THERMAL MANAGEMENT IN LARGE Bi2212 MESAS USED FOR TERAHERTZ SOURCES

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INTRODUCTION

We present a thermal analysis of an artificial mesa on a $Bi_2Sr_2CaCu_2O_8$ (Bi2212) single crystal that is based on tunneling characteristics of the c-axis stack of ~800 intrinsic Josephson junctions in the mesa. Despite the large mesa volume (e.g., 40x300x1.2 μm^3) and power dissipation that result in self-heating and backbending of the current-voltage curve (I-V), there are accessible bias conditions for which significant polarized THz-wave emission can be observed [1]. We estimate the mesa temperature by equating the quasiparticle resistance, $R_{qp}(T)$, to the ratio V/I over the entire I-V including the backbending region. These temperatures are used to predict the un-polarized black-body radiation reaching our bolometer and there is substantial agreement over the entire I-V. As such, backbending results from the particular $R_{qp}(T)$ for Bi2212 as discussed by Zavaritsky [2], rather than a significant suppression of the energy gap. This model also correctly predicts the observed disappearance of backbending above ~60 K.

EXPERIMENTAL

Single crystals of Bi2212 were grown by the floating zone technique. To obtain appropriately oxygen-deficient single crystals, required a special annealing treatment: as-grown crystals were baked at 375 ^{0}C in Ar flow (92 sccm) for 100 hours in a gettered furnace. The resulting underdoped crystals have a critical temperature of 78-82 K, are mounted on sapphire substrates using conductive epoxy. The typical contact resistance at the top of the mesa is ~10-30 ohms and it is achieved by cleaving the Bi2212 crystal in-situ whilst depositing Au to an eventual thickness of 100 nm. After that, mesas were fabricated using photolithography and Ar -ion milling. As there is only one contact on top of the mesa, we have a three-terminal measurement of the interlayer tunneling I-V and out-of-plane transport, including R_{qp} (T).

Finished mesas are mounted on a copper cold finger in a gas flow cryostat with THz transparent window directed at a Si-composite bolometer (IR labs). Copper tubes are used to channel the radiation and a mechanical chopper provides modulation for lock-in detection of the bolometer output to reduce background.

The analysis proceeds from separate measurements of I-V (black curve in Fig. 1) and $R_{qp}(T)$ (Fig. 2) from which the mesa temperature is determined. In addition, the far-field bolometer response is recorded simultaneously with the I-V (gray curve in Fig. 1).

RESULTS

Our method to determine the local temperatures, T, along an I-V curve finds the value of T for which $R_{qp}(T)$ from Fig. 2 equals V/I from Fig. 1. The mesa temperature is around bath temperature, T_0, during THz emission out of the patterned crystal and superconducting phase is maintained up to elevated voltage values.

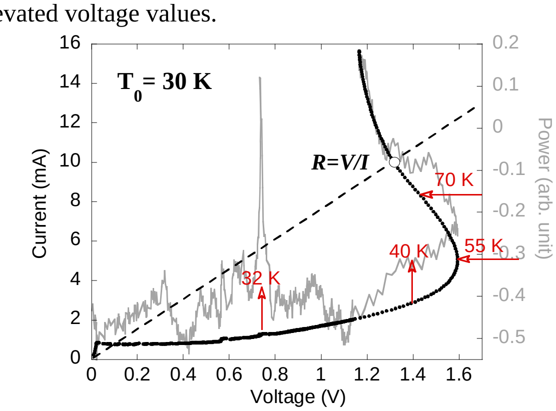

Fig.1 Current-voltage characteristics of the mesa at 30 K

The inset of Fig. 2 shows effective temperature of the mesa at different bath temperatures, which exhibits an approximately linear dependence of T on power dissipation, IV

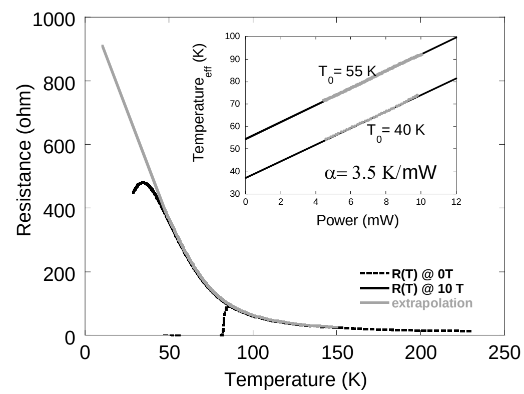

Fig.2 Out-of-plane transport measurement of mesa at 0 and 10 T

We demonstrate an understanding of the thermal management that has been achieved in relatively large mesas on Bi2212 crystals that emit considerable power in the THz frequency range [1]. In addition, the backbending universally seen in the I-V of Bi2212 mesas has its origins in the particular dependence of $R_{qp}(T)$ on temperature for Bi2212, rather than a significant suppression of the energy gap.

REFERENCES

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