Project Title:	Scale Up of Coated Conductor Technology at SuperPower
Organization(s):	**SuperPower**
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FY 2004 Funding:	FY 2004 Funding: $0 to date; FY 2003 Carryover: $434 K

Project Purpose and FY 2004 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 develop R&D solutions for scale up issues in pilot-scale operations to lay the foundation for a framework for large-scale manufacturing of coated conductors. As outlined in our FY'03 Peer Review presentation, the objectives for FY'04 were :

1) Modify existing Pilot facilities and add new Pilot facilities for IBAD, Buffer, HTS deposition, and Stabilizer to produce 100 m lengths.
2) Demonstrate at least 50 A over 100 m.
3) Demonstrate linear speed greater than 10 m/h in every processing step to produce 100 A conductor.
4) Modify and add QC tools for rapid reel-to-reel measurements over 100 m lengths.
5) Transition IBAD MgO technology from LANL.
6) Scale up a high rate IBAD process to produce 100 A conductor in at least meter lengths in Pilot facilities.
7) Continue to build on progress with performance of conductor in high magnetic fields, mechanical strain, and electrical stabilization.
8) Develop slitting technology to produce 1 - 10 m long conductors in 4 mm width with at least 100 A/cm performance.
9) Provide several 10 m single piece lengths of 4 mm wide conductor to our SPI partner, Sumitomo Electric Industries (SEI) for construction of prototype second-gen cable.

FY 2004 Performance and FY 2005 Plans: Significant progress was made in all of the FY 2003 objectives. (1) Substantial modifications were made to existing pilot-scale facilities as well as new pilot-scale facilities were installed with capabilities to produce 100+ m lengths 2) We focused on achieving 100 A performance in 50 m lengths. In March 2004, we reported world-record performance of 6000 A-m in 57 m long tape. 3) We demonstrated 100 A performance at a linear tape speed of 10 m/h in the MOCVD process. Existing equipment and new equipment have been added to achieve linear tape speeds of 10 m/h in other steps. 4) We have established automated reel-to-reel Ic measurements in two systems, one with 0.1 m – 1 m measurement intervals and another with 0.01 m measurement intervals. A Normarski microscope system with reel-to-reel tape handling capability has been established for qualification of substrates for IBAD MgO. An on-line thickness measurement system has been added to our Pilot IBAD facility. 5) A dedicated prototype IBAD facility has been established for transitioning IBAD MgO technology from LANL. IBAD MgO deposited tapes are being produced in this facility with a good degree of in-plane texture, enabled by strong support from LANL. 6) The IBAD MgO process is being scaled up to long lengths in the prototype IBAD facility and prototype buffer facility. 7) The performance of our tapes in a magnetic field has been improved over a wide range of field orientations using rare-earth substitution. A new conductor structure has been developed to achieve better electrical stabilization. Mechanical properties of this new structure have been examined. 8) Slitting processes have been developed to produce 1 – 10 m long conductors in 4 mm width with performance exceeding 100 A/cm-width 9) A total of 60 m of 4 mm wide, copper-stabilized conductor is being provided to SEI for the Albany Cable project.

In FY 2005, SuperPower will continue the scale up program to produce 100 m lengths of coated conductor with high tape throughput in all steps. High rate processes in IBAD and buffer deposition will

be scaled up to 100 m lengths. All post-HTS processing steps such as silver sputtering, copper electroplating, and slitting will be scaled up to 100 m lengths. Fully-processed conductors in long lengths would be provided to our SPI partner SEI for the Albany Cable Project and other customers. Mechanical, in-field, and ac loss performance of our tapes will be further improved. Additional QA/QC tools will be added, particularly for on-line tape inspection during processing.

FY 2004 Results: Key results from the FY 2004 program are summarized below.

1) Coated conductor tapes have been produced in lengths of up to 57 m. Critical currents exceeding 100 A have been achieved over 57 m length, corresponding to a world record of 6000 A-m. A second reel-to-reel critical current measurement system has been added for critical current profiling in 0.01 m steps over 50+ m long tapes. The critical current profiles of long tapes have been studied in detail and have been correlated to texture, room-temperature resistivity, composition, secondary phases, and microstructure. This detailed study has enabled us to determine the problems causing local degradation in Ic. Once these problems were identified, appropriate in-situ process monitors have been added to the process equipment to monitor and improve the stability of the process in fabrication of 50+ m tapes.

   A production-scale electropolishing system is routinely used to produce 200+ m long tapes with a high-degree of surface finish. Our Pilot IBAD facility has been retrofitted with longer ion sources and a new helix tape handling system which has enabled a 3x increase in tape throughput. A large deposition area that is 0.6 m in length and 7 cm in width has been achieved with this helix tape handling system. The IBAD process was optimized to achieve uniform texture over this entire large deposition area. This has enabled us to produce 100 m long IBAD tapes with uniformly good texture over the entire length. Rapid in-plane texture measurements have been obtained on all 100 m long IBAD tapes using a unique texture measurement tool. A new Pilot MOCVD facility was recently brought into operation. New QC tools have been added for on-line thickness measurements in Pilot IBAD facility, for on-line 100% tape inspection in the substrate electropolishing facility, and for reel-to-reel Normaski microscopy.
2) We demonstrated high deposition rates with MOCVD, up to 120 Angstroms/s and still achieved critical currents of 230 A/cm. Using such high deposition rates, we demonstrated a linear tape speed of 10 m/h and still demonstrated 100 A/cm performance. A new prototype IBAD facility equipped with a helix tape handling system and RHEED has been brought on line for scale up of IBAD MgO. This facility contains a helix tape handling system with a deposition zone of 20 cm in length and 7 cm in width. The RHEED system has been equipped for texture measurements on all the 6 tape tracks in the deposition zone. Tape speeds in excess of 10 m/h are possible with the helix tape handling system. Good in-plane textures have been achieved in IBAD MgO processed in the prototype facility. Buffer layers and HTS layers have been deposited on the IBAD MgO tapes. We have scaled up the electroplating process for copper stabilizer application to 50+ m lengths. Long tapes have been plated with copper stabilizer with no degradation in critical current. A slitter has been installed for slitting tapes to narrow widths. Long tapes have been slit to 4 mm widths with performance exceeding 100 A/cm. Tape speeds exceeding 10 m/h have been demonstrated in all post-HTS processing steps while maintaining Ic > 100 A/cm.
3) The magnetic field dependence of Ic has been further improved in our tapes in a wide range of field orientations using rare-earth substitution. The drop in Ic from zero field to 1 T is less than a factor of 5 both in the orientation of field perpendicular to tape as well as at 45 degrees to the tape. AC loss characteristics of our tapes have been improved by modification of the conductor structure. Sixty meters of 4 mm wide, copper stabilized tapes are being provided to SEI, our partner in the Albany Cable Project. The mechanical, physical, and electrical properties of these tapes have been inspected in detail.

Research Integration: SuperPower worked very closely with LANL and ANL during the course of this program. We are in the midst of a 2-year CRADA with LANL and research integration has occurred in

numerous areas. Progress with IBAD MgO has been accelerated by buffer deposition of SuperPower's IBAD tapes at LANL followed by texture measurements. Problems with electropolishing stability over long time periods were solved by collaborative work with LANL. Substantial collaboration with LANL occurred in tape characterization including ac loss measurements, 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. We worked closely with ANL on Raman Spectroscopy and Transmission Electron Microscopy studies on our MOCVD tapes, which have proved valuable in our process optimization for long lengths. 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. In addition to LANL and ANL, we worked with BNL for ac loss measurements as well as film composition measurements and with ORNL on buffer development. We also collaborated with the Air Force Research Laboratory and Air Force Institute of Technology for on-line plume monitoring in our PLD facility as well as on-line vapor composition monitoring in our MOCVD facility. We also enjoyed a close collaboration on advanced characterization of our coated conductors with NIST, U. Albany, U. Kansas, MIT, and U. Wisconsin.

The program has been reviewed in this FY on site at SuperPower by DOE and DOD lab representatives.