Evaluation of Nb_3Sn Superconductor for CERN's Accelerator Upgrade

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The High Luminosity (HiLumi) upgrade of the Large Hadron Collider (LHC) at CERN requires the first use of Nb_3Sn in accelerator magnets. Powder in Tube (PIT) wire with $NbSn_2$ powder encapsulated within Nb7.5wt.%Ta tubes (Fig 1) is a leading candidate for high current density (J_c) conductors for these magnets. The Nb_3Sn superconductor is made by a long heat treatment at ~630 °C that converts $NbSn_2$ to Nb_3Sn. Very high J_c comes from maximizing the amount of small grain (~0.1 µm diameter) Nb_3Sn formed in this reaction. However, about 25% of the Nb_3Sn does not contribute to high J_c. *A detailed study has been made of the reactions that occur between $NbSn_2$ in the core and the Nb-Ta tubes. Strategies to make greater conversion to small grain Nb_3Sn have been identified* [1].

A second, independent issue is the need to protect the high-purity matrix Cu from any contamination by the Sn contained in the tubes, so that magnet quenches are safe. Distortion of the filaments during wire fabrication or in cable manufacture produces asymmetric filament shapes (Fig. 3) that can allow the Nb_3Sn reaction front to reach the Cu matrix and locally destroy its high conductivity. *The study defined the permitted shape deformations and reactions to avoid such degradation. New conductor designs based on this study have begun.*

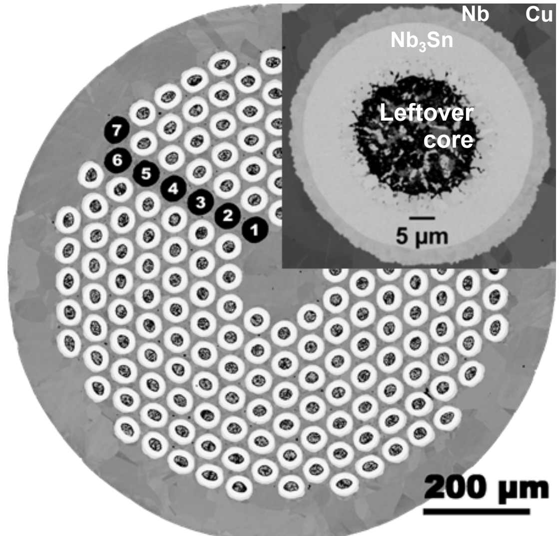

Figure 1: Images of transverse cross-sections of a reacted PIT wire with 7 rings of filaments and a typical filament shown in inset. This filament is 50 µm in diameter, or about half the width of a human hair.

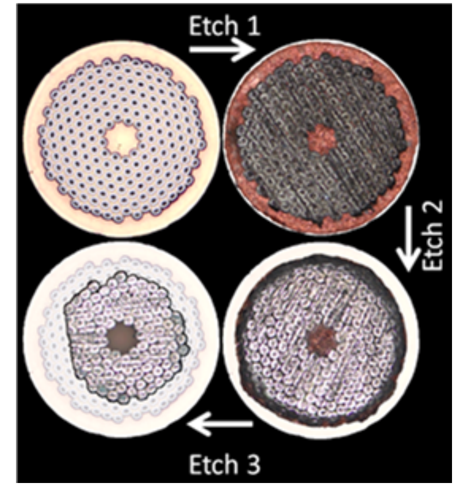

Figure 2. Light microscope images of a reacted PIT wire after progressively etching away exterior Cu matrix. The etched images are overlaid on the initial cross section. Sequential resistivity measurements showed that only Cu around outer distorted filaments degraded the conductivity.

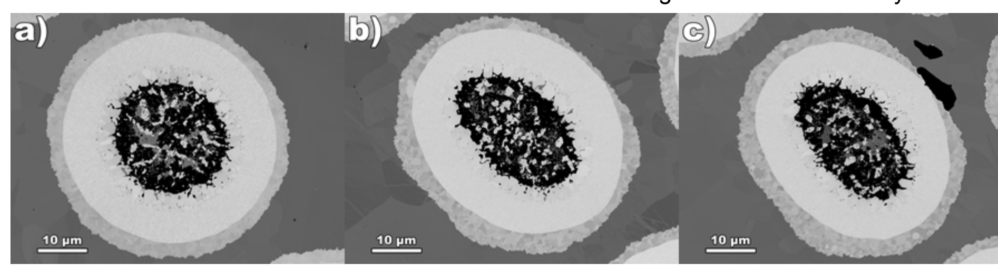

Figure 3: Variation of filament aspect ratio from a.) the inner 4 rings, b.) a typical filament found in the outer 3, more distorted rings, and c.) an outer ring which locally leaked Sn into the stabilizing Cu, degrading the Cu conductivity.

Facilities: MagLab's Applied Superconductivity Center

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