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GIANT TUNNELING ANISOTROPY OF A HIGH TEMPERATURE SUPERCONDUCTOR

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Abstract. We have performed tunneling measurements on break junctions from $Bi_2Sr_2CaCu_2O_8$ single crystals. We have found that for tunneling parallel and perpendicular to the CuO planes the tunneling spectra, and their temperature dependence, are entirely different. For "in plane" tunneling a gap structure is visible at low temperatures (2Δ=55meV), while the conductance is nearly independente of the voltage and temperature above T_c. For "perpendicular" tunneling the temperature dependence is well approximated with a logarithmic function, with no reference to T_c.

The two dimensional (2D) naure of the normal state electronic transport in copper oxide based high temperature superconductors is well estabilished by now , but little is known about the anisotropy of the superconducting energy gap (2Δ). Somewhat controversary results on the gap anisotropy reported in the literature (summarysized by Kirtley in ref. 1) are probably due to the ill-defined tunneling geometry.

In order to study the energy gap in the CuO plane (ab plane) and between the planes (c axis) we have performed tunneling measurements on break junctions of $Bi_2Sr_2CaCu_2O_8$ single crystals in the following way.

For the "ab plane" tunneling measurements we cleaved an approximately 1000 A thick, 100μm wide strip from a single crystal of $Bi_2Sr_2CaCu_2O_8$ and mounted it on a crystal of $Bi_2Sr_2YCu_2O_8$ (a high resistance semiconductor). Electrical contacts to gold wires were made by silver epoxy. After heat treatment the contact resistances were 1Ω, and a typical room temperature sample resistance was 300Ω. The $Bi_2Sr_2CaCu_2O_8$ /$Bi_2Sr_2YCu_2O_8$ assembly was glued to an elastic strip of metal and fixed on the cold finger of a He flow cryostat. A precision-mounted screw pushed the back side of the metal strip. When the temperature reached around 10K, a "break junction" was produced by bending the metal strip with the screw. The screw was driven manually by a screwdriver, inserted through the wall of the cryostat.

For "c axis" tunneling we first prepared electrical contacts on the opposite, cleaved surfaces of a crystal. We glued the sample to the inside of a U shaped elastic strip so that the electrical contacts were facing the two arms of the U. We cooled the device in vacuum and we observed typical c axis conductance: resistivity increasing with decreasing temperature, turning to superconductivity at T_c . At low temperature the crystal was cleaved by increasing the separation between the arms of the U with the screw mechanism. The break junction was formed between the freshly cleaved surfaces.

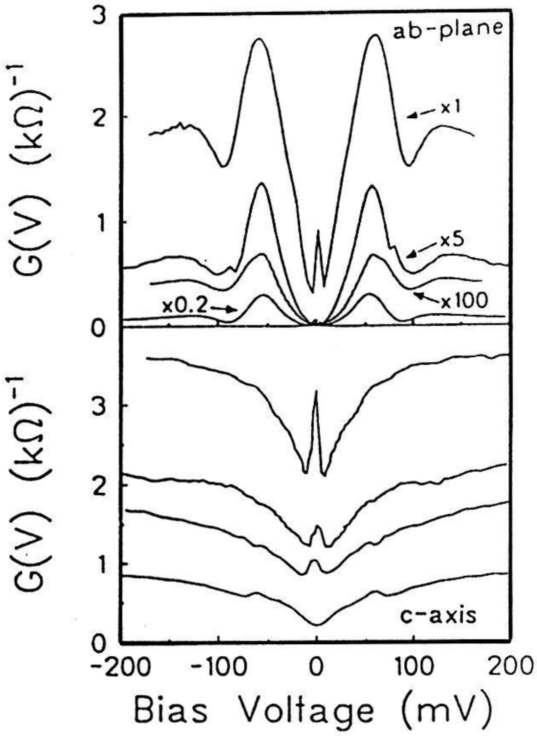

Fig.1. Differential conductance G vs. bias voltage at T=9K for several "ab plane"and "c axis" break junctions.

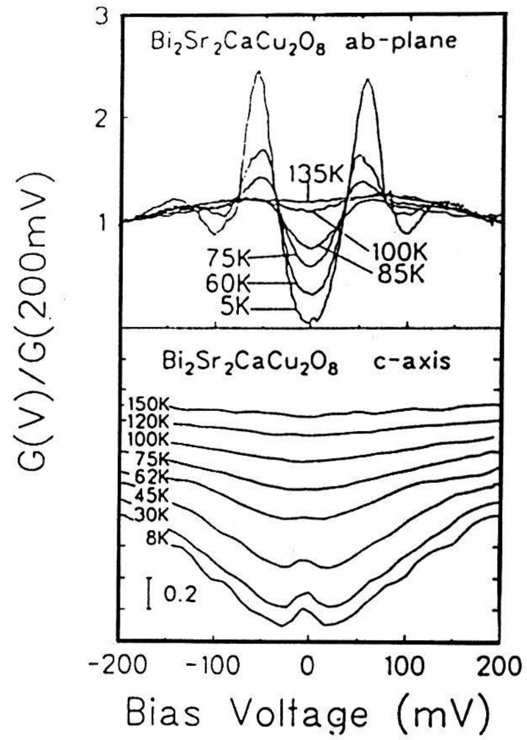

Fig.2. Tunneling conductance for "ab plane" and "c axis" tunneling at several temperatures as indicated in the Figure.

The results of tunneling conductances are shown in figs 1 and 2. The conclusions are the following:

a. The "ab-plane" tunneling exhibits a gaplike structure around V=55mV, while no well pronounced structure is seen in the c direction.

b. At low temperatures the zero bias conductance is zero for ab-plane tunneling while it is finite for c-axis tunneling.

c. At large bias the ab-plane tunneling conductance decreases while the c-axis conductance increases with increasing bias voltage.

Detailed description and discussion of the results is given in ref. 2.

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