TRANSVERSE MAGNETORESISTANCE IN BSCCO-Ag MULTI-FILAMENTARY TAPES

MAGNETORESISTENCIA TRANSVERSAL EN CINTAS MULTIFILAMENTALES DE BSCCO-Ag

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Understanding electric and magnetic properties of superconducting tapes and coatings has been a major concern in developing applications. The presence of certain defects, like micro-cracks caused by bending strain [1, 2, 3, 4] or created during the rolling process of fabrication of the tapes [5], which interrupt the transport of supercurrent in the longitudinal direction, has been well established. Such defects forces the current to flow in the direction transverse to the long dimension of the composite and may determine the fate of a transmission line. However, the transverse transport has been rarely studied [6, 7, 8] in composite superconductors: most efforts have been focused on the transport in the main direction.

In the present paper we study the magnetoresistance through resistive transitions in the transverse direction of $Bi_2Sr_2Ca_2Cu_3O_{1+x}$/Ag (Bi–2223/Ag) tapes, which allows to know, for example the critical temperature and the activation energy dependencies with the applied magnetic field.

The original tape was prepared with the powder-in-tube method [9]. It was 4.32 mm wide and 0.23 mm thick, and contains 61 filaments as seen from the cross-section displayed in Fig. 1(a). Each filament is 0.3–0.4 mm wide and a few microns thick. The engineering critical current of the tape was 65 A at 77 K, equivalent to a critical current density of approximately 6540 A cm^{-2}.

In order to force the current to flow in the transverse direction, a thin bridge was cut from a *Bi*–2223/*Ag* tape as it is shown in Fig. 1(b). The bridge was 0.64 mm wide. A magnetic field, in the interval 0–70 mT, was generated by a long solenoid, and applied perpendicular to the wide face of the bridge.

Transport measurements were performed using the four-probe technique. Voltage was measured using a Scitec Instruments 500 MC lock-in amplifier at 90 Hz, with a bias current of 1 mA through the sample, provided by a GW audio generator with a 1 kΩ resistor in series.

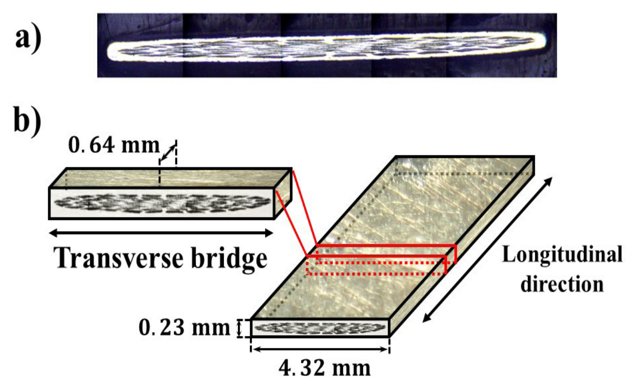

Figure 1: (a) Micrograph of the cross-section of the Bi–2223/Ag tape. (b) Sketch showing the transverse bridge cut from the tape.

In Fig. 2(a) is shown the resistive transitions of the transverse bridge for different values of the applied magnetic field. The resistivity was obtained from the measured resistance, *R*, using the formula $\langle\rho\rangle = RS/l$ where *S* is the cross-section area of the bridge and *l* is the distance between the voltage contacts. The voltages probes were put symmetrically l=2.01 mm apart from each other.

The slope observed before the resistive transitions to the normal state can be attributed to the effects of the self-field of the transport current, which weakens the superconducting properties of the filaments when the sample close enough to the transition. The inset represents the dependence between the critical temperature and the applied magnetic field. The critical temperature (T_c) was defined as the value of temperature that corresponds to the middle value of resistivity in the transition. As we can see, T_c decreases when the applied magnetic field increases and is very sensitive to it (magnetic field changes of the order of mT provoke measurable variations in the critical temperature). This may be related to two factors: first, the quality of the superconducting filaments and second, the morphology of the Bi–2223/Ag composite. Below we will explain our experimental results based on these two possibilities.

It is well known that as the motion of fluxons is a thermally activated process, the resistance shows an exponential increase with temperature [10, 11], which follows the law:

$$R = R_0 \exp(-U / kT), \quad (1)$$

where U is the activation energy and depends on the applied magnetic field. Due to the fact that resistance and resistivity are proportional, the last one exhibits the same temperature dependence given by equation (1).

Figure 2(b) presents the Arrhenius plot that allows to calculate the activation energy, U. The black lines follow equation (1). A decrease of the activation energy with the applied magnetic field is shown in the inset of Fig. 2(b). The resulting values of activation energy are very similar to those obtained for single crystals and thin films of the BiSrCaCuO compound [10, 12]. On the other hand, if we fit the relation between the activation energy and the applied magnetic field with a power law:

$$U = AB^{-n}, \quad (2)$$

we find $n = 0.31 \pm 0.05$ (the continuous curve in inset in Fig. 2(b) shows the fit). This value agrees very well with those reported for superconducting polycrystals [11], but it is different to the ones reported for thin films of BiSrCaCuO where $n = 0.5$ [10]. Therefore, although the activation energy for our sample is similar to the activation energy for single crystals and thin films, its dependence with the magnetic field is closer to the one typical of superconducting polycrystals. It is not strange that the absolute value of the activation energies are close to the pinning energies measured in crystals or films, since the superconducting filaments are expected to be well oriented with most of the current flowing along the a-b planes of the structure, coincident with the wide surface of the tape [1]. It is puzzling, however, that the exponent of the magnetic field dependence of the activation energy is closer to the analogous one in Bi-2223 polycrystals. This may be related to the morphological and microstructural details of the superconducting-metal composite, which are not well understood in the literature. This relation will be the subject of future work.

In summary, we have obtained by the first time the dependence of the activation energy and critical temperature with the applied magnetic field in the transverse direction of a multi-filamentary Bi–2223/Ag superconducting tape. We found that both decrease with the increase of the magnetic field. The activation energy shows interesting behavior which can be due to the morphology of Bi–2223/Ag composite: its values correspond to the ones obtained in single crystals and thin films, but the dependence with the magnetic field is like the one typical of polycrystals. These results are novel and may be potentially relevant to understand the behavior of multi-filamentary tapes in the presence of transverse cracks, when the current is forced to flow perpendicular to the main direction of the tape.

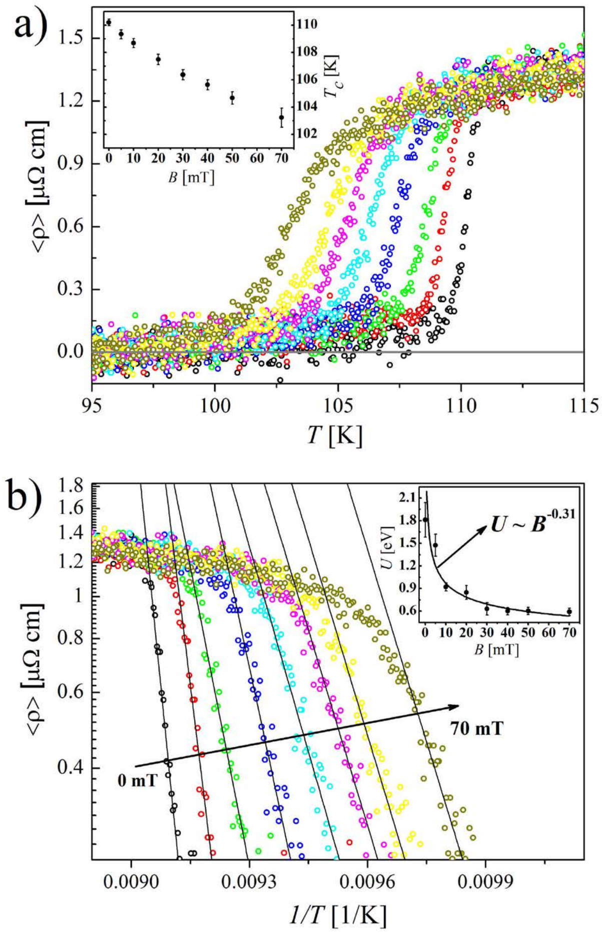

Figure 2: (a) Resistive transitions of a Bi–2223/Ag transverse bridge for different values of the applied magnetic field (B = 0, 5, 10, 20, 30, 40, 50 and 70 mT from right to left). The inset shows the dependence of the critical temperature with the applied magnetic field. (b) Arrhenius plot of the data shown in Fig. 2(a). The dependence of the activation energy with the applied magnetic field is shown in the inset.

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