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Lattice modulation induced by antiferromagnetic orderings in multiferroic $R\mathrm{Mn_2O_5}$

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X-ray diffraction measurements have been performed to observe lattice modulation induced by antiferromagnetic orderings in multiferroic compounds of $R\mathrm{Mn_2O_5}$(R = Y, Tb). A series of $R\mathrm{Mn_2O_5}$ compounds is well known as multiferroic materials in which antiferromagnetic and ferroelectric order coexist and their order parameters are mutually coupled. It has been revealed that the well-defined ferroelectric phase appears only in the commensurate magnetic (CM) phase[1]. However, the precise structure giving the spontaneous polarization is still unclear at the moment. In this report, we present the observation of satellite reflections appearing below the Neel temperature 45 K.

We surveyed the existence of superlattice reflections by X-ray at Photon Factory BL4C in KEK. A four-circle diffractometer with closed-cycle-type He-gas refrigerator was used. Used x-ray wavelength is 0.738A. The samples $\mathrm{YMn_2O_5}$ and $\mathrm{TbMn_2O_5}$, whose crystal sizes are about 200µm cube, were used. We found very weak superlattice and satellite reflections. The ratio between the fundamental and the strongest superlattice reflection is about 10^{6}. The lattice modulation wavevector $\mathbf{q}_L$ was carefully measured in (1) paraelectric (PE) with high-temperature incommensurate magnetic (HTICM) phase, (2) ferroelectric (FE) with magnetically commensurate(CM) phase, and (3) dielectrically active but unclear phase (X phase) with low-temperature incommensurate magnetic (LTICM) phase. The results for $\mathrm{TbMn_2O_5}$ are summarized in Fig. 1. As seen in the figure, lattice modulation vector $\mathbf{q}_L = (q_{Lx}, 0, q_{Lz})$ is exactly twice of the magnetic propagation vector $\mathbf{q}_M = (q_{Mx}, 0, q_{Mz})$, which was obtained by neutron diffraction[2], in all the phases. This indicates that the lattice distortion, giving the satellite reflection, is originated from the magnetic order. Very complicated extinction rule was found for the pattern of the satellite reflections, and it changes from phase to phase. Finally, we compared the characteristics of the intensity pattern between $\mathrm{YMn_2O_5}$ and $\mathrm{TbMn_2O_5}$, and almost similar tendency was found against (h, k, l) indices. This implies that the major displacement comes from Mn and O atoms.

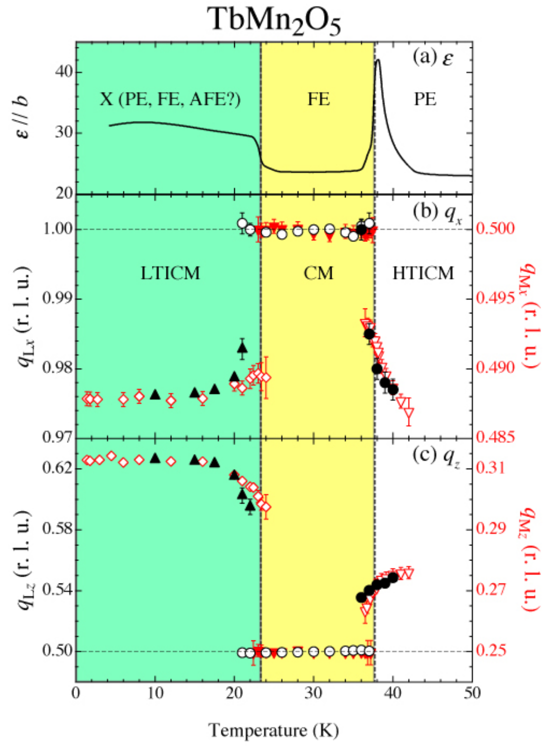

Fig. 1: (a) Dielectric constant as a function of temperature for $\mathrm{TbMn_2O_5}$. Temperature dependences of (b) x- and (c) z-components of lattice and magnetic modulation wave vector ($\mathbf{q}_L$ and $\mathbf{q}_M$) for $\mathrm{TbMn_2O_5}$. Black and red symbols indicate the data for $\mathbf{q}_L$ and $\mathbf{q}_M$, respectively.
Abbreviation
PE; paraelectric, FE; ferroelectric, AFE; antiferroelectric, HTICM; high-temperature incommensurate magnetic, CM; commensurate magnetic, LTICM; low-temperature incommensurate magnetic.

References

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