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Description of $R \times T$ dimensional dependence of YBCO samples with a percolation model

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ABSTRACT

In this work we report the dimensional dependence of local properties of polycrystalline and top seeded melting textured $YBa_2Cu_3O_{7-x}$/Ag superconducting samples. The cross sectional area of superconducting bars was successively decreased and the resistance–temperature ($R \times T$) curves for different cross section area was obtained. The results show that for a given current, the $R \times T$ curves, specially the onset of zero resistance (T_{C0}), are dependent on the bridges dimensions. The results obtained are in accordance with a percolation model considering a random mixture of normal and superconducting elements.

1. Introduction

There is great interest in the superconductors transport properties, mainly critical temperature and critical current density, which are important parameters in applications involving superconducting electronic devices, tapes and cables for energy transmission line and superconducting bars used in fault current limiters. Josephson junctions can be described as two superconducting regions separated by a non-superconducting one (weak link). In accordance with the weak link nature, the current–voltage characteristics (CVC) of the junctions present specific features adequate to their utilizations as electronic devices [1].

A simple technique to produce SNS Josephson junctions consists of reducing the cross sectional area of a superconducting bar, resulting in a constriction separating two superconducting banks [2,3]. For a given applied electrical current, if the current density in the constriction exceeds the critical value the superconducting state will be locally destroyed. Consequently, the region in the constriction will be in the normal state while the banks remain in the superconducting state.

The constriction dimensions (cross sectional area and length) affect the electrical properties of the superconducting samples. Their effects can be observed in the electrical resistance versus temperature ($R \times T$) curves as: (1) reduction of T_{C0} (onset of zero resistance) and (2) increase in the temperature interval for the superconducting transition. In CVC curves, the decrease in the constriction dimensions results in the reduction of the critical current and modification of the CVC shape in low voltage regimes.

The critical current and T_{C0} of SNS junctions based on constrictions separating superconducting regions depend on the microstructure of the constriction regions. This microstructure is constituted by grain boundaries that act as weak links. Therefore in this case, the constriction region can be considered as an array of Josephson junctions.

The effect of constriction dimension in the electrical properties of the superconducting samples can be explained by the existence of continuous percolations path and the fraction of normal and superconducting region along the electrical current paths as discussed in [4]. The decrease in the cross sectional area produces a similar effect in the $R \times T$ and CVC curves to that of an applied external magnetic field [4].

Polycrystalline and melt-textured samples present very different microstructures. Polycrystalline sample presents grains with micrometer dimensions and high anisotropy with crystallographic axes randomly distributed. The melt-textured samples are constituted of grains with *a*–*b* planes highly aligned (low angle grain boundaries) in regions of millimeter dimensions. However, the melt texturing process does not produce a single crystal. The sample microstructure presents porous and non-superconducting phases as Y_2BaCuO_5 precipitates and Ba-Cu-rich regions.

The present article reports the $R \times T$ curves of superconducting bars with constrictions and the utilization of a percolation model to describe the experimental results.

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2. Experimental

The YBCO silver doped (20 wt.%) textured samples were produced by the top seeded melting textured process (TSMT) [5] and the polycrystalline samples were produced by the standard solid state reaction technique.

The silver addition on YBCO increases the sample density due the filling of pores and improves the connectivity between the grains. In polycrystalline samples the silver addition produce grains up to 30 μm [6] and in melting textured samples it decrease in the microcrack density [7]. A typical microstructure of our samples is shown in Fig. 1a and b.

Electrical measurements were made on bars, which were cut with diamond saw from YBCO pellets. In the textured sample, the cut was made in order to obtain the current path parallel to the *a*–*b* crystallographic plane. In the bar, four electric contacts were made with silver epoxy and posterior thermal treatment in oxygen atmosphere. The bar was fixed onto a resin plate with epoxy glue. Four electric thin cooper wires were fixed in the electric contacts of each bar to connect it with the experimental setup.

With a diamond saw, the cross section area perpendicular to the electric current path, located between the two voltage contacts was gradually decreased in order to obtain the constriction. The cut was controlled by the samples resistance values in ambient temperature (R_{300}). The sample characteristics are summarized in Table 1. The textured and polycrystalline sample with no cut were named as TS0 and PS0, respectively. Analogously, TS1, TS2, PS1 and PS2 correspond to samples with progressive cuts.

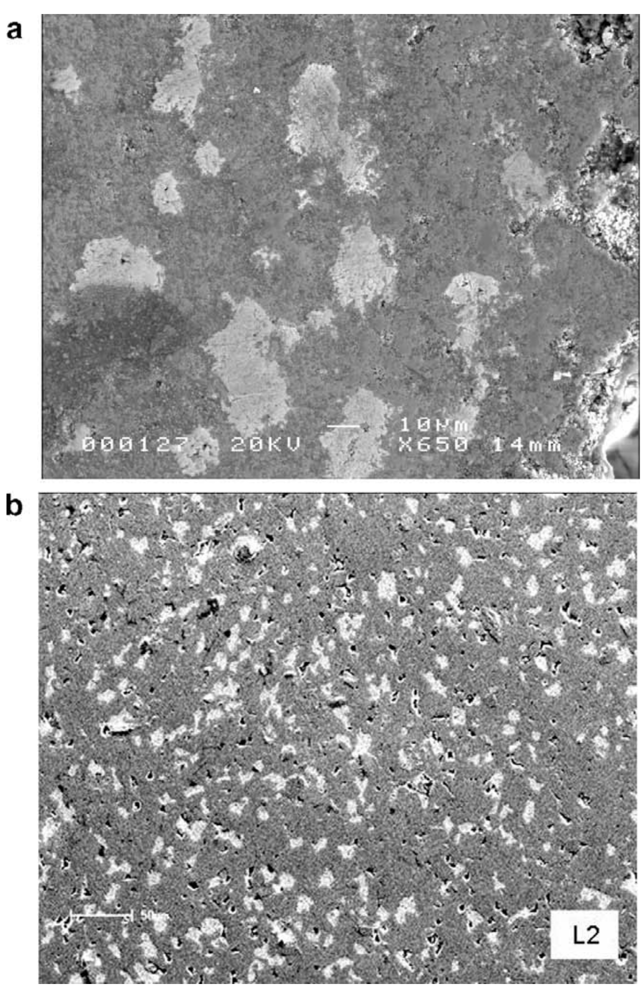

Fig. 1. A typical SEM photomicrographs of (a) melt-textured and (b) polycrystalline samples.

Table 1
Properties of samples for various cross sectional area values. R_{300} and R_{100} are the resistance of the samples in temperature of 300 K and 100 K, respectively. *A* and *L* are the effective cross sectional area (calculated through the ambient resistance) and the length of the constriction regions.

Sample	R_{300} (mΩ)	R_{100} (mΩ)	Dimension (mm^3)	*A* (mm^2)	*L* (mm)
TS0	14	5	11 × 2.5 × 1	2.5	
TS1	31	11		1.1	0.5
TS2	72	26		0.5	0.5
PS0	7	3	11 × 5.3 × 1	5.3	
PS1	28	12		1.3	0.5
PS2	40	17		0.9	0.5

The $R \times T$ curves were obtained through the four-point measurement technique using a differential resistometer with a biased electrical current of 100 mA. The temperature was measured using a Pt100 thermocouple and (*T*, *R*) values acquired and stored by an automated data acquisition HPIB interface. The cryogenic system was cooled with liquid nitrogen.

3. Experimental results and discussion

3.1. The resistive transitions

The dependence on normalized resistance versus temperature curves for TSMT samples with and without constrictions is shown

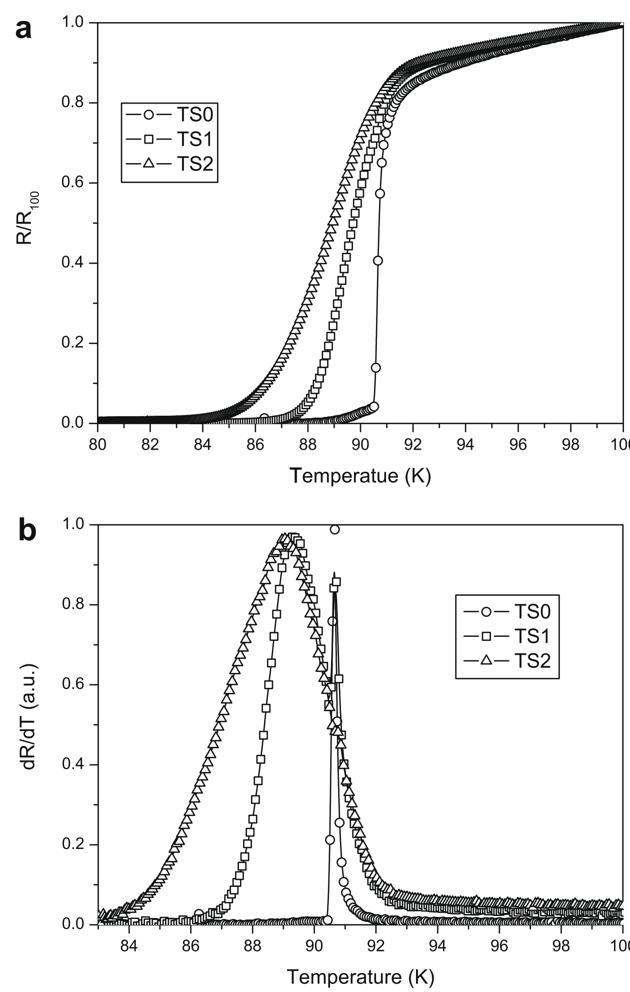

Fig. 2. (a) Normalized resistance of TSMT sample for different cross sectional areas. (b) $dR/dT \times T$ of the experimental curves. The R_{100} values for TS0, TS1and TS2 are, respectively, 5, 11 and 26 mΩ.