MAGNETIC-FERROELECTRIC INTERACTIONS IN $RMnO_3$

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ABSTRACT

Hexagonal $R\mathrm{MnO_3}$ is multiferroic material as a combination of frustrated antiferromagnet (T_N=72K) and ferroelectric (T_C=875K) which consists of multiple temperature and field-dependent phases. Strong coupling between the ferroelectric and magnetic orders has been observed at a spin reorientation transition between a P6'$_3$cm' and a P6'$_3$c'm magnetic phases in $HoMnO_3$, but the origin of this coupling is not well understood. Most $R\mathrm{MnO_3}$ order in a single magnetic phase with no spin reorientation transition, and so do not show any such strong magnetic-ferroelectric coupling. This work focuses on investigating what distinguishes $HoMnO_3$ from other $RMnO_3$ in order to better understand the magnetic-ferroelectric coupling in $RMnO_3$.

In order to study the transition between P6'$_3$cm' and a P6'$_3$c'm magnetic phases in $RMnO_3$, single-crystal samples of the hexagonal multiferroics $Ho_{1-x}Y_xMnO_3$, $Er_{1-x}Y_xMnO_3$ and $Dy_{1-x}Y_xMnO_3$ were grown at different compositions. $YMnO_3$ orders in a P6'$_3$cm', whereas $ErMnO_3$ and $ErMnO_3$ order in a P6'$_3$c'm phase. $HoMnO_3$ is in the P6'$_3$c'm phase at high temperatures and the P6'$_3$cm' phase at low temperature. Neutron diffraction measurements were used to establish

the magnetic phase diagram as a function of temperature and composition. For $Er_{1-x}Y_xMnO_3$ the transition from P6'$_3$cm' to P6'$_3$c'm happens over a very narrow composition range on the Y-rich side of the phase diagram. For $Dy_{1-x}Y_xMnO_3$ a spin reorientation transition occurs for samples with up to 40% Dy, the highest concentration sample. Unlike Ho doping, both Er- and Dy- doping initially produces the P6'$_3$c'm phase as a low-temperature phase as Y concentration decreases. Such differences suggest significant complexity in the magnetic phase competition in $RMnO_3$.

Our recent research is using inelastic neutron scattering to measure dynamics in $HoMnO_3$. Previous spin wave dispersion measurements have provided information about the Mn^{3+} spin interactions, and results can be modeled with a Heisenberg antiferromagnet with anisotropy. In addition, there are several low-energy crystal-field excitations in $HoMnO_3$. These levels change whenever the system undergoes a magnetic phase transition. Furthermore, inelastic neutron scattering measurements suggest that there is a direct interaction between these crystal field levels and the Mn^{3+} spin waves. Because ferroelectricity in $RMnO_3$ is due to displacement of the rare earth ions, we conclude that these interactions may be critical to the magnetic-ferroelectric coupling in $HoMnO_3$, and may help explain its unique properties.