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In-Plane Electrical Resistivity under Strong Magnetic Fields up to 27 T in $La_{2-x}Ba_xCuO_4$ and $La_{2-x}Sr_xCuO_4$ around $x = 1/8$

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Abstract. Magnetic-field effects on the so-called charge-spin stripe order, namely, the charge stripe order and spin stripe order in the La-214 system have been investigated from the in-plane electrical-resistivity, ρ_{ab}, measurements. In $La_{2-x}Ba_xCuO_4$ (LBCO) with $x = 0.10$ and $La_{2-x}Sr_xCuO_4$ with $x = 0.115$ where the incommensurate charge peaks are weak and unobservable in zero field from the elastic neutron-scattering measurements, respectively, the normal-state value of ρ_{ab} at low temperatures markedly increases with increasing field up to 27 T. As for $x = 0.11$ in LBCO where the charge stripe order is fairly stabilized in zero field, the increase in ρ_{ab} with increasing field is negligibly small. In conclusion, the magnitude of the increase in ρ_{ab} by the application of magnetic field is well correlated with the stability of the charge stripe order in zero field for the La-214 system around $x = 1/8$. Our understanding is as follows. When the charge-spin stripe order is not fully stable in zero field, magnetic field operates to stabilize the charge-spin stripe order. The value of ρ_{ab} increases with increasing field depending on the stability of the charge stripe order.

Keywords: stripe order, magnetic-field effect, La-based high-T_c superconductor, electrical resistivity
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In recent years, the magnetic-field effects on the so-called charge-spin stripe order, namely, the charge stripe order and spin stripe order in the La-214 system have been one of the most interesting issues. Elastic neutron-scattering measurements in magnetic fields for $La_{2-x}Sr_xCuO_4$ (LSCO) with $x = 0.10$[1] have revealed the enhancement of the incommensurate (IC) magnetic peaks corresponding to the spin stripe order by the application of magnetic field. On the other hand, the enhancement is quite small for $x = 0.12$,[2] which is believed to be due to the fairly good stability of the spin stripe order even in zero field at $x \sim 1/8$. As for the magnetic-field effect on the charge stripe order, no enhancement of the IC charge peaks is observed for $La_{1.6-x}Nd_{0.4}Sr_xCuO_4$ with $x = 0.15$[3] where the charge-spin stripe order is stabilized on the tetragonal low-temperature (TLT) structure (space group: $P4_2/ncm$).

In order to address this issue, we have investigated the in-plane electrical resistivity, ρ_{ab}, for $La_{2-x}Ba_xCuO_4$ (LBCO) with $x = 0.08$, 0.10 and 0.11 in magnetic fields parallel to the c axis up to 15 T.[4] It has been found that the superconducting transition curve shows a broadening in magnetic fields for $x = 0.08$, while it shifts toward the low-temperature side in parallel with increasing field for $x = 0.11$ where the charge-spin stripe order is formed at low temperatures even in zero field.[5] As for $x = 0.10$, where the intensity of the IC charge peaks is weak but that of the IC magnetic peaks is almost the same as that in $x \sim 1/8$,[5] the broadening is observed in low fields and it changes to the parallel shift in high fields above 9 T. Moreover, the normal-state value of ρ_{ab} at low temperatures markedly increases with increasing field up to 15 T. It has been inferred that these pronounced features of $x = 0.10$ are due to the magnetic-field-induced stabilization of the charge stripe order.

In this paper, we have expanded the applied magnetic field up to 27 T in the ρ_{ab} measurements of LBCO with $x = 0.08$, 0.10, 0.11 and also measured ρ_{ab} for LSCO with $x = 0.115$ where the superconductivity is a little suppressed, in order to clarify the relation between the magnetic field and the stability of the charge stripe order.

Single crystals of LBCO and LSCO were grown by the traveling-solvent floating-zone method.[6] The ρ_{ab} measurements were carried out up to 27 T using a hybrid magnet at the High Field Laboratory for Superconducting Materials (HFLSM), IMR, Tohoku University.

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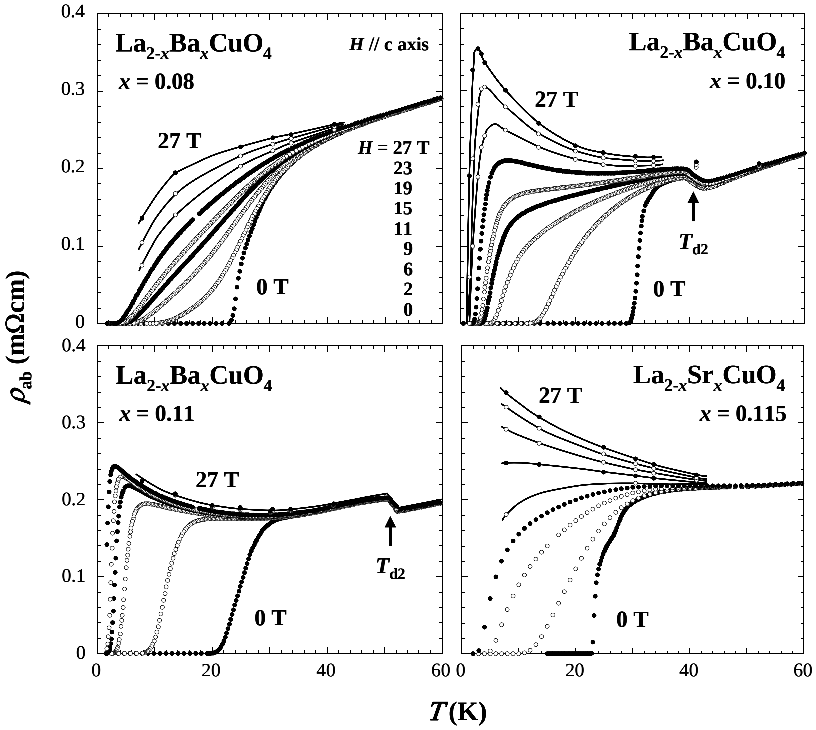

FIGURE 1. Temperature dependence of the in-plane electrical resistivity, ρ_{ab}, in various magnetic fields parallel to the c axis for $La_{2-x}Ba_xCuO_4$ with x = 0.08, 0.10, 0.11 and $La_{2-x}Sr_xCuO_4$ with x = 0.115. The temperature T_{d2} corresponds to the structural phase-transition temperature between the orthorhombic mid-temperature (space group: *Bmab*) and tetragonal low-temperature ($P4_2/ncm$) phases. Solid lines are to guide the reader's eye.

Figure 1 displays the temperature dependence of ρ_{ab} in various magnetic fields for LBCO with x = 0.08, 0.10, 0.11 and LSCO with x = 0.115. For x = 0.08, the broadening continues up to 27 T, which is an usual behavior in the underdoped high-T_c cuprates with a huge upper critical field, H_{c2}. For x = 0.10, the normal-state value of ρ_{ab} at low temperatures continues increasing up to 27 T and ρ_{ab} exhibits an insulating behavior in high fields. These suggest that the charge stripe order is further stabilized by the application of magnetic field up to 27 T. For x = 0.11, on the contrary, the increase of ρ_{ab} with increasing field is negligibly small up to 27 T. That is, ρ_{ab} seems stiff to the application of magnetic field, indicating the nearly perfect stabilization of the charge stripe order even in zero field at $x \sim 1/8$.

As for LSCO with x = 0.115, the broadening is observed at 2 T and changes to be like a parallel shift at 9 T. Moreover, ρ_{ab} at low temperatures increases with increasing field and shows an insulating behavior in high fields. These suggest that the magnetic-field-induced localization of carriers takes place also for LSCO around x = 1/8.

The behavior of ρ_{ab} for LSCO with x = 0.115 in each field appears to be quite similar to that for LBCO with x = 0.10. Elastic neutron-scattering measurements for LSCO with $x \sim 1/8$ in the orthorhombic mid-temperature phase (space group: *Bmab*) have revealed that no IC charge peaks are observed in zero field, though the spin stripe order is fairly stabilized in zero field.[7] Accordingly, it is possible that the charge stripe order is stabilized by the application of magnetic field also for LSCO with x = 0.115. The similarity of the response of ρ_{ab} to magnetic field between LBCO with x = 0.10 and LSCO with x = 0.115 implies the similar stability of the charge stripe order in zero field, as suggested from the thermal-conductivity measurements also.[8,9]

In conclusion, the present results suggest that the magnitude of the increase in ρ_{ab} by the application of magnetic field is well correlated with the stability of the charge stripe order in zero field for the La-214 system around x = 1/8. Our understanding is as follows. When the charge-spin stripe order is not fully stable in zero field, magnetic field operates to stabilize the charge-spin stripe order. The value of ρ_{ab} increases with increasing field depending on the stability of the charge stripe order.

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