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Observation of inverse a.c. Josephson effect in bulk Y-Ba-Cu-O possessing high T_c

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Abstract. Microwave-induced d.c. voltage due to inverse a.c. Josephson effect has been observed across bulk samples of Y-Ba-Cu-O. Variation of the d.c. voltage with small external magnetic field and temperature has been investigated. Our results indicate that weakly coupled superconducting grains exist up to 230 K.

Keywords. High temperature superconductivity; yttrium-barium-copper-oxide; Josephson tunnelling.

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It is well known that a d.c. voltage is induced across unbiased Josephson junctions by applied microwave radiations due to inverse a.c. Josephson effect (Langenberg *et al* 1966; Chen *et al* 1972). The d.c. voltage could be either discretely quantized or continuously varying. It is affected by applied external magnetic field and varies with microwave power. The continuously varying induced d.c. voltages have also been observed across bulk granular superconductors (Warman *et al* 1971; Saxena *et al* 1974; Yu and Saxena 1975).

We have observed microwave-induced d.c. voltage across several unbiased bulk samples of Y-Ba-Cu-O possessing high superconducting critical temperature. The samples are in the form of strips of dimensions 10 mm × 2 mm × 1 mm. The samples were prepared by direct oxide mixing technique described elsewhere (Jayaram *et al* 1987a). Typical resistance transition curve is as shown in figure 1. As may be seen the onset of superconductivity is at 91 K and the resistance becomes zero at 83 K.

For the microwave studies the samples are mounted inside an X-band wave guide and are irradiated with highly stabilized phase-locked microwave radiations having a stability of one part in 10^9 over a period of 2 hr. The d.c. voltage is measured using a high impedance nanovoltmeter. Correction for thermal e.m.f. is applied to each measurement. The overall uncertainty in the measurement of the induced voltage is $\pm 0{\cdot}1\ \mu$V which is mainly due to variation in the thermal e.m.f.

Figure 2 shows the variation of the microwave-induced d.c. voltage at liquid nitrogen temperature as a function of the microwave power. The lower curve shows the effect at zero magnetic field while the upper curve shows the effect at the finite magnetic field which is produced by passing a current of 250 mA in a single turn coil wound on the outer surface of the wave guide. The change in the magnitude of the induced voltage by the application of such a small magnetic field confirms that the induced voltage is due to Josephson effect between the weakly coupled superconducting grains of the sample.

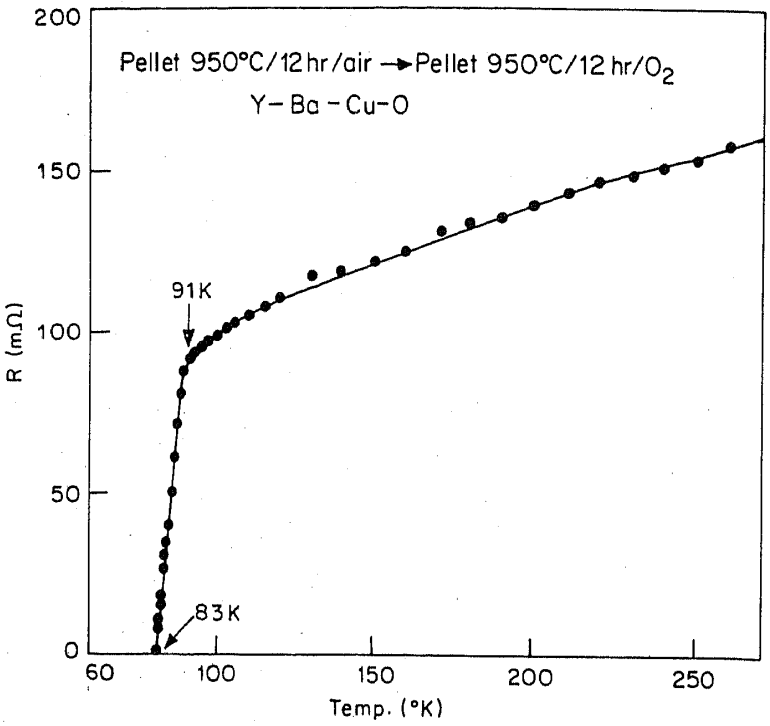

Figure 1. Resistive transition curve for the sample $Y_1Ba_2Cu_3O_{9-y}$.

The temperature variation of the microwave induced d.c. voltage for a fixed value of the microwave power is shown in figure 3. As the temperature is increased the induced voltage decreases, becomes constant at 150 K and disappears at 230 K. These results clearly indicate that weakly coupled superconducting grains are

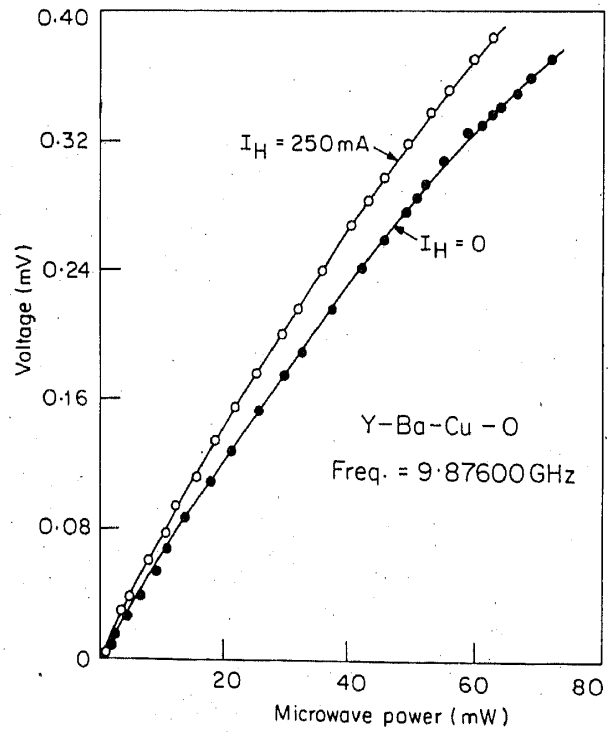

Figure 2. Variation of microwave-induced voltage as a function of microwave power at liquid nitrogen temperature.

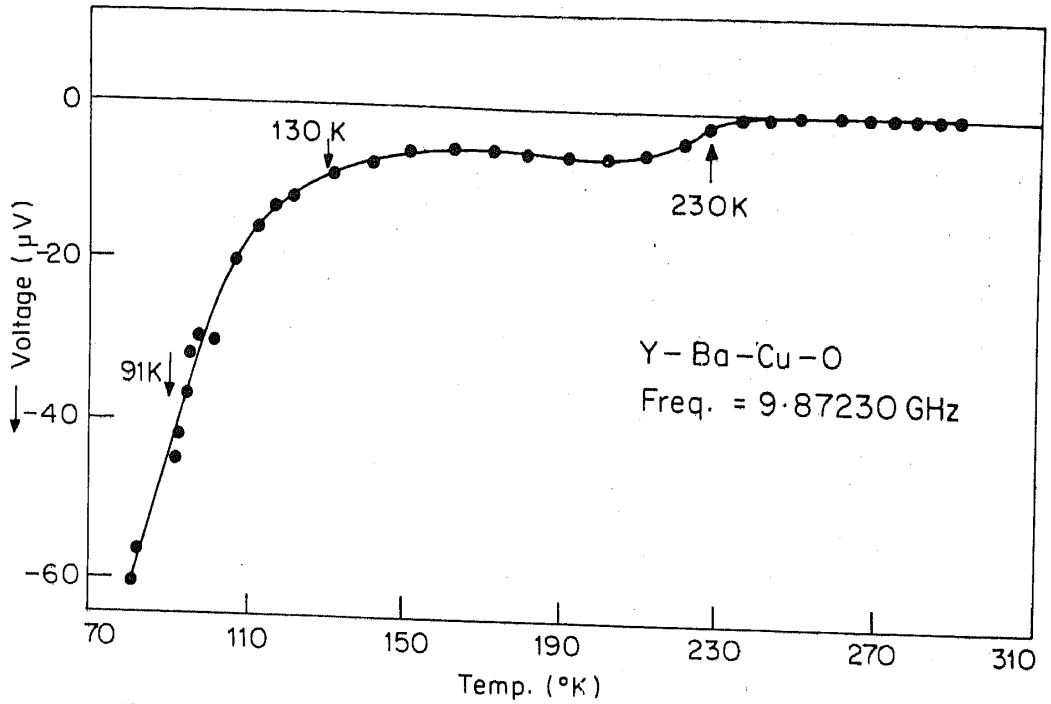

Figure 3. Temperature variation of the microwave-induced voltage for a fixed microwave power.

present in these samples up to as high a temperature as 230 K which are however not detected by resistive studies. In this context, it is interesting to mention that in a different series of samples reported elsewhere (Jayaram *et al* 1987b), the possibility of superconducting transition occurring above 230 K had been manifested by resistive studies. Their detailed inverse Josephson effect studies are currently in progress which will be reported later.

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