HYSTERESIS AND MEMORY EFFECTS IN C-AXIS MAGNETOTRANSPORT IN THE UNDERDOPED La$_{2-x}$Sr$_x$CuO$_4$

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Introduction

It is well established that lightly doped high-transition-temperature superconductors (HTS) exhibit spin-glass behavior at low temperatures $T$. The intertwining of spin and charge degrees of freedom in these structures suggests analogous features in the charge sector [1]. Indeed, in the hole-doped oxides La$_{2-x}$Cu$_{1-x}$Li$_x$O$_4$ and La$_{2-x}$Sr$_x$NiO$_4$, where the spin response is similar to that of La$_{2-x}$Sr$_x$CuO$_4$, the signature of the charge glassiness has been observed [2]. In order to probe the charge glass dynamics in the underdoped La$_{2-x}$Sr$_x$CuO$_4$, we employ a specific experimental procedure in magnetotransport measurements.

Experimental

C-axis magnetotransport measurements have been performed on a high quality single crystal of La$_{2-x}$Sr$_x$CuO$_4$ ($x=0.03$) in the temperature range $0.1 \, \text{K} \leq T \leq 0.6 \, \text{K}$ and in fields $B$ of up to 9 T parallel to the c-axis of the crystal. Magnetoresistance (MR) was measured using a standard four-probe ac technique (typically 7 Hz) in the Ohmic regime. The sweep rate of $B$ was kept low enough in order to avoid the eddy-current heating of the sample. Before each MR measurement at low $T$, the sample was warmed up to 10 K and then cooled down to the desired $T$.

Results and Discussion

The memory behavior of the MR is illustrated in Fig. 1. During the first $B$-sweep, the resistance increases and $R(B=0)$ never returns to its initial zero-field value. The subsequent sweeps to $B$ that are lower than the first one cause a reversible change of $R$. $R(B=0)$ changes irreversibly again upon the application of $B$ higher than the first applied $B$. Clearly, the system exhibits a memory: $R(B=0)$ is determined by the highest applied $B$. The hysteretic behavior of the MR is presented in Fig. 2. The arrows and numbers denote the order and the direction of $B$-sweeps. The system demonstrates return-point memory. The lack of congruency for the two subloops taken between the same $B$ but with different history (Fig. 2 inset) indicates the existence of interacting domains. The hysteretic effects decrease with increasing $T$.

Conclusions

We have observed for the first time glassy features in the transport of underdoped La$_{2-x}$Sr$_x$CuO$_4$, such as history dependence and memory effects. The results are consistent with the existence of the hole-poor antiferromagnetic domains in the CuO$_2$ planes, separated by the hole-rich domain walls. However, further work is required in order to arrive at a conclusive picture of the charge inhomogeneities in underdoped cuprates.

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References