MAGNETO-OPTICAL AND MAGNETIC PROPERTIES OF EXCHANGE-COUPLED TbNdFeCo FILMS

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Abstract - Magneto-optical and magnetic properties of single and exchange-coupled double-layered TbNdFeCo films were examined. Very thin TbNdFeCo films with small Tb content were found to be suitable as the 1st layer of double-layered TbNdFeCo films. Large coercivity and large Kerr rotation were concurrently realized in exchange-coupled double-layered TbNdFeCo films. It was also shown that the exchange-coupled double-layered TbNdFeCo film has a good recording characteristics at the wavelength of 830nm and the potentiality as a recording medium for shorter wavelength is suggested.

KEYWORDS : TbNdFeCo, MAGNETO OPTICAL DISK, EXCHANGE COUPLING, DOUBLE LAYER

INTRODUCTION

TbNdFeCo film is one of the candidates for future magneto-optical (M-O) recording media for shorter wavelength light source. In applying TbNdFeCo film to practical use, the main problem is its smaller coercivity than that of TbFeCo film [1]. Large H_c and large Kerr rotation angle θ_k seem to be irreconcilable demands. One solution is to divide the magnetic layer into two layers, one of which has larger θ_k and the other has larger H_c . We presented exchange-coupled double-layer TbFeCo films as a high performance recording medium [2][3]. In this study, we examined the magneto-optical and the magnetic properties of TbNdFeCo films and exchange-coupled double-layered very thin TbNdFeCo films in order to obtain a feasible recording medium.

EXPERIMENTAL PROCEDURE

TbNdFeCo films were sputter-deposited from FeCo target with Nd pellets and Tb target onto rotating glass substrates by a dc planer magnetron sputtering method. Double-layered TbNdFeCo films with SiN_x dielectric layers and Al reflective layer shown in fig.1 were sputter-deposited successively on a glass or a pregrooved polycarbonate (PC) substrate. Transition-metal(TM) dominant and rare-earth(RE) dominant compositions were chosen for the 1st and the 2nd TbNdFeCo layer, respectively.

Substrate	PC or Glass
Dielectric Layer	SiN_x
Magnetic Layer 1	TbNdFeCo
Magnetic Layer 2	TbNdFeCo
Dielectric Layer	SiN_x
Reflective Layer	Al
Protective Coat.	Resin

Fig.1 Sample configuration

Reflectivity R and Kerr rotation θ_k were measured in the wavelength range of 400-830nm. Kerr hysteresis loop were obtained in maximum field range of 15kOe. The saturation magnetizations M_s were measured by the vibrating sample magnetometer.

CHARACTERISTICS OF TbNdFeCo FILMS

Fig.2 shows the wavelength dependence of θ_k measured from the film sides of TbNdFeCo films whose thicknesses are 1200Å. M_s and H_c values of these samples are shown in table 1. θ_k increases as the wavelength is shortened and exceeds that of TbFeCo film which has the almost compensation composition. Tb addition decreases θ_k in the whole wavelength range, which agrees to Reim's results[1]. It is confirmed that to make the most use of the advantage of large θ_k

at shorter wavelength in TbNdFeCo film, Tb addition should be kept at a minimum.

On the other hand, TbNdFeCo films with small Tb content show Kerr hysteresis loops with poor squareness because of their large M_s values. Cape et al. showed that thinner garnet film has smaller saturation field H_s than that of thicker one and gave the theoretical interpretation[4]. We examined film thickness dependence of hysteresis loops of TbNdFeCo films. Fig.3 shows the results. Saturation field H_s decreases with decreasing the film thickness, and the almost perfect square loop is obtained at the thickness less than about 200Å. Solid curves in the figure show calculated H_s for several values of Bloch wall energy assuming the stripe domain configuration. It agrees very well to measured H_s when the Bloch wall energy is 0.5erg/cm².

As a result from above experiments, very thin TbNdFeCo film of small Tb content is preferable as the 1st layer of double-layered TbNdFeCo film for a recording medium.

Table 1 M_s and H_c of samples in fig.2

Tb content	M_s	H_c
X= 0 at%	580 emu/cc	310 Oe
X= 8 at%	260 emu/cc	860 Oe
X=16 at%	170 emu/cc	1120 Oe

Fig.2 Wavelength dependence of Kerr rotation angle of TbNdFeCo films. Dashed curve : Tb₂₁(Fe₉₀Co₁₀)₇₉

Fig.3 Thickness dependence of Kerr loop and saturation field H_s of TbNdFeCo film. Solid curves : calculated H_s for several Bloch wall energy σ_B [erg/cm²].

DOUBLE-LAYERED TbNdFeCo FILMS

Magnetic characteristics

The 1st and the 2nd TbNdFeCo layer are coupled magnetically by the exchange-coupling and it affects the hysteresis loop of the film. Two kinds of Kerr loops of exchange-coupled double-layered TbNdFeCo films were observed, which is shown as sample A and B in fig.4. These samples are the same except the thickness of the 2nd TbNdFeCo

Fig.4 Kerr loops of exchange-coupled double-layered TbNdFeCo films.

Table 2 Ms, Hc and t of sample A and B

Sample:	Ms1	Ms2	Hc1	Hc2	t1	t2
	[emu/cc]		[Oe]		[Å]	
A :	490	290	240	1800	100	100
B :	490	290	240	1800	100	200

layer. Magnetization direction ($\uparrow$ · $\downarrow$) and TM sublattice moment direction ($\uparrow$ · $\downarrow$) at each state of the loops are also illustrated in fig.4.

Sample A shows perfectly square hysteresis loop. The 1st and the 2nd layer reverses at the same field and no interface wall appears within measured field range. On the other hand, the 1st layer of sample B reverses alone and its hysteresis loop is shifted and slanted. Switching field of sample A and the loop shift of the 1st layer of sample B can be expressed respectively as

$$\frac{Ms1 \cdot t1 \cdot Hc1 + Ms2 \cdot t2 \cdot Hc2}{Ms1 \cdot t1 - Ms2 \cdot t2} \quad (1)$$

and

$$\frac{Uw}{2 \cdot Ms1 \cdot t1} \quad (2)$$

where Ms, t, Hc and Uw are saturation magnetization, thickness, coercivity and interface wall energy, respectively, and suffix 1 and 2 represent the 1st and the 2nd TbNdFeCo layer. Each value is summarized in table 2. From these values and equation (1), the switching field of sample A is calculated to be 3.2kOe which agrees well to the measured value of 3.5kOe. From the loop shift value of the 1st layer of sample B of 3.8kOe, and equation (2), the interface wall energy Uw is calculated to be 3.7erg/cm² which is slightly smaller than that of the exchange-coupled double-layered TbFeCo film of 5erg/cm²[2].

M-O AND RECORDING CHARACTERISTICS

Fig.5 shows wavelength dependence of the ratio of R·Θk of exchange-coupled TbNdFeCo film (sample C) to that of TbFeCo film (sample D) at each wavelength. R and Θk were measured from the glass substrate side. Sample compositions are shown in table 3. Refractive index of SiN_x film was measured in advance by ellipsometry and no absorption was observed through the wavelength range of 400-830nm.

Large enhancement in R·Θk were observed at the wavelength around 400nm. This is supposed to be attributed to large Θk of the 1st TbNdFeCo layer because the reflectivity of two samples were almost same at each wavelength. From this result, the exchange-coupled double-layered TbNdFeCo medium is expected to have larger read-out signal than TbFeCo medium around 400nm wavelength.

In order to estimate the potentiality of the exchange-coupled TbNdFeCo film as a recording medium, we measured recording characteristics at the wavelength of 830nm of two disks deposited on PC substrate simultaneously with sample C and D. Measurement conditions are summarized in table 4.

Table 3 Compositions of sample C and D

Sample C	Sample D
PC or Glass	<-----
SiNx 830Å	<-----
TbNdFeCo(1) Tc=260°C, 150Å	TbFeCo
TbNdFeCo(2) Tc=190°C, 150Å	Tc=195°C, 300Å
SiNx 350Å	<-----
Al 600Å	<-----
Resin (when the substrate is PC)

Fig.5 Wavelength dependence of ratio of R·Θk of double-layered TbNdFeCo film (sample C) to that of TbFeCo film (sample D).

Fig.6 shows recording laser power dependence of the carrier and noise level of two disks. Both carrier and noise level of sample C are smaller than that of sample D. Carrier to noise ratio are almost same for two samples. The difference in carrier level is ascribed to that $R \cdot \theta_k$ of sample C is smaller than that of sample D at the wavelength of 830nm as shown in fig.5. Carrier level of sample C is expected to surpass that of sample D at shorter wavelength range, e.g. 400nm, when $R \cdot \theta_k$ value exceeds 1.0 in fig.5.

Recording sensitivities of two samples are the same although sample C includes the layer with high Curie temperature. We measured Kerr loops at raised temperature to examine this. Fig.7 shows temperature dependence of H_c of two samples. At 200°C, H_c of sample C is below 2000e and Kerr hysteresis loop keeps squareness as shown in fig.8. Therefore, thermo-magnetic writing on sample C is supposed to take place at around 200°C which is near the Curie temperature of sample D.

CONCLUSION

Magneto-optical and magnetic properties of single and exchange-coupled double-layered TbNdFeCo films were studied. TbNdFeCo film, which has large θ_k at shorter wavelength and also has small H_c and large M_s , were utilized as the 1st layer of exchange-coupled film, and it was confirmed that the H_c can be substantially increased by the exchange-coupling. And the exchange-coupled TbNdFeCo film has a fairly good recording characteristics equivalent to that of TbFeCo films at the wavelength of 830nm, and has a potentiality for shorter wavelength applications.

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Table 4 Measurement conditions

Linear Velocity	: 7.53 m/s
Frequency	: 4.83 MHz
Pulse Width	: 59 ns
Wavelength	: 830 nm
N.A.	: 0.55
External Field	: 200 Oe

Fig.6 Write power dependence of carrier and noise of
Sample C:double-layered TbNdFeCo
Sample D:single-layered TbFeCo

Fig.7 Temperature dependence of H_c

Fig.8 Kerr loop of sample C at 200°C