
Project Title:	Scale up of Coated Conductor Technology at SuperPower
Organization(s):	SuperPower
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FY 2003 Funding:	\$735 K

Project Purpose and FY 2003 Objectives: The main purpose of this program is to scale up coated conductor technology to pilot-scale manufacturing. The emphasis of this program is to establish manufacturing protocols in pilot-scale operations to lay the foundation for a framework for large-scale manufacturing of coated conductor. As outlined in our FY'02 Peer Review presentation, the objectives for FY'03 were :

1) Improved performance in meter-long conductors, 2) Modify substrate, buffer, and YBCO deposition facilities to scale up coated conductor fabrication to 10 - 100 m lengths, 3) Demonstration of 10 - 100 m long substrate, buffer, and YBCO tapes with uniform performance over entire length, 4) Demonstrate increase in throughput in all fabrication steps, 5) Develop further QC tools for continuous off-line and on-line monitoring, 6) Continue defect analysis with various microstructural tools to provide feedback to process to enhance tape performance, 7) Execute a follow-on CRADA to continue current collaboration with LANL & ANL, 8) Aggressive on MOCVD scale up with ANL.

FY 2003 Performance and FY 2004 Plans: Significant progress was made in all eight of the FY 2003 objectives. (1) Critical currents in excess of 100 A were routinely achieved in meter-long lengths of coated conductors produced by both MOCVD & PLD. 2) New substrate polishing facility was brought on-line and modifications were made to IBAD facility to process multiple tape wraps to produce 10 – 100 m lengths, 3) 10-100 m long substrates have been produced with surface roughness of 1 nm. IBAD buffer layers have been deposited on tapes in excess of 10 m with uniform in-plane texture of 11 degrees. YBCO tapes with performance levels in excess of 100 A have been produced in 10 m lengths. 4) Throughput increase of 5 – 20x has been achieved in all fabrication steps, 5) A breakthrough QC tool has been constructed for in-plane texture measurements on continuously moving tapes. A reel to reel critical current measurement system has been constructed for detailed measurements of uniformity in tape performance 6) Raman Spectroscopy, X-ray Diffraction, Focussed Ion Beam Milling, Optical Profilometry, Magnetic imaging and other advanced characterization tools have been successfully used to provide feedback to tape fabrication process 7) A new 2-year, \$ 3.4 M CRADA has been executed with LANL to accelerate technology development 8) More emphasis has been placed on MOCVD scale up in collaboration with ANL including adding staff to the MOCVD group at SuperPower and procurement of a pilot MOCVD facility.

In FY 2004, SuperPower will continue the scale up program to produce 100 m lengths of coated conductor and further improve the performance of 10 m long lengths. We will work on increasing throughput to even higher levels in all steps of tape fabrication. Practical conductor configurations including narrower tape widths and stabilizer application will be scaled up to longer tape lengths. We will continue to build on our progress in developing a conductor with better performance in magnetic fields and under high mechanical strain. Several on-line and off-line process and QC tools will be refined for achieving better uniformity over tape length and better reproducibility from run to run. All efforts will be continued to be focussed on establishing manufacturing protocols for a strong manufacturing framework.

FY 2003 Results: Key results from the FY 2003 program are summarized below.

1. Coated conductor tapes have been routinely produced in lengths of few meters to over 10 m. Optimization of the MOCVD & PLD processes have yielded 100 A performance in these tape lengths. In order to scale up to longer lengths, a new production-scale substrate polishing facility has been brought on line. This and all other process equipment are designed to be modular so that additional modules can be added as and when necessary to increase throughput. The pilot IBAD facility at SuperPower has been retrofitted with a helical tape handling system to increase the throughput. The throughput of the process has been increased 7-fold by this retrofit. Also, new IBAD conditions were
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developed to achieve another factor of 2.5 increase in the throughput, resulting in an overall throughput increase of almost 18 times. The pilot IBAD facility has been operated continuously over time periods of a week. Several on-line process monitors are used to assure uniform process conditions over the long deposition periods. A high degree of in-plane texture has been achieved in lengths of over 10 m in IBAD tapes produced in this facility. Tape throughput in both the MOCVD & PLD processes has been increased by a factor of five. Higher throughput was achieved in our prototype MOCVD facility by increasing the deposition rate as well by using linear showerhead design to increase the deposition zone length. Higher throughput was achieved in the PLD process using higher laser pulse repetition rate with our industrial laser.

2. Several unique process control and quality control tools were brought into operation for continuous process and performance evaluation of lengths of tapes at various stages of fabrication. We designed and constructed an X-ray diffraction tool for rapid, direct, in-plane texture measurements on continuously moving tapes. In-plane texture values are obtained with this equipment at a rate 10 times faster than that possible even with XRD systems equipped with area detectors. We also brought into operation a reel-to-reel critical current measurement system that we used to measure critical currents on long tapes in one meter intervals as well as in 5 cm intervals. This fiscal year, we implemented reel-to-reel operation in an X-ray Fluorescence tool for thickness measurements on buffer and stabilizer layers. Reel-to-reel operation was also employed in our Field Emission Scanning Electron Microscope for microstructure analysis on long tapes. In collaboration with U. Albany and ANL, we have employed Focussed Ion Beam Milling to obtain cross-sectional information, and used Raman Spectroscopy to identify secondary phases and buffer layer problems. In collaboration with LANL, we are using a magnetic imaging technique to examine non uniformity in critical current performance across the tape width.
3. In addition to performance towards stated objectives, SuperPower has made major progress towards development of a practical conductor. Modifications to the HTS fabrication process has resulted in performance in magnetic fields that is 2 times better than that reported in typical coated conductors. Also, it has been found that our unreinforced tapes are able to retain higher currents at high levels of bend strain. Progress has also been made in slitting tapes to narrower widths suitable for cable applications as well as in development of new technologies to apply copper stabilizer for purposes of cryostability.

Research Integration: SuperPower worked very closely with LANL and ANL during the course of this program. Our 3-year CRADA with the labs was successfully completed this year and we implemented a new 2-year CRADA with LANL to continue building on this success. Several visits have been made by SuperPower employees to LANL and ANL and vice versa. SuperPower employees closely interacted with the lab scientists by frequent e-mail and phone communication. Strong assistance has been provided by LANL to address issues in IBAD & PLD scale up. Superconductor deposition has been conducted on the same buffer tapes at SuperPower and LANL in order to optimize the superconductor performance. Also, new substrate polishing technologies such as electropolishing that was developed by LANL in FY'02 were transferred to SuperPower this fiscal year. SuperPower began deposition of HTS layers on IBAD MgO tapes produced by LANL. Significant collaboration occurred in tape characterization including critical current measurements in magnetic field, reel-to-reel critical current measurements, and magnetic imaging to examine non uniformity in critical current across tape width. SuperPower has continued to augment its MOCVD program with support from ANL. We have been working closely with ANL to use their characterization tools such as Raman Spectroscopy and Transmission Electron Microscopy.

The program has been reviewed in this FY on site at SuperPower by ORNL, LANL, and ANL.
