Project Title:	**LANL-SuperPower CRADA: Development and Multi-Scale Characterization of IBAD MgO/MOCVD YBCO Coated Conductors**
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Presenters:	Leonardo Civale, Terry Holesinger and Venkat Selvamanickam
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Overall Project Purpose and Objectives:

The LANL-SuperPower CRADA has been in place since 2000 with the primary purpose of assisting SuperPower with the development of a coated conductor (CC) technology and assuring their commercial success as a 2G wire manufacturer. The technology is based on textured templates produced by ion-beam assisted deposition (IBAD) of bi-axially textured MgO films on high-strength, non-magnetic alloy substrates and metal-organic chemical vapor deposition (MOCVD) of high-performance YBCO films. Our goal is to provide a fundamental understanding of the properties and microstructures across all relevant length scales of SuperPower's MOCVD-REBCO CC. Now that SuperPower is systematically producing long lengths of coated conductors based on the LANL's IBAD MgO process, we are helping to further improve their product by supporting them in a broad spectrum of issues, from reducing the cost/performance ratio by simplification of their architecture, to assessing the performance of their long-length tapes, to helping to diagnose and solve processing and scale up problems.

LANL maintains the expertise and equipment to produce several components of the SuperPower CC architecture, such as electropolishing of Hastelloy tapes, IBAD MgO, buffer and barrier layers, and the more recently developed Solution Deposition Planarization (SDP) of metal substrates. LANL has also developed an extensive array of instruments and capabilities for characterizing HTS films and wires across all relevant length scales. We use several techniques, such as TEM, HRTEM, STEM, elemental mapping, SEM and XRD, to determine the structural and chemical properties, as well as transport and magnetization tools to investigate critical currents and other pinning properties. We developed facilities that allow us to measure nondestructively the position-dependent electrical response (I-V curves) of long lengths of tape at different fields and temperatures. The modular design of our devices provides versatility and unique capabilities such as field-orientation dependence studies of long tapes. These resources are made available to SuperPower to compare and contrast the superconducting properties, general microstructures, and key defect structures of their MOCVD / IBAD MgO wires. In addition, we have designed, build and delivered hardware to SuperPower for in-house characterization and study of CC.

2010 Approach and Results:

The initial step of the transfer of the Solution Deposition Planarization (SDP) technology from LANL to SuperPower was successfully accomplished when the in-house SDP system became operational at SP and started to produce planarized tapes with surface roughness small enough for CC fabrication, as reported in the Peer Review 2009. During the last year LANL continued supporting SuperPower to optimize the SDP technology through interchange of technical information, including visits of LANL personnel to SP and vice versa. In parallel, at LANL we built a new SDP system. In contrast to the first one, which is a "close loop" setup that can only process tapes with a fixed length of a few meters, the new one is a "reel-to-reel" setup that allows processing of indefinitely long tapes. In addition to the knowledge acquired during the design and fabrication process, the new system can be used to perform SDP of SuperPower substrates and to planarize LANL substrates to be sent to SP for further processing and evaluation.

We used our long-length characterization tools to explore widely separated segments of a long Zr-doped SuperPower production tape, to evaluate performance and process stability. We cut several ~10cm long pieces of each segment to perform detailed transport $I_c(H,\Theta,T)$ measurements. With that information we constructed a full map of the angular dependence of the exponent $\alpha(\Theta)$, which describes the power

law relation $I_c(H,\Theta) \propto H^{-\alpha(\Theta)}$ in the range of ~ 0.1T to ~1T. The results show good uniformity of the properties, indicated by the similarity in the $\alpha(\Theta)$ curves (both in absolute values and functional dependence) even for pieces separated by 400m in the production tape. In all cases $\alpha(\Theta)$ shows a minimum for H//c and very low α values, indicating a very good $I_c(H)$ dependence. For comparison purposes we measured several earlier production tapes and performed similar analyses on them.
After the transport measurements described above were completed we cut one small portions of the 10cm pieces and performed magnetometer studies over a wide temperature range. From hysteresis loops M(H) we determined $I_c(H)$ (for H//c). We found remarkably low α values (α~0.21 for T=65K), consistent with the transport results and indicative of correlated (columnar) pinning. We also performed measurements of the flux creep rate (S) covering a large portion of the H-T plane. From these data we built contour maps of S(H,T). We observed the characteristic peak in S at T ~ 25K - 30K and μ_0H ~ 0.3T - 0.5T that again evidences the presence of columnar pinning. For comparison purposes, also in this case we performed similar studies on previous SuperPower production tapes without Zr additions.

We continued exploring the processing/structure/properties/chemistry correlations in these SuperPower CC by TEM, STEM and other structural tools. In the Zr-doped tapes we observed $BaZrO_3$ nanorods and RE oxides nanoparticles, confirming the presence of a highly effective mixed pinning landscape.

We have developed a new capability to perform I_c measurements at any angular orientation for fields up to ~ 1 T that can be used in a reel-to-reel system. The new hardware consists of larger electromagnets that were custom-designed for our specific needs (particularly cryogenic use) mounted on computer-controlled rotating stages. The assembly of the system is almost complete, and we will soon start the test/troubleshooting stage. The new system is compatible with SuperPower test facilities and will be useful to perform reel-to-reel in-field characterizations there.

With the purpose of exploring and improving the transport properties of CC in realistic cable configurations, during past years at LANL we have measured the performance of REBCO films and CC in variable Lorentz force configurations. We have extended those studies to SuperPower MOCVD/IBAD-MgO CC. We found an overall increase in J_c in the variable Lorentz configuration. We also report the first observation of *in-field* critical current **higher** than self-field in a coated conductor.

2011 Plans and Expectations:

In FY 2011 we will continue supporting SuperPower in their CC technology. With the data obtained with our various tools and capabilities and our accumulated knowledge of the processing-structure-properties-chemistry relationships in CC, we will continue to help them optimize wire processing and performance, as well as scale up efforts. Specific work plans and expectations include:

(1) Continue the optimization of the SDP technology compatible with MOCVD process.
(2) Continue the analysis of the microstructure and superconducting properties of both research and production MOCVD CC, especially to improved critical current in thick films and in-field properties.
(3) Continue position-dependent evaluation of long lengths of tapes and improve the LANL capabilities to respond to the evolving needs of our industrial partner.
(4) Design and delivery of equipment for measurement of transport properties of CC.

Technology Transfer, Collaboration, Partnerships:

This project is entirely based on industry interactions, implemented via e-mail, conference calls, meetings in conjunction with conferences and program reviews, and mutual site visits. When possible, results from this collaboration are published in the open literature for the benefit of the whole HTS community.