Magneto-Optical and Magnetic Properties of DySmCo/Cr Thin Films

F. Jin, Z.Y. Li, Z.X. Huang *, X. Dan*, Z. Li, X.H. Xu, X.M. Cheng, G.Q. Lin

Department of Electronic Science and Technology, Huazhong University of Science and Technology, 1037 Luoyu Road, Wuhan, 430074, P. R. China

*Department of Physics, Huazhong Normal University, Wuhan, 430079, P. R. China

SmDyCo/Cr films have been prepared by an r.f magnetron sputtering system. The Cr underlayer was found to play an important role in increasing the coercivity (H_c) in the DyCo films because of the formation of granular structure¹⁾. The effects of Dy substituted by Sm on the magnetic and magneto-optical properties of DyCo/Cr films have been investigated. By analyzing the figure of $M_s \cdot H_c$ vs. Sm concentration, optimum Sm concentration should be found between 16~22 at% to obtain maximum $M_s \cdot H_c$. With increasing Sm concentration, the M_s is steadily increased, while the H_c is slightly decreased. With the increasing of Sm concentration, the reflectivity (R) and Kerr rotation angle (θ_k) are increased. It is believed that by choosing optimal sputtering conditions and suitable Sm substituting fraction, larger M_s and higher H_c can be obtained at room temperature for $(\text{Sm}_x\text{Dy}_{1-x})_{36}\text{Co}_{64}$ films.

Key words: hybrid recording media, heavy rare earth-transition metal (HRE-TM), light rare earth-heavy rare earth-transition metal (LRE-HRE-TM), magnetic properties.

1. Introduction

In the aspect of increasing storage densities, magnetic recording and magneto-optical recording have been hampered by super-paramagnetic effect, the limitation of the optical resolution and the Kerr rotation angle, respectively²⁾. In view of the limits of conventional magnetic and magneto-optical recording, hybrid recording has been of interest to investigators. Hybrid recording is a form of thermally assisted recording that combines thermo-magnetic writing and magnetic reading.

Hybrid recording requires three characteristics for recording media. One is high saturation magnetization (M_s) which is desired to yield larger flux density for GMR sensing; the second is high coercivity (H_c) at room temperature which is needed to ensure adequate stability of small-size domains³⁾; and the third is suitable Curie temperature. H.Sukeda et al. investigated heavy rare earth-transition metal (HRE-TM) double-layer films structure for hybrid recording. One layer is TbDyFeCo alloy for readout; and the other layer is TbFeCo alloy for recording⁴⁾. While much research has been undertaken on HRE-TM, less work has addressed the light rare earth-heavy rare earth-transition metal (LRE-HRE-TM) film for hybrid recording.

This article presents the magnetic properties of DyCo

layer with and without Cr underlayer, as well as the effects of Dy substituted by different Sm contents on the magnetic and magneto-optical properties of DyCo/Cr films.

2. Experiment

Films were fabricated by an r.f magnetron sputtering system. DyCo films were deposited onto water-cooled glass substrates with and without Cr underlayer from a mosaic targets. The composition of magnetic layer was controlled by adjusting the number of Dy pellets on Co target. Substituting Dy pellets on Co target for different number of Sm pellets can obtain different Sm contents in SmDyCo films. In order to prevent the rare earth metals from oxidation and to protect the entire film mechanically, the magnetic layer was covered by SiO_2 protective layer. The base pressure of the sputtering chamber was below 10^{-6} Torr. The sputtering parameters such as sputtering power, argon pressure, sputtering time and magnetic layer composition were varied to prepare films with large M_s and high coercivity. The optimal parameters for depositing films with large M_s and high coercivity were listed in table 1. The film thickness was controlled by sputtering time and determined by a surface profiler. The magnetic properties were evaluated from the M-H loops measured with a vibrating sample magnetometer (VSM). The composition was determined by energy dispersive X-ray spectroscopy (EDX).

Table 1. Optimal sputtering parameters for DyCo/Cr and SmDyCo/Cr films deposition

Film	Sputtering power	Argon pressure	Sputtering time	Sputtering rate
Cr	280W	4mTorr	2min.	32.7nm/min.
DyCo	250W	4mTorr	4min.	63.7nm/min.
SmDyCo	250W	4mTorr	4min.	53.1nm/min.
SiO_2	300W	4mTorr	3min.	---

3. Results and Discussion

The magnetic properties of DyCo layer with and without a Cr underlayer have been investigated. The Cr layer is commonly used as an underlayer to Co-alloy films for hard disk applications, since the Cr layer provides a close epitaxial match to the planes of hexagonal-close-packed (hcp) Co-alloy films⁵⁾. It was found that the Cr underlayer thickness could affect the H_c of DyCo films. Figure 1 shows the magnetic hysteresis loops of 255 nm thick Dy-Co films with and without 65nm

This work was supported by Cultivating Foundation for philosophy degree granted by Ministry of Education (20010487021).

thick Cr underlayer which were measured along the directions perpendicular and parallel to the film surface. The H_c as high as 3500 Oe was obtained in 255 nm $Dy_{31}Co_{69}$ films with a 65nm thick Cr underlayer, but it was only about 2000 Oe for the same thickness $Dy_{31}Co_{69}$ films without Cr underlayer.

Fig.1 Magnetic hysteresis loops of 255 nm thick Dy-Co films with 65 nm thick Cr underlayer measured along the directions perpendicular (a) and parallel (b) to the film surface, and without Cr underlayer measured along the directions perpendicular (c) and parallel (d) to the film surface.

Fig.2 H_c versus the thickness of Cr underlayers for $DyCo(255\text{ nm})/Cr$ films.

Figure 2 shows the H_c of $DyCo(255\text{ nm})/Cr$ samples with different Cr underlayer thickness. The Cr underlayer thickness was varied in the range from 16 nm to 330 nm to study its effect on magnetic properties in the films. It manifests that a maximum H_c value was obtained when the thickness of Cr underlayer is 65 nm. The Cr (110) plane will give rise to a {10.1} type Co-based alloy thin film texture¹⁾. Z.X. Huang and coworkers have confirmed that Cr underlayer benefits the in-plane orientation of the c-axis of hexagonal Co-alloy nano-crystalline⁶⁾.

Fig.3 Dependence of saturation magnetization (M_s) on Sm concentration x (at%) of $(Sm_xDy_{1-x})_{36}Co_{64}/Cr$

Fig.4 Dependence of coercivity (H_c) on Sm concentration x (at%) of $(Sm_xDy_{1-x})_{36}Co_{64}/Cr$

The magneto-optical and magnetic properties of $(Sm_xDy_{1-x})_{36}Co_{64}/Cr$ films have been researched. Figure 3 and Figure 4 show that with increasing Sm concentration x , the M_s is steadily increased and the H_c is slightly decreased. Figure 5 shows $M_s \cdot H_c$ as a function of the Sm concentration. An optimum Sm concentration should be found between 19~22 at% to obtain maximum $M_s \cdot H_c$. In the case of Sm contents up to about 21 at%, $M_s \cdot H_c$ reaches the maximum. Hence, we can obtain that the most proper values of H_c and M_s when the Sm content x is 21 at%. With increasing Sm concentration x , the reflectivity R and Kerr rotation angle θ_k are increased too (Fig.6).

The heavy rare earth-transition metal (HRE-TM) amorphous films possess high H_c but small saturation magnetization at room temperature. It is well known that the heavy rare earth-transition metal (HRE-TM) film exhibits a ferri-magnetic structure, and the moments of HRE elements and TM elements are antiparallely aligned, while the moments of light rare earth (LRE) elements are parallelly aligned with TM⁷⁾. Therefore, partial HRE element substituted by LRE element can lead to the increase of M_s , R and θ_k . By choosing optimal sputtering

parameters and suitable Sm substituting fraction, larger Ms and higher Hc can be obtained at room temperature for $(\text{Sm}_x\text{Dy}_{1-x})_{36}\text{Co}_{64}$ films.

Fig.5 Dependence of Ms*Hc on Sm concentration x (at%) of $(\text{Sm}_x\text{Dy}_{1-x})_{36}\text{Co}_{64}/\text{Cr}$

Fig.6 Dependence of reflectivity (R) and Kerr rotation angle (θ_k) on Sm concentration x (at%) of $(\text{Sm}_x\text{Dy}_{1-x})_{36}\text{Co}_{64}/\text{Cr}$

4. Conclusion

The effect of Cr underlayer on the magnetic properties of a DyCo layer has been investigated. The Cr underlayer can enhance the Hc of DyCo films. The effects of Dy substituted by Sm on the magnetic and magneto-optical properties of SmDyCo/Cr films have been investigated. The substitution effects on Ms, R and θ_k can be explained with the ferri-magnetic structure of RE-TM alloy. By analyzing the figure of Ms*Hc vs. Sm concentration, optimum Sm concentration should be found at 21 at% to obtain maximum Ms*Hc. By choosing optimal sputtering parameters and suitable Sm substituting fraction, larger Ms and higher Hc can be obtained at room temperature for $(\text{Sm}_x\text{Dy}_{1-x})_{36}\text{Co}_{64}/\text{Cr}$ films.

Acknowledgements: We wish to thank the national science foundation and colleagues in our lab.

References

- 1) Y.C. Feng and D.E. Laughlin: *J. Appl. Phys.*, **76**, 7311 (1994).
- 2) T.E. Schlesinger, T. Rausch: *Jpn. J. Appl. Phys.*, **41**, Part1, No3B, 1821 (2002).
- 2) J. Daval., B. Bechevet: *J. Magn. Magn. Mat.* **129**, 98 (1994).
- 4) H. Sakeda, H. Saga: *IEEE Trans. Magn.*, **37**, No.4, 1234 (2001).
- 5) D.E. Laugulin, B.Y. Wong: *IEEE Trans. Magn.*, **27**, 4713 (1991).
- 6) Z.X. Huang, Z.Y. Li, et al.: *Chin. Phys. Lett.*, **19**, No.10, 1531 (2002).
- 7) Z.Y. Lee, X.S. Miao, P. Zhu, Y.S. Hu, G.Q. Lin and D.F. Wan: *J. Phys. Soc. Jpn.*, **15**, 421 (1991).

Received April 19, 2004; Accepted July 22, 2004.