Niobium for Long-Length Fine-Filament Nb3Sn Conductors

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Nb used in Nb3Sn multifilamentary superconductor wire deforms throughout the fabrication process including the initial extrusion and subsequent drawing, restacking, re-extrusion, and final drawing steps. Unfortunately niobium, usually begins as a 300 mm diameter ingot with extremely large grains. While this ingot gets reduced to a 120-150 mm diameter bar before wire fabrication, the cast macrostructure persists. The result during wire fabrication is often non-uniform Nb – Cu co-deformation, the development non-circular Nb filaments, and the tendency for the filaments to sausage and fracture when the diameter gets small (5-10 microns). To improve conductor performance and meet the needs of advanced magnet applications, larger starting Nb bars and smaller diameter Nb filaments in Nb3Sn strands are needed. This can be accomplished by using highly grain-refined and homogeneous large cross section bars of Nb processed by severe plastic deformation. Microscopy including texture characterizations, and mechanical property measurements are reported on the grain refinement of a 175 mm diameter bar of Grade 1 Nb, to be used to fabricate a prototype multifilamentary Nb3Sn wire. This work presents success with scale-up of a new severe plastic deformation process as applied to starting Nb bar in the Nb3Sn wire fabrication process

Project Objectives

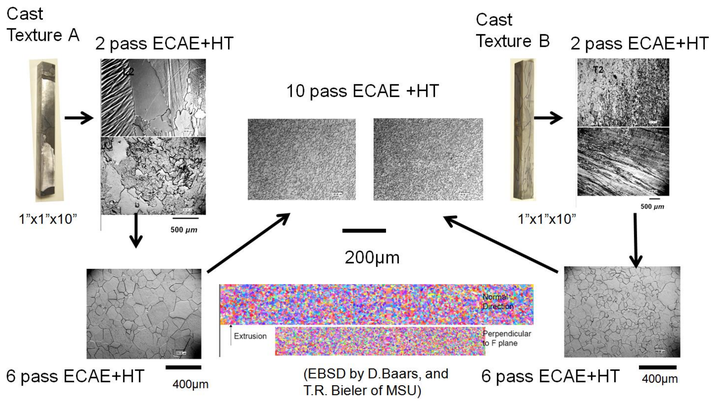
Thermal mechanical processing (TMP):

- Produce recrystallized fine grain size (less than 50 micron average)
- Develop a uniform recrystallized microstructure
- Demonstrate high product yield
- Confirm ECAE scale-up potential

Prototype wire fabrication using large scale-up Nb material:

- Demonstrate good Nb deformation characteristics
- Demonstrate good Cu-Nb codeformation characteristics
- Achieve smooth Cu-Nb interface characteristics throughout composite wire fabrication
- Achieve high level of Nb core circularity during Cu-Nb monofilament wire fabrication

Using Equal Channel Angular Extrusion to Converge Microstructures



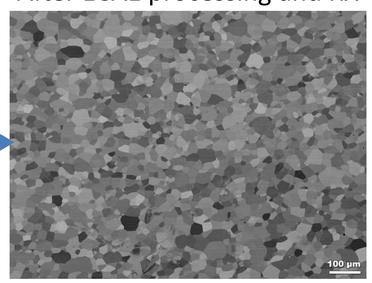
A well-designed thermomechanical processing strategy including ECAE can converge disparate large grained microstructures to a uniform fine grained material suitable for further forming.

Scale-up

Initial microstructure of bar

7in dia. ECAE Tool

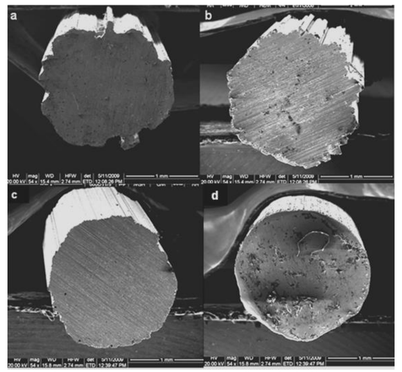
After ECAE processing and RX



Lessons from Small-Scale Wire Prototypes

Uniform Fine Grain Size is Highly Desirable

- A finer initial Nb grain size leads to better conformity of roundness of Nb rods in a Cu matrix.
- The initial hot extrusion process is important for achieving better Nb uniformity and deformation characteristics.
- Favorable microstructures for Cu-Nb codeformation by warm extrusion and wire drawing can be developed by ECAE.

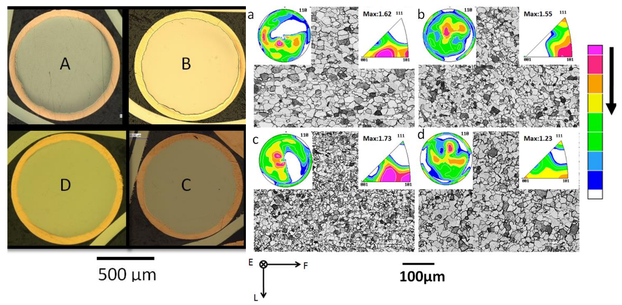


As-drawn Nb wire sections with the Cu etched off.
a) Sample #11049 initial grain size 10-40mm,
b) Sample #11050 initial grain size 1-3mm,
c) Sample #11052 initial grain size 70-170μm,
d) Sample #11051 initial grain size 20-60μm.

Macro Texture is Secondary

A small grain size in Nb with sufficient ductility leads to excellent filament deformation in composite conductors. Global texture effects are secondary.

However, this study did not consider the effects of local texture variation

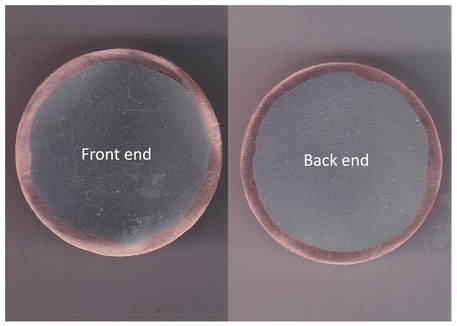


Full Scale Wire Prototype

SFI processed Grade 1 Nb bar for reduction and wire draw at Bruker-OST. Initial stages of wire drawing have been completed

180cm diameter ECAE processed Nb bars

Mono billet at 2.5cm after extrusion and draw



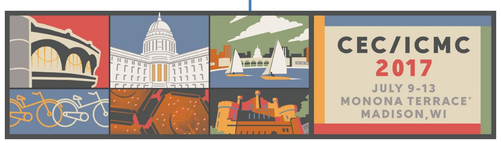
Future Plans and Unanswered Questions

SFI now has an in-house hydraulic press suitable for intermediate size ECAE processing. This will permit ECAE processing of Nb up to ~10cm across.

Will the large-scale Nb in the above study demonstrate improved drawability to fine wire?

Is the non-circularity in the large-scale Nb above due to remaining texture segregation?
Is this non-circularity detrimental?

How do we economically improve circularity?



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