Materials Science

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X-ray fluorescence holography of distorted rhombohedral GeTe

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Introduction

The magnetic ion doped IV-VI diluted magnetic semiconductor $Ge_{1-x}Mn_xTe$ is expected as a spintronics material, because it shows a ferromagnetic order below 140 K at x = 0.51 [1]. It is believed that the ferromagnetism largely relates to the arrangements of the Mn ions and the cation vacancies. Due to such vacancies, the crystal would distort, which may also influence the ferromagnetism of this material. X-ray fluorescence holography (XFH) is a powerful tool to investigate such atomic distortions by obtaining three-dimensional (3D) atomic images.

Recently, we performed the XFH experiments on the $Ge_{0.6}Mn_{0.4}Te$ [2, 3] in order to investigate the local structures around the Ge and Mn atoms. The results suggest that the Ge positions are not stable at the exact positions of fcc cation sublattice, and reveal the fluctuations of Ge positions and/or the existence of cation vacancies. It seems that the fluctuation is due to the pure GeTe, which is a distorted rhombohedral structure with the short and long bonds, as seem in Fig.1. Thus, the pure GeTe is an important standard material for the study on $Ge_{1-x}Mn_xTe$. In this study, the Ge $K\alpha$ XFH measurement was carried out on the GeTe thin film.

Experimental procedure

The GeTe single crystal thin film sample was grown on a BaF_2 (111) substrates by a molecular beam epitaxy technique. The Ge $K\alpha$ XFH experiment was performed at BL6C and BL15B of the PF/KEK. Incident X-rays were irradiated onto the (111) sample surface. The hologram data were collected in inverse mode at room temperature at different incident X-ray energies of 11.2–14.2 keV in 0.5 keV steps. The Ge $K\alpha$ (9.885 keV) fluorescent X-rays were detected by an avalanche photodiode via a cylindrical graphite energy-analyzer. From the hologram patterns obtained with 7 different incident X-ray energies, an atomic configuration image was reconstructed using Barton's algorithm [4].

Results and discussion

The obtained 3D atomic image from the Ge $K\alpha$ XFH of GeTe was depicted in Fig. 2. The central Ge atom locates at the center of the (111) plane. The images of the first-neighboring Te anions were clearly seen around the central Ge atom. The distance between the (111) plane on the first-neighboring Te and that on the central Ge is 1.45 Å. The value is shorter than the distance 1.60Å of the $Ge_{0.6}Mn_{0.4}Te$, as seen in Fig.3. Detailed analysis of the present XFH data are now in progress.

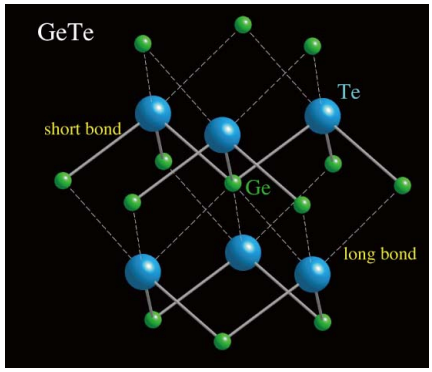

Fig. 1 Crystal structure of GeTe.

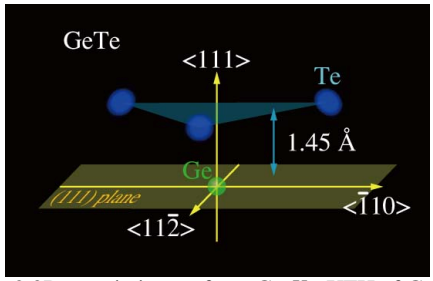

Fig. 2 3D atomic image from Ge $K\alpha$ XFH of GeTe.

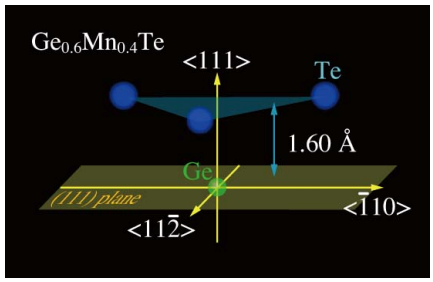

Fig. 3 3D atomic image of $Ge_{0.6}Mn_{0.4}Te$.

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