

# Magnetic, Electrical and Thermal Properties of $\text{La}_{0.80}\text{Sr}_{0.20}(\text{Mn}_y\text{Co}_{1-y})\text{O}_3$

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## Abstract

The thermal conductivity  $\kappa$ , thermoelectric power  $S$ , electrical resistivity  $\rho$  and magnetization  $M$  of  $\text{La}_{0.80}\text{Sr}_{0.20}(\text{Mn}_y\text{Co}_{1-y})\text{O}_3$  has been measured. By Mn substitution for Co, the initial ferromagnetic-metal behavior is promptly suppressed and  $\rho(T)$  becomes semiconductive. In the semiconductive composition range,  $S$  is remarkably enhanced and  $\kappa$  is reduced. As a result, pretty large values of the thermoelectric figure of merit  $Z$  are realized.

*Key words:*  $\text{La}_{0.80}\text{Sr}_{0.20}(\text{Mn}_y\text{Co}_{1-y})\text{O}_3$ ; thermal conductivity; thermoelectric power; thermoelectric figure of merit

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## 1. Introduction

$(\text{RE}_{1-x}\text{AE}_x)\text{MO}_3$  (RE: rare-earth, AE: alkaline-earth, M: 3d transition metal) type oxides with perovskite structure have attracted renewed interest. The hole doping into these oxides leads to novel and anomalous transport phenomena. The manganite,  $\text{La}_{1-x}\text{Sr}_x\text{MnO}_3$ , for example, exhibits the wellknown colossal magnetoresistance (CMR) [1], while the cobaltites,  $\text{La}_{1-x}\text{Sr}_x\text{CoO}_3$ , exhibits complex magnetism and metal-insulator transition depending the hole doping  $x$  [2,3]. Recently, cobaltites such as  $\text{NaCo}_2\text{O}_4$  were proposed to be hopeful candidates for thermoelectric application [4]. The undoped  $\text{LaCoO}_3$  is a nonmagnetic insulator with the low spin state at low temperatures. The hole-doped compound,  $\text{La}_{0.80}\text{Sr}_{0.20}\text{CoO}_3$  (LSCoO), transforms to a ferromagnet showing barely metallic electrical conduction. Because unusual physical phenomena tend to appear near the boundaries of competing phases, we examine Mn substitution effect in  $\text{La}_{0.80}\text{Sr}_{0.20}(\text{Mn}_y\text{Co}_{1-y})\text{O}_3$  (LSCoO( $y$ ),  $0 \leq y \leq 0.2$ ) and also survey the potential-

ity of the Mn-substituted perovskite cobaltate as a thermoelectric material.

## 2. Experimental

The single-phase  $\text{La}_{0.80}\text{Sr}_{0.20}(\text{Mn}_y\text{Co}_{1-y})\text{O}_3$  polycrystals were prepared by a solid-state reaction method. Automatic measurements of the thermal conductivity  $\kappa(T)$  and the Seebeck coefficient  $S(T)$  were performed by a steady-state heat flow method in a Gifford-McMahon (GM) cycle helium refrigerator. The magnetization  $M(T)$  was measured by a SQUID magnetometer.

## 3. Results and discussion

Figure 1(a) shows  $M(T)$  in the field of 0.5 T as a function of temperature  $T$ . In LSCoO(0.01, 0.02), the ferromagnetic (FM) transition temperature  $T_c$  decreases with increasing  $y$ . In LSCoO(0.05), the maximum of  $M(T)$  occurs at about 55 K and its value falls below a half of the saturation moment of

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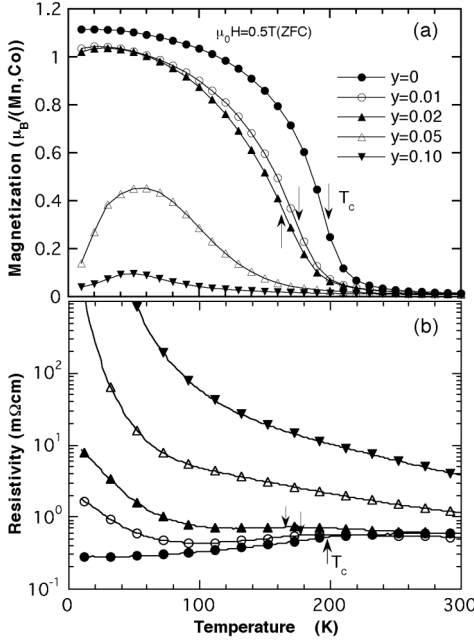


Fig. 1. (a)  $M(T)$  and (b)  $\rho(T)$  of  $\text{La}_{0.80}\text{Sr}_{0.20}(\text{Mn}_y\text{Co}_{1-y})\text{O}_3$  as a function of  $T$  for  $y=0, 0.01, 0.02, 0.05$  and  $0.10$ . The symbols are the same in (a) and (b).

$\text{La}_{0.80}\text{Sr}_{0.20}\text{CoO}_3$ . With further increase of  $y$  ( $\geq 0.10$ ), the FM order is completely quenched out. Figure 1(b) presents the temperature dependence of  $\rho(T)$ . The ferromagnetic LSCoO(0.01, 0.02) samples retain the metallic conduction below  $T_c$ , though  $\rho(T)$  increases at low temperatures due possibly to the localization effect. In LSCoO(0.05, 0.10), the quench of FM order results in a semiconductive behavior of  $\rho(T)$  and  $\rho(T)$  values sharply increase with increasing  $y$ .

Figure 2(a) gives  $\kappa(T)$  vs.  $T$ . The electronic component  $\kappa_e$  estimated on the basis of the Wiedemann-Franz law is also contained in the figure.  $\kappa(T)$  is remarkably reduced by only 1% Mn substitution, which originates from the heavy reduction in the phonon component  $\kappa_{ph}$ . The  $\kappa(T)$  reduction seems to saturate for  $y \geq 0.05$ . It may be worthwhile to note that  $\kappa(T)$  of LSCoO(0.05, 0.10) has a shoulder-like kink at around 50 K, where  $M(T)$  takes the maximum in these samples. Figure 2(b) presents the coefficient  $S$  as a function of  $T$ .  $S(T)$  increases with increasing  $y$  and LSCoO(0.10) shows the largest value of  $\sim 120 \mu\text{V/K}$  at around 160 K. For applicational purpose, a large value of the thermoelectric figure of merit  $Z$  ( $=S^2/\kappa\rho$ ) is of intrinsic importance. The calculated  $Z$  values are also given in Fig.2(b). Pretty large  $Z$  values are realized in LSCoO(0.10). These  $Z$  values are, however, more than an order smaller than those of typical semiconductive thermoelectric materials now on practical use. We found that the  $Z$  values of LSCoO(0.20) were greatly deteriorated because of too

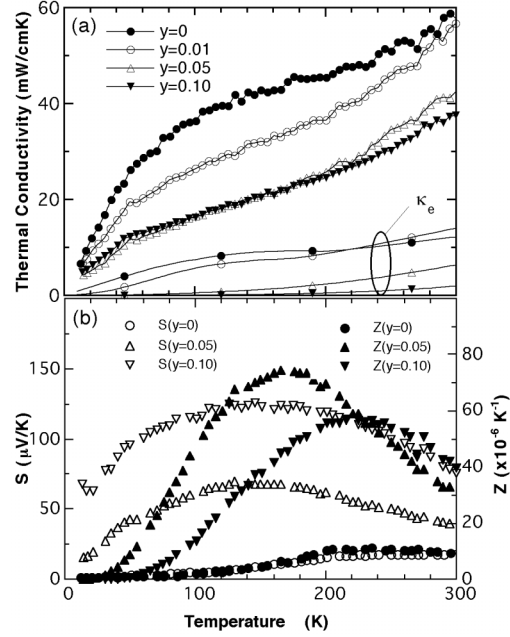


Fig. 2. (a) The temperature dependence of thermal conductivity  $\kappa(T)$ . The estimated electronic contribution  $\kappa_e(T)$  is also shown. (b) The Seebeck coefficient  $S(T)$  and the figure of merit  $Z$  ( $=S^2/\kappa\rho$ ) of  $\text{La}_{0.80}\text{Sr}_{0.20}(\text{Mn}_y\text{Co}_{1-y})\text{O}_3$  for  $y=0, 0.05$  and  $0.10$ .

large  $\rho$  values.

In summary,  $M(T)$ ,  $\rho(T)$ ,  $\kappa(T)$  and  $S(T)$  were measured for Mn substituted  $\text{La}_{0.80}\text{Sr}_{0.20}(\text{Mn}_y\text{Co}_{1-y})\text{O}_3$ . The FM-metal phase was preserved in initial narrow  $y$  region ( $y \leq 0.02$ ). For  $y \geq 0.05$ , the FM order was greatly damaged or destroyed and the  $\rho(T)$  behavior became semiconductive. The phonon component of  $\kappa(T)$  sharply reduced by Mn substitution for Co and the reduction saturated for  $y \geq 0.05$ . The Seebeck coefficient was noticeably enhanced by Mn substitution, especially in the semiconductive composition region. However, the values of the figure of merit  $Z$  remained an order of magnitude smaller compared to the level of the possible practical use. The other 3d transition metal substitution effect on  $S(T)$  adopting other RE ions are under way.

## References

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