Properties of $La_{1-x}Sr_xMnO_3$

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Abstract

Doped Manganese Perovskites($R_{1-x}A_xMnO_3$) are a special kind of transition metal oxides that exhibit a very interesting interplay between magnetic, electronic transport and structural properties. This is mainly due to the close similarities between the different energy scales involved; namely the electron phonon coupling, the kinetic energy of the charge carries and the Coulomb interactions. In this paper I am going to describe some of these properties as shown by the Doped Manganese Perovskite ($La_{1-x}Sr_xMnO_3$). In particular, it's strange behavior like GMR and a remarkable variation of it's magnetic, electronic transport and structural properties with a change in the doping level leads to some very interesting physics applications. It also shows an anomalous variation of the optical conductivity spectra with temperature.

1 Structure

Structure of ($La_{1-x}Sr_xMnO_3$) depends on several factors but here we mainly consider it's dependense on Sr doped level and temperature.

1.1 Structurel phase diagram

fig.(1) shows the Structural phase diagram of ($La_{1-x}Sr_xMnO_3$).

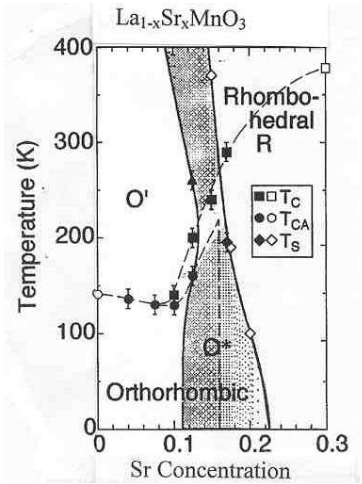

Figure 1: *Structural phase diagram. The squares and circles denote the onset of the ferromagnetic(FM) and antiferromagnetic(AF) components,respectively, while diamonds denote rhombohedral-to-orthorhombic phase transition temperatures.*

There are two orthorhombic phases. One is the well known distorted-perovskite orthorhombic o' phase, while the other is labeled as the o^* phase, which appears at the Sr concentration $0.125 \leq x \leq 0.17$ region. In addition there exist a rhombohedal phase in the much higher doped region with $x > 0.17$[5].

1.2 Lattice Parameter

Following fig.(2) shows the lattice parameter verses temperature in zero magnetic field.

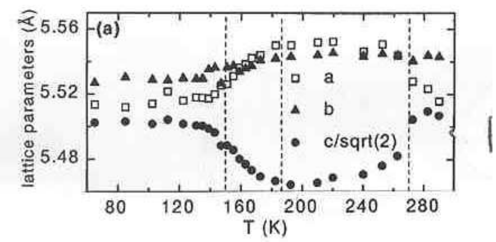

Figure 2: *Lattice parameters versus temperature of* ($La_{1-x}Sr_xMnO_3$) *at zero magnetic field.* T_c, T_{co}, *and* T_{str} *denote the Curie temperature, the charge odering temperature and the structural phase transition temperature, respectively.*

The internal structure parameters also shown as mutual behavior as a function of temperature and provide a microscopic understanding[4] for the lattice parameter behaviors.

2 Giant Magnetoresistance(GMR)

($La_{1-x}Sr_xMnO_3$) has recently attracted considerable attention because of a huge negative magnetoresistance near room temperature. This is important not only for the basic physics of strong electron correlations, but for technical applications too, because the temperature at which the GMR occures can be controlled by tuning the carrier numbers[1]. Fig. (3) shows the temperature dependent of magnetoresistance of ($La_{1-x}Sr_xMnO_3$).

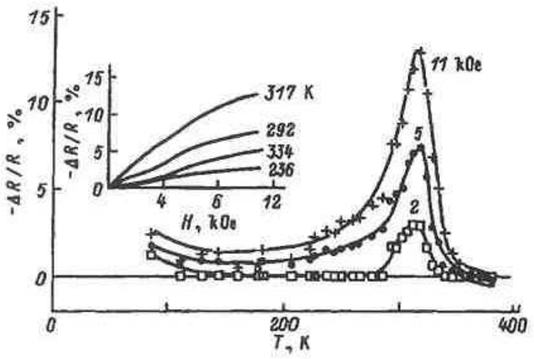

Figure 3: *Temperature dependences of magnetoresistance of a* ($La_{1-x}Sr_xMnO_3$) *film with* $x = 0.23$ *measured in different magnetic fields H. Inset: magnetoresistance isotherms of this film.*

3 Resistivity

The temperature dependance of resistivity is shown below.

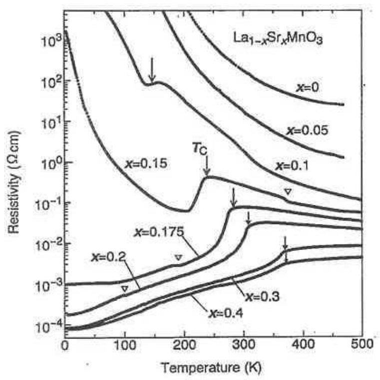

Figure 4: *Temperature dependance of resistivity for* ($La_{1-x}Sr_xMnO_3$) *crystals. Arrows indicate the critical temperature for the ferromagnetic phase transition. Anomalies indicated by open triangles are due to the structural transition*

Fig. (4) shows the temperature dependance of resistivity ρ of $La_{1-x}Sr_xMnO_3$ ($0 \leq x \leq 0.4$). ρ at $x = 0.1$ and 0.15 once decreases immediately below T_c, but then, increases due to some localization effects. In the high-temperature paramagnetic phase $T_c \leq T$, the ρ -T curve is still charactaristic of nonmetal(semiconductor), i.e., $d\rho/dT < 0$, for $x \leq 0.2$. The curve becomes metallic with further increasing $x(> 0.3)$. Anomalies indicated by open triangles for $x = 0.15, 0.175$, and 0.2 crystals are due to the structural transition from the rhombohedral(R3c;Z=2) to orthorhombic (Pbnm;Z=4) form[6].

4 Susceptibility

The pressure dependance of susceptibility with the changing in temperature is shown below fig. (5). It shows the χ-T curves for ($La_{1-x}Sr_xMnO_3$) crystals under various pressure[2]; The upper panel is for x=0.20 and the lower panel for x=0.30. Under pressure, the χ -T curves shifts rigidly to the high temperature side. A stricking feature is the magnitude of the pressure shift is considarably suppressed at x=0.30(lower panel) compared with the x=0.20(upper panel).

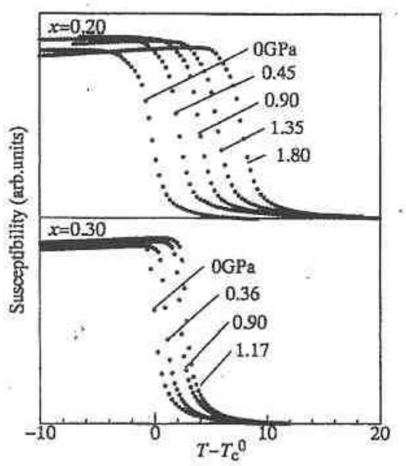

Figure 5: *Pressure dependence of susceptibility for ($La_{1-x}Sr_xMnO_3$) crystals; the upper panel is for x=0.20 and the lower panel for x=0.30. T_c^0 is the Curie temperature at ambiant pressure (0 GPa).*

5 Specific Heat

Fig. (6) shows $C_p(T)$ in a small temperature region arround T_c for different applied magnetic field up to 14T. For finite B_{ext} a "softening" of the sharp zero field anomaly is observed. There is no longer a sharp edge in the $C_p(T)$ curve but only a broad feature, that results in an increased specific heat up to T-240k [4].

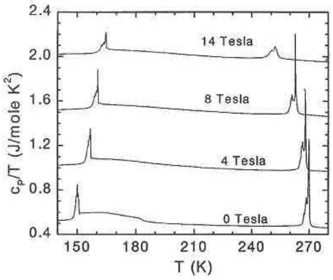

Figure 6: *Specific heat C_p of $(La_{0.875}Sr_{0.125}MnO_3)$ plotted versus temperature at different applied magnetic field.*

6 Teperature dependance of dielectric permitivity $\epsilon^{'}(7.5cm^{-1})$, dynamic $(\sigma^{'}_{1,2}(7.5cm^{-1}))$ and static (σ_{do}) conductivity and ac magnetic susceptibility χ_{ac}

Apparent anomalies were observed in the temperature dependence of the dielectric permitivity and conductivity fig. (7)[3]. A pronounced jumplike behavior for $\epsilon'(T)$ and a maximum for $\sigma'(T)$ between 100 and 120k indicate the existance of an additional phase transition besieds the magnetic transition at T_c. The anomalous behavior of the ac magnetic susceptibility at $T < T_c$ confirm this conclusion. One possible origin of the transition may be relative to a polaron ordering correlated with a freezing of holes on the lattice site.

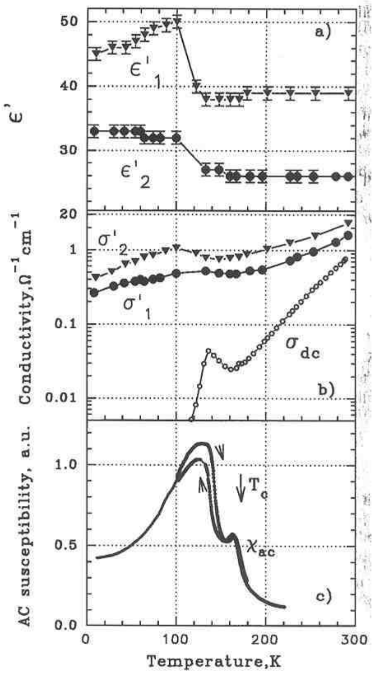

Figure 7: *Temperature dependence of the dielectric permittivity $\epsilon^{\prime}_{1,2}(7.5cm^{-1})$ (a), dynamic $[\sigma^{\prime}_{1,2}(7.5cm^{-1})]$ and static (σ_{do}) conductivity (b) and ac magnetic susceptibility χ_{ac} of $(La_{0.9}Sr_{0.1}MnO_3)$. Indices 1,2 correspond to the two crystallographic directions:1-[-110] and 2-[11-2].*

7 Optical Properties

It has observed anomalous variation of the optical conductivity spectra with temperature for a crystal of $(La_{1-x}Sr_xMnO_3)$ (x=0.175) near the nonmetal-metal composition phase boundary [7]. The results indicate the unconventional features for the electronic structure and their variation with spin polarization extending over several eV; these arise from the extreamly strong coupling between the $3de_g$ conduction electrons and $3dt_{2g}$ local spins.

7.1 Reflectivity Spectra

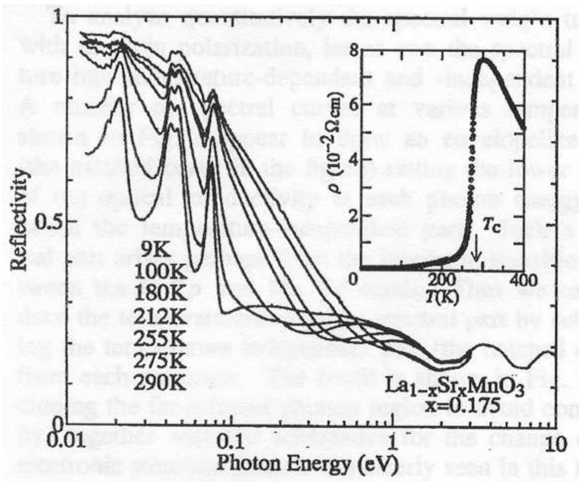

Figure 8: *Reflectivity spectra of* $(La_{0.875}Sr_{0.125}MnO_3)$ *(x=0.175 and* T_c *283k) at various temperatures in the photon energy range 0.01-3.0 eV and at 290k above 3.0 eV.*

Fig. 8 shows reflectivity spectra of $(La_{0.875}Sr_{0.125}MnO_3)$ (x=0.175) taken at various temperatures. Corresponding to the changes of the electrical conduction, the reflectivity spectrum below 3 eV shows a large variation with temperature. The reflectivity spectrum above and near T_c shows up as typical of a nonmetal with sharpe far-infrared features due to the optical phonons at 0.02, 0.04 and 0.08 eV. As the temperature decreases, the lower energy reflectivity is gradually increased and then the spectrum turns into the metalic reflectance band at low temperatures. The phonon structures are observed to fade away with decreasing temperatures due to the dielectric screening effect.

7.2 Optical conductivity Spectra

Spectra of the optical conductivity $\sigma(\omega)$ are shown in the fig. 9. It is clearly discernible that the temperature-dependent change in the spectra extends beyond 2 eV, indicating that the energy scale of the quantity (say, the exchange energy J) responsible for the change in the electronic structure is quite large. The spectrum at 290k ($> T_c$)with no spin polarization shows gaplike features. The gap region appears to be gradually filled in with decrease of temperature or with increase of the spin polarization. Remarkably, the temperature-dependent spectral change persists down to the lowest temperature with no sign of saturation. Such a conspicuous temperature dependance of $\sigma(\omega)$ over a wide

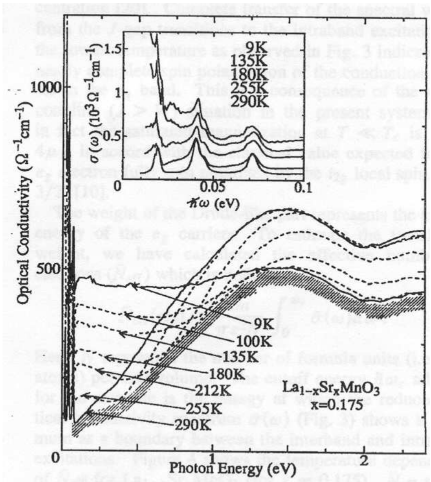

Figure 9: *Optical conductivity spectra of* $(La_{0.875}Sr_{0.125}MnO_3)$ *(x=0.175 and* T_c *=283k) at various temperatures. The hatched curve represents the temperature-independent part of the spectra deduced from the envelop of the respective curves. The inset shows a magnification of the far-infrared part.*

energy region, as it were a sort of thermochromism, is quite unusual as compared with other strongly correlated electron systems near the metal insulator phase boundary.

8 Conclusion

It is clear that many properties of $(La_{1-x}Sr_xMnO_3)$ depends on several parameters like temperatuer, pressure etc. and it shows drastic changes in certern values of those parameters. Therefore, it can be used in physical applications and up to now, $(La_{1-x}Sr_xMnO_3)$ has been extensively used as cathode material since its electrical conductivity is very high and its thermal expansion coefficient fits well with the stabilized Zirconia electrolite.

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