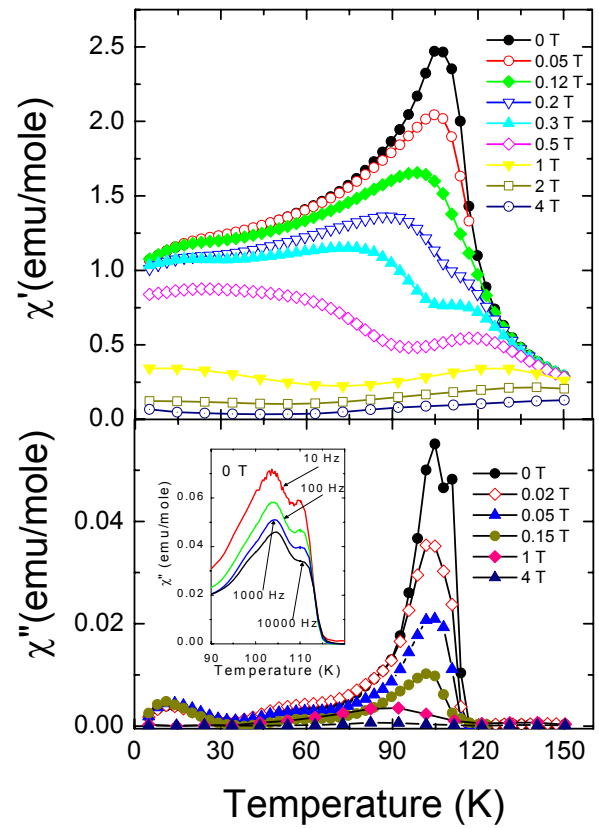
Studies of Unusual Ferromagnetic Materials

Peter Schiffer, Penn State University, DMR-0101318

This grant's primary focus has been the study of unusual ferromagnetic materials with a particular emphasis on the properties of magnetoelectronic materials, those in which the electronic and the magnetic properties are closely coupled. These materials are especially promising for so-called "spintronic" applications where the magnetic moment of the electron would be exploited to allow greater device capabilities.

One class of such materials is the family of "colossal magnetoresistance" oxides in which the ground states are a separated mixture of ferromagnetic electrically conducting regions and antiferromagnetic electrically insulating regions. This combination leads to physical behavior which can be characterized as glass-like, and we have been comparing the properties with those of traditional magnetic "spin" glasses -- finding significant differences which demonstrate that this "phase separation" leads to a novel form of glassiness.



The real and imaginary parts of the a.c. susceptibility of the colossal magnetoresistance compound $Pr_{0.7}Ca_{0.3}MnO_3$. The peak which is suppressed by magnetic field and is also frequency dependent is characteristic of glassiness in these materials but differs significantly from traditional spin glass behavior (I. Deac et al., Physical Review B 2001)

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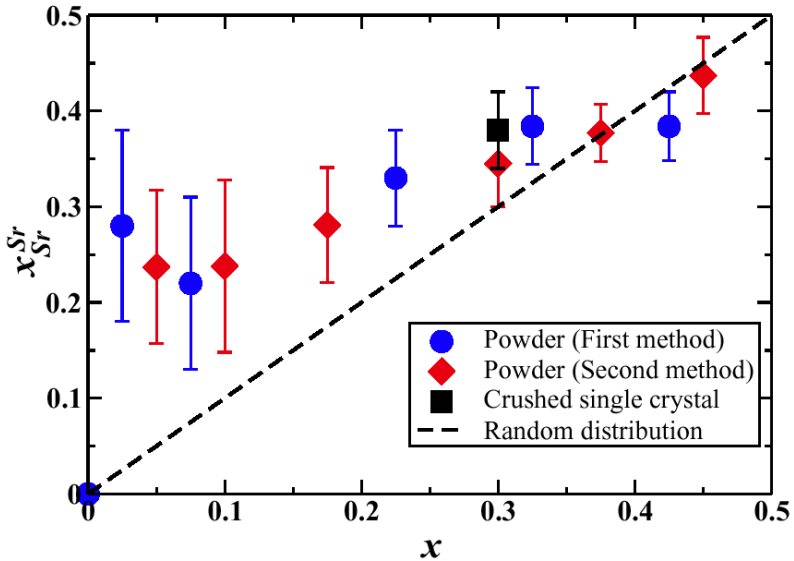
Since the ground state of the colossal magnetoresistance compounds is inhomogeneous, one question which arises is how homogeneous the materials are on a microscopic scale. By performing x-ray absorption fine structure measurements on these material (in collaboration with Bruce Bunker and Tomohiro Shibata at the University of Notre Dame), we find that there is nanoscale clustering of the different types of ions in some of these materials. This fine-scale inhomogeneity may explain how the phase separation between different types of magnetoelectronic states nucleates, i.e. how it comes into being.



Third-shell Sr coordination about Sr atoms in $La_{1-x}Sr_xMnO_3$. If the site occupancy for these atoms were random, the results would be a linear function of x, as shown by the dashed line. The excess Sr at low doping region indicates a tendency towards Sr-Sr (and thus also La-La) clustering. (T. Shibata et al., Physical Review Letters 2002).