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MAGNETIC PROPERTIES OF FACING TARGETS SPUTTERED NdFeMo FILMS

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Abstract. Structures and magnetic properties of NdFeMo films prepared by Facing Targets Sputtering (FTS) were investigated. The addition of Mo can raise the Curie temperature of the films. Domain parameters of Nd42Fe56Mo2 film with θk = 0.42 degrees and KE1 ~ 9.6 × 10^8 J/m^3 were estimated. The influence of DC substrate biasing on magnetic anisotropy was also studied.

Introduction

Nd based alloy films are promisable for magneto-optic recording media because they have larger Kerr effect than heavy RE alloys such as Gd, Tb and Dy [1]. In this work, we prepared NdFeMo films by facing targets sputtering (FTS), and investigated their magnetic properties.

Experimental procedure

NdFeMo films were deposited onto glass substrate with DC 320W sputtering power and 5 Å/s deposition rate at 5 × 10^-3 Torr argon pressure. The EPMA confirmed film contents were controlled by adjusting the areas of Nd and Mo plates on iron targets. Magnetic properties were measured by a LDJ-9500 type VSM, a Torque meter and a force balance meter. Structural investigations were performed by X-ray diffraction analysis. Polar Kerr effect was measured at room temperature with 6328 HeNe laser. The relation of Hall resistivity with intensity of measuring field which normal to film plane were obtained by Van Der Pown technique with I = 3 mA and H = 3.0 × 10^6 A/m [2].

Results and discussion

X-ray diffraction patterns indicated that all the films were amorphous but partially crystallized with ε-Fe7Nd (330) and α-Fe(110) peaks appeared in Nd42Fe56Mo2 films.

Typical perpendicular M − H loops without compensation of demagnetization of NdFeMo films were shown in figure 1. According to the model provided by Coey [3], we found that when Nd concentration was less, the films showed speromagnetic order. Magnetism ascended fast to half saturation at lower measuring field and then increased slightly as the increase of measuring field, which was in accordance with the arrangement of speromagnetic domains and closing up before and after the ankle of the curves. Despite the higher field, all the magnetizations could not easily parallel to saturation. This is due to the Random local crystal anisotropy to be larger than the interactions of atomic magnetizations [3]. We also found that at x = 42 at. %, the film exhibited ferromagnetic order, and at x = 45 at. %, ferromagnetic order disappeared. We raised the ideas to explain the fact that the ferromagnetic order disappeared at x = 45 at. %.

(1) Orbit hybridization and electron transformation cause the variation of net spin which contribute to magnetism.

(2) In the vicinity of rij = 3 Å, the exchange energy of J(rij) will change its sign, the ferromagnetic order disappears [3].

Figure 2 showed the M(T) curves measured under 6 × 10^6 A/m. Two Curie temperatures and a crystallized hump was observed on each curve as temperature rised. The curves of Nd22Fe78 and Nd33Fe67 indicated that Tc slightly rised as Nd content increased. The ad-

Fig. 1. - Typical M − H loops of NdFeMo films.

Fig. 2. - Typical M(T) curves of NdFe based films.
Table I. - The influence of $V_b$ and $H_b$ on the magnetic properties of Nd$_{42}$Fe$_{56}$Mo$_2$ films. $V_b=-90$ volts and $H_b=2\times10^8$ A/m.

<table>
<thead>
<tr>
<th>Condition</th>
<th>$H_s$(10$^5$ A/m)</th>
<th>$M_s$(10$^5$ A/m)</th>
<th>$H_c$(10$^3$ A/m)</th>
<th>S.R.</th>
<th>$K_1$/($J/m^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_b$</td>
<td>4.2</td>
<td>10.68</td>
<td>77</td>
<td>0.08</td>
<td>$-1.30 \times 10^5$</td>
</tr>
<tr>
<td>$H_b$</td>
<td>4.2</td>
<td>8.85</td>
<td>97</td>
<td>0.13</td>
<td>$-3.00 \times 10^5$</td>
</tr>
</tbody>
</table>

The dependence of $V_b$ on $K_1$ and $K_2$ for Nd$_{14}$Fe$_{84}$Mo$_2$ films was shown in figure 3. It is suggested from this figure that the magnetic anisotropy be affected by negative DC substrate biasing. When $V_b$ was about $-90$ volts, $K_1=1.0 \times 10^6$ J/m$^3$, $K_2 \approx 0$. Parallel magnetic anisotropy was calculated from the perpendicular $M - H$ loops [4]. Table I showed the magnetic parameters of Nd$_{42}$Fe$_{56}$Mo$_2$ films with the condition of $-90$ volts bias voltage and $2 \times 10^5$ A/m inducing magnetic field applied perpendicular to substrate during sputtering respectively.

Perpendicular magnetic anisotropy of $x=14$ and 42 at. % films were obtained by torque differential method [5]. The results were shown as follows:

$x$ $K_1(10^6$ J/m$^3$) $K_2(10^6$ J/m$^3$)

14 $-1.92$ 1.30
42 0.96 $-0.096$

The ratio of exchange constant $J$ to the single ion anisotropy constant $D$ and bubble domain parameters for $x=42$ films were estimated by the method provided by Boucher and Herd [6, 7]. Exchange energy

$$A \approx KT_c/(2z).$$ (1)

Taking coordination number $z=12$, $T_c=400$ K, and $K_{u1}=9.6 \times 10^6$ J/m$^3$, then

$$A \approx 8 \times 10^{-13} J/m^3.$$ (2)

Fig. 3. - DC substrate biasing dependence of magnetic anisotropy constant $K_1$ and $K_2$ for Nd$_{42}$Fe$_{56}$Mo$_2$ films,

and the energy density of domain surface,

$$\sigma_w = 4\sqrt{AK_{u1}} = 3.6 \times 10^{-3} J/m^3.$$ (3)

the width of domain wall was

$$r_w = \pi \sqrt{A/K_{u1}} = 30 \AA.$$ (4)

there were about $n=12$ atoms which consisted of the domain walls. Character length,

$$L_w = \sigma_w/(4\pi M_s) = 3 \times 10^{-4} \text{ m}.$$ (5)

the ratio of $J$ to $D$ was

$$J/D \approx n^{1/2} = \sqrt{12} = 3.5.$$ (6)

Ordinary and anomalous Hall efficiency of $x=42$ film were obtained by fitting the Hall $\rho_H - H$ loops.

$$R_0 = 1.65 \times 10^{-9} (m^2\Omega/A)$$ (7)

$$R_s = 10.95 \times 10^{-9} (m^2\Omega/A).$$ (8)

The concentration of carrier was

$$n = 0.84 \text{ el./at.}.$$ (9)

this is less than the average electrons of this alloy since main spins were more mobility than others for conducting [8].

Kerr rotation angle of $x=42$ films measured under $8 \times 10^6$ A/m magnetic field was 0.42 degrees. This value is higher so far.