Magnetotransport properties of $Y_{1-x}Pr_xBa_2Cu_3O_{7-\delta}$ single crystals

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Abstract

Magnetotransport investigations of $Y_{1-x}Pr_xBa_2Cu_3O_{7-\delta}$ ($x = 0,\ 0.13,\ 0.2,\ 0.32,$ and 0.42) single crystals revealed for $x \geq 0.20$ a two regime pseudogap with a crossover at a temperature $T_{cr}(x)$. For $T > T_{cr}$, the results conform with the picture of the pseudogap with its origin in the near antiferromagnetic Fermi liquid renormalized by the strong superconducting fluctuations. Between T_c and T_{cr}, there is a vortex-like response in magnetoresistivity.

Key words: magnetoresistivity; vortex-like excitations; pseudogap; $Y_{1-x}Pr_xBa_2Cu_3O_7$.

Charge carrier density in high temperature superconductors (HTS) is triggered by the amount of oxygen or by other doping. As dopant, praseodymium exhibits special advantages: *i*) the compound series $Y_{1-x}Pr_xBa_2Cu_3O_7$ is isomorphous to $YBa_2Cu_3O_7$ for $0 \leq x \leq 1$; *ii*) with increasing Pr content, the O2p-R4f Fahrenbacher-Rice band crosses the Fermi level and begins to exhaust the CuO_2 $pd\sigma$ band of holes; *iii*) the integrity of the Cu-O chains is preserved even in strongly Pr-doped HTS. So, changing Pr content allows the sweep of the whole behavior of cuprates, from optimally doped to strongly underdoped, at a fixed oxygen content.

It is known that in underdoped HTS, below a temperature $T^*(x)$, a **k**-dependent *pseudogap* (PG) in the quasiparticle density of state (DOS) opens. There are two models put forward to explain the PG, both based on the existence of strong superconducting fluctuations (SCF) in underdoped HTS. One model considers the PG as a continuation of the near antiferromagnetic Fermi liquid (NAFL) renormalized by the strong SCF. In the other model, the PG is the result of the loss of the coherence of the superconducting state due to strong phase fluctuations of the order parameter. In both models a momentum-dependent gap in the spectral weight of quasiparticles results from their interaction with SCF.

We used resistivity and angular magnetoresistivity measurements on $Y_{1-x}Pr_xBa_2Cu_3O_7$ ($x = 0.0, 0.13, 0.20, 0.32,$ and 0.42) to shed light on the physics underlying the PG. Depending on the temperature range, the data agree with the former model close to T^* and with the latter one close to T_c, suggesting a crossover between two subregimes of the PG.

Electrical measurements were performed on single crystals of $Y_{1-x}Pr_xBa_2Cu_3O_7$ using a six-lead configuration [1]. The samples fabrication is given elswhere [2].

As expected, the critical temperature is supressed with increasing Pr content from 92 K for $x = 0.0$ to 39 K for $x = 0.42$, while the normal-state resistivity strongly increases. The T dependence of ρ_{ab} is linear for $x = 0.0$ and 0.13, but a quadratic contribution is present in the former. For $x \geq 0.20$, the linearity range moves to higher T, outside of the measured T range, and PG opens. Within this range of concentrations, $\rho_{ab}(T)$ exhibits a power-law dependence. The exponent α is $0 \leq \alpha < 1$ for $T_{cr} < T < T^*$, indicating an underlinear T dependence. Below T_{cr}, $\alpha > 1$ marks

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a regime with overlinear $\rho_{ab}(T)$. T_{cr} evolves to higher values (from 99 to 145 K) when Pr content is increased.

The behavior of the resistivity is consistent with the model of PG originating in the SCF renormalized NAFL [3]. Specifically, as T decreases, the **k**-dependent gap opens around hot spots, the Fermi surface approaches the magnetic Brillouin zone, and the area of hot spots widens on the account of the cold spots. This would give rise to an increase in resistivity. However, the fast decrease of $\rho_{ab}(T)$ for $T_{cr} < T < T^{*}$ is the effect of the freezing of the low frequency spin fluctuation, the main scatterer in NAFL. At even lower T, the hot spots spread, and the increase of the gap makes the resistivity cease its rapid decrease.

Magnetotransport reveals further aspects of the processes involved in the two subregimes. We extracted the *orbital magnetoresistivity* as $\Delta\rho_{ab} = \left|\frac{\rho_{ab}(90^o)-\rho_{ab}(0)}{\rho_{ab}(0)}\right|$ from the angular magnetoresistivity. The magnetocon-

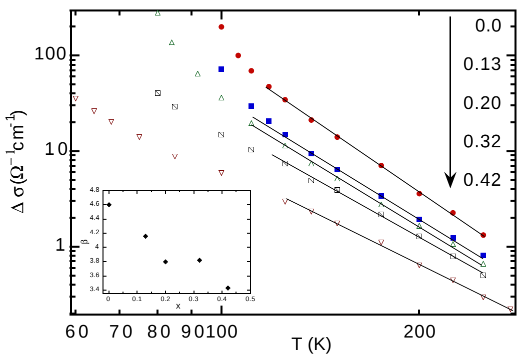

Fig. 1. Log-log plot of magnetoconductivity $\Delta\sigma$ vs temperature T. Inset: Dependence of exponent β on Pr content x.

ductivity $\Delta\sigma_{ab} \approx -\frac{\Delta\rho_{ab}}{\rho_{ab}^2}$, follows the law $\Delta\sigma_{ab} \propto T^{-\beta}$ for $x = 0.0$ and 0.13 at all T, and above $T_{cr}(x)$ for $x \geq 0.20$ (Fig. 1). The exponent β decreases from 4.6 for $x = 0.0$ to 3.35 for $x = 0.42$ (see inset to Fig. 1). The upper limit value of β is in good agreement with the prediction of NAFL [4]; i.e., $\Delta\sigma_{ab} \propto (T + T_0)^{-1.5}T^{-3}$, where T_0 is a reference temperature. The decrease of β in the PG regime for $T > T_{cr}$ is consistent with the model developed by Kontani [5]. For $T < T_{cr}$, the power law in $\Delta\sigma_{ab}(T)$ fails.

The angular magnetoresistivity $\frac{\Delta\rho_{ab}}{\rho_{ab}}(\theta)$ exhibits the expected $\sin^2\theta$ dependence, which, however, is no longer valid below T_{cr}. Subtracting the $\sin^2\theta$ term, we have obtained a θ dependence similar to the magnetoresistivity below T_c due to flux flow (see Fig. 2). This flux-flow like response (FFR) suggests the presence of vortex-like excitationa between T_c and T_{cr}. We mention that such vortex-like excitations were also reported in other type of measurements[6,7].

In summary, we performed a detailed study of the charge transport within the pseudogap PG state

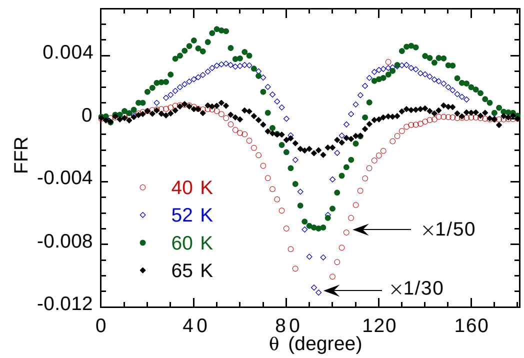

Fig. 2. Angular flux-flow like response (FFR) for $x = 0.32$ and $T = 60$ and 65 K after subtracting the normal state $sin^2\theta$ term. For comparison, the FFR in the superconducting state (T=40 and 52 K) is also shown with empty symbols

and of its evolution with underdoping in Pr-doped $YBa_2Cu_3O_7$. We found two regimes inside PG, a high temperature one which is consistent with the model derived from near antiferromagnetic Fermi liquid with renormalization due to strong superconducting fluctuations, and a low temperature regime where the effect of the gap is enhanced and where fingerprint of vortex-like excitation are arresting.

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