November 1995

Magnetic and Magneto-Optical Properties of Mn_xCuBi (x =0.75 - 3.5) Films†

Jian Chen
University of Nebraska - Lincoln

K. Wierman
University of Nebraska - Lincoln

Roger D. Kirby
University of Nebraska-Lincoln, rkirby1@unl.edu

David J. Sellmyer
University of Nebraska-Lincoln, dsellmyer@unl.edu

Chen, Jian; Wierman, K.; Kirby, Roger D.; and Sellmyer, David J., "Magnetic and Magneto-Optical Properties of Mn_xCuBi (x =0.75 - 3.5) Films†" (1995). *Faculty Publications, Department of Physics and Astronomy*. 55.
http://digitalcommons.unl.edu/physicsfacpub/55

Magnetic and Magneto-Optical Properties of Mn_XCuBi (x =0.75 - 3.5) Films†

Jian Chen, K. Wierman, R. D. Kirby, and D. J. Sellmyer
Center for Materials Research and Analysis
and Behlen Laboratory of Physics,
University of Nebraska, Lincoln, NE 68588 - 0111

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 (θ_k) and ellipticity (η_k) spectra from all samples measured from substrate side are similar, with θ_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 relevent 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 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.

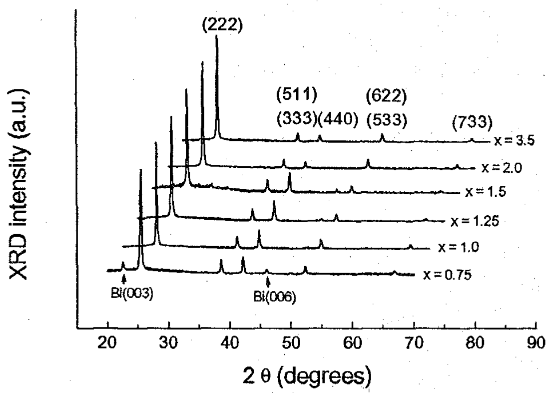


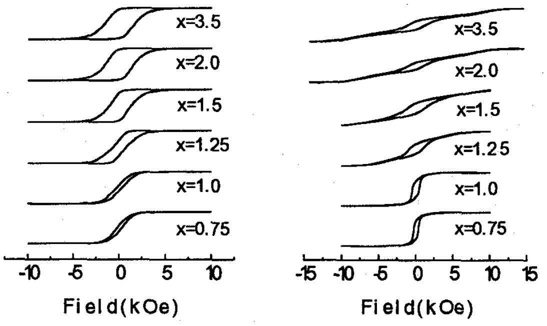
Fig.1. XRD patterns of Mn_xCuBi films.

---

† manuscript received on February 17, 1995

The marked peaks are from the $Mn_3Cu_4Bi_4$ 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 Mn_xCuBi 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, 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 X 10^6 erg/cm^3 to 1.0 X 10^6 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 emu/cm^3, while that of x = 0.75 is only 240 emu/cm^3, apparently because of the incomplete reaction.



(a) perpendicular (b) in-plane

Fig. 2 (a) perpendicular and (b) in-plane hysteresis loops of Mn_xCuBi films measured by AGFM at room temperature.

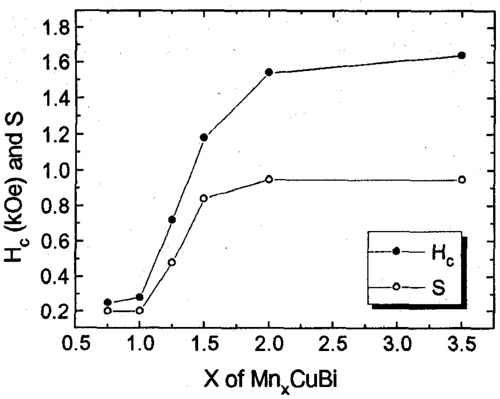


Fig. 3. Mn concentration dependence of coercivity H_c and remanence squareness S of Mn_xCuBi films.

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

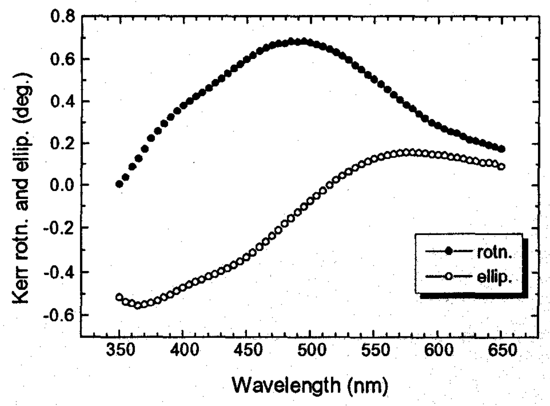


Fig. 4. Kerr rotation and ellipticity spectra of $Mn_{1.0}CuBi$ film measured from substrate side.

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

The coercivity H_c of Mn_xCuBi decreases with increasing temperature, and vanishes near the Curie temperature. Figure 6 displays H_c vs. temperature for sample $Mn_{3.5}CuBi$.

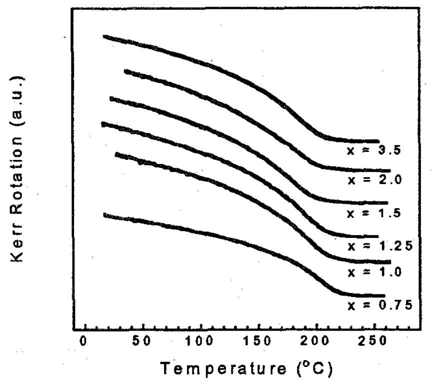


Fig. 5. Kerr rotation (at λ = 490 nm) vs. temperature curves of Mn_xCuBi films. The Kerr rotation for each curve is offseted for visual purpose.

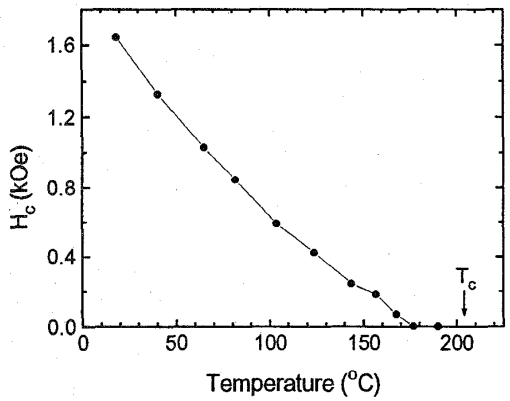


Fig. 6. Temperature dependence of coercivity H_C for $Mn_{3.5}CuBi$. H_c was obtained from MOKE hysteresis loops.

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.

We are indebted for financial support of this work to the Advanced Research Projects Agency / National Storage Industry Consortium under grant MDA972-93-1-0009, and to the Center for Materials Research and Analysis.

References

[1] G. Bryan Street, J. C. Suits and Kenneth Lee, "New compounds in the Mn-X-Bi system where X = Ni, Cu, Rh or Pd," *Solid State Communications*, vol. 14, pp. 33-36, 1974.

[2] A. Szytula, H. Binczycka, and J. Todorovic, "Crystal and magnetic structure of $Ni_2Mn_5Bi_4$ and $Cu_4Mn_3Bi_4$," *Soild State Communications*, vol. 38, pp. 41-43, 1981.

[3] A. Katsui, "Magnetic and magneto-optic properties of ferromagnetic MnCuBi thin films," *Journal of Applied Physics*, Vol.47, pp. 3609-11, August 1976.

[4] A. Katsui, A. Shibukawa, H. Terui, and K. Egashira, "New magneto-optic thin films for storage application," *Journal of Applied Physics*, Vol.47, pp. 5069-71, November 1976.

[5] A. Katsui, "Dy-doped $MnCuBi_{0.86}$ films for magneto-optic storage application," *Journal of Applied Physics*, Vol.47, pp. 4663-65, October 1976.

[6] Kazunori Chida, Bunjiro Tsujiyama, Akinori Katsui, and Kazumichi Egashira, "Magnetooptical memory experiments on a rotating Mn-Cu-Bi disk medium," *IEEE Transactions on Magnetics*, Vol. MAG-13, pp. 982-988, May 1977.

[7] B. W. Roberts, "Neutron diffraction study of the structures and magnetic properties of manganese bismuthide," *Physical Review*, Vol. 104, pp. 607-616, November 1956.