PREPARATION, MICROWAVE AND MAGNETIC FIELD RESPONSE OF YBaCuO THIN FILM MICROBRIDGES*

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Summary

On YBaCuO thin films, which were deposited at ambient temperature and were superconducting after post-deposition annealing in oxygen, microbridges and d.c. superconducting quantum interference devices (SQUIDS) were constructed by lift-off. Over a temperature range from 4.2 to >70 K the devices show well-developed Josephson-like behaviour when irradiated with microwaves. Also, SQUID operation can be observed in this temperature range.

Thin superconducting films of YBaCuO were sputtered by r.f.-magnetron onto MgO substrates from a stoichiometric ceramic target [1]. During the deposition, the films were kept at ambient temperature. The films were then annealed at 920°C in flowing oxygen, after which they show electrical transitions to superconductivity with zero resistance at about 80 K.

As a result of the low deposition temperatures, standard photoresist can be used for construction of the thin films by lift-off technique [2]. In that way, single microbridges as well as d.c. superconducting quantum interference devices (SQUIDS) and flux transformers were made. The width of the microbridges was below $10\text{ }\mu\text{m}$, the thickness of the films typically being 400 nm. The operating temperature of the resulting devices reveals that almost no degradation of the film properties takes place during this lithographic process.

For microbridge applications, low critical current densities J_c are desirable. Typically, films with critical current densities of $2 \times 10^5\text{ A cm}^{-2}$ at 4.2 K and 10^3 A cm^{-2} at 74 K were used for our measurements (Fig. 1), determined after construction of the devices and including the small degradation of the superconducting properties by the lithographic process.

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The microwave measurements were carried out using x-band (9.34 GHz) microwave equipment with a klystron source [3]. The incident microwave power was measured with a 30 dB direction coupler and the I - V characteristics were determined by a four-terminal method. The temperature in the helium cryostat can be varied between 4.2 K and room temperature.

On application of microwave power, well-developed microwave-induced steps in the I - V characteristics are visible. Increasing the power results in re-entrant behaviour of the step current values I_{cn} (Fig. 2), as is generally observed in Josephson junctions but not in wide microbridges. These measurements were carried out at different temperatures. The Bessel-function-like behaviour was observed at all temperatures up to 71 K, except at very low temperatures (4.2 K), as the available microwave power (6×10^{-2} mW) was not sufficient to suppress the I_{c0} in this case.

On application of an external perpendicular magnetic field, d.c.-SQUID operation can be observed. For these measurements, d.c.-SQUIDS with a coupling hole of $4200 \mu\text{m}^2$ and microbridges with a width of $40 \mu\text{m}$ each were chosen because of the lower critical current densities in the case of the polycrystalline films (2.5 kA at 4.2 K). Because of this polycrystalline structure of the films, the modulation behaviour is quite complicated at low ($T < 40$ K) temperatures. In this case, a very high modulation voltage was achieved ($V_{\text{mod}} = 20 \mu\text{V}$); the small modulation period indicates increase in SQUID sensitivity by enhanced flux compression. Nevertheless, the quite irregular modulation behaviour seems to stem from a network-like behaviour of the Josephson junctions in the microbridge region. At higher temperatures ($T > 40$ K) a clear SQUID modulation can be seen with modulation voltages up to $8 \mu\text{V}$. From these values a temperature-dependent effective area of the SQUID, a result of flux compression, of $6000 \mu\text{m}^2$ at 39 K and $4500 \mu\text{m}^2$ at 62 K can be deduced. Coupling of a single-coil superconducting flux transformer to the SQUID further extends the SQUID's field detection limit.

Fig. 1. Temperature dependence of the critical current density J_c of the microwave-irradiated microbridge.

Fig. 2. Dependence of the critical current I_{c0} and the microwave-induced steps I_{cn} ($n = 1, 2, 3$) on the irradiated microwave power at 56 K.

References

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