ_T. The periodic thickness Λ_T consists of Λ_M piled few times and a Pd buffer layer. If the periodic thickness is piled N times, the total film thickness is expressed $N\Lambda_M$ in Co/Pd films and is expressed $N\Lambda_T$ in MSM Co/Pd films.

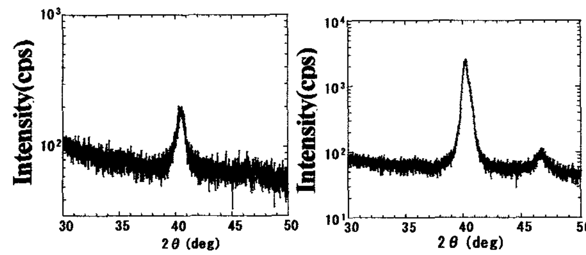


(a) Co/Pd film (b) MSM Co/Pd film

Fig.1 Comparison of periodic structure



(a) low angle region.



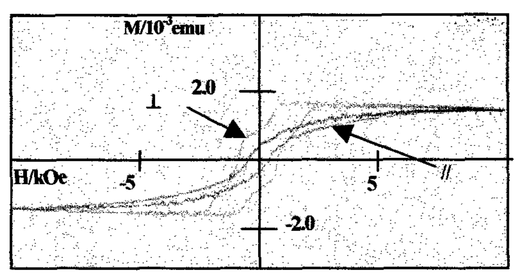
(b) high angle region.

Fig.2 XRD patterns of Co/Pd films and MSM Co/Pd films

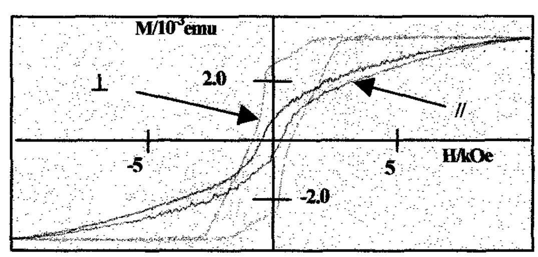
Fig.2 shows the XRD patterns of Co/Pd films and MSM Co/Pd films. For both films, the XRD peaks based on their periodic thickness were observed in the low angle region. In the high angle region, main peaks and satellite peaks were observed. Here, the main peaks are complex peaks of Co and Pd, and the satellite peaks are based on the periodic thickness. MSM films contain two periodic thickness, so their XRD patterns are more complicated than of Co/Pd films.

3-2 Multistage hysteresis loops and effects of the groundwork

Figure 3 shows the hysteresis loops of MSM-1 and MSM-2. The structure of MSM-1 is $2\times\Lambda_T$ and the structure of MSM-2 is $4\times\Lambda_T$ (as shown in fig.4). They show perpendicular anisotropic and multistage loops. Compared with Co/Pd films (MSM-3), the increases in saturated magnetizations and coercive forces are observed.



(a) MSM-1



(b) MSM-2

Fig. 3 Hhysteresis loops of MSM Co/Pd films

The increase in the saturated magnetization is understood as the increase in Co mass. The cause of the multistage loops thought to be the groundwork effect.

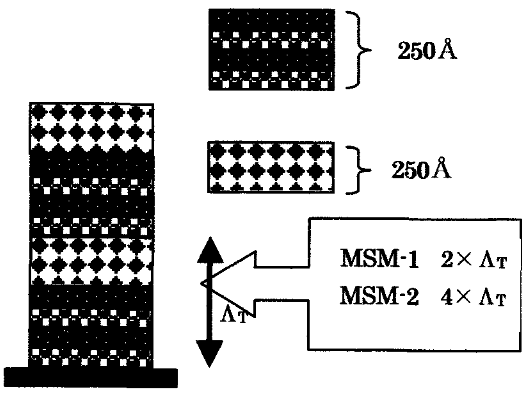


Fig.4 Structure of MSM-1 and MSM-2

3-2 Relation between coercive force and thickness of buffer layer (the groundwork effect)

In the samples of MSM-4, Pd buffer layer thickness on the substrate is changed from 0 to 1000Å as shown in fig.5. Figure 6 shows the relation between the coercive force and the buffer layer thickness. The thicker the buffer layers become, the larger coercive forces become. This increase in coercive forces is due to the groundwork effect The increase in coercive force becomes the saturated state when the buffer layer thickness exceeds about 500Å.

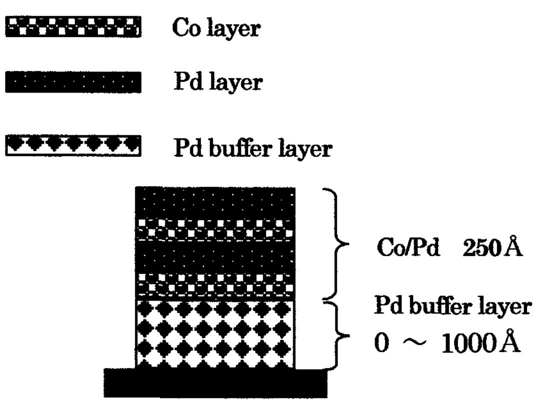


Fig.5 Samples of MSM-4
Pd buffer layer thickness is changed from 0 to 1000Å

The reason why the hysteresis loops in fig.3 become multistage loops is as follows: the lowest Co/Pd layer does not suffer the effect of the groundwork layer, and the upper Co/Pd layer suffers the total groundwork effect from the buffer layer and the lowest Co/Pd layer. And since there is large coercive force difference between the lowest Co/Pd layer and the upper Co/Pd layer, the hysteresis loop becomes multistage shape.

However, the groundwork effect enters the state of saturation when the groundwork becomes thicker. Therefore, it is thought that the coercive force difference of between the 2nd Co/Pd layer, the 3rd Co/Pd layer and the 4th Co/Pd layer is small, so steps did not appear there. The cause of the multistage hysteresis and the magnetization value in each step can be explained to the above-mentioned state. The multistage hysteresis materials can be expected as multiple function memories, switches, and sensors.

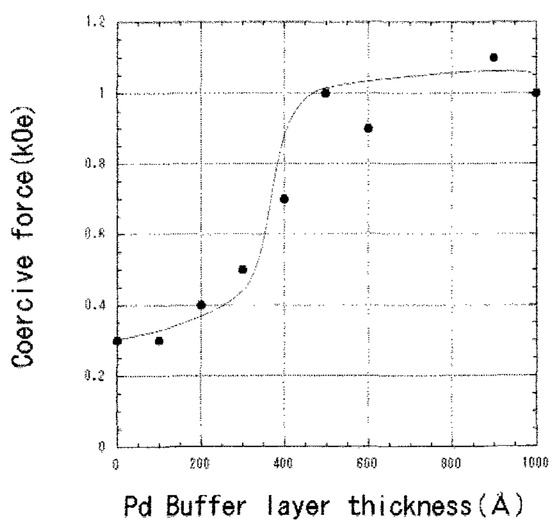
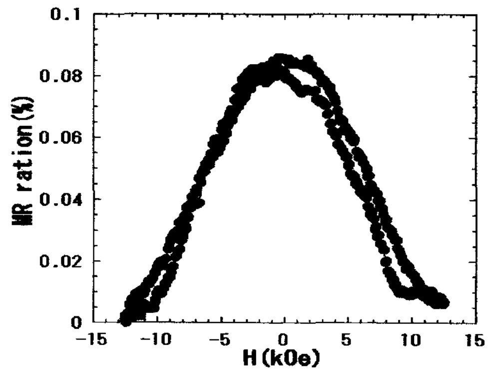


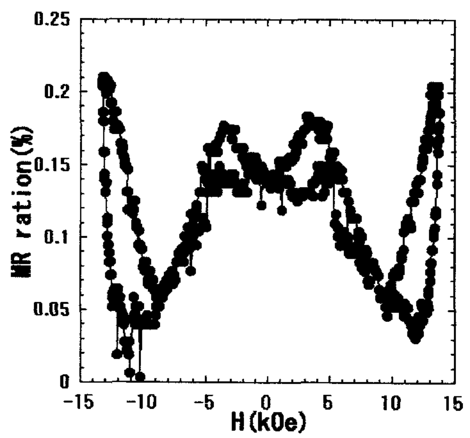
Fig.6 Relation between coercive force and buffer layer thickness

3-4 MR effect

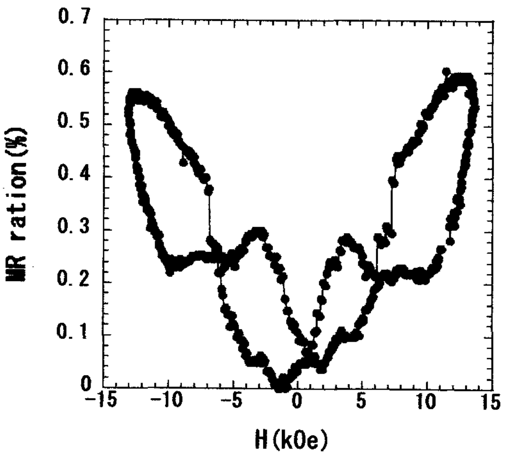
Figure 7 shows the MR loops before and after annealing. The MR measurement was measured while annealing (373K,473K,573K,673K) the sample of MSM Co/Pd The GMR curve that resistance decreases when the magnetic field increases before MSM Co/Pd film is annealed showing the result in Figure 8. In annealing 573K,0.5h, the MR curve of the valley type (anisotropic magnetoresistance = AMR) is seen a little in about magnetic field 0, and AMR is coexistent to GMR.



(a) as-sputtered



(b) 573K,0.5h Annealed

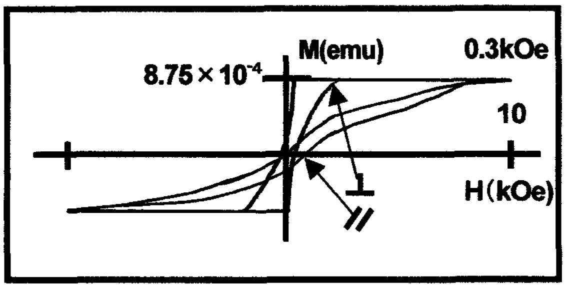


(c) 573K,1h Annealed

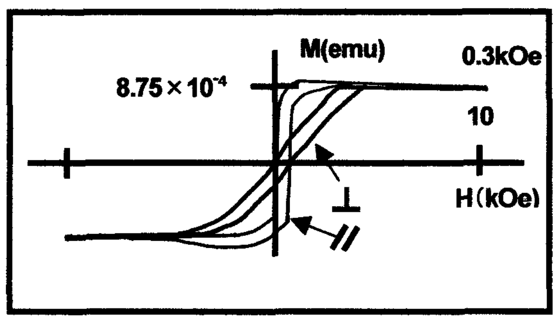
Fig.7 Anneled of MSM Co/Pd

3-5 Annealing of MSM Co/Pd

Fig. 8 shows the hysteresis loops of MSM Co/Pd films. As-sputtered hysteresis loops were perpendicular magnetized film. In annealing at 573K for 0.5h, hysteresis loops were in plane magnetic films. It is the cause that the Co layer mixed with the Pd layer by the annealed. It is thought that this is a cause in the change from GMR to AMR.



As-sputtered



573K, 0.5h annealed

Fig.8. Hysteresis loops of MSM Co/Pd

4. CONCLUSIONS

Compared with Co/Pd films, the increases in saturated magnetizations and coercive forces are observed in MSM films. Moreover, they show perpendicular anisotropic and multistage loops. The reason why the hysteresis loops become multistage loops is due to there is large coercive force difference between the lowest Co/Pd layer and the upper Co/Pd layer. This difference in coercive forces is due to the groundwork effect. As a result of the GMR measurement, a comparatively big GMR value of 6.5% was obtained.

REFERENCES

[1] R Koiwai et al. Trans.MRS-J .27[4] pp.747-750(2002)
[2] R Koiwai et al. Trans.MRS-J .28[4] pp.1271-1274(2003)

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