CHARACTERIZATION OF MAGNETIZATION BEHAVIOR IN Co/Pd PERPENDICULAR ANISOTROPIC MULTILAYERS

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Abstract - Magnetization behavior of sputter-deposited Co/Pd multilayers were characterized, and it has been found that even when the multilayers are sputtered at low pressure(10 mTorr), the coercivity of the multilayers can be increased to large extent without noticeable change of saturation magnetization by increasing the deposition pressure of Pd underlayer. It turned out that the surface topology of Pd underlayer gets rough as deposition pressure increases, which consequently affects the magnetization reversal mode of Co/Pd multilayers from domain wall motion to magnetic spin rotation. The enhancement of coercivity is attributed to the domain wall pinning effect which is connected with the surface roughness of Pd underlayer on which Co/Pd multilayers grow.

I. INTRODUCTION

In the last decade, Co/Pd and Co/Pt multilayers have been actively studied because of their novel properties and technological potentials especially for high density magneto-optical recording. The interest on these multilayers stems from their strong perpendicular magnetic anisotropy, large Kerr rotation angle in the blue wavelengths, and good corrosion resistance[1-4]. However, when these multilayers are fabricated by sputtering method using Ar gas, which is most commonly used in sputtering process, they show unattractively low coercivity and perpendicular magnetic anisotropy compared with the ones prepared by evaporation technique[2]. Since sputtering method is preferred in manufacturing, it is important to develop a sputtering process that can produce the multilayers showing better magnetic properties.

It has been reported that Co/Pd multilayers deposited at high Ar pressure(>20 mTorr) show high coercivity by domain wall pinning mechanism which results from the change of microstructure[3,4], and the predominant mode of magnetic reversal of the film changes from domain wall motion to spin rotation as sputtering pressure increases[5]. But Kerr rotation angle of the film deposited at high pressure is small because of lower saturation magnetization value compared the one deposited at low pressure and the optical noise in disks deposited at high pressure is unacceptably high[2]. Coercivity of the multilayers can also be enhanced by using the metallic underlayers such as Pd or Pt. These underlayers are known to increase the coercivity by enhancing the perpendicular anisotropy energy of the multilayer which is caused by the improvement of (111) texture of the film[3]. But too thick metallic underlayers are undesirable from an optical viewpoint and the multilayers deposited on thick Pd or Pt underlayers show small Kerr rotation angle[4].

In this work, we first examined about the effect of sputtering pressure on the magnetization behavior of ultrathin Co/Pd multilayers which were deposited on the glass substrates with or without Pd predeposition layer, and then found out that even when these multilayers are prepared at low Ar pressure(10 mTorr), the coercivity of the multilayers can be enhanced to great extent without noticeable change of saturation magnetization value by increasing the sputtering pressure of Pd underlayer.

II. EXPERIMENTAL

$[Co(4Å)/Pd(10Å)]_{15}$ multilayers were fabricated by rf magnetron sputtering with or without 100 Å Pd underlayer on the glass substrates. The chamber was evacuated with a turbo molecular pump to below 5×10^{-7} Torr prior to sputtering, and the Ar gas presure during the sputtering was varied from 5 to 20 mTorr. When we concentrated on the effect of Pd underlayer, Co/Pd multilayers were deposited at constant 10 mTorr. The structure and surface morphology were characterized with X-ray diffraction (Cu Kα) and atomic force microscopy (AFM), respectively, and the magnetic properties were analyzed with vibrating sample magnetometer (VSM). Perpendicular magnetic anisotropy K_u was determined from the area between perpendicular and parallel(in-plane) magnetization curves. Angular variation of coercivity was measured in order to investigate about the magnetic reversal feature[6,7], and the two remanence curves (IRM and DCD) were also measured to understand the magnetization behavior. The isothermal remanence magnetization (IRM) curve is a measurement of the remanence magnetization obtained as a function of the magnetizing filed applied to an originally ac-demagnetized film and the DC demagnetization (DCD) curve is a measurement of the remanence after the application of a demagnetizing field to an initially saturated sample[8,9].

III. RESULTS AND DISCUSSION

Sputtering pressure effect on the coercivity of $[Co(4Å)/Pd(10Å)]_{15}$ multilayers is shown in Fig. 1. As can be seen in the figure, the coercivity increased to great extent by increasing the sputtering pressure, and in case of using the Pd underlayer, the coecivity enhancement effect was much more remarkable. Since the degree of coercivity enhancement by Pd underlayer increased as the sputtering pressure increased, it can be thought that the Pd underlayer deposited at higher Ar pressure has stronger effect on the coercivity of Co/Pd multilayers. Fig. 2 shows the initial magnetization curves of the multilayers shown in Fig. 1. It can be noticed that saturation magnetization value decreases and domain wall motion becomes more difficult as the sputtering pressure increases, which is consistent with the previous reports by other researchers[3,4]. Interesting feature in Fig. 2 is that domain wall pinning effect is more serious in case of the multilayers deposited on the Pd underlayer compared with the one deposited directly on the glass substrate, therefore, it is inferred that the increase of coercivity by Pd underlayer could be closely related to the domain wall pinning effect. Since it is generally accepted that Pd underlayer contributes to the increase of coercivity by enhancing the perpendicular uniaxial anisotropy of the film, which is connected with the improvement of (111) texture of the sample[3], we can think that Pd underlayer can contribute to increasing the coercivity of the multilayers by two different mechanisms, namely the enhancement of perpendicular anisotropy and the domain wall pinning effect.

To investigate which one is the more dominant factor in terms of the contribution to increasing the coercivity of the multilayers when Pd underlayer is predeposited, we prepared Pd underlayers sputtered at different pressure ranging from 5 to 20 mTorr, and then deposited Co/Pd multilayers at constant 10 mTorr on them. Fig. 3 shows the effect of sputtering pressure of Pd underlayer on the perpendicular M-H curves and initial magnetization curves of [Co(4Å)/Pd(10Å)]$_{15}$/Pd(100Å). As the deposition pressure during the formation of Pd underlayer increased, coercivity increased monotonically (upper part of Fig.3) and pinning effect of domain wall in the early stage of magnetization process gets more serious(lower part of Fig.3).

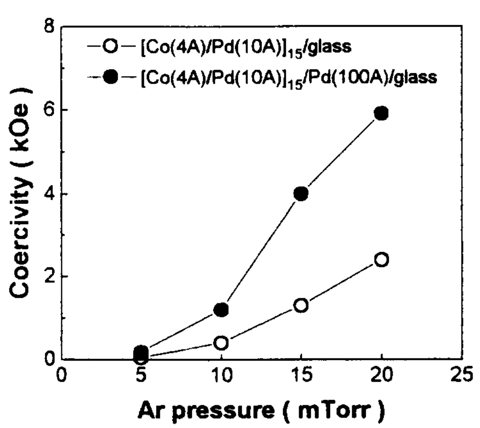

Fig. 1 Effect of sputtering pressure on the coercivity of [Co(4Å)/Pd(10Å)]$_{15}$/Pd(0, 100Å) multilayers.

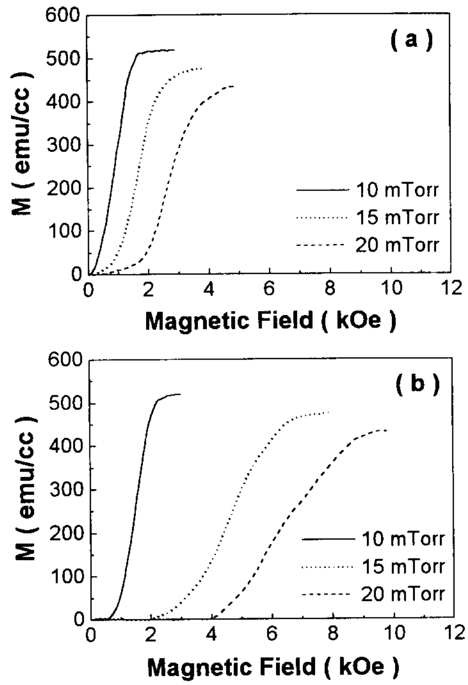

Fig. 2 Initial magnetization curves of [Co(4Å)/Pd(10Å)]$_{15}$ multilayers deposited at different sputtering pressure. (a) without Pd underlayer (b) with 100 Å Pd underlayer.

Surface morphologies of 100 Å thick Pd layers deposited at different pressure are shown in Fig. 4. It can be clearly seen in Fig. 4 that the surface topology of Pd layer deposited at 20 mTorr is much rougher than that of one sputtered at 5 mTorr, which is thought to be closely connected with the strong wall pinning effect in the multilayers grown on the Pd layer deposited at 20 mTorr.

Dependence of perpendicular magnetic anisotropy energy K_u on the sputtering pressure of Pd underlayer is shown in Fig. 5. Since K_u decreases as sputtering pressure of Pd underlayer increased, it is inferred that the increase of coercivity is mainly caused by domain wall pinning mechanism and perpendicular anisotropy energy is not a major factor that contribute to the enhancement of the coercivity.

Variation of coercivity with respect to the angle between the direction of the applied magnetic field and the film normal direction of the film is shown in Fig. 6. The vertical axis is the reduced coercivity normalized by the easy axis(perpendicular) coercivity. For the multilayers prepared on the Pd underlayer deposited at 5 mTorr, the reduced coercivity increased monotonically with the angle θ below 70°, which suggests that domain wall motion is the dominant magnetic reversal mode[7], and then decreased rapidly near the hard axis. As the deposition pressure of the Pd underlayer increased, the maximum value of the reduced coercivity near the hard axis gradually decreased, and in the case of the multilayers deposited on the underlayer prepared at 20 mTorr, the reduced coercivity decreased monotonically as θ increases, which implies that magnetic spin rotation is the dominant mode of magnetic reversal[7]. Therefore, it can be said that as the deposition pressure of the Pd underlayer increases, the predominant mode of magnetization reversal changes from domain wall motion to magnetic spin rotation.

In order to investigate about the magnetization behavior of the multilayers in more detail, two remanence magnetization curves(DCD and IRM) were measured and then δM plots were obtained(Fig. 7) from the two remanence magnetization curves[8,9] As shown in this figure, all the samples show a small positive peak of δM at a magnetic field less than H_c and a large negative peak at a field higher than H_c, which suggests that the negative magnetostatic interaction is stronger than the ferromagnetic coupling between the magnetic grains[10] and it can also be noticed that absolute value of positive peak as well as negative peak decreases slightly as the sputtering pressure of the Pd underlayer increases, which implies that the intergranular interaction between the magnetic grains in the multilayers becomes weaker as the deposition pressure of Pd underlayer increases.

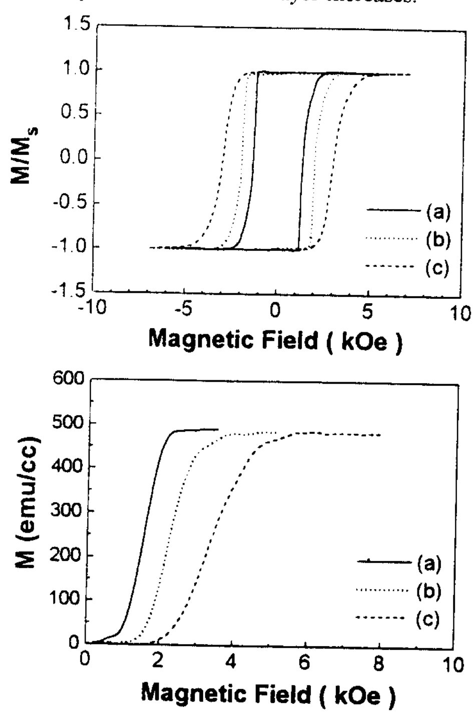

Fig. 3 Dependence of M-H curves and initial magnetization curves of $[Co(4Å)/Pd(10Å)]_{15}/Pd(100Å)$ films on the sputtering pressure of Pd underlayer. (a) 5 (b) 10 (c) 20 mTorr.

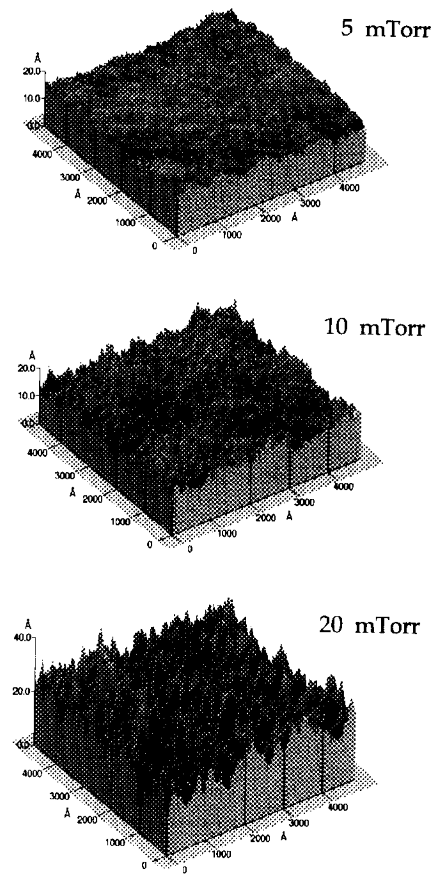

Fig. 4 Change of surface topology of 100 Å thick Pd layer deposited on glass substrate as a function of sputtering pressure.

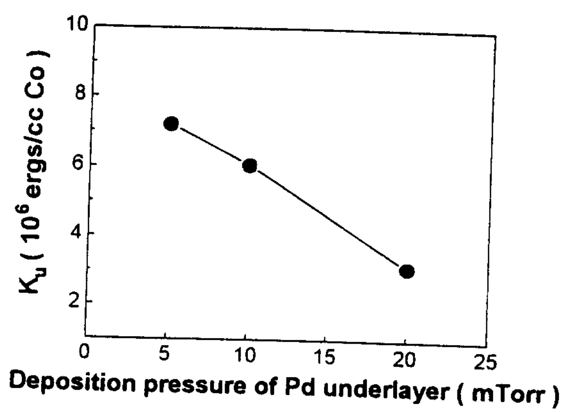

Fig. 5 Effect of sputtering pressure of Pd underlayer on the perpendicular magnetic anisotropy energy K_u of $[Co(4Å)/Pd(10Å)]_{15}/Pd(100Å)$ multilayers.

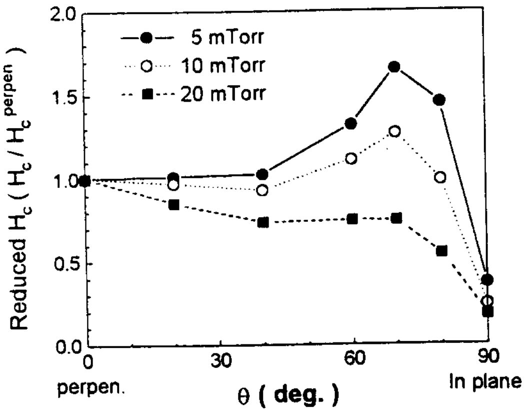

Fig. 6 Angular variation of coercivity of [Co(4Å)/Pd(10Å)]$_{15}$/Pd(100Å) multilayers with respect to the deposition pressure of Pd underlayer.

Weakening of the intergranular interaction should be closely connected with the change of film structure, but the detailed analysis on the layered structure of our samples has not been made yet, and further study on the film structure is required to elucidate the relationship between the film structure and magnetic characteristics of these multilayers.

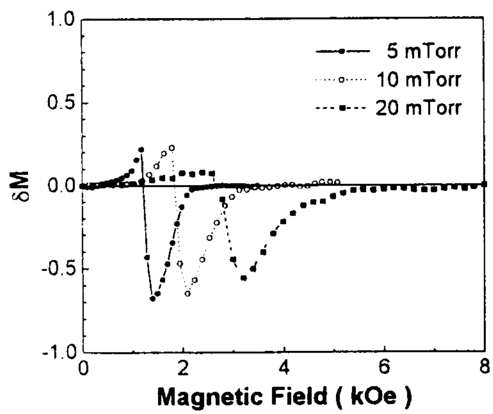

Fig. 7 Variation of δM (H) value as a function of deposition pressure of Pd underlayer.

IV. CONCLUSION

[Co(4Å)/Pd(10Å)]$_{15}$ multilayers were sputtered on the Pd underlayer deposited on the glass substrates, and the effects of deposition pressure during the formation of Pd underlayer on the magnetization behavior of Co/Pd multilayers were characterized. It has been found that even when the multilayers are sputtered at not so high pressure, the coercivity of Co/Pd multilayers can be increased remarkably without noticeable change of saturation magnetization by increasing the sputtering pressure of Pd underlayer. The enhancement of coercivity is attributed to the domain wall pinning effect, which is closely connected with surface roughness of Pd underlayer. It turned out that the predominant mode of magnetization reversal changes from the domain wall motion to the magnetic spin rotation with increase of the sputtering pressure of Pd underlayer, and δM plots indicate that the intergranular interaction between the magnetic grains in Co/Pd multilayers gets gradually weaker as the deposition pressure of Pd underlayer increases.

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