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# Magnetic and Magneto-Optical Properties of $\text{Mn}_x\text{CuBi}$ ( $x = 0.75 - 3.5$ ) Films

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## Magnetic and Magneto-Optical Properties of $Mn_xCuBi$ ( $x = 0.75 - 3.5$ ) Films<sup>†</sup>

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**Abstract** - Magnetic and magneto-optical properties of  $Mn_xCuBi$  ( $x = 0.75 - 3.5$ ) thin films are presented. With increasing Mn concentration  $x$ , the perpendicular anisotropy constant ( $K_u$ ), the remanence squareness ( $S = M_r/M_s$ ) and the coercivity ( $H_c$ ), of the perpendicular hysteresis loop increase. Remanence squareness as high as 0.95 has been obtained. Kerr rotation ( $\theta_k$ ) and ellipticity ( $\eta_k$ ) spectra from all samples measured from substrate side are similar, with  $\theta_k$  exhibiting a broad peak in the blue wavelength region with maximum Kerr rotation up to 0.7 degrees.

### I. Introduction

The Mn-Cu-Bi ternary system forms the compound  $Mn_3Cu_4Bi_4$  with face-centered cubic structure [1, 2], and the related  $MnCuBi$  thin films were proposed and investigated [3 - 6] for magneto-optical (MO) recording applications.  $MnCuBi$  thin films possess properties of practical interest in regard to MO recording media, such as perpendicular magnetic anisotropy, low Curie temperature, and moderately high magneto-optical Kerr effect. However, along with other problems,  $MnCuBi$  films if grown on glass substrates do not possess unity remanence squareness in their hysteresis loops. It was found [3-5] that the use of quartz substrates and doping with elements like Ti, V, or Cr could improve the magnetic hysteresis characteristics. In this report, by merely changing the Mn concentration, we demonstrate that the relevant magnetic hysteresis characteristics can be improved as well.

### II. Experimental Procedure

Six  $Mn_xCuBi$  samples, with  $x = 0.75, 1.0, 1.25, 1.5, 2.0,$  and  $3.5$  respectively, were made by vacuum deposition of Bi, Mn, and Cu successively on glass

substrates, and overcoating with  $SiO_x$ ; *in-situ* thermal annealing (300°C for an hour) followed to form the crystalline phase. For all six samples, the amounts of Bi (36nm) and Cu (30nm) as well as their 1:1 atomic ratio were kept the same while the amount of Mn was varied. The thickness of the  $SiO$  overcoat was 200nm.

The structure of  $Mn_xCuBi$  thin films was characterized by X-Ray Diffraction (XRD). Both perpendicular and in-plane magnetic hysteresis loops were measured by an Alternating Gradient Force Magnetometer (AGFM). The Kerr rotation and ellipticity spectra were measured on a Magneto-Optic Kerr Effect (MOKE) setup based on a photoelastic modulator. The Curie temperature was obtained from Kerr rotation vs. temperature measurements, and the temperature dependence of the coercivity was obtained from the MOKE hysteresis loops.

### III. Results and Discussion

Figure 1 displays the XRD patterns of all six samples.

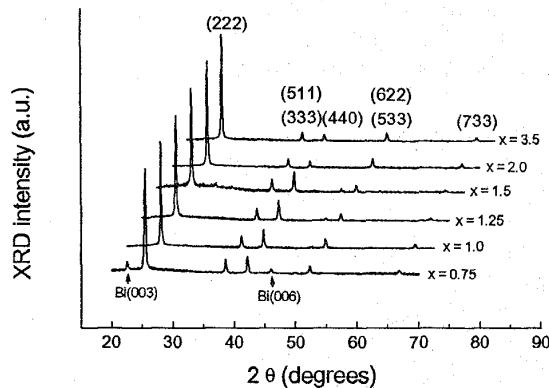


Fig.1. XRD patterns of  $Mn_xCuBi$  films.

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The marked peaks are from the  $\text{Mn}_3\text{Cu}_4\text{Bi}_4$  phase. Note that the free Bi peaks on sample  $x = 0.75$  indicate the incomplete reaction for that Mn concentration. The XRD patterns are characterized by a strong (222) diffraction peak, which indicates that  $\text{Mn}_x\text{CuBi}$  films are highly textured with the dense-packed plane parallel to the substrate surface. But the extra peaks indicate that crystallites with other orientations also exist.

Figures 2 (a) and (b) display the perpendicular and the in-plane magnetic hysteresis loops of all six samples. As the Mn concentration increases, the remanence squareness and the coercivity of the perpendicular loops increase, which are quantitatively shown in Fig. 3. Also,

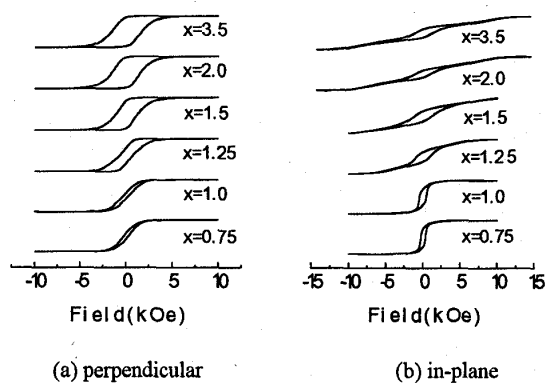


Fig. 2 (a) perpendicular and (b) in-plane hysteresis loops of  $\text{Mn}_x\text{CuBi}$  films measured by AGFM at room temperature.

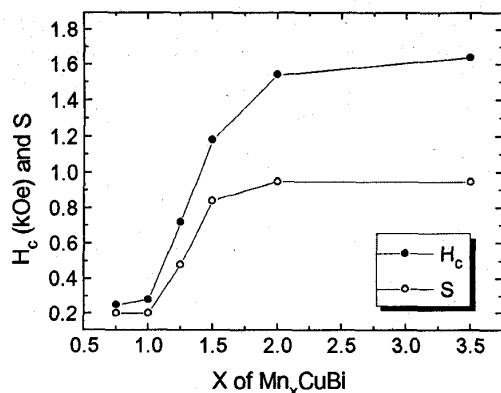


Fig. 3. Mn concentration dependence of coercivity  $H_c$  and remanence squareness  $S$  of  $\text{Mn}_x\text{CuBi}$  films.

the in-plane saturation field increases drastically with increasing Mn concentration. Measurement of the area between the in-plane and the perpendicular loops, with correction for the demagnetization fields, shows that the anisotropy constant  $K_u$  increases from  $0.5 \times 10^6 \text{ erg/cm}^3$  to  $1.0 \times 10^6 \text{ erg/cm}^3$  as  $x$  increases from 0.75 to 3.5. Note that both  $H_c$  and  $S$  tend towards saturation for  $x > 2.0$ . The magnetization of samples  $x = 1.0$  to 3.5 is roughly  $300 \text{ emu/cm}^3$ , while that of  $x = 0.75$  is only  $240 \text{ emu/cm}^3$ , apparently because of the incomplete reaction.

The Kerr rotation  $\theta_k$  and Kerr ellipticity  $\eta_k$  spectra of the sample  $\text{Mn}_{1.0}\text{CuBi}$  measured from the substrate side are shown in Fig. 4.  $\theta_k$  exhibits a broad peak at the wavelength 490 nm with peak value at 0.7 degrees. The other compositions show similar  $\theta_k$  and  $\eta_k$  spectra with slightly different magnitudes ( $\pm 0.1$  degrees for  $x > 1.0$ , and about 0.2 degrees smaller for  $x = 0.75$ ).

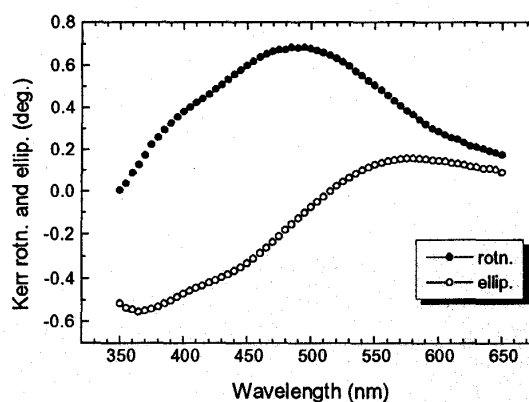


Fig. 4. Kerr rotation and ellipticity spectra of  $\text{Mn}_{1.0}\text{CuBi}$  film measured from substrate side.

Kerr rotation  $\theta_k$  vs. temperature curves are plotted in Fig. 5. The Curie temperature slightly decreases with increasing Mn concentration, ranging from  $225^\circ\text{C}$  for  $x = 0.75$  down to  $205^\circ\text{C}$  for  $x = 2.0$  and 3.5. All the  $\theta_k$  vs. temperature curves are reversible upon heating and cooling, indicating that  $\text{Mn}_x\text{CuBi}$  films are thermally stable above their Curie temperatures in contrast to the instability of the  $\text{MnBi}$  system [7].

The coercivity  $H_c$  of  $\text{Mn}_x\text{CuBi}$  decreases with increasing temperature, and vanishes near the Curie temperature. Figure 6 displays  $H_c$  vs. temperature for sample  $\text{Mn}_{3.5}\text{CuBi}$ .

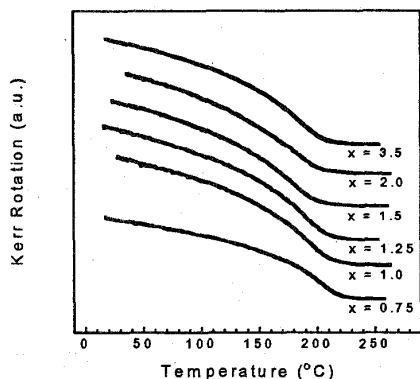


Fig. 5. Kerr rotation (at  $\lambda = 490$  nm) vs. temperature curves of  $Mn_xCuBi$  films. The Kerr rotation for each curve is offset for visual purpose.

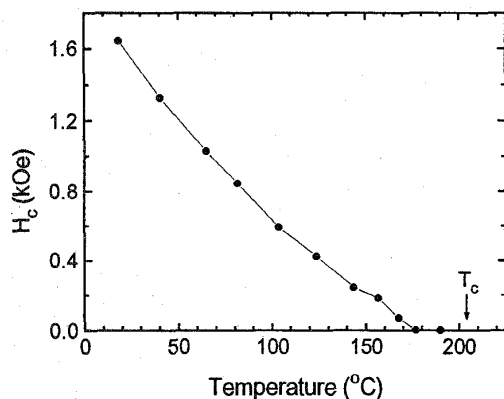


Fig. 6. Temperature dependence of coercivity  $H_c$  for  $Mn_{3.5}CuBi$ .  $H_c$  was obtained from MOKE hysteresis loops.

#### IV. Conclusions

The magnetic properties of  $Mn_xCuBi$  films can be changed by varying the Mn concentration. The perpendicular magnetic anisotropy, remanence squareness, and the coercivity increase with increasing Mn concentration, and these values tend to saturate at  $x = 2.0$ . Kerr rotation and ellipticity spectra of  $Mn_xCuBi$  measured from the substrate side exhibit fairly large Kerr rotation (0.7 degrees) in the blue wavelength region, and the spectra are not altered by the varying Mn

concentration. Although hysteresis loops of  $Mn_xCuBi$  with  $S = 0.95$  have been obtained, a square loop with fairly large nucleation or switching field needs to be further pursued if this material is to be used for MO recording applications.

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