Materials Science

6C/2009G584, 2009G551, 2009G608

X-ray fluorescence holography of ferromagnetic semiconductor $Ge_{0.6}Mn_{0.4}Te$

Naohisa HAPPO[*1], Shinya SENBA[2], Wen HU[3], Shinya HOSOKAWA[4], Kouichi HAYASHI[5]
[1]Hiroshima City University, Hiroshima 731-3194, Japan
[2]Ube National College of Technology, Ube 755-8555, Japan
[3]SPring-8/JAEA, Hyogo 679-5148, Japan
[4]Hiroshima Institute of Technology, Hiroshima 731-5193, Japan
[5]Tohoku University, Sendai 980-8577, Japan

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 ~100 K at x = 0.25–0.98 [1]. It is believed that the ferromagnetism largely relates to the arrangements of the Mn ions and the vacancies, the latter of which may be induced at the cation positions. 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. Note that the distortions in crystals cannot be directly obtained from a usual x-ray diffraction technique. We recently performed the XFH experiments on $Cd_{0.6}Mn_{0.4}Te$ [2] and $Zn_{0.4}Mn_{0.6}Te$ [3] in order to investigate the local structure around the Mn and Zn atoms, and the distortions in these mixed crystals were discussed in detail. In this study, the Ge $K\alpha$ XFH measurement was carried out on $Ge_{0.6}Mn_{0.4}Te$ thin film.

Experimental procedure

A $Ge_{0.6}Mn_{0.4}Te$ 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 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

Figure 1 shows an example of the hologram pattern at 11.2 keV, which is projected from the <111> direction. The straight or curved lines originate from the X-ray standing waves. These clear patterns suggest that the $Ge_{0.6}Mn_{0.4}Te$ sample has a good crystallinity.

The obtained 3D atomic image from the Ge $K\alpha$ XFH was depicted in Fig. 2. The central Ge atom locates at the center of the figure, and the pink and blue circles indicate the unit cell of the host GeTe crystal. A NaCl-like sublattice of Te anions was clearly seen around the central Ge atom. On the contrary, the images of cations are hardly visible in the figure. This result suggests that the positions of cations largely fluctuate in $Ge_{0.6}Mn_{0.4}Te$.

References

[1] W. Q. Chen, *et al.*, J. Appl. Phys. **99**, 08D515 (2006).
[2] N. Happo *et al.*, J. Cryst. Growth **311**, 990 (2009).
[3] S. Hosokawa *et al.*, Phys. Rev. B **88**, 134123 (2009).
[4] J. J. Barton, Phys. Rev. Lett. **67**, 3106 (1991).
* happo@hiroshima-cu.ac.jp

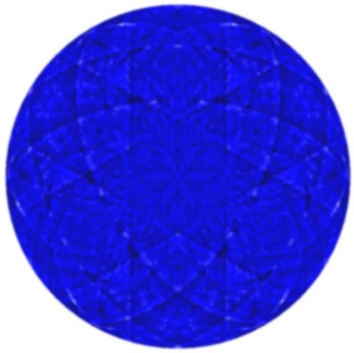

Fig. 1 Hologram obtained at 11.2 keV.

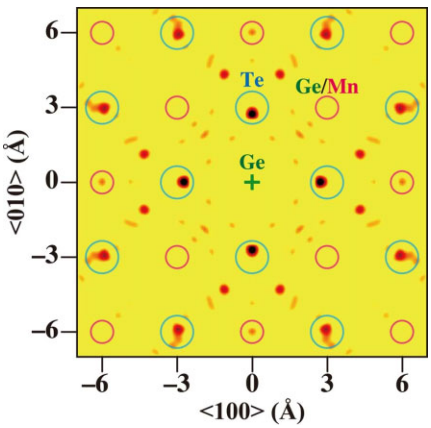

Fig. 2 Atomic image on (001) plane.