THE INFLUENCE OF DEPOSITION CONDITIONS ON THE MAGNETO-OPTIC EFFECT IN GDTBCO FILMS

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ABSTRACT - Magneto-optic effects of amorphous GdTbCo thin films prepared by r.f. sputter-deposition were studied as functions of fabrication parameters. Kerr rotation angles θ_κ were found to be related to argon bleeding pressure and substrate table bias voltage applied during sputtering, but reflectivity did not vary significantly with these parameters. The variations in θ_κ do not correlate with the cobalt content, but instead with the argon content of the films. Other researchers have shown correlation between anisotropy and argon content and we suggest that the correlation of anisotropy and θ_κ may be indicative of a pair ordering mechanism. The compensation point of these films, however, was found to be dependent upon the cobalt content and independent of deposition conditions.

INTRODUCTION

Achieving an adequate signal-to-noise ratio (SNR) is one of the major obstacles to developing practical magneto-optic (M-O) recording systems. In the quest for improving the SNR, researchers have sought to increase the intrinsic M-O coefficients of materials by careful selection of material composition and to increase the Kerr rotation angle (θ_κ) by the use of multi-layer optical interference structures.(1,2) Although multi-layer structures can be used effectively to increase the SNR, the gains which can be made with these structures are limited because the M-O effect must be traded against reflectivity of the medium. To provide the optimum SNR, the intrinsic M-O coefficients of the materials must be maximized. In an attempt to obtain improved materials, other researchers have studied the dependence of M-O coefficients on film composition. The influence of third components on the Faraday and polar Kerr effect in ternary alloys such as $(GdFe)_{1-y}M_y$ (M=Bi,Sn,Pb) have been attributed to the pronounced influence of the third elements on the iron moment and the exchange constant, resulting from the tendency for the third elements to alter the electronic structure by surrounding the rare-earth (RE) atoms and avoiding the neighborhood of transition-metal (TM) atoms during the formation of the ternary alloy.(3) Co substitution in GdFe has been shown effective in increasing θ_κ, especially at temperatures higher than the ambient.(4) In this paper, we report the finding that M-O coefficients of sputter-deposited films depend not only upon the composition of the films, but also upon the deposition conditions used during sputtering.

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EXPERIMENT

Amorphous films of GdTbCo were prepared by r.f. sputtering from a composite target onto Corning 0211 glass substrates. The sputtering chamber was evacuated to a pressure below $8x10^{-7}$ Torr before admitting high purity argon. The Ar bleeding pressure (P_{Ar}) was monitored by a capacitance monometer. By varying the substrate table bias voltage (V_b) and P_{Ar} in the sputtering chamber, a series of samples with a range of compositions were produced with a given target. The 35 nm thick magnetic layer was coated with 25 nm of SiO_2 in situ. The M-H loop and thus the room temperature coercivity (H_c) as well as the compensation temperature (T_{comp}) were characterized using a Kerr magneto-optic M-H hysteresis loop tracer. The θ_κ was measured from the film and the substrate sides, with an incidence angle of about 10°, using an ellipsometer with a He-Ne laser (λ=633 nm) light source. The ellipsometric measurements were read to 0.01°. The reflectivity was determined using a Leitz MPV-3 microscope/photometry system at a wavelength of 644 nm. Film composition was determined by x-ray fluorescence analysis.

RESULTS

The Kerr rotation angles of as-deposited 35 nm thick GdTbCo films, sputtered at V_b= -160 to -200V and P_{Ar}=40 mTorr, on glass substrates without any overcoat were measured from the glass substrate and the film sides. As shown in Fig. 1, θ_κ ranged from 0.22° to 0.28°, depending on the V_b applied during sputtering. No measurable difference in θ_κ was found between measurements from the film top surface or from the substrate side of just deposited films, although films which had been exposed to the atmosphere for some time exhibited a smaller θ_κ at the top surface.

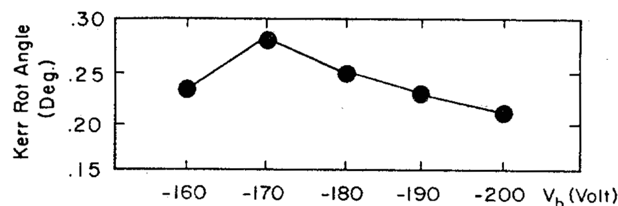

Fig.1: The polar Kerr rotation angle θ_κ is plotted as a function of V_b for uncoated GdTbCo films.

For a set of GdTbCo films with 25 nm thick SiO_2 overcoat, θ_κ measured through a SiO_2 overcoat and through glass-substrate sides are plotted as a function of V_b at different P_{Ar} in Figs 2a and 2b, respectively. For comparison, the Ar atomic composition ratio measured in the films by x-ray fluorescence is shown in Fig. 2c. The data show that the measured values for θ_κ and Ar inclusion in the

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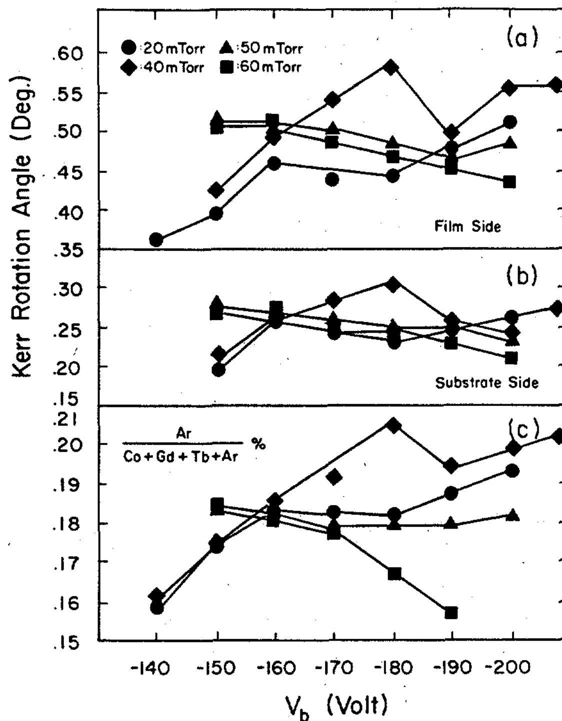

Fig.2: (a) and (b) are the θ_κ as a function of V_b at different P_{Ar} measured through film and substrate sides, respectively, for SiO_2 overcoated GdTbCo films. (c) is the Ar content in the films.

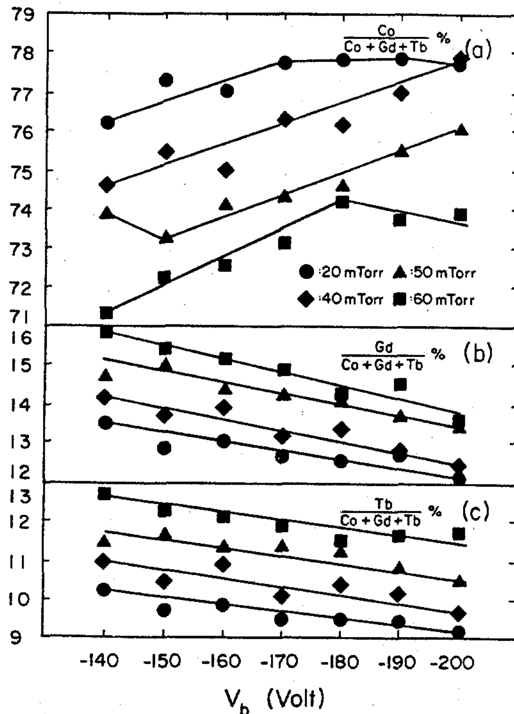

Fig.3: (a), (b), and (c) are the Co, Gd, and Tb atomic composition ratio of the films, respectively.

films are strong functions of V_b and P_{Ar}. The reflectivities of these films measured from the film side are all within 30±2%; while reflectivities measured from the substrate side are all within 41±2%. These small fluctuations are within the accuracy of measurement apparatus.

Co, Gd, and Tb atomic composition ratios for the same films are depicted in Figs. 3a, 3b, and 3c, respectively. The TM content of the films generally increases monotonically with increasing $|V_b|$ at constant P_{Ar} but decreases with increasing P_{Ar} at the same V_b; while the RE contents decrease monotonically with increasing $|V_b|$ at constant P_{Ar}, but increase with increasing P_{Ar} at the same V_b.

In Fig. 4, T_{comp} of the set of GdTbCo samples is shown as a function of V_b. H_c of the films deposited at P_{Ar}=20 mTorr are also plotted as dashed lines in the same figure. The T_{comp} as a function of Co content in the same films are plotted in Fig. 5. The relation between T_{comp} and Co% indicates that T_{comp} is a strong function of material composition, and is independent of preparation parameters.

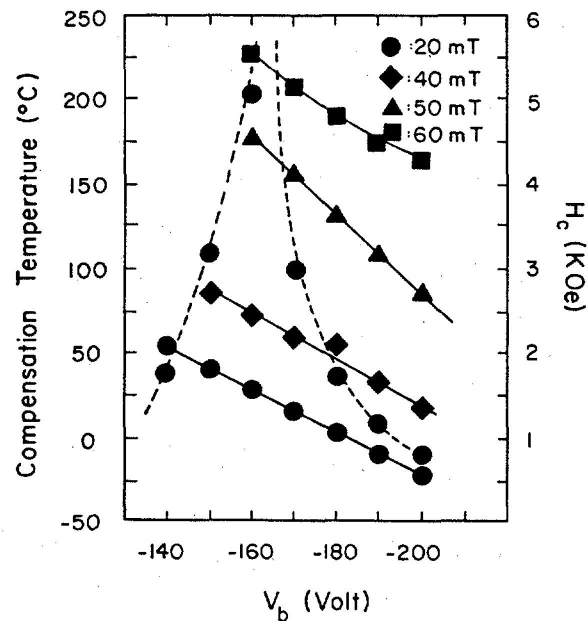

Fig.4: T_{comp} is plotted as functions of film deposition parameters, V_b and P_{Ar}. The dashed lines are the H_c for the films deposited at P_{Ar}= 20 mTorr.

DISCUSSION

The ellipsometric measurements on the uncoated GdTbCo films in Fig. 1 indicates that the Kerr rotation angles were virtually identical when measured through either the glass substrate or the uncoated top surface of the as-deposited films. The θ_κ depends on the sputtering parameter, V_b, applied during sputtering.

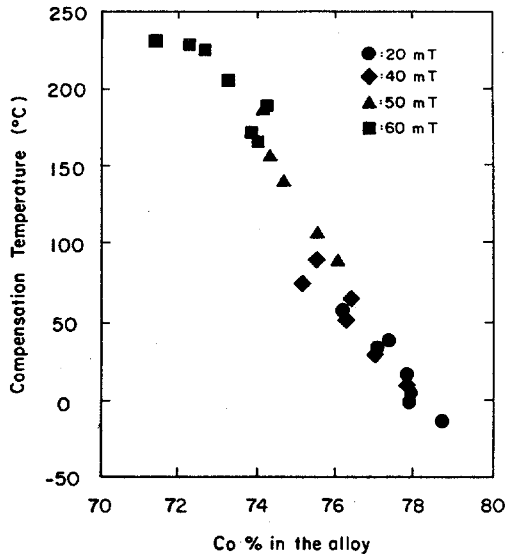

Fig.5: T_{comp} is depicted as a function of Co content in the films. The linear dependence of T_{comp} as Co % implies that T_{comp} is uniquely characterized by the Co content in the films.

The parameters applied during the deposition significantly influenced the properties of sputter-deposited films. Data in Figs. 4 and 5 indicate that the films deposited at higher P_{Ar} have higher T_{comp} indicating a lower TM (Co) content. Furthermore, Fig. 4 shows that at the same P_{Ar}, a higher $|V_b|$ causes films to have lower T_{comp} and therefore to be TM-rich. These dependences are due to the preferential resputtering of the RE atoms. The linear dependence of T_{comp} on Co% in Fig. 5, independent of V_b and P_{Ar}, implies that T_{comp} is uniquely characterized by the Co content in the film.

The M-O effect is generally attributed to the magnetization of the TM subnetwork in amorphous RE-TM alloys.(5) Except for the factor of two difference in θ_κ caused by the SiO_2 antireflective overcoat when measured through the film side and the substrate side, the θ_κ variations in Figs. 2a and 2b are very similar. The data demonstrate that sputtering conditions significantly alter the measured values for θ_κ. On the other hand, measurements show that reflectivity does not vary significantly from film to film. Therefore, SNR can be enhanced by choosing appropriate deposition conditions. Fig. 2 also reveals that there is a strong correlation between θ_κ and the Ar content in the films; whereas, Fig. 3 shows that the θ_κ variations in Fig. 2 do not correlate with variations in TM or RE contents in the alloy.

Previous investigators have reported that the perpendicular uniaxial anisotropy constant (K_u) of r.f. sputtered GdCo films also shows a similar dependence on V_b and correlates with argon content of the films.(6,7,8) Data collected in this laboratory indicate that the K_u of GdTbCo films like those described here also exhibits a similar dependence on V_b and correlates with argon content of the films.(9) Although some researchers suggested that the argon was somehow responsible for the anisotropy, this seems unlikely and we suggest that it is more likely that the conditions which give rise to maximum argon incorporation are the same as those required to produce maximum anisotropy, but there is no direct role of argon in producing the anisotropy. A likely anisotropy mechanism for these films is short range pair-ordering.(7)

Similarly, in spite of the correlation between θ_κ and argon content, we are doubtful that the argon plays a direct role in enhancing the θ_κ. Argon is inert and it is difficult to hypothesize a plausible direct effect on either anisotropy or magneto-optic effect.

It seems much more plausible that a physically significant correlation may be between the K_u and θ_κ. In fact, since the M-O effect in 3d-4f alloys is generally considered to result mainly from the polarization of 3d electrons,(4) a correlation between anisotropy and M-O effect is possibly indicative that the anisotropy is in fact due to some short range type of pair-ordering mechanism since that could affect not only the anisotropy, but also the polarization of 3d electrons.

CONCLUSIONS

It is concluded that the M-O effect in r.f. sputtered GdTbCo films depends upon V_b and P_{Ar} used during sputtering, while reflectivity is nearly independent of deposition conditions. These dependences correlate with similar dependences of Ar content in films and K_u on V_b, but not with RE or TM contents of the films. On the other hand, the T_{comp} of these films is unaffected by sputtering parameters and only depends upon film composition. It is suggested that the correlation between the M-O effect and perpendicular anisotropy may indicate that the anisotropy mechanism is short range pair-ordering.

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