LOW TEMPERATURE ELECTRONIC-MASS ENHANCEMENT IN THE NORMAL STATE OF La$_{1.78}$Sr$_{0.22}$CuO$_4$

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The microscopic mechanisms that produce high Tc superconductivity have remained a mystery since their discovery almost two decades ago. The theoretical proposal of a quantum critical point (QCP) inside the superconducting region of the temperature-doping phase diagram (Fig. 1, inset), which could be responsible for it, has generated an intense experimental effort with limited success so far [1,2]. We used a calorimeter made out of Si and plastic materials, originally designed for operation in pulsed magnetic fields [3], to measure the specific heat vs. temperature in a 10.9 mg single crystal sample of La$_{1.78}$Sr$_{0.22}$CuO$_4$ (LSCO 0.22 AC). The sample selected for this experiment was cut from the same crystal that produced a piece (LSCO 0.22 AB) that displays linear electrical resistivity between Tc = 32 K and room temperature (Fig 1A). A linear temperature dependence in the resistivity is considered signature of quantum critical regime.

When a magnetic field of 45 T is applied along the c-axis the linear-in-T range is observed down to approximately 5 K, where the resistivity saturates at 15 $\mu\Omega$cm. This remarkable behavior has not been observed in other compositions in the series La$_{2-x}$Sr$_x$CuO$_4$. Low field ($\mu_0 H \leq 15$T) specific heat measurements were done in a superconducting magnet, while measurements up to 45 T were accomplished in the 45 T hybrid magnet at the National High Magnetic Laboratory, Tallahassee, Florida. From these measurements, the Sommerfeld coefficient $C/T_0$ was extracted and plotted vs $(H)^{1/2}$ in Figure 1(B). An apparent electronic-mass enhancement over the $H^{1/2}$ dependence expected in the vortex state of $d$-wave superconductors is observed as the magnetic field approaches $H_{c2}$. This enhancement could be a consequence of the QCP uncovered only after suppressing superconductivity with a magnetic field of 45 T. Additional measurements to reduce the error bars in the present sample, as well as measurements for other doping values x are under course.

Figure 1. (A) The in plane resistivity $\rho_{ab}$ is linear in temperature and extrapolates to zero at T=0. The resistivity measured at 45 T is displayed in blue, slightly higher than the H = 0 values in the normal state due to positive magnetoresistance. Inset: schematic (T,x) phase diagram showing the expected pseudogap line ending at a quantum critical point. (B) Sommerfeld coefficient measured in sample LSCO 0.22 AC in a superconducting magnet for magnetic fields $\mu_0 H \leq 15$ T, and in a hybrid magnet up to 45 T. A deviation from the $H^{1/2}$ law is observed above 40T.

References