Transactions of the Materials Research Society of Japan 29[4] 1573-1575 (2004)

Relationship between Surface Morphology and Magnetic Property of Co/Pd Multilayers

H. Yoshikawa and S. Nakagawa
Department of Physical Electronics, Tokyo Institute of Technology, 2-12-1 Ookayama ,Meguro-ku, Tokyo 152-8552, Japan
Fax: 81-03-5734-2513, e-mail: hironori@spin.pe.titech.ac.jp

Magnetic properties of Co/Pd multilayers seem to be strongly dependent on surface and interface morphology of the films. Pd underlayer for Co/Pd multilayers promotes the increase of surface roughness R_a. Such an increase of surface roughness tended to cause large increase of H_c. The continuity of grains seems to enhance exchange coupling. In order to confirm the effect of Co and Pd layer, respectively, we tried to deposit $[Co/Pd]_{20}$ at different Ar gas pressure P_{Ar} for each layer. When Pd layer was deposited at low P_{Ar}, the multilayer didn't reveal high H_c. It is clearly observed that the deposition of Pd layers at high P_{Ar} enhances surface roughness of the multiulayers. High H_c may be attributed to the surface roughness. Meanwhile, when Co and Pd layers were deposited at low and high P_{Ar}, respectively, the film exhibited high squareness ratio S and H_c, but $\alpha(=4\pi(dM/dH)@H=H_c)$ of the film was quite high. It is found that higher P_{Ar} condition during Pd deposition is essentially required for the appearance of H_c.
Key words: Co/Pd multilayers, AFM images, surface roughness, sputter Ar gas pressure

1. INTRODUCTION

Though Co/Pd multilayer is one of hopeful candidates of perpendicular magnetic recording media[1]-[3], it still has relatively high media noise originated from large exchange coupling among grains in the film. The origin of perpendicular magnetic anisotropy of the films is attributed to the interface of Co and Pd layers. The structure at the interface seems to be strongly related to the exchange coupling between grains. The relationship between magnetic properties and surface morphology is investigated to control the exchange coupling, since the surface morphology reflects the interface structure. In this study, it is investigated how the surface roughness and the grain size at the film surface affect on the magnetic properties.

2. EXPERIMENTAL

Co/Pd multilayers were prepared on Si wafer substrates at room temperature at Ar gas pressure P_{Ar} of 30 mTorr by facing targets sputtering. Thicknesses of Co and Pd were set at 0.2 and 0.6 nm, respectively. The number of Co/Pd periods N was changed from 10 to 50. Pd underlayer with its thickness t_{Pd} ranging from 0 to 20 nm were prepared for $[Co/Pd]_{20}$ multilayers. In order to clarify the relationship between magnetic properties and roughness of Co and Pd layers, Co and Pd layers were deposited at different P_{Ar} of 1 mTorr and 30 mTorr in $[Co/Pd]_{20}$ multilayers. Surface roughness R_a and average grain size D were evaluated from Atomic Force Microscopy (AFM) observation.

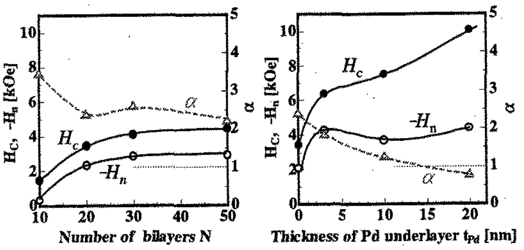
3. RESULTS AND DISCUSSION

3.1 Difference between increase N and attaching Pd

Figure 1 shows the changes of nucleation field H_n, coercivity H_c and a loop gradient factor $\alpha(=4\pi(dM/dH)_{@H=Hc})$ of $[Co(0.2\ nm)/Pd(0.6\ nm)]_N$ and $[Co(0.2nm)/Pd(0.6\ nm)]_{20}/Pd(t_{Pd}\ nm)$, respectively. Although H_c, H_n and α change gradualy while N increased from 10 to 20, they didn't change too much for further N. On the contrary, they changed drastically when Pd underlayer was prepared even though t_{Pd} was as small as 3 nm. Pd underlayer was so effective to attain higher H_c and smaller α.

Figure 2 shows AFM images of $[Co(0.2\ nm)/Pd(0.6\ nm)]_N$ and $[Co(0.2\ nm)/Pd(0.6\ nm)]_{20}/Pd(t_{Pd}\ nm)$. In both cases, surface becomes rough with increase of film thickness but their tendencies were quite different each other. When N was increased, D enlarged mainly and when t_{Pd} was increased, R_a was increased drastically. These results are confirmed from the TEM images of multilayers such as for $[Co(0.2\ nm)/Pd(0.6\ nm)]_{20}/Pd(3\ nm)$ as shown in Fig.3.

Figure 4 and 5 show changes of R_a and reciprocal of α, D and H_n of $[Co\ (0.2\ nm)/Pd\ (0.6\ nm)]_N$ and $[Co\ (0.2\ nm)/Pd\ (0.6\ nm)]_{20}/Pd\ (t_{Pd}\ nm)$ as a function of the total thickness T, respectively. We took reciprocal of α to simplify relationship. According to these two figures, R_a and α seem to have strong relationship. Increase of roughness R_a seems to make isolation of grains and decrease of exchange coupling, resulting to decrease of α in M-H loop. D and H_n have a weak relationship, too.



(a) $[Co/Pd]_N$ (b) $[Co/Pd]_{20}/Pd(t_{Pd}\ nm)$

Fig.1 Changes of H_c, H_n and α (a) as a function of N for $[Co(0.2nm)/Pd(0.6nm)]_N$ films and (b) as a function of t_{Pd} for $[Co(0.2\ nm)/Pd(0.6\ nm)]_{20}/Pd(t_{Pd}\ nm)$ films.

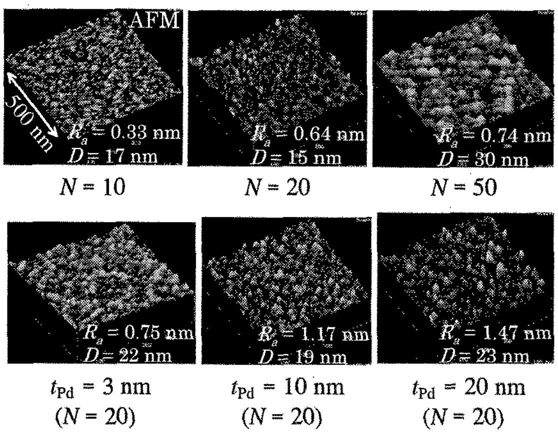


Fig.2 AFM images of [Co(0.2 nm)/Pd(0.6 nm)]$_N$ and [Co(0.2 nm)/Pd(0.6 nm)]$_{20}$/Pd(t_{Pd} nm).

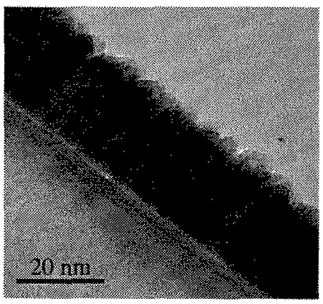


Fig.3 TEM image of [Co(0.2nm)/Pd(0.6nm)]$_{20}$/Pd (3 nm).

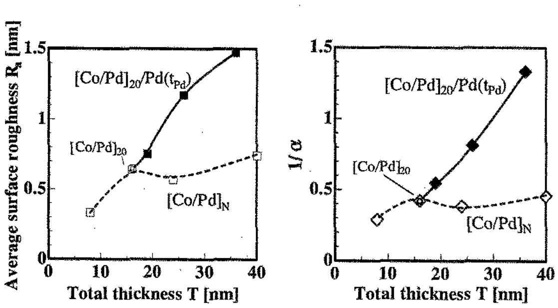


Fig. 4 Changes of the surface roughness R_a and reciprocal of α of [Co(0.2 nm)/Pd(0.6 nm)]$_N$ and [Co(0.2 nm)/Pd(0.6 nm)]$_{20}$/Pd(t_{Pd} nm) multilayers as a function of the total thickness.

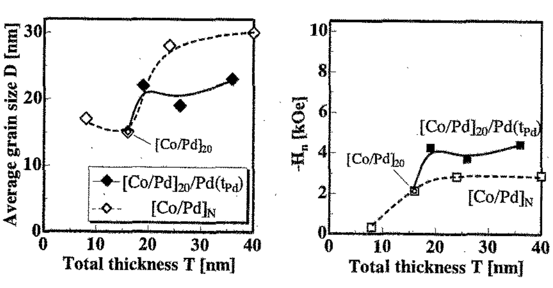


Fig. 5 Changes of the grain size D and $-H_n$ of [Co (0.2 nm)/Pd(0.6 nm)]$_N$ and [Co(0.2 nm) /Pd(0.6 nm)]$_{20}$/Pd(t_{Pd} nm) multilayers as a function of the total thickness.

3.2 [Co/Pd]$_{20}$ deposited at various P_{Ar} for each layer

In order to clarify the effect of process conditions that affect the surface roughness and grain size of the multilayer, Ar gas pressure P_{Ar} of the each layer during the deposition changed individually. Figure 6 shows perpendicular M-H loops of [Co(0.2 nm)/Pd(0.6 nm)]$_{20}$ deposited at various P_{Ar} of 1 mTorr and 30 mTorr for each layer. When Pd layer was deposited at P_{Ar} of 1 mTorr, the multilayer didn't reveal high H_c. AFM images of the films were shown in Fig.7. The film deposited both layers at 30 mTorr is already indicated in Fig.1 (N = 20). It is clearly observed that the deposition of Pd layers at 30 mTorr enhances surface roughness of the multiulayers. High H_c of the films may be attributed to the surface roughness. Meanwhile, when Co and Pd layers were deposited at P_{Ar} of 1 and 30 mTorr, respectively, the film exhibited high squareness ratio S and H_c, but α of the film was quite high. Since the high α means higher exchange coupling between grains in the films, the continuity in Co layers seems to enhance exchange coupling. It is found that higher P_{Ar} condition during Pd deposition is essentially required to attain high H_c. Fig.8 shows XRD diagram of Co and Pd monolayers and [Co(0.2nm)/Pd(0.6nm)]$_{20}$ multilayers, in which Co and Pd layers were deposited at different P_{Ar}. It is observed that Co in multilayers induced the shift of Pd (111) peak which indicates the expansion of Pd lattice. The deposition of Co thin layers at P_{Ar} of 1 mTorr seem to cause large expansion of Pd lattice.

Figure 9 and 10 show AFM images and M-H loops of [Co(0.2nm)/Pd(0.6nm)]$_{20}$/Pd (20 nm), in which multilayers were deposited at 1 mTorr and Pd underlayers at different P_{Ar}, respectively. The film without underlayer is already indicated in Fig.6 (Co: 1 mTorr, Pd: 1 mTorr).

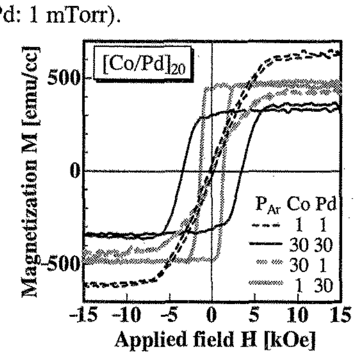


Fig.6 Perpendicular M-H loops of [Co(0.2nm)/Pd(0.6nm)]$_{20}$ multilayers, in which Co and Pd layers were deposited at different Ar gas pressure P_{Ar}.

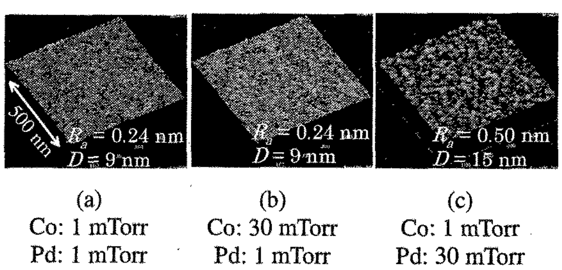


Fig.7 AFM images of [Co(0.2nm)/Pd(0.6nm)]$_{20}$ multilayers, in which Co and Pd layers were deposited at different Ar gas pressure P_{Ar}.

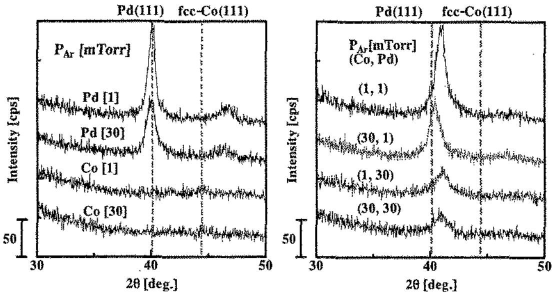


Fig.8 XRD diagrams of (a) Co and Pd monolayers and (b) $[Co(0.2nm)/Pd(0.6nm)]_{20}$ multilayers, in which Co and Pd layers were deposited at different Ar gas pressure P_{Ar}.

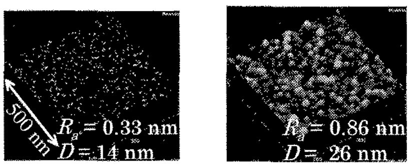


Fig.9 AFM images of $[Co(0.2nm)/Pd(0.6nm)]_{20}/Pd$ (20 nm), in which multilayer were deposited at 1 mTorr and Pd underlayers at (a)1 mTorr or (b)30 mTorr

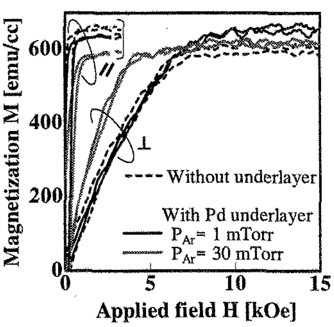


Fig.10 M-H loops of $[Co(0.2nm)/Pd(0.6nm)]_{20}/Pd$ (20 nm), in which multilayers were deposited at 1 mTorr and Pd underlayers at various P_{Ar}.

R_a and D of the multilayer deposited on the Pd layer at P_{Ar} of 30 mTorr exhibited large values which indicates the enhancement of roughness. The roughness induced by the underlayer seems to cause the slight increase of perpendicular magnetic anisotropy, since the inclination of perpendicular magnetization characteristic became slightly steep. However, the film deposited on the rough underlayer didn't reveal perpendicular H_c and high squareness ratio. Since the morphological continuity in the Co/Pd multilayers deposited at P_{Ar} as low as 1 mTorr are regarded as very high, high perpendicular H_c and H_n could not be obtained even if the roughness is induced from the underlayers. It is clarified that the discontinuity of the grains during the deposition is essentially required to high perpendicular H_c and H_n.

4. CONCLUSION

It was found that higher P_{Ar} condition during Pd deposition is essentially required for appearance and further increase of H_c, addition of Pd underlayer is more effective than increase of the number of periods N. We focused on grain size D and roughness R_a for film surface parameters which induces magnetic properties suitable as perpendicular magnetic recording media. There was a strong relationship between R_a and α. Large R_a caused the decrease of α. It is concluded that increasing of roughness, which is induced during the film formation by high pressure deposition condition seems to make isolation of grains and decrease of exchange coupling, resulting to decrease of α in perpendicular M-H loop.

REFERENCE

[1] T. Onoue, J. Kawaji, K. Kuramochi, T. Asahi and T. Osaka, *J. Magn. Magn. Mat.* 235, 82-86 (2001).
[2] J. Geshev, A. Morrone and J.E. Schmidt, *J. Magn. Magn. Mat.* 226-230, 1711-1713, (2001).
[3] S. Hashimoto and Y. Ochiai, *J. Magn. Magn. Mat.* 88, 211-226 (1990).

(Received October 8, 2003; Accepted January 22, 2004)