
Project Title:	Scale-Up of Coated Conductor (2G) Technology at AMSC
Organization(s):	American Superconductor Corporation
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FY 2004 Funding:	\$1,000,000

Project Purpose and FY 2004 Objectives: The purpose of this project is to develop a low-cost and robust manufacturing process for Coated Conductor (2G) composite wire. Key elements of this project include: (a) establish a fundamental understanding for the substrate, buffer and HTS layer properties and processing, (b) improve I_c , (c) achieve uniform performance over 10 meter lengths (determine process windows for each process step and eliminate process defects), and (d) confirm low-cost processes to justify Pilot scale-up.

The FY 2004 Objectives were focused toward three critical areas:

- 1) Demonstrate I_c progress ($>250\text{A/cm-w}$)
- 2) Confirm process uniformity over length (10 meter process lengths)
- 3) Demonstrate process capability for high risk Pilot-scale equipment concepts.

Comments from the 2003 Peer Reviewer team suggested that AMSC should consider revising the demonstration objectives to include increasing performance and wire length, and to address potential long length-related problems early.

FY 2004 Performance and Results, and FY 2005 Plans: Significant progress has been made against all key elements of the project and the FY 2004 Objectives. The AMSC 2G efforts over the past year have been directed toward four major areas of research and development:

- 1) **Baseline Manufacture** – AMSC maintains a documented baseline 2G wire manufacturing process; this is the standard to which we compare all new process improvements. Over time, new processes are inserted into the baseline process, improving the overall I_c , uniformity, reliability and cost-performance of the 2G wire. Process changes are only incorporated when they equals or exceeds the performance of the baseline practice. During February 2004, AMSC conducted a process capability study, manufacturing four consecutive baseline wires (1 cm wide, 10 meters long, neutral axis wire configuration). All four of these wires exceeded 250 A/cm-w and 3.4 MA/cm² in the HTS (77K, sf) and showed excellent uniformity (1 standard deviation $<4\%$ for all wires) and reproducibility. This compares to a previous capability study performed in May 2003, averaging 168 A/cm-w for 45 meters of wire (1.5 m x 30 wires), this demonstration was presented at the 2003 Peer Review. **High I_c and uniformity achieved**
- 2) **New Technology Process Insertions** – Innovation, detailed understanding of fundamental and applied aspects of each 2G layer, and thorough failure analysis have all contributed to improvement in wire performance, establishing broad processing windows and reducing the cost AMSC's 2G process. The significant increase in I_c observed in the February 2004 baseline capability study was directly related to improvements in substrate (0.5° FWHM reduction), buffer (improved diffusion characteristics), and HTS (optimized HTS nucleation and growth). Additional process insertions include buffer thickness reduction (barrier layer reduced $>50\%$), reactive sputtering buffer deposition (up to 10x increase in deposition rate), and HTS nano-dots (increasing the in-field I_c performance). **Continuous process improvement is on-going.**
- 3) **R&D Equipment Conversion to 4 cm wide and 100 meters long** – AMSC intended to upgrade the existing (slow) R&D equipment for 4 cm wide x 10-20 meter long operation. Based on the comments from the 2003 Peer Reviewers, AMSC modified this plan to increase the capability of this R&D equipment to 4 cm wide x 100 meter long operation. The increase in length did not

materially change the 4 cm wide deposition or reaction processes, however significant additional work has been required to accommodate the physical size of spools, weight of 100 meter tapes, and adjustments to the build-up of tape on the take-up spools. Conversion of all R&D equipment to the 4 cm x 100 meter standard is still underway. Uniform (across width and length) 4 cm processing has been confirmed for substrate, buffer seed, buffer barrier, and lamination steps.

Pre-Pilot R&D equipment is being modified for 4 cm wide x 100 meter long 2G wire manufacture.

- 4) **High Risk Pilot-scale Equipment Demonstration** – The basic AMSC RABITS/MOD HTS process can be divided into five generic types of Pilot equipment: rolling mill, PVD deposition tools, linear heat treatment ovens, lamination, and slitting. Of these, the PVD tools and linear heat treatment ovens are significantly unique to 2G processing. AMSC’s plan is to demonstrate the Pilot-scale tooling concepts for these unique pieces of equipment prior to purchasing the additional PVD tools and heat treatment ovens needed to construct the 2G Pilot manufacturing facility. AMSC is now commissioning the Pilot-scale PVD tool at our Devens, MA facility. Tape handling, deposition rates, and uniformity have been confirmed. The Pilot reaction heat treatment concept has been confirmed and was utilized to fabricate the baseline 250+A/cm-width wires discussed above. A larger and more capable linear reaction oven is now in the final stages of fabrication and will be used to test material handling and atmospheric control for all Pilot-scale oven types. **Risk mitigation strategy is confirming AMSC Pilot scale-up planning and cost models.**

FY 2005 plans focus on establishing a reliable pre-pilot production capacity of over 10,000 m/yr., based on the 4 cm wide wire process with subsequent slitting to 4 mm wire width, and with 100m length capability. Continuing efforts include demonstrating commercially practical wire configurations (mechanical and electrical stabilization and hermeticity), increasing performance, improving process reliability, reducing wire cost for both industrial and military 2G applications, and confirming readiness for Pilot scale manufacture.

Research Integration: AMSC has leveraged the DoE 2G funding by developing partnerships with a broad array of government, laboratory, university, and commercial entities and has been a leader in supplying robust lengths of 2G HTS wire for characterization by DOE labs and other parties. Many of these groups also contribute to the innovations that will result in future process improvement insertions. Our partners include:

Substrate: ORNL, WPAFB, IFW, DARPA, MDA

Buffer: ORNL, SNL, LANL, WPAFB, IFW, ATFI, NRL

HTS: SNL, ANL, University of Wisconsin, BNL, NIH, NIST, NRL, LANL, IRL, NHMFL, University of Albany, ARACOR, MIT