PROJECT TITLE:	Wire Development Group: Understanding and Engineering the Performance of 2G HTS Wire
ORGANIZATION:	Los Alamos National Laboratory, Argonne National Laboratory, Oak Ridge National Laboratory, University of Wisconsin and American Superconductor Corporation
PRESENTERS:	Martin Rupich (AMSC), Terry Holesinger (LANL), Matt Feldman (UW), Dean Miller (ANL)
FY 2006 FUNDING:	LANL - \$600K; ANL - \$250K; ORNL - \$300K; UW – \$250K foreseen (\$65K allocated); (DoE-EERE Funding) AMSC - \$1.2M

Project Purpose and FY 2006 Objectives: The Wire Development Group (WDG) is a unique multi-institutional collaboration focused on advancing the materials science of high temperature superconductor wires for energy and magnet applications in the US and international marketplace. The WDG leverages the expertise and resources of three DOE national laboratories (ANL, LANL and ORNL) and a leading university program in applied superconductivity (UW-Madison) with the world's leading company (American Superconductor – AMSC) involved in developing and manufacturing HTS wire and wire products. The fundamental knowledge generated from the WDG research over the past 15 years was instrumental in establishing the US as the world leader in the development of commercial first generation (1G) wire. As the HTS industry has transitioned from 1G to second generation (2G) HTS technology, the WDG is now focused on identifying and solving fundamental material science challenges that will facilitate the broad commercialization of a low-cost 2G wire technology.

This project aims at understanding the fundamental properties and processing of 2G HTS wire with the goals of improving its performance and establishing the US as the world-wide leader in commercial 2G HTS wire development and manufacturing. During the past year, the WDG has focused on enhancing the critical current density (J_c) through the full thickness of increasingly thicker YBCO films, developing a fundamental understanding of the transport characteristics of 2G wire as a function of temperature, magnetic field and field angle, and understanding the temperature and field dependence of the critical current in grain boundaries and within grains of YBCO.

Specific technical goals for the past year included:

1. Engineer *ex-situ* MOD-based YBCO films that carry over 500 A/cm-width at 77K, self field for cable applications.
2. Engineer the pinning properties of *ex-situ* MOD-based YBCO films to achieve greater than 250 A/cm-width (H//*ab*) and 120 A/cm-width (H//*c*) at 65 K, 3 T for magnet applications
3.. Quantify grain-boundary and bulk-pinning limited regimes for both H//*ab* and H//*c*, comparing *ex-situ* and *in-situ* YBCO using tools such as low temperature laser scanning microscopy (LTLSM).
4. Quantify J_c enhancement and pinning mechanism of meandering grain boundaries in ex-situ films

FY 2006 Performance and FY 2007 Plans:

Significant progress was made during the year in developing a comprehensive understanding of the thickness dependence of the critical current of *ex-situ* YBCO films, the microstructural basis of pinning mechanisms and the advantage of meandering grain boundaries in *ex-situ* YBCO coatings made by the MOD/RABiTS™ process. This knowledge was successfully used to engineer 2G wires, based on the MOD/RABiTS technology, with record self field and in-field performance levels. The core WDG group was also expanded to include the University of Houston. The addition of the UH scientists will provide additional resources and expertise, enabling the WDG to address a broader range of critical issues facing the commercialization of 2G wire in the coming years.

FY 2006 Results:

Key results and accomplishments in FY2006 include:

- Studies of the nucleation and growth of YBCO established processing paths for maintaining a high through thickness J_c in MOD/RABiTS-based YBCO films.
    - A critical current of just over 500 A/cm-width (77K, self field) was achieved in MOD-based YBCO

films on a RABiTS template.

- Extensive microstructural and electrical characterization of YBCO films and nanodot enhanced YBCO films established the role of 124-type intergrowths on *ab*-plane pinning.
  - Potential mechanisms for the formation of 124-type stacking faults were developed and exploited for improving the performance of AMSC's 344 superconductors.

- A fundamental understanding of the microstructural characteristics of pinning sites (nanodots and 124-type stacking faults) in the MOD-based YBCO films enabled optimization of the I_c of 2G wire as a function of field strength, field orientation and temperature.
  - High performance and an $I_c[H//ab]$ / $I_c[H//c]$ ratio of ~ 2, at 65K in a 3T magnetic field, was achieved in a thick YBCO film (> 1 micron) specifically engineered for coil performance.

- An in-field LTLSM system was developed, and for the first time, the transition from grain boundary limited to bulk pinning regimes was directly observed as a function of applied field in high performance MOD/RABiTS materials.

- The benefits of meandering grain boundaries on the critical current density of thick, *ex-situ* YBCO films on RABiTS templates were established.
  - Characterization of individual grain boundaries showed that meandering of *ex-situ* YBCO grain boundaries mitigates the effects of high angle grain boundaries in RABiTS substrates

- Publications and presentations
  - Twenty four presentational at national/international meetings
  - Nine papers published or submitted to refereed journals

For FY 2007 plans, the central objective of the WDG project is to address the critical issues to enable the broad commercial penetration of 2G HTS wires. One such issue is the development of a low cost, commercial 2G wire with a critical current of >1000 A/cm-width at 77 K, self-field, consistent with the DOE goal. This achievement will enable more compact and low-cost fault current limiters, and ultra-low-loss superconductor cables for the commercial electrical grid. Progress has been inexorable over time using the low-cost MOD/RABiTS process, enabled by ongoing new insights into the materials science and current limiting mechanisms. Demonstration of over 650 A/cm-width at 77 K, self field, is targeted in FY2007, on the way to 1000 A/cm-width by FY2010.

A second issue is improving the pinning in low-cost 2G wire at temperatures and fields targeted for coil applications. The WDG focus will be the progressive elucidation of fundamental pinning mechanisms in YBCO films and the development of novel approaches to engineer the performance in the low-cost MOD-based YBCO films for specific applications and operating conditions.

A third issue is an improved understanding and control of defects in 2G wires that may limit their performance and utilization in commercial applications. This includes understanding the role of current limiting mechanisms and manufacturing defects on the current uniformity, electrical and thermal stability and quench propagation of 2G wire and relating these limitations to performance in fault current limiters, cables, motors and generators.

Research Integration: The WDG is, by its very nature, a close integration of multiple institutions working effectively together to develop the materials science underlying HTS wire and enabling unquestioned world leadership in HTS wire production by a US company. The WDG has also accessed the expertise of other leading scientists (Amit Goyal, Elliot Specht) to help develop a better understanding of novel of pinning mechanisms. Trimester meetings, video conferences, individual visits, emails, phone calls, and inter-organizational sample exchanges insure rapid coordinated progress by exploiting the unique skills at the different laboratories. A sensible balance of proprietary technology and publishable results is maintained. An atmosphere of trust supports a positive and enthusiastic *esprit de corps*. The range of expertise and cooperation in the group allows a comprehensive approach to issues in 2G wire development. Key national laboratory and university results are tech-transferred effectively to AMSC, enabling rapid introduction of new developments in AMSC's 2G wire manufacturing process.