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Magnetoresistance Effect in Sol-gel Prepared Double Layered CMR Manganite $Nd_{1.2}Sr_{1.8}Mn_2O_7$

Y. S. Reddy

Department of Physics,
Chaitanya Bharathi Institute of Technology (A), Gandipet, Hyderabad - 500 075 INDIA.
email:ysreddy.ou@gmail.com.

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ABSTRACT

A polycrystalline double layered colossal magnetoresistive manganite $Nd_{1.2}Sr_{1.8}Mn_2O_7$ was prepared by sol-gel method and characterized using powder X-ray diffraction. The sample shows single phase body-centered tetragonal structure. The electrical resistivity measurements, both in absence and presence of applied magnetic field, were undertaken in the temperature range 70 K - 300 K. The sample shows an insulator-to-metal transition temperature (T_{IM}) at 86 K. The analysis of temperature dependent resistivity data above T_{IM} reveals that the conduction follows Mott type of variable range of hopping mechanism. The sample shows MR ≈ 30% at T_{IM} with an applied magnetic field of 3 T.

Keywords: Magnetoresistance, Variable range hopping, Conduction process, Layered perovskite, Manganite.

1. INTRODUCTION

The double layered (DL) perovskite manganites with general formula $R_{2-2x}A_{1+2x}Mn_2O_7$ (R = rare earth ion and A = alkaline earth ion) attract considerable attention because of their unique properties, such as colossal magnetoresistance (CMR), Jahn-Teller effect and metal-insulator (M-I) transition[1]. These materials belong to the n = 2 member of Ruddlesden-Popper (RP) series. The DL manganites consist of two perovskite blocks of MnO_6 octahedra, separated by a single rock-salt (R,A)O layer. The anisotropic two dimensional Mn-O-Mn network gives rise to remarkable changes in electrical properties of the DL manganites.

The studies on $R_{2-2x}A_{1+2x}Mn_2O_7$ show that the properties of the layered perovskites are very sensitive to the size and concentration of R and A site ions. In particular, $La_{2-2x}Sr_{1+2x}Mn_2O_7$ compounds are widely studied because of their simple synthesis process and significant CMR effect[2,3]. However, there are few reports about the electrical and magnetic properties of

DL manganites with other rare earth ions (Pr, Nd, Sm, etc.)[4,5]. In this paper, we report the results obtained with $Nd_{1.2}Sr_{1.8}Mn_2O_7$ with a main focus on its electrical transport and CMR effect in the temperature range 70 K - 300 K.

2. EXPERIMENT

The polycrystalline DL manganite sample $Nd_{1.2}Sr_{1.8}Mn_2O_7$ was synthesized by sol-gel method. The obtained powder was calcined in air at 1100°C for 10 h and then pressed into circular pellets. These pellets were sintered at 1400°C for 6 h in air. The structural characterization was done using powder X-ray diffraction using M/s PANalytical X-ray diffractometer giving Cu-K_α radiation (λ = 1.54056 Å) in 2θ range 20° – 80° with step size 0.01° and a count time of 0.6 s per step. The temperature dependent electrical resistivity measurements from 70 K to 300 K were made using four-probe method in absence and presence of applied magnetic field (H = 1.5 T, 3 T). A superconducting magnet system of OXFORD was used to produce the required magnetic fields.

3. RESULTS AND DISCUSSION

The powder X-ray diffraction results indicate the single phase formation of $Nd_{1.2}Sr_{1.8}Mn_2O_7$ with $Sr_3Ti_2O_7$-type body-centered tetragonal perovskite structure with space group *I*4/*mmm* (Z = 2). The values of lattice parameters (*a* and *c*) and cell volume (V) are *a* = 3.8745 Å, *c* = 19.8768 Å and V = 298.38 Å^3.

The variation of electrical resistivity with temperature, in absence and in presence of applied magnetic field (H = 1.5 T, 3 T), is shown in Fig. 1. It can be seen that the resistivity of the sample increases largely with decreasing temperature and the sample shows insulator-to-metal transition at 86 K (T_{IM})[3].

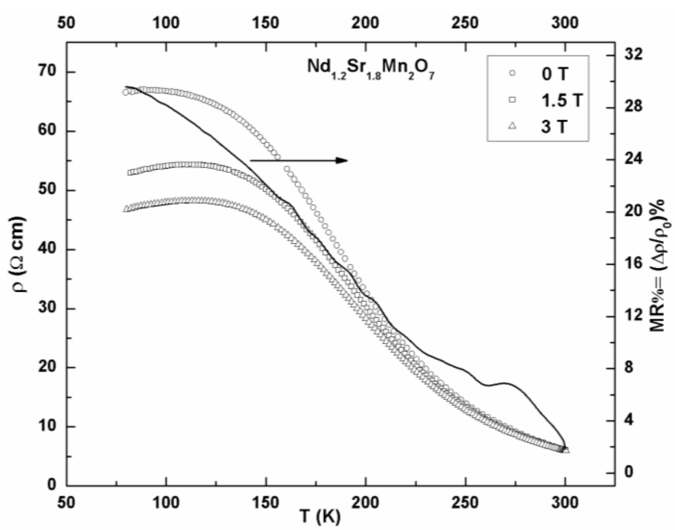

Fig. 1 Variation of electrical resistivity and MR with temperature

The conduction mechanism in semiconducting region in manganites is usually explained by four models: semiconduction (SC) model[6], nearest neighbor small polaron hopping (SPH) model[7], Mott type of variable range hopping (VRH) model[8] and Efros-Shkloskii (ES) type of VRH model[9]. Each model predicts a different temperature dependence of the resistivity and fits the resistivity data in different temperature ranges. Generally, electron hopping is variable range type at low temperatures, where the thermal energy is not great enough to allow electrons to hop to their nearest neighbors. In that case, electrons choose to hop farther to find a smaller potential difference. At high temperatures, conduction may be by activation by mobility edge or narrow band gap. In the intermediate temperature range, nearest neighbor (small polaron) hopping dominates.

In the present study, the ρ-T data above T_{IM} are analyzed by fitting the data to all the equations of the conduction models mentioned above. The ρ-T data are well fitted the Mott VRH model equation $\rho = \rho_\infty \exp(T_0 / T)^{1/4}$ (Fig. 2). Here, ρ_∞ is a pre-factor and T_0 is characteristic temperature whose value is given by $24/\pi L^3 k_B N(E_F)$, where L is localization length of trapped charge carriers (here, $L = 10^{-10}$ m), $N(E_F)$ is density of the localized states at Fermi level. The results indicate that the conduction above T_{IM} in the present sample is mainly contributed by one-electron hopping.

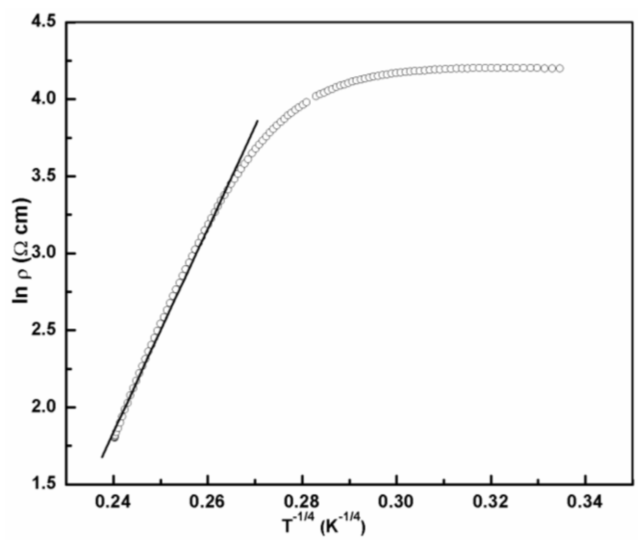

Fig. 2 Plot of *lnρ vs. $T^{-1/4}$* for $Nd_{1.2}Sr_{1.8}Mn_2O_7$

MAGNETORESISTANCE

MR is defined as $MR\% = 100 \times (\rho_0 - \rho_H) / \rho_0$, where ρ_0 and ρ_H represent the resistivity in absence and in presence of applied magnetic field H, respectively. The temperature dependent MR (H = 3 T) plot is shown in Fig. 1.

Usually, cubic perovskite manganites show MR peak at T_{IM} in their MR-T plots. But, the present manganite sample does not show MR peak at its T_{IM} although resistivity peak is observed at T_{IM} and this property is similar to many DL manganite systems[10]. The maximum MR% shown by the sample is ≈ 30% at its T_{IM} and nearly 26-30% MR% is exhibited in the temperature range 80 K - 120 K. This kind of exhibiting large and nearly constant value of MR over a wide temperature range supplies the potential applications for layered perovskite manganites.

4. CONCLUSION

A polycrystalline DL manganite $Nd_{1.2}Sr_{1.8}Mn_2O_7$ was synthesized in single phase by the sol-gel method. The sample has insulator-to-metal transition at 86 K and the conduction mechanism ($T > T_{IM}$) is found to be of Mott type of VRH indicating the dominance of one electron hopping rather than electron-electron interactions in the conduction process. The sample shows reasonably good values of MR over a wide temperature range indicating its suitability for MR based device applications.

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