FCC-hh Nb_3Sn wire development: superconducting and magnetic properties of prototype samples

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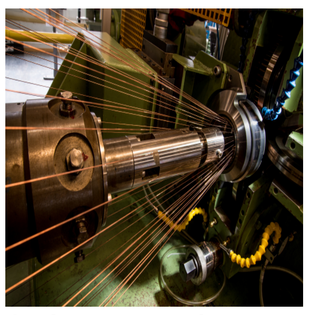
Introduction

Nb_3Sn is the principally envisaged superconductor for the Future Circular Collider (FCC-hh) dipole magnets. We present the superconducting and magnetic characterization of prototype internal tin Nb_3Sn wires, manufactured at the Bochvar Institute (RU) with different designs and heat treatments. AC susceptibility was used to assess the critical temperatures, evaluating as well the longitudinal inhomogenities. The local properties were investigated using scanning Hall probe microscopy (SHPM): field maps of the Meissner-state revealed the effective geometry of prototype designs (sub-elements structure, barriers, width of resistive separators) whereas scans of the remnant fields enabled us to calculate the local critical currents.

State of the art

Pushing Nb_3Sn to its performance limits

- FCC-hh dipole-magnets conductor standards are: **1.5 kA/mm²** non-Cu J_c at **4.2K** and **16T**
- Performances not yet reached with Nb_3Sn but J_c still enhanceable
- Nb_3Sn is a cheaper conductor than HTS and produced worldwide



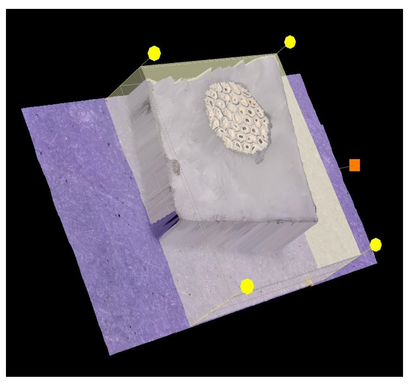
- New research lines re-started after years of inactivity (new manufacturing technologies, layouts, doping)

Samples

2 samples prepared in thin slices:

Wire identification	"Standard layout"	"Clusters layout"
Wire dia, mm	0.7	0.7; 0.36
Barrier	Distributed Nb	Distributed Nb+Ta
Subelement number	37	37
Subelement size, µm	80	80; 40
Clusters number	-	37×3
Clusters size, µm	-	47; 24
Resistive separator	-	Cu
Number of filaments	29082	29082
Filament diameter, µm	1.6	1.6
Nominal doping, at%Ti	1.4	1.4
Cu-non-Cu ratio	1.3	1.15

Local properties investigation methods require high-quality sample preparation:



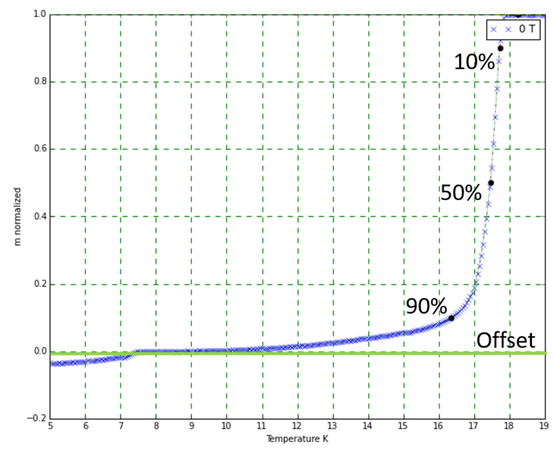
- Specimens cut with diamond saw and polished with gradually decreasing-roughness grinding paper (Al/Si-oxide)
- Thickness of the sample should be reduced towards the thinnest achievable slice(best result = 20μm)

- Same slices are used for SHPM and SEM/TEM
- Cu-etching is sometimes required in order to better evaluate the A-15 phase homogeneity of single sub-elements over the radial direction

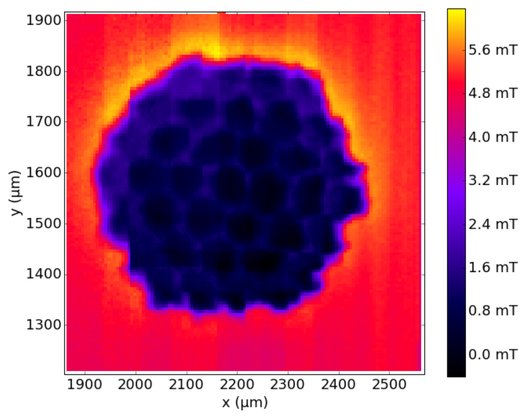
Results

AC Magnetometry

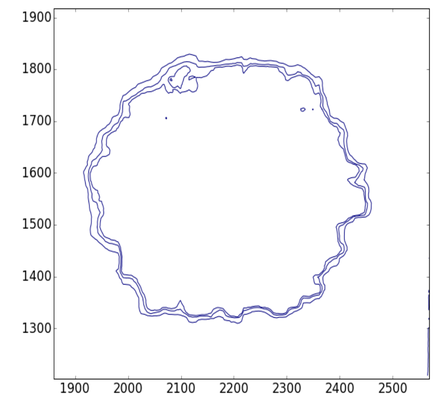
- T_c measured via AC susceptibility over 8 different samples
- Small step found at 6.9K in all samples (bigger in Nb+Ta distributed barrier)
- Small step found at 8.55 K in samples with Cu-Mn resistive separators
- Longitudinal inhomogeneity in the signal magnitude of ~20% over a short length



Scanning Hall Probe Microscopy



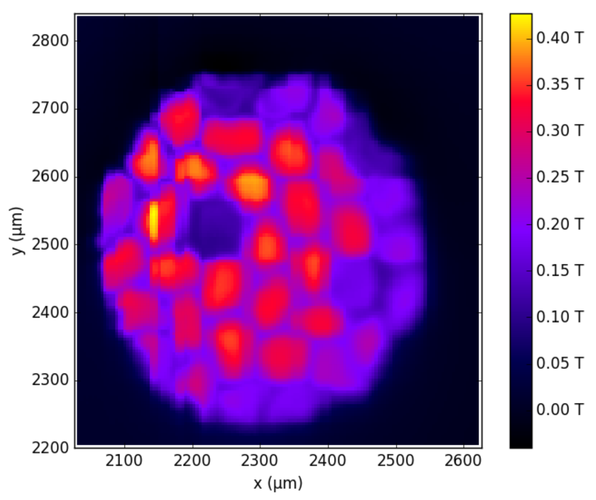
Clusters layout:
Scan of the Meissner state at 10 K, B_{appl} =5mT



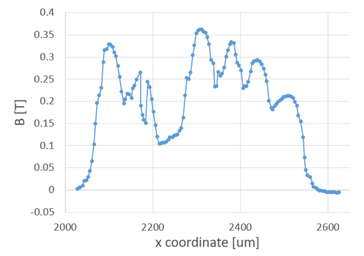
Shielding contours at 80, 50 and 1/e % of B_{appl} :no field penetration, sub-elements not distinguishable

Remanent-field scans (sample fully magnetized, then scanned in self-field) allow the evaluation of single sub-element magnetization profiles at different temperatures

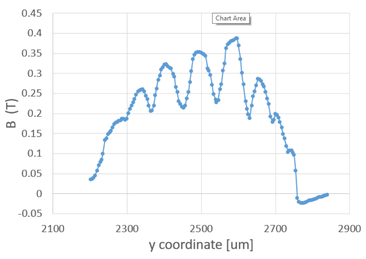
By inverting the remanent field profiles it is possible to evaluate the local currents flowing over the cross section

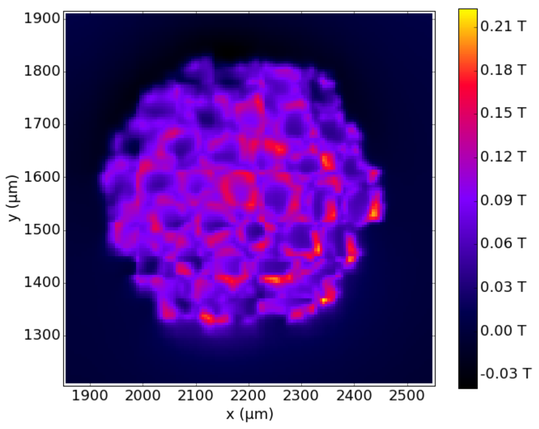


Standard layout:
Remanent-field profile at 10 K

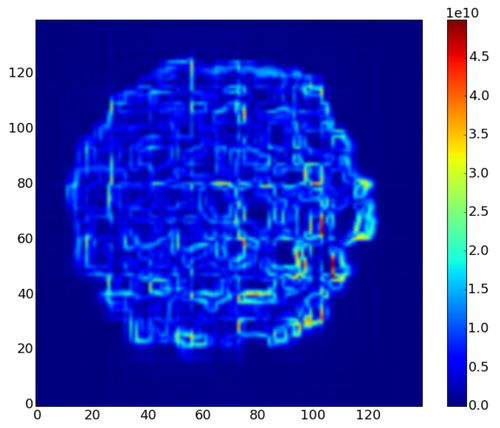


Single line scans show inter-filaments coupling:





Clusters layout:
Remanent-field profile at 10 K



Local J_c evaluation (A/m^2)

Summary and Outlook

- T_c assessed for all specimens, local J_c evaluated for 2 layouts
- Sn radial concentration analysis not achievable via magnetization methods within these layouts configuration
- Further investigation on Cu-etched samples ongoing
- Next steps: investigation of the common Nb+Ta clusters-layout samples with Cu-Mn resistive separators

Acknowledgments

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