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Colossal magnetoresistance in layered manganite $Nd_{2-2x}Sr_{1+2x}Mn_2O_7$ ($0 \leq x \leq 0.5$)

K SHAH[1], D K ASWAL[1], AJAY SINGH[1], L C GUPTA[2], S K GUPTA[1]
and V C SAHNI

[1]Technical Physics and Prototype Engineering Division, Bhabha Atomic Research Centre, Mumbai 400 085, India

[2]Tata Institute of Fundamental Research, Homi Bhabha Road, Mumbai 400 005, India

Abstract. The layered manganite $Nd_{2-2x}Sr_{1+2x}Mn_2O_7$, with x varying between 0 and 0.5, has been synthesized using solid-state reaction method. We have found that $Nd_{2-2x}Sr_{1+2x}Mn_2O_7$ do not form the single-phase layered compound with $A_3B_2O_7$ structure. Instead, mixtures of various phases, such as, orthorhombic perovskite, i.e., $Nd_{1-z}Sr_zMnO_3$, layered manganite and unreacted starting compounds, have been obtained. Except for $x=0.4$, which is found to be an antiferromagnetic insulator, all other x values yielded metal–insulator transition and ferromagnetic ordering.

Keywords. Colossal magnetoresistance; layered manganites; $Nd_{2-2x}Sr_{1+2x}Mn_2O_7$.

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1. Introduction

The observation of colossal magnetoresistance (CMR) in layered manganites, which is $n =$ 2 phase of Ruddlesdden–Popper (RP) series, i.e., $A_3B_2O_7$ structure (space group I4/mmm), has attracted considerable interest because of their two-dimensionality [1]. So far, majority of the research work has been centered on $La_{2-2x}Sr_{1+2x}Mn_2O_7$. This material, for $x = 0.3$–0.45, exhibits an insulator–metal transition (T_{IM}) at ~ 130 K, and a ferromagnetic ordering at temperature T_c, which is much higher than T_{IM}. The observation of $T_c \gg T_{IM}$ suggests that the double exchange mechanism alone does not explain the CMR in this material. On the other hand, the analogous compound $Nd_{2-2x}Sr_{1+2x}Mn_2O_7$ has not been studied in detail. Interestingly, this material, for $x = 0.45$, is found to be an antiferromagnetic insulator but exhibited a CMR over a wide range of temperature [2]. However for $x = 0.3$, the material showed IM transition [3] and ferromagnetic ordering. In this paper, we report on the synthesis of $Nd_{2-2x}Sr_{1+2x}Mn_2O_7$ series, with x varying between 0 and 0.5, and study their transport and magnetic properties.

2. Experimental

Polycrystalline $Nd_{2-2x}Sr_{1+2x}Mn_2O_7$ samples were prepared using standard solid-state reaction method. Stoichiometric quantities of Nd_2O_3, MnO_2 and $SrCO_3$ were calcined at

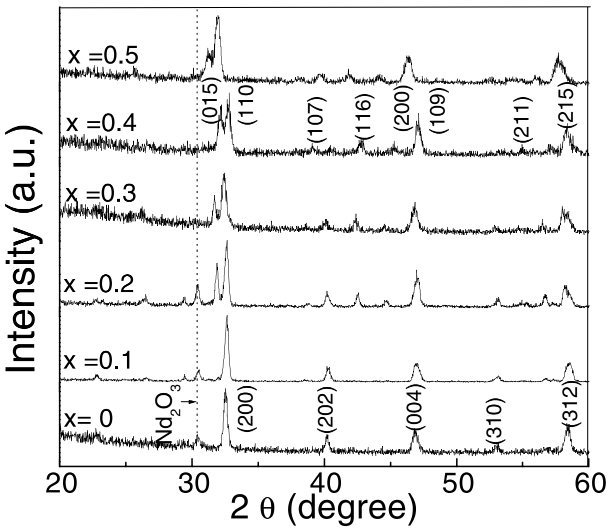

Figure 1. XRD plots recorded for $Nd_{2-2x}Sr_{1+2x}Mn_2O_7$ samples with different x values. The dotted line shows the peak corresponding to impurity phase Nd_2O_3.

1200°C for 48 h. The material was reground, pelletized and sintered at 1250°C for 24 h. This process was repeated twice to obtain the homogeneous material. The phase identification in each case was carried out using X-ray powder diffraction (XRD). The magnetotransport measurements were carried out under an applied magnetic field of 1 T using standard four-probe resistivity technique.

3. Results and discussion

The XRD patterns recorded for $Nd_{2-2x}Sr_{1+2x}Mn_2O_7$, with different x values, are shown in figure 1. It is seen that single-phase material with $A_3B_2O_7$ structure has not been formed for any of the x values. The lattice parameters for the major phase formed in each case were determined using the least square fitting and, the results are shown in table 1. For $x = 0$ and 0.1, the major phase formed is orthorhombic perovskite $Nd_{1-z}Sr_zMnO_3$. The layered $Nd_{2-2x}Sr_{1+2x}Mn_2O_7$ phase with orthorhombic structure, as a major phase, is formed for x values between 0.2 and 0.4. The orthorhombicity $\{(a-b)/(a+b)\}$ is found to be minimum for $x = 0.4$. However, for $x = 0.5$ again $Nd_{1-z}Sr_zMnO_3$ phase is seen to be the major phase.

The temperature dependence of normalized resistance in zero and 1 T magnetic field is shown in figure 2a. It is seen that except for $x = 0.4$, all the samples exhibit an insulator-to-metal transition and a negative magnetoresistance. The T_{IM} is found to decrease with x. For $x = 0$ and 0.1, the highest MR was obtained in the vicinity of T_{IM}, while for other compositions a monotonous increase in MR with decreasing temperature was observed. The temperature dependence of magnetization for $Nd_{2-2x}Sr_{1+2x}Mn_2O_7$ samples is shown in figure 2b. Except for $x = 0.4$, which has an antiferromagnetic behavior, all other samples exhibit paramagnetic to ferromagnetic transition. The T_c was found to be $\sim$ 275 K, which

Table 1. Lattice parameters of the major phase formed during synthesis of $Nd_{2-2x}Sr_{1+2x}Mn_2O_7$.

x	Major phase	a (Å)	b (Å)	c (Å)
0	$Nd_{1-z}Sr_zMnO_3$	5.434	5.801	7.698
0.1	$Nd_{1-z}Sr_zMnO_3$	5.45	5.812	7.697
0.2	$Nd_{2-2x}Sr_{1+2x}Mn_2O_7$	3.844	3.932	20.137
0.3	$Nd_{2-2x}Sr_{1+2x}Mn_2O_7$	3.844	3.91	20.137
0.4	$Nd_{2-2x}Sr_{1+2x}Mn_2O_7$	3.847	3.904	20.029
0.5	$Nd_{1-z}Sr_zMnO_3$	5.466	5.697	7.829

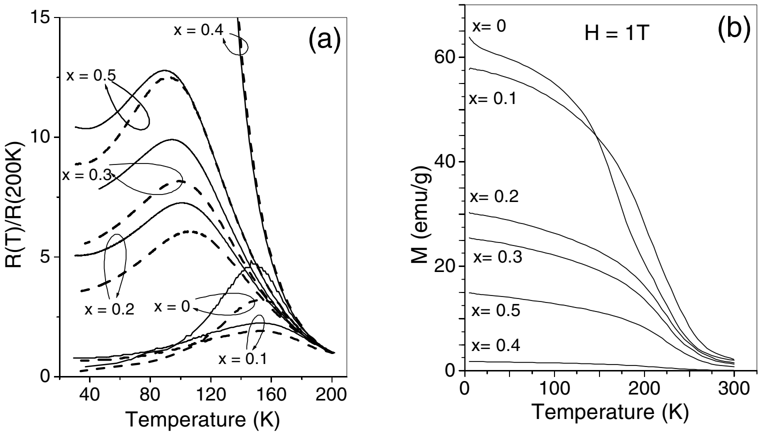

Figure 2. Temperature dependence of (**a**) normalized resistance (solid lines in zero field and dotted lines in 1 T magnetic field) and (**b**) magnetization for $Nd_{2-2x}Sr_{1+2x}Mn_2O_7$ samples with different x values.

is much higher than T_{IM}. As mentioned in the introduction, $T_c \gg T_{IM}$, which has also been observed for $La_{2-2x}Sr_{1+2x}Mn_2O_7$, and several explanations for this have been proposed and are a subject of debate at present. The proposed explanations basically fall into two categories. In the first category, the observation of $T_c \gg T_{IM}$ has been attributed to the intrinsic character of this layered material. According to this explanation, the MnO_2 layers act like 2D ferromagnets at temperatures between T_{IM} and T_c and 3D ordering takes place around T_{IM} [4]. The second category of explanations suggests that the higher T_c is due to extrinsic phases [5]. Our results indicate that the difference in T_c and T_{IM} arises from the second mechanism. However, more experiments are needed to resolve the issue.

4. Conclusion

The layered manganite $Nd_{2-2x}Sr_{1+2x}Mn_2O_7$ ($x = 0.0$–0.5) has been synthesized and characterized for transport and magnetic properties. It has been found that this material does not form a single phase with layered $A_3B_2O_7$ structure. For $x = 0.4$, the material is antiferromagnetic insulator and does not show CMR properties. For all other x values, the CMR properties arise due to the presence of extrinsic phases.

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