Grain Alignment under 1-dimensional Confinement in High Critical Current Density Bi2212 Round Wires

F. Kametani, J. Jiang, N. Craig, M.R. Matras, E.E. Hellstrom, D.C. Larbalestier (High Magnetic Field Laboratory, Applied Superconductivity Center)

Introduction

It is a basic rule of cuprate superconductivity that high angle grain boundaries (HAGBs) must be eliminated if high critical current densities are to be obtained. This had been thought of as a universal rule for all HTS materials until $Bi_2Sr_2CaCu_2O_x$ (Bi2212) round wires recently achieved J_c of 4000 A/mm^2 at 4.2 K, 5 T by utilizing the over pressure reaction technique to produce full density wires containing many HAGBs. This extremely promising and potentially breakout result is what has caused us to learn much more about the local texture in such wires.

Experimental

In order to understand whether HAGBs in Bi2212 are superior to those in $Bi_2Sr_2Ca_2Cu_3O_x$ (Bi2223) or $REBa_2Cu_3O_{7-\delta}$ (REBCO), or whether other mechanisms compensate for the generally believed obstructing effects of HAGBs, we extensively studied the grain and GB structure of Bi2212 round wires using electron backscatter diffraction orientation image analysis (EBSD-OIM).

Results and Discussion

An EBSD-OIM generated inverse pole figure (IPF) grain map for a 2212 filament section is shown in figure 1a. The grain and grain boundary (GB) structure are visualized based on the crystal orientation of Bi2212 grains parallel to the projection axis. Red, blue and green colors representing the (001), (110) and (100) crystal planes respectively have been used to color the image. Due to the anisotropic crystal structure, Bi2212 tends to form whisker-like grains which are 10-100 μm long, ~1 μm thick, forming a unique GB structure where planar GBs parallel to the ab-plane are more dominant than those parallel to the c-axis (figure 1a). The IPF plots derived from the EBSD-OIM represent the distribution of Bi2212 grain orientation along the axis normal (ND, figure 1b) and parallel to the wire direction (RD, figure 1c). On an IPF, in-plane crystal misorientations are represented as a spot distribution between (100) and (110), whereas the out-of-plane misorientations can be seen between (100)/(110) and (001). The grain orientations along the defined axis are plotted on an IPF as a single point if there is no plastic deformation inside the grains. However, plastically deformed 2212 grains show continuous drifts toward the deformation direction on the plot as seen in figure 1b, suggesting that almost all Bi2212 grains tend to plastically twist their whisker-like shape, possibly minimizing local misorientation of ab-planes of adjacent grains. Furthermore, the Bi2212 grain misorientation of both in-plane and out-of-plane along the wire axis is ±15°, which is surprisingly smaller than that found in uni-axially textured Bi2223 tapes, presumably because of a whisker-like grain growth which occurs in the geometrical confinement of the 20 μm diameter filaments in these wires.

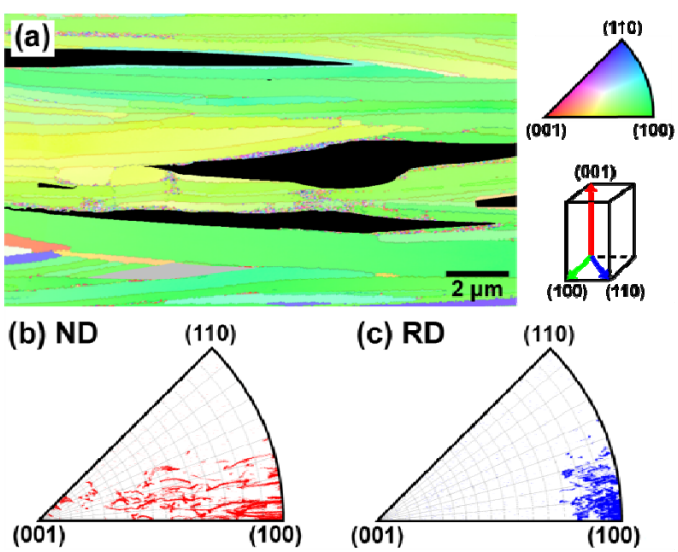

Figure 1 (a) Inverse pole figure (IPF) grain map derived from EBSD showing the grain/GB structure in a high J_c Bi2212 round wire cross-section sliced parallel to the wire axis. (b)(c) IPFs showing the distribution of Bi2212 grain orientations for projection axes of perpendicular (ND) to and along (RD) the wire axis respectively.

Conclusions

The EBSD-OIM technique has revealed a unique grain/GB structure in Bi2212 round wires. Large grain misorientations are is accommodated by plastic bending and self-alignment of Bi2212 grains possibly due to the 1-dimensional geometrical confinement within the filaments. These unique features of the Bi2212 grain structure may help explain the strong grain-to-grain coupling and high J_c that we have observed.