Charge Ordering and Polaron Formation in CMR Oxides

C. Adams[1,2], J. Lynn[1,2], and Y. Mukovskii[3]
[1]Materials Research Science and Engineering Center
University of Maryland, College Park, MD 20742
[2]NIST Center for Neutron Research, National Institute of Standards and Technology
Gaithersburg, Maryland 20899
[3]Moscow Steel and Alloys Institute
Moscow 117936, Russia

The recent discovery of huge magnetoresistance effects in the manganese oxide class of materials (such as $La_{1-x}A_xMnO_3$ (A=Sr, Ca, Ba)) has rekindled intense interest in these systems. In contrast to traditional isotropic ferromagnets such as Fe, Co, Ni, and EuO where the spin system is isolated from the lattice, in the manganites the charge, spin, and lattice degrees of freedom are strongly coupled together, leading to a delicate balance of interactions that gives rise to a rich variety of physical phenomena of current interest in condensed matter physics. These include a metal-insulator transition concomitant with ferromagnetic ordering, charge and orbital ordering, polaron formation, electronic phase separation, and spin and charge stripes. The manganites are also related to the high T_C cuprate oxides, with a commonality of many of the materials properties and underlying physical concepts. Recent progress in our understanding of the cuprates has provided insights into the manganites, and a deeper understanding of the fundamental properties of the manganites will surely elucidate the shared concepts underlying both classes of materials. Finally, the colossal magnetoresistance (CMR) offers potential in a number of technologies, such as for read/write heads, sensors, and spin-polarized electronics, and this potential has also generated enormous interest.

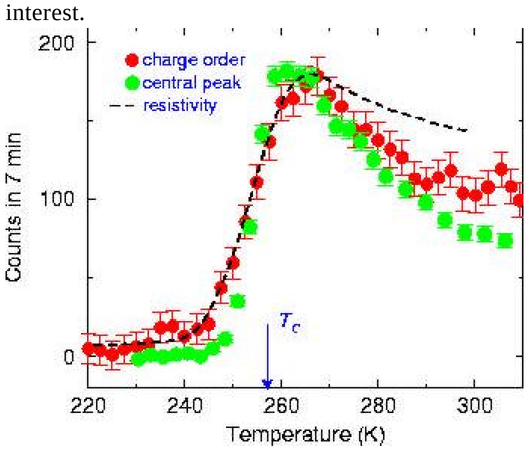

Figure 1. T dependence of the polaron peak, compared to the central fluctuation magnetic scattering, and the resistivity.

The scattering from a lattice polaron arises from the structural distortion that surrounds a carrier, and traps it. Individual polarons generate diffuse (Huang) scattering around the fundamental Bragg peaks, and we observe such diffuse scattering in the present neutron scattering measurements on a $La_{0.7}Ca_{0.3}MnO_3$ single crystal.[1] We also observe well-developed polaron-polaron correlations, which give rise to short range satellite peaks with a commensurate polaron ordering wave vector (1/4,1/4,0).

The temperature dependence of the intensity of the polaron peaks is shown in the figure. We see that the scattering begins to develop in this sample ~30 K below T_C, rapidly develops as $T \rightarrow T_C$, and peaks just above the ordering temperature. This behavior is very similar to the temperature dependence of the resistivity, which is shown as the dashed curve in the figure (scaled to the peak in the scattering). The intensity of the quasielastic component of the spin fluctuation spectrum[2] [measured at (1.03,0,0)] has been similarly scaled and is also shown in the figure. We see that the temperature dependence of the two types of scattering through the ferromagnetic phase transition is virtually identical to the resistivity, indicating that they all have a common origin.

These experimental neutron scattering results reveal that both the spin and charge correlations associated with the polarons in $La_{0.7}Ca_{0.3}MnO_3$ appear together, and have a very similar spatial and temperature dependence. The metal-insulator crossover in the conductivity also occurs close to T_C. This coincidence may explain the amplified magnetoresistive effects, as well as the absence of conventional magnetic critical behavior, both in the Ca-doped system as well as in other materials. Further experimental work is in progress to investigate these polarons correlations as a function of magnetic field, composition, and applied stress.

References

1. [1]C. P. Adams, J. W. Lynn, Y. M. Mukovskii, A. A. Arsenov, and D. A. Shulyatev, Phys. Rev. Lett. **85**, 3954 (2000). J. W. Lynn, C. P. Adams, Y. M. Mukovskii, A. A. Arsenov, and D. A. Shulyatev, J. Appl. Phys. **89**, (1 June, 2001).
2. [2]J. W. Lynn, R. W. Erwin, J. A. Borchers, Q. Huang, A. Santoro, J-L. Peng, and Z. Y. Li, Phys. Rev. Lett. **76**, 4046 (1996)