TECHNISCHE UNIVERSITÄT WIEN

ATOMINSTITUT

Characterization of FCC conductors at TU Vienna

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FCC week, Brussels, June 27th 2019

Outline

- **Motivation**
- **Inhomogeneities**
  - Prospects
  - Commercial wires
  - Prototype wires
- **Artificial pinning**
  - Neutron irradiation
  - Ternary APC wires (internal oxidation)

Motivation

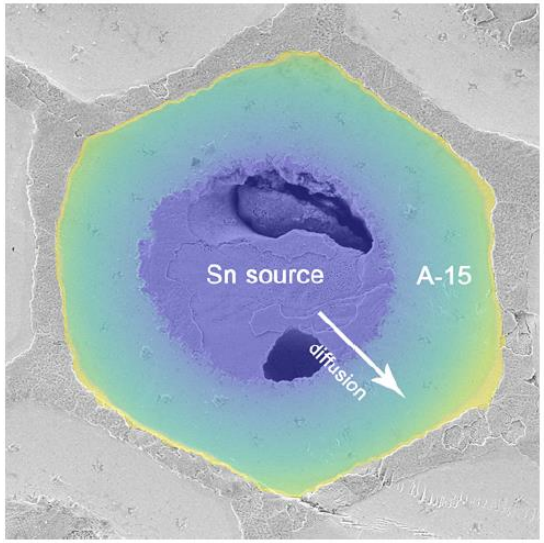
- **FCC-hh requirements**
  Performance increase of about 50% (1500 A/mm^2 (nonCu) @ 16 T)

- **How to achieve?**
  - Reduction of inhomogeneities (e.g. Sn-gradients)
  - Introduction of artificial pinning centers/grain refinement

- **Support conductor development**
  Advanced characterization of microstructure (TEM, SEM) and superconducting properties. Comparison of the local properties.

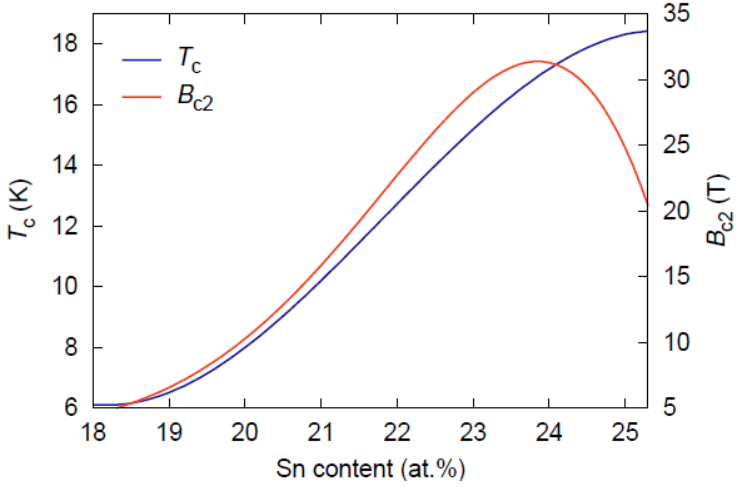
INHOMOGENEITIES

Prospects

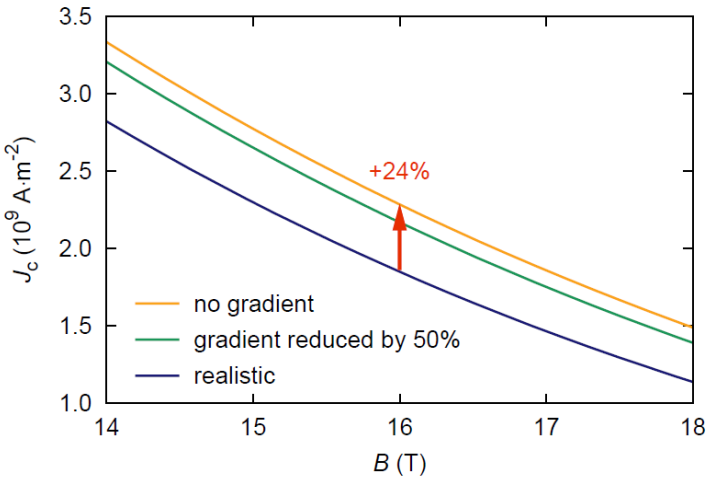


- Nb_3Sn is formed during heat treatment by a diffusion reaction
- In modern wires a Sn source diffuses outwards into a region containing densely stacked Nb filaments (RRP) or a Nb tube (PIT)
- Consequently, a radial gradient in stoichiometry is always present

Quantitative modelling proposed in T. Baumgartner et al., SUST 31 (2018) 084002



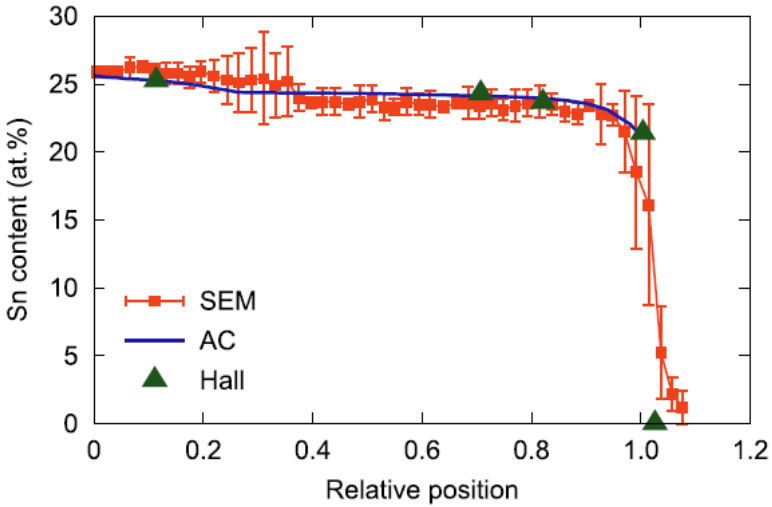
Y. Li, Y. Gao, Sci. Rep. 7 (2017) 1133



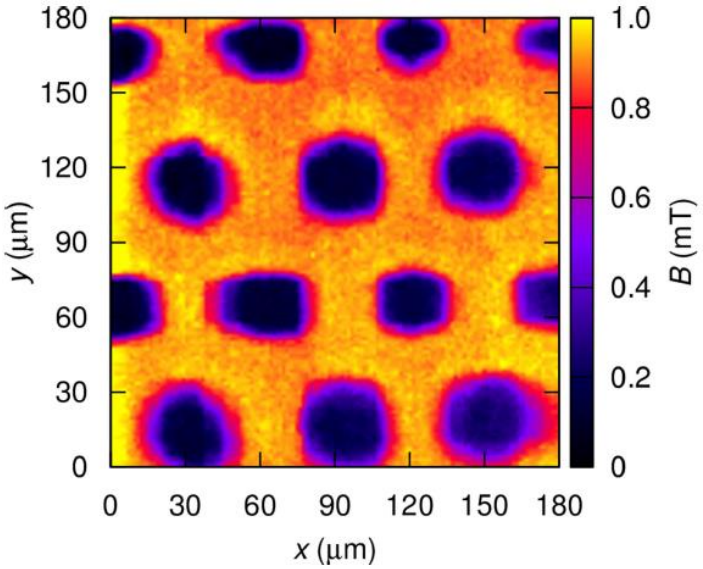
Courtesy of T. Baumgartner

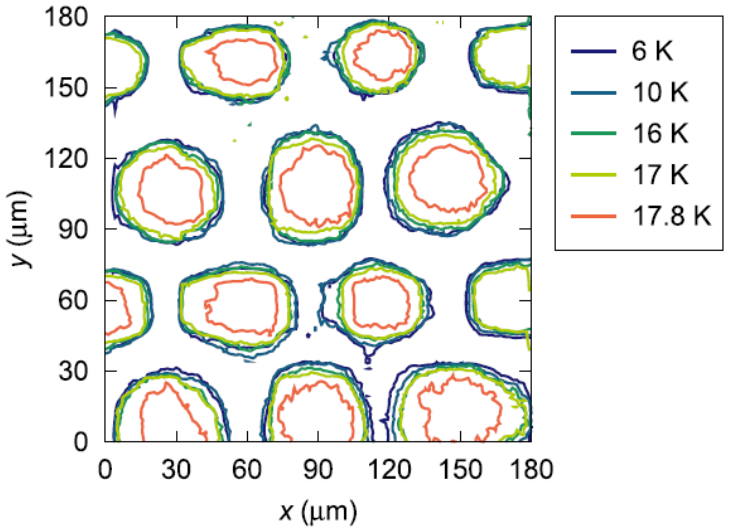
Sn gradients (assessment)

Directly by SEM: EDX
Magnetic measurements (AC, SHPM):
Flux penetration near T_c



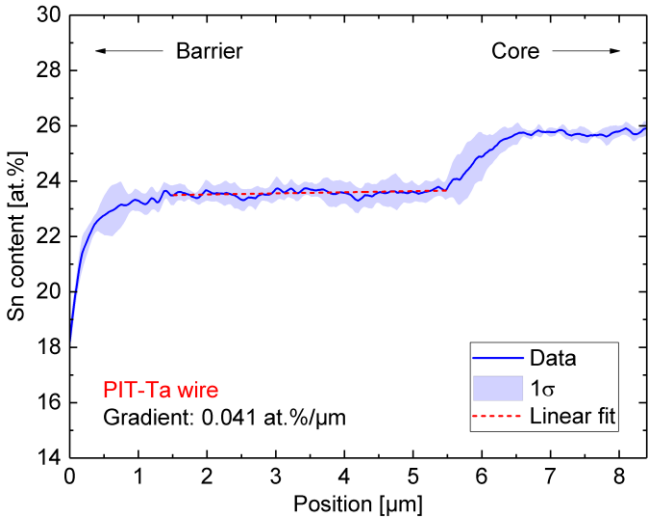
SHPM

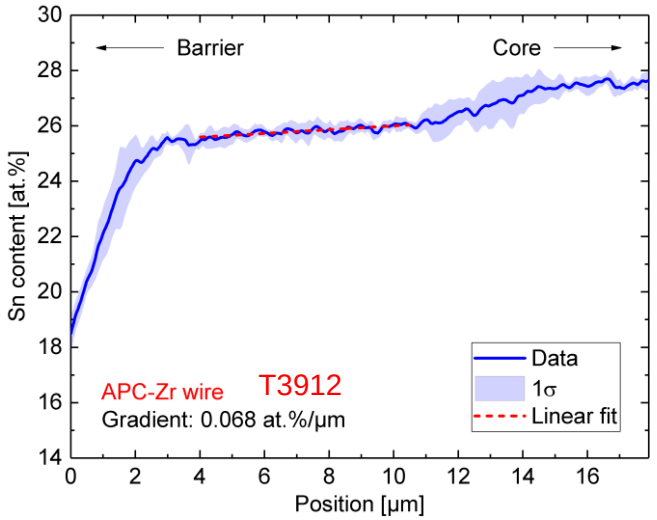


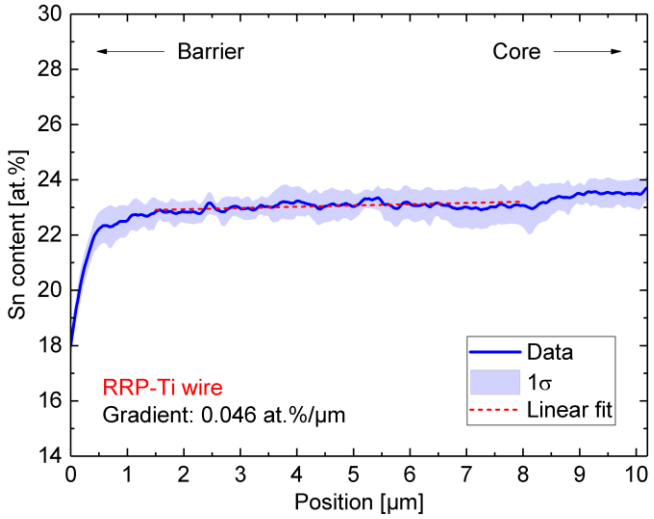


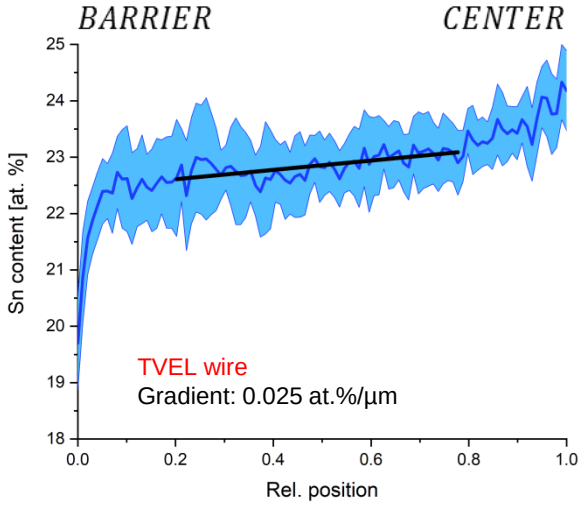
T. Baumgartner et al., SUST 30 (2017) 014011

Sn gradients (some results)









Sn gradients (TVEL wires)

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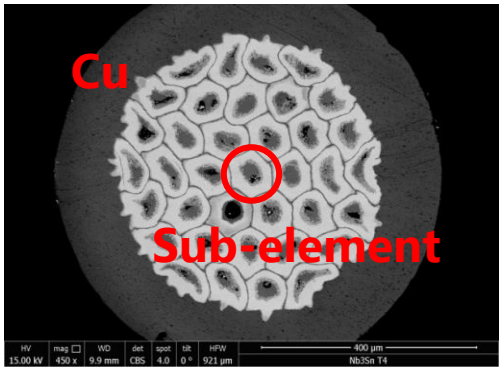
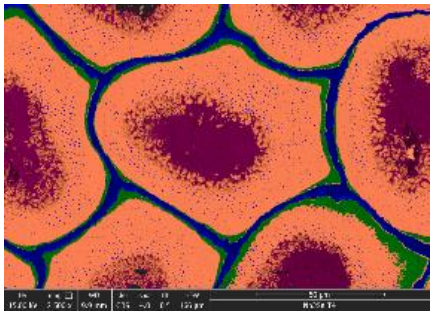
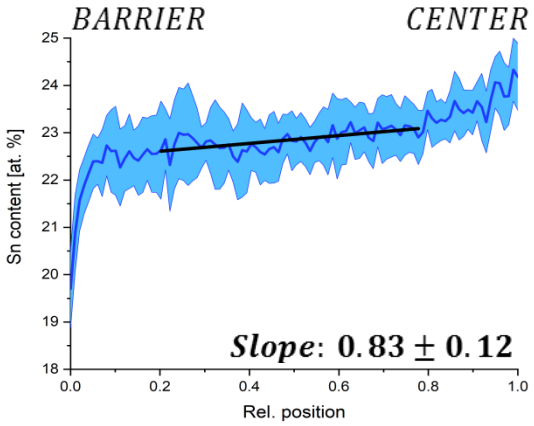
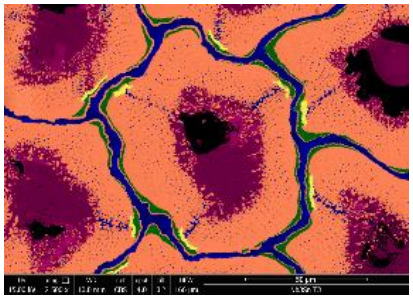


Ta-alloyed Nb_3Sn

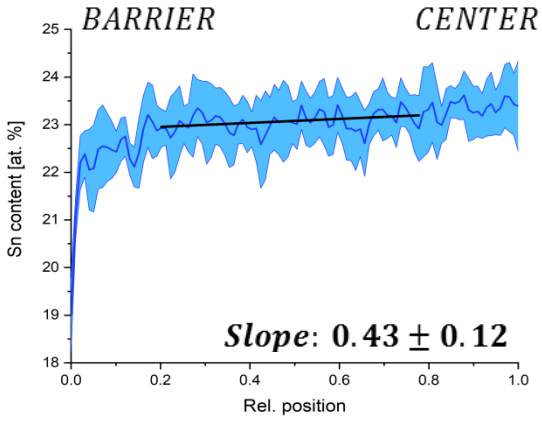


„Standard“ sample





Sample with clusters

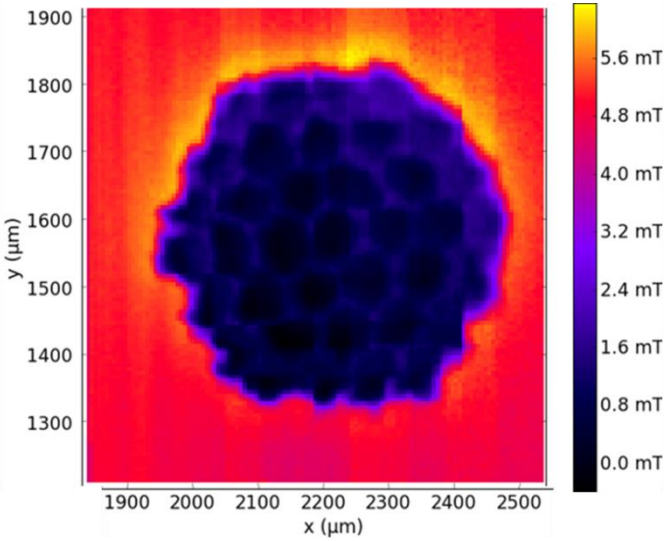


TVEL wires

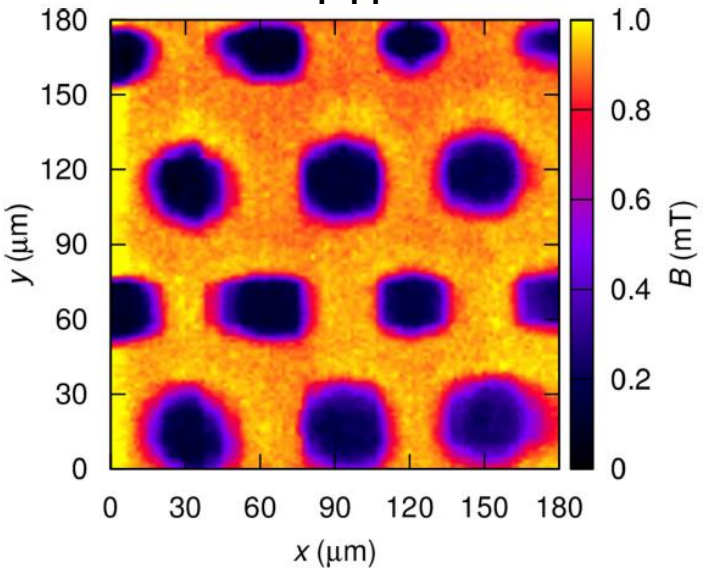
Ta-alloyed Nb_3Sn

Field profile in Meissner state

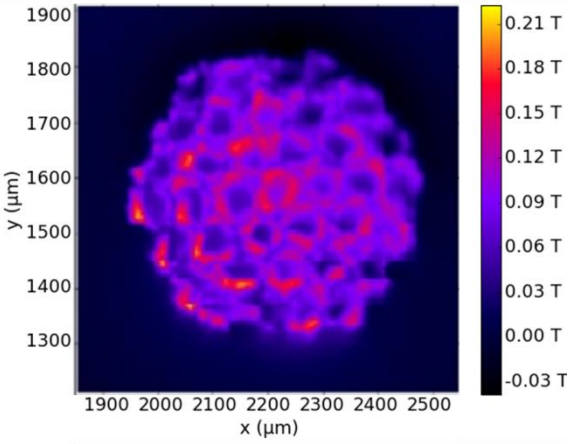
TVEL

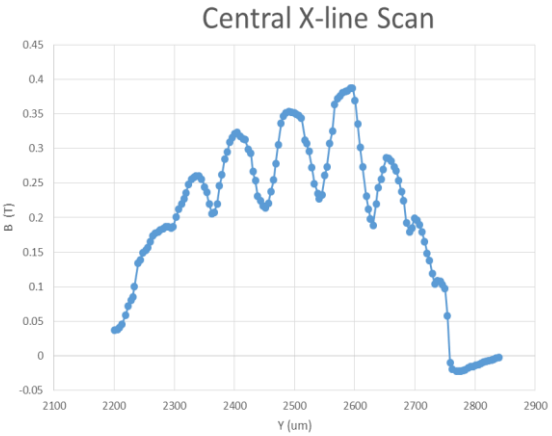


PIT



Remanent field





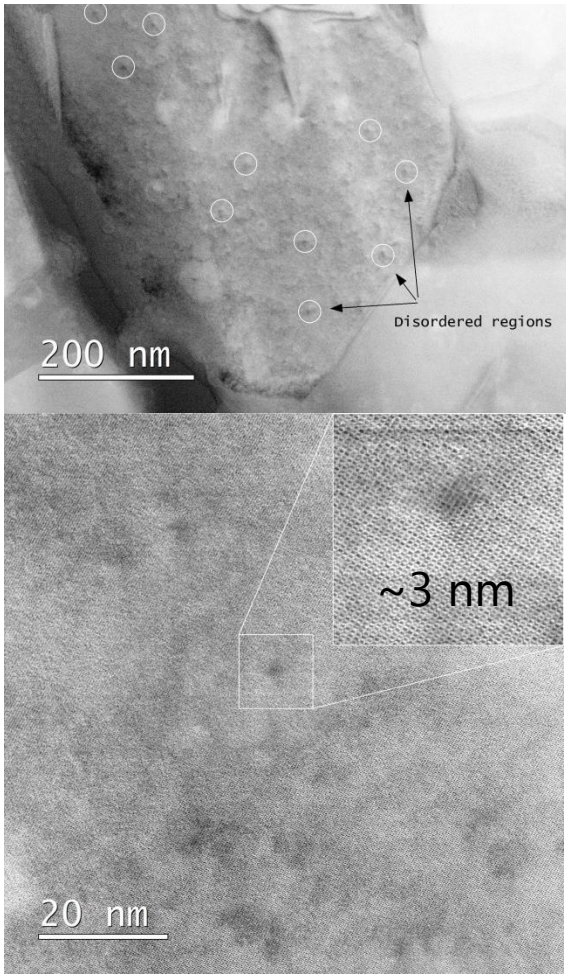
Interfilament coupling?

Reaching the FCC specifications

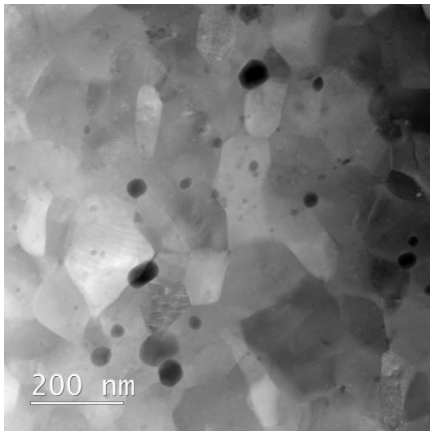
ARTIFICIAL PINNING

Artificial Pinning Centers (APC)

Neutron irradiation

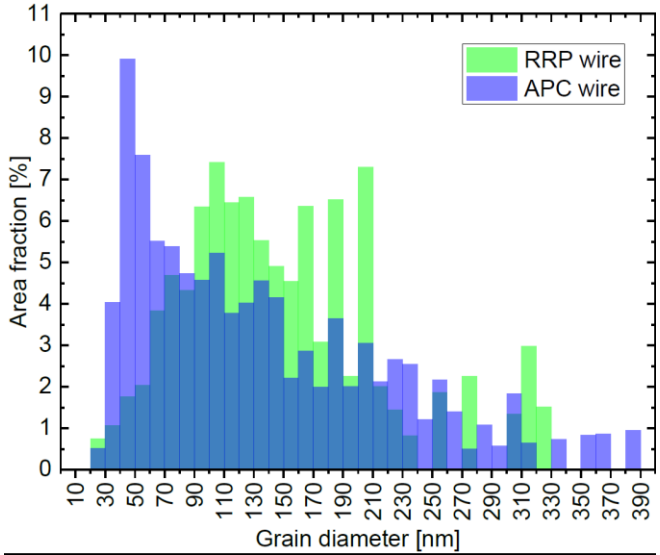


Internal oxidation



Wire made by Hyper Tech and heat-treated at Fermilab

Formation of ZrO_2 nanoparticles

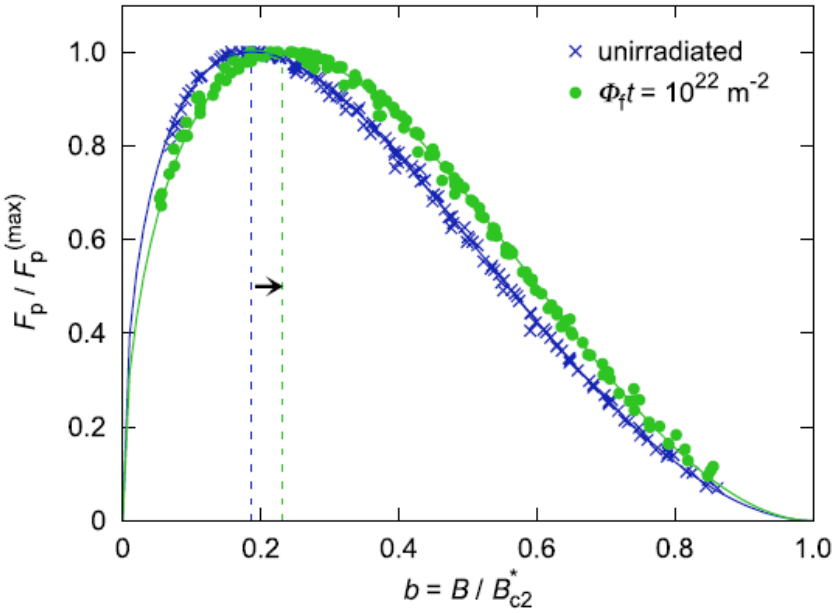


Grain Refinement

(Data obtained from TKD)

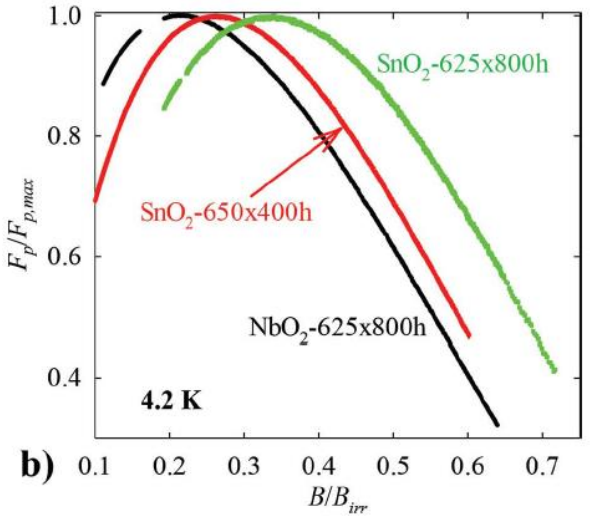
Artificial Pinning Centers (APC)

Neutron irradiation



T. Baumgartner et al., SUST 27 (2014) 015005

Internal oxidation



X. Xu et al. Adv. Mat. 27 (2015) 1346

Similar behavior despite differences in microstructure.

Outlook

- Understanding pinning in Nb_3Sn wires
- Advanced characterization to foster wire development
- Assessment of local currents by scanning Hall probe microscopy
- Correlation with local microstructure (e.g. Sn-content) assessed by TEM