X-ray Magnetic Circular Dichroism study of $MnGeP_2$ 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_2 (chalcopyrite) type DMSs show room-temperature ferromagnetism, and attract much attention. For instance, it is reported that T_C's of $ZnGeP_2$:Mn and $CdGeP_2$:Mn are ~350 K and ~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 *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_2 or non-stoichiometric (II, Ge, Mn)GeP_2 [3]. In $ZnGeP_2$:Mn, 100% Mn substitution i.e. $MnGeP_2$ was achieved [4].

In this work we have measured soft X-ray absorption (XAS), and soft X-ray magnetic circular dichroism (XMCD) spectra of $MnGeP_2$ thin film to clarify the electronic state and the origin of ferromagnetism of the $MnGeP_2$ thin film by studying the magnetic state of the Mn atoms.

Experimental

The $MnGeP_2$ thin film was fabricated by the MBE method. The thin film was deposited on a Ge buffer layer at 435 °C which was grown on a GaAs(001) substrate at 380 °C. The Ge buffer layer enables a two-dimensional growth of $MnGeP_2$ thin film [5]. In order to eliminate surface effects, the sample was capped with a 3nm Ge layer over the thin film. The fabricated $MnGeP_2$ 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 $MnGeP_2$ thin film in advance. The sample showed T_C~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 ≒ 5.0, M_{orb}(200 K) ~0.039 μ_B/Mn and M_{orb}(30 K) ~0.159 μ_B/Mn. It appears that at low temperature contributions from the paramagnetic component becomes large and that the sizable orbital magnetic moment appears.

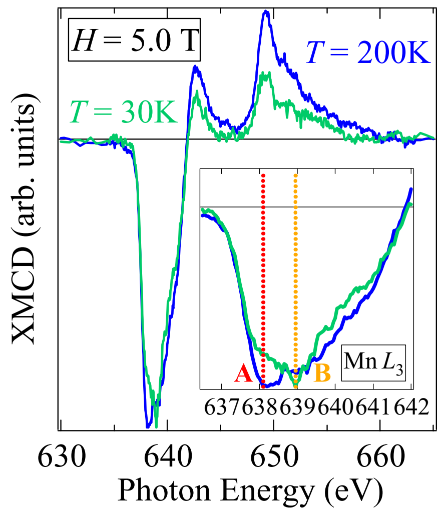

Fig. 1: Mn $L_{2,3}$ XMCD spectra of the $MnGeP_2$ thin film

References

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