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Spin-lattice coupling in multiferroic $MnWO_4$

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Introduction

$MnWO_4$ is one of the multiferroic materials, in which the cycloidal spin structure induces the ferroelectricity [1].

According to neutron diffraction results [2], AF1 ($T < T_1$), AF2 ($T_1 < T < T_2$) and AF3 ($T_2 < T < T_N$) are a commensurate (C) collinear AFM-phase, an incommensurate (IC) cycloidal-spiral-phase, and an IC-collinear AFM-phase, respectively. In the present study, we have investigated the coupling between the lattice and the spin order in each magnetic order phase of $MnWO_4$ through the synchrotron-x-ray diffraction [3].

Results and discussion

A single crystal of $MnWO_4$ measured in this study was grown by the floating zone method. Off-resonant single crystal x-ray diffraction measurements were performed on beam line 3A at Photon Factory.

The superlattice reflections were measured in the reciprocal space around $(h\ -5\ l)$ with h~1/2, l~0. An intense C superlattice peak is discernible in the AF1-phase, whereas an IC superlattice peak is observed in the AF2 and the AF3 phases. The emergence of the C and IC lattice modulation seems to correspond to the magnetic modulation, since the lattice propagation vector ($\boldsymbol{q}^l$) of each phase is almost twice of the magnetic propagation vector ($\boldsymbol{q}^m$) obtained from a neutron diffraction measurement [2]. This relationship between $\boldsymbol{q}^l$ and $\boldsymbol{q}^m$ indicates that the magnetic modulation induces the lattice modulation through the spin-lattice coupling termed exchange striction.

The temperature dependence of the superlattice propagation vector, $\boldsymbol{q}^l$, is shown in Figs. 1 (a) and (b). The x- and z- components of the lattice propagation vector, q_x^l and q_z^l, continuously shift from the AF3- to the AF2-phase around T_2, whereas q_x^l and q_z^l discontinuously change to C values, $q_x^l = -0.5$ and $q_z^l = 1$, around the IC-C transition temperature (T_1) from the AF2- to the AF1-phase. This discontinuous transition indicates that the IC-C phase transition is a first order type one. Figure 1 (c) shows the temperature dependence of the integrated intensities for the C and IC superlattice peaks. The IC peak gradually grows in intensity below T_N until the development of the superlattice peak intensity is suppressed below T_2. Taking into account of exchange striction, the suppression of the peak intensity development below T_2 would be ascribed to the suppression of the lattice modulation caused by theelliptic al spiral spin structure. We have also confirmed

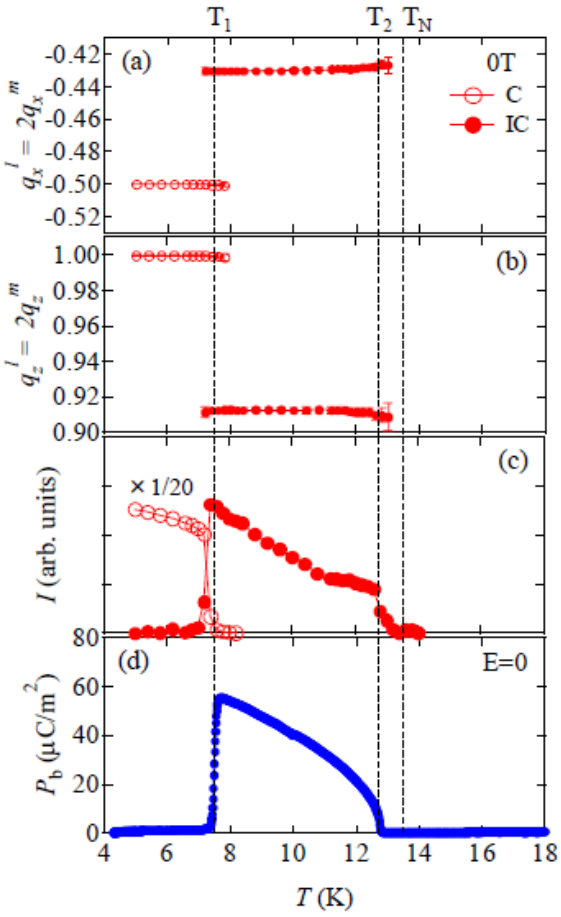

Figure 1.Temperature dependence of [(a) and (b)] lattice propagation vector q_x^l and q_z^l, (c) integrated intensities of IC (closed circle), C (open circles) superlattice peak, and (d) electric polarization along the b axis at 0T.

that the AF2 phase, which is ferroelectric (Fig. 1(d)) and stabilized by the magnetic field parallel to the c-axis, accompanies the IC lattice modulation in magnetic field. This fact indicates that the magnetic-field-induced AF2 phase also takes IC magnetic structure.

References

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