Contribution ID: **450** Type: **Contributed Oral**

M1Or3F-03: Nucleation and Growth of Oxide Nanoparticles in APC Nb3Sn

Monday 10 July 2023 16:45 (15 minutes)

APC Nb₃Sn wires are made using an internal oxidation process to create ZrO₂ or HfO₂ nanoparticles during diffusional growth of Nb₃Sn. These particles introduce a second pinning mechanism, as well as refine the grain size, strengthening the grain-boundary pinning above that in non-oxidized Nb₃Sn. The two mechanisms taken together increase the flux pinning force F_p, and also shift the peak pinning force to higher field, increasing the J_c at high fields while suppressing the magnetization at low fields. The nanoparticles form at the interface between the Nb₃Sn and the Nb alloy, and these particles get trapped as the interface progresses. The particles then grow over the remaining heat treatment time via diffusion of the solutes through the Nb₃Sn. The size and size distribution of the nanoparticles has been characterized through image analysis of transmission electron micrographs. A phase field model has been created which uses known thermodynamic and kinetic properties of the component materials to model the nucleation and growth process. Combining the model with microscopy allows evaluation of the effect of heat treatment temperature and explanation of the different nanoparticle sizes seen when the oxidizing element is Hf vs. Zr. This model will aid in the optimization of strand design and heat treatment for high field magnets.

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Session Classification: M1Or3F: Nb3Sn, MgB2, BSCCO Wires and Joints