Magnetic ordering of multiferroic $LuMn_2O_5$

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Multiferroic RMn_2O_5 (R = rare earth ions) that exhibits both antiferromagnetic ordering and ferroelectricity, has been the subject of intensive research since around 2000. It has been revealed that (1) ferroelectric ordering occurs simultaneously with the magnetic phase transition from the incommensurate to commensurate (CM) phase of magnetic Mn ions, (2) the behavior of (1) can be systematically understood regardless of the type of rare earth ion, and (3) the giant magnetoelectric (ME) effect that appears at low temperatures is induced by electric polarization due to a change in magnetic order under an external magnetic field [1,2]. The ME effect changes significantly depending on the R ions, and the giant ME effect at low temperatures is closely related to magnetic moments of the rare earth ions. On the other hand, YMn_2O_5 with nonmagnetic Y ions has also been extensively investigated to elucidate the role of Mn ions and variety of magnetic features including successive magnetic phase transitions associated with ferroelectricity were observed. However, the magnetic ordering of $LuMn_2O_5$ has not been studied in detail. In this study, we performed neutron diffraction experiments using four-circle off centered diffractometer (FONDER). The wavelength of incident neutrons was 1.2464 Å.

From the temperature dependence of reciprocal lattice scans along the a^* and c^* directions, we found that a two-dimensional incommensurate magnetic (2DICM) phase characterized by the magnetic propagation vector $\mathbf{q}_M = (0.46, 0, 0.22)$ appears below $T_{N1} \sim 45$ K. As the temperature decreases, $\mathbf{q}_M$ starts to change with temperature at the ferroelectric ordering temperature, $T_D = 35$ K and a magnetic phase transition to a one-dimensional incommensurate magnetic (1DICM) phase with $\mathbf{q}_M = (0.45, 0, 0.25)$ occurs at $T \sim 20$ K. The temperature dependence of $\mathbf{q}_M$ along the a^* and c^* direction, q_x and q_z, respectively, is shown in Fig. 1. The temperature dependence of $\mathbf{q}_M$ for $LuMn_2O_5$ is significantly different from that of other RMn2O5 systems, which exhibit a CM phase with $\mathbf{q}_M$ = (0.5, 0, 0.25) below T_D and another 2DICM phase at low-temperatures below T_{N2} [1]. This difference may be due to the small ionic radius of Lu [2] or the presence of oxygen vacancies that prevent the appearance of the CM phase [3]. Further neutron diffraction experiments using high-quality $LuMn_2O_5$ single crystal samples is planned.

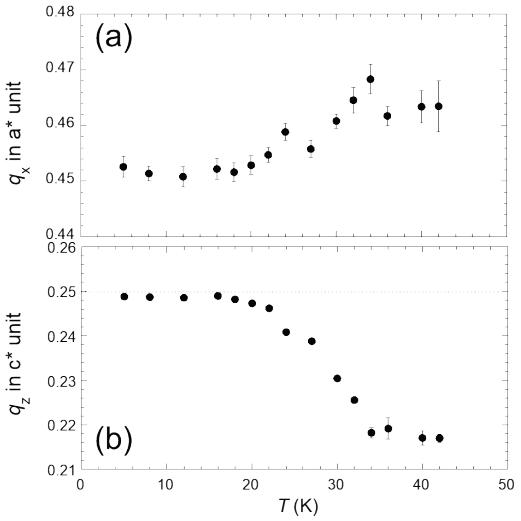

Fig. 1: Temperature dependence of (a) q_x and (b) q_z

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[2] I Kagomiya *et al*., Ferroelectrics 280 (2002) 131.

[3] S. Kobayashi, Y. Noda et al., J. Phys. Soc. Jpn. 73 (2004) 3439.