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Measurements of the transport critical current density (J_{ct}) of textured sintered samples of $DyBa_2Cu_3O_7$ have been made as a function of temperature in magnetic fields up to 27 T. Data with the current orthogonal to the applied field for the high B_{c2} (T) ($B \perp c$ axis) and the low B_{c2} (T) ($B \parallel c$ axis) orientations are presented. We report the anomalous suppression of the transport critical current when current flows along the c axis at 24 T and 4.2 K, a field which is well below B_{c2} (~ 100 T) at this temperature.

The transport critical current density of high-temperature bulk oxide superconductors is at present still rather low in high magnetic fields. The problem lies in the granular nature of polycrystalline bulk material[1-4] which causes the transport current density (J_{ct}) to be three to five orders of magnitude less than the magnetization current density (J_{cm}).[5,6] A number of workers have proposed that well-aligned samples would permit J_{ct} to be raised towards J_{cm}. In recent work we have studied the J_c properties of well-aligned polycrystalline $DyBa_2Cu_3O_{7-\delta}$ samples but found that the J_{ct} values remain very small,[7] J_{cm}/J_{ct} being of order 10^5 at 4.2 K. However, for one orientation ($B \perp c$, i.e., the high B_{c2} orientation), we found that J_{cm} (77 K) showed an approximately exponential[6] drop off with field, declining to zero at between 1 and 3 T, even though B_{c2} is above 30 T at this temperature. In this letter we report additional results on the transport critical current data of new oriented polycrystalline samples of $DyBa_2Cu_3O_7$. The present J_{ct} data are taken at much higher fields than the J_{cm} and J_{ct} data of our earlier study[5,6] and we here report on a second anomaly in the J_{ct} of $DyBa_2Cu_3O_7$.

The details of our sample preparation have been outlined in previous publications.[1,6] The basic synthesis consists of mixing Dy_2O_3, $BaCO_3$, and CuO powders followed by a series of grindings and firings at 940 °C. The powders were then aligned[8] in an applied field of 0.5 T while suspended in an alcohol solution. After the liquid evaporated, the dried cake was isostatically pressed, sintered, and oxygenated at 400 °C.

The resistivity at 100 K of these aligned samples was measured as 250 $\mu\Omega$ cm for the current within the a-b plane and 800 $\mu\Omega$ cm for $J \parallel c$ axis. (We here associate the c axis with the alignment field axis since the moment of Dy points in the c direction.) The inductive and resistive T_c transitions were sharp (~ 4 and 2 K respectively for the 10–90% points).

Gold pads (~ 0.5 mm^2) were sputtered onto samples of dimensions $6 \times 1 \times 1$ mm which were all cut from the same pellet. Standard four-terminal voltage-current data were generated. It was concluded that self-heating was negligible, since currents typically twice those presented here produced no self-heating effects in zero field.

The applied magnetic field was generated in a hybrid magnet at MIT. The temperature control was maintained by two different methods: in the pool-boiling mode, at 4.2, 66, 67.5, and 77 K, the sample lay in intimate thermal contact with LHe or LN_2 as required and the temperature was regulated using vapor pressure control. At 30 and 40 K, a variable temperature insert which isolated the sample from the helium bath was used. Temperature control was maintained using a carbon glass thermometer in a closed loop feedback system with a heater. The uncertainty in temperature due to the magnetoresistance of the carbon glass thermometer and temperature gradients in the sample space is expected to be ~ 3 K.

In Fig. 1, critical current data are presented for $I \perp B$, $B \parallel c$ which is the low B_{c2} (T) good current flow orientation. The value of J_{ct} is determined at a criterion of 2 μV cm^{-1}. The principal characteristics of the results are the low absolute values of J_{ct} (30–35 A/cm^2 at 4.2 K, ~ 1 A/cm^2 at 77 K) and their very considerable field independence over the range 5–27 T at 4.2–40 K. Zero J_{ct} is reached at 10 T at 77 K, whereas in prior work,[6] we believed that we located B_{c2} (77 K) for $B \parallel c$ at 6–7 T. The decline observed in J_{ct} between 7

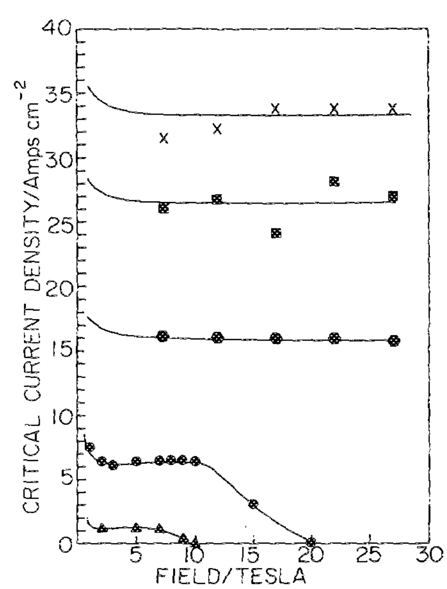

FIG. 1. Transport current density at the onset of voltage (2 μV cm^{-1}) as a function of field and temperature for the low B_{c2} (T) orientation ($B \parallel c$) and for J in the ab plane. (×) 4.2 K; (■) 30 K; (●) 40 K; (●) 67.5 K; (▲) 77 K.

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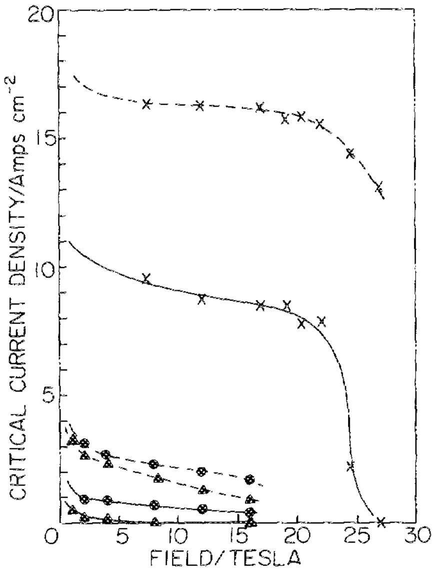

FIG. 2. Transport current density, at a criterion of 50 μV cm^{-1} (broken lines) and the onset of voltage ($<2\,\mu$V cm^{-1}) (solid lines), as a function of field and temperature for the high B_{c2} (T) direction ($B\perp c$) and for J along the c axis. (×) 4.2 K; (⊗) 66 K; (▲) 77 K.

and 10 T may result from suppressing a percolative path through a few misaligned grains.

Figure 2 shows J_{ct} for the poor current flow direction ($J\parallel c$) and for a high B_{c2} orientation ($B\perp c$). J_{ct} is presented at two criteria: 2 μV/cm and 50 μV/cm. It can be seen that the apparent J_{ct} is increased by 50–100% at the higher criterion and significant features of the J_{ct} vs B characteristic are smeared out. In agreement with our own earlier results,[5] we find that the J_{ct} value is lower in this orientation [e.g., J_{ct} (4.2 K, 10 T) is ~9 A/cm^2 in Fig. 2, as compared to >30 A/cm^2 in the good current flow configuration of Fig. 1]. A qualitatively similar result has also been obtained by Livingston.[9]

The most striking aspect of the results is the steep drop in J_{ct} (4.2 K) between 22 and 27 T shown in Fig. 2. Within the sensitivity of our measurements, there was a supercurrent below 22 T and no detectable supercurrent above 27 T. Clearly 27 T is well below any reasonable value of B_{c2} (4.2 K) for this orientation [Ginzburg–Landau calculations would suggest B_{c2} (4.2 K) exceed 100 T]. We are led to interpret this behavior in terms of a continuous region of B_{c2} ~ 27 T which surrounds the high B_{c2} phase or to the destruction of flux pinning, either generally or in a continuous network of barriers at 27 T. It is not clear whether these regions are intergranular or intragranular or whether they are intrinsic or extrinsic properties of these sintered samples. Further investigations of these anomalous effects are now under way.

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