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Magnetoresistance properties in polycrystalline $Gd_{0.7}Ca_{0.3}MnO_3$

Sanjay Biswas, Sudipta Pal

Abstract—The magnetoresistance properties in polycrystalline $Gd_{0.7}Ca_{0.3}MnO_3$ have been investigated. The compound crystallizes in orthorhombic structure with *Pnma* space group. In this work, we have tried to find out the characteristics of temperature dependent resistivity and magnetoresistance properties. The temperature dependent electrical resistivity (ρ) satisfies the Arrhenius like relation $\rho/T = \rho_\alpha \exp(E_p / K_B T)$ with activation energy (E_p) =156.4 meV. The field dependent resistance at various temperatures shows the hysteresis nature and the hysteresis also increases with temperature. The magneto-resistance (MR) shows a linear dependence with the square of the applied magnetic field. At temperatures 250K, 200K, 150K and 125K the maximum value of magnetoresistance reaches respectively -1.24%, -2.96%, -8.65%, -18.5%

Index Terms— Manganites, Perovskite, Electrical resistivity, Magneto-resistance

1 Introduction

The discovery of colossal magneto-resistance (CMR) effect in perovskite manganese oxides with the general form $R_{1-x}A_xMnO_3$, (where R is a trivalent rare earth ion such as Gd, La, etc., and A is a divalent alkaline earth ion such as Ca, Sr) generated much attention on their electrical and magnetic properties as well as their potential technological applications [1–4]. The CMR effects in these types of hole doped compounds can be explained by the double-exchange (DE) model. Polaron formation is a necessary ingredient for modelling a temperature-dependent magnetic and transport behaviour of CMR materials [5]. Doping of Ca^{2+} (1.12Å) in $GdMnO_3$, in place of Gd^{3+} (0.938Å) leads to lattice distortion and due to the replacement of Mn^{3+} (0.65Å) by Mn^{4+} (0.53Å) [6] causes polaron formation [5]. We have tried to find out the characteristics of temperature dependent resistivity and MR properties of the $Gd_{0.7}Ca_{0.3}MnO_3$ on the basis of polaron hopping conduction.

2 Experimental

High quality polycrystalline sample $Gd_{0.7}Ca_{0.3}MnO_3$ was prepared in air via solid-state reaction method. The precursors Gd_2O_3, CaO, MnO_2 were mixed in proper stoichiometric ratio and initially heated at 800°C for 24 h. This preheated powder was pelletized and fired in air at 1500° C for 18 h with intermediate grindings to obtain single phase. The temperature dependent resistivity and magnetic field dependent resistance at various temperatures were measured by the standard four probe method using PPMS.

3 Results and Discussion

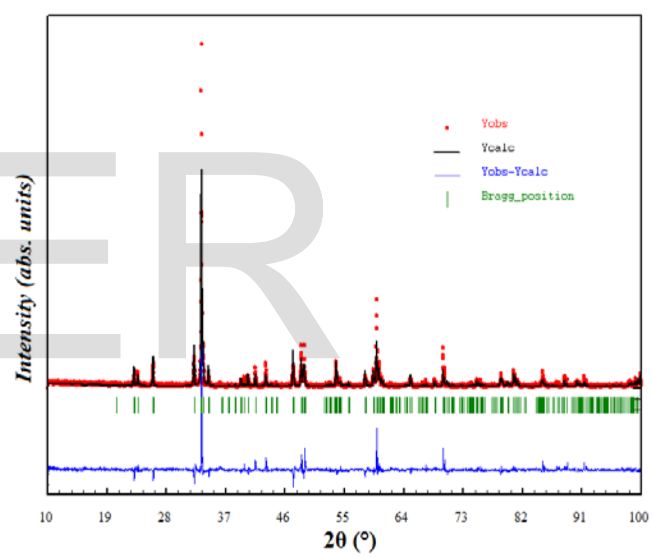

Fig. 1. X-Ray Diffraction pattern of $Gd_{0.7}Ca_{0.3}MnO_3$

Fig. 1. shows the room temperature powder x-ray diffraction pattern of $Gd_{0.7}Ca_{0.3}MnO_3$. The Rietveld refinement (using the Full Prof program) [7] of XRD pattern confirmed the formation of a single phase compound which crystallizes in an orthorhombic perovskites structure under the space group *Pnma.*

The temperature dependent resistivity curve of the sample $Gd_{0.7}Ca_{0.3}MnO_3$ is shown in fig. 2. In the paramagnetic state, the small polaron hopping conduction mechanism in the adiabatic limit has been reported by several authors [1-3]. The electrical resistivity due to polaron hopping conduction satisfies the Arrhenius like relation

$$\rho / T = \rho_\alpha \exp(E_p / K_B T) \quad (1)$$

Where the pre-exponential factor ρ_α is the residual electri-

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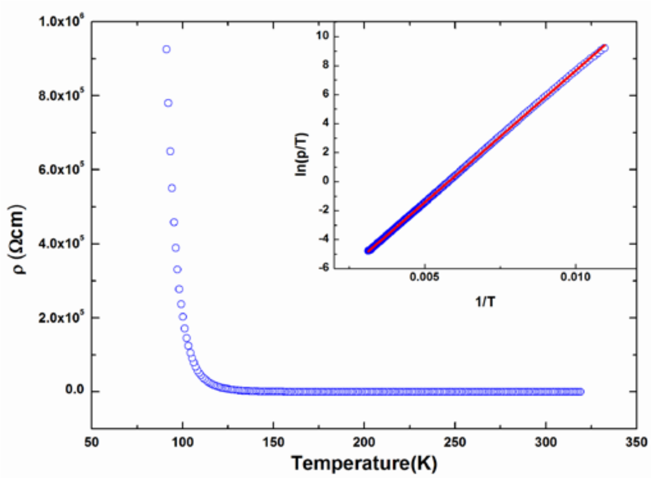


cal resistivity, E_p is the total activation energy of a polaron,

Fig. 2. Temperature dependent resistivity curve. Inset shows plot of lnρ versus *1/T* and red solid line represents the fitting line using Eq.1

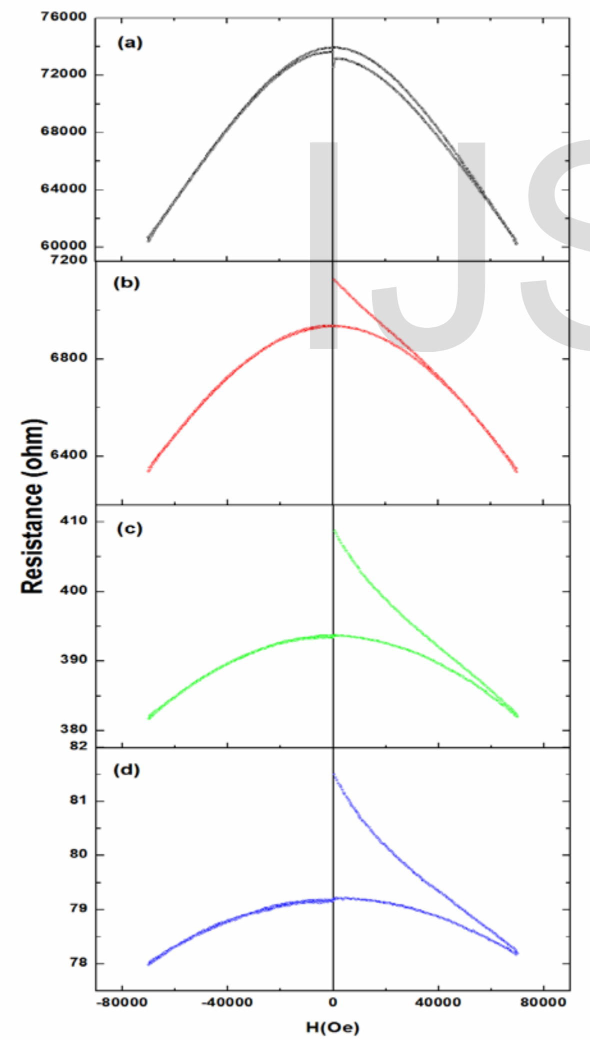


Fig. 3 . Field dependent resistance (a) at 125K, (b) at 150K, (c) at 200K, (d) at 250K

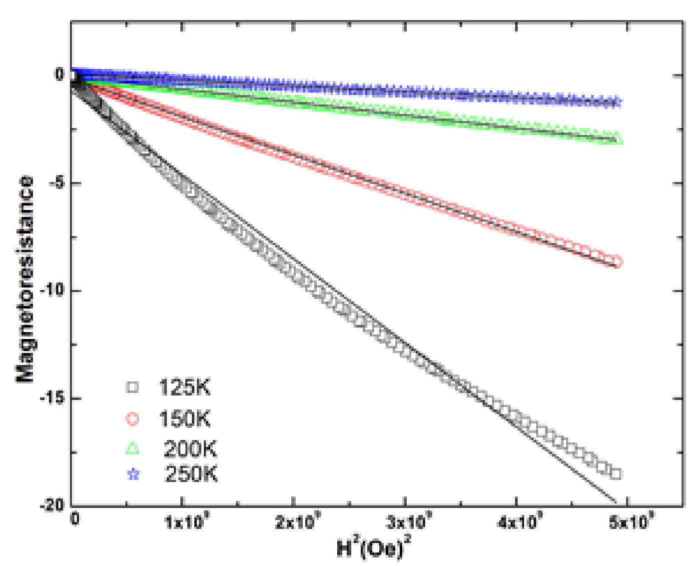
K_B is Boltzman constant. The experimental resistivity data was found to be well fitted with Eq.1 as shown in the inset of the fig. 2. Using the equation (1), we get the value of the activation energy (E_p) =156.4 meV. The value of activation energy investigated in various compounds like $Pr_{2/3}(Ba_{1-x}Cs_x)_{1/3}MnO_3$ [8], $La_{2/3}Ba_{1/3}Mn_{1-x}Sb_xO_3$ [9] and $La_{0.67}Sr_{0.33}MnO_3$ [2] are comparable as we get in the $Gd_{0.7}Ca_{0.3}MnO_3$.

In fig. 3, we have shown the field dependence resistance at various temperatures. The measurement has been done in a sweeping magnetic field (0→70000→ -70000→0 Oe) [10]. An applied magnetic field suppresses the spin disorder of the manganese ion, aligning the manganese ion parallel to the field. This results in increased mobility of the electrons, which in turn results in the drop of electrical resistance. It is to be noted that with the increase of magnetic field resistivity decreases but does not follow the previous path with decrease of magnetic field.

Fig. 4 shows the nature of magneto-resistance (MR) with H^2 at different temperatures and the nature of the curves are well fitted with the linear equation, in which the field dependent magneto-resistance is defined as [3]

$$MR(H) = [(\rho_H - \rho_0 / \rho_0) \times 100\% \qquad (2)$$

Where ρ_H and ρ_0 are resistivity at the applied field of H and 0 respectively. As shown in fig. 4, MR of the sample increases as the external magnetic field increases but decreases with the temperature. At temperatures 250K, 200K, 150K and



125K the maximum value of MR reaches respectively -1.24%, -2.96%, -8.65% and -18.5%. The H^2 dependence of the isothermal magnetoresistance may be attributed to spin dependent nature.

Fig. 4 . Plot of magnetoresistance versus square of applied magnetic field. Solid lines represents linear fitting.

4 Conclusion

. Polycrystalline $Gd_{0.7}Ca_{0.3}MnO_3$ has been investigated through magnetotransport properties. The electrical resistivity due to polaron hopping conduction satisfies the Arrhenius like relation. The field dependent resistance also indicates spin disorder of ions presence in the compound. So, it shows the hysteresis nature. Small magnetoresistance was found in this compound. Isothermal magnetoresistance show H^2 dependence indicating spin dependent nature.

Acknowledgment

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