
Project Title:	ORNL-American Superconductor Strategic Research
Organization(s):	Oak Ridge National Laboratory/American Superconductor Corporation
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Project Purpose and FY 2004 Objectives: The objective of this research is to develop a basic material sciences understanding of the fundamental issues related to fabrication of RABiTS templates for high critical current coated conductor wires (second generation – 2G). This understanding will assist in the development of a reliable, low-cost manufacturing process based on a 4 – 10-cm-wide reel-to-reel process. The program is also focused on characterizing and understanding issues related to ac losses and stability effects in wires and cables made with RABiTS-based 2G wires. FY 2004 plans included:

- 1) Fabrication of pilot line quality (10-cm wide by 100-m long) alloy substrates using the ORNL rolling mill facility with clean room.
- 2) Demonstration of scalable continuous processing of the MOD-YBCO on RABiTS through implementation of 4-cm-wide process.
- 3) Assistance by ORNL to AMSC's production of 20-m lengths of 2G wire with an I_c of 250 A/cm from the 4-cm-wide manufacturing process.
- 4) Characterization of buffers, using microstructural techniques such as TEM, SIMS, EBSP, SEM, Auger Spectroscopy, etc., to optimize the buffer layer stack for long length production of 2G wire.
- 5) Correlation of texture to J_c to facilitate the improvement of the texture of AMSC alloy substrates. Analyze the importance of out-of-plane misorientation with respect to J_c .

FY 2004 Performance and FY 2005 Plans: Major progress has been made in demonstrating a, reproducible, low-cost manufacturing process for a commercial 2G conductor. Increased understanding of the fundamental properties of the substrate and each buffer layer allowed the implementation of an improved, highly stable manufacturing process at AMSC. These improvements led to AMSC's successful fabrication of a series of 4 consecutive runs of continuously processed 10-m lengths with outstanding performance (250-270 A/cm-w at 77 K). Other studies were directed to understanding of substrate components on ac losses, conductor stability, and the investigation of high risk approaches with the potential reward to drastically improve performance or reduce cost. Several approaches to define suitable buffer stacks on nonmagnetic substrate materials were investigated. FY 2005 Plans include:

- 1) ORNL assistance to AMSC in producing pilot line quality (4 cm wide by 100 m long) alloy substrates using the ORNL rolling mill facility with clean room,
- 2) Improvement of RABiTS template manufacturing process reliability through fundamental characterization of the buffer layer properties.
- 3) Reduction of the substrate/buffer manufacturing cost through improved understanding of the interactions of buffer deposition rates and intrinsic properties.
- 4) Detailed analysis of the role of RABiTS template texture and manufacturing defects as current limiting mechanisms in long length, 4-mm-wide YBCO wires.
- 5) Analysis of the uniformity and reproducibility of long length, 4-cm-wide RABiTS templates produced in a high-rate reel-to-reel manufacturing process.
- 6) Development of new, low-cost template architectures that are applicable to Ni-5at%W as well as nonmagnetic Ni-9at%W and NiCrW substrates

FY2004 Results: Close collaboration between AMSC and ORNL has produced significant progress in the development of a reproducible, robust reel-to-reel fabrication process for MOD-YBCO/RABiTS wires and the development of practical conductor architectures. Key Results include:

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- ◆ 250-270 A/cm-width performance, uniformity and reproducibility of 10-m continuously processed 2G wires based on RABiTS templates confirmed the quality of the RABiTS template and reel-to-reel manufacturing process.
 - ◆ The microstructure of AMSC buffers was studied in detail using a combination of SEM, TEM, X-ray diffraction and SIMS, in a collaborative program of ORNL with Sandia National Laboratory. This provided an improved understanding of the function of each layer in term of diffusion properties and interface reactions. A model was developed explaining the buffer properties for the current $Y_2O_3/YSZ/CeO_2$ architecture.
 - ◆ Grain boundary assemblages in AMSC substrates were studied with electron backscatter Kikuchi diffraction and X-ray microdiffraction techniques. The total misorientation at each grain boundary was separated into in-plane and out-of-plane contributions. It is found that grain boundary maps of the in-plane misorientation correlate better with the J_c levels attainable for YBCO films grown epitaxially on these substrates compared to grain boundary maps of the total misorientation.
 - ◆ The properties of substrate materials were investigated to determine their effect on conductor properties. Total ac losses of 1-cm- and 4-mm-wide YBCO/ CeO_2 YSZ/ Y_2O_3 /Ni/NiCrW sample were found to scale inversely with the square of the total conductor critical current. It was confirmed that the contribution to the ferromagnetic losses from the substrate was reduced for Ni/NiCrW compared to Ni-5at%W substrates.
 - ◆ Several buffer architectures were investigated for the nonmagnetic NiCrW and Ni9at%W substrates. Since direct deposition of oxide buffer layers on NiCrW is not thermodynamically favored, we have investigated two approaches for the seed layer:
 - ⇒ TiN seed layers were used in a $CeO_2/LMO/MgO/TiN$ architecture. 0.8- μ m-thick MOD YBCO films were grown on these samples with critical current densities of 1.8 MA/cm². Extensive structural and chemical characterization was performed on TiN-based architectures.
 - ⇒ Ni-9at%W coatings were deposited on both Ni-5at%W and NiCrW alloys to test the viability of this approach to reduce the magnetic contribution of the template. This approach may allow the use of the standard buffer layers comprising of $CeO_2/YSZ/Y_2O_3$ on the nonmagnetic substrates.
 - ◆ The effectiveness of Cu stabilizers, required to protect against a 10 \times overcurrent in thermally isolated YBCO conductors, was studied. Centimeter-wide YBCO samples with 50 microns of copper stabilizer survived overcurrent pulses for 35 ms without significant degradation. This overcurrent resulted in a peak temperature of 280 K.
 - ◆ The ORNL rolling mill facility with clean room was used to fabricate wide substrates for AMSC in this period. Homogeneity of the textured substrates was confirmed by X-ray techniques at ORNL. Increased processing width followed by a final slitting to conductor size is a necessary contribution to a cost effective manufacturing process.

Technology Integration: Close collaboration and interaction between ORNL and AMSC has resulted in significant advancement in process understanding and subsequently in production processing at AMSC. Regular weekly conference calls, frequent sample exchanges, CRADA meetings, joint development and joint materials evaluation and testing have resulted in significant and rapid progress over the course of the last year. Technical staff from AMSC routinely visited ORNL to perform week-long rolling runs. AMSC views ORNL as their fundamental RABiTS template research laboratory. An even closer interaction is envisioned for future work. Several joint publications and many joint presentations have resulted from this work.