

GaMnAs における誘電率テンソルの非対角成分

Estimation of the off-diagonal element of the dielectric tensor of GaMnAs

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Magnetic circular dichroism (MCD) measurements have been performed in ferromagnetic semiconductors to characterize the ferromagnetism and band structures. Indeed, the band structures of GaMnAs has been discussed from the results of MCD measurements [1] [2]. However, MCD spectra are strongly dependent on the sample structures. In particular, in reflection MCD measurements, MCD spectra are influenced by multiple reflection effects [2]. To solve this problem and obtain the intrinsic properties of materials, we must evaluate an off-diagonal element ε_{xy} of dielectric tensor $\tilde{\varepsilon}$. Determination of ε_{xy} is important, because MCD is expressed by ε_{xy} which is inherent to a material.

In this study, we grew GaMnAs thin film samples with various thicknesses d , and we estimated ε_{xy} of GaMnAs. To estimate ε_{xy} , we assumed that the diagonal element ε_{xx} of $\tilde{\varepsilon}$ is equal to the dielectric function in ref [3], and that the magnetization of the samples is perpendicular to the film plane. We adopted the dielectric dispersion equation based on Kubo formula [4], in the estimation of ε_{xy} . We took into account the multiple reflection in the calculation of MCD spectra. We estimated $\tilde{\varepsilon}$ and calculated MCD spectra to fit to the experimental d dependence of MCD spectra.

Schematic sample structure is shown in the inset of Fig. 1 (a). $\text{Ga}_{0.98}\text{Mn}_{0.02}\text{As}$ (d nm)/ GaAs (100 nm) structure was grown on a semi-insulating GaAs (001) substrate by low temperature molecular beam epitaxy. The Curie temperature T_C of the samples was estimated by the Arrott plot using the MCD intensity vs. magnetic field characteristics. Because T_C was about 45 K and was nearly constant among the samples with various d , the influence of the fluctuation of Mn content and crystallinity of the samples is negligible. The main graph of Fig. 1 (a) shows the reflection MCD spectra of GaMnAs with $d = 10$ nm, 20 nm, and 100 nm measured at 5 K at a magnetic field of 1 T applied perpendicular to the film plane. As shown in Fig. 1 (a), MCD spectra were strongly dependent on d . Fig. 1 (b) and Fig. 1 (c) show calculated MCD spectra and estimated ε_{xy} , respectively. In the calculation, we shifted d for

better fit. In Fig. 1 (c), ε_{xy}' and ε_{xy}'' represent the real part and the imaginary part of ε_{xy} , respectively. As shown in Fig. 1 (a) and (b), we semi-quantitatively succeeded in explaining the d dependence of MCD spectra with estimated ε_{xy} . We can conclude that ε_{xy} of $\text{Ga}_{0.98}\text{Mn}_{0.02}\text{As}$ was estimated with good accuracy.

This work was partly supported by Grant-in-Aids for Scientific Research including Specially Promoted Research, and Project for Developing Innovation Systems of MEXT.

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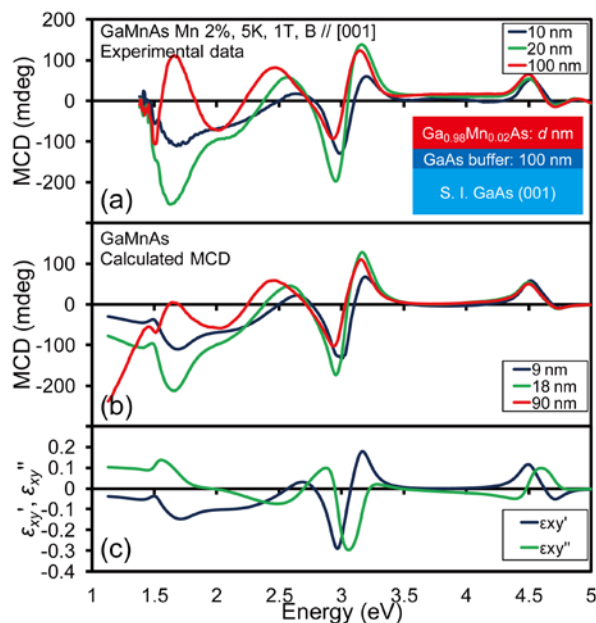


Fig. 1 (a) MCD spectra of GaMnAs with $d = 10$ nm, 20 nm, and 100 nm, measured at 5 K, 1 T, B // [001]. Inset: Schematic structure of the sample. (b) Calculated MCD spectra of GaMnAs from estimated ε_{xy} . (c) Estimated ε_{xy}' and ε_{xy}'' .