Effects of intermediate rolling force on the texture of Ag/BSCCO composite tapes


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(Bi,Pb)$_3$Sr$_2$Ca$_2$Cu$_2$O$_{10+\delta}$ (Bi,Pb(2223)) is a superconducting compound exhibiting a transition to the superconducting state above 100K. Until now, it appears as one of the most promising materials in view of the manufacture of devices operating at the boiling temperature of liquid nitrogen. For this purpose, the Bi,Pb(2223) phase must be surrounded by a Ag sheath. The preparation of such Ag-Bi,Pb(2223) composites is not straightforward and necessitates several sintering and mechanical deformation steps. The most important parameter of the composites is the critical current density as measured at 77K in self-field. This parameter depends on several characteristics of the superconducting ceramic. One of the most important factors is the relative orientation of the crystallites (texture), owing to the structural anisotropy of the material. Obtaining information on the average texture of Ag-Bi,Pb(2223) tapes is not straightforward. X-ray synchrotron radiation is the only non-destructive method for this purpose, owing to the ability of high energy radiation to penetrate the Ag sheath, which is about 100µm thick. It was commonly believed that intermediate densification steps improve the overall texture of the ceramic cores, thus improving the critical current density. However, recent investigations utilizing various methods suggest that this might not be the case [1].

In the present series of measurements, several samples were prepared, using various forces during the intermediate rolling steps. This deformation was followed by a final annealing, after which the tapes were investigated. Transmission diffraction measurements were performed at beam line BW5. The details of the experimental set-up and data analysis can be found in [2]. In brief, the tapes were placed vertically, with their plane forming an angle of 75° with the primary beam. The diffracted intensities were collected on a CCD plate. The (117) reflection of the Bi,Pb(2223) phase was used for extracting information about the c-axis orientation, using the software package FIT2D [3]. The FWHM was obtained from a fit to a Gauss function.

As can be seen in Fig. 1, the application of higher rolling forces results in a significant decrease of the texture of the Bi,Pb(2223) phase. This feature can be explained in the following way. Prior to the mechanical densification step, the ceramic core of the tapes include a non-negligible porosity. It mainly consists of Bi,Pb(2223) crystallites, which have a high aspect ratio and are easily bent or broken when subjected to an uni-axial pressure. Furthermore, some more resistant grains of secondary phases that have more regular shapes are also present. According to microscopic investigations, the Bi,Pb(2223) crystallites tend to be broken during the application of the rolling force. Thus, filling the porosities and being pressed around the edge of round-shaped secondary phases, the Bi,Pb(2223) grains will lose a part of the orientational coherence they gained during the preceding sintering steps. Since the final annealing treatment does not induce extended texture modifications, the average orientation resulting from the last mechanical deformation will determine this aspect of the final microstructure of the ceramic core. The critical current densities of these samples however increase with the rolling force.

The same diffractograms were used to extract information on the phase composition of the different samples. Besides the Bi,Pb(2223) phase, which is forming more of 80% of the ceramic, some (Bi,Pb)$_2$Sr$_2$CaCu$_2$O$_{6+\delta}$ Bi,Pb(2212) as well as a Pb-rich phase (Ca,PbO$_x$ or Pb,Sr$_2$Bi$_5$Ca$_2$Cu$_2$O$_y$) are present in small amounts. Nevertheless, the relative proportion of these different compounds is the same, notwithstanding the rolling force. This indicates that the origin of the higher critical current densities in the tapes rolled with the highest forces must be found elsewhere. Such parameters as ceramic density and grain boundary coupling are likely to play a major role. A complete understanding of the interplay of these various parameters requires further investigations by means of complementary techniques.
Figure 1: FWHM determined on the (117) reflection of the Bi,Pb(2223) phase versus force applied during the intermediate deformation process (rolling).

References