

Orbital ordering in TbVO₃ controlled by hydrostatic pressure

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Introduction

In addition to the charge and spin degrees of freedom, the orbital degree of freedom plays an important role in determining the electric and magnetic properties of the perovskite transition metal oxides. The orbital ordering is strongly coupled with the lattice distortion, i.e. Jahn-Teller distortion. Therefore, the purpose of the present study is to demonstrate the control of the orbital ordering phases in term of the lattice distortion by applying pressure.

RVO_3 (R : rear earth or Y) shows various physical properties coupled with the spin and orbital states depending on R -ions [1]. RVO_3 (R =Tb-La) with large R -ionic radius undergoes a phase transition from an orbital disordered state to a G -type orbital ordering (G -OO) at T_{001} . The crystal structure also changes from orthorhombic ($Pbnm$) to monoclinic ($P2_1/a$) structure at T_{001} reflecting the orbital state. Moreover, the ground state of the magnetic structure becomes C -type spin ordering influenced by the orbital ordering. RVO_3 (R =Lu-Dy) with smaller R -ionic radius has the G -OO phase at $T_{002} < T < T_{001}$, and a C -type orbital ordering (C -OO) with $Pbnm$ below T_{002} . In addition, the ground state of magnetic structure becomes the G -type spin ordering [2]. Consequently, the ground state of the orbital ordering in RVO_3 changes from the G -OO to the C -OO by R -ions substitution. In order to clarify the pressure effect on the orbital states, the pressure-temperature phase diagram of the orbital ordering in TbVO₃, which locates near the phase boundary between G -OO and C -OO, have been studied by x-ray scattering technique.

Experiments

The high-quality single crystals of TbVO₃ were grown by a floating-zone method. X-ray scattering experiments were carried out at beam lines 1B, 4C and 9C. The x-ray energy was tuned to 18.0 keV with a Si(111) double-crystal monochromator, and the beam was focused by a bent cylindrical mirror. For the low-temperature and high-pressure experiments, a helium gas driven diamond-anvil cell (DAC) was mounted on a closed-cycle He cryostat, and the helium gas pressure and the temperature were controlled by a computer. Pressure was generated in the DAC using a 1:1 mixture of pentane and isopentane, or nitrogen. In addition, pressure was calibrated from a

lattice constant of NaCl enclosed with the sample in the DAC. A typical sample size is 0.08x0.08x0.02mm³.

Results

We tried to determine the pressure-temperature phase diagram of the orbital state in TbVO₃. The intensity of the forbidden reflection (4 0 1) of $Pbnm$ and the temperature dependences of lattice constants were measured. The forbidden reflection is only observed in the G -OO phase with the space group $P2_1/a$. Fig. 1 shows the temperature dependences of the (4 0 1) intensity under high pressure. The intensities at 0.7 GPa are observed below $T_{001} \sim 190$ K and exist until the minimum temperature. In contrast, the intensities at 1.9 GPa are suddenly disappeared below $T_{002} \sim 80$ K. This result indicates that the G -OO is disappeared by applying pressure. Moreover, the temperature dependences of lattice constants represented a jump related to the phase transition G -OO to C -OO. Therefore, it is clear that the ground state in TbVO₃ is changed the G -OO to the C -OO under high pressure. In addition, the transition temperature T_{001} goes down and T_{002} goes up with increasing pressure. This result is similar to that of YVO₃.

In summary, we succeed in controlling the ground state of TbVO₃ by applying pressure.

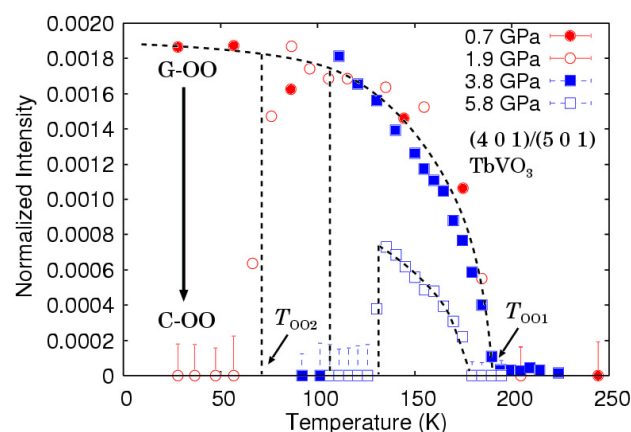


Fig. 1. The intensities of (4 0 1) forbidden reflection under high pressure.

References

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