
Project Title:	Alternative Buffer Layer Architectures for YBCO Coated Conductors
Organization(s):	Oak Ridge National Laboratory
Presenters:	M. Paranthaman and C. Cantoni (ORNL)
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Project Purpose and FY 2003 Objectives: To develop a basic understanding of and practical synthesis paths for epitaxial buffer layers on biaxially textured metal tapes for YBCO coated conductors. The primary objectives for FY 2003 are:

1. Research and develop faster, potentially lower cost, and simpler RABiTS buffer-layer architectures that are compatible with ex-situ BaF₂ or TFA processes.
2. Develop a viable high rate solution process to fabricate high quality buffer layers.
3. Collaborate with LANL and ANL to develop suitable buffer architectures on IBAD-MgO and ISD-MgO substrates for compatibility with ex situ YBCO.
4. Continue fundamental studies of epitaxial growth on textured nonmagnetic substrates, including copper and copper alloys.

FY 2003 Performance and FY 2004 Plans: In FY 2003 most of the milestones were achieved as planned. As an alternative to the standard RABiTS four-layer architecture of CeO₂/YSZ/Y₂O₃/ Ni/Ni-W, we have developed simpler architectures based on two effective Ni diffusion barrier layers, LaMnO₃ (LMO) and La₂Zr₂O₇ (LZO). These buffers were grown epitaxially on biaxially textured and strengthened Ni-W metal tapes by scalable vapor and/or solution techniques. Using the sol-gel alkoxide precursor route, we have grown 20-nm-thick epitaxial LZO layers in a single coat directly on Ni-W substrates. Smooth, epitaxial, crack-free buffer layers with desired thickness in the range of 60-100 nm were produced using multiple coating. YBCO films grown on top of LZO layers using the BaF₂ or TFA precursor route resulted in the formation of BaZrO₃ layers at the buffer/YBCO interface. Hence, we explored the use of solution CeO₂ cap layers known to be compatible with ex-situ YBCO processes. Using the metal-organic decomposition (MOD) approach, we have successfully developed a method to grow epitaxial CeO₂ cap layers on LZO-buffered Ni-W substrates. In collaboration with American Superconductor Corporation (AMSC), we have grown high current YBCO films using their proprietary trifluoroacetate (TFA) based MOD precursor approach on LZO solution buffers. To reduce the number of solution coating steps, we are in the process of developing a methodology to coat more than 50-nm-thick epitaxial LZO layers in a single coat on Ni-W substrates. Some of the results will be presented.

In collaboration with LANL, a single LMO buffer layer has been developed for the growth of superconducting thick YBCO films on polycrystalline Ni-alloy substrates where a biaxially textured MgO layer, produced by ion-beam assisted deposition (IBAD), was used as a template. Cross-sectional TEM bright-field images of a PLD-grown YBCO film on LaMnO₃-buffered IBAD-MgO template layers revealed a clean, planar interface between the LaMnO₃ and YBCO layers and no signs of any interfacial reactions between the two layers. It also indicated that a clean and abrupt interface exists between the LaMnO₃ and IBAD-MgO layers. In addition, there was no indication of metal diffusion through the buffer layers. However, YBCO films grown on LMO surfaces using the ex-situ processes resulted in tilting of the YBCO texture and poor performance. Hence, CeO₂ cap layers were deposited by sputtering for compatibility with BaF₂ or TFA process and achieved high current YBCO films.

It is important to further assess the feasibility of Cu as base metal for RABiTS conductors since this material would enable reduced ferromagnetism, higher electrical conductivity, higher heat capacity, and lower cost compared with nickel alloys. Fundamental studies were conducted by depositing buffer layers and YBCO films on biaxially textured Cu substrates. We identified TiN as a promising Cu diffusion barrier, and use this material as a seed layer grown epitaxially on a textured Cu substrate. A layer of MgO was then deposited cube-on-cube on the TiN film, and subsequently capped with LMO for structural compatibility with YBCO. An alternative approach to avoid detrimental Cu diffusion and oxidation was also considered. Protective Ni films with a thickness of ~1.5 μm were deposited epitaxially

on the Cu textured tapes and consequently capped with LMO buffer layers. Similarly, conducting $\text{La}_{0.7}\text{Sr}_{0.3}\text{MnO}_3$ (LSMO) buffer layers were grown on Ni capped Cu substrates and this architecture also yielded high current density YBCO films.

The FY 2004 plans are:

1. Perform studies aimed at an all solution route to buffers that are capable of sustaining a high quality and thick ($>1 \mu\text{m}$) YBCO layer by a scalable superconductor process, such as evaporated BaF_2 precursors or a TFA-derived MOD process.
2. Demonstration of an I_c of over 200 A/cm-width on solution LZO layers.
3. Continue the collaboration with LANL and ANL to develop suitable buffer layer architectures on IBAD-MgO and ISD-MgO substrates.
4. Continue research and develop robust and simpler RABiTS buffer-layer architectures that are compatible with ex-situ BaF_2 or TFA processes.
5. Continue fundamental studies of epitaxial growth of suitable buffers on textured non-magnetic substrates, including copper and copper alloys and demonstrate high I_c YBCO films.

FY 2003 Results:

Solution Studies on LZO Buffers - Studies were 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 high quality and thick YBCO layers by a scalable process. In collaboration with AMSC, we have fabricated high current YBCO films with a TFA-derived MOD process. Alternative architectures developed in this study are: YBCO ($I_c = 184 \text{ A/cm-width}$)/(sputtered) CeO_2 /(sputtered) YSZ/(solution) $\text{La}_2\text{Zr}_2\text{O}_7/\text{Ni-W}$; YBCO ($I_c = 136 \text{ A/cm-width}$)/(sputtered CeO_2 /(solution) $\text{La}_2\text{Zr}_2\text{O}_7/\text{Ni-W}$; YBCO ($I_c = 32 \text{ A/cm-width}$)/(solution) CeO_2 / (solution) $\text{La}_2\text{Zr}_2\text{O}_7/\text{Ni-W}$. Results of efforts to fabricate dip-coated LZO layers in 20-30 cm lengths will be presented.

Demonstration of High Current Density YBCO Films on Buffered Copper Substrates - Copper substrates with a high degree of texture have been attained with a true FWHM of $\sim 4.1^\circ$ and with out-of-plane textures of 4.1° and 5.5° in and about the rolling direction. Conductive LSMO and nonconductive LMO buffer layers have been developed for Cu substrates. Two nonconductive buffer layer architectures, LMO/MgO/TiN/Cu and LMO/Ni/Cu, resulted in J_c of $\sim 1 \text{ MA/cm}^2$ at 77 K and self-field. The conductive buffer layer architecture of LSMO/Ni/Cu resulted in a J_c of $\sim 2 \text{ MA/cm}^2$ at 77 K and self-field.

Results on MgO-IBAD, MgO-ISD, and MgO-RABiTS Substrates - Using pulsed laser deposition, a $1.65\text{-}\mu\text{m}$ -thick YBCO film with a critical current density of $1.4 \times 10^6 \text{ A/cm}^2$ in self-field at 75 K has been achieved on sputtered LaMnO_3 -buffered IBAD-MgO substrates. This corresponds to an I_c of 231 A/cm-width. In collaboration with both LANL and AMSC, epitaxial YBCO films with a thickness of $0.9 \mu\text{m}$ have been deposited by ex-situ conversion of a trifluoroacetate-based metal organic decomposition precursor on CeO_2 capped LMO/IBAD-MgO Hastelloy substrates. I_c values at 77 K, and self-field, as high as 194 A/cm have been achieved. In collaboration with ANL, YBCO films with a J_c of over $2.5 \times 10^5 \text{ A/cm}^2$ were obtained on LMO-buffered ISD-MgO Hastelloy substrates.

In order to develop a robust oxygen diffusion barrier layer, MgO has been chosen as the potential candidate since the oxygen diffusivity in MgO at 800°C is $8 \times 10^{-22} \text{ cm}^2/\text{sec}$. The oxygen diffusion into the metal/buffer interface could potentially oxidize the substrate surface to NiO, WO_3 , CrO_2 , etc., based on the substrate composition. This may lead to delamination of the buffers and superconductors. It could also adversely affect the mechanical properties of the conductors. To overcome these issues, MgO has been grown directly on textured Ni or Ni-alloy substrates. Preliminary results will be presented based on the MgO-RABiTS architecture.

Research Integration: This project is related to the objectives of five CRADA teams that are working directly with ORNL. These teams are led by American Superconductor Corporation, MicroCoating

Technologies, Neocera, Oxford Superconducting Technology, and SuperPower. The materials science base for buffer layers for YBCO coated conductors also involves collaborations with universities and other national laboratories, including University of Florida, University of Kansas, University of Wisconsin-Madison, University of Houston, ANL, LANL, and SNL. Numerous publications (including a Web-based posting of the FY 2002 ORNL annual report) and presentations help assure transfer of information to industry.
