Phase Separation in Pr$_{0.7}$Ca$_{0.3}$MnO$_3$

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The importance of phase separation to the behavior of colossal magnetoresistance (CMR) materials is becoming widely acknowledged due to an accumulation of experimental and theoretical work on this issue (see Dagotto et al.\textsuperscript{1} for a recent review). The observation of phase separation perhaps comes as no surprise considering the wide variety of ground state phases exhibited by CMR materials when subjected to small perturbations. An example is the Pr$_{1-x}$Ca$_x$MnO$_3$ system, in which the replacement of Pr ions by identically-sized Ca ions results in low temperature ground state phases ranging from antiferromagnetic insulating ($x \leq 0.15$) to ferromagnetic insulating ($0.15 \leq x \leq 0.3$) to CE-type charge and orbitally ordered, antiferromagnetic, insulating ($0.3 \leq x = 0.5$).\textsuperscript{2,3} The expected small energy differences between these three low temperature phases suggest the possibility of phase separation in this system, and therefore an $x = 0.3$ sample was chosen for an x-ray diffraction investigation.

The Pr$_{0.7}$Ca$_{0.3}$MnO$_3$ single-crystal was grown by floating zone techniques at JRCAT. The sample was determined to be fully twinned, with a (110)/(002)-oriented surface normal (in orthorhombic, Pbnm, notation). For simplicity, reflections are referenced using the (110) surface normal direction. Measurements were carried out at 100 K in a high resolution mode using a Ge(111) analyzer. Three phases associated with different domains were observed. Two of these phases are consistent with a CE-type charge and orbital order—with (100)/(010) and (0.5 0 0)/(0 0.5 0) wavevectors, respectively—while the third phase exhibited only a (100)/(010) ordering wavevector. A contour plot of a reciprocal space mesh scans at the (030) reflection, in which all three phases can be clearly seen, is shown below in Figure 1.

The uniqueness of the three phases was determined via measurements of their respective temperature dependences. The two CE-type phases were found to have ordering transitions at 130 K and 200 K, and are therefore labeled D, for disappearing, and CO, for conventional charge and orbital ordering, respectively, in Figure 1. The ordering in the third phase persisted up to room temperature, and its (030) reflection is labeled P, for persistent.

While the observation of phase separation in Pr$_{0.7}$Ca$_{0.3}$MnO$_3$ is interesting in itself, the more important question concerns the relationship between the three phases. With this goal in mind, a series of studies of the polarization, azimuthal, and energy dependences of the three phases is currently in progress.

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