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Temperature hysteretic effect and its influence on colossal magnetoresistance of $La_{0.33}Nd_{0.33}Ca_{0.33}MnO_3$

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Abstract. Electrical resistance (R) measurements of a bulk $La_{0.33}Nd_{0.33}Ca_{0.33}MnO_3$ perovskite in magnetic fields up to 40 kOe have revealed anomalous temperature hysteretic effects both in 0 Oe and 20 kOe magnetic fields. The sharp peak observed in the R vs. T plot indicates the occurrence of metal-to-insulator (M–I) transition at a temperature of $T_{MI} = 110$ K and 140 K, for cooling and warming paths, respectively. An applied magnetic field of 20 kOe reduces the resistance and shifts T_{MI} to 160 K and 185 K for cooling and warming, respectively. We have observed a much higher resistance in the cooling path than in the warming path leading to the hysteretic resistance ratio (R_{cool}/R_{warm}) of 200 at 110 K and 1.8 at 160 K for 0 Oe and 20 kOe, respectively. Record values of colossal magnetoresistance (CMR) have been achieved. The CMR value reaches nearly 99% in the temperature ranges of 90 K to 140 K and 90 K to 170 K for 20 kOe and 40 kOe magnetic fields in the cooling mode, respectively. The observed unusual behavior is attributed to the co-existence of La-rich and Nd-rich domains assumed to be distributed randomly in the compound.

Keywords. Colossal magnetoresistance; temperature hysteretic effect; domains.

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1. Introduction

The giant and the colossal magnetoresistance (GMR and CMR, respectively) effects observed in bulk $La_{0.33}Nd_{0.33}Ca_{0.33}MnO_3$ by a number of investigators [1–3] have attracted considerable attention because of the fundamental physics involved and the potential technological applications [4]. A bulk sample of $La_{0.33}Nd_{0.33}Ca_{0.33}MnO_3$ (LNCMO) gives a very prominent negative CMR, larger than $\sim 90\%$ at a particular temperature $T = 90$ K [3]. This bulk sample also shows temperature hysteretic effects in resistivity [2,3]. No attempts has been made to study the effects of higher magnetic fields on the CMR and temperature hysteretic effects in bulk LNCMO. The motivation for this investigation is to study the effect of higher magnetic fields up to 40 kOe on bulk $La_{0.33}Nd_{0.33}Ca_{0.33}MnO_3$ sample in enhancing CMR effect up to 99% in the wide temperature range of 90 K to 170 K and suppression of the temperature hysteretic effects.

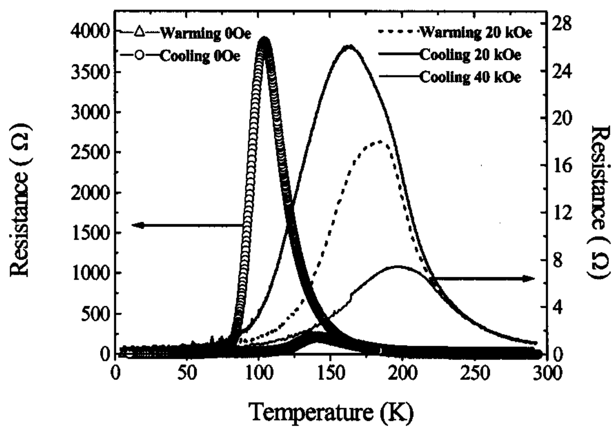

Figure 1. Temperature dependence of resistance for $La_{0.33}Nd_{0.33}Ca_{0.33}MnO_3$ taken in cooling and warming runs with applied magnetic fields of 0 Oe, 20 kOe and 40 kOe.

2. Experimental

The sample with nominal composition of $La_{0.33}Nd_{0.33}Ca_{0.33}MnO_3$ has been prepared by the standard solid state reaction route using stoichiometric quantities of La_2O_3, Nd_2O_3, $CaCO_3$ and MnO_2 (all 99.9% pure). The powders were ground, then fired at 1173 K for 24 h. The powders, thus obtained, were again ground, pelletized and sintered at 1373 K and 1473 K for 48 h in air with intermediate grindings and finally, the furnace cooled down to room temperature. The phase purity and crystal structure of the synthesized sample was examined by X-ray diffraction (XRD) using CuKα radiation. The resistance of the bulk LNCMO sample was measured in the temperature range of 10 K to 300 K using a computer controlled four-point probe system with a maximum applied magnetic field of $H = 40$ kOe.

3. Results and discussion

The XRD analysis revealed the single phase perovskite structure with space group $Pbnm$ with unit cell parameters $a = 5.428$ Å, $b = 5.442$ Å and $c = 7.683$ Å for LNCMO sample. This compares very well with the reported data [1,2]. The temperature dependence of resistance for LNCMO taken in cooling and warming runs with applied magnetic fields of 0 Oe, 20 kOe and 40 kOe is shown in figure 1 and it displays temperature hysteretic effects at $H = 0$ Oe and 20 kOe. The sharp peak observed in R vs. T plot (figure 1) at 0 Oe indicates the occurrence of metal-to-insulator (M–I) transition at $T_{MI} = 110$ K and 140 K for the cooling and the warming paths, respectively. An applied magnetic field of 20 kOe reduces the resistance and shifts T_{MI} to 160 K and 185 K for cooling and warming, respectively. At $H = 40$ kOe, the resistance decreases and T_{MI} shifts to 205 K in cooling mode.

We have observed a much higher resistance in the cooling paths than in the warming paths leading to the hysteretic resistance ratio R_{cool}/R_{warm}. Figure 2 shows the variation of

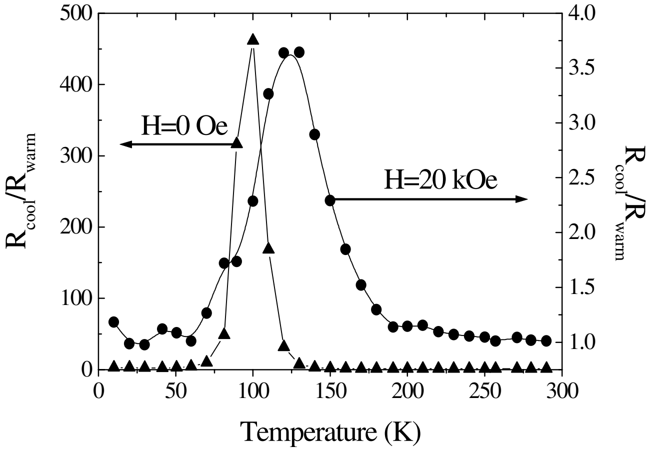

Figure 2. Temperature hysteretic ratio $R_{\mathrm{cool}}/R_{\mathrm{warm}}$ vs. temperature for $La_{0.33}Nd_{0.33}Ca_{0.33}MnO_3$ at $H = 0$ Oe and 20 kOe.

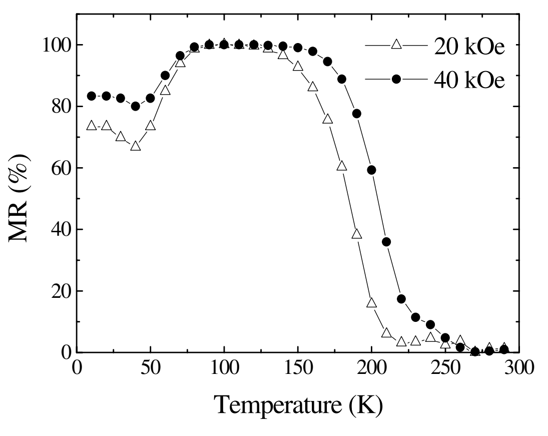

Figure 3. Temperature dependence of magnetoresistance for $La_{0.33}Nd_{0.33}Ca_{0.33}MnO_3$ at $H = 20$ kOe and 40 kOe

$R_{\mathrm{cool}}/R_{\mathrm{warm}}$ as a function of temperature for 0 Oe and 20 kOe. The ratio at $T_{\mathrm{MI}} = 110$ K for 0 Oe and $T_{\mathrm{MI}} = 160$ K for 20 kOe are 200 and 1.8, respectively. This shows suppression of temperature hysteretic effect with increasing applied magnetic field. The temperature dependence of magnetoresistance ($\mathrm{MR} = \Delta R/R_0$) calculated from figure 1, using only the cooling mode of R vs. T plot, is displayed in figure 3 for $H = 20$ kOe and 40 kOe. It is evident from figure 3 that the CMR value reaches nearly 99% in the temperature ranges of 90 K to 140 K and 90 K to 170 K for 20 kOe and 40 kOe, respectively.

It is a natural assumption that different local structures resembling those in $La_{0.67}Ca_{0.33}MnO_3$ and $Nd_{0.67}Ca_{0.33}MnO_3$ can be formed in $La_{0.33}Nd_{0.33}Ca_{0.33}MnO_3$, respectively, around La and Nd ions. The temperature hysteretic effects could originate from different local distortions of the lattice around La^{3+} and Nd^{3+} ions, since in the crystal structure of $La_{0.33}Nd_{0.33}Ca_{0.33}MnO_3$ compound, Nd^{3+} ions are in tension, while La^{3+} ions are in compression. Taking into account that the La-rich and Nd-rich compounds are ferromagnetic and nonferromagnetic, respectively, the inhomogeneous local distortion might give La-rich ferromagnetic domains and insulating Nd-rich domains.

Acknowledgements

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