LOW-TEMPERATURE RESISTANCE NOISE STUDY IN UNDERDOPED CUPRATES

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Introduction

Studies of high-transition-temperature superconductors (HTS) in the underdoped regime have revealed spin glass ordering at low temperatures, and suggested analogous effects in the charge sector [1]. The notion of charge glassiness is further supported by the measurements of the dielectric constant in La$_{2-x}$Sr$_x$CuO$_4$ and La$_{2-x}$Sr$_x$NiO$_4$, the materials which, although not superconducting, exhibit the spin response that is almost identical to that of cuprate superconductors [2]. In order to probe the dynamics of charge carriers in the underdoped HTS La$_{2-x}$Sr$_x$CuO$_4$, we employ resistance noise spectroscopy, a technique that has proved to be extremely successful in studies of various glassy systems.

Experimental

Measurements of resistance fluctuations were carried out on a single crystal of La$_{2-x}$Sr$_x$CuO$_4$ with $x=0.03$. In order to minimize the effects of contact noise and temperature ($T$) fluctuations, resistance noise was measured using a five-probe balanced bridge technique (Fig. 2 inset). The excitation current $I$ was kept low enough to avoid heating of the sample. The background noise was measured by setting $I=0$ for all $T$. This white noise was subtracted from the measured power spectra.

Results and Discussion

Fig. 1 shows the fluctuations of resistance $\Delta R = R - \langle R \rangle$, where $\langle \rangle$ denotes the time average, measured along c-axis at different $T$. It is apparent that the amplitude of the fluctuations increases as $T$ decreases. A typical power spectrum $S_R$ of the relative fluctuations $\Delta R/\langle R \rangle$ is presented in Fig. 2. The spectra follow the empirical law $S_R \sim 1/f^\alpha$, where $\alpha$ increases dramatically from $0.6$ to $1.7$ as $T$ decreases from $0.3$ K to $0.1$ K. The observed non-Gaussian noise is also analyzed by calculating the second spectrum, a fourth order noise statistic. The second spectra are found to be non-white in the entire $T$ range studied so far, strongly suggesting cooperative charge dynamics. These results are similar to those obtained in some Coulomb glass systems [3].

Conclusions

While our results support the notion of a charge glass order in the underdoped La$_{2-x}$Sr$_x$CuO$_4$, further measurements over an extended temperature range, in a magnetic field, as well as noise measurements of the in-plane resistivity are necessary in order to obtain more definitive information on charge ordering and the nature of the electronic phases in HTS.

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References