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Tunneling Study of High T_c $YBa_2Cu_3O_{7-\delta}$ Ceramic

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Abstract: The Pb-SiO-$YBa_2Cu_3O_{7-\delta}$ junctions were fabricated on the ceramic $YBa_2Cu_3O_{7-\delta}$ and the V-dI/dV characteristic was measured at temperatures ranging over from 4.4 to 94.1 K, and furthermore under several magnetic fields at 4.4 K. It was found that the temperature dependence of energy gap almost agrees with the one of the BCS theory, and the value of $2\Delta_0/k_BT_c$ is 4.06. This suggests that the superconducting mechanism of high T_c $YBa_2Cu_3O_{7-\delta}$ is something like the BCS theory.

Since the high T_c ceramic superconductor, Ba-La-Cu-O system had been discovered by Bednorz and Muller [1] at 1986, many high T_c ceramic superconductors have been developed. These oxide superconductors have not only a high critical temperature but also extraordinary properties which are different from predictions ofthe BCS theory. Thereby, it is most exciting problem for a physisist to make clear a microscopic mechanism of the superconducting state. The mechanism intimately relates to the electronic states near the Fermi energy.

The tunneling spectroscopy is powerful probe in elucidating the mechanism, because it gives direct informations about the electronic states near the Fermi energy with high resolving power.

The tunnel junctions were fabricated by depositing SiO as a tunnel barrier and then Pb on $YBa_2Cu_3O_{7-\delta}$ ceramic with T_c=88.5 K (the off-set temperature in a temperature dependence characteristic of resistance). The V-dI/dV characteristics were traced at temperatures ranging over from 4.4 to 94.1 K as shown in Fig. 1. The scale of vertical axis is for the characteristic at 4.4 K. The V-dI/dV characteristic at 4.4 K has a valley centered at zero-bias and two peaks at ± 5 mV. These structures weaken with increasing temperature and disappear at temperature higher than 6.8 K and under the magnetic field higher than 1.2 kOe. Thereby, these structures come from a superconducting state of Pb.

The characteristic has two gentle curves ranging over from 10 mV (-10 mV) to

50 mV (-50 mV). These structures weaken with increasing temperature, and disappear higher than 80.5 K. Thereby, these structures come from the superconducting state of $YBa_2Cu_3O_{7-\delta}$. Each characteristic is normalized with the one at 94.1 K, which is in the normal state, and then an energy gap Δ at each temperature is obtained by using the Dynes' formula [2]

$$N_S(E)/N_N(0) = (E - i\Gamma) / \sqrt{(E - i\Gamma)^2 - \Delta^2} \quad .$$

The temperature dependence of energy gap is shown in Fig. 2, where Δ_0=15.5 meV, T_c=88.5 K. Here, the value of energy gap at 4.4 K, 15.5 meV is assumed to be equal to a value at 0 K, Δ_0. A solid line is the characteristic obtained by the BCS theory, and an open circle is the present value. As seen in Fig. 2, the present value agrees with the characteristic of BCS theory. Using Δ_0=15.5 meV and T_c=88.5 K, we obtain $2\Delta_0/k_BT_c$=4.06. The value, 4.06 is near 4.3 for the strong coupling superconductor Pb. Recently, Tachiki and Takahashi theoretically showed that the BCS theory modified with a charge fluctuation gives a high T_c and a weak isotope effect. Our results seem to support Tachikis' theory.

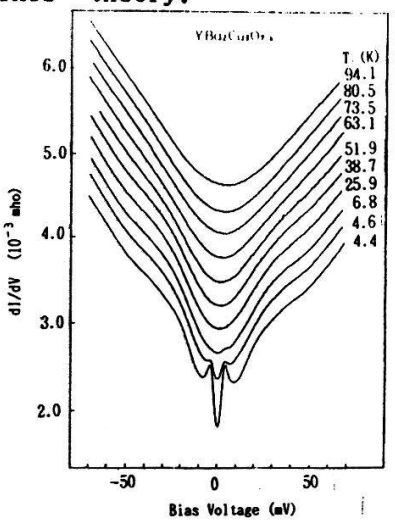


Fig. 1 V-dI/dV characteristics of Pb-SiO-$YBa_2Cu_3O_{7-\delta}$ junction at temperatures ranging over from 4.4 to 94.1 K.

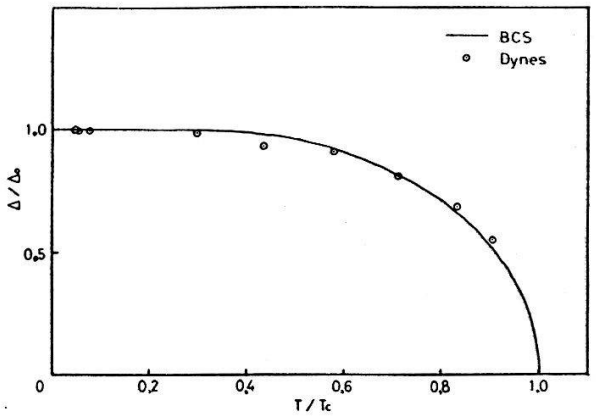


Fig. 2 Temperature dependence of energy gap for $YBa_2Cu_3O_{7-\delta}$. A solid line is the BCS characteristic, and a circle the experimental value.

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