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Temperature and Field Dependence of Resistivities and Anisotropy of Layered Manganites $La_{2-2x}Sr_{1+2x}Mn_2O_7$ *

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In-plane ρ_{ab} and out-of-plane ρ_c resistivities of $La_{1.2}Sr_{1.8}Mn_2O_7$ and $LaSr_2Mn_2O_7$ have been measured by a multiterminal technique. We focus on the effects that magnetic and charge ordering transitions have on the anisotropy σ_{ab}/σ_c which reflects the ratio of the phase coherence lengths in the respective directions. Both resistivities of $La_{1.2}Sr_{1.8}Mn_2O_7$ decrease dramatically below the Curie temperature $T_C \approx 135\ K$. Anisotropy changes with temperature nonmonotonically and displays a peak close to T_C. In $LaSr_2Mn_2O_7$, ρ_c and ρ_{ab} display a broad peak close to the paramagnetic-antiferromagnetic transition temperature $T_N \approx 165\ K$. The anisotropy exhibits an even more complex behavior than in $La_{1.2}Sr_{1.8}Mn_2O_7$, displaying a maximum at the charge ordering temperature and a minimum at T_N.

There is currently a great deal of interest in understanding the relationship between conduction and spin ordering transitions in layered manganites. Here we concentrate on the effects of the phase transitions on the resistive anisotropy of the 40 and 50% doped $La_{2-2x}Sr_{1+2x}Mn_2O_7$. The importance of studying the anisotropy in layered crystals, such as superconducting cuprates, have been recently discussed [1]. The anisotropy σ_{ab}/σ_c is of fundamental importance because it reflects the ratio of the phase coherence lengths $\ell_{\varphi,ab}$ and $\ell_{\varphi,c}$ in the ab- and c-direction, respectively; namely $\sigma_{ab}/\sigma_c = \ell^2_{\varphi,ab}/\ell^2_{\varphi,c}$.

The resistive anisotropy and each component of the resistivity tensor of $La_{1.2}Sr_{1.8}Mn_2O_7$ and $LaSr_2Mn_2O_7$ single crystals were measured as a function of temperature T and magnetic field H by a multiterminal method [2].

The 40% doped $La_{1.2}Sr_{1.8}Mn_2O_7$ undergoes a Curie transition at $T_C \approx 135\ K$. Below T_C, both ρ_{ab} and ρ_c drop by two orders of magnitude within a T range of $10-20\ K$. Here we present the data showing the effect of this phase transition on the anisotropy ρ_c/ρ_{ab}. Figure 1 shows the T dependence of ρ_c/ρ_{ab} for several values of $H||c$. The anisotropy is strongly T dependent

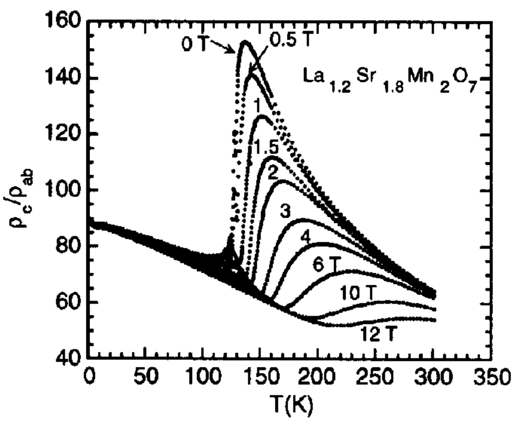

Figure 1. *Anisotropy ρ_c/ρ_{ab} vs temperature T for $La_{1.2}Sr_{1.8}Mn_2O_7$ in different magnetic fields $H \parallel c$.*

and displays a peak near T_C. With increasing H, the peak becomes less pronounced and its location shifts to higher T, approaching 300 K in a field of 14 T. The T-dependent ρ_c/ρ_{ab} indicates that $\ell_{\varphi,c}$ and $\ell_{\varphi,ab}$ do not change with T at the same rate. It is likely that, similar to underdoped superconducting cuprates [1], the interlayer transitions are incoherent so that $\ell_{\varphi,c} \sim \ell_0 \approx 20\AA$, where ℓ_0 is the interlayer spacing. Then, the

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T-dependence of the anisotropy mostly reflects the T-dependence of the in-plane phase coherence length.

The peak in ρ_c/ρ_{ab} at T_C is consistent with the presence of double-exchange mechanism. This *scenario* requires that the phase coherence length of the electrons near T_C correlates with the correlation length of the spin waves which increases near T_C. However, note that, even in zero field, $\ell_{\varphi,ab} \approx (\rho_c/\rho_{ab})^{1/2}\ell_0$ changes rather weakly, from a peak of approximately 255 Å at $T = 135$ K to 180 Å at $T = 120$ K, while both ρ_c and ρ_{ab} decrease hundredfold. This raises doubt that the double-exchange mechanism alone can account for such a drastic decrease of the resistivities.

The 50% doped $LaSr_2Mn_2O_7$ is a much more complex system. It has an antiferromagnetic transition at $T_N \approx 165$ K as well as a charge ordering transition at $T_{CO} \approx 210$ K. The details of the two transitions are very well illustrated by Fig. 2 which is a plot of the derivative of the susceptibility $d\chi/dT$ vs T measured on the same crystal as the resistivities. The inset to Fig. 2(a) shows the magnetic susceptibility $\chi(T)$.

The two resistivities of $LaSr_2Mn_2O_7$ display a broad peak at $T \approx 180$ K, a weaker drop compared with $La_{1.2}Sr_{1.8}Mn_2O_7$ just below 180 K, and an increase with further decreasing T, indicating insulating behavior at low temperatures. A magnetic field suppresses the magnitude of the peak but does not shifts its position.

Figure 2(b) shows ρ_c/ρ_{ab} vs T. First, note that the features in $d\chi/dT$ at T = 140, 165, and 215 K are closely reflected in ρ_c/ρ_{ab}. Outside the phase transition regions (215 < T < 300 K and T < 145 K), the anisotropy monotonically increases with decreasing T, pointing out again to an incoherent out-of-plane transport. A broad peak at T_{CO} indicates the increase of the in-plane phase coherence length near the charge ordering transition. The effect of the Néel transition on anisotropy and, hence, in-plane phase coherence length is opposite to that of both charge ordering and Curie transition (see Fig. 1); namely, $\ell_{\varphi,ab}$ decreases near T_N. This is again consistent with the double-exchange scenario.

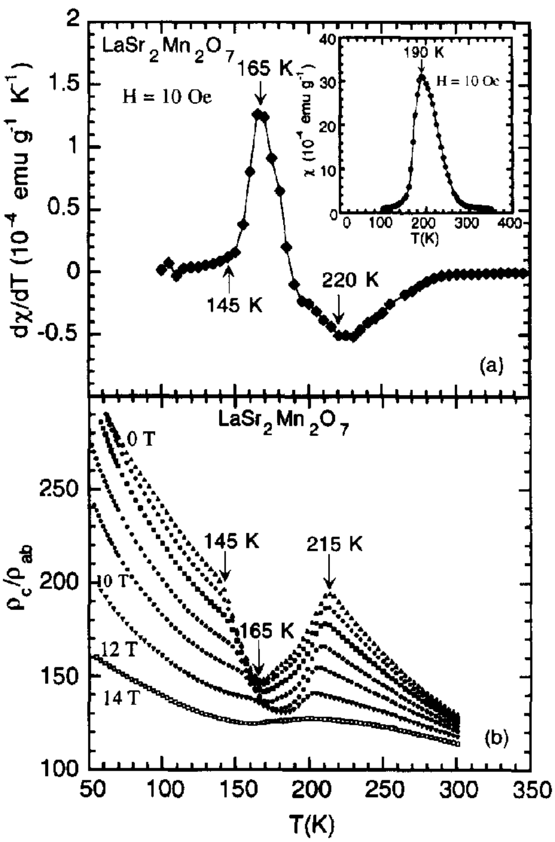

Figure 2. *(a) Derivative of the susceptibility $d\chi/dT$ vs temperature T for $LaSr_2Mn_2O_7$. Inset: Magnetic susceptibility χ vs T. (b) Anisotropy ρ_c/ρ_{ab} vs T for the same crystal.*

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