

Structural analysis and magnetic properties of nitrogen co-doped II-VI diluted magnetic semiconductor (Zn, Fe) Te grown by MBE

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In many of the diluted magnetic semiconductors (DMS), the open d or f shells of the incorporated magnetic ions form a localized level within the band gap of host semiconductors [1], which opens the scope to trap carriers introduced by external impurities. Because of this trapping, the charge state of magnetic ions changes and thus makes impact on their mutual Coulomb interaction [2]. Among various II-VI DMSs, Fe-doped selenides or tellurides have been known as van-Vleck type paramagnetism [3]. The isoelectronic Fe^{2+} state on the substitutional site of II-VI compounds produces only field-induced magnetic moments. However, the trap of carriers introduced by additional charge doping is expected to deviate the Fe charge state from Fe^{2+} , resulting in a possible modification of magnetic properties. Therefore, we are motivated to investigate how the co-doping of acceptor impurity nitrogen (N) affects the magnetic properties of Fe-doped ZnTe, which has not yet been experimentally studied.

We grew $\text{Zn}_{1-x}\text{Fe}_x\text{Te}$ thin films by molecular beam epitaxy (MBE) in excess of Te flux over Zn flux with the Fe composition fixed at $x = 0.015$ and the N concentration varied in the range of $8 \times 10^{17} - 4 \times 10^{19} \text{ cm}^{-3}$. We used N plasma source with N_2 gas excited by rf plasma. Structural analysis was done by x-ray diffraction (XRD) and x-ray absorption fine structure (XAFS) measurements. In the XRD θ -2 θ scan, no extrinsic precipitates were detected. However, the XAFS measurement reveals the deviation of Fe from substitutional site due to the N-doping as shown in Fig. 1; the radial distribution function (RDF) shows variation with N-doping, suggesting the change in the Fe position from the substitutional site in the zinc-blende (ZB) structure to that in the Fe-N compounds. The magnetization measurement using superconducting quantum interference device (SQUID) reveals a drastic change of magnetic properties by the N-doping, as represented by the evolution of magnetic-field dependence of magnetization (M - H curve) in Fig. 2; the linear M - H curve in the film without N-doping changes into a ferromagnetic feature with hysteresis in the N-doped films in the range of $[\text{N}] = 8 \times 10^{17} - 7 \times 10^{18} \text{ cm}^{-3}$, and comes back to the linear dependence at a higher N concentration of $[\text{N}] = 4 \times 10^{19} \text{ cm}^{-3}$. The observed ferromagnetic behaviors in the $[\text{N}]$ range studied here could be attributed to the formation of precipitates of ferromagnetic Fe-N compounds such as $\gamma\text{-Fe}_4\text{N}$ (fcc) or $\epsilon\text{-Fe}_{2.3}\text{N}$ (hcp) [4]. The linear M - H dependence at higher $[\text{N}]$ may originate from another type of precipitates such as $\zeta\text{-Fe}_2\text{N}$ (orthorhombic) [4], which exhibits antiferromagnetism in bulk form.

References

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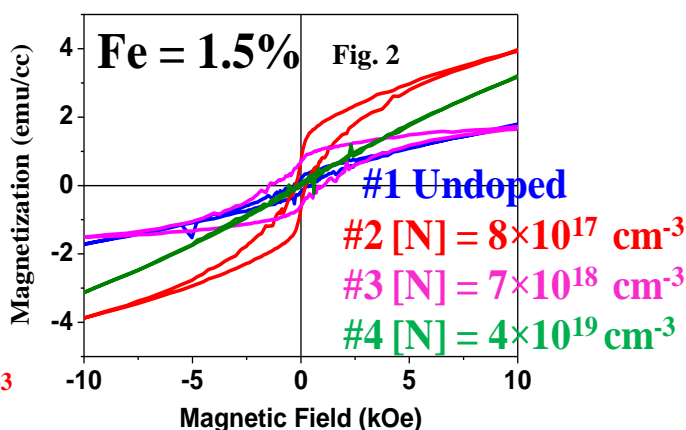
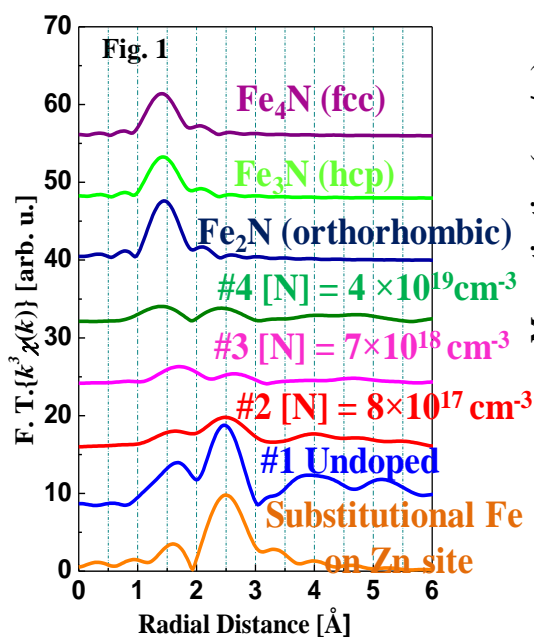


Fig. 1 RDF spectra of $\text{Zn}_{1-x}\text{Fe}_x\text{Te}$ ($x = 0.015$) films without (#1) and with N-doping (#2-#4). The results of simulation assuming an Fe atom in the substitutional site in the ZB structure and various Fe-N compounds are also plotted.

Fig. 2 M - H curves of $\text{Zn}_{1-x}\text{Fe}_x\text{Te}$ ($x = 0.015$) thin films without (#1) and with N-doping (#2-#4). The measurement was performed at 2K under magnetic field perpendicular to the film plane.