The Influence of Temperature on the Coercivity and Kerr Rotation for MnBiRE(RE=Ce,Pr,Nd and Sm)Thin Films

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MnBiRE thin films possess large magneto-optical(MO) Kerr rotation angle θ_k ¹⁾. We investigated the influence of temperature on the coercivity H_c and MO Kerr rotation angle θ_k for MnBiRE (RE=Ce,Pr,Nd and Sm) thin films and their writing characteristics. The temperature dependence of H_c and θ_k of MnBiRE thin films as the functions of the temperature are studied. The thermo-magnetic writing was carried out. The readout and writing characteristics of the samples are discussed.

Key words: MnBiRE thin films, Kerr rotation angle, coercivity, temperature dependence, writing and readout characteristics

1. Introduction

The early studies on the magnetic and magneto-optical properties for MnBi films have been shown that it exhibited large Kerr effect at the visible light band, positive magnetic anisotropy^{2,3)}, and might be promising magneto-optical storage disk medium. But it was not realized due to some disadvantages⁴⁾: the high temperature quenched phase remained after Curie writing, large grain boundary noise and difficult for preparation. Recently, much efforts have been made to improve the properties of MnBi films by doping with other transition metals or rare earth elements. Reports on MnBiAl and MnBiAlSi⁵⁻⁷⁾, and also MnBiRE_x(RE=Ce,Pr,Nd and Sm)^{8,9)} films show that θ_k is more than 2° and the reflectivity is about 0.3-0.5 at $\lambda=633\text{nm}$, the high temperature quenched phase was restricted and the grain size is lower than 100 nm. But they have not given the temperature dependence of those properties above room temperature and the writing characteristics for these doped MnBi films with rare earth elements. Here we will report the studies on the magnetic properties and Kerr rotation angle as a function of the temperature and the writing and readout characters for the MnBiRE(RE=Ce,Pr,Nd and Sm) thin films.

2. Experimental

The mechanism of enhancing MO properties by

doping with some rare earth elements into MnBi thin films has been proved in experiment and theory in our previous work^{8,10)}. Here, the MnBiRE(RE=Ce,Pr,Nd and Sm) thin film samples were prepared by co-evaporation method at about 2×10^{-6} Torr. The Mn, Bi and RE elements were deposited onto the glass substrate with the thickness of 0.17 mm, cooled by the liquid nitrogen. The surface of the films was covered by the SiO_x(100nm) for the protection, then the prepared films were annealed at 350 °C for 4 hours. The thickness of the MnBiRE thin films is 30, 40, 60 and 90 nm.

The magnetic and magneto-optical properties of the MnBiRE thin films were measured by VSM and MO spectrum meter respectively. In order to investigate the temperature dependence of MO properties in a remanance state for MnBiRE thin films, we arranged the sample on a special holder in a vacuum-pumped quartz glass tube which was wound by a resistance wire for heating from Room temperature to 400 °C at 2×10^{-6} Torr. The maximum strength of the magnetic field is 8000 Oe. The error of measuring signal intensity is 0.2% and the error of measuring magnetic field is 1-2%. The measurement and data collection were collected by computer.

3. Results and Discussion

3.1 The temperature dependence of the MO Kerr angle θ_k and coercivity H_c of MnBiRE thin films

The dependence of the polar Kerr angle θ_k for MnBiNd, MnBiCe and MnBiSm film samples on temperature is shown in Fig.1. It was found that the Kerr rotation angle θ_k decreases with increasing temperature. This behavior is consistent with that of remanance σ_r as temperature increasing.

The magnitude of coercivity of MO films is important for writing information. The higher coercivity will make the written information stable, but the higher writing power will be required. We studied the temperature dependence of the magnetic properties of MnBiRE films. Figure 2 and 3 indicate the influence of temperature on the coercivity for MnBiRE(RE=Ce, Nd and Sm). It is shown that the

coercivity H_c increased as the temperature increased. This result is consistent with X.Guo's experiment result for pure MnBi films¹¹⁾. Here, it is found that the increasing tendency of H_c is different among the samples doped with different rare earth elements as

Fig.1 Temperature dependence of the polar Kerr angle for MnBiRE films. The light incidented from glass substrate side and $\lambda=632.8$ nm.

Fig.2 Temperature dependence of coercivity of $Mn_{1.15}BiCe_{0.10}$ and $Mn_{1.15}BiNd_{0.10}$ films.

Fig.3 Temperature dependence of coercivity of $MnBiNd_{0.20}$ and $Mn_{1.15}BiSm_{0.10}$ films.

well as among different compositions. When the samples were cooled to room temperature, the coercivity and Kerr angle almost returned to their initial values. These results satisfy the needs of thermo-magnetic writing of the magneto-optical recording media.

The magnitude of H_c increases with increasing temperature for MnBiRE samples may lead a higher writing power and a higher bias magnetic field.

3.2 The static readout and writing characteristics for the MnBiRE film samples

Figure 4 shows that the relative output signal of MnBiPr and quadri-layer structure TbFeCo samples as a function of the writing power at pulse width $\Delta t=5\mu s$, the bias magnetic field $H_b=400$ Oe and the readout power $P_{readout}=1.5mw$. It can be seen when the writing power is lower than 10 mw, the relative output signal for MnBiRE samples is weaker than that of the quadri-layer structure TbFeCo samples. However, when the writing power is higher than 11mw, the relative output signal for MnBiRE is stronger than that for the quadri-layer structure TbFeCo samples and increases more rapidly with increasing power.

The relations between the relative output signal for the MnBiRE samples and the bias magnetic field H_b are shown in Fig.5. In Fig.5, it can be seen that the relative output signal for MnBiRE is higher than that for the quadri-layer structure TbFeCo samples as the bias magnetic field is more than 50 Oe.

In addition, the relations between the relative output signal for the samples and the pulse width are shown in Fig.6. It is found that the relative output signal for MnBiRE samples is double of that for the quadri-layer structure TbFeCo samples when the pulse width is $5\mu s$.

3.3 The magnetic homogeneity of the samples and the shape of the bubble domain

Fig.4 Relations between the relative output signal and writing power (P_w) for $MnBiPr_{0.10}$ and quadri-layer structure TbFeCo samples ($\Delta t=5\mu s$, $H_b=400$ Oe, $P_{readout}=1.5mW$).

The magnetic homogeneity of MnBiRE film samples and the shape of the bubble domain are observed with a polarizing microscope. It is found that the samples with thinner film thickness (30,40 and 60 nm) were easy to reach saturation and be single domain. In contrast, the samples with the relative thicker film thickness (>190nm) were not easy to reach saturation. When the

writing power (He-Ne Laser) was 12.5mw and the pulse width was 2 μ s, the written cylindrical bubble domain was considerably circular and its edge was very clear (see Fig. 7). This phenomenon indicates that the writing characteristics can meet the needs of the thermo-magnetic writing, if the writing power could be relatively lower.

Fig.5 Relations between the relative output signal and the bias magnetic field (H_b) for MnBiPr_{0.10} and quadri-layer structure TbFeCo samples ($P_w=11.9\text{mW}$ $\Delta t=5\mu\text{s}$ $P_{\text{readout}}=1.5\text{mW}$).

Fig.6 Relations between the relative output signal and the pulse width (Δt) for MnBiPr_{0.10} and quadri-layer structure TbFeCo samples ($P_w=11.9\text{mW}$ $H_b=400\text{Oe}$ $P_{\text{readout}}=1.5\text{mW}$).

Fig.7 The shape of the written bubble domain observed with a polarizing microscope.

4. Conclusions

The MO Kerr rotation angle θ_k and H_c of MnBiRE thin films are dependent on temperature. The Kerr angle θ_k of MnBiRE films decreases with increasing temperature, while the coercivity H_c of MnBiRE films increases with increasing temperature. The readout signal of the MnBiRE samples is much larger than that of quadri-layer structure TbFeCo films but at a higher writing power. In addition, the MnBiRE films with relatively thinner thickness are easy to reach saturation and be single domain.

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