ZEEMAN-SCALED PSEUDOGAP IN SUPERCONDUCTING ELECTRON-DOPED CUPRATES

L. Krusin-Elbaum (IBM T.J. Watson Research Center); T. Shibauchi, T. Kawakami, Y. Terao, M. Suzuki (Kyoto University, Department of Electronic Science and Engineering)

Superconductivity in cuprates can be induced by doping the antiferromagnetic (parent) Mott insulator compound with either electrons or holes. By many appearances, however, the phase diagram on the two sides of the doping divide seems to be particle-hole asymmetric. In addition to lower transition temperatures, T_c, in electron-doped (*n*-type) cuprates the antiferromagnetic phase persists to much higher doping levels, while superconductivity is observed in a narrower doping range. A feature that dominates the normal state phase space is the anomalous depletion in the density of states referred to as pseudogap. It is ubiquitous in the underdoped hole-doped (*p*-type) cuprates, and has been also reported in underdoped albeit *non-superconducting* $Nd_{2-x}Ce_xCuO_{4-\delta}$. The relevance of this pseudogap to superconductivity has not been established, and a question remains as to even the pseudogap existence in the normal state of *superconducting* cuprates of *n*-type.

To probe the pseudogap in *n*-type materials we performed first interlayer transport measurements on 30 nm-thin mesa structures fabricated from superconducting $Sm_{2-x}Ce_xCuO_{4-\delta}$ (SCCO) single crystals — structures sufficiently thin to be free of recently reported partial epitaxial decomposition problems [1]. This enabled us to uncover the intrinsic behavior of the interlayer magnetoresistance (MR) and compare it to the bulk behavior in fields up to 45 T (see Figure 1).

We find that in one key aspect, the *p*- and *n*-type superconducting cuprates are surprisingly similar; the observed behavior of negative MR establishes a simple Zeeman connection of the pseudogap onset temperature T^* (~ 38 K) to its closing field H_{pg} (~ 28 T), suggesting a common (spin correlation) origin of the pseudogap, see inset in Fig. 1a.

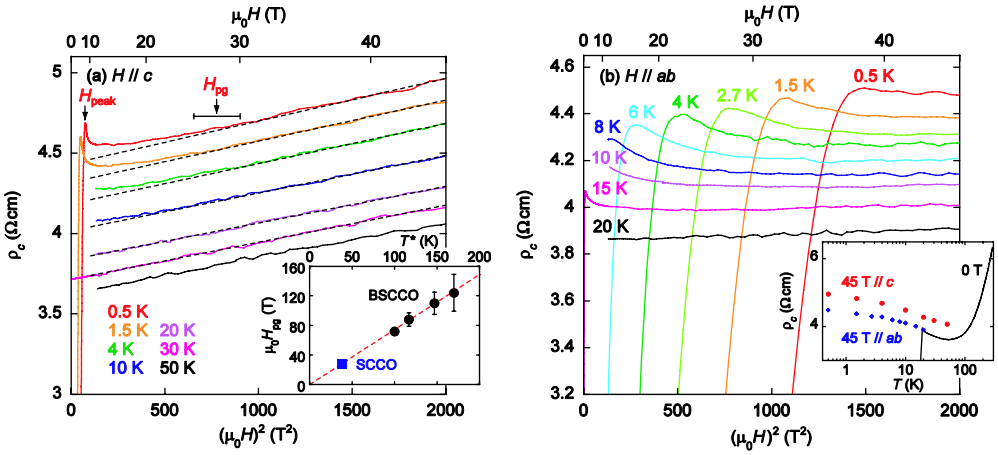

Figure 1. ρ_c vs. H^2 at various temperatures in an SCCO bulk sample for (a) $H \parallel c$ and (b) $H \parallel ab$. Dashed lines are high-field fits to H^2 dependence. Insets: (a) H_{pg} (at low T) vs. T^* (at 0 T) in SCCO (square) and overdoped BSCCO (circles) [2,3]. Dashed line is the Zeeman scaling line with $g = 2$. (b) T-dependencies of ρ_c of the bulk sample without field (solid line) and in 45 T (filled symbols).

All observed intrinsic features in *n*-type SCCO consistently support the presence of the pseudogap with the origin analogous to the one in *p*-type cuprate superconductors. The energy scale T* ~ 38 K at zero field in our $x \sim 0.14$ SCCO samples is considerably smaller than T* > 300 K in underdoped BSCCO for $p \sim 0.14$ [Ref. 2]. This begs an intriguing question as to the real doping level in the electron-doped cuprates. With this uncertainty of *n*, the smallness of the pseudogap energy scale in SCCO may be simply due to an undercount of the doping level, and the electron-hole asymmetry of the pseudogap scale may not be as severe as it appears.

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References

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