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ANISOTROPY OF THE CRITICAL CURRENT DENSITY IN Bi-2223/Ag TAPES

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ABSTRACT

The effect of thermomechanical processing on texture in Bi-2223 Ag-sheathed tapes as determined from the anisotropy of the critical current density J_c in an applied magnetic field will be discussed. Model calculations for a distribution of grain orientations in the tape produce good fits to the data and allow characterization of the degree of long-range texture. There is a qualitative correlation of J_c with global texture, but other factors, such as intergrain connectivity, are also important.

INTRODUCTION

$(Bi,Pb)_2Sr_2Ca_2Cu_3O_x$ (Bi-2223) is a high temperature superconductor (transition temperature T_c ~112 K) with very anisotropic electronic properties. For fields oriented within the crystallographic *ab* planes, which contain the Cu-O layers, the pinning is very large and is believed to be a consequence of "intrinsic" pinning by the Cu-O planes. In contrast, for fields oriented along the *c* axis, the magnetic flux vortices in the superconductor are only weakly coupled (pancake vortices) between sets of Cu-O planes resulting in very low pinning force. The result of this anisotropy in the pinning is also a very large anisotropy in J_c for Bi-2223, which increases as either the temperature or magnetic field are increased. Thin films of Bi-2223 [1] and single crystals of the related compound Bi-2212 [2] exhibit these phenomena.

Some of these properties of single crystalline material carry over to Bi-2223/Ag tapes, for which the core is polycrystalline, consisting of well oriented "colonies" of grains with large area twist boundaries along the *c* axis. For optimum performance, these colonies would have their *ab* planes in the tape rolling plane, but there is always some misalignment between adjacent colonies and a distribution of the *ab* plane orientations with respect to the tape rolling direction results. Defects and second phase particles or intergrowths may also be present between colonies of grains. The amount of texture in a Bi-2223 silver-sheathed (Bi-2223/Ag) tape depends on both the initial powder (to achieve a phase-pure product which can also be textured during the tape fabrication process) and the thermomechanical processing (to achieve the best texture from iterative mechanical deformation and chemical reaction).

We use the angular anisotropy of J_c in a magnetic field as a tool to investigate the global texture (the degree of alignment of the grains with respect to an externally applied magnetic field). This method has been used by us and other groups as an indicator of the quality of a tape. We explore this method, correlate it with independently measured texture values; and also briefly consider current flow mechanisms in Bi-2223/Ag tapes.

EXPERIMENTAL

The tapes were prepared at American Superconductor Corporation by a standard oxide powder in tube (OPIT) process. Multifilament (19 core) tapes were prepared by packing the powder into cylindrical silver billets, which were deformed into tape using standard deformation techniques, including wire drawing to a hexagonal shape, repacking to a 19 filament bundle in another cylindrical silver billet, wire drawing, and rolling. For monofilament tapes the rebundling step was omitted. The samples were given two heat treatments at temperatures between 800 and 830°C in 7.5% oxygen with an intermediate pressing (for the monofilament tapes) or rolling (for the multifilament tapes) operation. Approximate final dimensions of the tapes were 100-200 μm thick by 2.5 mm wide.

A 1.5-cm long specimen was cut from each sample, leads attached, and the critical current I_c was measured over a length of 0.5 cm with an electric field criterion of 1 μV/cm. The samples were immersed in liquid nitrogen at 75 K and 64 K, and I_c data were collected with a magnetic field B up to 1 T applied parallel to the tape normal n ($\phi = 0°$), perpendicular to the tape normal t($\phi = 90°$, in the tape plane, transverse to the rolling direction), and then rotated from $\phi = -20°$ to 200°. See Figure 1 for the geometry.

X-ray rocking curves (Ω scans) were measured on the (0 0 14) line of Bi-2223 on tapes from which the silver sheath had either been stripped mechanically or chemically etched. The measurements were performed on a Scintag Model XDS 2000 diffractometer using Cu Kα radiation. The plane of the rocking angle Ω was coincident with the tape rolling direction. The rocking curves were corrected for x-ray absorption in the sample before the full width half maximum (FWHM) was estimated.

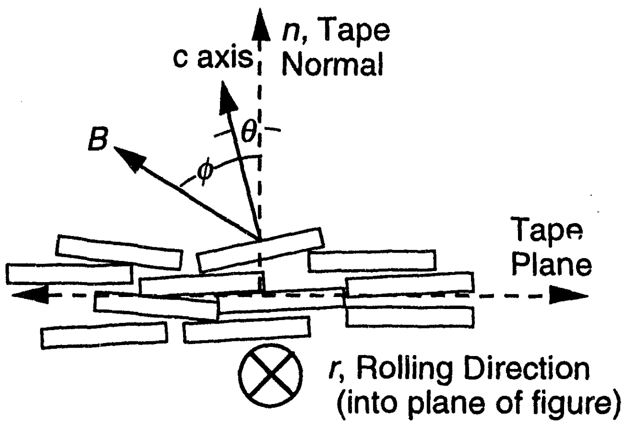

Fig. 1. Schematic diagram of the grains in a tape showing the principal directions and the definition of the angles θ and ϕ.

RESULTS AND DISCUSSION

We analyze the $J_c(B, \phi)$ data in terms of a model 3, 4] which assumes 1) that J_c is dependent only on the c-axis component for each grain in the tape; and 2) that the orientation of the grains follows a Gaussian distribution with a variance σ^2. Using the measured value of the J_c for $\phi = 0°$ ($B \parallel n$), the $J_c(B, 90°)$ data is calculated by fitting to σ. Figures 2 and 3 show a set of data on a multifilament tape which were fit to this model. Alternatively, another characteristic angle [5] can be determined from the deviation of the $J_c(B = B_o, \phi)$ (fixed field, varying field angle) data from the $J_c(B, 0°)$ data when both are plotted *vs.* $B\cos\phi$. As ϕ approaches 90°, the $B\cos\phi$ dependence eventually breaks down when the typical misorientation of the grains is comparable with 90°-ϕ, which we define as θ_d. The x-ray Ω scans have also been obtained for some of the tapes. Typical results on mono- and multifilamentary tapes are given in Table 1.

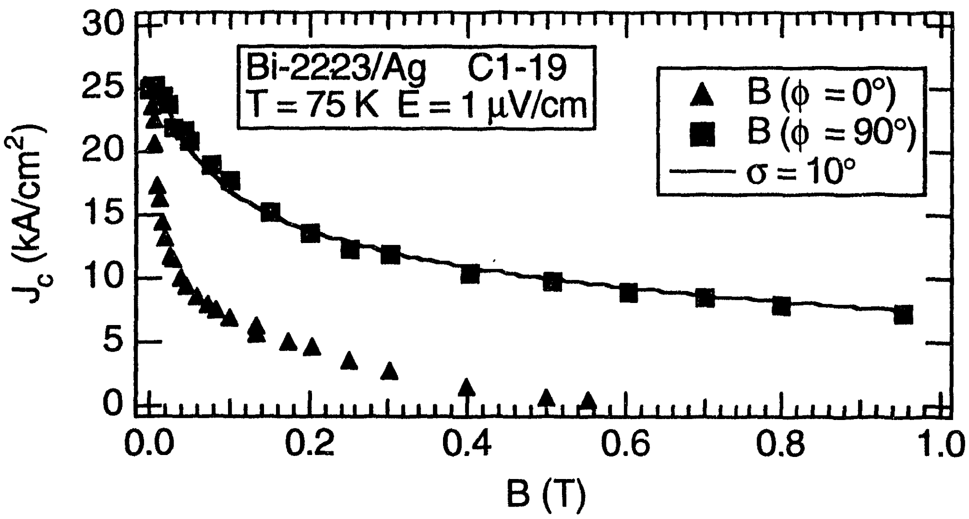

Fig. 2. Field dependence of J_c at 75 K for sample C1-19 for the field B oriented along the tape normal (ϕ=0°) and parallel to the tape plane. The solid line is a result of the fit to the model.

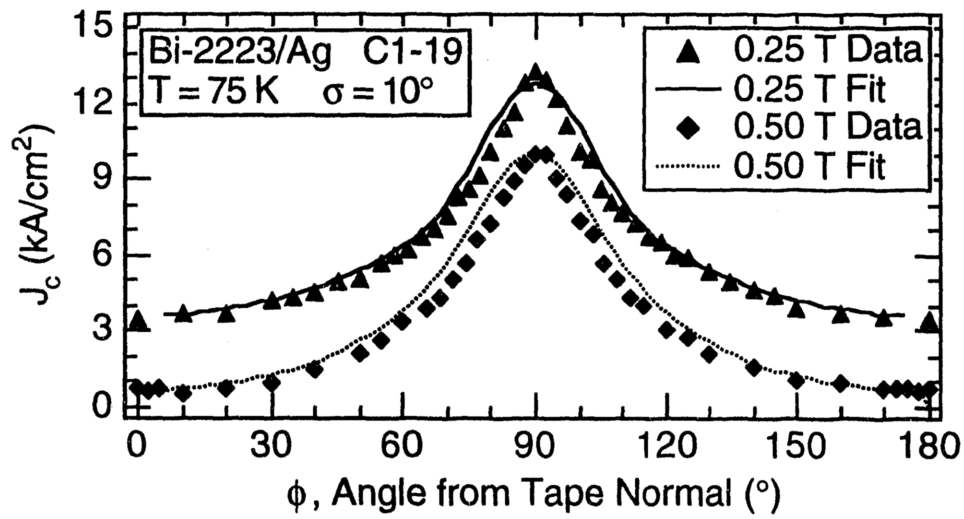

Fig. 3. J_c of tape C1-19 at 75 K *vs.* the normal angle ϕ for fields of 0.25 and 0.50 T. The lines are calculated using the model and the σ value of 10° obtained from fitting the data of Fig. 2.

Table 1. Critical current density J_c, grain orientation distribution function width parameter σ, deviation angle θ_d [= 90° - ϕ], and rocking curve (Ω scan) width for monocore (designated with a "-1" suffix) and multifilament (designated with "-19") Bi-2223/Ag tapes.

Sample	J_c (77 K, B = 0) (kA/cm^2)	σ of Grain Orient. Dist. (°)	θ_d (75 K) (°)	Ω scan FWHM (°)
AA2-1	20	20	10.1	19
A1-19	17	14	9.0	12.5
A16-1	13	16	8.9	25
A17-19	19	12	5.1	-
C1-19	25	10	7.6	-
C2-19	27	10±2	6.2	-
C3-19	29	10	7.2	-

CONCLUSIONS

There are several general trends that can be seen in these data. The first is that the multifilament tapes tend to have a narrower orientation distribution width than the monofilament tapes. This is also seen in the limited Ω scan data as well. The second is that, especially for the multifilament tapes, there is a weak inverse correlation of J_c values with σ. This has been pointed out by others as well.[6] Although texture, and what is determined by these measurements is global, not necessary grain-to-grain texture, is clearly important in obtaining high J_c values, even the best grain-aligned tapes measured here and elsewhere have much lower J_c values than those achieved by thin, nearly single-crystalline films of Bi-2223.[1] This suggests that other limitations, such as weak links, or poor connectivity may be the source of the shortfall in the performance of these really high performance, polycrystalline tapes. Both texture and connectivity must be the subjects of future study in order to improve the quality of present day Bi-2223/Ag conductors.

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