Magnetic Circular Dichroism in the Mn 2p-3d Absorption of IV-VI Diluted Magnetic Semiconductor $Ge_{1-x}Mn_xTe$

K. Fujimoto[A](8939), H. Sato[B*](6147), Y. Fukuma[C](13923), K. Tsuji[A](13787), A. Kimura[A](4385), H. Asada[D], T. Koyanagi[D], S. Senba[E], A. Tanaka[F] and M. Taniguchi[A,B](6211)

[A]Graduate School of Science, Hiroshima University, [B]HSRC, Hiroshima University, [C]Yamaguchi Prefectural Industrial Technology Institute, [D]Graduate School of Science and Engineering, Yamaguchi University, [E]Ube National College and Technology, [F]ADSM, Hiroshima University

VI-VI diluted magnetic semiconductor (DMS) $Ge_{1-x}Mn_xTe$ exhibits ferromagnetic behavior with the highest Currie temperature T_C of 140 K at x=0.51 [1]. With increasing carrier concentration, saturation magetization and T_C increase. However, its electronic structure has less been known, so far. In this study, we have investigated the Mn 3d states in $Ge_{1-x}Mn_xTe$ by means of the Mn 2p-3d soft x-ray absorption spectroscopy (XAS) and its magnetic circular dichroism (XMCD).

Samples used for the present experiments were thin films prepared by the ionized-cluster beam methods [1]. The sample surface was *in situ* capped by a 20Å Au layer and the spectra were collected with no surface treatment.

Fig. 1 shows the Mn 2p-3d XAS and XMCD spectra of $Ge_{1-x}Mn_xTe$ (x=0.32). The spectra show the complicated multiplet structure characteristic to the divalent Mn ion and are similar to those of III-V DMS $Ga_{1-x}Mn_xAs$ [3]. From the total area of the XMCD signal, the orbital magnetic moment relative to the spin magnetic moment was estimated to be ~8 %, slightly larger than that of $Ga_{1-x}Mn_xAs$ [3].

We have also analyzed the XAS and XMCD spectra with the $MnTe_6$ cluster model calculation taking into account the configuration interaction. The theoretical result with adjustable parameters of U=4.0, Δ=2.5, $(pd\sigma)$=0.4 and $10Dq$=0.4 eV, well reproduces the experimental result, where U represents a 3d-3d Coulomb interaction energy, Δ a charge transfer energy, $(pd\sigma)$ a p-d transfer integral and $10Dq$ a crystal field splitting energy. The effective p-d transfer integral of $Ge_{1-x}Mn_xTe$ is smaller than that of $Ga_{1-x}Mn_xAs$. Detailed analysis is now in progress.

[1] Y. Fukuma *et al.*, Physica E **10**, 273 (2001).
[2] Y. Fukuma *et al.*, Appl. Phys. Lett **80**, 1013 (2002).
[3] S. Ueda *et al.*, Physica E **10**, 210 (2001).

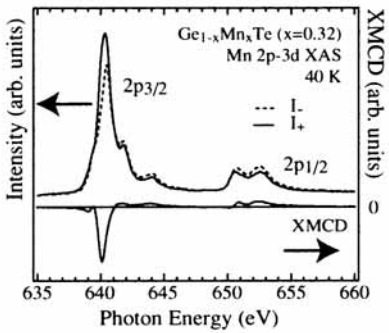

Fig. 1. Mn 2p-3d XAS and MCD spectra of $Ge_{1-x}Mn_xTe$.

Magnetic moments and electronic states of Ce 4f and Rh 4d electrons of $CeRh_3B_2$

S. Imada(1257)[*], E. Miyata(8469), A. Yamasaki(5263), Y. Ishida(8462), A. Sekiyama(1256), and S. Suga(1250)

Division of Materials Physics, Graduate School of Engineering Science, Osaka University,

$CeRh_3B_2$ is a ferromagnet with an exceptionally high Curie temperature (T_C = 115 K) among the ferromagnets composed of no other magnetic element except for Ce[1]. Band structure calculation suggests that the direct mixing between the Ce 4f orbitals along the c-axis cannot be neglected[2]. It is therefore possible that ferromagnetism of this system is characterized by band ferromagnetism.

According to the above-mentioned band structure calculation, among the 4f state, the magnetic quantum number l_z=0 state has the large mixing with the conduction bands and thus is the ground state of the crystal field. It was also shown that, due to the large (ffσ), this 4f state has strong dispersion along the c-direction creating 4f holes. This 4f hole formation is the origin of the ferromagnetism and the anomalous magnetic properties of $CeRh_3B_2$.

In order to verify this scenario, it is highly required to clarify experimentally the electronic state, especially that of Ce 4f electrons. For this purpose, we have carried out measurements of bulk sensitive photoemission and photoabsorption including magnetic circular dichroism by utilizing the circularly polarized soft x-ray from BL25SU of SPring-8.

Resonant photoemission around the Ce 3d → 4f photoabsorption edge was adopted in order to disentangle the Ce 4f and Rh 4d excitation spectra. The high photon energy (~900 eV) approves high bulk sensitivity. The Rh 4d spectrum, which is characterized by its peak near the Fermi level (E_F), is qualitatively consistent with the band structure calculation. The Ce 4f spectrum also had a peak near E_F but the spectral shape was qualitatively different from that of the Kondo materials but was more similar to that of itinerant Ce 4f systems. This indicates that the Ce 4f band is formed.

Magnetic circular dichroism of soft x-ray photoabsorption (XMCD) was measured with both magnetic field of 1.4 T and the incident circularly polarized light parallel to the a-axis, which is in the easy magnetization plane. The result was qualitatively consistent with a preliminary cluster model calculation taking into account the hybridization between the conduction band and the Ce 4f orbital with only l_z = 0, where z-axis is parallel to the c-axis. Photoabsorption with the incident circularly polarized light parallel to the c-axis, which is perpendicular to the magnetization easy axis was also measured. A prominent difference was found between the spectra with incident axis along the c-axis and the a-axis. This is also qualitatively in good agreement with the preliminary model calculation.

1. S. K. Dhar, et al: J. Phys. C 14 (1981) L321.
2. K. Takegahara, et al.: J. Phys. Soc. Jpn, 54 (1985) 4743.