Physica C 162-164 (1989) 1059-1060
North-Holland

ELECTRON TUNNELING IN THE HIGH T_c SUPERCONDUCTING CERAMIC $Bi_2Sr_2Ca_1Cu_2O_{8+\delta}$

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Tunneling experiments were made on different types of tunnel junctions. In single crystals we used tungsten point contact junctions and we observed the energy gap feature. The ratio for this superconductor gives $2\Delta/K_BT_c$=7.5. Using bulk Bi-based material we studied break junctions which present very good electrical stability from room temperature to 4.5 K. We observed interesting features that are related to the energy gap. The temperature dependence of the features shows a BCS-like behavior.

Ceramic superconductors have been exhaustively studied since their discovery in 1986. One of the main features of the superconductive state: the energy gap, has been difficult to measure[1]. This difficulty probably is related to sample granularity, rapid oxygen loss and surface degradation.

Two kinds of samples were used for the tunneling experiments, single crystals and bulk sintered ceramics, both of the 80 K phase Bi-material. Point contact tunnel junctions were made driving a tungsten needle into the surface of the single crystal in the (001) face, to avoid surface problems. The needle was sharpened using electrochemical etching. Many junctions were made and the clearest results were found with dV/dI (zero bias) of the order of 30-300 KΩ. Lower resistance junctions displayed a large zero bias anomaly.

Fig. 1a and 1b show the I-V, dV/dI and d^2V/dI^2 characteristics measured[2] at 4.5 K. From these figures we determined an energy gap value of $\Delta \cong 25.5$ meV. and from this value the ratio $2\Delta/K_BT_c$=7.5, structure can be observed at $\pm$67 meV. Fig. 2 shows another structure at higher energies of $\pm$120meV.

Many tunnel junctions were measured, and only a few of them gave the clean structures shown. However, the results presented are reproducible and taken from different sets of measurements.

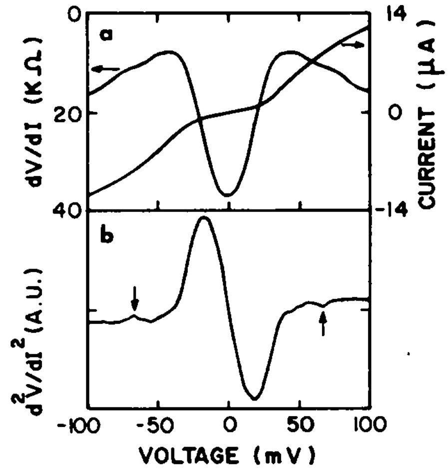

FIGURE 1. Point contact characteristics a) I-V and dV/dI. b) d^2V/dI^2 - V.

The temperature dependence of the energy gap with point contact tunnel junctions is almost impossible to measure and all attempts failed, however another kind of junction was prepared.

This junction was made with a pellet of 80 K phase material[3]. X-ray powder diffraction showed clean structure with the 80 K phase (2212). The pellet was broken in two pieces, glued with high vacumm epoxy and mounted on a sapphire holder. The values of differential resistance at zero bias in this junction were always in the range of 60-600 Ω .

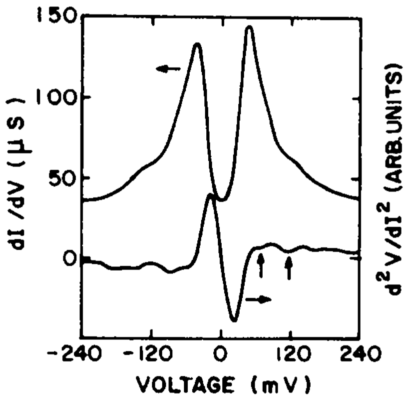

FIGURE 2. dI/dV and d^2V/dI^2 vs V at higher energies

Fig. 3 shows measurements of the dI/dV vs V characteristics of the break junction at various temperatures. Three peaks can be observed[4] at 23.9, 29.1 and 46 meV. We are interested in the temperature dependence, which can be related to the energy gap.

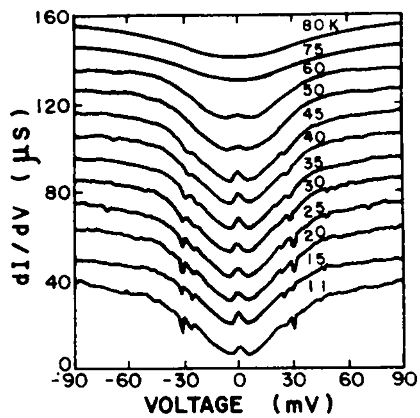

FIGURE 3. dI/dV vs V at various temperatures for the break junction

In Fig. 4 we plot the temperature dependence of the 23.9 meV. feature. The data are shown as crosses. It is worth observing that the three features show a similar behavior with temperature and the 23.9 and 29.1 meV. peaks are close to the subharmonic values of the 46 meV peak, that we associate with the energy gap.The values of $2\Delta/K_BT_c$ for the peaks are 3.97, 4.83 and 7.64 respectively, using the measured critical temperature of the sample $T_c(R=0)=70$ K. The BCS prediction is shown in the figure as a full line. In order to compare it to the experiment, one has to normalize the temperature using $T_c=60$ K. The results are shown as dots with error bars. The renormalization can be justified if one considers a depression of T_c in the surface due to two factors: The short coherence lenght which depresses the order parameter, and the oxygen loss.

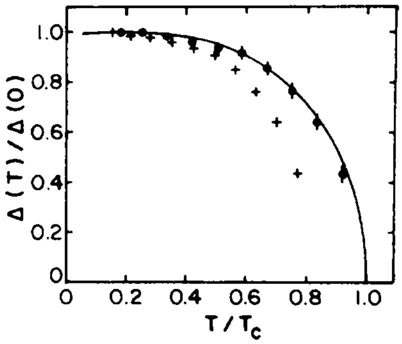

FIGURE 4. Temperature dependence of the gap.

In summary we obtained a clear measurement of the gap in the single crystal point contact junction, which has a value of 25.5 meV. and $2\Delta/K_BT_c=7.5$. Results with the bulk ceramic give features with a similar value which have a BCS-like temperature dependence. We also observe structure at ±67 meV. and ±120 meV, which could be related with the pairing mechanisms of these superconductors.

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