

Process Innovations for HTS Wire Manufacturing

Advancing cost-competitiveness of superconducting material for use in next generation electric machines

High Temperature Superconducting (HTS) wire conducts approximately 200 times the current as copper wire of the same dimensions. It can be used in a wide variety of applications including commercial electric grid, wireless communications, military, electric motors, and medical devices.

Today's HTS devices include fault current limiters, wireless radio frequency filters, high performance magnets for science and advanced electric grid cables that improve grid reliability while increasing capacity. However, due to overall cost, today it remains uneconomical to unlock the potential of additional large scale applications such as wind turbines, highly efficient and compact industrial scale generators, Superconducting Magnetic Energy Storage (SMES) and advanced HTS MRI machines.

This project will develop an innovative second generation (2G) HTS wire by combining a number of important process improvements. HTS wire is manufactured by depositing a mixture of rare earth elements with barium and copper oxide to grow a thin film on a substrate. The microstructure of the film greatly influences the ability of the layer to carry current.

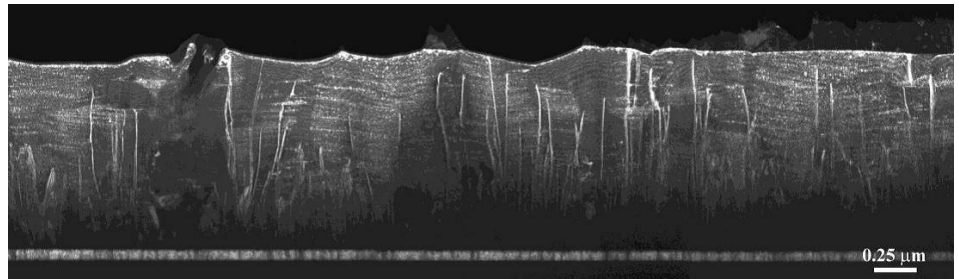
The current carrying performance of HTS wire can be improved a number of ways. One way to improve performance is to increase the thickness of the HTS layer within the wire. This can be achieved by increasing the thickness of a single layer or by including multiple layers of HTS material within a single wire.

The operational performance of superconducting material varies based upon the temperature and the magnetic field present. Another way to optimize the HTS wire for a specific application is to adjust the chemical composition either by adjusting the ratio of elements or by adding doping elements. This will change the superconducting characteristics which can then be optimized for the desired conditions.

Benefits for Our Industry and Our Nation

This project seeks to improve upon existing 2G HTS wire, which could result in the following benefits:

- Reduction of at least 50% in wire cost is expected at the target operating conditions.
- HTS wire that performs well at 65 K (degrees Kelvin) will enable reduced machine size and allow the use of lower cost liquid nitrogen-based cryogenic cooling systems.
- Improved wire performance in the area of critical current capacity for high magnetic field applications will open up new markets and applications such as HTS transformers and advanced wind turbine generators.
- Annual energy savings of over 6,000 GWh are estimated if existing large motors and generators were replaced by superconducting machines that are anticipated to increase efficiency from ~96% to 98%.



Tunneling electron microscope image of a layer of a High Temperature Superconducting film. Photo credit Superconductor Technologies Inc.

- The use of HTS wire in large motors and generators has the potential to reduce U.S. annual electricity consumption by 0.2%.

Applications in Our Nation's Industry

Although the performance of today's HTS wire meets the technical requirements for electric machines operating at these conditions, the quantity of wire necessary to achieve the specification for rotating machines makes the technology less favorable for full scale commercial deployment. The critical current carrying performance of the wire has a direct impact on the amount of wire needed in each device. Improved wire performance equals significant reduction of wire needed that lowers cost per device, meeting required economics for large scale adoption. The research underway is expected to result in large step improvements of wire performance and cost reductions needed to address the commercial electric machine market. Advancements in magnetic performance will also help the deployment of HTS wire in other markets including electric grid components, electric aircraft, magnetic energy storage, scientific instrumentation, and medical imaging.

Project Description

The project objective is to develop a novel 2G HTS wire capable of carrying up to 1440 A/cm (ampere/centimeter) at 65 K in a perpendicular magnetic field of 1.5 Tesla, and verify wire performance in a prototype electric motor coil. 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

- Individual technologies and enhancements cannot be combined to produce the desired wire performance.
- Scale-up of the various processes used; however, the project team plans to use industrial scale manufacturing equipment to manufacture their test wires.

Pathways

The project team will seek to improve HTS wire performance by focusing on key process improvements. The project team plans to optimize the ratio of elements deposited in the HTS layer to maximize current capacity at the desired temperature and magnetic field. This will be done both by varying the concentration of elements within the film and also by exploring the addition of doping elements to improve wire performance within a magnetic field. Once the optimum composition is determined the project team will develop and implement in-situ real time feedback monitoring and control processes to ensure the manufacturing process results in the desired optimum wire composition.

The project team will also improve current capacity by both increasing the thickness and number of film layers. First, the team will optimize the manufacturing process to increase HTS film thickness. Then the team will modify the process to allow the use of buffer materials to create a multi-layer superlattice to increase HTS thickness and current capacity while minimizing degradation in performance. The net results from all of these avenues of research will be integrated into a final, high performance wire design and tested. The final wire will then be used to fabricate and test an electric motor coil.

Milestones

This three-year project began in 2017.

- Validate production of 50m+ length of HTS with up to 2x the initial film thickness (2017).
- Validate production of 100m+ of HTS wire with increased performance due to optimization of composition with doping additives (2018).
- Validate production of 100m+ length of HTS utilizing an alternating superlattice (2018).
- Manufacture multiple runs of the final wire design and fully characterize the HTS wire (2018).
- Manufacture the final high performance HTS wire and fabricate a new 500 hp motor coil (2019).

Technology Transition

Superconductor Technologies Inc., the lead organization for this project, has experience manufacturing and marketing HTS products. Upon successful completion of the project, participants anticipate the resulting reduction in the cost per kA-m for HTS wire will open a number of potential markets including; industrial scale electric motors and generators, and magnets for HTS MRI machines. Many of the experiments in the project will be carried out on production scale manufacturing equipment, which should reduce the time between experimental and commercial production of the advanced HTS wire.

Project Partners

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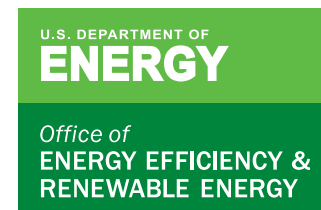
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