

論文 / 著書情報  
Article / Book Information

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種別(和文)	論文要旨
Type(English)	Summary

## 論文要旨

THESIS SUMMARY

専攻 : Department of	Physics	専攻	申請学位 (専攻分野) : Academic Degree Requested	博士 Doctor of	(Philosophy)
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要旨 (英文 800 語程度)

Thesis Summary (approx.800 English Words )

$\text{Ba}_2\text{CoTeO}_6$  is a hexagonal perovskite type compound, the structure of which is closely related to hexagonal  $\text{BaTiO}_3$ . In  $\text{Ba}_2\text{CoTeO}_6$ , the magnetic moment of  $\text{Co}^{2+}$  ion, which is surrounded octahedrally by six  $\text{O}^{2-}$  ions, is described with the fictitious spin-1/2 at low temperatures. There are two different crystallographic  $\text{Co}^{2+}$  sites, Co(1) and Co(2). Co(1) sites form a two-dimensional (2D) triangular lattice parallel to the  $ab$ -plane, while Co(2) sites form a bilayer triangular lattice. The exchange interactions for Co(2) can be mapped onto a honeycomb lattice with two exchange interactions ( $J_1$  and  $J_2$ ). We refer to the triangular and honeycomb lattices composed of Co(1) and Co(2) as subsystems A and B, respectively. From the crystallographic data, we can expect that the spins of subsystems A and B are Heisenberg-like and Ising-like, respectively. Thus, it is considered that subsystem A is described as spin-1/2 Heisenberg-like triangular lattice antiferromagnet (TLAF), while subsystem B is described as Ising-like  $J_1$ - $J_2$  honeycomb lattice antiferromagnet ( $J_1$ - $J_2$  HLAf). We performed magnetic and specific heat measurements to clarify quantum and many-body effects in  $\text{Ba}_2\text{CoTeO}_6$ .

First we have grown single crystals of  $\text{Ba}_2\text{CoTeO}_6$  by the flux method, using  $\text{BaCl}_2$  as the flux. Plate-shaped single crystals with a maximum size of  $3 \times 3 \times 0.4 \text{ mm}^3$  were obtained. Using single crystals of  $\text{Ba}_2\text{CoTeO}_6$ , we performed magnetic susceptibility, specific heat, high-field magnetization and electron spin resonance (ESR) measurements.

Temperature dependence of magnetic susceptibility and specific heat show two anomalies at  $T_{N1} = 12.0 \text{ K}$  and  $T_{N2} = 3.0 \text{ K}$  at zero and 0.1 T, which indicate successive magnetic phase transitions. With increasing magnetic field up to 7 T for  $H \parallel c$ ,  $T_{N1}$  clearly shifts toward the low-temperature side, while  $T_{N2}$  does not change. However, for  $H \perp c$ ,  $T_{N2}$  starts to split into two transitions at approximately 7 T with increasing magnetic field, whereas  $T_{N1}$  shifts slightly toward the low-temperature side. The behavior of the phase boundaries related to  $T_{N2}$  is very similar to that observed in  $S=1/2$  Heisenberg-like TLAF  $\text{Ba}_3\text{CoSb}_2\text{O}_9$ , in which the environment of  $\text{Co}^{2+}$  and the exchange paths are very similar to those observed in subsystem A. This suggests that the phase transition at  $T_{N2}$  corresponds to the magnetic ordering of Heisenberg-like subsystem A.

High-field magnetization processes were measured at 1.3 and 4.2 K up to magnetic field

of 60 T. It was found that total magnetization is approximately given by the superposition of magnetizations of isolated subsystems A and B. This indicates that these two subsystems are almost decoupled. For  $H \perp c$ , the magnetization curve of subsystem A shows the magnetization plateau at 1/3 of saturation magnetization, which is in quantitative agreement with the theoretical calculation for  $S=1/2$  Heisenberg TLAF. However, for  $H \parallel c$ , the magnetization curve of subsystem A exhibits no plateau. These results indicate that the magnetic anisotropy of subsystem A is easy-plane type, as observed in  $\text{Ba}_3\text{CoSb}_2\text{O}_9$ . In case of  $H \parallel c$ , subsystem B shows step-wise magnetization process with plateaus at 0, 1/3 and 1/2 of saturation magnetization. Because this step-wise magnetization process was also observed at 4.2 K that is between  $T_{N1}$  and  $T_{N2}$ , we can deduce that  $T_{N1}$  corresponds to the ordering temperature of subsystem B.

Using all the experimental data from susceptibility, high-field magnetization, specific heat measurement, magnetic field vs. temperature phase diagrams for both field directions were obtained. Spin configuration at each magnetization plateau state for subsystem B and the phase diagram for magnetic field vs.  $J_1/J_2$  were determined within the framework of Ising  $J_1$ - $J_2$  HLAFF model. The calculated critical fields are in good agreement with the observed critical fields. It was found that the spin configurations for 1/3 and 1/2 plateau states are infinitely degenerate.

Multifrequency ESR measurement for  $H \parallel c$  has been performed at 1.5 K ( $< T_{N2}$ ) in the frequency range of 80-450 GHz. The resonance data are summarized in the frequency vs. field diagram. Two collective modes consist of two distinct branches were observed. Their frequencies are degenerate at zero magnetic field. As the magnetic field increases, the energy of one branch increases and tends to approach the EPR line, whereas the energy of the other branch decreases monotonically toward zero. Because the field evolutions of these two modes are characteristic of the TLAF with the small easy-plane anisotropy, we can deduce that observed collective ESR modes are originated from subsystem A. Introducing effective interlayer exchange interaction  $J'$  between triangular lattices, we analyzed the collective mode within the framework of the molecular field theory combined with the magnetization process. The intralayer exchange interaction  $J$ , its anisotropy  $\Delta J$ , interlayer exchange interaction  $J'$  and  $g$ -factor for  $H \parallel c$  were determined as  $J/k_B = 20.5$  K,  $\Delta J/k_B = 0.86$  K,  $J'/k_B = 1.6$  K and  $g_A^{\parallel} = 3.65$ . The result proves that the intralayer exchange interaction is dominant over the interlayer and anisotropic one, so that subsystem A closely approximates two-dimensional  $S = 1/2$  Heisenberg TLAF. Above the second critical field of 14.8 T, an ESR mode with the linear field dependence of resonance frequency was observed. This mode can be assigned as the single flip of Ising spin in subsystem B. From the analysis of this local mode, the  $g$ -factor of the subsystem for  $H \parallel c$  was evaluated as  $g_B^{\parallel} = 6.27$ .

備考：論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。

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