Colossal magnetoresistance in the double perovskite oxide La 2 CoMnO 6

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Colossal magnetoresistance in the double perovskite oxide La_2CoMnO_6

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Polycrystalline sample of La_2CoMnO_6 has been synthesized by sol-gel technique. The powder x-ray diffraction data confirm the single phase nature of the sample. This compound has monoclinic crystal structure (space group $P2_1/n$) at room temperature. The temperature dependence of magnetization in low field shows considerable variation between zero-field-cooled and field-cooled magnetization curve below ~210 K (T_C) and it follows Curie–Weiss law in the paramagnetic region. The hysteresis loop at 5 K indicates a coercive field of ~6 kOe and remnant magnetization of ~2.32 μ_B/f.u. The temperature dependence of the resistivity data shows semiconductorlike behavior in the temperature range of 5–350 K and follows variable range hopping conduction mechanism in the temperature range 215–350 K. A colossal magnetoresistance of ~80% is observed at 5 K in an applied field of 80 kOe and MR has a negative sign. © *2010 American Institute of Physics*. [doi:10.1063/1.3350907]

I. INTRODUCTION

Double perovskites have gained immense interest in particular after the observation of the ferromagnetic metallic behavior in Sr_2FeMoO_6[1] and Sr_2FeReO_6.[2] The variation in structural, transport, and magnetic properties by changing the A, B′, and B″-site cations in A_2 B′ B″O6 type double perovskites has also received attention in order to understand the mechanism of transport properties and colossal magnetoresistance (CMR).[3–7] Dass and Goodenough[8] reported the existence of diverse phases in the double perovskite La_2NiMnO_6 and La_2CoMnO_6 compounds and explained the magnetic and structural properties. But it is noteworthy to study the magnetoresistance (MR) of these compounds prepared by chemical route. Here we report magnetic and CMR properties of a double perovskite oxide La_2CoMnO_6.

II. EXPERIMENTAL DETAILS

Polycrystalline double perovskite La_2CoMnO_6 was prepared using sol-gel technique. The synthesis details are presented elsewhere.[9] The sample was sintered at 1200 °C for 12 h. The phase purity and crystal structure of the sample were studied by powder x-ray diffraction at room temperature using Cu K_α radiation. The surface morphology and composition analysis of the sample were carried out by scanning electron microscopy (SEM) attached with the energy dispersive x-ray analysis (EDAX) (FEI, Quanta-200). Direct current magnetization measurements in the range 5–350 K in magnetic fields up to 50 kOe were performed using a vibrating sample magnetometer—physical properties measurements system (PPMS) (Quantum Design). The temperature dependence of resistivity was studied by conventional four probe method using PPMS.

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III. RESULTS AND DISCUSSION

The powder XRD data of La_2CoMnO_6 confirms that the sample has monoclinic crystal structure with space group $P2_1/n$ at room temperature, as reported earlier.[8] The phase composition is confirmed by SEM and EDAX analysis.

The temperature dependence of zero-field-cooled (ZFC) and field-cooled (FC) magnetization is measured from 5 to 300 K in 100 Oe magnetic field and is shown in Fig. 1. Below 210 K, divergence has been observed between ZFC and FC magnetization curves. Similar difference in low field ZFC and FC magnetization data has been reported for La_2MnCoO_6.[10] The FC magnetization reaches a maximum value of ~1.7 μ_B/f.u. at 5 K. Paramagnetic susceptibility in the temperature range of 225–300 K is fitted to Curie–Weiss law (inset in Fig. 1). The paramagnetic Curie temperature of ~208 K and the effective paramagnetic moment of ~3.82 μ_B per formula unit, which is less than the theoreti-

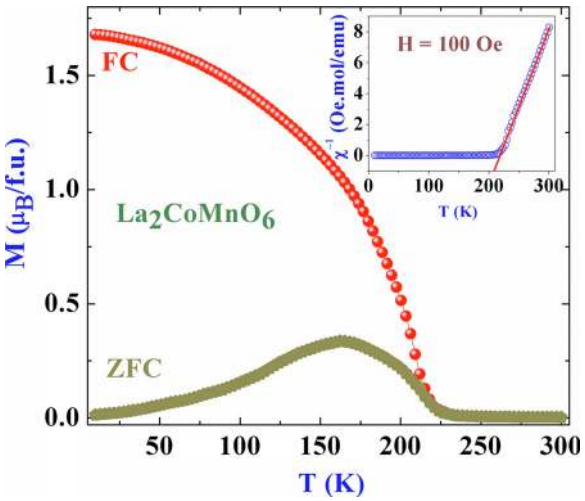

FIG. 1. (Color online) Temperature dependence of zero-field-cooled and field-cooled magnetization of La_2MnCoO_6 in an applied field of 100 Oe. Inset shows the Curie–Weiss fit to paramagnetic susceptibility.

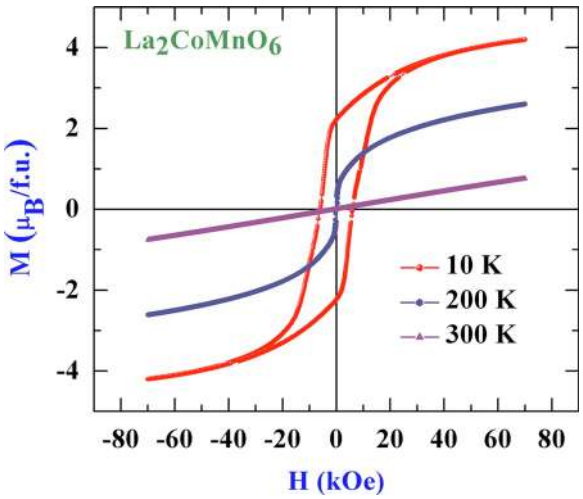

FIG. 2. (Color online) Magnetization vs field data of La_2MnCoO_6 at different temperatures.

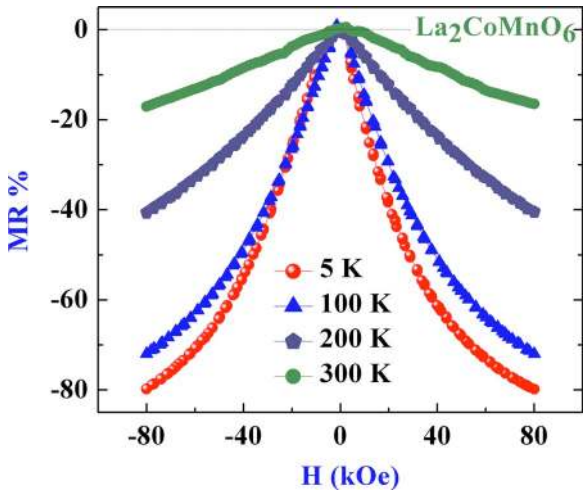

FIG. 4. (Color online) Field dependence of MR of La_2MnCoO_6 at different temperatures.

cally obtained spin only moment (5.89 μ_B), have been obtained. Figure 2 shows the magnetization versus field (M-H) curves at different temperatures. Hysteresis loop has been observed at 10 K with a coercive field of ~6 kOe and remnant magnetization of ~2.3 μ_B/f.u. At temperatures higher than T_C ($T > 210$ K), the M-H behavior is linear, corresponding to a paramagnetic state.

The temperature dependence of resistivity (ρ) is measured in zero field and applied magnetic field of 50 kOe and is shown in Fig. 3. The resistivity of the sample increases with decreasing temperature and it shows semiconductorlike behavior in the temperature range of 5–350 K. The resistivity in the temperature range 200–5 K could be interpreted on the basis of the nearest-neighbor hopping[11] of polarons model, according to which resistivity is expressed as $\rho/T = \rho_0 \exp(E_P/\kappa_B T)$, where E_P (activation energy of polarons) ~110 meV. The temperature above 200 K fits well with variable range hopping (VRH) model,[12] i.e., $\ln \rho$ versus $1/T^{1/4}$ (see inset of Fig. 3). So the VRH conduction mechanism dominates in the temperature range from 200 to 350 K and according to it the resistivity can be written as

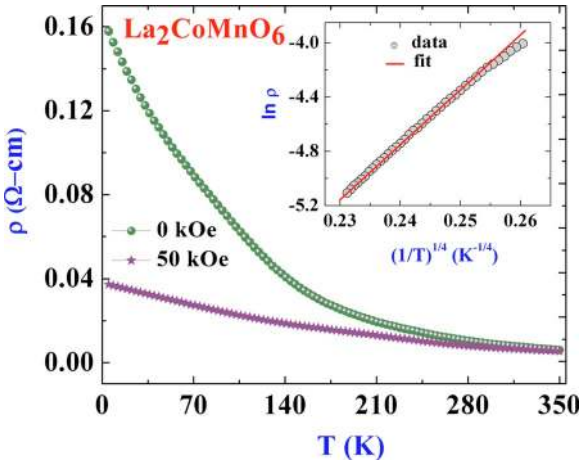

FIG. 3. (Color online) Temperature variation in electrical resistivity ρ of La_2MnCoO_6. Inset shows the fit to VRH model.

$$\rho = \rho_0 \exp\left(\frac{T_0}{T}\right)^{1/4}, \quad (1)$$

where ρ_0 is the prefactor and T_0 is the characteristic temperature. The characteristic temperature T_0 is related to the localization length $1/\alpha$ of the electrons by $T_0 = 24\alpha^3/\pi g_{(E_F)} \kappa_B$, where $g_{(E_F)}$ denotes the density of states at the Fermi level. Assuming the localization length $1/\alpha \sim 10^{-10}$ m, the density of states $g_{(E_F)}$ is estimated to be $\sim 10^{18}$/eV cm^3. The order of $g_{(E_F)}$ obtained is in the range that of oxide semiconductors[13] [$g_{(E_F)} \approx 10^{17}$ to 10^{19}/eV cm^3]. The field dependence of MR is plotted for various temperatures (Fig. 4). The MR ratio has been computed using the relation

$$\mathrm{MR}\% = \frac{\rho(H) - \rho(0)}{\rho(0)} \times 100, \quad (2)$$

where $\rho(0)$ is the resistivity at zero applied magnetic field and $\rho(H)$ is the applied field resistivity. Figure 4 shows that the MR value decreases as the temperature increases and at 300 K maximum value of MR is found to be ~17% for an applied field of 80 kOe. A CMR of ~80% is observed at 5 K in an applied field of 80 kOe and MR has negative sign. With such a large value of MR, this material could be the promising candidate for low temperature magnetoresistive spintronic devices.[14]

IV. CONCLUSION

The double perovskite La_2MnCoO_6 sample synthesized by sol-gel method, has monoclinic crystal structure at room temperature. This sample undergoes paramagnetic to ferromagnetic transition ~210 K. It has semiconductorlike resistivity behavior in the temperature range 5–350 K. Resistivity variation above 200 K is explained by VRH model. A CMR of ~80% is observed at 5 K in an applied field of 80 kOe.

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