

Temperature-induced ferromagnetic ordering transition in bulk Cr-doped CdTe crystal

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In II-VI dilute magnetic semiconductor (DMS), 2+ magnetic ions can be incorporated on cation site of host lattice. Ferromagnetism of Cr-doped DMS might be affected by ferromagnetic Cr-Te compound or magnetic clusters [1,2]. The NiAs CrTe and pseudo-NiAs Cr_{1-x}Te or monoclinic Cr_3Te_4 phases revealed ferromagnetism with Curie temperature of 300~340K depending on Cr content [3]. The transition between ferromagnetic (or antiferromagnetic) and paramagnetic phases are second order phase transition, while ones between antiferromagnetic and ferromagnetic phases first order phase transition [4]. In this research we report the temperature-induced ferromagnetic ordering transition at the vicinity of Curie temperature on the Cr-doped CdTe crystal.

Bulk $(\text{Cd}_{1-x}\text{Cr}_x)\text{Te}$ crystals that prepared from vertical solidification method were investigated using powder and surface high resolution X-ray θ - 2θ diffraction with logarithmic scale. Both samples ($x=0.04$ and 0.06) displayed single phase Zinc-Blende structure showing no existence of second phase as NiAs-type CrTe, MnP-type CrTe, trigonal Cr_2Te_3 and monoclinic Cr_3Te_4 phases as is shown in Fig.1. The lattice parameter and quality for growth were determined using high resolution X-ray epitaxy process, and estimated as polycrystals growth with $a=6.481\text{\AA}$, $a=6.474\text{\AA}$ respectively. Metallurgical investigation using SEM with EDX and EPMA equipments showed that the solubility of Cr-substitution on Cd-atom seem to be less than $\sim 0.055(\text{wt.}\%)$ at $x=0.04$ and $\sim 0.116(\text{wt.}\%)$ at $x=0.06$ within limit of resolution. Small clusters with less than $10\mu\text{m}$ with locally constitutional heterogeneous region rarely appeared in dispersion, and it contains a little lower Cr-contents compared to other regions and Te nearly constant. It cannot be confined as second phase but named as clusters depending on its size and amount. Magnetic measurement using SQUID and superconducting VSM were investigated in temperature range of 5~600K. Fig. 2 show temperature dependant magnetization curve for $x=0.04$ and 0.06 under zero field cooling and field cooling in indicated field. The increase of magnetization after zero field cooling occurs at $\sim 25\text{K}$ and $\sim 19\text{K}$ higher than ones for the magnetization measured for field cooling, and it shows temperature-induced first order magnetic phase transition in contrast to ferromagnetic-paramagnetic transition presented with most of second order phase transition, respectively. Especially ferromagnetic Curie temperature $\sim 395\text{K}$ calculated from Arrott plot after zero field cooling is very higher than one reported ferromagnetic CrTe, Cr_{1-x}Te and Cr_3Te_4 crystals. Saturated magnetic moment measured under magnetic field of 1T showed $0.0035\mu_{\text{B}}/\text{molecule}$ corresponding to 0.2% polarization compared to ferromagnetic

Cr_{1-x}Te ($\sim 1.79\mu_B/\text{formular}$). Assuming ferromagnetism is introduced by Cr_{1-x}Te or Cr_3Te_4 phase ($M_s \sim 60\text{emu/g}$), the fraction of Cr_3Te_4 phase is estimated about 8.0%, enough to detect by X-ray measurement. This strongly support that ferromagnetic moment mainly did not result from ferromagnetic Cr_{1-x}Te or Cr_3Te_4 phase with no canted ferromagnetic structure. Broad deviation between zero field cooling and field cooling indicates that spin glass-like local moment disordered states [5] or weak interacting magnetic clusters [6] could exist. Temperature

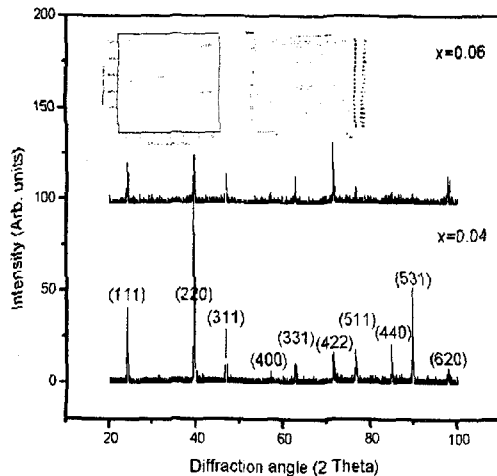


Fig. 1 Powder and surface high resolution θ - 2θ X-ray diffraction results

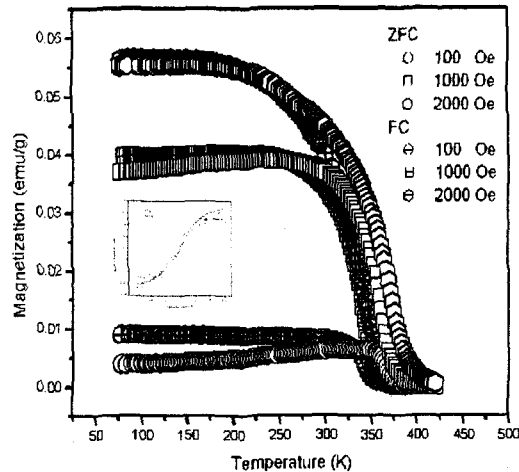


Fig. 2 Temperature-dependent magnetization at $x=0.04$ (Insert, hysteresis loop)

-dependent resistance showed higher value ($> 10^{11}$) exhibiting insulating characters that increased with decreasing temperature indicating enhancement of localization [7] and Efros-Shklovskii-type variable hopping proportional to $1/T^{1/2}$. In summary, Cr-doped CdTe crystals showed ferromagnetism and first order magnetic phase transition after zero field cooling and field cooling at the vicinity of Curie temperature. The ferromagnetic interactions of Cr atoms existing in (Cd-less Cr)Te phase is responsible for appearance of ferromagnetism with Curie temperature of around 395K.

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