Homogeneity in Nb_3Sn Wires: A Route towards High Quality Superconductors

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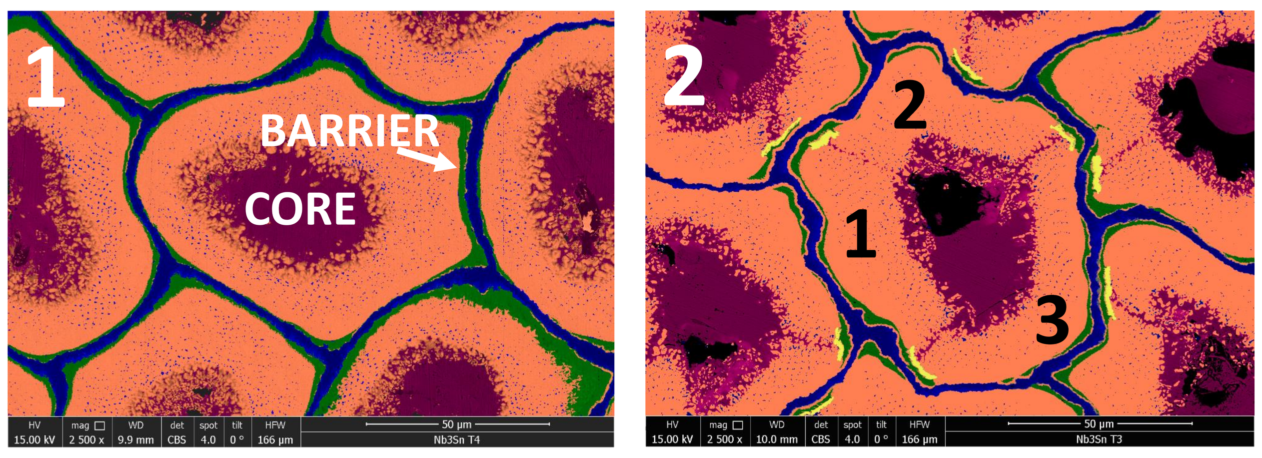
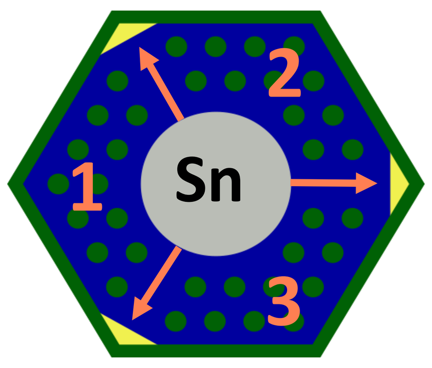
Introduction

Within the CERN Future Circular Collider Study, Nb_3Sn represents the best candidate for the construction of dipole magnets providing a J_c of 1.5 kA/mm^2 at 16 T and 4.2 K. In that context, a new *cluster layout (2)* of prototype internal tin Nb_3Sn wires, manufactured by the Bochvar Institute, was analyzed and compared first to a *standard layout (1)* produced with the same heat treatment by the same manufacturer, then to a standard *rod restack processed* (RRP) (3) and a *powder in tube* (PIT) (4) wire produced by other manufacturers. The main reason for dividing the sub-element into *clusters* is reducing the "effective" sub-element size (d_{eff}).

Wire identification	T4 (1) Standard	T3(2) Cluster	(3) RRP	(4) PIT
Wire Ø [mm]	0.7	0.7	0.8	1
Barrier	Distrib. Nb	Distrib. Nb + Ta	Distr. Nb	Distr. Nb
Subelements	37 (Ø=80 μm)	37 (Ø=80 μm)	108 (Ø=40 μm)	192 (Ø=40 μm)
Dopant	Ti	Ti	Ti	Ta
Cu-non-Cu ratio	1.3	1.15	1.02	1.24



Nb_3Sn Nb Cu Cu-Sn Ta



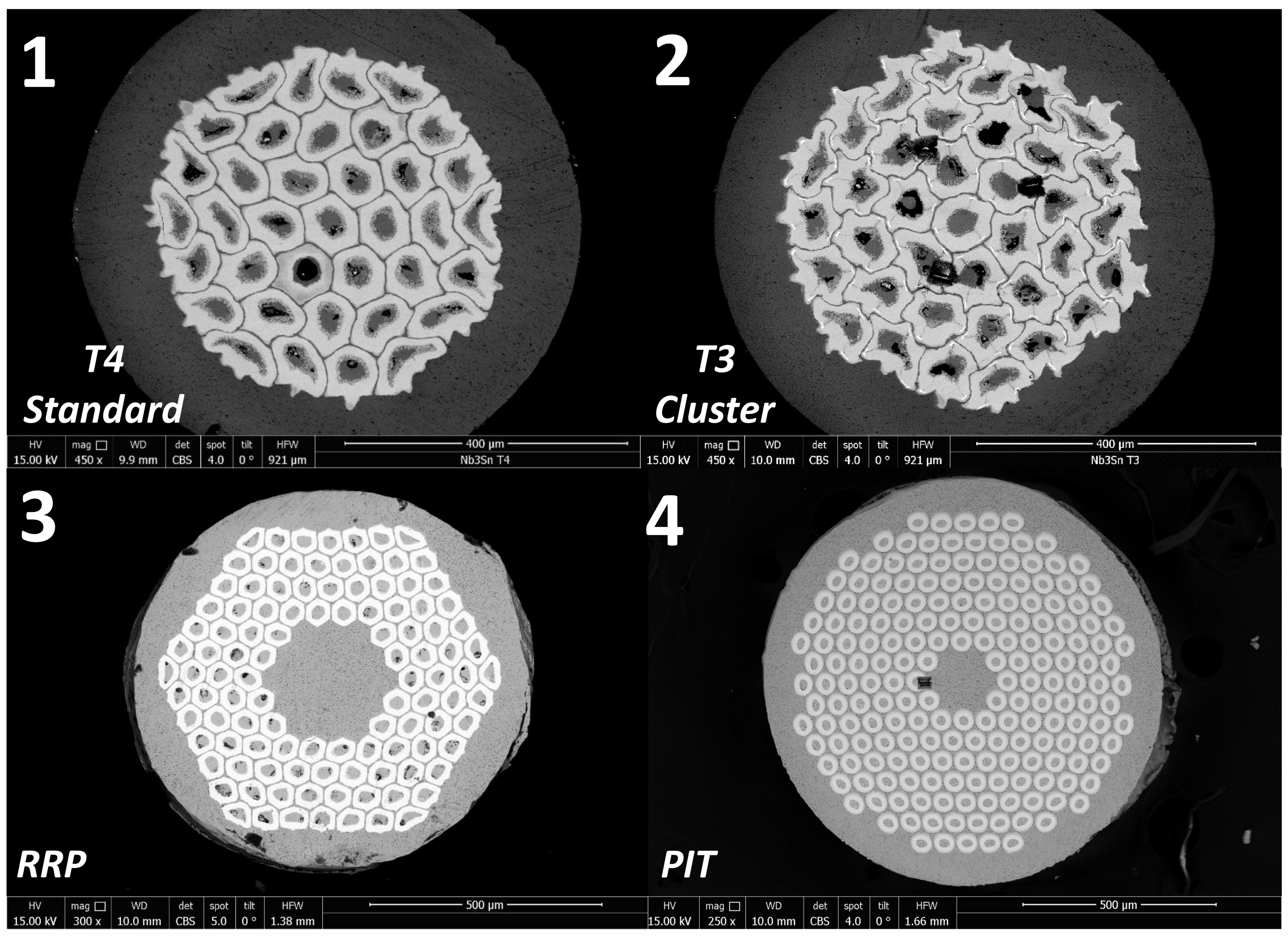
Schematic of the *cluster layout (2)* before heat treatment

As the homogeneity in Sn concentration influences the wire superconducting properties, the effect of the cluster layout on the Sn concentration gradient all over the wire cross section was evaluated by employing *energy dispersive X-ray* (**EDX**) spectroscopy with *scanning electron microscopy* (**SEM**).

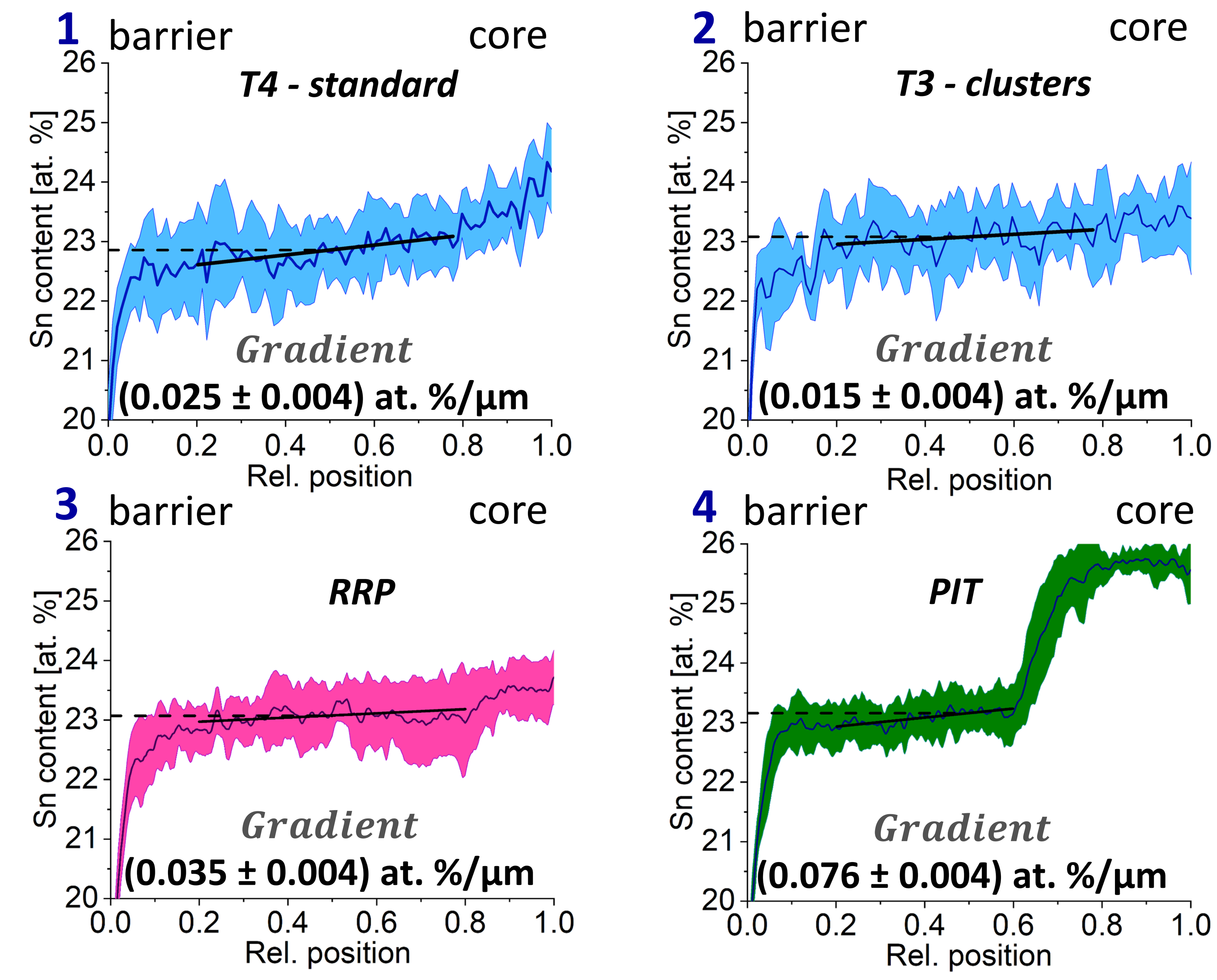
Furthermore, *scanning Hall probe microscopy* (**SHPM**) measurements were performed in order to understand how the sub-elements with the cluster geometry influence the local currents flowing all over the wire cross section on a microscale level.

SEM-EDX homogeneity analysis: Sn gradient

For both wires (1) and (2), EDX line scans were performed over different sub-elements along the radial direction, from the Nb barrier to the Cu-Sn core. The obtained results were then compared to the Sn gradients obtained for standard RRP (3) and PIT (4) wires produced by other manufacturers.

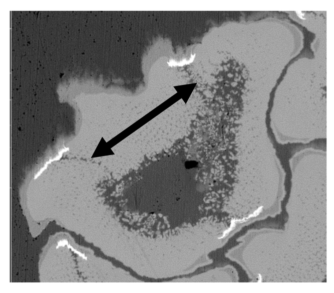


Sn gradient evaluation



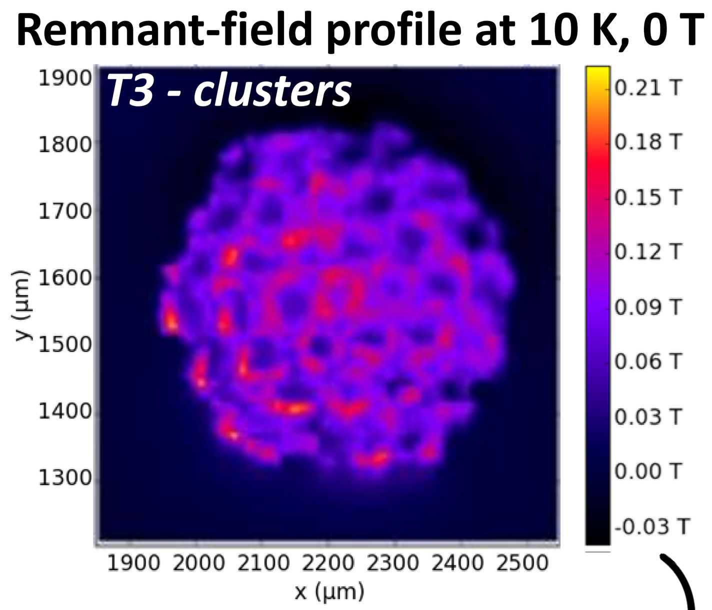
The Sn concentration gradient is smaller in the cluster layout than in the other cases: the cluster sub-elements seem thus to have a great potential in terms of producing wires with higher homogeneity.

In wires with cluster sub-elements, the Sn concentration gradient was evaluated along the tangential directions (cluster width) too, and found to be negligible.

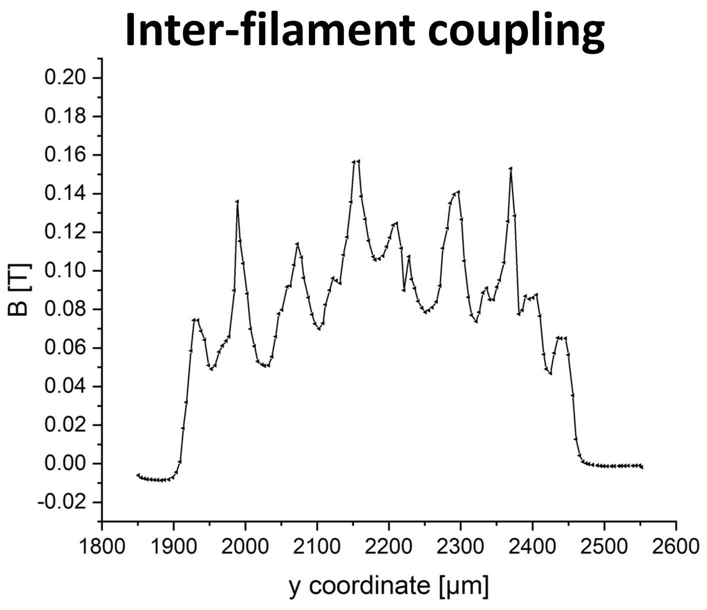


SHPM: remnant field map & local currents evaluation

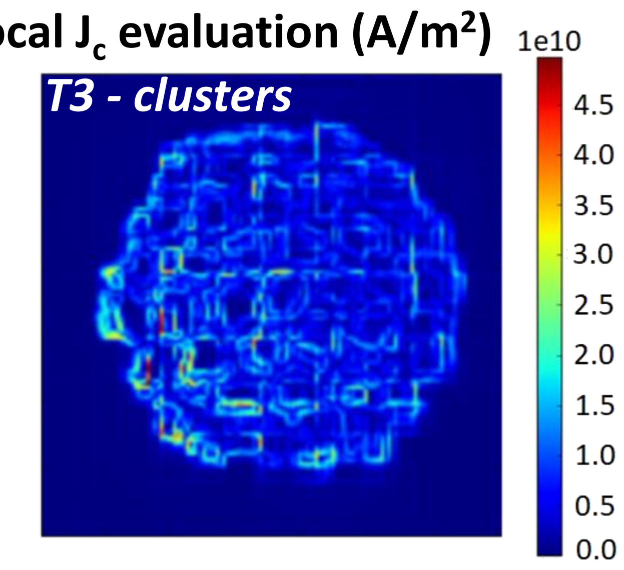
Remnant-field profile at 10 K, 0 T



Inter-filament coupling



Local J_c evaluation (A/m^2)



The sample was fully magnetized, then scanned in self-field. Remnant-field line scans show inter-filament coupling.

By inverting the remnant field profile it is possible to evaluate the contribution of each sub-element to the local current flow over the cross section. The average local J_c value is comparable with the ones found in literature for standard RRP wires at 10 K, self-field.

Conclusion and Outlook

- The new cluster layout shows the smallest Sn concentration gradient.
- The average local current value is in line with state-of-art RRP wires.
- Other possible cluster configurations can lead to further improvements towards reaching the FCC target.

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