U.S. DEPARTMENT OF
ENERGY

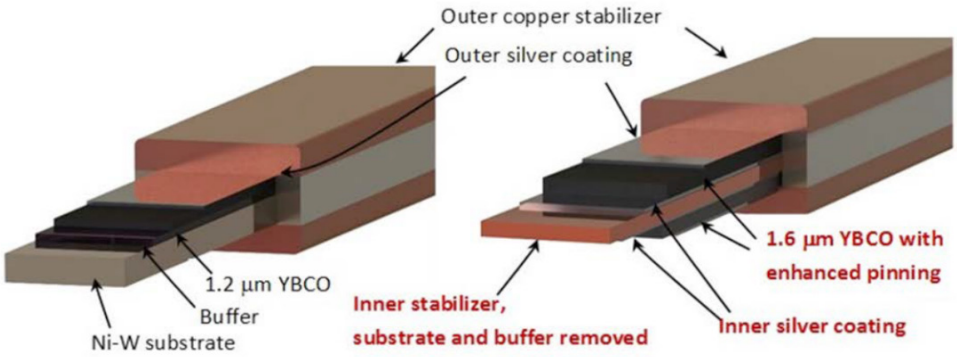
Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

Enhanced 2G High Temperature Superconducting (HTS) Wire for Electric Motor Applications

Advancing second generation technology to enable high efficiency electric machines

High Temperature Superconducting (HTS) wire conducts approximately 200 times the current as copper wire of the same dimensions. However, the current cost and performance of HTS wire makes it uneconomical for many potential applications such as wind turbine generators and transformers.

This project will develop an innovative Second Generation (2G) HTS wire combining an extremely uniform point-defect flux pinning microstructure produced by a reel-to-reel irradiation process along with a novel wire architecture comprising two 1.6 micrometer (μm) thick HTS layers within a single wire. This innovative wire is projected to achieve a current capacity up to 1,300 Amp/centimeter-watts (A/cm-w) at 77 degrees Kelvin (K), self-field and up to 1000 A/cm-w at 77 K, 1.5 Tesla (T). The combination of a highly effective flux pinning microstructure and novel wire architecture is expected to result in the first practical, production length 2G HTS wire that meets the demanding performance and cost requirements for broad-scale use in commercial electric machines at a range of operating temperatures.



Schematic Comparing (a) standard HTS wire architecture with (b) the proposed enhanced wire. The novel enhancements to the architecture are shown in red.
Graphic image courtesy of American Superconductor Corporation.

Another key technology being applied in this project is enhanced pinning via ion irradiation. This process results in wires that have fewer defects, resulting in higher performance at higher temperatures. The process also uses more inexpensive equipment that reduces the energy required by a factor of four versus existing manufacturing methods.

Benefits for Our Industry and Our Nation

Although the performance of current HTS wire meets the technical requirements for electric machines, the wire cost necessary to achieve the needed amp-turns makes the technology prohibitively expensive for the commercial market. The research underway is expected to result in the large step improvements in wire performance and cost reductions needed to address the commercial electric machine market. This project seeks to improve upon existing 2G HTS wire resulting in the following potential benefits:

- Wire cost reduction of at least 50% at the target operating conditions.
- Development of HTS wire that perform well at 65 K will reduce machine size and allow the use of lower cost liquid nitrogen cooling systems.
- Improved performance will open up new markets and applications for high performance HTS wire such as HTS transformers and advanced wind turbine generators.
- An estimated electricity savings of over 6 billion kilowatt-hours (kwh) if existing large motors and generators were replaced by superconducting machines which are anticipated to increase efficiency from ~96% to 98%.
- The use of HTS wire in large motors and generators could reduce U.S. annual electricity consumption by 0.2%.

Applications in Our Nation's Industry

HTS can be used in a wide variety of applications including: commercial electric grid, military, electric motors, and medical devices. Current applications include fault current limiters, advanced ship protection capabilities, and advanced electric grid cables that improve grid reliability while increasing capacity.

Project Description

The project objective is to develop a novel 2G HTS wire capable of carrying up to 1400 A/cm-w at 65 K in a perpendicular magnetic field of 1.5 T, verify wire performance in a prototype electric motor, and analyze the cost of the proposed manufacturing processes in comparison to existing commercial 2G wire. The project is expected to validate a reduction in wire materials and manufacturing cost at targeted operating conditions of up to 50% from current levels.

Barriers

- Feasibility of the ion irradiation process and associated cost.
- Compatibility of integrating individual technologies in the final wire.

Pathways

The project team will seek to improve HTS wire performance by focusing on three key process improvements simultaneously. They will attempt to increase HTS film thickness by 25%. This will be done by focusing on optimization and process improvements to their existing manufacturing process. The project team is also developing a novel double sided deposition process to produce wire with two HTS layers. This results in a wire with double the current capacity versus standard commercial wire. While this process has been demonstrated in the lab, it will need to be scaled up.

Finally, the project team will modify and optimize the ion irradiation process. This process is needed because when a superconductor encounters a magnetic field, tiny vortexes for that dissipate energy and reduce the performance. However, these vortices can be "pinned in place." This irradiation process has been shown to be an effective way to improve the pinning performance of HTS wire. When properly optimized this process is expected to achieve current capacity improvements of 2.5-3 times at operating conditions of 65 K and 1.5 T.

The project team will then integrate the three processes into a single HTS wire product in order to achieve their performance and cost reduction goals. The final wire will be used to manufacture a 500 horsepower (HP) electric motor that will be tested for performance improvements.

Milestones

This three year project began in 2017.

- Optimize ion irradiation process to achieve a critical current (Ic) enhancement of greater than 2.5 times at 65 K, 1.5 T relative to an un-irradiated control sample (2017).
- Develop the equipment and processes required for producing the double HTS layer wire with each layer retaining greater than 90% of its original Ic (2017).
- Increase the single coat thickness of HTS by 25% (2018).
- Integrate the three technologies developed to achieve a four-fold increase in Ic at 65 K, 1.5 T relative to a single layer un-irradiated wire (2018).
- Produce four wires with a length of up to 200 meters and fully characterize their mechanical and electrical performance, then use them to fabricate and test a representative coil for a 500 HP electric motor and benchmark against predicted performance (2019).

Technology Transition

American Superconductor Corporation, the lead organization for this project, is an industry leader in the manufacture of HTS wire. Upon successful completion, project participants anticipate the resulting reduction in the cost per kA-m for HTS wire will substantially move industry towards initial commercial purchases, and eventual widespread market adoption, of HTS rotating machines and similar high field HTS products. AMSC has the manufacturing, marketing, and distribution resources to quickly scale up and meet market demand.

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