Strong Influence of Filament Bridging in Enhancing Supercurrent Transport in Melt Processed Multifilament Ag/Bi-2212 Round Wire

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Introduction

High critical current density ($J_c$) Bi$_2$Sr$_2$CaCu$_2$O$_x$ (Bi2212) conductor is vital to next generation high-field superconducting magnets, but the material and physical understanding of $J_c$ in Bi-2212 round wire (RW) is limited, particularly due to the complexity of the processing and microstructure. We report a three dimensional current flow model that assumes filament bridging plays a key role in carrying high $J_c$ between filaments in AgX/Bi2212 multifilamentary round wire by examining and characterizing its microstructure occurring in the partial-melt process.

Experimental

Short length Bi2212 RW is quenched into brine from high temperature to room temperature from a series of points along entire partial melt process. Such quenching freezes the microstructure and electromagnetic properties. After quenching, we examine the microstructure using a field emission scanning electron microscope (SEM), and the phase chemistry using energy dispersive spectroscopy (EDS).

Results and Discussion

Figure 1 shows the characteristic transverse cross-section of Bi2212 RW quenched just before Bi2212 starts to form. This sample was melted at 894 °C, slowly cooled at 2.5 °C/h and quenched from 872 °C. Shown is one of the six outer 85 filament bundles. The grey matrix is Ag or AgMg. Within each filament, EDS identified the black region as Sr$_x$Ca$_{14-x}$Cu$_{24}$O$_y$ (14:24 alkaline earth cuprate) or as a pore, white as Bi$_9$Sr$_x$Ca$_{16-x}$O$_y$ (9:16 copper-free), and grey as an amorphous liquid phase. There are two significant features: a substantial amount of porosity is present in the filaments, significantly diminishing the supercurrent carrying cross-section, and filaments bonded together in the melt state, linking the filaments three-dimensionally as shown in fig. 2. As a result, Bi2212 filament bridges develop across filament-filament bonding. We believe this type of filament bridge conducts current transversely from one filament to another, resulting in a three-dimensional current flow path that bypasses the significant porosity that blocks the current flow within each individual filament.

Conclusions

There are two significant results from this study. First, a heterogeneous melt process step causes significant porosity and large non-superconducting phases, especially AEC, thus forcing the previous macroscopically uniform Bi2212 microstructure to become very inhomogeneous. As a result, Bi2212 filaments are segmented by gigantic material defects, restraining Bi2212 grain growth and severely blocking current flow within each individual filament. Second, filaments bond together in the melt state, resulting in significant filament bridging that enables the current to flow three-dimensionally from one filament to another, bypassing the porosity and non-superconducting phases. We conclude that the three-dimensional current flow provided by filament bridging significantly enhances the connectivity of Bi2212 RW.

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