Hysteresis and Memory in the Magnetoresistance of Underdoped La$_{2-x}$Sr$_x$CuO$_4$ Thin Films

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Introduction

In doped Mott insulators, such as hole-doped cuprates, charge heterogeneities are expected to arise due to the existence of several competing ground states, and may be even to exhibit glassy dynamics. Various experiments suggest that glassiness of both spins and charges emerges with the first added holes and evolves with doping $x$. Recently, in a $x=0.03$ single crystal La$_{2-x}$Sr$_x$CuO$_4$, magnetotransport and resistance noise measurements have provided evidence for charge glassiness at very low temperatures [1]. In the current study, we span a broad range of temperatures $T$ and magnetic fields $B$ to investigate the evolution of the charge dynamics with doping using transport measurements.

Experimental

We have studied the in-plane magnetoresistance (MR) in atomically smooth, MBE grown La$_{2-x}$Sr$_x$CuO$_4$ thin films with dopings $x$ that span the region from non-superconducting to superconducting samples. The MR was measured at temperatures $0.3 \text{ K} \leq T \leq 20 \text{ K}$ and in magnetic fields $0 \leq B \leq 9 \text{ T}$, applied both parallel and perpendicular to the $c$-axis.

Results and Discussion

At low $T$, the MR shows the emergence of a strong, positive contribution, which exhibits hysteresis and memory. Moreover, the zero-field resistances $R(B=0)$ obtained after field cooling (FC) and zero-field cooling (ZFC) are found to be different. These glassy features, which reflect the slow dynamics of holes [1,2], become more pronounced as $T$ is reduced. As $x$ increases, i) the hysteresis and the difference between FC and ZFC resistances become smaller (Fig. 1), and ii) the temperature (marked by arrows in Fig. 1) where the difference between FC and ZFC $R(B=0)$ vanishes is reduced.

Conclusions

A detailed magnetotransport study in La$_{2-x}$Sr$_x$CuO$_4$ thin films shows hysteresis and memory effects at low $T$ over a range of dopings. Similar behavior was first observed in a single crystal La$_{1.97}$Sr$_{0.03}$CuO$_4$ and established to result from Coulomb interactions [1]. Here we find that these glassy effects are strongly diminished by adding more holes. The work is in progress to explore the superconducting range of dopings in more detail.

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References