

An XAFS study of the local environment of Cr ions in the diluted magnetic semiconductor $\text{Zn}_{1-x}\text{Cr}_x\text{Te}$

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Introduction

Novel processing storage devices are anticipated to result from the unique combination of the magnetism due to *d* electrons and the semiconducting transport properties due to *s* and *p* electrons that is realized in diluted magnetic semiconductors (DMSs) based on II-VI, II-V and IV compounds. Representative examples of DMSs with long-range ferromagnetic order are $\text{In}_{1-x}\text{Mn}_x\text{As}$ and $\text{Ga}_{1-x}\text{Mn}_x\text{As}$. It is difficult to control their magnetic and semiconducting properties independently, however, because the ferromagnetism originates by virtue of holes self-supplied by Mn ion impurities. The Curie temperature T_c reaches 170 K with heavy doping.

Recently the DMS $\text{Zn}_{1-x}\text{Cr}_x\text{Te}$ has been found to exhibit ferromagnetism at room temperature[1, 2]. There was no evidence for secondary phase precipitates detectable by either X-ray diffraction or transmission electron microscopy. Magnetic circular dichroism measurements (MCD) indicated that the origin of the ferromagnetism was $\text{Zn}_{1-x}\text{Cr}_x\text{Te}$, not from different phase precipitates. In this study, we examined ferromagnetic $\text{Zn}_{1-x}\text{Cr}_x\text{Te}$ from a structural perspective; the local structure about Cr ions was probed by X-ray absorption spectroscopy at the Cr K-edge.

Experiment

$\text{Zn}_{1-x}\text{Cr}_x\text{Te}$ films, 200 – 400 nm thick, with a Cr concentration $x \leq 0.2$ were grown at 250 – 300 °C on semi-insulating GaAs (001) substrates using a molecular beam epitaxy.

XAFS measurements at the Cr K-edge were performed at beamlines BL9A and BL12C in fluorescence mode. Harmonics were removed using a Ni mirror at BL9A or by detuning the crystals of the monochromator at BL12C. The Cr K_{α} fluorescence X-ray was collected using a 19-channel SSD.

Results and Discussion

The local structure of Cr ions was analyzed using extended X-ray absorption fine structure (EXAFS). The EXAFS function $\chi(k)$ for the first shell was well fit by a model in which Cr ions substitutionally occupied the Zn sites of a zincblende ZnTe (substitutional-ZB model).

The near-edge structure (XANES) at the Cr K-edge of the $\text{Zn}_{1-x}\text{Cr}_x\text{Te}$ films was compared with that

of dilute-Cr-doped single crystal $\text{Zn}_{1-x}\text{Cr}_x\text{Te}$, $x = 0.0004$ (bulk ZnCrTe) as well as theoretical calculations performed using Feff8[3]. The characteristic features observed in the XANES of the bulk ZnCrTe sample were well reproduced by a theoretical calculation based upon a substitutional-ZB model. The solid lines in Fig. 1 are XANES spectra taken at the Cr K-edge for $\text{Zn}_{1-x}\text{Cr}_x\text{Te}$, $x = 0.08$ and $x = 0.20$, which were identified as single phase DMS based upon MCD measurements. They are nearly identical and the characteristic features are well-matched by the substitutional-ZB model calculated spectrum. Thus we conclude, Cr ions substitutionally occupy Zn sites in zincblende ZnTe in $\text{Zn}_{1-x}\text{Cr}_x\text{Te}$ films with $x \leq 0.2$, and the ferromagnetism at room temperature at $x = 0.2$ originates from Cr ions, not from the secondary phase CrTe.

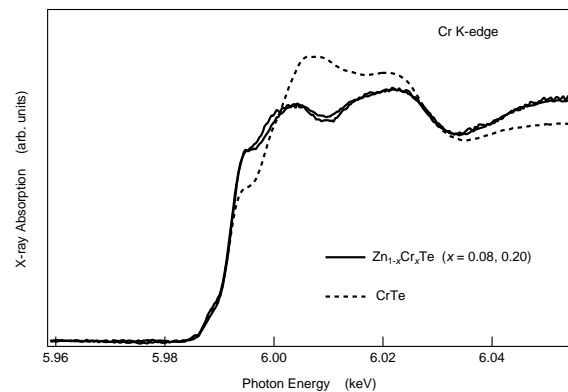


Figure 1: XANES spectra at the Cr K-edge for $\text{Zn}_{1-x}\text{Cr}_x\text{Te}$, $x = 0.08$ and $x = 0.20$ (solid lines) and that for CrTe (dashed line).

References

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