Hafnium greatly improves Nb_3Sn superconductor for high field magnets

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Niobium-Tin, Nb_3Sn, conductors are the conductor of choice in high-field magnet applications for nuclear magnetic resonance, accelerators, and fusion. Nb_3Sn magnets will be needed for a next-generation (100TeV) proton collider; however, the desired non-Copper current density (J_c) of 1500A/mm^2 (at 16T and 4.2K) is substantially above the best presently available Nb_3Sn conductor designs.

A variety of variants of Nb_3Sn monofilament wires were fabricated in-house at the MagLab to include Nb_4Ta rods with Zirconium (Zr) and Hafnium (Hf) additions, both with and without SnO_2 suitable for internal oxidation of the Zr and Hf. The properties of the various wires were measured over the entire superconducting range at fields up to 31T at MagLab.

*Researchers found that group IV alloying (by Zr and Hf) in the presence of Tantalum (Ta) increases the global vortex pinning force (Layer F_P) at 4.2K, **more than doubling any previous Nb_3Sn production wire** (Figure 1)*. This, in turn, raises the irreversibility field (H_{irr}) of the wire, thus expanding the magnetic field range over which the superconductor has a zero resistance.

The layer critical current density (Layer J_c) at 16T and 4.2K, exceeds 3500 A/mm^2 (Figure 2.), which at the typical 60% fill factor of present high-J_c wires, suggests a non-Copper J_c of 2000 A/mm^2, ***exceeding the goal for the next-generation Future Circular Collider (FCC) planned for CERN.***

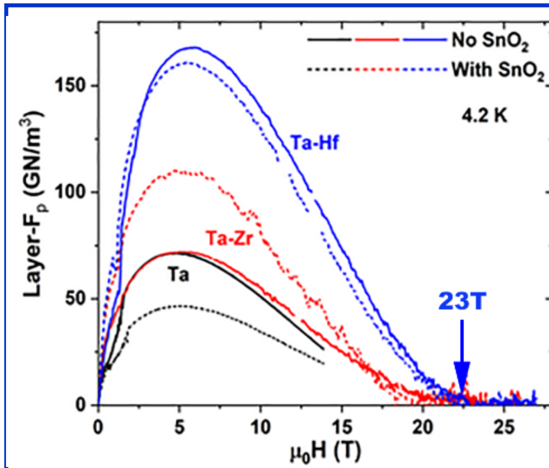

Figure 1. Pinning force curves over the full superconducting range indicates a doubling in force magnitude in Hf-based Nb_3Sn (**blue**) over conventional present-day Ta (**black**) based conductors

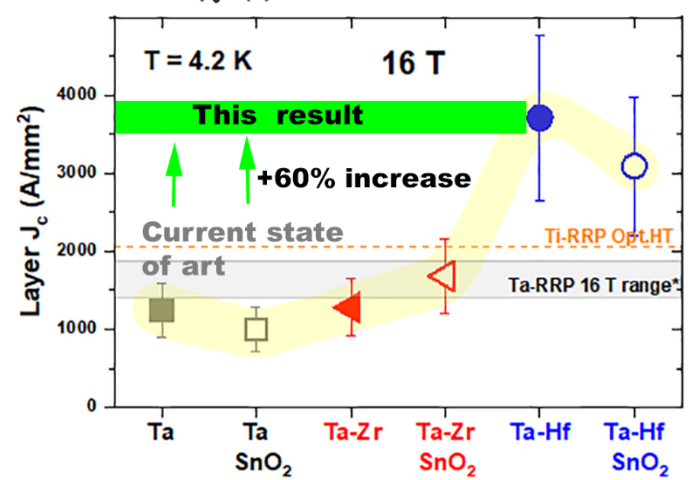

Figure 2. Layer critical current density in Hf-based conductors indicate a performance boost of 60% at 16T above the present state-of-the-art Restack Rod Process (RRP) commercial wire.

Facility used: DC Field Facility's 31T, 50mm Bore Magnet - Cell 7

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