Giant Magnetoimpedance and Local Inhomogeneity in Manganite La$_{0.65}$Ba$_{0.35}$MnO$_3$

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The magnetoimpedance and local inhomogeneity of the manganite La$_{0.65}$Ba$_{0.35}$MnO$_3$ were investigated in the temperature range from 98 to 289 K. A metal – insulator transition peak occurs in the temperature dependence of impedance for the manganite La$_{0.65}$Ba$_{0.35}$MnO$_3$. Under application of a dc magnetic field, the metal – insulator transition temperature $T_{MI}$ derived from the ac transport shifts to a higher temperature. The local inhomogeneity within the sample can be revealed through the application of ac currents with different frequencies. The ac frequency dependence of impedance for the manganite La$_{0.65}$Ba$_{0.35}$MnO$_3$ is found to vary with temperature. The peak value of the magnetoimpedance $\Delta Z/Z_0$ can reach $\sim$ 26.3% at 100 kHz under a field $H = 3.98 \times 10^5$ A/m. The impedance of the manganites can be influenced by magnetic fields through permeability and resistivity.

(Rceived July 7, 2003; Accepted September 4, 2003)

Keywords: magnetoimpedance, inhomogeneity, magnetoresistance, manganite, metal – insulator transition, ac transport

1. Introduction

There has been great interest in perovskite manganites due to the dc colossal magnetoresistance (CMR) effect. The basis for the theoretical explanation of the CMR is usually a notion of the double exchange interaction, which considers the exchange of electrons between neighboring Mn$^{3+}$ and Mn$^{4+}$ with strong Hund’s coupling. However recent calculation showed that in addition to the double exchange, the electron – phonon coupling with the Jahn – Teller distortion also plays an important role in the CMR effect. In the doping range $0.2 < x < 0.5$, manganites La$_{1-x}$A$_x$MnO$_3$ (A=Ca, Ba and Sr) undergo a paramagnetic insulator to ferromagnetic metal transition upon cooling, leading a sharp resistance peak. Application of an external magnetic field of few teslas at/near the metal – insulator transition temperature $T_{MI}$ suppresses the resistance greatly. Recently, the giant magnetoimpedance (GMI) effect was observed in manganites La$_{1-x}$A$_x$MnO$_3$ (A=Ca, Ba and Sr), which reveals a novel aspect of interplay between magnetism and electronic transport. Besides, recent studies on the CMR suggested that the ground states of manganite models tend to be intrinsically inhomogeneous due to the presence of strong tendencies toward phase separation, involving ferromagnetic metallic and antiferromagnetic charge and orbital ordered insulating domains. It has been found that the local inhomogeneity resulting from mixed-separated state in La$_{1-x}$Ca$_x$MnO$_3$ ($x \approx 0.3 \sim 0.33$) manganites. Meanwhile, the grain boundary with magneto-electronic properties different from the inside-grain, being another kind of inhomogeneities, also plays an important role in the magneto-transport of manganites. In the present work, the magnetoimpedance and local inhomogeneity effects for the manganite La$_{0.65}$Ba$_{0.35}$MnO$_3$ were investigated in the temperature range from 98 to 289 K.

2. Experimental

The manganite La$_{0.65}$Ba$_{0.35}$MnO$_3$ was prepared by the solid state reaction method. Mixed powders of La$_2$O$_3$, MnO$_2$ and BaCO$_3$ were ground for 60 min, ball – milled for 30 min and pressed into pellets. The pellets were first heated at 1073 K for 24 h and then subsequently pulverized. After being milled for 30 min they were pressed into pellets again and then sintered at 1513 K for 24 h, followed by furnace cooling. Powder X – ray diffraction showed that the La$_{0.65}$Ba$_{0.35}$MnO$_3$ has one single - phase - like pattern with perovskite structure. The thermal -magnetization curve was measured using a thermal-magnetization analyzer (TMA) under a field of 2.39 $\times 10^4$ A/m. The Curie temperature can be derived as $T_C = 308$ K from the thermal – magnetization curve. The magnetoimpedance measurements of the La$_{0.65}$Ba$_{0.35}$MnO$_3$ with 2 mm thickness, 2.5 mm width and 10 mm length were performed using a HP4294A impedance analyzer. The sample, connected with the analyzer by the test lead - accessory, was placed in the low temperature system. Both ac currents with the amplitude of 20 mA and dc magnetic fields were applied along the length direction of the sample. The magnetoresistance was measured with a TH2512B dc resistance device.

3. Results and Discussion

The temperature dependence of the dc resistance for the La$_{0.65}$Ba$_{0.35}$MnO$_3$ under magnetic fields $H = 0$ and $H = 3.98 \times 10^5$ A/m are shown in Fig. 1, respectively. The metal – insulator transition temperature $T_{MI}$ is about 230 K, which is smaller than Curie temperature $T_C = 308$ K. This may be attributed to the inhomogeneity in magnetic and electronic transport behavior. Values of dc resistance are smaller under $H = 3.98 \times 10^5$ A/m than under $H = 0$, showing a negative magnetoresistance effect. As shown in Fig. 1, the magnetoresistance ratio $\Delta R/R_0$ has a peak value of $\sim 6.5\%$ under $H = 3.98 \times 10^5$ A/m at about 235 K near $T_{MI}$. The temperature dependence of the impedance for the
manganite La$_{0.65}$Ba$_{0.35}$MnO$_3$ under dc magnetic fields $H = 0$ and $H = 3.98 \times 10^5$ A/m at ac frequencies $f = 100$ kHz and 5 MHz are shown in Fig. 2, respectively. Similar to the dc resistance case, a metal - insulator transition peak can be observed in ac transport. At $f = 100$ kHz, the metal - insulator transition temperature $T_{MI}$ under zero field is 229 K, which is very close to the $T_{MI}$ value 230 K obtained from the dc case. Under a field of $3.98 \times 10^5$ A/m, the $T_{MI}$ shifts to a high temperature 243 K. Such shift has been also observed in the dc CMR effect. At $f = 5$ MHz, the $T_{MI}$ under zero field is about 268 K, larger than the $T_{MI}$ observed at $f = 100$ kHz. The different values of $T_{MI}$ reflects the inhomogeneity of the magnetic and electro - transport within the sample. The lower (higher) $T_{MI}$ observed at a low (high) frequency represents the phase with the weaker ferromagnetism/low conductivity (stronger ferromagnetism/higher conductivity). With increasing frequency, the impedance of the phase with a higher conductivity may increase sharply due to the skin effect. Therefore, the higher $T_{MI}$ appears at high frequencies. In other words, the local inhomogeneity of magnetic and electro - transport within the sample can be revealed through the application of ac currents with different frequencies. As shown in Fig. 2, there are two metal - insulator transition peaks in the temperature dependence of impedance at $f = 5$ MHz under a field of $H = 3.98 \times 10^5$ A/m. The higher $T_{MI}$ is larger than 289 K, whereas the lower $T_{MI}$ locates at about 226 K which is the trace of the phase with a weaker ferromagnetism/low conductivity within the sample. The inhomogeneities may result from the two-phase coexistence due to the intrinsic chemical disorder, or from the nanometer scale coexisting clusters due to electronic phase separation, or from various grain boundaries.

The temperature dependence of the change ratio of magnetoimpedance $\Delta Z/Z_0 = (Z(H) - Z(0))/Z(0)$ with $H = 3.98 \times 10^5$ A/m for the manganite La$_{0.65}$Ba$_{0.35}$MnO$_3$ is shown in Fig. 3. The magnetoimpedance ratio $\Delta Z/Z_0$ has its peak value of $-26.3\%$ at about 163 K for $f = 100$ kHz, and $-5.6\%$ at about 268 K for $f = 5$ MHz, respectively. It was showed that at the case of strong skin effect, the impedance $Z$ of manganite flake is proportional to the square root of transverse permeability and resistivity $\sqrt{\mu_s\rho}$. The magnetoimpedance of the manganites can be attributed to the variation of the permeability and resistivity under applied fields, connected with the combined effects of double exchange interaction, the Jahn-Teller lattice distortion with electron – phonon coupling and skin effect. In addition, the...
temperature where the peak $\Delta Z/Z_0$ occurs differs greatly for cases $f = 100$ kHz and 5 MHz, which may be due to the existence of local inhomogeneity.

The ac frequency dependence of impedance for the manganite $\text{La}_{0.65}\text{Ba}_{0.35}\text{MnO}_3$ was also measured. As shown in Fig. 4, at a low temperature such as $T = 98$ K, the impedance under fields $H = 0$ and $H = 3.98 \times 10^5$ A/m increase with increasing ac frequency. This can be attributed to the skin effect of the metal state below $T_{\text{MI}}$. On the contrary, at a high temperature such as $T = 213$ K, with increasing ac frequency, the impedance under fields $H = 0$ and $H = 3.98 \times 10^5$ A/m decrease slightly at first up to $f = 1$ MHz, but turn to increase sharply for $f > 1$ MHz, which may be due to the coexistence of the metallic and semiconducting phases in the manganite at this temperature. With increasing ac frequency, the impedance increases for metal phase but decreases for semiconducting phase. The impedance of the sample is controlled by semiconducting phase at low frequencies but is dominated by metal phase at high frequencies. Meanwhile, it can be seen from Fig. 4 that the impedance is lower for $H = 0$ for different frequencies, showing the negative magnetoimpedance effect.

4. Conclusion

A metal – insulator transition occurs in the temperature dependence of the impedance for manganite $\text{La}_{0.65}\text{Ba}_{0.35}\text{MnO}_3$. The local inhomogeneity within the sample $\text{La}_{0.65}\text{Ba}_{0.35}\text{MnO}_3$ can be revealed through the application of ac currents with different frequencies. The magnetoimpedance of the manganites may be attributed to the variation of the permeability and resistivity under applied fields, and the dc magnetoresistance is also involved in the ac magnetoimpedance for the manganite $\text{La}_{0.65}\text{Ba}_{0.35}\text{MnO}_3$ at low temperatures.

REFERENCES