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TRANSPORT AND MAGNETIZATION CURRENT IN A THIN LAYER
OF $\text{Bi}_{1.8}\text{Pb}_{0.4}\text{Sr}_{2.0}\text{Ca}_{2.2}\text{Cu}_{3.0}\text{O}_y$ ADJACENT TO SILVER
SHEATHING IN BSCCO-2223 TAPES*

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**TRANSPORT AND MAGNETIZATION CURRENT IN A THIN
LAYER OF $\text{Bi}_{1.8}\text{Pb}_{0.4}\text{Sr}_{2.0}\text{Ca}_{2.2}\text{Cu}_{3.0}\text{O}_y$ ADJACENT TO
SILVER SHEATHING IN BSCCO-2223 TAPES,***

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ABSTRACT

The thin superconducting region next to the silver sheath appears to be the region of high critical current density in BSCCO-2223 tapes. Transport current measurements on $\text{Bi}_{1.8}\text{Pb}_{0.4}\text{Sr}_{2.0}\text{Ca}_{2.2}\text{Cu}_{3.0}\text{O}_y$ tape at 77 K in a low magnetic field applied parallel to the tape thickness indicate an exponential field dependence [$J / J_c \propto \exp(-B / B_0)$] for transport currents. Magnetic hysteresis was measured in a 10- μm -thick layer of superconductor near the silver sheath as a function of temperature, intensity, and orientation of applied field with respect to the tape. The characteristic field for full penetration depth, B^* , for a superconducting slab was found to have a power law dependence on temperature. Magnetization currents as a function of temperature and applied field oriented parallel to the tape thickness, $J_{c,m}(B,T)$, were determined from the magnetization loop width with a Bean- model expression adapted for an orthorhombic sample. The critical-state model, adjusted for scaling and magnetic relaxation, correlates well with the magnetization current of the thin layer at 77 K.

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EXPERIMENTAL

A precursor powder of the $\text{Bi}_{1.8}\text{Pb}_{0.4}\text{Sr}_{2.0}\text{Ca}_{2.2}\text{Cu}_{3.0}\text{O}_y$ composition was prepared by a freeze-drying process incorporating a splat-freezing step¹⁶. The freeze-dried powder showed high reactivity and chemical homogeneity. The powder was heat treated at 845 °C for 2 h in a 7 % O_2 atmosphere. Before it was packed into the silver tube, the powder had an average particle size of 1 μm , and X-ray analysis showed 2212 phase peaks. The packing density was 25 % of the theoretical density of the 2223 phase. The tube was drawn and rolled to a tape thickness of $\approx 200 \mu\text{m}$. Short samples were cut and thermomechanically processed at 810 °C in a 7 % O_2 atmosphere. The transport critical current, $I_{c,t}$ (77 K, self field, 1 $\mu\text{V}/\text{cm}$ criterion) was measured by a conventional four probe method.

Tapes were sliced to expose a 10- μm -thick layer next to the silver sheath. An $I_{c,t}$ of 20 A (77 K and self field) was measured after slicing the sample. A part of this sample, measuring 0.31 cm wide, 0.47 cm long, and 10 μm thick, was used for magnetic measurements with a SQUID magnetometer at temperatures of 10, 35, 50, and 75 K. Magnetic hysteresis loops for fields applied parallel to the tape thickness ($\mu_0 H_{\text{app}} \parallel c$) were made between ± 0.2 T.

RESULTS AND DISCUSSION

Figure 1 shows the normalized magnetic field dependence of the critical current in a field applied parallel to the tape thickness at 77 K.

Figure 1. Normalized transport critical current as a function of magnetic field applied parallel to tape thickness at 77 K

An exponential field dependence was found for transport currents in the investigated magnetic field regime:

$$J/J_c \propto \exp(-B/B_0). \quad (1)$$

At 10 K, in the remanent state, the magnetic response of the sample remains unchanged but then undergoes a slow decrease. At 50 K, the initial magnetic response reaches B^* at ≈ 0.01 T, followed by a steady decrease up to an applied magnetic field of 0.2 T.

Figure 4. Characteristic field for full penetration depth of superconducting slab, B^* , as a function of temperature for $\mu_0 H_{app}$ parallel to c-axis. Power law dependence is indicated by solid line

[$B^*(T) = B_0 \times T^{-1.34}$, where $B_0 = 2.1$ T].

From the initial magnetization curves for $\mu_0 H_{app} \parallel c$, the characteristic field for the full penetration B^* as a function of temperature was extracted. Figure 4 shows a power law dependence of B^* on temperature according to:

$$B^* = B_0 \times T^{-1.34}, \quad (2)$$

where $B_0 = 2.1$ T. The magnetization current density $J_{c,m}(\mu_0 H_{app}, T)$ was determined from the magnetization loop width $\Delta M(\mu_0 H_{app})$ with a Bean-model expression adapted for an orthorhombic sample¹⁸:

$$J_{c,m}(\mu_0 H_{app}, T) = \frac{20 \Delta M(\mu_0 H_{app})}{w (1 - w / 3 l)}, \quad (3)$$

where $J_{c,m}(\mu_0 H_{app}, T)$ is in A/cm², $\Delta M(\mu_0 H_{app})$ is in emu/cm³, sample width $w = 0.31$ cm and sample length $l = 0.47$ cm for $\mu_0 H_{app} \parallel c$. Only ΔM values for $\mu_0 H_{app} > B^*$ were used in the calculation. Comparison of the magnetization results with transport measurements is complicated by the different length scales for the two experiments⁹ and different experimental time constants⁷. The critical-state scaling argument $\Delta M^{uncut}(1 \text{ cm}) / \Delta M^{cut}(0.5 \text{ cm}) = 1.4$ was used⁹. The argument is based on the Bean model dimensional scaling for an orthorhombic sample. Magnetization measurements were made on a slow time scale (≈ 60 s), after setting the applied magnetic field. Maley et al.⁷ found that during this period, rapid flux creep allows relaxation of the flux profile away from the critical state by an amount that is a strong function of temperature and field. The rate dM/dt for a number of temperatures and fields was found generally to be < 0.01 (emu/cm³-s) for the time scale of interest. In this study, flux creep relaxation was accounted for by using the interval of 60 s between the application of the magnetic field and the time of measurement.

CONCLUSIONS

The thin superconducting region next to the silver sheath appears to be the region of high critical current density. Transport current measurements were performed on the 2223 tape at 77 K in a low magnetic field parallel to the tape thickness. An exponential field dependence $J / J_c \propto \exp (- B / B_0)$ was found for transport currents in the investigated magnetic field regime at 77 K. Magnetic hysteresis was measured on the 10- μm -thick layer of 2223 near the silver sheath as a function of temperature and intensity of the applied field. The characteristic field for full penetration depth, B^* , for a superconducting slab was found to have a power law dependence on temperature. Correlating the magnetic and transport measurements demonstrated that the "self-field" for transport critical current of 20 A at 77 K was ≈ 0.04 T. Magnetization currents as a function of temperature and applied field oriented parallel to the thickness of the tape, $J_c(\mu_0 H_{\text{app}}, T)$, were determined from the magnetization loop width with a Bean-model expression adapted for an orthorhombic sample. Only ΔM values for $\mu_0 H_{\text{app}} > B^*$ were used in the calculations. A critical-state scaling factor and the flux creep relaxation rate were incorporated in calculating J_c values for $\mu_0 H_{\text{app}} \gg c$.

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