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EFFECT OF THE COLONY MICROSTRUCTURE ON TRANSPORT CRITICAL CURRENT OF HIGH-J_C Tl-1223 THICK FILMS

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High J_c, polycrystalline, $TlBa_2Ca_2Cu_3O_{8+x}$ thick films on poly-YSZ substrates were examined by x-ray microdiffraction, electron microscopy, and electron back scatter diffraction (EBSD). The superconducting phase was formed by vapor phase thallination of thallium-free precursor deposits [1]. Typically, the FWHM of a c-axis rocking curve is 1-2°, indicating very good c-axis texture. Grains tend to be 0.2-1 μm thick (in the c-direction) and 3-10 μm in the plane [2]. J_c measured resistively with voltage contact spacing in the range of 1 to 4 mm (therefore spanning hundreds of grains) is typically 0.5 - 1 x 10^5 A/cm^2 in self-field at 77 K and has good field dependence [1]. At 40 K in fields up to 9T, J_c remains well above 10^4 A/cm^2 [1]. X-ray phi scans were used to study the local and macroscopic in-plane texture [2-4]. A large x-ray beam (4 x 8 mm) which illuminated most of the specimen surface indicated random a-axis orientations, i.e., no macroscopic in-plane texture. However, restricted beams of 0.25 mm^2 and 0.01 mm^2 showed a very high degree of in-plane texture [3]. These results can be interpreted as indicating the presence of colonies of grains with similar a-axis orientations.

Electron backscatter kikuchi diffraction was used to discern the actual grain structure within the colonies [4]. Within a colony there are few high angle grain boundaries, hence current flow within a colony is expected to be strongly linked. For current flow across colonies, the misorientation of grain boundaries at the colony intersection determines the transport behavior, Figure 1a & b show two typical colony intersections. Since the c-axis of all the grains are well aligned, only the a-axis of the grains projected on the sample plane is indicated. It can clearly be seen that in Fig. 1a the colony intersection is well-defined and high angle. Within each colony there are only small angle boundaries. Furthermore, it is found that at the colony intersection in Fig. 1a, more than 50% of the boundaries are low sigma boundaries. In Fig. 1b, the colony orientation changes gradually from one orientation to the other. In such a case the colony intersection is broad and diffuse. It is found that most of the boundaries are small angle. Similar measurements have been made on many films and over 1500 grain boundaries have been characterized. It is found that there is a preponderance of small angle boundaries. The presence of colonies and colony intersections suggests percolative current flow between colonies. This was confirmed by dependence of transport critical current density on the measurement-bridge width. Increasing the width beyond the average colony size results in an increase in J_c.

The character of colonies can be determined by the full-width-half-max (FWHM) of a X-ray phi-scan. The effect of colony characteristics on the macroscopic transport properties was simulated by a limiting path calculation which clearly shows the existence of an optimum FWHM [5]. Fig. 2 shows the results of a limiting path calculation of J_c as a function of the colony mosaic. The optimum arises due to competing effects of decrease in intracolony J_c and an increase in the intercolony J_c with increase in mosaic or FWHM of the colonies.

Examination of films quenched from various stages into the growth process show that the colonies form during crystallization. Microstructural examination shows that the Tl-1223 phase first crystallizes at the substrate/film interface. The crystallization front then moves up through the film and along the length of the film. The presence of a well-defined growth front was revealed by microstructural examination and x-ray diffraction. In addition, various processing parameters were found to affect the colony characteristics and may be used to optimize the microstructure.

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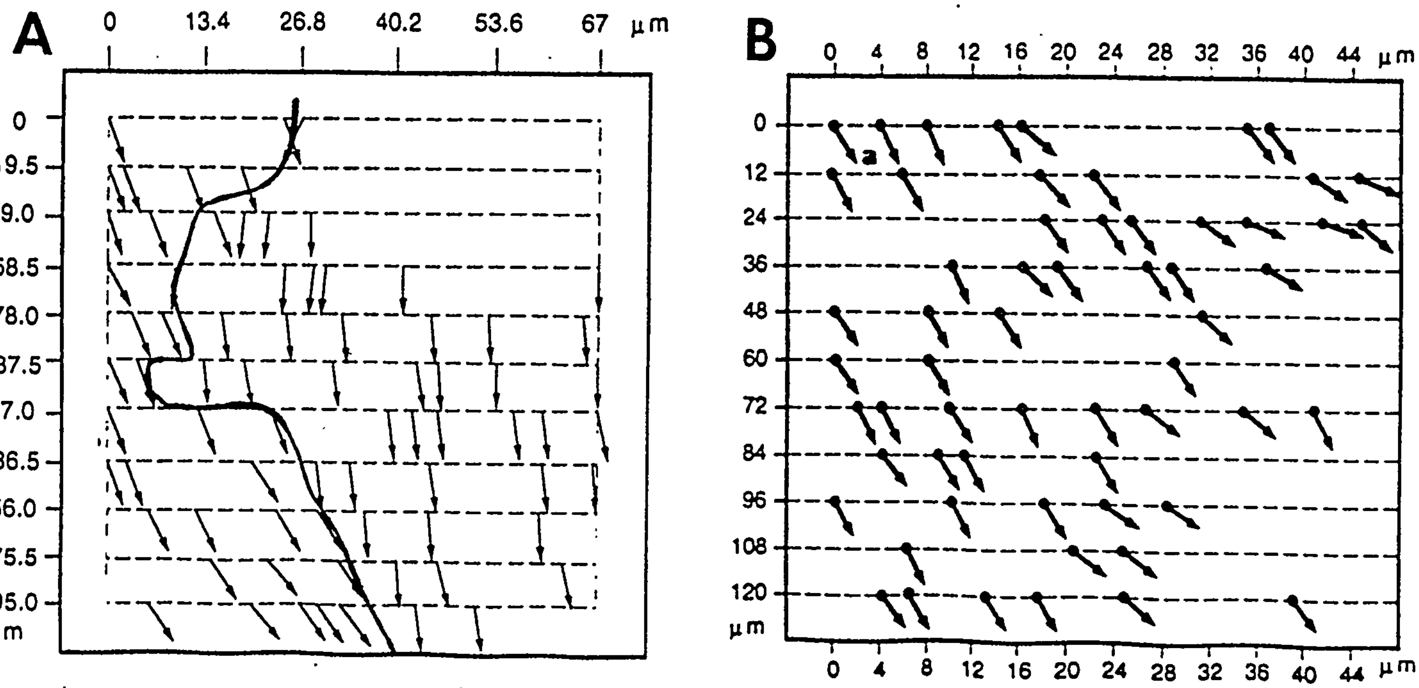

Fig. 1a: Orientations of the a-axis of the grains are plotted for an area containing two colonies. Arrows are placed at the grain boundaries and represent the orientation of the grain on the right. The colony intersection is indicated by the hand-drawn curve. About 75% of boundaries in this region are <10° and 54% of boundaries at the colony intersection are within the Brandon criterion for an ideal CSL.

Fig. 1b: Orientation of a-axis of grains in a region where the orientation gradually from one colony to another without a well-defined colony intersection. About 52% of boundaries are small angle, and 14% of the boundaries are within the Brandon criterion for an ideal CSL.

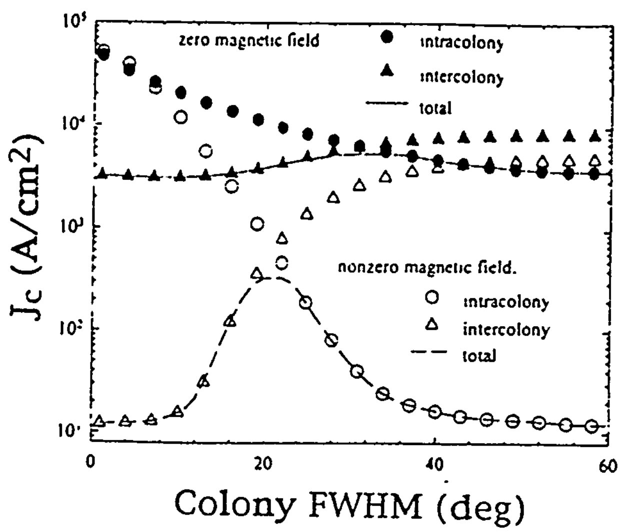

Fig. 2: Simulated critical currents for 100 x 100 arrays of colonies as a function of grain alignment within the colonies. Calculations at H = 0 & 0.01T are indicated. The intragranular J_c decreases with increase in FWHM of the colonies whereas the intergranular J_c increases with FWHM, resulting in an optimum FWHM.