Room temperature ferromagnetism in diluted magnetic semiconductor $Zn_{1-x}Cr_xTe$

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The most distinguishing character of diluted magnetic semiconductors (DMSs) is a strong interaction between *sp*-carriers and localized *d*-spins (*sp-d* exchange interaction). Recently many "room-temperature (RT) ferromagnetic DMS" have been reported. However, it should be noted that their *sp-d* exchange interactions have not been confirmed yet [1,2]. The lack of a clear evidence of the *sp-d* exchange interaction causes the controversy on the origin of the observed ferromagnetism. For the detection of the *sp-d* exchange interaction, magneto-optical spectroscopy such as a magnetic circular dichroism (MCD) measurement [3] is the most powerful tool. By using the MCD spectroscopy, we have shown the *sp-d* exchange interactions in $Zn_{1-x}Cr_xTe$ [4]. Recently, we have obtained the RT ferromagnetism in a $Zn_{1-x}Cr_xTe$ ($x = 0.20$) film [5,6].

$Zn_{1-x}Cr_xTe$ films with $x \leqq 0.20$ were grown on GaAs (001) substrates by a molecular beam epitaxy method. No sign of a secondary phase was detected in any of the films by the reflection high-energy electron and X-ray diffractions (XRD). Magnetization *M* measurements were carried out using a SQUID. The *M-H* curves of $Zn_{1-x}Cr_xTe$ ($x=0.20$) showed a ferromagnetic behavior up to about RT. T_C was estimated to be 300±10 K by the Arrott plot analysis. However, XRD and SQUID data are not enough to attribute the observed ferromagnetsim to $Zn_{1-x}Cr_xTe$. In general, SQUID is too sensitive to be affected by a small amount of ferromagnetic impurities while crystallographic tools such as XRD are too poor to detect the impurities [1,2].

In order to confirm the intrinsic ferromagnetism of $Zn_{1-x}Cr_xTe$, MCD spectral shape analyses were done. MCD spectra were measured in a transmission mode. A strong enhancement of the MCD signal at the optical transition energies of critical points of host ZnTe (Fig.1(b)) was observed in $Zn_{1-x}Cr_xTe$ (Fig.1(c) and (d)), indicating a strong *sp-d* exchange interaction. The magnetic field dependence of the MCD spectra (Fig.1 (c') and (d')) indicated that the observed MCD signals come from a single material, that is, $Zn_{1-x}Cr_xTe$. The spectral shape of $Zn_{1-x}Cr_xTe$ (Fig.1(c)) is completely different from that of the possible ferromagnetic second phase material, hexagonal CrTe (Fig.1(a)). Furthermore, the MCD data showed the same T_C as that obtained from magnetization data (Fig.2). These results indicate that $Zn_{1-x}Cr_xTe$ ($x=0.20$) is an intrinsic DMS with RT ferromagnetism. The observed T_C (300±10K) is the highest value ever reported for ferromagnetic DMSs in which *sp-d* exchange interactions were confirmed.

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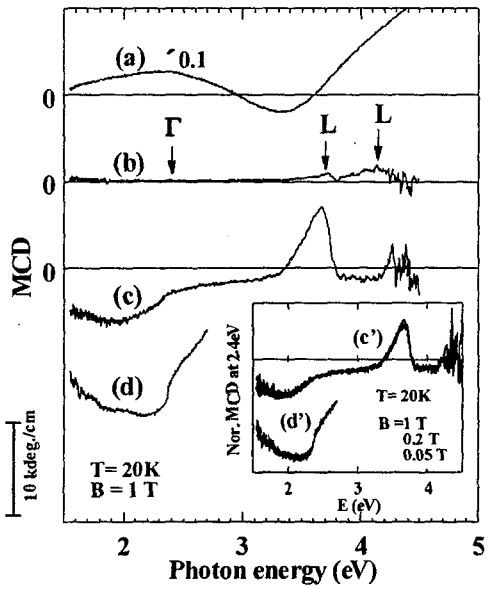

Fig.1 MCD spectra of (a) room-temperature ferromagnetic compound CrTe film, (b) 100-nm thick ZnTe film, (c) 80-nm thick $Zn_{1-x}Cr_xTe$ (x=0.20) film on ZnTe buffer with several monolayers, and (d) 400-nm thick $Zn_{1-x}Cr_xTe$ (x=0.20) film on 200-nm thick ZnTe buffer at T = 20 K and $\mu_0 H$ = 1 T. MCD spectra of both 80- and 400-nm thick $Zn_{1-x}Cr_xTe$ (x=0.20) films at T = 20 K measured in any magnetic fields can be superposed upon a single spectrum over the whole photon energy range ((c') and (d')) [Ref.5].

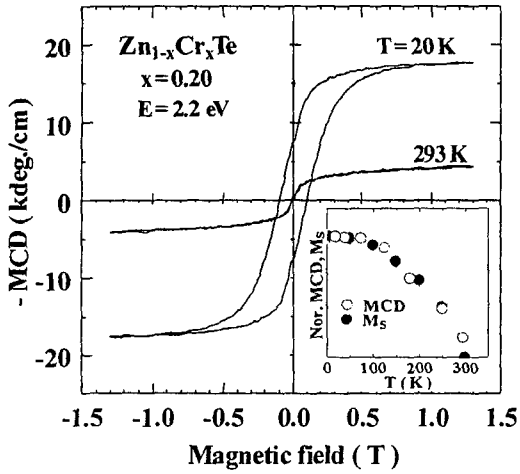

Fig.2 Arrott plots of MCD intensity of $Zn_{1-x}Cr_xTe$ (x=0.20) film at E = 2.2 eV and various T. The inset shows the temperature dependence of MCD intensity (open circles) extrapolated to $\mu_0 H$ = 0 T obtained by the Arrott plot, together with that of M_S (solid circles). [Ref.5]