# Study of Bi-2212 for High-field Magnets

Eric Hellstrom, TengMing Shen, Justin Schwartz, David Larbalestier (NHMFL-ASC)

2212 round wire is a promising material for high-field (30-50T) magnet applications because it has high Jc (critical current density) in very high fields and it is round. We are investigating the fundamental aspects of 2212 thermal processing to understand what how Jc develops during the heat treatment, what limits Jc, and how we can increase Jc in coils.

During thermal processing, the microstructure of 2212 wire changes drastically, going from bundles of distinct filaments to bundles of bridged filaments. A question we asked is whether the bridges that grow between the filaments are beneficial or detrimental to Jc. Prior to our studies, bridges were thought decrease Jc because they decreased the 2212 grain alignment in the filaments. In contrast, our studies indicate bridges are vital for high Jc. But not just any bridge increases, Jc. The critical bridges are those that form between two or more bonded filaments, which we think form an interconnected 3-D filament network that provides a continuous high-Jc path through the wire.

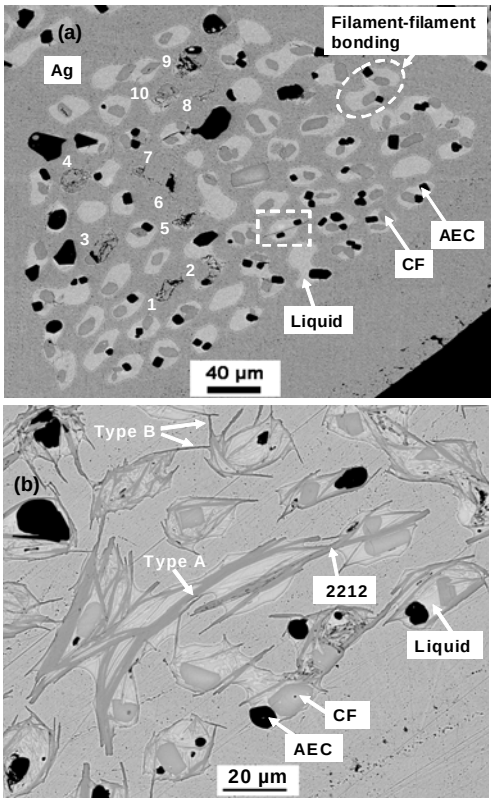


**Fig. 1** Transverse cross sections of 2212 wire cooled at 2.5°C/h quenched (a) just before 2212 begins to form and (b) just after 2212 begins to form. (a) Micrograph shows liquid, copper free (CF), alkaline earth cuprate (AEC), where filaments are pinched off or missing (1-10) due to the presence of a pore in the filament, and regions where filaments have bonded together. (b) Micrograph shows liquid, CF, AEC, and large filaments (type A) that grew between bonded filaments, and small filaments (type-b) that grew through the Ag between the filaments. Type b filaments typically form a high-angle GB with 2212 in one of the filaments.

Using quenching we studied high-temperature microstructure during the heat treatment. We knew from previous work that when 2212 melts it forms nonsuperconducting phases, liquid, and gas filled pores. Pores form because the 2212 powder is only ~75% dense in the filament, and on melting, the gas in the ~25% pore space agglomerates into large pores that can block the filament. A new insight from our studies is that melting segments every 2212 filament into regions containing melt (i.e., liquid plus nonsuperconducting crystalline phases) that are separated from each other by the large pores. The filaments are still segmented when 2212 forms, which is a serious problem because 2212 grains cannot grow across the pores (Fig. 1a). We also found the filaments bond together before 2212 forms (Fig 1a). Bonded filaments are important because they form a 3-D network connecting the melt regions in the filaments. Large 2212 grains can bridge between bonded filaments (Fig. 1b). We believe these large 2212 bridges between bonded filaments provide a path for supercurrent to by-pass current limiting pores and nonsuperconducting phases in one filament by moving to another filament.

We can design new heat treatments to increase Jc based on our new understanding of the microstructure of the 2212 filaments, filament bonding, and bridge growth between bonded filaments