Project Title:	**ORNL-American Superconductor CRADA: Development of 2G YBCO-RABiTS Wires**
Organization(s):	**Oak Ridge National Laboratory, American Superconductor Corporation**
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Project Purpose and FY 2003 Objectives: To develop a basic understanding of fundamental issues, and provide guidance for the practical solution of problems related to reel-to-reel processing of coated conductor for high-temperature and high-field applications. FY 2003 plans included:

1. Develop methods to characterize the relationships between "texture" and "grain boundaries," and develop a metric to use in the development of alloy substrates with respect to texture on AMSC's substrates.
2. Jointly develop improved alloy substrates in long lengths which could have any or all of the following characteristics–sharper texture, higher strength, lower magnetism, and/or surfaces on which it is easier to deposit epitaxial oxide layers.
3. Develop simpler, faster, lower-cost, alternate buffer layer architectures that are compatible with the TFA-YBCO process.
4. Develop methods to fully characterize the properties of barrier layers using microstructural techniques such as TEM, SIMS, EBSP, SEM, Auger Spectroscopy, etc., and suggest corresponding metrics for each method.
5. Work with AMSC to help enable demonstration at AMSC of a high performance, 10-m, continuously processed YBCO tape on RABiTS, fabricated via reel-to-reel processing at all steps.

FY 2003 Performance and FY 2004 Plans: In FY 2003, most milestones were achieved as planned. Detailed analysis of several AMSC alloy substrates as well as buffered substrates was performed by electron backscatter Kikuchi diffraction and X-ray texture analysis. Correlations were developed with measured data and superconducting properties of YBCO films grown epitaxially on these substrates. Long lengths of textured Ni alloys were fabricated at AMSC based on processes first developed at ORNL. A sharp ~100% cube texture with high homogeneity was obtained. In some of these alloys, undesirable secondary recrystallization, resulting in grain growth was observed. This results in restriction of processing conditions to lower temperatures as well as limits to the best texture that can be obtained. AMSC rolled alloys were annealed under a variety of conditions at ORNL to determine processing conditions wherein high temperature annealing was possible without secondary recrystallization. Solution routes for depositing the seed layer, the barrier layer as well as the cap layer were developed on AMSC substrates. Solution routes are potentially faster, cheaper,and a low-cost alternative to vacuum routes. AMSC standard buffer layer optimization was performed using a variety of microscopic characterization techniques. A successful demonstration of a 10-m-ong YBCO on RABiTS was completed with an I_c of over 180 A/cm-width in self-field, 77 K.

A close collaboration between AMSC and ORNL has produced significant progress in all steps of reel-to-reel fabrication of fully buffered RABiTS, resulting in a reproducible, robust process. Epitaxial YBCO on meter long tapes was found to show excellent properties and uniformity. The team has furthered its joint development of a potentially low-cost manufacturing process for a commercial conductor.

FY 2004 Plans include:

1. Develop a metric to correlate "texture" to J_c to facilitate the improvement of the texture of AMSC alloy substrates. Analyze the importance of out-of-plane misorientations with respect to J_c.
2. Improve the properties of alloy substrates produced in long lengths with respect to the following characteristics: sharper texture, higher strength, lower magnetism, and/or surfaces on which it is easier to deposit epitaxial oxide layers using ORNL's new rolling facility with a class 1000 clean room.

3. Replace a buffer layer in the current architecture with a lower-cost alternative with improved performance characteristics including diffusion and/or texture that is compatible with the MOD-YBCO process.
4. Produce a standard method and quantitative metrics to evaluate alternative buffer architectures prior to HTS.
5. Work with AMSC to prove scalability of continuous processing of the MOD-YBCO/RABiTS process though implementation of 4-cm-wide processing.

FY 2003 Results: Several AMSC Ni-5at%W substrates processed differently were examined in detail using electron backscatter Kikuchi diffraction. Detailed analysis of the grain boundary misorientation distribution, grain size distribution, grain orientation maps and pole figure analysis was performed. Similar analysis was also performed on fully buffered samples on the same substrates. This analysis was then compared to superconducting properties obtained on YBCO films deposited on the fully buffered substrates.

Annealing studies were conducted for AMSC-ORNL developed Ni-Cr-W ternary alloy substrates to determine conditions in which secondary recrystallization could be avoided. Detailed X-ray analysis of the substrates has revealed that the secondary recrystallization temperature can vary depending on the annealing conditions.. This finding is very significant because it allows for possible solution-processed buffer layers on these substrates, which may require higher processing temperatures. Also, the texture becomes more perfect with higher processing temperatures. Similar analysis was also performed on Ni-5at%W substrates and the results obtained will be reported.

The standard AMSC buffer stack on Ni-5at%W comprises Y_2O_3/YSZ/CeO_2. In the standard buffer stack, these buffer layers have certain thicknesses which seem to work but it is desired to improve the stack robustness further for growth of even thicker YBCO films. Detailed SEM, TEM, Auger, SIMS and X-ray diffraction techniques were used to study oxygen and cation diffusion in the standard buffer stack when processed under different conditions. Also, individual layer thicknesses were then varied to determine the optimal thickness of each layer. An aim of this work is also to develop a methodology to test any new buffer layer architecture to see whether or not it is good enough to sustain a thick YBCO film.

Using the sol-gel alkoxide precursor route, $La_2Zr_2O_7$ (LZO) was epitaxially grown directly on Ni-W substrates. Smooth, crack-free buffer layers with a thickness in the range of 20-100 nm were grown using multiple coatings. Using the metal-organic decomposition (MOD) approach, epitaxial CeO_2 cap layers were grown on LZO-buffered Ni-W substrates. AMSC has grown high current YBCO films using their proprietary trifluoroacetate (TFA) based MOD precursor approach on this buffer stack. Work is ongoing to improve the properties of superconducting films on the all-solution buffers. Studies were also performed aimed at substituting at least one layer in the standard buffer architecture by a solution process so that the total buffer stack is capable of sustaining a high quality and thick YBCO layer deposited by the AMSC process. For a buffer layer configuration where the seed layer was deposited by solution techniques and only one cap layer by a sputtering process, an I_c of 136 A/cm was obtained in self-field, 77 K. The specific configuration of the sample was YBCO/(sputtered CeO_2/(solution) $La_2Zr_2O_7$/Ni-W. When only the seed layer was deposited by solution processing, both YSZ and CeO_2 layers were deposited by rf-sputtering similar to what is done in the standard AMSC buffer stack, an I_c of 184 A/cm was obtained. The specific configuration of the sample was YBCO/(sputtered)CeO_2/ (sputtered)YSZ/(solution)$La_2Zr_2O_7$/Ni-W. The Ni overlayer on NiW is not needed for this architecture.

Transport ac loss measurements were performed on a series of RABiTS-processed YBCO coated conductors at 77 K. While each sample possessed a 1-µm layer of YBCO and a 3-µm silver cap layer, two different nickel alloy substrates were used and their impact on the ac loss was examined. Both substrates possessed a 75-µm Ni-5at%W base, but one substrate also had a 2-µm nickel overlayer as part of the buffer layer architecture. The ac losses, which were determined by thermal and electrical measurements, contained two dominant contributions: superconductor hysteresis in the YBCO and ferromagnetic hysteresis in the substrates. The superconductor component followed the Norris elliptic model for the substrate with the nickel overlayer and the Norris thin strip model for the substrate without nickel overlayer. While the overall loss was lower for the thin-strip like conductor with no nickel overlayer, further research is necessary to strengthen this connection.

Continuous processing of MOD-YBCO based RABiTS conductors has improved significantly in both performance and maturity to the level where wire could be supplied to produce a 1-m demonstration cable. Commercial quality wire has been produced from conductors up to 10 m in length with performance of 180 A/cm-w., including copper stabilizer for electrical and thermal protection of the wire.

Research Integration: A very close collaboration and interaction between ORNL and AMSC has resulted in significant advancement of technology at AMSC. Regular weekly conference calls, frequent sample exchanges, joint development, and joint materials evaluation and testing have resulted in significant and rapid progress over the course of the last year. An even closer interaction is envisioned for future work. Several joint publications and many joint presentations have resulted from this work.