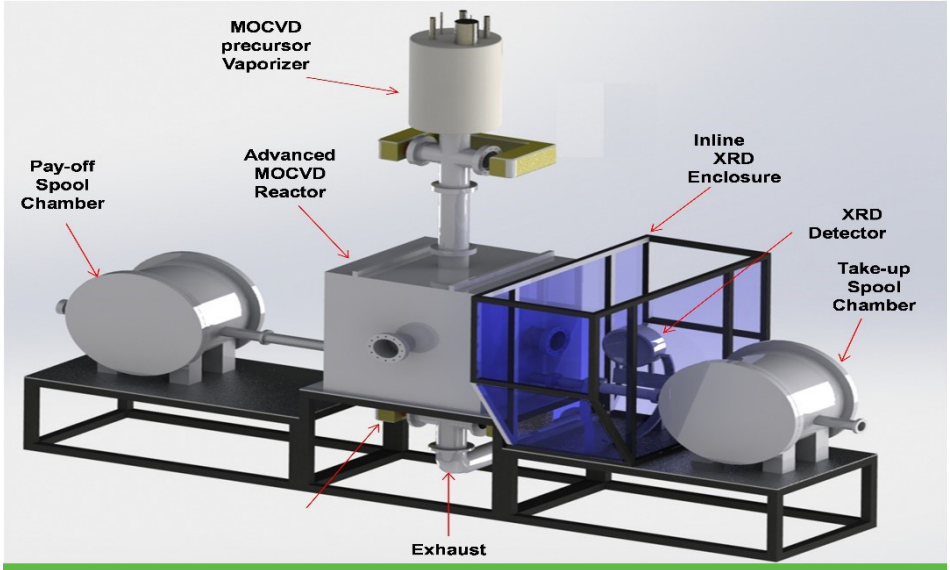
U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Advanced Manufacturing of High Performance Superconductor Wires for Next Generation Electric Machines

Developing high-performance, low-cost, light-weight superconductor wires for advanced motor systems



Schematic illustrating the design of an Advanced MOCVD tool with in-line x-ray diffraction (XRD) system for real-time Quality Control at the University of Houston.
Photo credit The University of Houston.

Superconducting materials have high application potential for advanced electrical motor systems. High Temperature Superconductors (HTS) are being manufactured as wires for high-performance devices over a wide range of magnetic fields and temperatures. A roll-to-roll thin film process is used to manufacture HTS wires. Conventional processes to manufacture these HTS wires are currently very expensive, which has limited previous commercial implementation efforts.

This project will improve the performance and reduce the fabrication costs of doped RE-Ba-Cu-O (REBCO, RE=rare earth) HTS wires for advanced motor systems. These REBCO wires are expected to have an improved performance and reduced overall wire costs based on the critical current at cryogenic operating conditions. A critical current improvement to 1440 A/cm (ampere/centimeter-width) at operating conditions of 65 K (degrees Kelvin) and 1.5 T (Tesla) is expected, as well as a 50% wire cost reduction is targeted. These improved performance metrics can be realized for REBCO wires when produced with an Advanced Metal Organic Chemical Vapor Deposition (MOCVD) reactor. This Advanced MOCVD tool has the potential to grow films as thick as 5 microns with a controlled incorporation of nanoscale defects for enhanced performance in high magnetic fields. The Advanced MOCVD tool can also lead to an increase of the precursor-to-film conversion efficiency more than five-fold by implementing laminar flow and plasma-activated decomposition of complex organic ligand precursors. This reduces the cost of these precursors, which are typically the most expensive cost component of the HTS wire. The REBCO wires are then scaled up to 50 meter (m) lengths, which are subsequently used to fabricate coils to be tested at 65 K. The coils are then utilized and tested as a rotor pole of a 500 HP-rated motor.

Benefits for Our Industry and Our Nation

Using REBCO materials for fabricating superconducting wires for advanced motor systems has many benefits, including the following:

- Increasing machine efficiency to approximately 99.9%, which is a 2% improvement over existing technologies, depending on the target motor.
- Light-weight, compact motors that can operate at high power levels which can be especially useful in applications where size and space are constrained.

Applications in Our Nation's Industry

This technology could provide the oil and gas (O&G), mining, energy and the transportation industries with high-performance advanced motor systems that are very efficient, compact and light weight. The technology can be integrated into the existing infrastructure for O&G, mining, transportation and wind energy industries, including industrial motors, utility generators, wind turbine generators, and propulsion motors. The REBCO wire can provide a high-performance, highly-efficient replacement to conventional wires with an acceptable return on investment

Project Description

The project objective is to develop, fabricate, and test the performance of a new superconducting wire manufactured from REBCO materials for advanced motor systems. The REBCO superconducting wire will be tested and validated for a critical current improvement to 1440 A/cm at operating conditions of 65 K and 1.5 T. In addition, the wire's manufacturing costs are expected to decrease 50% when fabricated with an advanced MOCVD method. This improved performance and low-cost REBCO wires will be utilized in the design of a 500 HP motor and validated for motor coil operating conditions at 65 K.

Barriers

- Fabrication of 5 micron thick REBCO films with no deterioration in performance and uniform distribution of nanoscale defects throughout films thickness to achieve critical current of 1440A/cm-width at 65 K, 1.5 T.
- Increase precursor-to-film conversion efficiency by 5.4X while maintaining good performance.
- Scaling up the wire to 50 m lengths without compromising uniformity critical current performance.
- Fabricating and testing motor coils with high-performance wires, with no degradation.

Pathways

Project partners are developing the REBCO superconductor wires using an Advanced MOCVD process with thick films, nanoscale defects and high precursor-to-film efficiency. REBCO superconductor development is being led by the University of Houston initially with 3-5 micron thick HTS films. Nanoscale defects using dopants such as zirconium will be introduced into these thick films to achieve a critical current of 1440 A/cm at 65 K, 1.5 T.

The MOCVD reactor tool is concurrently modified to improve the precursor-to-film efficiency. During the project, team members expect to increase this efficiency from 15% to 80%, a 5.4 times improvement. By this increase in efficiency, the cost of fabricating a REBCO wire with 5 micron thick HTS film can be reduced by 50%.

The Advanced MOCVD process will be scaled up in a pilot manufacturing tool to produce 50 m long wires with superior performance. Novel in-line Quality Control (QC) tools will be developed for real-time monitoring of the REBCO film quality and controlling of process parameters to achieve consistency in performance of 50 m long wires.

The project team will then validate a motor prototype using the superconductor wire. A prototype 500 HP motor based on the performance parameters of the improved REBCO wire will be designed by TECO-Westinghouse. A rotor pole coil based on the design will be constructed and tested by E2P Solutions.

Milestones

This three year project began in 2017.

- Develop REBCO wires with a critical current of 1440 A/cm at a temperature of 65 K and a magnetic field of 1.5 T (2019).
- Validate a 50% reduction in REBCO wire costs and a 5.4X improvement in precursor-to-film efficiency using the advanced MOCVD reactor for 50 m long wires (2019).
- Design, fabricate, and test coils for a 500 HP-rated superconductor motor using the improved superconductor wires (2020).

Technology Transition

At the conclusion of the project, the project team will target technology transition to applications in the O&G, mining, energy and transportation industries. The project team will partner with TECO-Westinghouse Motor Company, a leading Original Equipment Manufacturer (OEM) capable of incorporating the technology in HTS rotating machines. Other major companies including OEMs and end users have also expressed interest in using the wire for superconducting machines. The project team expects the advanced, low-cost REBCO wire could be manufactured at high-yield by SuperPower Inc. in wire lengths of 500 meters.

Project Partners

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