Performance Enhancement of Nb_3Sn Superconductors by Artificial Pinning Centres

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Introduction

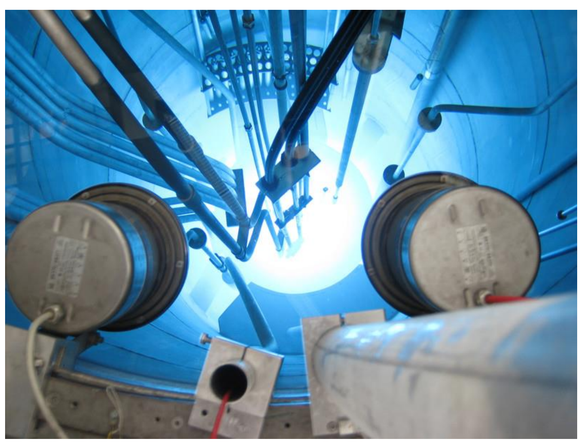
Presently available state-of-the-art Nb_3Sn wires have not yet reached the required FCC performance, which heavily depends on the microstructure. New manufacturing techniques aim to push the material further to its limits through **grain refinement and pinning enhancement by the introduction of artificial pinning centres (APCs).**

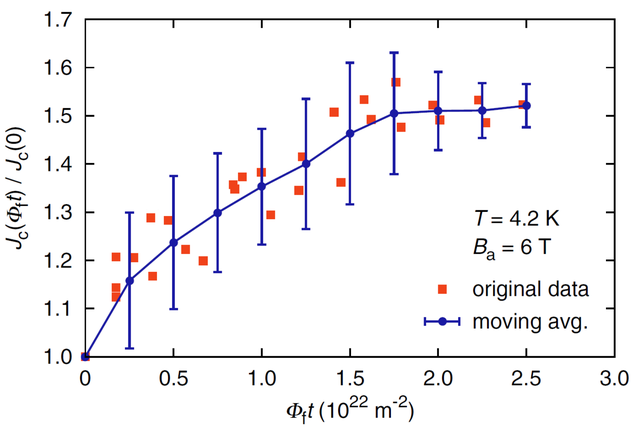
In this study, two approaches that recently managed to achieve the FCC target critical current density are presented. One revolves around a novel manufacturing technique based on **internal oxidation and formation of nano-precipitates**, while the other relies on the introduction of **defects by fast neutron irradiation.**

The influence of the resulting microstructure on the superconducting properties was examined through combined microstructural and magnetic analysis: by means of **Transmission Electron Microscopy, Scanning Hall Probe Microscopy and SQUID magnetometry.**

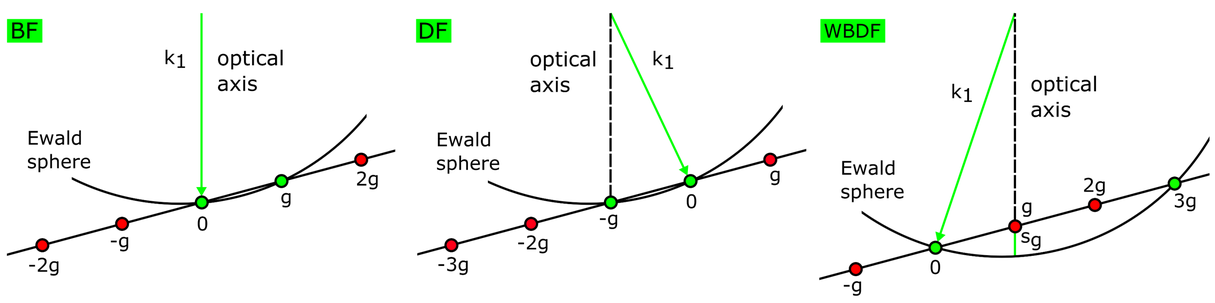
Artificial Defects by Fast Neutron Irradiation

- Irradiation of wires in neutron reactor
- J_c increase of 50% in irradiated wires

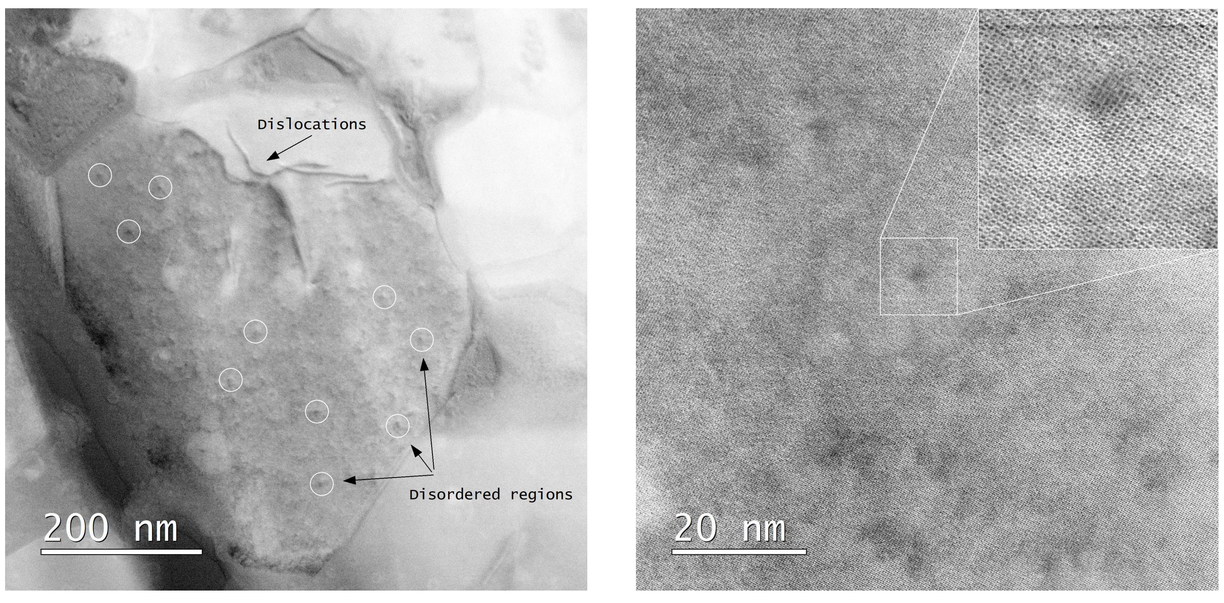




- Preparation of thin lamellae using Focused Ion Beam (FIB)
- Investigation of neutron impact sites using Transmission Electron Microscopy (TEM)



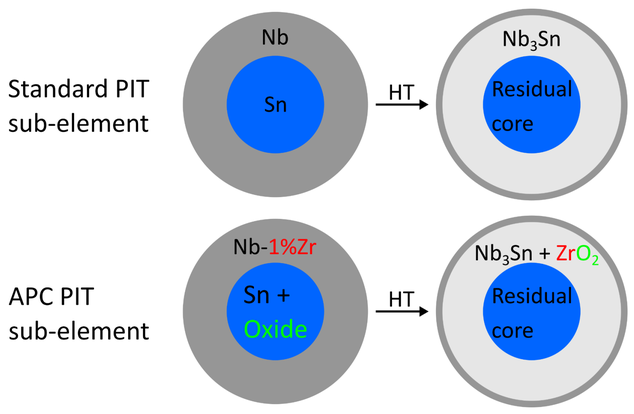
- Analysis by bright field, dark field, weak beam dark field and high resolution TEM
- Structure factor contrast and strain contrast due to deformed lattice

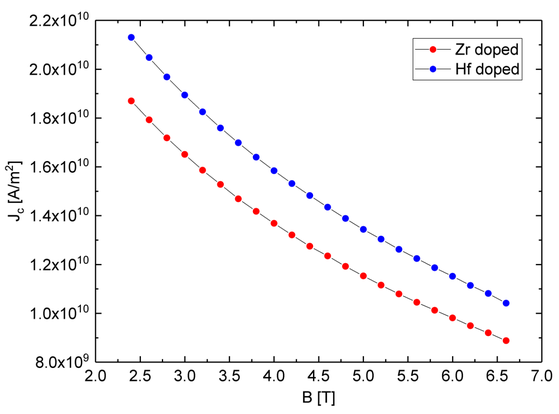


- Neutron irradiation leads to disordered regions of a few nm

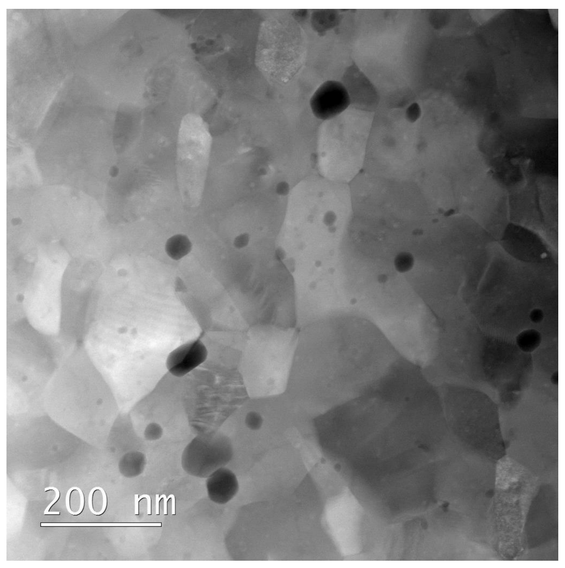
Grain Refinement by Internal Oxidation

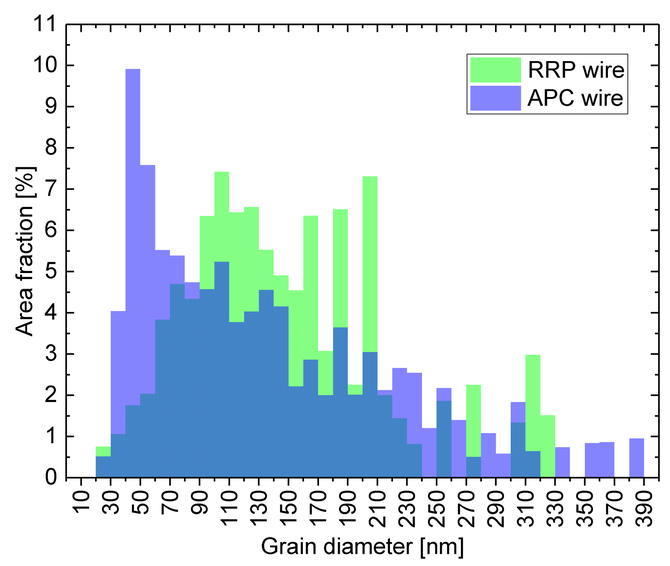
- Internal oxidation method produces nano-precipitates by the addition of Zr or Hf
- Precipitates serve as nucleation centres for grain boundaries
- Grain refinement leads to increase in J_c





- Analysis of precipitates by Scanning Transmission Electron Microscopy (STEM)
- Precipitate size of around 5 - 20 nm





- Grain size analysis by Transmission Kikuchi Diffraction (TKD)
- APC wires show clear reduction in grain size compared to standard wires