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Order Parameters and Phase Diagram of Multiferroic RMn2O5

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Recently there has been great interest in systems which display phase transitions at which incommensurate magnetic order and a spontaneous polarization develop simultaneously. Perhaps the most puzzling and seemingly complicated behavior occurs in the series of compounds RMn_2O_5, where R=Y, Ho, Er, Tb, Tm, and Dy. (For references to experimental data, see [1].) The sequence of magnetoelectric phases of the type I systems R=Tb, Ho, and Dy is slightly different from that of the type II systems R= Y, Tm, and Er. At about 45K both types develop essentially collinear modulated magnetic order into a "high-temperature ordered" (HTO) phase with a wave vector $\mathbf{q} = (1/2 - \delta, 0, 1/4 + \epsilon)$ where δ and $|\epsilon|$ are of order 0.01 and the spontaneous polarization is zero. There is a lower-temperature phase transition to a ferroelectric phase in which transverse magnetic order appears and produces a magnetic spiral with $\delta = \epsilon = 0$. In type I systems, this transition occurs directly from the HTO phase, whereas for type II systems, there is an intervening ferroelectric phase in which $\epsilon = 0$, but δ remains nonzero. and II description. I will discuss a Landau free energy[1] which allows both type I and type II sequences of phase transitions. This theory is couched in terms of the uniform polarization vector $\mathbf{P}$ and two complex-valued magnetic order parameters $\sigma_1(\mathbf{q})$ and $\sigma_2(\mathbf{q})$ whose symmetry follows from the magnetic structure analyses.[2] The magnetoelectric coupling and the competition between commensurate and incommensurate phases are analyzed.

[1] A. B. Harris, A. Aharony, and O. Entin-Wohlman, Phys. Rev. Lett. **100**, 217202 (2008) and J. Phys. Condens. Mat. **20**, 434202 (2008).

[2] A. B. Harris, Phys. Rev. **76**, 054447 (2007); A. B. Harris, M. Kenzelmann, A. Aharony, and O. Entin-Wohlman, Phys. Rev. B **78**, 014407 (2008).