# Thermal transport of Cr-doped double-layered $LaSr_2Mn_2O_7$

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**Abstract**

We have carried out thermoelectric power ($S$), magnetization and magnetoresistance measurements on $LaSr_2Mn_{2-y}Cr_yO_7$ compounds (y=0.1, 0.2 and 0.4). In the bilayer manganite $LaSr_2Mn_2O_7$ (hole doping level x=1/2), it is well known that the coexistence of metallic A-type antiferromagnetic (AF) phase and CE-type charge/orbital order (CO/OO) phase is essential to understand physical properties. The Cr-doping strongly suppressed the AF transition temperature and its associated peak in $S$ down to lower temperatures. The Cr impurities on the Mn site in the bilayer manganite system did not cause such a dramatic influence as the insulator to metal transition in cubic manganites. This finding is discussed on the basis of phase separation model concerning the A-type majority and CE-type minority phases.

*Key words:* bilayer manganite ; thermoelectric power; Cr-doping;

The CMR bilayer compounds $La_{2-2x}Sr_{1+2x}Mn_2O_7$, in which $MnO_2$ bilayers and $(La,Sr)_2O_2$ blocking layers are alternatively stacked, have a rich variety of physical properties depending on hole doping (x). In $LaSr_2Mn_2O_7$ (hole doping level x=1/2), neutron diffraction studies have revealed the coexistence of A-type antiferrmagnetic (AF) phase and the CE-type charge/orbital ordered (CO/OO) phase [1]. It has been reported that the Cr-doping on the Mn site in the cubic manganites with the CO/OO phase cause the phase separation into the metallic and insulating states associated with occurrence of the CMR [2].

In order to investigate the Cr-doping effect on physical properties in the bilayer manganites, $LaSr_2Mn_2O_7$, we have performed thermopower ($S$), magnetization and magnetoresistance measurements on $LaSr_2Mn_{2-y}Cr_yO_7$ (y=0.1,0.2 and 0.4) compounds. Thermopower measurements provide direct information about the energy derivative of density of states and polaronic states. The $Cr^{3+}$ has the electronic configuration of $t_{2g}^3e_{2g}^0$ (spin quantum number $S$= 3/2) which is the same as the $Mn^{4+}$, and acts on the Mn site as the $e_g$-orbital deficiency . Cr-doped polycrystalline samples were prepared with the solid-state reaction method. A y=0 single crystal with high quality was grown with the floating zone method. The thermopower was measured with a steady-state heat-flow method using GM-type refrigerator. Thermoelectric voltage and thermal gradient generated in the longitudinal direction of samples were detected with Cu wires and differential thermocouples (AuFe-Chromel), respectively. Magnetoresistance was measured with a four-probe technique at IMR of Tohoku Univ. Magnetic measurement was carried out using a SQUID magnetometer.

First, we showed in Fig.1 the temperature dependence of magnetization in the Cr-doped $LaSr_2Mn_2O_7$ bilayer manganites. The Cr-doping strongly suppressed the AF transition temperature from 210K (y=0) down to 125K (y=0.2). On the other hand, the low-T second peak was more enhanced with an increase of Cr-impurities. The resistivity data of Cr-

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doped samples showed a temperature variation of thermal activation type and were in the magnitude more enhanced with an increase of Cr-content , in contrast with those in cubic manganites (not shown here). A pronounced peak of the pure crystal near the AF and CO transition temperature disappeared due to Cr-doping.

Next, in Fig.2 , we displayed the thermopower of our samples as a function of temperatures. For all samples, the $S$ data showed almost negative sign over the measured temperature range and the observed peak in $S$ reached a very small-value around $T_N$. The $S$ behavior at y=0.1 is almost similar to the $T$-dependence of $S_{ab}$ of the y=0 single crystal. It should be noted that a strong decrease in $S_{ab}$ of the y=0 crystal at higher $T$ is associated with the formation of Zener-polarons in [3], where Zener pairs are two-manganese clusters of $Mn^{3+}$-O-$Mn^{4+}$ and are confined to $MnO_2$ double layers. Thus, it is expected that the formation of Zener pairs is disturbed due to Cr-impurities as orbital-deficiencies so that the value of $S$ of Cr-doped samples showed a weak dependence at higher $T$.

Finally, Magnetoresistance data at selected temperatures are shown in Fig.3, where the current supplied is parallel to the direction of applied field. Magnetoresistance at y=0.1 showed a relatively large decrease of 40 percent (in a field of 8T at 80K) comparable with reported data at y=0, which seems to originate from the low temperture orbital-disordered state [4].

In half hole-doped bilayer manganites, the volume fraction of the CE type phase is estimated to be about 18 percent at 115 K by Kubota et al. in other words, this system has been separated into the A-type majority and CE-type minority regions. If we assume this situation is also realized in our samples, it is expected that most of Cr-impurities are doped for the majority phase of the A-type AF state in comparison with the minority phase of the CE-type CO state. This finding is consistent with our experimental results on a strong degradation of $T_N$ due to Cr-doping. The Cr-impurities act on the Mn site as orbital-deficiencies and through the spin-orbital interaction suppress a AF long-range spin correlation in the major phase.

In summary, we have carried out thermopower , magnetization and magnetoresistance measurements on Cr-doped $LaSr_2Mn_2O_7$ compounds. Our data strongly support the phase separation model in which in the half-doped bilayer manganite system coexist both the A-type AF metallic and CE-type CO/OO insulating phases.

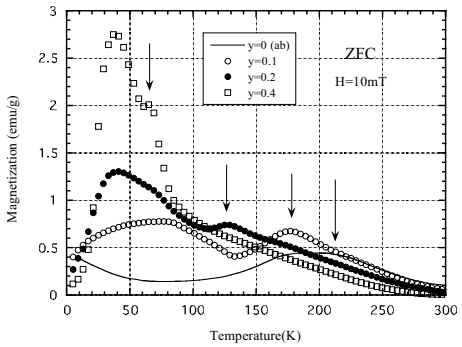


Fig. 1. Temperature dependence of magnetization in the Cr-doped $LaSr_2Mn_2O_7$ bilayer manganites. The y=0 single-crystal data are enlarged by a factor of ten. The arrows denote the AF transition temperature.

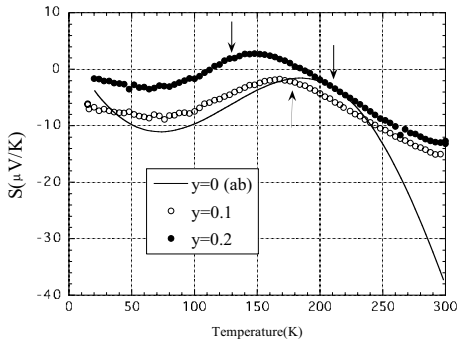


Fig. 2. Temperature dependence of thermoelectric power in the Cr-doped $LaSr_2Mn_2O_7$ bilayer manganites. The arrows denote the AF transition temperature determined from magnetic measurements.

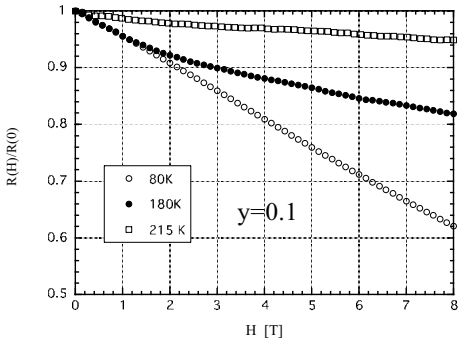


Fig. 3. Magnetoresistance at selected temperatures in the Cr-doped $LaSr_2Mn_2O_7$ (y=0.1).


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## References


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