Josephson Effects in U-Shaped $\text{YBa}_2\text{Cu}_3\text{O}_{7-y}$ microbridges

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We have fabricated U-shape $\text{YBa}_2\text{Cu}_3\text{O}_y$ high- T_c microbridges on $\text{SrTiO}_3(001)$ substrates. The bridge is microprocessed by means of photolithography and wet etching. The fabricated configuration of the bridge is 20 μm wide, 10 μm long and 10 - 40 nm thick. Current-voltage curves show a hysteretic behavior. The junction capacitance is 0.57 pF and the $I_c R_n$ product is 0.5 mV at 35 K. Shapiro steps are observed under microwave irradiation; voltage spikes are occasionally observed in current-voltage curves and are owing to the absence of the phase locking in the weak links.

Fabrications of various types [1-5] of high- T_c Josephson junctions has been of current interest because of the potential applications of Josephson junctions in superconducting instruments. In this work we fabricate U-shape microbridges of 20 μm wide, 10 μm long and 10 - 40 nm thick by photolithography and wet etching and report the current-voltage (I-V) characteristics and microwave effects of the bridges.

The $\text{YBa}_2\text{Cu}_3\text{O}_y$ (YBCO) films on $\text{SrTiO}_3(001)$ were prepared by sputtering a 51 mm stoichiometric YBCO target. A detailed description of the as grown films was reported in reference [6]. The as grown YBCO films were black, smooth and shining. The x-ray diffraction pattern shows a preferred orientation with the crystal c axis perpendicular to the plane of $\text{SrTiO}_3(001)$.

The main steps for making the U-shape microbridge were described as followings: We etched the as grown YBCO films into a long stripe line of 20 μm wide by photolithography and wet etching. A U-shaped channel of 10 μm long was etched across the YBCO stripe to form the microbridge. The weak link in the U-shape region is 20 μm wide, 10 μm long and 10 - 40 nm thick. The etching chemical were 1 cc of hydrochloric and 1 cc of methanol in 300 cc of the distilled water. The geometrical configuration of the fabricated U-shaped bridge is shown in the inset of Figure 1.

We measured the current-voltage (I-V) curves of the U-shape bridge at various temperatures with and without microwave irradiation. The microwaves with frequencies vary from 12 to 18 GHz were irradiated on the samples. The temperature of the sample was measured by a calibrated silicone diode.

Figure 1 shows the temperature dependence of the resistance of the YBCO bridge. The film shows T_c onset at about 90 K and a resistance tail in the temperature range between 82 K and 50 K. The resistance tail is due to the presence of the weak links in the U-shape region.

Figure 1 Resistance as a function of temperature for a typical U-shape YBCO bridge. The geometrical configuration of the bridge is shown in the inset; the bridge is 20 μm wide, 10 μm long and 10 - 40 nm thick.

Figure 2 shows typically the I-V characteristics of the U-shape weak links at 35 K. The I-V curves show a hysteretic behavior and concave downward features at a low current density. The hysteretic parameter $\alpha = I_{c1}/I_c$ was equal to 0.95 estimated from the hysteretic I-V curve at 35 K. The $I_c R_n$ product is 0.53 mV. If one uses the relation of α and β_j in reference [7], one obtains the dimensionless parameter $\beta_j = 0.92$, where $\beta_j = 1/\beta_c^{1/2}$ and $\beta_c = 2eR^2 C I_c / h$ is the Stewart-McCumber parameter.

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Using the normal state resistance, $R_n = 1.3 \, \Omega$, at 35 K, one gets the junction capacitance $C = 0.57 \, \text{pF}$ for the bridge. We have observed Shapiro steps under the microwave irradiation and the voltage step follows the relation: $V_n = nh\nu/2e$, where $n = 1, 2, 3, \dots$, h is the Plank constant and ν is the frequency of the microwave and e is the electronic charge. We attribute the results to the weak links in the U-shape region. We note that all the Shapiro steps in the I-V curves were rounded such that the steps have nonzero steps and voltage spikes were occasionally observed in I-V curves under the microwave irradiation as shown in Figure 2(b). The voltage spikes in the I-V characteristics seem to be related to the unlocked phase of the bridges

Figure 2 shows (a) I-V characteristics of YBCO bridge with and without microwave irradiation (b) voltage spikes were occasionally observed under microwave irradiation, the data were taken.

Figure 3 shows the temperature dependence of the critical current density of YBCO bridge. The temperature-dependent critical current data can be fitted to the formula: $I_c \propto (1 - T/T_c)^{\beta}$ with $\beta = 1.56$.

Figure 3 Temperature dependence of I_c in the YBCO bridge.

In summary, we report the fabrication of the U-shape microbridge in YBCO films by using standard photolithography techniques. The fabricated bridge is $20 \, \mu\text{m}$ wide, $10 \, \mu\text{m}$ long and $10 - 40 \, \text{nm}$ thick. The bridge shows hysteretic current-voltage characteristics. By shining microwaves to the bridge, the current-voltage characteristics show Shapiro steps. Voltage spikes were occasionally observed and occurred owing to the unlocked phase of the bridge. It is possible that the "junction" arises from weak links in the bridge.

References

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