X-ray Magnetic Circular Dichroism study of MnGeP\textsubscript{2} thin film

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Introduction

Recently the discovery of diluted magnetic semiconductors (DMSs) which show room-temperature ferromagnetism has been a hot issue. These materials are promising candidates for spintronics devices. Some of Mn-doped II-IV-V\textsubscript{2} (chalcopyrite) type DMSs show room-temperature ferromagnetism, and attract much attention. For instance, it is reported that $T_C$'s of ZnGeP\textsubscript{2}:Mn and CdGeP\textsubscript{2}:Mn are $\approx$350 K and $\approx$320 K respectively, well above room temperature [1, 2]. It is found that Mn atoms substitute mainly for the II (Zn, Cd) sites in these materials. By \textit{ab initio} calculations based on local density approximation, the ferromagnetism derives from the carriers which arise from the system with vacancies (II, Vc, Mn)GeP\textsubscript{2} or non-stoichiometric (II, Ge, Mn)GeP\textsubscript{2} [3]. In ZnGeP\textsubscript{2}:Mn, 100% Mn substitution i.e. MnGeP\textsubscript{2} was achieved [4].

In this work we have measured soft X-ray absorption (XAS), and soft X-ray magnetic circular dichroism (XMCD) spectra of MnGeP\textsubscript{2} thin film to clarify the electronic state and the origin of ferromagnetism of the MnGeP\textsubscript{2} thin film by studying the magnetic state of the Mn atoms.

Experimental

The MnGeP\textsubscript{2} thin film was fabricated by the MBE method. The thin film was deposited on a Ge buffer layer at 435\textdegree C which was grown on a GaAs(001) substrate at 380 \textdegree C. The Ge buffer layer enables a two-dimensional growth of MnGeP\textsubscript{2} thin film [5]. In order to eliminate surface effects, the sample was capped with a 3nm Ge layer over the thin film. The fabricated MnGeP\textsubscript{2} thin film was transferred into a superconducting magnet under an ultra high vacuum of $10^{-9}$ Torr. The XAS and XMCD spectra were taken in a total electron yield mode at 200 K and 30 K with applied magnetic field at 5.0 T.

We have done a magnetization measurement for the MnGeP\textsubscript{2} thin film in advance. The sample showed $T_C$ $\approx$320 K and thus it was confirmed to be a room-temperature ferromagnet. Additionally the $M$-$T$ curve indicated that there was a component which obeyed the Curie-Weiss law in the sample. This fact suggested that a paramagnetic component existed in the sample.

Results and Discussion

Figure 1 shows Mn $L_{2,3}$ XMCD spectra taken at $T=200$ K and 30 K at $H=5.0$ T. The intensity has been normalized to at the Mn $L_3$ edge. The XMCD signal was observed even at 30 K, indicating that the MnP phase is not a dominant component of the sample, because in MnP a ferromagnetic-to-anti-ferromagnetic transition occurs at 47 K. The XMCD spectra have two negative fine structures at the Mn $L_3$. Structure A is dominant at 200 K and structure B is dominant at 30 K. This difference may be caused by a paramagnetic component in the sample. Furthermore by applying the XMCD sum rules, $M_{orb}$ and $M_{spin}$ were obtained. Assuming that $n_d \approx 5.0$, $M_{orb}(200 \text{K}) \approx$0.039 $\mu_B$/Mn and $M_{orb}(30 \text{K}) \approx$0.159 $\mu_B$/Mn. It appears that at low temperature contributions from the paramagnetic component becomes large and that the sizable orbital magnetic moment appears.

![XMCD spectra](chart.png)

Fig. 1: Mn $L_{2,3}$ XMCD spectra of the MnGeP\textsubscript{2} thin film

References


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