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Physica B 378–380 (2006) 499–500
PHYSICA B
www.elsevier.com/locate/physb

Thermal conductivity anomaly in $La_{0.52}Ca_{0.48}MnO_3$ under applied field

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Abstract

The temperature and magnetic field dependences of the thermal conductivity $\kappa(T, B)$ have been investigated for $La_{0.52}Ca_{0.48}MnO_3$. $\kappa(T, B)$ markedly changes at the phase transition between the charge-orderd antiferromagnetic (CO-AFM) state and the ferromagnetic (FM) metal state. $\kappa(T, B)$ is enhanced in the FM state because the phonon scattering by the local Jahn–Teller strain around Mn^{3+} spins is released in the metallic phase. The $\kappa(T, B)$ behaviors can be understood on the basis of the volume fraction ratio of the FM and CO-AFM phases.

PACS: 65.40.−b; 66.30.Xj; 75.47.Lx

Keywords: Thermal conductivity; Manganites; Charge order; Ferromagnetic order; Phonon scattering

1. Introduction

In the perovskite manganite $La_{1-X}Ca_XMnO_3$ system, where the lattice, charge and spin are closely and complicatedly correlated with each other, a variety of dramatic phenomena such as the colossal magnetoresistance (CMR) and the insulator–metal (IM) transition take place. The thermal conductivity $\kappa(T)$ measurement can be a useful tool to investigate the effect of the lattice dynamics on the phase transitions. For $0.19 \leqslant X \leqslant 0.45$, $\kappa(T)$ increases abruptly at the onset of metallic phase below the ferromagnetic (FM) transition temperature T_c mainly due to the reduction of the local lattice distortion. For $X \sim 0.50$, where the Mn^{3+} and Mn^{4+} ions exist in nearly equal number, the charge-ordered antiferromagnetic (CO-AFM) state competitive to the FM state appears. The $\kappa(T)$ reduction is observable around the CO transition temperature T_{CO}, which originates from the locking of the local strain as a result of reduced charge carrier hopping [1]. The coexistence of the CO-AFM phase and the FM or paramagnetic phase for $X = 0.47$ and 0.49 in our sample was confirmed by the X-ray diffraction under applied fields and the volume fraction V_{FM} of the FM-phase was estimated [2].

In this paper, we investigate the temperature and magnetic field dependences of the thermal conductivity $\kappa(T, B)$ for $La_{0.52}Ca_{0.48}MnO_3$ sample and discuss the $\kappa(T, B)$ anomalies around these phase boundaries.

2. Results and discussion

The $La_{0.52}Ca_{0.48}MnO_3$ polycrystal was fabricated by a standard solid-state reaction method [1]. The thermal conductivity $\kappa(T, B)$ was measured by a steady-state heat flow method from 10 to 300 K applying a magnetic field up to 5 T parallel to the heat flow direction in the processes of zero field cooling (ZFC), field cooling (FC) and field warming (FW). The measurement error in κ due to the radiation loss is within 10% at 300 K The magnetization $M(T, B)$ was measured using a SQUID magnetometer.

Fig. 1(a) shows $\kappa(T)$ in various magnetic fields and Fig. 1(b) shows $\kappa(T)$ in $B = 5$ T in the ZFC, FC and FW runs. Fig. 1(c) presents $M(T, B)$. The FM and the CO-AFM transition temperatures were determined as $T_c = 230$ K and $T_{CO} = 160$ K in $B = 0.05$ T, respectively. Because of the high electrical resistivity, the heat conduction is almost due to phonons ($\kappa = \kappa_{ph}$). $\kappa(T,0)$ in zero field monotonically decreases with decreasing T and then shows a plateau

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0921-4526/$ - see front matter
doi:10.1016/j.physb.2006.01.216

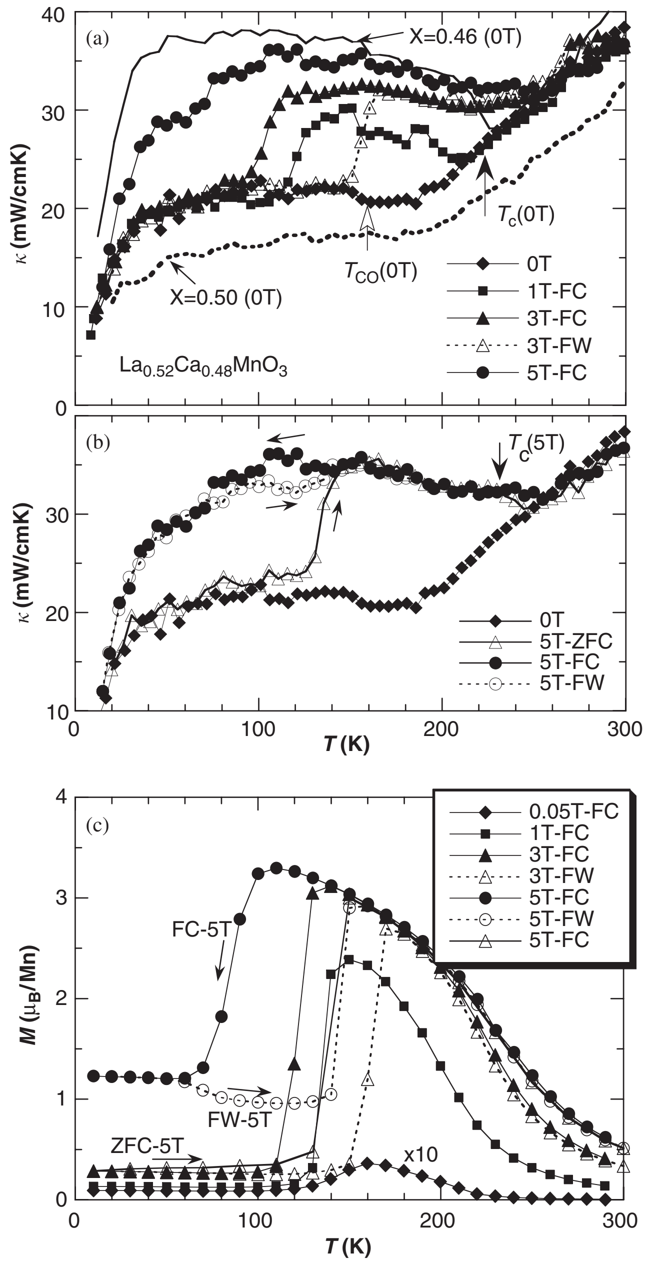

Fig. 1. (a) κ(T) for the $La_{0.52}Ca_{0.48}MnO_3$ sample in the magnetic fields. (b) κ(T) in $B = 5$ T in ZFC, FC and FW runs. (c) $M(T)$ in the magnetic fields.

below 200 K. For $B = 1$ and 3 T in the FC run, κ(T) is enhanced below T_c and shows a local maximum. Below T_{CO}, κ(T) is suddenly reduced and then approaches the κ(T,0) curve. κ(T) shows a large hysteresis around T_{CO} similar to $M(T)$ shown in Fig. 1(c), which suggests that a first-order phase transition between FM and CO-AFM state takes place. κ(T) in $B = 5$ T is enhanced at low temperatures compared with that for $B = 3$ T, but is smaller than that for the $X = 0.46$ sample. The FM state is fully present in the $X = 0.46$ specimen and the CO-AFM state is fully present in the $X = 0.50$ specimen. The FM volume fraction V_{FM} at low T estimated from the measured M value increases with increasing applied field and reaches about 35% in $B = 5$ T.

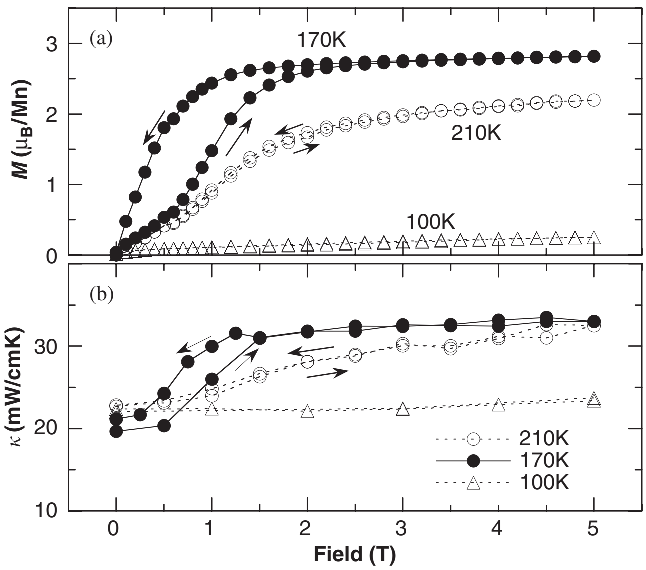

Fig. 2. The magnetic field dependences of (a) $M(B)$ and (b) κ(B) for the $La_{0.52}Ca_{0.48}MnO_3$ at $T = 210$, 170 and 100 K.

The magnitude of κ changes depending on the V_{FM} value. It should be noted that the κ(T) in the CO-AFM phase is smaller than that in the FM phase. These results suggest that the phonon scattering is enhanced in the CO-AFM phase due to the increase of local lattice distortion below T_{CO} as observed by the thermal dilatation [3].

In Fig. 1(b), κ(T), in $B = 5$ T shows a relatively small hysteresis around T_{CO} for the FC and FW runs in contrast to $M(T)$. In the 5 T-ZFC run, κ(T) remains at the low value below $T_{CO} = 130$ K but suddenly jumps to the high value just above T_{CO}.

Fig. 2 shows the magnetic field dependence of (a) $M(B)$ and (b) κ(B) at $T = 210$, 170 and 100 K. $M(B)$ and κ(B) increase with increasing applied field at $T = 210$ and 170 K. On the other hand, at $T = 100$ K, these quantities show no field dependence up to 5 T which suggests the stable CO-AFM phase.

In summary, the thermal conductivity κ(T, B) of the $La_{0.52}Ca_{0.48}MnO_3$ sample changes depending on the charge and magnetic order. The phonon thermal conductivity $κ_{ph}$ is enhanced in the FM-metal phase, while it is reduced in the CO-AFM phase. The novel κ(T, B) behaviors can be understood on the basis of the volume fraction V_{FM} of the FM phase in accord with the previous results of the X-ray diffraction.

References

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