Point Contact Spectroscopy of Pr$_{2-x}$Ce$_x$CuO$_4$ in High Magnetic Fields

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Introduction

The normal state of copper-oxide (cuprate) superconductors has been the subject of intense research because it may hold the key to understanding the mechanism leading to the observed high-critical temperatures ($T_c$) in these materials. In conventional superconductors both the formation and condensation of paired carriers into a zero resistance state occurs at $T_c$, which is accompanied by the formation of the superconducting gap. A striking feature of cuprate superconductors is the formation of a gap in the density of states well above $T_c$. Although, the pseudogap has been studied extensively in hole-doped cuprates mainly by probing the region outside the superconducting dome in the temperature - hole-doping ($T - x$) phase diagram, the presence of a pseudogap in electron-doped cuprates remains controversial.

Experimental

Point contact spectroscopy (PCS) is similar to scanning tunneling spectroscopy, in the sense that the current injection occurs between a sharp tip and the sample. However, in PCS the tip is actually in physical contact with the sample. Hence, PCS is less susceptible to mechanical vibrations than scanning tunneling spectroscopy, which is an important factor to consider when choosing a measurement method for the water-cooled magnets in the DC High Field Facility at the National High Magnetic Field Laboratory in Tallahassee (NHMFL). The PCS data were taken using a custom built probe designed for operation in the 32 mm bore DC field magnets at the NHMFL [1]. The PCCO crystals were grown by the self-flux technique followed by an oxygen reduction procedure to achieve a $T_c \approx 21 \pm 0.8$ K.

Results and Discussion

Fig. 1(a) shows the variation of the point contact spectra as a function of magnetic field. The weak dependence of the spectra on magnetic field for $B > 10$ T is clear from the figure. Fig. 1(b) shows that the normal state gap (NSG) would collapse at an extrapolated magnetic field value of about 90 T [2]. The inset shows that the NSG is similar to the square root anomaly found in the density of states of disordered conductors.

Conclusions

We have studied the density of states near the Fermi level in the normal state of the electron-doped cuprate Pr$_{2-x}$Ce$_x$CuO$_4$ ($x = 0.15$) using point contact spectroscopy. We have observed a normal state gap in the density of states, which persists even in a magnetic field of 31 T. The weak magnetic field dependence of the normal state gap leads to two possible explanations: (1) The pseudogap closing field is higher (by about a factor of 3) than expected from a pure Zeeman relation and therefore, preformed pairing above $T_c$ is not the origin of the pseudogap or (2) the NSG observed in electron-doped cuprates is not analogous to the pseudogap in hole-doped cuprates. Instead it is formed due to electron-electron interactions at the surface of electron-doped cuprates.

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References