THE REASON OF LARGE ENHANCEMENT OF KERR ROTATION IN MnBiAl THIN FILM

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A new kind of magneto-optical thin film MnBi$_{0.8}$Al$_{0.2}$ covered by SiO layer has been prepared by vacuum deposition and a large enhancement of Kerr rotation about $2^\circ$ nearby 633 nm at the room temperature has been found [1]. The question remained is which kind of reason causes the enhancement.

Generally, due to Al doping there are two possibilities to explain it: an intrinsic effect caused by change of band structure and optical enhancement. In order to make it clear which one is of concern. We consider the optical enhancement at first.

From the spectra of Kerr rotation and the optical reflectivity measured at room temperature for MnBiAl, the optical constants, refractive index n, distinction coefficient k and off-diagonal elements $\sigma_{1xy}$ and $\sigma_{2xy}$, which are required for the calculation of Kerr rotation of MnBiAl, were derived by means of Kramers-Krönig analysis and the calculation of the effective dielectric tensor model developed by Abe [2]. His calculation was on the basis of Maxwell equation and boundary condition in a general case, assuming that the magnetic fine ellipsoids are separately arrayed in a nonmagnetic matrix. Here we quote the expression for the diagonal and off-diagonal elements of the efficient dielectric tensor as follows

$$\varepsilon'_j = \varepsilon_1 + f(\varepsilon_2 - \varepsilon_1)/[1+(1-f)(\varepsilon_2 - \varepsilon_1)\varepsilon_1^{-1}N_j], \quad (j=xx,yy) \quad (1)$$
$$\varepsilon'_{xy} = \varepsilon_{xy}f/[1+(1-f)(\varepsilon_2 - \varepsilon_1)\varepsilon_1^{-1}N_y] \quad (2)$$

where f is the volume fraction of the magnetic material. $\varepsilon_1$, $\varepsilon_2$ is the diagonal elements for the nonmagnetic matrix Al$(Al_2O_3)$ and MnBi respectively. N is the depolarization vector. In the layer case $N=0$, while in the cylinder case $N=1/2$ (see Fig 1).

On the basis of preparation of the samples [1] we assumed Al or $Al_2O_3$ existed as the form of the thin layer or dielectric matrix on the top of glass substrate, which is corresponding to the case of $N=0$ and $N=1/2$ mentioned above. Consequently, the efficient magneto-optical layer ($d_0$ about 20 nm thick) reacting with the incident light on the interior side of the substrate is composed by the doping impurities and MnBi.

The calculations of $\theta_k$ vs wavelength for both layer and cylinder structure under $Al_2O_3$ doping is indicated in Fig.2 and Fig.3. The layer structure or cylinder structure of MnBi/Al does not cause any enhancement, while after introducing of $Al_2O_3$ a
large enhancement appears. These results are in good agreement with our experiments. In the case of layer structure MnBi/Al₂O₃, when the appropriate ratio of d_{MnBi}/d₀ is chosen, the Kerr rotation can be greatly enhanced, while in the cylinder case the enhancement is not so large.

The experimental curve of θₖ vs. wavelength for MnBi₀.₈Al₀.₅ could be fitted if the contribution from both the layer and the cylinder structure is taken into account. Fig.4 shows the theoretical calculation and the experiment and they agree well. However, a slight shift (about 0.2 ev) of the Kerr peak still exists. It may be caused by the intrinsic effect resulting from the orbit hybridization due to Al doping. Therefore we speculate the Kerr enhancement for MnBiAl film is a multi-effect from the optical enhancement and the intrinsic effect.