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

DE-E0007870

American Superconductor Corporation
Brookhaven Technology Group
Brookhaven National Laboratory
University of Buffalo

June 1 2017 – May 31, 2018

Martin Rupich – American Superconductor Corporation

U.S. DOE Advanced Manufacturing Office Program Review Meeting
Washington, D.C.
July 17-19, 2018

This presentation does not contain any proprietary, confidential, or otherwise restricted information.

Overview

Timeline

- Award issued - June 2017
- Projected End Date - November 2020
- 6 month no-cost extension after 3 quarters to accommodate relocation of AMSC manufacturing facility
- Project 25% complete

Budget

	Budget Period 1 Costs	Budget Period 2 Costs	Budget Period 3 Costs	Total Planned Funding
DOE Funded	$1,474,976	$1,250,159	$1,026,048	$3,751,183
Project Cost Share	$422,309	$376,827	$326,604	$1,125,740
Total	$1,897,285	$1,626,986	$1,352,652	$4,876,923

Barriers

- Performance of today's 2G HTS wire, at targeted operating conditions for rotating machines (65K, 1.5T), requires large quantity of wire, increasing cost for commercial machines.

Partners

- Brookhaven Technology Group (BTG)
  - Co-development of key exfoliation technologies and processing
- Brookhaven National Laboratory (BNL)
  - Ion irradiation development and characterization
- University of Buffalo (UB)
  - Micro-structural analysis and characterization
- All partners are contributing a 20% cost share

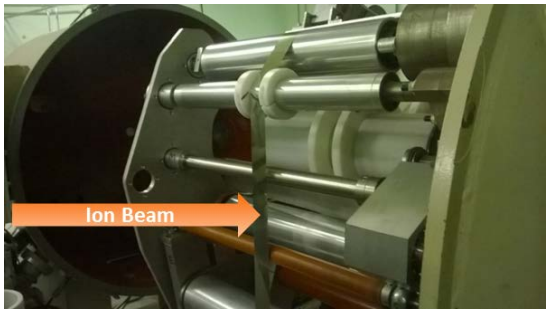
Project Objectives

- Project is part of the Next Generation Electric Machines 2 portfolio which supports AMO's MYPP target 3.4: Increase the efficiency of targeted electric machines by 2-3% (a reduction in losses of 28 - 75%)
- A 7-fold increase in critical current (I_c) and a 50% reduction in cost of 2G HTS wire designed for commercial electric machine applications operating at ~65K in magnetic fields of ~1.5T
  - Supports development of energy efficient rotating machines for industrial applications that are commercially competitive with current technology
  - Supports development of motors, generators, etc. for advanced military applications.
- Project focuses on development of innovative, low-cost and reproducible, American-based manufacturing processes
- Approach relies on development of new technologies and manufacturing processes, not incremental improvements

Objectives

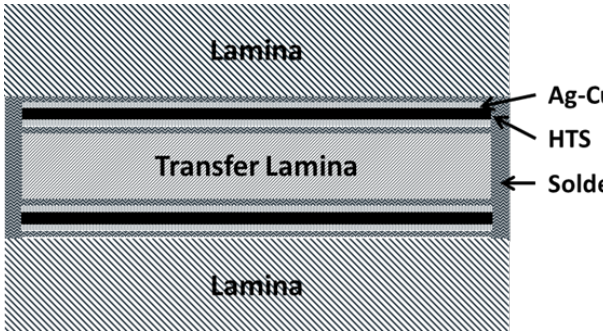
Enhance Pinning through Reel-to-Reel Ion Irradiation

- Identification of optimal ion and dosage for target conditions
- Electrical and microstructural characterization of optimal pinning centers
- Transfer short length process to reel-to-reel irradiation process



Develop Innovative Manufacturing Process for Double-sided HTS Conductor Architecture

- Develop reproducible process for double-sided HTS layer transfer
- Develop production scale equipment for transfer process
- Establish reproducibility of process
- Characterize electrical/mechanical properties of double-sided wire



Increas3 the Thickness of Individual HTS Layers

- Modification of HTS pyrolysis process to increase layer thickness

Technology Integration

- Integration of 3 technologies into manufacturing process
- Evaluation of reproducibility and yield of integrated process

Demonstratie of Wire Performance in Prototype 500 hp Motor Coil

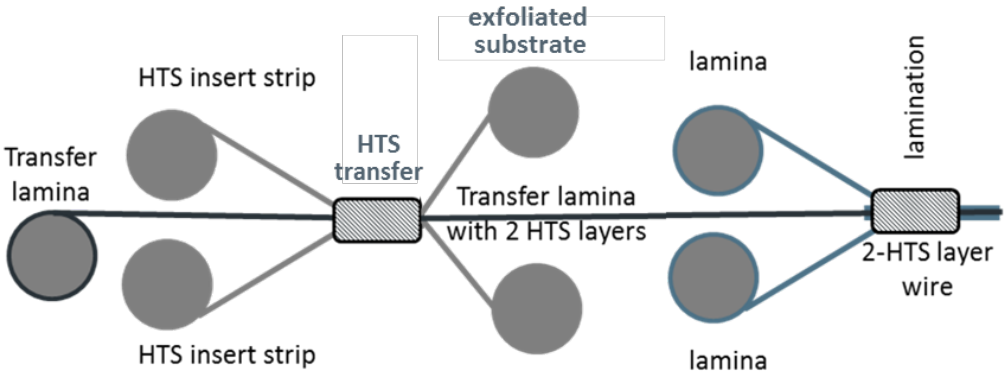
- Wire fabrication
- Coil design and fabrication
- Coil test and evaluation

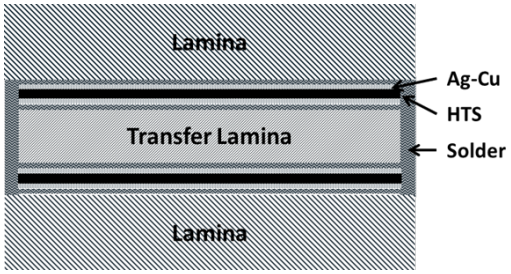
Technical Innovation

- Performance of today's "state-of-the-art" wire is suppressed in the presence of the magnetic field in rotating machines at the desired operation temperature of ~65K
  - Current solutions (lower operation temperatures, incremental increase in HTS thickness, complex pinning structures) add cost and decrease yield
- AMSC approach relies on novel 2-layer HTS wire architecture and ion irradiation
  - 2-layer HTS architecture is based on established wire components
  - Ion irradiation produces point defects with inherently uniform structure and density
  - Both approaches engineered for cost reduction, high yield and reproducibility (along length and wire to wire)
- Significant reduction in wire cost ($/kAm)
  - Reduced materials cost
  - Increased I_c: 2 x at 77K, sf; up to 7X at 65K, 1.5T
- Coil based applications operating at target conditions will require up to 7X less wire, leading to reduced cost and more compact systems.

Technical Innovation

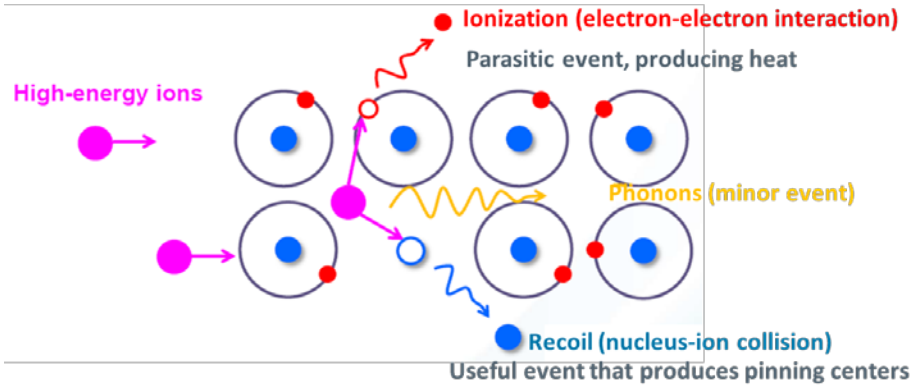
2-sided wire architecture

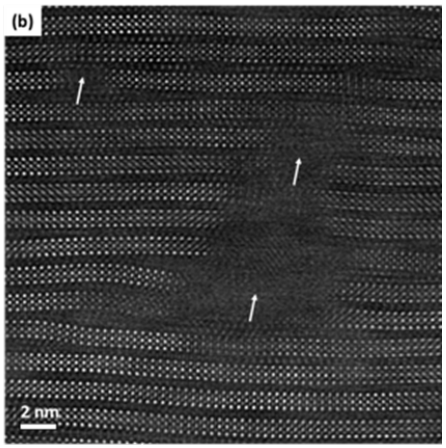




Same patented laminated wire architecture and dimensions

Ion Irradiation





Defect size: 2-5 nm
Defect density 1.2 – 3.6 x 10^{11}/cm^2
Defect spacing: ~50 nm

Technical Approach

Develop an innovative double HTS wire architecture with controlled pinning centers and optimize manufacturing process for cost, yield and reproducibility.

AMSC:

Leader in development of 2G HTS wire and commercial /military applications

- State-of-the-art 2G wire technology developed with focus on cost, reproducibility and yield.
- HTS wire used in both commercial and military cable and coil applications.
- Leader in development of near-term commercial markets.
- Integration of technologies and development of high-yield, reproducible manufacturing processes

Brookhaven National Laboratory - Qiang Li (Partner)

- Development of ion irradiation process and optimization for target conditions
- Characterization of pinning enhancement
- Facility for reel-to-reel pilot manufacturing

Brookhaven Technology Group - slowa(Partner)

- Development of exfoliation technology and supporting processes (slitting, rapid, low-temperature annealing, etc.)
- Characterization of double-sided conductor

University of Buffalo - Amit Goyal (Partner)

- Microstructural characterization of ion induced pinning centers and HTS layers.

The team, lead by AMSC, has years of experience solving challenging scientific and engineering issues

Results and Accomplishments

Project Status / Accomplishments (Q1-Q3)

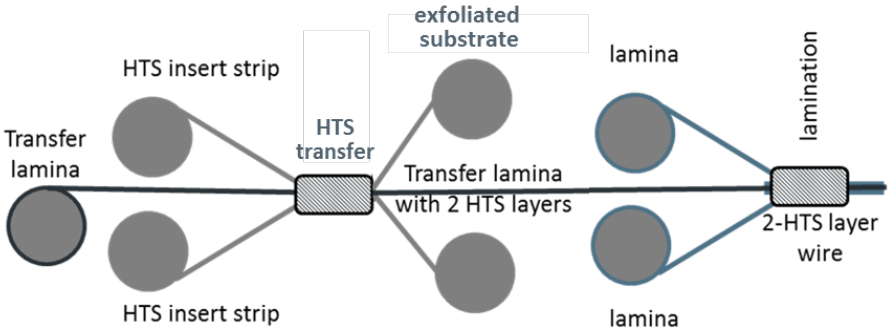
- Established viability of exfoliation process at 100 meter length
- Developed and validated key technologies for 2-layer HTS wire architecture
- Optimized ion irradiation process for targeted operating conditions of 65K, 1.5T
- Correlated pinning defect microstructure and density with irradiation parameters
- Explored new pyrolysis approach for increasing thickness of single layer HTS film
- Developed new reel-to-reel manufacturing equipment for exfoliation process

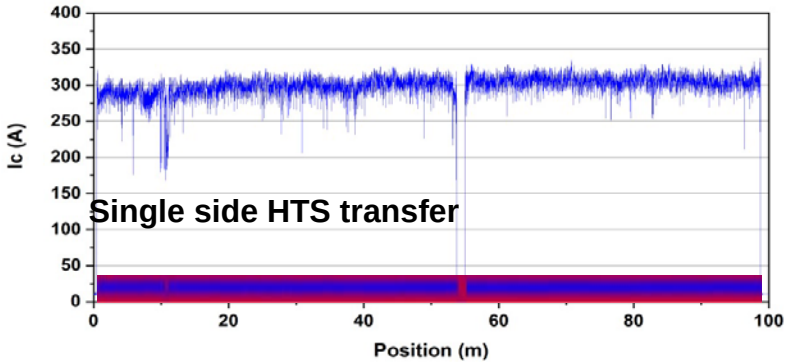
Future Work (Q4)

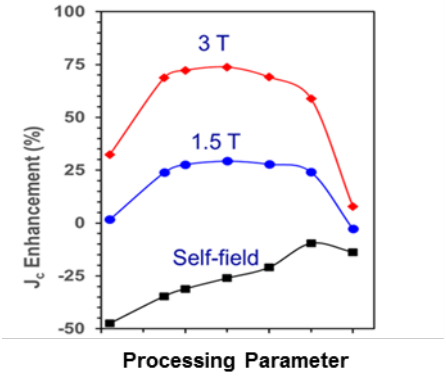
- Validate double-sided exfoliation process in length

Future Work Year 2 / Year 3

- Validate mechanical properties of 2-layer architecture
- Integration of individual technologies
- Manufacture long length wire
- Validate capability and yield of manufacturing process
- Validate wire performance in test coil







Transition

- **Commercialization Approach**
  - Provide system based solutions to end users
  - Collaboration with OEM's to offer system based solutions
  - Direct wire sales to OEM's and other customers
- **Technology Sustainment**
  - Identify applications and establish price sensitivity (wire and system)
  - Target applications based on market size and price sensitivity
  - Increased manufacturing capacity will reduce wire cost and open new markets
  - Target additional markets

Motors

Cables

Degaussing

Wind Turbines/Generators

Questions?