In-Plane Quasi-Particle Tunneling into Bi$_2$Sr$_2$CaCu$_2$O$_8$

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In-plane quasi-particle tunneling into Bi$_2$Sr$_2$CaCu$_2$O$_8$

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Planar tunneling spectroscopy is performed into the a-b plane of the high-temperature superconductor Bi$_2$Sr$_2$CaCu$_2$O$_8$. The tunneling spectra exhibit a zero-bias conductance peak (ZBCP). Preliminary studies as a function of temperature, crystallographic orientation, magnetic field magnitude and direction confirm the ZBCP is an Andreev bound state (ABS) at zero energy. Below 5K, a depletion in the density of states at zero energy is observed.

A study of planar quasi-particle tunneling spectroscopy into the a-b plane direction of optimally-doped (T$_c$=95K) Bi$_2$Sr$_2$CaCu$_2$O$_8$ (Bi2212) is reported. Junctions are fabricated on 300μm thick single-crystals embedded in epoxy and polished to expose a surface parallel to the c-axis. Polishing is done in a dry, dust-free, nitrogen atmosphere, using Al$_2$O$_3$ and diamond polishing paper. A resulting surface roughness of ~80Å, is measured by AFM. An artificial barrier of CaF$_2$(10Å) and silver counter-electrode are subsequently deposited. Junction resistances of ~500Ω with temperature dependencies less than 40% from room to 1.2 K are obtained.

Fig 1 shows tunneling spectra taken at 10K for two different a-b plane crystallographic orientations, ~45 degree apart. The first spectrum, shows a gap-like feature at ~35 meV and a ZBCP. In comparison, the second spectrum shows a weaker gap-like feature and a more pronounced ZBCP. The energy width of the ZBCP, that it only appears below T$_c$ for all five junctions studied, and the crystallographic orientation dependence of the tunneling conductance are all consistent with identifying the ZBCP as an ABS at the surface of Bi2212, as expected for certain surfaces of an unconventional superconductor[1,2].

The tunneling spectra for several magnitudes of magnetic field applied parallel and perpendicular to the c-axis is presented in Fig. 2, top and bottom panels, respectively. Note that a stronger suppression of the ZBCP is observed with the field applied parallel to the c-axis. This anisotropy is consistent with that expected for the Doppler shift of an ABS under applied field [3,4], $v_F\cdot p_s$, where $v_F$ is the Fermi velocity of the quasiparticles in the ABS and $p_s$ is the superfluid momentum induced by the applied field. The inset to the top panel demonstrates a hysteresis obtained in the H//c geometry, with the field be-
Figure 2. Field dependence of the ZBCP: top panel: \(H/\langle c = 0, 0.3, 1, 2, 3, 4, 6, 9\) T. Bottom panel: \(H \parallel c = 0, 6, 9\) T. Inset: Hysteresis in ZBCP height normalized to value at 50mV.

A dip around zero bias is observed to deepen with decreasing temperature below 4.5K in two junctions measured, as shown in Fig. 3. Data taken at 1.5K convolved with the derivative of the Fermi function at a higher temperature, is compared with actual data obtained at that higher temperature. The dip at zero-bias cannot be accounted for by thermal population effects alone, as shown by the inset for the case of T=4.5K. We attribute the dip to a depletion in the density of states at zero energy. The possibility of a broken-time reversal symmetry state at a disordered interface is being investigated.

Figure 3. Temperature dependence of low-bias tunneling conductance for \(T = 8, 6, 4.5, 3.5, 2.5, 2, 1.5\) K. Inset: Data taken at 1.2K convolved to 4.2K (dotted) and experimental data at 4.2K.

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