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Orbital Ordering in $TbVO_3$ Studied by a Resonant X-ray Scattering

Daisuke BIZEN[1], Naoto Shirane[1], Hironori NAKAO[1*], Youichi MURAKAMI[1], Toshio YASUE[3], Jun FUJIOKA[3], Shigeki MIYASAKA[2], Yoshinori TOKURA[3,4]
[1]Department of Physics, Tohoku University, Sendai 980-8578, Japan
[2]Department of Physics, Osaka University, Toyonaka, 560-0043, Japan
[3]Department of Applied Physics, University of Tokyo, Tokyo, 113-8656, Japan
[4]Cross-Correlated Materials Research Group, RIKEN, Wako 351-0198, Japan

Introduction

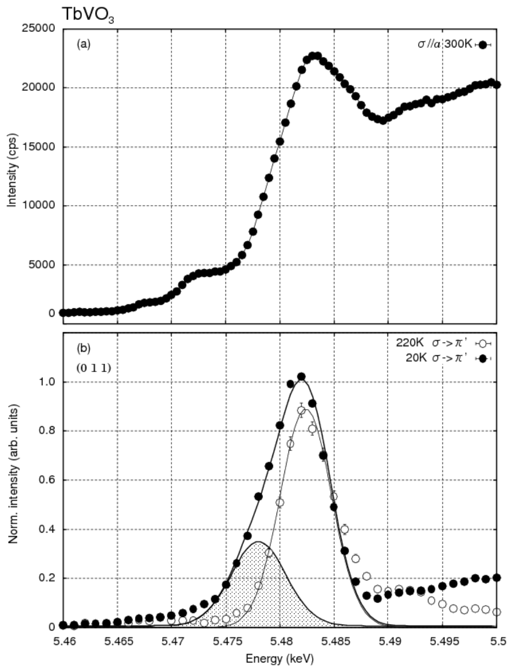
Perovskite-type vanadium oxides, RVO_3 (R: rare earth or Y), have two *3d* electrons on the V^{3+} ions, which have the orbital degree of freedom of t_{2g} electron. As a result, RVO_3 shows various physical properties coupled with the orbital and spin states depending on R-ions [1]. Though the orbital ordering plays an important role in determining the physical property, the experimental technique to observe the orbital ordering is limited. The resonant x-ray scattering (RXS) is one of the techniques for measuring the order-parameter of the orbital ordering and determining the wave function of the ordered orbitals. The orbital orderings in YVO_3 have been investigated by the RXS technique [2]: YVO_3 shows a phase transition from the orbital disordered (OD) state to the G-type orbital ordering (G-OO) at T_{OO1}, and that from the G-OO and the C-type orbital ordering (C-OO) at T_{OO2} ($<T_{OO1}$). The orbitally ordered structure in C-OO and G-OO phases was estimated by the azimuthal angle dependence of the RXS signal at (0 1 1). However, the result was not clear. It may be a problem that the RXS intensity reflects not only the orbital ordering but also the local crystal symmetry. In this study, we have investigated the RXS in $TbVO_3$: that has the OD/G-OO phase transition at T_{OO1}=200 K, and the ground state is the G-OO phase. The RXS was precisely measured in the OD and the G-OO phases to extract the RXS component reflecting the orbital state.

Experiments

The high quality single crystal of $TbVO_3$ was grown by a floating-zone technique. The (0 1 1) surface was cut and polished with fine emery paper. The RXS experiments were performed by four-circle diffractometers at beam lines 4C and 3A of the Photon Factory. The incident beam was monochromatized by a pair of Si(111) crystals, giving an energy resolution about 2 eV, and focused by a bend cylindrical mirror. The x-ray energy near the V *K*-edge (~5.48 keV) was utilized for measuring the RXS signal. Polarization analysis was performed using a PG(004) analyzer crystal. For low temperature experiment, the sample was mounted in a closed cycle He cryostat.

Results

Figure (b) shows the energy dependence of the RXS intensities at (011) in the G-OO phase (20 K) and the OD one (220 K), where only the σ->π' scattering component was measured by the polarizer. The resonating signal was clearly observed near the V *K*-edge, which can be evaluated by the fluorescence spectrum as show in Fig. (a). We elucidated that the RXS peak width at 20 K is broader than that at 220 K. It indicates that the new RXS component emerges at 5.478 keV in the G-OO phase as denoted by the shaded gauss function. We also measured the azimuthal angle dependence of the RXS component, which is different from that at 5.482 keV and is consistent with the model calculation of G-OO. Namely, the energy observing the azimuthal angle dependence is important to discuss the orbital state.



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* nakao@iiyo.phys.tohoku.ac.jp