Electronic, Magnetic and Structural Properties of Mn Perovskites GR/K95802, Final Report

Introduction

We have studied the distorted manganese perovskites with the composition $R_{1-x}A_xMnO_3$ where R is a trivalent rare earth and A is a divalent alkali earth. These materials have been shown to exhibit a range of extraordinary magnetic, electronic and structural properties including colossal negative magnetoresistance (CMR), charge ordering and magnetic field induced changes in structure. The project has included the growth of single crystals, neutron scattering studies and laboratory based investigations of the physical characteristics of these systems. The objective of this work has been to gain a better understanding of the structural, magnetic and transport properties of these materials as a function of doping level x, temperature, magnetic field and pressure.

The work carried out during the course of this work has resulted in 25 publications

Single crystal growth

Single crystals with the general formula $(R_{1-x}A_x)_{n+1}Mn_nO_{3n+1}$ (where A=Sr, Ca, and R=Pr, La, Nd, with n=infinity and R=Pr, La, Nd, Ho, or Dy with n=2) have been grown in an infra-red image furnace by the floating zone technique. We have produced a large number of high quality single crystals. These samples have been used our own research and have also been supplied to 9 groups in the UK and 7 groups overseas.

The influence of magnetic field and pressure on the phase transitions in $La_{0.835}Sr_{0.165}MnO_3$

We have performed a series of neutron-diffraction measurements on a single crystal of $La_{0.835}Sr_{0.165}MnO_3$ in which we have directly observed and confirmed the bulk nature of the magnetic field induced orthorhombic-rhombohedral structural phase transition seen in this material. Transport, thermal expansion and neutron diffraction studies under pressure have been performed in order to study the strong coupling between the structural and magnetic ordering in this material. The P-T phase diagram for $La_{0.835}Sr_{0.165}MnO_3$ has been shown to contain a number of extremely unusual features including a pressure independence of the Curie temperature in the orthorhombic phase, a re-entrance of the rhombohedral phase at low temperatures and a change in the type of the magnetic phase transition from second to first order due to the strong coupling between the structural and the magnetic properties of this material. We have shown that in this material it is the structural change which is driving the magnetic transition.

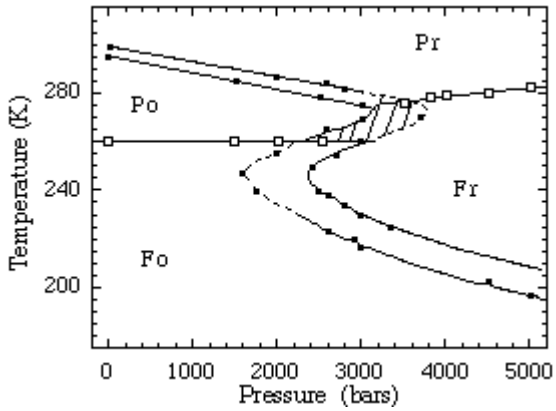

Fig. 1. The structural and magnetic phase diagram of $La_{0.835}Sr_{0.165}MnO_3$. T_c and T_s are marked by squares and circles respectively. The hatched area indicates the crossing point between the four possible phases.

P=paramagnetic, F=ferromagnetic, r=rhombohedral and o=orthorhombic.

Structural, magnetic and transport properties of $Pr_{1-x}Ca_xMnO_3$ and related materials

We have studied the magnetic and transport properties of the $Pr_{1-x}Ca_xMnO_3$ system for all values of x. We were one of the first groups to observe CMR in bulk materials and to demonstrate that there is a strong correlation between the transport and magnetic properties of these materials.

We have also studied the $Pr_{0.6}(Ca_{1-x}Sr_x)_{0.4}MnO_3$ (0 <x <1) system. This work has contributed towards the development of a general understanding of the behaviour of the MnO_3 materials as a function of doping level, temperature and magnetic field and has helped substantiate the idea that the properties of the manganites can be controlled by varying the one-electron bandwidth of the material. For x~1.0 we have shown there is a low temperature structural transition to a monoclinic I2/a phase. This allotype had never previously been observed in the $R_{1-x}A_xMnO_3$ manganese perovskite system.

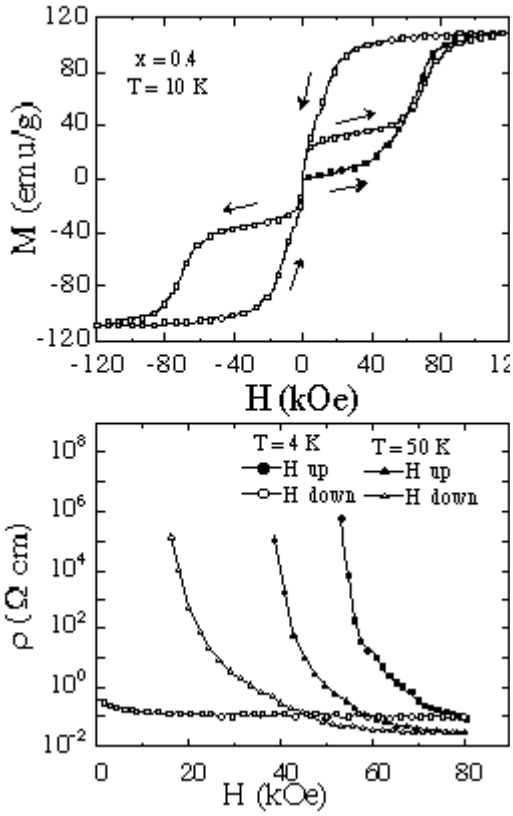

Figure 2. (Upper panel). Low temperature M vs H loop for $Pr_{0.6}Ca_{0.4}MnO_3$ showing the metamagnetic transition from an AFM to a FM state. (Lower panel). ρ vs H curve showing the magnetic field induced insulator-conducting transition in $Pr_{0.6}Ca_{0.4}MnO_3$.

Studies of two dimensional layered $(R_{1-x}A_x)_3Mn_2O_7$

We have investigated the magnetic and magneto-transport properties of single crystal samples in the (Nd-Sr) and $(Pr-Sr)_3Mn_2O_7$ systems. Phase diagrams as a function of doping level x and magnetic field have been constructed. We have also undertaken in depth studies of some of the individual members of each series of compounds. We have studied the pressure dependence of the magnetic and transport properties of a number of single crystals of the layered materials with the formula $(R_{1-x}A_x)_3Mn_2O_7$ These measurements have provided us with a clearer picture of how the properties of these materials can be controlled by the dimensionality of the system, and by the nature and strength of interactions within the Mn-O network. This is important, since this MnO framework is a common characteristic of all these materials.

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