PROJECT TITLE:	ANL/SP CRADA: Characterization of 2G Conductor
ORGANIZATION:	Argonne National Laboratory (ANL) and SuperPower, Inc. (SP)
PRESENTERS:	Dean Miller, Victor Maroni, and Venkat Selvamanickam
FY 2008 FUNDING:	$400K

Overall Project Purpose and Objectives:
The purpose of this project is to help SP improve performance of their long-length 2G HTS wires through detailed characterization and analysis to identify key factors that influence performance. A primary emphasis is on understanding the influence of both current-blocking defects and beneficial flux-pinning defects. Based on the insights gained from these characterization studies, we recommend process modifications to improve properties that are implemented at SP and provide additional guidance through subsequent characterization. Our in-depth characterization/ analysis couples capabilities that are unique to the ANL program, including an emphasis on advanced electron- and ion-beam microscopy examinations coordinated with x-ray- and laser-based spectroscopy studies. Through this work, we provide an understanding of the underlying causes for track-to-track and pass-to-pass non-uniformities in the multiple MOCVD layers that are deposited by SP's "helix" process.

2008 Approach and Results:
SP has adopted a helix-based process for their production-scale long-length manufacturing of MOCVD coated conductor. The focus of our FY 2008 effort has been on identifying the YBCO phase evolution pathways and microstructure growth modes in SP's pilot "helix" deposition reactor. It is important to know how the microstructure evolves during various stages of this process in order to adjust conditions to achieve uniformly high critical currents over long lengths. Our insights derive from specially designed experiments that provide a "snapshot" of growth at various points of the helix deposition process. Through these experiments, we identified local defects and phase inhomogeneity in long-length conductor specimens from SP and in short length specimens from ORNL and BNL. We also identified key aspects of the growth mode both for specific locations in the deposition chamber and at specific times during the continuous growth process that contribute to these performance-limiting defects. As a result of these findings, SP modified their process to better control initial nucleation and growth uniformity as a function of track position in the helix system.

In a second major area of research, we extended our characterization approach to address formation of beneficial flux-pinning defects in MOCVD derived YBCO films. Raman microscopy and extended x-ray absorption fine structure (EXAFS) spectroscopy were used to probe the effects of BZO concentration on phase distributions and lattice disorder in BZO-doped MOCVD YBCO films prepared at ORNL.

(1) The process modifications suggested by our FY2007 studies were successfully implemented by SP. Electron microscopy and through-thickness Raman on multi-pass track-to-track tapes revealed improvements in microstructure and thickness uniformity from track-to-track, as compared to the previous (FY2007) configuration. These studies also provided evidence of reduced misorientation in the YBCO grain structure in subsequent passes, although there is still a tendency towards increasing CuO content through the second pass. (Proposed FY2008 task.)

(2) The "directional" precipitation of certain second phases was identified and shown to be orthogonal to the growth direction. Likewise, a "fish scale-like" growth of YBCO in the earliest stage of overall film growth was identified and a connection between this fish-scale growth

morphology and directional precipitation was proposed that suggested the need for further process modifications to improve performance. (Proposed FY2008 task.)

(3) The power of our through-thickness Raman microscopy technique was again demonstrated, here on a series of MOCVD YBCO films with varying mole% BZO (prepared by ORNL). These results showed (i) that the Ba-Cu-O phase content tends to increase through-thickness for all BZO concentrations, (ii) that the cation disorder tends to increase with increasing BZO concentration, and (iii) evidence for an increase in the YBCO oxygen stoichiometry from substrate to top surface. (Redirected FY2008 task.)

(4) A detailed structural characterization of the BZO precipitates as a function of mole% BZO in the YBCO matrix was obtained from EXAFS measurements on the same series of BZO-doped samples performed at the Advanced Photon Source. (Added task in FY 2008.)

(5) We have verified that as-made SP long-length tapes are fully oxygen over-doped. A study of the field angle dependence of Jc is underway, with the long-term goal of identifying the various pinning mechanisms through comparisons with microstructure analyses and theoretical models. (Proposed FY2008 task.)

2009 Plans and Expectations:

The primary focus of this research will continue to be on improving microstructure development in SP's "helix" MOCVD process during growth. As the quality of SP's tapes continues to improve, this activity involves continuous discussion and reassessment of key issues and experiments between ANL and SP. The key issues we plan to address are (1) establishing optimum nucleation and growth in the critical first pass of helix growth, (2) establishing the factors that contribute to misoriented and "a-axis" YBCO grain growth and devising approaches to mitigate the effects of un-textured domains, especially in the second and later passes of helix growth, and (3) establishing the causes and degree of variations in composition from pass-to-pass and from track-to-track.

A second major activity is aimed at improving in-field performance in SP's MOCVD-derived tapes through coordinated activities that include identifying pinning microstructures, measuring Jc as a function of magnetic field angle and temperature, connecting these through theoretical modeling, and providing feedback to SP's MOCVD growth process to optimize performance.

Technology Transfer, Collaboration, Partnerships:

The ANL/SP CRADA forges direct collaboration and partnership between ANL and SP. We work closely with SP staff to develop work plans, design experiments, and evaluate results. Results are exchanged and solutions to issues are developed through periodic meetings, telephone conferences, and by e-mail. The samples supplied by SP for characterization/analysis at ANL are prepared specifically to address key issues identified through meetings and discussions. Our insight into processing is also aided by collaborations with additional partners on topics of relevance to SP's process. In FY 2008 we expanded our collaboration with Tolga Aytug at ORNL to provide through-thickness Raman and synchrotron x-ray measurements on samples from MOCVD research studies being carried out at ORNL as part of their CRADA with SP. We also performed through-thickness Raman examinations on thick film MOCVD YBCO films provided by Slowa Solovyov at BNL. Taken collectively, the process insight and guidance derived from our microstructure and chemistry characterization efforts has helped SP achieve improved performance uniformity in long-lengths and is starting to provide new knowledge pertinent to enhanced flux pinning, thus contributing to the achievement of key DOE/EERE/OE program goals.