UNUSUAL POSITIVE C-AXIS MAGNETORESISTANCE IN UNDERDOPED La$_{2-x}$Sr$_x$CuO$_4$

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Introduction

One of the puzzling issues in the studies of underdoped high-transition-temperature superconductors is the peculiar coupling between charge carriers and the background spins. The magnetoresistance (MR) has been a very useful probe of this unusual coupling [1]. Our experiments on lightly doped La$_{2-x}$Sr$_x$CuO$_4$ at low temperatures $T$ and relatively low magnetic fields $B$ (up to 9 T) have revealed a strong positive c-axis MR that exhibits hysteretic behavior [2]. In order to investigate the origin of this positive contribution to MR and its hysteretic effects, we use magnetotransport measurements at higher $T$ and higher $B$.

Experimental

The experiments were carried out in the 18 T superconducting magnet with a He$_3$ system in SCM2. We have performed c-axis magnetotransport measurements on a high quality single crystal of La$_{2-x}$Sr$_x$CuO$_4$ with $x=0.03$ in $B$ parallel and perpendicular to the c-axis. All the data were collected by sweeping $B$ at fixed $T$ in the range 0.6 – 50 K. MR was measured using a standard four probe ac technique at 7 Hz in the Ohmic regime. We paid particular attention to make sure that our data are not adversely affected by the eddy-current heating.

Results and Discussion

We have established that the hysteretic behavior of the longitudinal ($B||c$) MR (LMR), previously observed in this sample at low $T$, disappears at ~1.5 K. In order to avoid the memory effects and their influence on our data, the LMR below 1.5 K was measured after warming the sample up to 10 K and cooling it down to the desired $T$. While the LMR is positive and enormous (~100%) at low $T$ with no sign of a saturation in this $B$-range (Fig. 1 inset), it decreases in magnitude and crosses over to a negative MR with increasing $T$ (Fig. 1). At the same time, the crossover moves towards lower $B$. The positive contribution to MR disappears at $T\approx 50$ K. The behavior of the transverse ($B\perp c$) MR is similar to that of the LMR (Fig. 2), but the magnitude of the positive contribution to MR is significantly smaller for $B\perp c$, and higher $B$ are required to suppress it.

Conclusion

We have observed an unusual strong positive c-axis MR at low $T$ in both field orientations in the underdoped La$_{2-x}$Sr$_x$CuO$_4$. The crossover to a more conventional negative MR occurs at higher $B$ and $T$, indicating the presence of different mechanisms. We note that the appearance of the positive MR seems related to the onset of the insulatinglike transport in CuO$_2$ planes. The $T$ scale on which the hysteretic behavior of the MR develops does not correlate with the onset of glassy spin dynamics (~7 K).

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References