JOSEPHSON EFFECTS ON $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ *

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The magnetic field and temperature dependence of the Josephson supercurrent are measured in different temperature ranges in order to study the tunneling effect in $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ samples. Causes for tunneling will be discussed.

1. Introduction

Recently high- T_c oxide superconductors have been discovered and numerous works [1, 2] have been done on this system. Regarding to the works of weak links, Nishino et al. [3] have studied the I - V characteristics of Josephson point contacts, Tsai et al. [4] have studied the dc and ac Josephson effect of crack junctions.

In this work we report the magnetic field and temperature dependence of the Josephson supercurrent in $\text{Pb}/\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ contacts. From the magnetic field dependence of the Josephson supercurrent, we want to demonstrate a phase coherence in the contacts. From the temperature dependence of the supercurrent, we want to study the dc Josephson tunneling in $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$.

2. Experimentals

The sintered samples of $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ were prepared from high purity Y_2O_3 , BaCO_3 and CuO powders. The samples were preheated in air at 950°C for one day, then pressed into pellets and annealed at 950°C in oxygen with a flow rate of about 20 cc/min for about 16 hrs followed by a twelve-hour annealing at 700°C . A

standard four-point method was used to measure the resistivity of the sample, and the resistance of $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ becomes zero at 92 K.

In studying the Josephson tunneling, the samples were $\text{Pb}/\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ contacts. In $\text{Pb}/\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ contacts, an insulating point was used to press a lead foil, which then formed the $\text{Pb}/\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ contact. The lead-foil was etched with solution of H_2O_2 and acetic acid. The purity of the lead-foil was 99.9995%. The external fields were shielded by layers of Mu-metal. A standard four-wire method was used to measure the I - V characteristics of the contacts.

3. Results and discussion

Fig. 1 shows the magnetic field dependence of the critical current density of $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ at

Fig. 1. Magnetic field dependence of critical current density in $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ at $T = 78$ K.

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Fig. 2. I - V characteristics of a $\text{Pb}/\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ contact.

Fig. 3. Magnetic field dependence of I_c in a $\text{Pb}/\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ contact with fields parallel to the surface of $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$.

78 K. The critical current density is sensitive to the external magnetic field, only a field of about 30 G, the critical current was depressed to a value which is about one-tenth the value at zero field. This sensitive response of the critical current to external magnetic fields tends to indicate there is a proximity grain structures in the sample and Josephson supercurrent flows through the grains via proximity effects.

Fig. 2 shows the I - V characteristics of a $\text{Pb}/\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ contact at 6.9 K, the supercurrent is zero up to $I_c = 460 \mu\text{A}$, above which the voltage of the weak link rises sharply. The normal state resistance of the contact was about 0.1Ω at 6.9 K. The $\text{Pb}/\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ contact had a resistance of about 1.2Ω at room temperature and a resistance of about 0.15Ω at liquid nitrogen temperature.

Superconducting contacts are two superconductors weakly coupled by small contact area, which is realized by pressing a sharp superconducting point on a flat superconductor. In fact, a thin oxide layer is formed so the contact is just a tunneling-type junction. To test these ideas in high- T_c superconductors, the magnetic field dependence of I_c was measured. The applied field is parallel to the surface of the $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ and the results are shown in fig 3. The solid line is a guide to the eyes. The magnetic field dependence of Josephson supercurrent is similar to that of tunneling junctions with SNS or SIS structures. Meissner-like behavior of I_c was observed at low magnetic fields and Fraunhofer-like behavior was found at higher fields. Tunneling-type junctions were clearly indicated.

Fig. 4 shows the magnetic field dependence of the supercurrent with fields perpendicular to the surface of the $\text{YBa}_2(\text{Cu}_{1-x}\text{Ag}_x)_3\text{O}_{7-\delta}$, $X = 0.03$.

Fig. 4. Magnetic field dependence of I_c in a $\text{Pb}/\text{YBa}_2(\text{Cu}_{1-x}\text{Ag}_x)_3\text{O}_{7-\delta}$ contact with fields perpendicular to the surface of $\text{YBa}_2(\text{Cu}_{1-x}\text{Ag}_x)_3\text{O}_{7-\delta}$, $X = 0.03$.

Fig. 5. Temperature dependence of I_c in a $\text{Pb}/\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ contact.

Fig. 6. $\log I_c$ versus T in a $\text{Pb}/\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ contact.

The solid line is a guide to the eyes. An oscillatory I_c versus H was also found in the contact.

Fig. 5 shows the temperature dependence of I_c

in $\text{Pb}/\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ contact. The data near T_c are shown in the inset. The solid line is a guide to the eyes. The I_c data increase linearly as one decreases the temperature down to 6.95 K. Below 6.95 K, the critical current increases more rapidly. The $\log I_c$ versus T curve is shown in fig. 6. At low temperature I_c increases exponentially which is similar to the theoretical prediction of $S_1\text{NS}_2$ junctions or $S_1\text{NIS}_2$ junctions [5]. In such junctions I_c is proportional to $\exp(-d_n/\xi_n)$ where d_n is the thickness of the normal and insulating layer, and ξ_n is the coherence length. For the $\text{Pb}/\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ sample reported here, a thin oxide layer is easily formed, which forms the $S_1\text{I}$ structure. The $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ disk may have a thin normal conducting layer, which form the NS_2 structure. Therefore the contact may have $S_1\text{INS}_2$ structures. For $S_1\text{NS}_2$ structure, the Pb-foil may be superconducting short with the high- T_c superconductors.

4. Conclusions

Josephson supercurrent was found in $\text{Pb}/\text{YBa}_2\text{CuO}_{7-\delta}$ contacts. The supercurrent is magnetic field dependent. This field dependence of I_c indicated that there is a phase coherence between Pb and high- T_c superconductor and the phase can be modulated by external fields.

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