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Magnetoresistance Effect in the $\text{La}_{1-x}\text{Sr}_x\text{MnO}_3$ Ceramics

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Abstract. In this paper, we present the experimental investigation on the MR effect with particular emphasis on the ceramic processing of the $\text{La}_{1-x}\text{Sr}_x\text{MnO}_3$ system. The MR ratio is defined here as $\Delta \rho / \rho(H) = (\rho(H) - \rho(0)) / \rho(H)$ where $\rho(0)$ is the zero field resistivity and $\rho(H)$ the resistivity in the applied magnetic field, e.g., $H = 1000 \text{ kA/m}$. The MR ratio is dependent on the chemical composition and firing conditions. At room temperature, the higher $\Delta \rho / \rho(H)$ value of $\sim 12\%$ has been obtained for the $\text{La}_{0.8}\text{Sr}_{0.2}\text{MnO}_3$ ceramics fired at 1673K. This value is comparable to higher values for the so-called "giant-magnetoresistance(GMR)"-type materials of metallic multilayer. The order of magnitude change in electrical resistivity could be useful for various magnetic and electric device applications.

1. INTRODUCTION

The ferromagnetic state in the $\text{La}_{1-x}\text{Sr}_x\text{MnO}_3$ system has been known as a prototypical example for the double-exchange interaction.¹⁾ The Mn^{3+} ion in normally hole-undoped LaMnO_3 has the electrons on the Mn site, $t_{2g}^3 e_g^1$. Among the four 3d electrons on the Mn site, t_{2g}^3 electrons may be viewed as a local spin ($S=3/2$) because of the relatively poor hybridization with O2p states, while the strongly hybridized e_g^1 state is either itinerant or localized. Therefore deviation of e_g electron, or the so-called hole doping governs the electronic properties including temperature and field-dependent metal-nonmetal phenomena. In 1969 the first magnetoresistance(MR) measurements were reported on a flux-grown single crystal of $\text{La}_{1-x}\text{Sr}_x\text{MnO}_3$ ($x=0.31$).²⁾ Recently, La-manganite thin films have been prepared and MR behavior has been reported for La-Ba-Mn-O³⁾ and La-Ca-Mn-O⁴⁾. In this article, we report the electrical, magnetic, and magnetoresistance behaviour in La-Sr-Mn-O ceramics focussed for the ceramic processing.

2. Experimental

Ceramic samples were prepared by the conventional method. Raw materials La_2O_3 , SrCO_3 and MnO_2 were mixed and calcined at 1273K for 24h in air. After pulverization, the calcined powder was supplemented with polyvinyl alcohol binder. The powder was granulated and cold pressed into disks under a pressure of 1Ton/cm². These disks were sintered

at 1473~1773K for 3h in air. Some samples were quenched from 1573K and annealed at 1273K for 40h in air. Densities were measured by Archimedes method. The final products were examined by X-ray diffraction using $\text{CuK}\alpha$ radiation. The magnetic field dependence of the resistivity of samples was measured for the determination of MR ratio.

3. Results and discussion

The densities of samples were increasing with the increase of sintering temperature and over 95% of relative density at 1673K. X-ray diffraction patterns show that only single perovskite phase exists for the range of $0.4 \geq x \geq 0$ in the $(\text{La}_{1-x}\text{Sr}_x)\text{MnO}_3$ system. As the ionic radius of Sr^{2+} is smaller than that of La^{3+} , the resultant lattice parameter of the essentially cubic La-Sr-Mn-O perovskite material decreases monotonically with the amount of Sr substitution reaching 3.877Å for $\text{Sr}_{0.2}$ smaller than $a \sim 3.895\text{\AA}$ for the LaMnO_3 material. Figures 1 and 2 show the MR ratio vs magnetic field for furnace cooled and quenched samples, respectively. It is found from these figures that the higher MR ratio is obtained at around $x=0.2$. The reason for the improvement of MR ratio in the $\text{La}_{1-x}\text{Sr}_x\text{MnO}_3$ system is not clearly understood but one of the possible explanations is that the modification of MR behavior is due to a lattice parameter decrease which is induced by the partial substitution of La^{3+} (ionic radius $\sim 1.15\text{\AA}$) with smaller Sr^{2+} (ionic radius $\sim 1.13\text{\AA}$)⁵.

In conclusion, the highest $\Delta\rho/\rho(H)$ value of $\sim 12\%$ has been obtained for the $(\text{La}_{0.8}\text{Sr}_{0.2})\text{MnO}_3$ ceramics at room temperature. The order of magnitude of change in electrical resistivity could be useful for various magnetic device applications.

4. References

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Fig.1 MR curves for furnace-cooled samples.

Fig.2 MR curves for quenched samples.