Thermal Conductivity of $Pr_{0.65}(Ca_{1-Z}Sr_Z)_{0.35}MnO_3$ under Applied Field

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Abstract

The thermal conductivity $\kappa(T)$ of $Pr_{0.65}(Ca_{1-Z}Sr_Z)_{0.35}MnO_3$ (0≤Z≤1.0) has been measured under the applied field of up to 5 T. For Z=0.3 and 0.4, where the ferromagnetic metal (FM-M) state is competitive with the charge/orbital ordered (CO/OO) state, $\kappa(T)$ is enhanced and shows the hysteresis below the FM-M transition temperature T_c. The hysteresis of $\kappa(T)$ is wiped out and T_c increases rapidly with the increase of the applied fields. These $\kappa(T)$ behaviors originate from the stabilization of the FM-M state due to the rapid suppression of the CO/OO state.

Key words: $Pr_{0.65}(Ca_{1-Z}Sr_Z)_{0.35}MnO_3$; thermal conductivity; ferromagnetic metal; charge/orbital order

1. Introduction

In the $RE_{1-X}AE_XMnO_3$ manganites (RE and AE being the trivalent rare-earth elements and divalent alkaline-earth ones, respectively), the electrical and magnetic properties are dependent on the hole concentration X (band filling) and the effective one-electron bandwidth W [1]. If the average radius of $RE_{1-X}AE_X$ ions decreases, W is reduced and the charge/orbital ordered (CO/OO) state becomes dominant over the ferromagnetic-metal (FM-M) phase. By alloying a larger AE ion at a constant X, $Pr_{0.65}(Ca_{1-Z}Sr_Z)_{0.35}MnO_3$ undergoes the transition from the CO/OO insulating phase (Z≤0.1) to the FM-M phase (Z≥0.4) [2]. The phonon component of the thermal conductivity $\kappa(T)$ of $La_{1-X}AE_XMnO_3$ systems (AE=Ca, Sr) shows a characteristic enhancement below the FM-M transition temperature T_c [3,4]. The $\kappa(T)$ enhancement is also observed at the field-induced FM-M transition in $Pr_{0.65}Ca_{0.35}(Mn_{1-Z}Co_Z)O_3$ system [5]. In this paper, we report $\kappa(T)$ of the $Pr_{0.65}(Ca_{1-Z}Sr_Z)_{0.35}MnO_3$ system under the applied fields.

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2. Experimental

The single-phase $Pr_{0.65}(Ca_{1-Z}Sr_Z)_{0.35}MnO_3$ (0≤Z≤1.0) polycrystals were prepared by a solid-state reaction method. $\kappa(T)$ was measured by a steady-state heat flow method using an automated measuring apparatus [6]. The electrical resistivity $\rho(T)$ was measured by a four-probe method. The magnetization M(T) was measured using a SQUID magnetometer under 0.5 T in the process of zero field cooling (ZFC).

3. Results and discussion

Figure 1(a) shows M(T) as a function of temperature T. The CO/OO insulating phase is stable for Z≤0.1 and the FM-M phase is stable for Z≥0.6 at low temperatures. In the intermediate Z region (0.2≤Z≤0.4), the CO/OO insulating phase is competitive with the FM-M phase. Figures 1(b) and 1(c) show $\rho(T)$ of the Z=0.3 and 0.4 samples, respectively. For Z=0.3, the characteristic $\rho(T)$ upturn is observable below the CO/OO transition temperature T_{CO}=210 K and the FM-M state is induced below $T_c(down)$=70 K and $T_c(up)$=100 K in zero field. In the 2 T field, T_c increases rapidly with

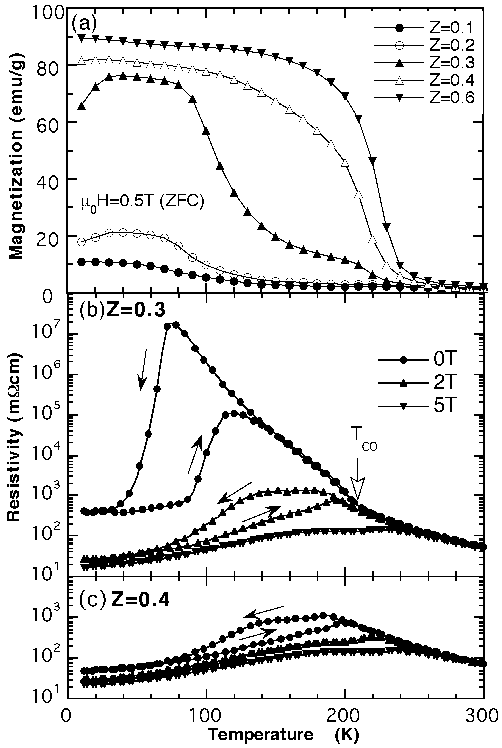

Fig. 1. (a) M(T) for the $Pr_{0.65}(Ca_{1-Z}Sr_Z)_{0.35}$ MnO_3 samples ($0.1 \leq Z \leq 0.6$). The electrical resistivity $\rho(T)$ of the (b) Z=0.3 and (c) 0.4 samples under the magnetic fields.

applied fields and the hysteretic $\rho(T)$ behavior is completely wiped out at 5 T. For Z=0.4, the hysteresis of $\rho(T)$ can be seen at 0 T, which is completely wiped out for B$\geq$2 T. The hysteresis suggests the survival of the CO/OO order at 0 T.

Figures 2(a) and 2(b) show $\kappa(T)$ of the Z=0.3 and 0.4 samples under the applied fields. In both samples, $\kappa(T)$ is overwhelmingly due to phonons. In Fig.2(a), at 0 T on the cooling run, $\kappa(T)$ is enhanced below $T_{c(down)}$=70 K and then reaches a maximum at 40 K and decreases with decreasing T. On the subsequent heating run, $\kappa(T)$ is drastically reduced at $T_{c(up)}$=90 K and monotonously increases with the further increase of T. When the 2 T field is applied, the hysteretic $\kappa(T)$ behavior becomes broarder and $T_{c(down)}$ and $T_{c(up)}$ rapidly increase to $\sim$200 K. For the applied field of 5 T, $\kappa(T)$ does not show the hysteresis and T_c increases to 220 K. In Fig.2(b), the absolute values of $\kappa(T)$ are larger than those for Z=0.3 and the hysteresis is observable only at 0 T. These hysteretic $\kappa(T)$ behabiors are consistent with those of $\rho(T)$ as shown in Fig.1. In accord with $\rho(T)$ and $\kappa(T)$ behaviors, the thermal expansion dL(T)/L of the Z=0.3 sample (not shown) shows a clear contaction below T_c accompanying a large hysteresis in 0 and 2 T.

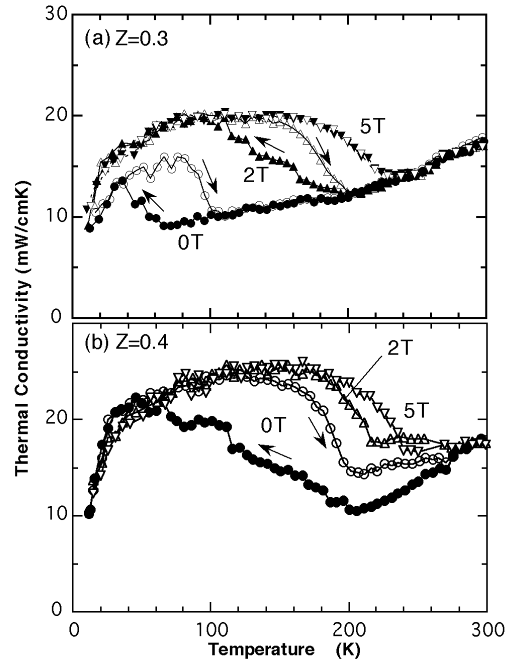

Fig. 2. Magnetic field dependence of $\kappa(T)$ for the (a) Z=0.3 and (b) Z=0.4 samples.

With increasing mobility of the charge carriers due to the metallic conduction, the local Jahn-Teller (JT) lattice distortion is relaxed in the FM-M phase as the observed contraction of dL/L indicates [4]. The $\kappa(T)$ enhancement below T_c is considered to originate from the reduced phonon scattering as a result of the relaxed local JT distortion. The disappearance of the hysteresis in $\kappa(T)$ suggests that the CO/OO phase give place to the FM-M phase in the applied field and the existence of the CO/OO phase brings about the rapid increase of T_c in the applied field.

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