Magnetotransport in Lightly Doped La$_{2-x}$Sr$_x$CuO$_4$ and La$_2$Cu$_{1-x}$Li$_x$O$_4$

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Introduction

There is growing evidence that spin and charge inhomogeneities in hole-doped cuprates play an important role in macroscopic properties of these compounds [1]. In particular, in both high-temperature superconductor La$_{2-x}$Sr$_x$CuO$_4$ (LSCO) and La$_2$Cu$_{1-x}$Li$_x$O$_4$ (Li-LCO), an insulating system in which holes are doped directly into CuO$_2$ planes, this mesoscopic phase separation develops already at very low doping. Experiments performed on both materials show that the magnetic behavior of lanthanum cuprate is relatively insensitive to the type and strength of the quenched disorder [2], suggesting that the glassiness in these materials is primarily self-generated. Recent low-temperature ($T<1$ K) magnetotransport and noise study of lightly doped LSCO ($x=0.03$) has revealed both signatures of charge glassiness and strong coupling between holes and spins [3]. Here we report an extensive and comparative study of magnetotransport on single crystal $x=0.03$ LSCO and Li-LCO with the goal of extracting detailed information about the coupling between spins and charges in these cuprates.

Experimental

Measurements were performed in the 18 T superconducting magnet with a He$^3$ system in SCM2 at $0.300 < T$ (K) < 70 K and in magnetic fields $B$ parallel ($B \perp c$ axis) and perpendicular to the CuO$_2$ planes ($B || c$). The magnetoresistance (MR) was measured at fixed $T$ using a standard four-probe ac technique (~7 Hz) in the Ohmic regime.

Results and Discussion

The MR in the two materials are similar when $B \perp c$. Namely, both in-plane and out-of-plane low-field MR are positive at low $T$ and become negative at higher $T$ and $B$. Furthermore, the magnitude of the negative MR decreases with increasing $T$ and, only in LSCO, a small positive MR is observed again at $T \geq 30$ K. However, when $B || c$, while the features of the MR in LSCO do not change qualitatively [Fig. 1 (a)], both in-plane and out-of-plane MR of Li-LCO exhibit a step-like decrease at high $T$ [Fig. 1(b)]. The step reflects a transition to the Néel state, similar to the results on LSCO with $x=0.01$ [4].

Conclusions

While the low-field positive MR at low $T$ seems to be a precursor of the glassy behavior in the charge sector [3], a step-like decrease of the MR at higher $T$ for $B || c$ signifies a transition to the Néel state. The step is not observed in $x=0.03$ LSCO, where the long-range antiferromagnetic order is absent. The detailed analysis of this first-order phase transition will provide valuable information on the spin and charge coupling.

Acknowledgements

This work was supported by NSF Grant No. DMR-0403491, NHMFL via NSF No. DMR-0084173, The Royal Society, the EURYI scheme and MEXT-CT-2006-039047. We are grateful to X. Shi for technical assistance.

References