Magnetic Structure in the Shastry-Sutherland Lattice TmB_4

Iga F.(a), Shigekawa A.(a), Michimura S.(a), Takabatake T.(a), Yoshii S.(b), Yamamoto T.(b), Hagiwara M.(b), Kindo K. (c), Ohoyama K.(d)

(a) ADSM, Hiroshima Univ., (b) KYOKUGEN, Osaka Univ., (c) cInstitute for Solid State Physics, Univ. of Tokyo, (d) IMR, Tohoku Univ.

Rare-earth tetraborides RB4 have a tetragonal crystal structure with a space group P4/mbm which is characterized by the 2-dimensional orthogonal dimers in the c-plane. Such dimer systems are equivalent to the Shastry-Sutherland lattice (SSL) [1] where nearest-neighboring dimers geometrically frustrated.

The previous study of TmB4 indicates an antiferromagnetic order at 11.7 K by the measurements of temperature dependences of electrical resistivity and magnetic susceptibility [2]. From our recent experimental results, we have found that TmB4 exhibits three phase transitions at TN1=11.7K, T*=11K and TN2=10K [3]. The phase transitions at TN1 and TN2 were already reported by Fisk et al [2]. In order to clarify these ordering vectors in these magnetic phases, we have performed neutron diffraction experiment on Tm11B4.

First, high-quality single crystal TmB4 was grown by floating zone method using a four-xenon lamps image furnace. Next, these crystals were crushed to powder. The neutron powder diffraction experiment was performed on the powder diffractometer for high efficiency and high resolution measurements, HERMES. Measured temperatures were set at 3K (antiferro-magnetic phase, IV), 10.7K (unknown phase, III), 11.7K (unknown phase, II) and 20K (paramagnetic phase, I).

Figure 1 shows the powder pattern for the four phases of TmB4. The pattern at 20 K was used for the nuclear scattering standard. Phase IV shows a simple antiferromagnetic pattern with a propagation vector of k4=(1, 0, 0). This is consistent with the previous report [2]. The Phase III has been assigned with propagation vector k4 and an additional long period modulation vector k3=(0.13, 0, 0). Furthermore, the phase II was also indexed with the k4 and k2=(0.012, 0.012, 0) and k2=(0.036, 0.012, 0). However, we have not yet succeeded in obtaining complete fitting parameter.

Magnetization process M(B//c) in TmB4 shows 1/8 and 1/2 plateaus at 1.7-1.4 T and 2-3 T, respectively. These characteristic behavior may be originated from geometric frustration in not only magnetic dipole interactions but also electric multipole interactions.

References

[1] B. S. Shastry and B. Sutherland, Physica B & C 108B (1981), p. 1069.

[2] Z. Fisk et al., Solid State Commun. 39 (1981), p. 1189.

[3] F. Iga et al., J. Magn. Magn. Mater. (2007) in press.

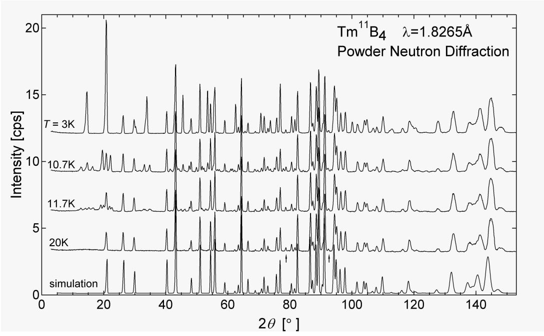

Fig. 1. Fig. 1 Neutron powder diffraction patterns for the four phases of TmB4. The bottom shows a simulation in the paramagnetic state.