MAGNETO-OPTICAL PROPERTIES OF (Pr, Ce)-Fe ALLOY COATED TbFeCo ALLOY AMORPHOUS FILMS

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ABSTRACT

Light rare earth-iron alloys were coated on TbFeCo amorphous thin films by magnetron sputtering successively in a vacuum chamber. The coated films exhibit a larger polar Kerr rotation angle than that of the uncoated single layer films when the TbFeCo amorphous alloy contains more transition metal elements than the compensation composition. The coercive force changes little by coating light rare earth-iron alloys on the TbFeCo films.

1. INTRODUCTION

Light rare earth-transition metal alloy amorphous films have been reported as potential candidate for magneto-optical recording medium, because of the large magneto-optical Kerr rotation angle.[1],[2] Recently, light rare earth-transition metal alloy films of a large perpendicular magnetic anisotropy have been successfully fabricated by Tsutsumi et al.[3], Suzuki[4],[5] and Suzuki et al.[2]. These films exhibit a large perpendicular magnetic anisotropy constant of $10^5$ to $10^7$ erg/cc at room temperature. The Kerr hysteresis loop is suggestive of magneto-optical recording material. However it is difficult to use a polymer substrate, because it requires a high substrate temperature to get enough perpendicular magnetic anisotropy for the recording medium. The purpose of this study is to avoid this difficulty and to obtain the higher Kerr rotation angle by overcoat light rare earth-transition metal alloys on heavy rare earth-transition metal alloy amorphous film which has a large coercive force and large perpendicular magnetic anisotropy.

2. EXPERIMENTAL

The samples used in this study were double layer films of TbFeCo alloy and light rare earth (Ce,Pr,Nd)-iron alloys. Each layer was deposited in Ar atmosphere by dc and rf magnetron sputtering in a chamber without exposure to air. The Ar pressure was 5x10^{-3} Torr. Before introducing Ar gas into the vacuum chamber, the back ground pressure was kept lower than 5x10^{-7} Torr. Composite targets which consist of rare earth metal(99.9%) chips on iron metal(99.9%) target and terbium(99.9%) chips on an iron-cobalt(99.9% each) alloy target were used. The composition analysis was made by the ICP method. The film thickness of TbFeCo was approximately 7000 Å. Films were deposited on a glass substrate at an ambient temperature.

Polar Kerr rotation angle $\theta_k$ dependence on wave length was measured by an automatic null type Kerr spectrometer in air.[6] The wave length range was 230-800 nm and the angle of incident light was 10 degrees. The dependence of $\theta_k$ on overcoat layer thickness was measured by a commercial laser diode type Kerr hysteresis loop tracer at 780 nm wave length in air where the angle of incident light was 1 degree.

3. RESULTS AND DISCUSSION

Figure 1 shows the absolute value of the polar Kerr rotation angle $|\theta_k|$ as a...
function of overcoat layer thickness for TbFeCo films. The compositions of the overcoat layers are Ce$_{40}$Fe$_{60}$, Pr$_{52}$Fe$_{48}$, and Nd$_{52}$Fe$_{48}$ and that of the underlayer is Tb$_{20}$Fe$_{72}$Co$_{8}$. The value of the \( \theta k \) increases from 0.28 degrees for the single layer Tb$_{20}$Fe$_{72}$Co$_{8}$ film up to 0.34 degrees for Pr$_{52}$Fe$_{48}$ overcoated film where the thickness of the overcoat layer is 40~70 Å. The enlargement of \( \theta k \) depends on the light rare earth element contained in the overcoat layer alloy. Pr alloy gives the maximum \( \theta k \) enlargement effect. The enlargement effect lessens in the order of Nd, Ce alloy. When the thickness of the overcoat layer is larger than 100 Å, \( \theta k \) becomes smaller in all three cases of the light rare earth element alloys.

The dependence of polar rotation angle \( \theta k \) on wave length \( \lambda \) in Pr$_{48}$Fe$_{52}$ and Ce$_{54}$Fe$_{46}$ overcoated Tb$_{20}$Fe$_{72}$Co$_{8}$ films is shown in Fig. 2. The thickness of the overcoat layer of both films is 60 Å. Together with these, the \( \theta k \) of the Pr$_{40}$Fe$_{60}$, Tb$_{20}$Fe$_{72}$Co$_{8}$ single layer and the reflectivity \( R \) of the Pr$_{48}$Fe$_{52}$ overcoated and Pr$_{40}$Fe$_{60}$ single layer films are also shown. In Fig. 2, the \( R \) of the Pr$_{40}$Fe$_{60}$ was measured for a film fabricated at a substrate temperature of 220°C. The \( R \) of Ce$_{54}$Fe$_{46}$ overcoated film is almost the same as that of the Pr$_{48}$Fe$_{52}$ overcoated film. As shown in Fig. 2, the \( \theta k - \lambda \) curve of the overcoated films shifts to the lower direction of \( \theta k \) in the whole range of \( \lambda \) and the sign of the \( \theta k \) changes at a shorter \( \lambda \) than that of the TbFeCo single layer. In the case of the Pr$_{48}$Fe$_{52}$ overcoated film, the sign of the \( \theta k \) does not change and is still negative even at the shortest \( \lambda \) measured. Although it is difficult to discuss this fact quantitatively, it does not imply that the enlargement of \( \theta k \) is induced by the usual optical enhancement of the surface oxidization layer, rather, it implies that the enlargement of \( \theta k \) is induced by substantial magneto-optical effect of the overcoat layer.

Figure 3 shows the dependence of \( \theta k \) on the overcoat layer thickness in Pr$_{52}$Fe$_{48}$ overcoated Tb$_{26}$Fe$_{67}$Co$_{7}$ films. In this case, the significant enlargement effect on \( \theta k \) by the overcoat layer does not appear. The polar Kerr hysteresis loop polarity of this film is opposite to that of the Tb$_{20}$Fe$_{72}$Co$_{8}$ film because the dominant magnetic moment carrier of the underlayer is different.

There is not enough experimental data to discuss quantitatively the difference in \( \theta k \) enlargement by PrFe between transition metal rich and terbium rich underlayers. However, an attempt has been made to explain this result as follows. In transition metal rich alloys (underlayer), the magnetic moment of the transition metal is dominant and aligns parallel to the direction of the applied field. Although the spin structure of the PrFe alloy is not clear enough at present, the iron moment is dominant for magnetization. So the iron moments align parallel or nearly parallel to the applied field direction. Therefore the moment of the transition metals of both layers can align parallel when an external field is applied, even if not collinear. The transition metal moments couple ferromagnetically at the interface of the overcoat layer.
the two layers. Then the large $\theta_k$ of PrFe contributes positively. However, the perpendicular anisotropy of PrFe film is too weak to magnetize perpendicularly to the film plane. So the $\theta_k$ decreases when the overcoat layer becomes thicker. On the other hand, when the underlayer contains more Tb than the compensation composition, the magnetic moment of transition metals of both layers should align antiparallel to each other, if both of the layers magnetize to the same direction. The condition mentioned above may cause a higher energy state at the interface of the layers, if the exchange interaction between the iron moment of both layers is positive. Therefore, the PrFe overcoat layer can not contribute to the enlargement of $\theta_k$, when the underlayer is in the Tb rich region.

It should be noted that the coercive force of the light rare earth-iron alloy coated TbFeCo film changes little from that of the uncoated films as illustrated in Fig. 4. This may be a favorable factor for the coated films to be designed for a recording medium.

4. CONCLUSION

Polar Kerr rotation angle $\theta_k$ of TbFeCo amorphous films is enlarged by coating light rare earth (Ce, Pr, Nd)-iron alloys when the amorphous film contains more transition metal than the compensation composition. The value of the $\theta_k$ goes up to 0.34 degrees for Pr$_{52}$Fe$_{48}$ overcoated about 60 Å thick onto Tb$_{20}$Fe$_{72}$Co$_8$ amorphous film, while it is 0.28 degrees for the uncoated film. On the other hand, a significant enlargement of the $\theta_k$ is not observed in the case of the terbium rich composition underlayer.

REFERENCES

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