Resonant soft x-ray scattering study of the multiferroicity in TbMn$_2$O$_5$

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— TbMn$_2$O$_5$ is one of the fascinating multiferroic compounds whose spontaneous polarization can be controlled by applying magnetic field. Neutron diffraction measurements reported that incommensurate-commensurate transition of antiferromagnetic ordering is related to the appearance of ferroelectricity. In order to investigate the relationship between magnetic ordering and ferroelectricity associated with electronic structures of the Mn 3$d$ states, we measured soft x-ray resonant magnetic scattering of the single crystalline TbMn$_2$O$_5$ with photon energies around Mn $L_{2,3}$ edge. We observed that antiferromagnetic ordering of TbMn$_2$O$_5$ with incommensurate propagation vectors ($\frac{1}{2}+\delta_x$, $0$, $\frac{1}{4}+\delta_z$) coexists with antiferromagnetic ordering with a commensurate propagation vector ($\frac{1}{2}$, $0$, $\frac{1}{4}$) in the ferroelectric phase ($22$ K $< T$ $< 37$ K). Comparing the temperature dependence of resonant x-ray scattering and the arguments based on symmetry considerations, we discuss the magnetic ordering which leads to the magneto-electric effect in TbMn$_2$O$_5$.

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Date submitted: 26 Nov 2006

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