PERPENDICULAR MAGNETIC ANISOTROPY AND MAGNETO-OPTICAL PROPERTIES IN Fe(Co)/Pt MULTILAYER FILMS

S. Iwata*, H. Notarys, S. S. P. Parkin and T. Suzuki

IBM Research Division, Almaden Research Center,
650 Harry Road, San Jose, CA 95120-6099, U.S.A.

*Dep. Electronics, Nagoya University, Nagoya, Japan

Abstract- A systematic study on structure, magnetic and magneto-optical properties of Fe/Pt and FeCo/Pt multilayer films has been performed. It is found that the microstructure observed by cross-sectional TEM as well as the effective perpendicular anisotropy K_{eff} varied according as substrate-deposition-temperature. In Fe/Pt multilayer film deposited on the substrate above room temperature, a fine columnar structure were discerned and the perpendicular anisotropy was fairly large. In the sample grown on a cooling substrate, however, the structure with irregular small crystal grains appeared instead of a columnar structure and the K_{eff} reduced. This result implies that the columnar microstructure contributes to the perpendicular anisotropy of multilayer films.

KEYWORDS : MULTILAYER, PERPENDICULAR ANISOTROPY, MAGNETO-OPTICS, COLUMNAR STRUCTURE, CURIE TEMPERATURE

INTRODUCTION

Since Co/Pt and Co/Pd multilayer films exhibit a strong perpendicular magnetic anisotropy and a large magneto-optical Kerr effect at short wavelength [1,2], they are considered to be potential candidates for magneto-optical recording media at a blue-wavelength. On the other hand, although Fe/Pt multilayers also exhibit a perpendicular anisotropy and an enhancement of Kerr rotation at short wavelength, the magnitude of the anisotropy is not sufficient for practice use as a magneto-optical recording media [3-5]. The origin of the perpendicular anisotropy in transition metal and novel metal multilayer films is considered to be magnetocrystalline surface anisotropy [6] and magneto-elastic effect at the interfaces [7,8]. However, a very little work has been made on the correlation between the perpendicular anisotropy and the microstructure of the films[9,10].

The present paper describes a detailed results of magnetic and magneto-optical properties of Fe/Pt and FeCo/Pt multilayer films. In particular, to reveal the origin of the anisotropy, we investigated the substrate-deposition-temperature dependence on the anisotropy and the microstructure.

EXPERIMENTAL

Fe/Pt multilayer films were prepared onto glass (Corning #7059), fused quartz and Si substrates by electron-beam evaporation method. The base pressure before deposition was $1.0\sim 1.6\times 10^{-8}$ torr and the pressure during the deposition was better than 5×10^{-8}

torr. The deposition rate was $0.10\sim 0.20\text{\AA}/\text{s}$ for the Fe layers and $0.35\sim 0.40\text{\AA}/\text{s}$ for the Pt layers. The substrate-deposition-temperature T_s was varied from -165°C to 220°C . The first layer is Fe and the surface layer is Pt.

(Fe₅₀Co₅₀)/Pt multilayer films were prepared by dc sputtering deposition onto 50Å Pt buffer layer deposited on Si substrate. The number of the bilayers was 30 and the thickness of the final Pt layer was fixed to 30Å.

The crystallographical structure was examined by XRD. The magnetic properties were obtained from VSM and torque magnetometer. The cross-sectional transmission electron microscopy (TEM) were used to examine the microstructure of the films.

RESULTS AND DISCUSSION

A. Perpendicular Anisotropy for Fe/Pt and FeCo/Pt multilayer Films

Figure 1 shows the Fe and FeCo thickness t dependence of tK_{eff} , where K_{eff} is the effective perpendicular anisotropy constant per unit Fe and FeCo volume, which corresponds to the torque amplitude at 20 kOe. For the Fe/Pt, although perpendicular magnetized films are obtained for the Fe layer thickness less than 3Å, the magnitude of perpendicular anisotropy is rather small. The K_{eff} for FeCo/Pt multilayer films is improved compared to Fe/Pt [11]. However, it still smaller than that for Co/Pt multilayers [2].

Fig. 1. Magnetic layer thickness t dependence of Effective perpendicular anisotropy K_{eff} times t for Fe/Pt, FeCo/Pt and Co/Pt [2] multilayer films.

B. Microstructure and Perpendicular Anisotropy

Figures 2 (a) and (b) show the low and wide angle XRD patterns for $2.5\text{ÅFe}/18\text{ÅPt} \times 40$ films, respectively, where the substrate-deposition-temperature T_s was varied as a parameter. Figures 3 (a)~(c) show the cross-sectional TEM images for the films shown in Fig.2. In the photograph of the film grown at 18°C , the columnar structure with $80\sim 150\text{Å}$ width can be seen and the multilayered structure can be also observed within the columns. The similar structure in sputtered Co/Pd multilayer films has been reported by Hashimoto et al. [9].

The sample grown at 220°C exhibits more densely columnar structure as shown in Fig.3(a). The dense structure and processed crystallization obtained from the heating of substrate result in higher XRD peak of fcc (111) texture compared to the film grown at 18°C . On the other hand, the multilayer structure can be discerned no longer in the TEM image in Fig.3(a), which is considered to be caused by interdiffusion at the surface between Fe and Pt layers. The occurrence of interdiffusion in the films prepared on heated substrates would be supported by the fact that the Curie temperature of the Fe/Pt multilayers decreases as increasing T_s as shown in Fig.4 (a). However, the low angle XRD peak arising from artificial periodic structure can be clearly seen in Fig.2 (a), which implies that the compositionally modulated structure is still preserved in spite of the interdiffusion in the high T_s samples.

In the film prepared onto cooling substrate shown in Fig 3(c), small irregular crystal grains with $80\text{Å}\sim 120\text{Å}$

Fig.2. Low and wide angle XRD patterns for $(2.5\text{ÅFe}/18\text{ÅPt}) \times 40$ films with various substrate-deposition-temperature T_s .

can be observed instead of the columnar structure and the intensity of fcc (111) peak becomes smaller as shown in Fig.2(b). It is also confirmed through XRD rocking curve shown in Fig.5 that the dispersion of (111) orientation increases as decreasing T_s .

The effective perpendicular anisotropy K_{eff} measured at 77K and 293K strongly depends on T_s as shown Fig.4(b). One possible mechanism accounting for this T_s dependence of K_{eff} is due to the magneto-elastic contribution through stress between the substrate and the film as reported in [5]. However, the influence of the microstructure of the films on the anisotropy should not be ignored. The disappearance of the columnar structure and the increment in dispersion of the (111) orientation in the low T_s sample would be one cause of the decrement of K_{eff} . In the high T_s range, the variation in K_{eff} is very small in spite of the following consideration. If the major part of the origin of the perpendicular anisotropy is magnetocrystalline surface anisotropy or magneto-elastic effect at the interfaces, the occurrence of the interdiffusion would affect the anisotropy. For this problem, further investigation should be required.

C. Magneto-Optical Kerr Effect

Figure 6 shows the wavelength dependence of Kerr rotation angle θ_k for Fe/Pt and FeCo/Pt multilayer films. The θ_k of FeCo/Pt takes a maximum around 290nm, which is similar to those of Fe/Pt and Co/Pt [12] multilayers. Comparing the θ_k spectra for the films of $3\text{ÅFeCo}/10\text{ÅPt}$, $3\text{ÅFe}/9\text{ÅPt}$ and $3.4\text{ÅCo}/10.2\text{ÅPt}$

whose magnetic and Pt layer thickness are nearly same, the value of θ_k for FeCo/Pt is larger than that for Fe/Pt while it is smaller than that for Co/Pt in the whole region ($270 \leq \lambda \leq 800 \text{ nm}$).

SUMMARY

The correlation between the structure and the perpendicular anisotropy and magneto-optical properties of Fe/Pt and FeCo/Pt multilayer films were studied. It is found that the microstructure observed by

Fig.3. Cross-sectional TEM images for $(2.5\text{\AA}\text{Fe}/18\text{\AA}\text{Pt})\times 40$ films with various T_s .

Fig.4. Substrate-deposition-temperature T_s dependence of Curie temperature T_c , saturation magnetization M_s and effective perpendicular anisotropy K_{eff} for $(2.5\text{\AA}\text{Fe}/18\text{\AA}\text{Pt})\times 40$ films.

Fig.5. XRD rocking curve of fcc (111) texture for (2.5ÅFe/18ÅPt)×40 films.

Fig.6. Spectra of Kerr rotation angle θ_k for Fe/Pt, FeCo/Pt and Co/Pt [12] multilayer films.

cross-sectional TEM varied according as substrate-deposition-temperature T_s . The columnar structure with 80~150Å width was seen in Fe/Pt multilayer film prepared by electron-beam evaporation at room temperature. If the T_s was raised to 220°C, this becomes more densely columnar structure and the interdiffusion occurs. In contrast to this, in the sample grown on cooling substrate, the structure with small irregular crystal grains with 80~120Å in diameter appeared instead of columnar structure. The disappearance of columnar structure and the larger dispersion of (111) orientation are considered to be one cause of decrement of effective perpendicular anisotropy in low T_s samples.

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