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三元化合物(Mn,Cr)Te 薄膜の MBE 成長と磁性評価

Magetic property of ternary transition-metal chalcogenide (Mn,Cr)Te thin films grown by MBE

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In decades, diluted magnetic semiconductors (DMSs), in which magnetic impurities substitute lattice atoms of a host nonmagnetic semiconductor, have been energetically studied for application to semiconductor- spintronics. One of the main issues in the study of DMSs is how to realize high ferromagnetic transition temperature (*Tc*) above room temperature (RT). However, there have been few reports of DMSs with intrinsic RT ferromagnetism. In this study we choose MnTe, which is known as an antiferromagnetic semiconductor, as a host semiconductor material. And we doped Cr atoms in the MnTe as magnetic impurities. Theoretical studies have predicted that a magnetic interaction between Cr atoms doped in MnTe with zinc-blende structure (ZB) is ferromagnetic [1], and, ZB-(Mn,Cr)Te, which has more than 8% Cr composition, may become a half-metallic ferromagnet [2].

The growth of MnTe and (Mn,Cr)Te thin films were performed by MBE using solid sources of Zn, Cd, Mn, Cr, and Te. Firstly a thick buffer layer (~600nm) of ZnTe or CdTe was grown on a GaAs(001) substrate, then a MnTe or (Mn,Cr)Te layer was deposited. During the growth, the substrate temperature was kept at 200℃. We prepared MnTe and $Mn_{1-x}Cr_xTe$ films with fixed flux ratio between Mn and Te ([Mn]/[Te]=0.1), and various Cr composition *x* ranging from 0 to 14 %. A surface during the growth was monitoring in situ using reflection high-energy electron diffraction (RHEED) to exploring flatness and symmetry of growth surface of the layer. The crystal structure analyses of the grown films were performed using X-ray diffraction (XRD) and transmission electron microscopy (TEM).The magnetic properties of MnTe and (Mn,Cr)Te films were investigated using superconducting quantum interference device (SQUID) magnetometer with magnetic fields applied perpendicular to the film plane. The composition analyses of the grown films were performed using electron probe micro analyser (EPMA).

From results of XRD and TEM, it is concluded that we could fabricate a ZB-(Mn,Cr)Te with Cr atoms substituting a part of the Mn sites of the host, when Cr composition was less than 5.9%. On the other hand, we observed the existence of precipitates with an incoherent hexagonal crystal structure by TEM for films with much larger Cr composition. Figure 1 shows *M-H* curves at 2K for MnTe and (Mn,Cr)Te films whose compositions were less than 5.9%.While the MnTe film did not exhibit any ferromagnetic behavior, open hysteresis curves were clearly observed for all (Mn,Cr)Te films. These results suggest that ferromagnetic domains were formed by doped Cr atoms. Furthermore, as shown in the Figure 2, *Tc* increased with the increase of Cr composition. From this result, it is expected that (Mn,Cr)Te film with higher *Tc* may be realized by the improvement of the growth condition in order to fabricate (Mn,Cr)Te films which have good crystalline quality and high Cr composition. In the presentation, we will also report growth temperature dependence of the properties of (Mn,Cr)Te films.

[1] Jian-Ming Wu, Xing-Yuan Chen, Shi-Yuan Lin, and Yu-Jun Zhao, J.Appl.Phys. **114**,083905 (2013)

[2] Nguyen Hoang Long, J. Supercond. Nov. Magn. **20**,473 (2007)

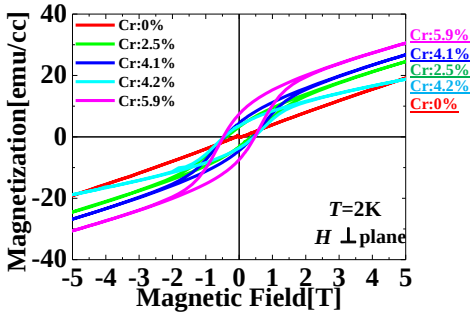

Fig.1 *M-H* curves of (Mn,Cr)Te films at 2K. The magnetic field was applied perpendicular to the layer at 2K.

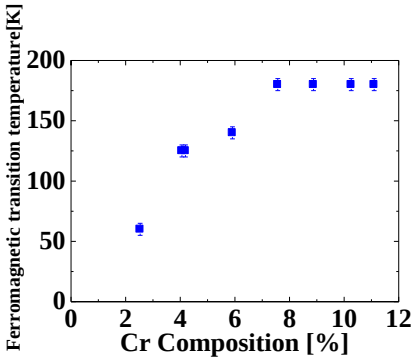

Fig.2 Cr composition dependence of ferromagnetic transition temperature of (Mn,Cr)Te films grown on CdTe(001).