Comment on ”Single intrinsic Josephson junction with double-sided fabrication technique” by You et al [Appl. Phys. Lett. 88, 222501 (2006)]

In a recent letter, henceforth referred to as Ref.[1], You et al postulate that Bi2212 factually represents a series array of SIS junctions and claim that the nonlinear current-voltage characteristics (IVC) of their bridge are free of heating. Earlier experiments cast serious doubt upon the accuracy of the principal postulate (of this letter), see Ref.[2] and references therein. In what follows I will demonstrate that the major claim by the authors of Ref.[1] is at odds with their own data which suggest an extrinsic cause for the IVC nonlinearities.

The authors of Ref.[1] claim that ”Joule heating can easily be ruled out”, alleging that 10\mu W dissipated in a sample with a twenty-fold difference in area causes the very same heating. This assumption is incorrect as the heat (W = IV), dissipated in a sample, escapes through its surface area (A). So heating depends on the heat load \(P = W/A\) and, in comparable conditions, 10\mu W will cause 20 times higher overheating in a sample of 20 times smaller A, see Ref.[2] for details. For this reason, evaluation of heating using \(R_{th}\) measured in a sample of different A is not possible unless the area-dependence of the thermal resistance \(R_{th} \propto 1/A\) is taken into account, see Ref.[3] for details. Provided the findings by Ref.[3] are applicable to Ref.[1] (as assumed by its authors), the original \(R_{th}\) adjusted for a tenfold area difference between the samples of Refs.[1,3] suggests that \(P \approx 330W/cm^2\) caused by 10W applied to \(A = 3\mu m^2\) bridge by Ref.[1] overheats it by 6.5K. A quantitatively similar overheating (8K) is also suggested by the estimates by ref.18 from ref.[1], corrected for a 21-fold A-difference. Thus, the authors of Ref.[1] seriously underestimate the heating, which is not at all negligible, since the gap-like feature promoted by Ref.[1] corresponds to the bridge overheating well above 2.57\(T_B\). The estimates above are not extremely accurate as the heat transfer efficiency in Ref.[1] is not the same as in Ref.[3]. Indeed, while the heat escape from the sample of Ref.[3] (and also of Ref.18 in Ref.[1]) was facilitated by a metal electrode of high thermal conductivity, the bridge in Ref.[1] is particularly prone to local overheating as it is sandwchiced between a mass of Bi2212, whose poor thermal and electric conductivities are additionally damped by the inevitable strains and cracks introduced into the bulk Bi2212 by its splitting using a ”scotch tape” technique by Ref.[1]. For these reasons it is natural to expect that a significantly smaller heat load is required to overheat the bridge by Ref.[1].

Ref.[3] provides sufficient experimental means for the quantitative verification of this a-priori conclusion. Indeed, it shows that at sufficiently high heat loads the heating-induced IVC nonlinearities exceed the intrinsic ones so radically that the latter might be safely ignored. The experimental IVC in such circumstances is primarily determined by the normal state resistance, \(R_N(T)\), while the mean temperature, \(T\), of the self heated sample is appropriately described by Newton’s Law of Cooling (1701),

\[ T = T_B + P/h, \]

where \(T_B\) is the temperature of the coolant medium (liquid or gas) and \(h\) is the heat transfer coefficient, which depends neither on \(A\) nor \(T\), see Refs.[2,4] for details. Ref.[1] presents IVC together with \(R(T)\) of the same sample hence allowing a straightforward estimate of the actual heat transfer efficiency.

As seen in Fig.1, \(R_N(T)\) reconstructed from IVC by Ref.[1] using Ohm’s law and Eq.(1) correlates reasonably with \(R(T)\) of the same bridge, hence suggesting a heating origin for the IVC non linearity and allowing estimation of \(h \approx 1.7Wcm^{-2}K^{-1}\). In remarkable agreement with the a-priori expectations mentioned above, the overall heat transfer efficiency in Ref.[1] is at least an order of magnitude poorer than in Ref.[3] and is about the same as in the very early ”mesa” design used by Ref.[5] for example, where heating issues were ignored. Using this \(h \approx 1.7Wcm^{-2}K^{-1}\) we estimate the heating caused by 4-12\mu W dissipated at \(T_B = 4.2K\) in a 3\mu m^2 sample as 78-230K, thus confirming the heating origin of the data by Ref.[1].

As far as the \(dR_N/dT\) is concerned, Fig.1 suggests that \(dR_N/dT\) remains negative throughout the temperature range below \(T^*\), the temperature at which the out-of-
plane resistance reaches its minimum. Such behaviour agrees reasonably with the direct $R_N(T)$ measurements under conditions where the superconductivity of Bi2212 was suppressed by a high magnetic field (see Ref.[6] and references therein) or current Ref.[7].

It can be seen, therefore, that the conclusions by the authors of Ref.[1], like the similar findings discussed in Refs.[2-4], are not beyond dispute as their experimental results are most likely caused by self-heating.

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