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Effects of Sputtering Parameters on the Properties of Co/Pd Multilayered Films

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Multilayered films of Co/Pd have been studied as a candidate material for a high density perpendicular recording medium due to higher anisotropy energy. However, high exchange coupling among grains results in large transition noise. To reduce the exchange coupling and grain size, addition of 3rd elements and physical separation of grains have been attempted. In the present paper, effects of sputtering pressure, Co sublayer thickness and Pd underlayer thickness on magnetic properties and microstructures were studied. It was found that by increasing sputtering pressure from 5 mTorr to 25 mTorr, *Ms* decreased to one half and coercivity increased more than 5000 Oe. The increase of the coercivity is associated with physical separation of grains by high pressure sputtering. *Ms* per volume of Co for Co/Pd multilayered film deposited at 25 mTorr shows continuous decrease with increasing Co sublayer thickness. This was related to void formation and intermixing of Co/Pd interface. Also, effect of Pd underlayer thickness on magnetic properties will be discussed.

Key words : Co/Pd multilayer, sputtering pressure, Co sublayer, saturation magnetization

1. Introduction

Recently as recording density increases beyond 100 Gbit/inch^2, perpendicular magnetic recording is considered as an alternative for the present longitudinal recording. Even in perpendicular recording, thermal stability problem will become a critical issue as the recording density increases to ultra high density region provided the present CoCrPt type recording layers are used.

The Co/Pd multilayered films developed as magneto-optical recording media earlier are recently being studied as an alternative recording layer in double layered perpendicular recording media due to its high saturation magnetization (*Ms*), high perpendicular anisotropy energy and high negative nucleation field.

However, high exchange coupling among grains induces transition noise. In order to overcome this problem, research works are concentrated on exchange decoupling and grain size reduction. There are two approaches to achieve these goals; a third element addition and underlayer control. As third elements B [1] or Cr is added in Co layer, to segregate B and Cr into grain boundaries. In order to increase physical separation, the unique underlayers were used as ITO [2], Pd-SiN, Au-SiO_2, Pd-SiO_2 and Ag-Al_2O_3 type granular layers [3] and C layer [4].

In the present paper, effects of sputtering pressure, Co sublayer thickness and Pd underlayer thickness on magnetic properties and microstructural change were studied.

2. Experimental

Deposition of Co/Pd multilayered films was done at room temperature by a D.C. magnetron sputtering system controlled by a computer on thermally oxidized Si substrates. DC power of 10 W was used for 4 inch target guns. Thickness of each layer was determined at first by a linear fitting of thickness as a function of sputtering time and the thickness of Co/Pd bilayer was calibrated by low angle x-ray diffraction. By this calibration we could make more precise control of each layer thickness. Magnetic properties were measured by VSM at room temperature and microstructure was examined by TEM.

3. Results and Discussion

Magnetic properties of Ti(5 nm)/Pd(20 nm)/[Co(0.5 nm)/Pd(0.9 nm)]$\times$25 deposited at 5 and 25 mTorr sputtering pressure were appeared in Fig. 1. By increasing sputtering pressure from 5 mTorr to 25 mTorr, *Ms*

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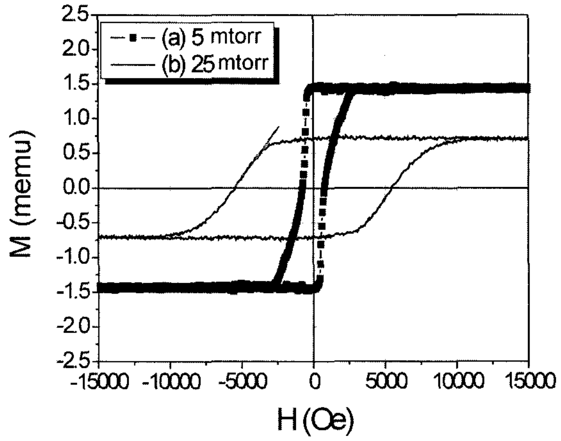

Fig. 1. Hysteresis loops of Co/Pd multilayered films deposited at (a) Ar 5 mTorr (b) Ar 25 mTorr.

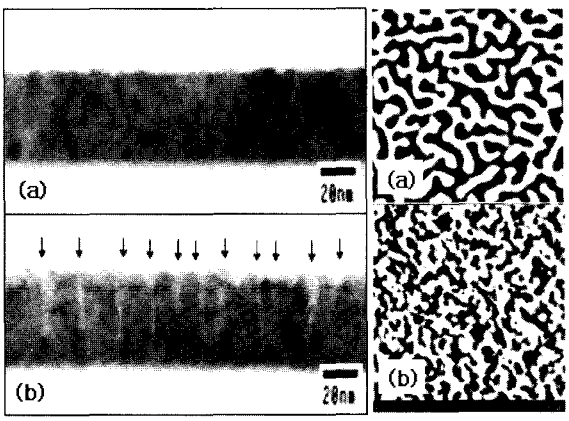

Fig. 2. Cross sectional TEM images and ac-erased MFM images (3×3 μm) of Co/Pd multilayered films at (a) Ar 5 mTorr (b) Ar 25 mTorr.

decreased from 510 emu/cc to 210 emu/cc, coercivity increased from 743 Oe to 5520 Oe. However, the most drastic change in the hysteresis loop is the decrease of exchange slope. The change of exchange slope is associated with physical separation of columns by high pressure deposition as shown in Fig. 2. The column size could be reduced to around 20 nm size by the physical separation. However, the domain size of 137 nm observed by MFM is much larger than the observed column size. This may indicate some strong magnetic interaction among columns due to incomplete separation. According to the formula proposed by Carcia *et al.* [5] the surface anisotropy energy, Ks of 0.32 and 0.106 mJ/m^2 and bulk anisotropy energy, Kv of -0.87 and -0.24 J/m^3 were obtain for 5 mTorr and 25 mTorr, respectively. These values indicate severe intermixing between Co and Pd layer due to the high sputtering pressure and the intermixing is supported by the drop in *Ms* at the 25 mTorr specimen.

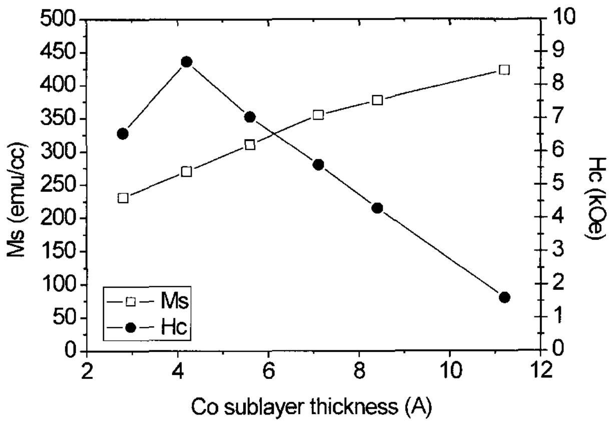

Fig. 3. Dependence of coercivity (Hc) and saturation magnetization (Ms) on the Co sublayer thickness at Ar 25 mTorr sputtering pressure.

In order to study the effect of Co sublayer on magnetic properties of the multilayered film, Ti(5 nm)/Pd(20 nm)/[Co(t nm)/Pd(0.9 nm)]×25 layer was studied by varying the Co sublayer thickness from 0.28 nm to 1.12 nm at 25 mTorr deposition. These results are summarized in Fig. 3. As shown in Fig. 3, coercivity shows the maximum value at the thickness of 0.42 nm and decreased with further increase of the Co sublayer thickness. However, as the Co sublayer thickness increases, *Ms* of the Co/Pd multilayered film increases. When *Ms* per volume of Co is separated for the specimens, *Ms* is decreasing with the Co sublayer thickness increase as shown in Fig. 4. In the Fig. 4, *Ms* of bulk Co and of 0.42 nm Co sublayer for the films with the same structure deposited at 5 mTorr are plotted as reference. It is shown that *Ms* of 0.42 nm Co sublayer deposited at 5 mTorr is higher than that of the bulk Co value. This is consistent with that fact that the nearest neighboring Pd is magnetized when Co/Pd

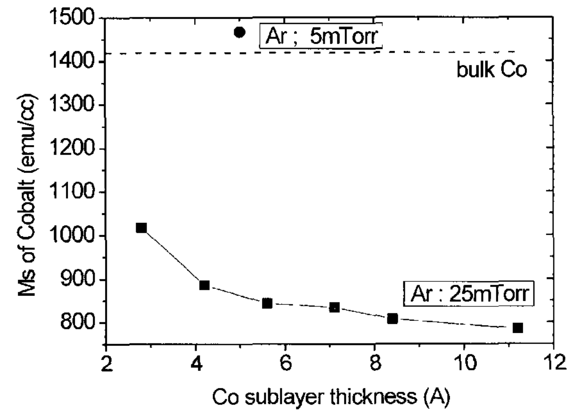

Fig. 4. Dependence of Ms (emu/volume of Co) on the Co sublayer thickness at Ar 25 mTorr sputtering pressure.

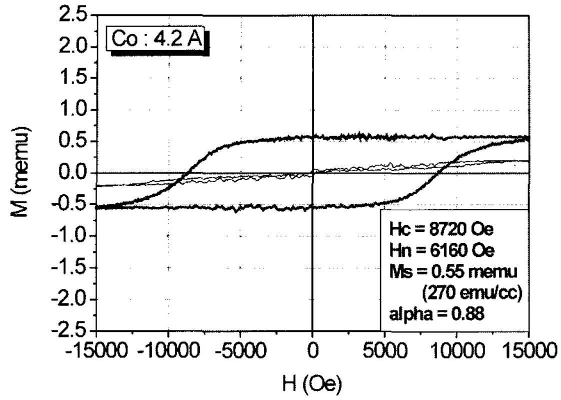

Fig. 5. Hysteresis loop of Ti(5 nm)/Pd(20 nm)/[Co(0.42 nm)/Pd(0.9 nm)] × 25 layer.

interface are more flat and Co sublayer thickness is very thin as have been published [6, 7]. However, *Ms* of Co sublayer in the multilayered films deposited at 25 mTorr shows a continuous decrease of *Ms* per volume of Co from 1000 emu/cc to 800 emu/cc. Generally the decrease of *Ms* at the high pressure is associated partly with void formation. Another reason for the decrease of *Ms* must be associated with intermixing of Co and Pd due to rough surface formation. As the Co sublayer thickness increases number of magnetized Pd atoms per Co atom will decrease and this can contribute to the *Ms* decrease. However, this is applicable for the lower pressure deposition case. Therefore, we conclude the intermixing is another reason for the *Ms* decrease in the present case. The coercivity decrease with increasing Co sublayer thickness is related to the reduction number of interface layer which contributes to perpendicular anisotropy of the strong surface anisotropy. An example of hysteresis loop for a Ti(5 nm)/Pd(20 nm)/[Co(0.42 nm)/Pd(0.9 nm)] × 25 layer is shown in Fig. 5.

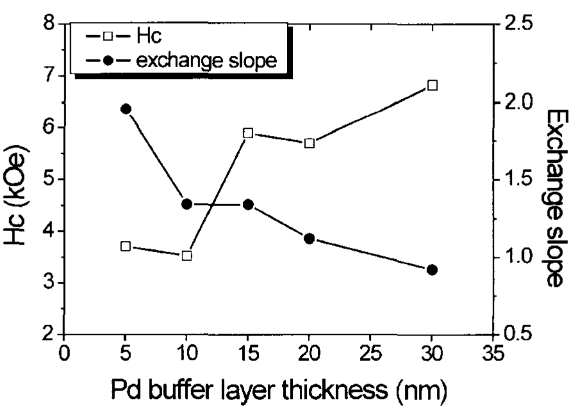

Fig. 6. Dependence of Hc and exchange slope on Pd buffer layer thickness for Co/Pd multilayered films at 25 mTorr sputtering pressure.

Effects of Pd buffer layer thickness on the properties of Co/Pd multilayered films have been investigated. For this purpose Ti(5 nm)/Pd(t nm)/[Co(0.5 nm)/Pd(0.9 nm)] × 25 multilayered films were made at 25 mTorr sputtering pressure. As Pd buffer layer thickness increased from 5 nm to 30 nm, coercivity of the film increased from 3710 Oe to 6835 Oe and the exchange slope decreased from 1.96 to 0.92 as shown in Fig. 6. The increase of coercivity and the decrease of exchange slope are associated with enhanced physical separation among columns as the Pd buffer layer thickness increases. As the buffer layer thickness increased, the surface roughness of the buffer layer increased. This induced the enhanced physical separation of the columns at 25 mTorr sputtering.

4. Conclusion

By increasing sputtering pressure from 5 mTorr to 25 mTorr, physically separated columns were formed resulting in the increase of coercivity and the decrease of exchange slope of Co/Pd multilayered films. By increasing Co sublayer thickness in Co/Pd multilayered film deposited at 25 mTorr, coercivity showed maximum around 0.42 nm range and monotonically decrease with increasing Co sublayer thickness. *Ms* per volume of Co continuously decreased with increasing Co sublayer thickness. The *Ms* decrease is due to void formation and intermixing of Co/Pd interface. As Pd buffer layer thickness increased, coercivity of the film increased and the exchange slope decreased. This is probably due to enhanced physical separation among columns as the Pd buffer layer thickness increases.

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