(28b1 = replaced by your program number!)

High-field magnetic properties of caged rare-earth borides RB_n (n = 4, 12)

F. Iga[1], Michimura S.[1], Murakami K.[1], Takabatake T.[1], Suga K.[2], Kindo K.[2], Yoshii S.[3]

[1] ADSM, Hiroshima University, Higashi-Hiroshima, Hiroshima 739-8530
[2] Institute for Solid State Physics, University of Tokyo, Kashiwa, Chiba 277-8581
[3] Institute for Materials Research, Tohoku University, Sendai, Miyagi 980-8577

The Rare earth borides exhibit a variety of physical properties ranging from superconductor (YB_6, ZrB_{12}), to typical Kondo lattice system with a quadrupole ordering (CeB_6), valence fluctuating system with a correlated small energy gap (SmB_6 (valence=2.6), YbB_{12} (valence=2.9-3.0)), multi-step magenetization system RB_4 (R=Tb-Tm). Single crystals of these rare earth borides have been prepared by a floating zone method using an image furnace with four xenon lamps.

YbB_{12} is called "Kondo semiconductor" in which an energy gap of 200 K gradually opens as temperature is decreased below 100 K [1]. Application of magnetic field of approximately 50 Tesla destroys the gap and induces a first-order transition from a semiconducting state to a metallic state [2]. The magnetization of the single crystalline sample increases suddenly in an anisotropic way at the critical fields B_{C1} = 47 Tesla for B//[100] and B_{C2} = 54 Tesla for B//[110] and [111]. In the present study, we have measured both magnetization and magnetoresistance up to 68 Tesla by using a long-pulse magnet (pulse width 36 ms). Thereby, heating effect was much reduced. Magnetization $M(B)$ at 1.3 K reproduced the previous data described above with hysteretic behaviors at B_{C1} and B_{C2}. Above 60 Tesla, $M(B)$ increases linearly up to the highest field of 68 Tesla as shown in Fig. 1.

Rare-earth tetraboride RB_4 has a tetragonal crystal structure where the sublattice of R ions in the *c*-plane is equivalent to the Shastry-Sutherland lattice, that is known as a model of a quantum spin system $SrCu_2(BO_3)_2$ [3]. A novel magnetic ordering state is expected by the geometric frustration between the orthogonal R-R dimmers as seen in DyB_4 and HoB_4 [4].

We have determined magnetic phase diagrams of isostructural system TbB_4, ErB_4 and TmB_4 from the measurements of magnetization, magnetoresistance, magneto-striction, specific heat, neutron diffraction and Hall effect. Magnetization process for B//*c* and *a* in ErB_4 [5] and TmB_4 [6] shows a plateau at half moment and the full saturated moment, respectively. Otherwise, TbB_4 shows nine plateaus for B//*c* [7], but a simple metamagnetic transition for B//*a*. These field dependences and obtained magnetic phase diagrams would be explained as a result of competition between the frustration effect and Zeeman effects.

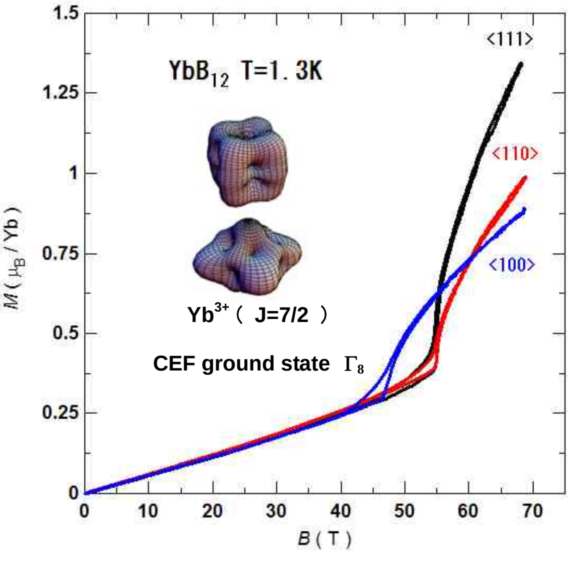

Fig. 1 Magnetization process at 1.3 K of YbB_{12} for B//[100], [110] and [111] up to 68 T.

References

1) F. Iga *et al*., J. Mag. Mag. Mater. **177-181** (1998) 53.
2) S. Kawasaki *et al*., Physica B **281&282** (2000) 234.
3) H. Kageyama, *et al*., Phys. Rev. Lett. **82** (1999) 3168.
4) R. Watanuki *et al*., J. Phys. Soc. Jpn. **74** (2005) 2169.
5) S. Michimura *et al*., Physica B **378-380** (2006), 596.
6) F. Iga *et al*., J. Magn. Magn. Mater. **310** (2007) e443.
7) S. Yoshii *et al*., J. Magn. Magn. Mater. **310** (2007) 1282.