| Organization: | Oak Ridge National Laboratory |
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| Project Title: | Continuous Processing and Characterization of YBCO Coated Conductors |
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| FY 2002 Funding: | $1.9 million (DOE to ORNL) |

**Project Purpose and FY 2002 Objectives:** The purpose of this project is to address issues associated with continuous processing of lengths of YBCO coated conductors. Our primary objectives for FY 2002 are:

1. Understand, optimize, and modify individual processing steps to improve further the overall quality and consistency of RABiTS.
2. Using reel-to-reel and batch furnaces to *ex situ* process YBCO conductors with $J_c$ consistent with the underlying RABiTS texture.
3. Using conversion furnaces, research the influences of processing pressure and furnace geometry on the efficiency of large-area conversion.
4. Measure quench behavior and ac characteristics of *ex situ* processed YBCO coated conductors.

**FY 2002 Performance and FY 2003 Plans:** In FY 2002, the capability to perform each step in the fabrication of lengths of conductor by the RABiTS approach was improved. New systems have been made operational for some steps. To obtain a conductor with good performance characteristics, every processing step must be carried out correctly. Process parameter studies have led to improved reproducibility and properties at intermediate stages and in the final product.

Noteworthy accomplishments in the fabrication of RABiTS include demonstration of the ability to prepare 5-10-m lengths of fully buffered substrate with reproducibly good characteristics. A $Y_2O_3$ seed layer is preferred over $CeO_2$ because it is less prone to cracking. By ex-situ conversion of vapor deposited precursor, high $J_c$ has been obtained on meter lengths of strengthened alloy. Good uniformity of $J_c$ over lengths has been demonstrated. A successful methodology for improving continuous precursor conversion parameters has been developed and is being applied to studies of processing of lengths with thicker YBCO precursor layers. The understanding of the precursor conversion process has been advanced. Studies of the effects of reduced pressure and flow geometry on the conversion process are on-going.

Detailed studies were conducted on the quench and stability of a 20-cm-long YBCO tape. The top surface was coated with a 1-:m-thick layer of silver. Measurements of critical current of the sample were performed over a temperature range of 44-80 K with conduction cooling provided by a G-M cryocooler. Measurements were performed over this temperature range to determine the stability margin, minimum propagation current, and the speed of normal zone propagation.

FY 2003 plans are:

1. Continue to improve eacb step in the continuous fabrication of conductor by the RABiTS approach.
2. Use the new rolling mill at ORNL to address issues in the fabrication of highly textured nonmagnetic and strengthened alloy tapes.
3. Using reel-to-reel, scalable processing, improve the understanding of growth kinetics and development of texture and microstructure during conversion of thick precursors.
4. Investigate issues related to large area conversion using low pressure conversion and batch conversion systems which became operational during the past year.
5. Continue quench and stability studies on longer, more uniform, and higher critical current YBCO tape samples with different substrate materials and silver layer thickness. Perform tests of a 1-m-long YBCO cable and a 1-T YBCO coil as conductor is available from industrial partners.

**FY 2002 Results:** Strengthened alloy with excellent texture, )M<7< and )T<5<, has been obtained. Buffer layers in which that texture is replicated have been deposited reproducibly on lengths up to several meters. Development of a sulfur superstructure on the metal surface by exposure to a low pressure of $H_2S$ during the texturing anneal has proved to be an important step in obtaining reproducible buffers on lengths. By ex-situ conversion of vapor deposited $BaF_2$ precursor, excellent $J_c$'s have been obtained on greater than one-meter lengths of strengthened alloy in 300-nm-thick YBCO coatings. Longer lengths of thin YBCO on nickel substrates have been converted which exhibit $J_c$ in accordance with the texture of the underlying metal. Studies of conversion of thicker YBCO layers are on-going.

Several new pieces of equipment have become operational during the year. ORNL acquired and began operation of a new state-of-the-art four-high rolling mill. The mill will be used for strategic research and by industrial partners in studies aimed at improving the texture of alloy substrates. An rf sputter system with three 24-in.-long sputter guns for rapid deposition of YSZ and the $CeO_2$ cap layer was completed. Epitaxial buffers can now be deposited on 5- to 10-m lengths at tape traversal rates ~1m/hr. A new reel-to-reel x-ray diffraction system has been designed and constructed which is dedicated to the superconductivity effort. A reel-to-reel tape cleaning system using high velocity steam has been constructed. A reel-to-reel system for optical measurement of roughness has been set up and and used by CRADA partners. Correlations between surface roughness and the properties of buffer layers have been observed. A pulse tube refrigerator cooled superconducting magnet system for characterization of short samples as a function of temperature from 4 K to 300 K and in magnetic fields to 9 T is now operational.

In connection with a new CRADA with Neocera, a pulsed electron beam deposition system is operational at ORNL. This deposition process is similar in many respects to pulsed laser deposition, but appears to have the advantage of lower capital cost. The chamber has been designed to be compatible with the addition at a later time of a tape transport system.

ORNL industrial partners have continued to progress in continuous fabrication of lengths of RABiTS-based conductor. 3M has made significant progress in the all aspects of conductor fabrication. They make fully buffered RABiT substrates in a single pass physical vapor deposition process at the rate of 30 cm/min. Typical run lengths are 20 m, limited by the capacity of ORNL's roll-to-roll XRD characterization system, although the deposition system capacity is approximately 500 m. $BaF_2$ precursor is deposited in 10- to 20-m lengths, depending on thickness, and the precursor conversion is done in 5-m lengths. Oxford Superconducting Technology and MicroCoating Technologies (MCT) have continued to work towards scaling the RABiTS and Combustion Chemical Vapor Deposition (CCVD) processes. Oxford has concentrated on Ni surface quality improvements, the development of a continuous annealing system, and the texturing of alloy substrates. They have scaled their batch annealing system to >75-m lengths. PLD YBCO layers have been grown on MCT's CCVD RABiTS with critical current densities exceeding 1 $MA/cm^2$, and MCT has demonstrated CCVD YBCO on single crystal $LaAlO_3$ with a critical current density of 1 $MA/cm^2$. American Superconductor Corporation (AMSC) is incorporating ORNL conductor technology into their long length process facility. They have obtained $J_c$ >1 $MA/cm^2$ over lengths and high critical current density on an alloy substrate.

**Technology Integration:** Five CRADA teams, led by 3M, AMSC, MCT, Oxford, and Neocera work with ORNL on implementing and scaling RABiTS technology. We collaborate with LANL on PLD of YBCO on lengths of RABiTS. ORNL has established a suite of laboratories for implementation of the Accelerated Coated Conductor project. The first industrial user, from MCT, came in March of this year. Hundreds of meters of tape at various stages of fabrication have been analyzed for 3M, AMSC, MCT, and Oxford in the reel-to-reel x-ray diffraction system.