Transport properties of Cr and Fe doped $Sm_{1.4}Sr_{1.6}Mn_2O_7$ at low temperature

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Abstract

The resistance and magnetisation of bilayer manganites $Sm_{1.4}Sr_{1.6}(Mn_{1-x}M_x)_2O_7$, M = Cr, Fe, x = 0.0, 0.01, 0.05 are investigated at low temperature down to 4.2 K under different magnetic fields upto 4 Tesla. The parent compound for x = 0.0 exhibits insulator - metal transition (IM) at about T_{IM} = 112 K. The replacement of Mn by Cr reduces IM transition to 60 K. The substitution of Mn by Fe drastically affects the resistivity at low temperature. The resistivity increases sharply below 100 K and does not show any maximum down to 50 K. The application of magnetic field induces IM transitiom around 60 K. A large magnetoresistance (99%) at low temperature is found for Fe doped samples.

Key words: Manganites, Colossal magnetoresistance, magnetisation, low temperature

1. Introduction

The layered manganites have recently been attracted very much attention by the researchers due to the colossal magnetoresistance, highly anisotropic tranposrt and magnetic propertires and low dimensional effect [1,2]. These materials are generally described by $(R_{1-x}D_x)_{n+1}Mn_nO_{3n+1}$ where R is the trivalent rare earth and D is divalent ion. The bilayerd with n=2 compounds of Ruddlesden-Propper series consist of two MnO_6 alternately stacked along the c axis of the structure compared to the over all extension of MnO_6 in the cubic manganites with n=∞. In the present study, we have investigated the detailed magnetoresistance amd magnetisation as a function of magnetic field and temperature of $Sm_{1.4}Sr_{1.6}Mn_2O_7$ by the substitution of Fe and Cr at Mn sites.

2. Experimental

Polycrystalline samples of $Sm_{1.4}Sr_{1.6}(Mn_{1-x}M_x)_2O_7$ with x=0.01 and 0.05 and M= Cr, Fe were prepared by the standard solid state reaction technique. The appropriate amounts of Sm_2O_7, $SrCO_3$, $MnCO_3$ and Cr_2O_3/Fe_2O_3 were mixed, ground and calcinied at 800 C. The intermediate grindings were performed after heating at 1200 C and 1400 C for 24 hours. The samples were pressed into pellets and sintered into 1450 C for 30 hours and cooled down slowly at the rate of 30 C/hour to room temperature. The purity and compositions of the samples were verified by powder X-ray diffraction and energy dispersive X-ray analysis. The electrical resistivity of the samples was measured by four probes method under magnetic field of 0-4 Tesla and temperature down to 4.2 K.

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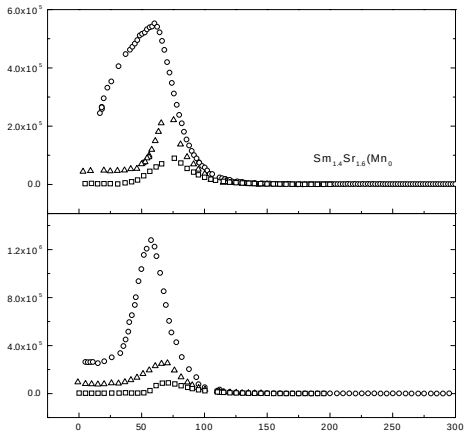

Fig. 1. The temperature dependence of electrical resistivity of $Sm_{1.4}Sr_{1.6}(Mn_{1-x}Cr_x)_2O_7$ for x=0.01 and 0.05

3. Results and Discussions

The temperature dependence of resistivity of $Sm_{1.4}Sr_{1.6}(Mn_{1-x}M_x)_2O_7$ for Cr and Fe at various magnetic fields are shown in Figs. 1 and 2 respectively. At zero magnetic field, Cr substituted samples exhibit insulator - metal (IM) transition at about 60 K while IM tramsition is completely absent in Fe doped samples. The IM transition temperature (T_{IM}) of undoped samples $Sm_{1.4}Sr_{1.6}Mn_2O_7$ (SSMO) is around 112 K. Thus the value of T_{IM} reduces with Cr substitution but does not depend significantly on the doping level of Cr. In both compositions of Cr samples, the resistivity decreases sharply with the application of field. The magnetic field induces IM transition for Fe doped samples with x= 0.01. The most interesting fact is that IM transition is not observed even in presesence of 4 T field for Fe concentration , x= 0.05. Fig. 3 shows the variation of magnetoresistance (MR) with temperature of undoped SSMO, Cr and Fe doped samples at two different magnetic fields of 2 T and 4 T. The MR of SSMO shows a peak at IM transition temperature. On contarary, the distinct peak in MR is not found in the Cr doped samples in spite of sharp peak in resistivity data. In case of both Cr doped materials, MR increases monotonically with temperature but decreases below 40 K whereas MR continuously increases with temperature for Fe doped samples. The magnetoresistance is

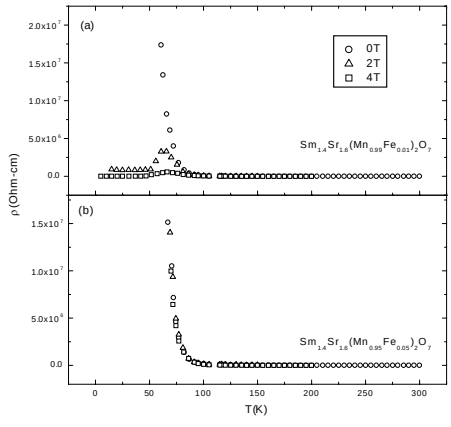

Fig. 2. The temperature dependence of electrical resistivity of $Sm_{1.4}Sr_{1.6}(Mn_{1-x}Fe_x)_2O_7$ for x=0.01 and 0.05

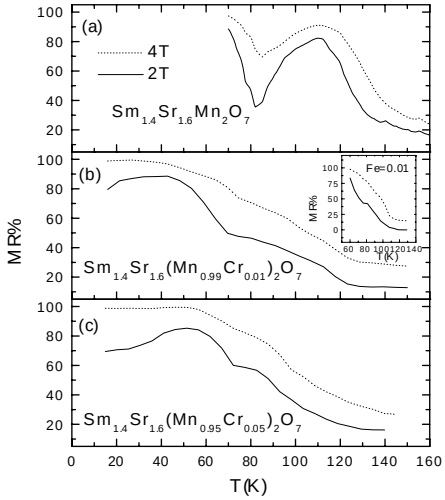

Fig. 3. Temperature variation of magnetoresistance of $Sm_{1.4}Sr_{1.6}(Mn_{1-x}M_x)_2O_7$ for x=0.0,0.01 and 0.05; M = Cr and Fe

defined as MR = (R(0)-R(H))/R(0), where R(0) and R(H) are resistance at zero field and an applied field respectively. The large MR values vary from 80 to 99 % . The magnetisation data exhibits ferromagnetic transition at T_{IM} of SSMO at low temperature. The magnetisation increases with temperature and shows a maximum at about 50 K indicating the formation of antiferromagnetic phase for both Cr and Fe doped materials. The appearance of IM is generally described by the double exchange (DE) interaction. The absence of IM in Fe case suggests that Fe weakens DE. The insulator-metal transitions in the antiferromagnetic phase is also found in other systems [3].

4. Conclusion

The Cr doped samples show insulator-metal transition in the absence of long range ferromagnetic order . The only 1% doping of Fe destroys the IM transition and favors the formation of antiferromagnetic state. Magnetic field induces IM transition observed for low doping level of Fe. The large magnetoresistance may be due to the electron tunneling between layers.

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