Properties of Ion Beam Mixed Co/Pt Multilayered Films

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Ion beam mixing method, which has an advantage in forming a metastable alloy phase, was applied to Co/Pt multilayered films to produce an enhanced magneto-optical (MO) property, and the influence of external magnetic field during ion beam mixing on the property was investigated. Co/Pt multilayered films of [Pt(131Å)/Co(45Å)] ×4 and [Pt(88Å)/Co(88Å)] ×4 were prepared onto SiO₂ substrates by alternating electron-beam evaporation. Ion beam mixing by 80 keV Ar⁺ was carried out at various temperatures with and without external magnetic field. Polar MO Kerr effects were investigated by using Kerr spectroscopy at room temperature. The phase formation and intermixing of ion beam mixed Co/Pt multilayered films were determined using x-ray diffraction and Rutherford backscattering spectroscopy, respectively and showed a correlation with polar MO results.

Keywords: Co/Pt multilayered film, ion beam mixing, polar Kerr rotation angle, structure

1. Introduction

Co/Pt multilayered (ML) films have attracted great interest as a high density magneto-optical (MO) recording medium due to their large perpendicular magnetic anisotropy, large polar Kerr rotation angle at short optical wavelength, and good corrosion resistance. However, some technical difficulties in obtaining these enhanced properties still remain. The perpendicular magnetic anisotropy of the Co/Pt ML films, which is correlated with the polar MO properties, can be obtained only below a Co sublayer thickness of few monolayers. The thickness of Co sublayer must be exactly controlled to avoid a transition from perpendicular to in-plane magnetic anisotropy.

In this study, ion beam mixing (IBM) method, which has an advantage in forming a metastable alloy phase, was applied to the Co/Pt ML films to propose another way of producing the enhanced MO property. Recent researches have reported that the magnetic and MO properties of the Co/Pt ML films are correlated with the spin hybridization between Co 3d and Pt 5d and can be affected by their chemical structures. It was reported that IBM ML films show different electronic structures from those of thermodynamically stable alloy. An influence of external magnetic field on the MO property was also investigated.

2. Experiments

Co/Pt ML films of [Pt(131Å)/Co(45Å)] ×4 and [Pt(88Å)/Co(88Å)] ×4 were prepared onto SiO₂ substrates by alternating electron-beam evaporation. The typical deposition rate and base pressure were 0.84 Å/s and below 10⁻⁷ Torr, respectively. The thickness was chosen to match the calculated mean projected range of 80 keV Ar⁺ in Co and Pt layers by using TRIM code simulation. IBM by 80 keV Ar⁺ was carried out at various temperatures with and without external magnetic field. The strength of the external perpendicular magnetic field by a permanent magnet was 1.2 kOe.

The phase formation of films was analyzed by using glancing-angle x-ray diffraction (GXR). A monochromatized Cu Kα line at a wavelength of 1.5406 Å was used as an x-ray source. The intermixing between Co and Pt sublayers by IBM was confirmed by Rutherford backscattering spectroscopy (RBS) with a He⁺ ion beam at an incident angle of 10° from the surface normal. The energy of the He⁺ was 2.0 MeV after passing the tandem-typed pelletron accelerator. The MO polar Kerr rotation was measured at room temperature (RT) in a saturating field of 10 kOe by MO Kerr spectroscopy. The employed photon source was a Xe lamp (150 W : Hamamatsu, type L2175) for a wavelength range from 4000 to 7000 Å. InGaAs photocathode (Hamamatsu, R2655) was used as an optical detector.

3. Results and Discussion

Figure 1 shows the RBS spectra of the Co and Pt regions of the [Pt(88Å)/Co(88Å)] ×4 ML film before, and after IBM by 80 keV Ar⁺ at RT and 250°C. The high channel peaks of Co and Pt represent the top sublayers, while the lower ones are from the deeper sublayers. The deficiency in Pt area after IBM resulted from Ar⁺ sputtering, but the total film thickness after IBM was nearly the same as that before IBM. It can be seen that the sublayer intensities of Pt
Fig. 2 X-ray diffraction patterns of the (a) [Pt(88 Å)/Co(88 Å)]×4 and (b) [Pt(131 Å)/Co(45 Å)]×4 ML films before and after IBM. B means magnetic.

decrease and smear out after IBM at RT and 250°C, respectively. This reflects that the intermixing between Co and Pt sublayers occur by IBM and the mixing efficiency of IBM at 250°C is larger than that at RT. The [Pt(131 Å)/Co(45 Å)]×4 ML film showed the same trend as that of [Pt(88 Å)/Co(88 Å)]×4 (not shown here).

Figure 2 shows the GXRd patterns of the (a) [Pt(88 Å)/Co(88 Å)]×4 and (b) [Pt(131 Å)/Co(45 Å)]×4 ML films before and after IBM. The peaks at 40.2° and 46.1° of unmixsed samples are assigned to Pt (111) and (002), respectively. A shift of peaks to high angle are observed after IBM, which is associated with the formation of CoPt (111) and (002) texture. The lattice spacing (d_{111}) of the IBM [Pt(88 Å)/Co(88 Å)]×4 and [Pt(131 Å)/Co(45 Å)]×4 films are 2.20 and 2.23 Å, respectively, and these values are larger than those of the thermodynamic equilibrium CoPt and CoPt alloy films (2.16 and 2.21 Å, respectively). It was suggested that IBM ML films show a disordered alloy phase which is similar to that of a rapid quenched alloy from the melting temperature, and have different valence band structure from unimixed one. GXRd pattern of the [Pt(131 Å)/Co(45 Å)]×4 ML film after IBM at RT in a magnetic field reveals a quite different shape from the others in Fig. 2(b), while all the patterns of the [Pt(88 Å)/Co(88 Å)]×4 ML film show a similar shape for various experimental conditions. This reflects that the atomic transport of Co atoms by IBM is affected by an external magnetic field, which results in the formation of a disordered CoPt metastable phase.

Figure 3 is the polar Kerr rotation angles (θK) of the (a) [Pt(88 Å)/Co(88 Å)]×4 and (b) [Pt(131 Å)/Co(45 Å)]×4 ML films at various experimental conditions. The θK of both films before IBM is very small, even though that of [Pt(88 Å)/Co(88 Å)]×4 is slightly larger than that of [Pt(131 Å)/Co(45 Å)]×4. It seems to be that this low intensity comes only from the ferromagnetic Co sublayers, because the thickness of sublayer is too thick to induce the perpendicular magnetic anisotropy. It was reported that the transition of magnetic anisotropy from perpendicular to in-plane occurs, when the sublayer thickness of Co is larger than 9 Å. However, the θK of both films after IBM at RT increases dramatically in the overall wavelength range and these values are comparable to or larger than those of the Co/Pt ML and Co-Pt alloy films with a large perpendicular anisotropy at the corresponding wavelengths. This indicates that an alloy phase is induced by ion beam mixing, which is different from a thermodynamic equilibrium alloy phase
as mentioned in Fig. 2.

The $\Theta_K$ of the IBM [Pt(88Å)/Co(88Å)] × 4 ML film shows an insignificant change with various experimental conditions, while that of the IBM [Pt(131Å)/Co(45Å)] × 4 ML film increases with an external magnetic field, but decreases at 250°C. This seems to be due to a higher Curie temperature of [Pt(88Å)/Co(88Å)] × 4 than [Pt(131Å)/Co(45Å)] × 4. The corresponding compositions of the IBM [Pt(88Å)/Co(88Å)] × 4 and [Pt(131Å)/Co(45Å)] × 4 ML films are CoPt and CoPt$_3$, respectively, and Curie temperatures of CoPt and CoPt$_3$ are 800 and 480 K, respectively.$^{14,15}$ This also explains the decrease in $\Theta_K$ of the IBM [Pt(131Å)/Co(45Å)] × 4 at 250°C. The $\Theta_K$ of both films after IBM at RT increases with photon energy (decrease with optical wavelength). This behavior is strongly correlated with the spin-orbit coupling of the Pt 5$d$ electrons hybridized with the Co 3$d$ electrons, since a transition energy for the spin-polarized Pt 5$d$ electrons is 4.3 eV$^{16}$.

4. Conclusions

IBM method was applied to Co/Pt ML films to establish alternative way of producing the enhanced polar MO properties. The $\Theta_K$ of both [Pt(88Å)/Co(88Å)] × 4 and [Pt(131Å)/Co(45Å)] × 4 films after IBM at RT increased significantly in the overall wavelength range, even though the sublayer thicknesses of Co and Pt are so large that the perpendicular magnetic anisotropy was hardly obtained in the ML films before IBM. The overall MO results are strongly correlated with the formation of a metastable disordered phase by IBM.

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References