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Investigation of coexistent phase of AFQ and AFM orders in TbB_2C_2 by resonant x-ray scattering in magnetic fields

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Introduction

RB_2C_2(R=Tb,Dy,Ho) has antiferroquadrupole (AFQ) phase transitions at high temperatures. Among these three, TbB_2C_2 has been expected to exhibit magnetic field induced AFQ order, while the ground state in zero field is an antiferromagnetic (AFM) phase[1]. This AFM phase, called phase IV with T_N=21.7 K, is described by the propagation vectors of $\boldsymbol{k}_2$=(1 0 1/2), $\boldsymbol{k}_4$=(0 0 1/2), and $\boldsymbol{k}_L$=(1±δ 0±δ 0). $\boldsymbol{k}_2$ has a large moment along [1 -1 0], and TbB_2C_2 has a simple magnetic structure with its moments directed along the <1 -1 0> directions. In spite of this simple magnetic structure in phase IV, we observed a periodic alignment of aspherical charge distributions of 4*f* electoron of Tb by resonant x-ray scattering in a previous experiment. We consider the mechanism of this strange quadrupole order as follows: First, the composite magnetic moment in phase IV is canted within the c plane because the propagation vector $\boldsymbol{k}_4$ has a small moment along [1 1 0] that is perpendicular to the moment of $\boldsymbol{k}_2$. Second, the charge distribution of the 4*f* electrons becomes aspherical in a sufficiency low temperature where no orbital degree of freedom remains. These effects make the principal axis of the aspherical charge distribution coincident with the direction of the magnetic moment by the strong spin-orbit interaction.

In the present experiment, we examined the coexistent phase of AFQ and AFM orders, called phase III, in a magnetic field above H_Q≈5000 Oe. This magnetic structure is described by the propagation vector of $\boldsymbol{k}_1$=(1 0 0), $\boldsymbol{k}_2$=(1 0 1/2), $\boldsymbol{k}_3$=(0 0 0), and $\boldsymbol{k}_4$=(0 0 1/2), like phase III of DyB_2C_2[2]. We checked the existence of the AFQ order in this phase and compared the observed propagation vectors and the scattering intensities in phase III with those in phase IV.

Experimental Results

Figure 1 shows the energy dependences of the observed reflections at T=8 K and H=12000 Oe in phase III. Reflections with propagation vectors of $\boldsymbol{k}_1$, $\boldsymbol{k}_2$, and $\boldsymbol{k}_4$ for σ-σ' and σ-π' channels were found. The spectrum for the σ-σ' channel of $\boldsymbol{k}_1$ exhibits a resonant enhancement at the L_{III} absorption edge of Tb at E=7.5165 keV. In σ-π' channel of $\boldsymbol{k}_1$ both E1 and E2 resonances are observed. The spectrum for σ-σ' of $\boldsymbol{k}_2$ exhibits a nonresonant Thomson scattering from lattice distortion. σ-π' channel of $\boldsymbol{k}_2$ has strong resonances of E1 and E2 processes. The reflection for σ-σ' channel of $\boldsymbol{k}_4$ also has resonances of E1 and E2 processes. The reflection for the σ-π' channel of $\boldsymbol{k}_4$ has weak resonances of E1 and E2. Since these features are very similar with those of DyB_2C_2, we conclude that the quadrupole order of TbB_2C_2 in phase III is very similar to that of DyB_2C_2[3].

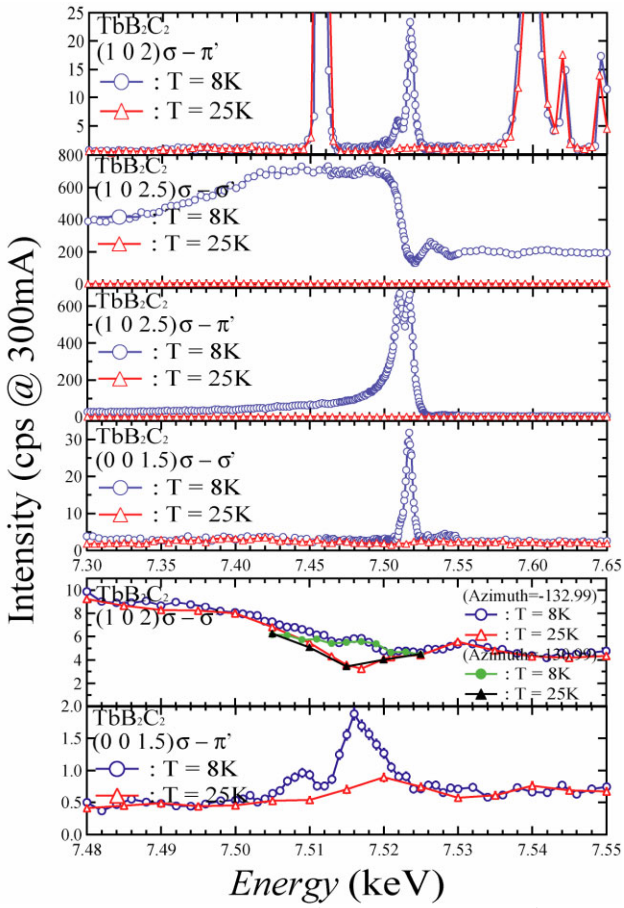

Fig. 1 Energy dependences of all the observed reflections at H=12000 Oe.

References

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