Correlation between Electric Polarization and Sence of Helix in $MnWO_4$

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In a magnetoelectric compound $MnWO_4$, sinusoidal incommensurate antiferromagnetic ordering of the Mn^{2+} moments takes place at $T_{N1} = 13.5$ K with a magnetic wave vector with $k \approx (-0.214$ $1/2$ $0.457)$. The ferroelectric polarization along the b axis (P_b) emerges upon the magnetic phase transition from collinear to spiral spin structure at $T_{N2} = T_C = 12.7$ K. Below $T_{N3} = 7.6$ K, the spin structure alters into a commensurate collinear type with k $=(-1/4,\ 1/2,\ 1/2)$ and the ferroelectricn polarization is dismissed. We report here the quantitative elucidation of such magnetically induced ferroelectricity in terms of the spin ellipticity as the order parameter and show the successful electric control between the clockwise (CW) and counter-clockwise (CCW) spin helixes.

Spin-polarized neutron diffraction measurements were performed with a triple-axis spectrometer PONTA at JRR-3. A single crystal was mounted on a sapphire plate in a closed-cycle helium refrigerator and irradiated with a spin-polarized neutron beam. A Heusler monochromator was utilized to obtain the spin-polarized neutron beam. The spin of the neutron beam could be flipped by a spin-flipper, so as to be parallel or anti-parallel to the scattering vector Q_s with a guide-field of about 10 gauss applied by a Helmholtz coil.

All the neutron diffraction measurements were performed in zero electric field after cooling the sample from the paramagnetic phase in a poling electric field. Peak profiles of magnetic satellite reflections with Q_s $=(-1\ 0\ 2)\pm k$ were measured along the $(-1\ 0\ 2)$ line in the reciprocal lattice.

Figure 1(a) shows the profiles of the magnetic satellites for the ferroelectric state at 9 K. The flipping ratios are far from one only for the ferroelectric phase ($T_{N3} < T < T_{N2}$). Moreover, the result shows that the sense of the spiral is controlled by the ferroelectric polarization direction. Such a behavior seems to be common to the recently discovered magnetic ferroelectrics. However, the short principal axis of the spiral of $MnWO_4$ at 8K is estimated to be more than 90 % of the long axis. This is rather a contrast to the case of $TbMnO_3$, where the spiral is more elliptic with $m_c/m_b \sim 0.7$. The small ellipticity in this material is advantagious for the investigation of low energy excitations in the multiferroic.

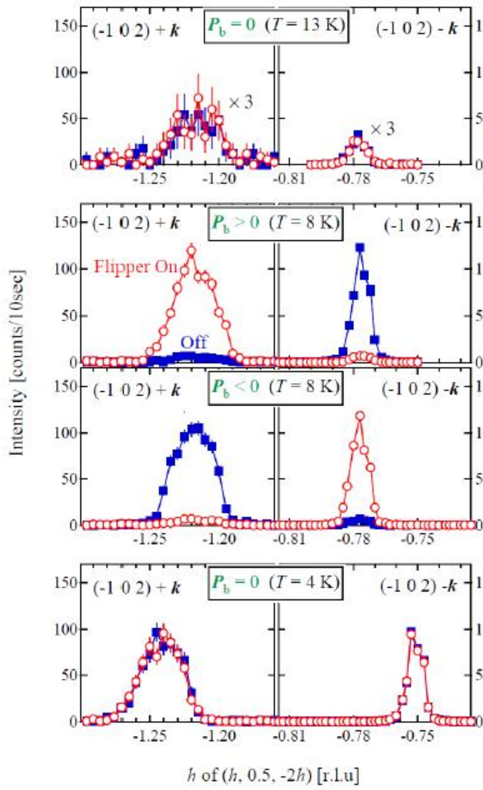

Fig. 1. Profiles of magnetic satellites $(-1\ 0\ 2\ )\pm k$ in three magnetic phases.