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| **Project Title:** | **RABiTS-Based Strategic Research** |
| **Organization(s):** | **Oak Ridge National Laboratory** |
| **Presenters:** | A. Goyal, S. Sathyamurthy, and T. Aytug (ORNL) |
| **FY 2004 Funding:** | $900 K (DOE to ORNL) |

**Project Purpose and FY 2004 Objectives:** To develop a basic understanding of and practical synthesis paths for epitaxial buffer layers and YBCO superconductors on biaxially textured metal tapes for improved coated conductor performance. The primary objectives for FY 2004 were:

1) Develop all solution buffer architectures that are compatible with MOD TFA YBCO
   a. Achieve over 200 A/cm-w on solution LZO seeds
   b. Develop two-sided LZO layers
   c. Extend to 4-cm-wide substrates
2) Continue fundamental studies of epitaxial growth of both PVD and solution buffers on textured substrates, including copper and copper alloys.
   a. For copper-based substrates, develop a fully conductive architecture.
3) Achieve high-$I_c$ YBCO films on Cu or Cu-alloy templates by *in-situ* or *ex-situ* approach.
4) Enhance flux-pinning in YBCO films on RABiTS through practical, growth-controlled pinning centers in the films

**FY 2004 Performance and FY 2005 Plans:** We have developed a simple, solution based buffer layer architecture using $La_2Zr_2O_7$ (LZO) as a barrier layer to nickel diffusion. LZO buffers were grown epitaxially on biaxially textured and strengthened Ni-W metal tapes by a scalable sol-gel alkoxide precursor route, yielding 50-100-nm-thick epitaxial LZO layers in a single coat directly on Ni-W up to 4-cm wide. Using the metal-organic decomposition (MOD) approach, we have successfully developed a method to grow epitaxial $CeO_2$ cap layers on LZO-buffered Ni-W substrates. Results of YBCO films grown on all solution $CeO_2$/LZO buffered Ni-W substrates will be presented.

As an alternative RABiTS architecture, we have developed combinations of $La_{0.7}Sr_{0.3}MnO_3$ (LSMO) and Iridium (Ir) metal that provide effective diffusion barriers for both inward oxygen and outward substrate cation diffusion. Since both LSMO and Ir are conductive materials, we have assessed the feasibility of LSMO/Ir structure as a conductive buffer interface on Ni-W substrates. High current YBCO films grown by PLD on Ni-W are fully electrically connected to the substrate tape.

We have explored Cu-based substrates as RABiTS templates since they are nonmagnetic, have high thermal conductivity, and high electrical conductivity, which could be exploited for conductor stability provided a fully conductive buffer architecture is developed. Based on our findings on Ni-W substrates, we have begun development of conductive buffer layers using Ir-based architectures on biaxially textured Cu tapes.

We have incorporated second phase, nano-particles in YBCO films grown epitaxially on RABiTS substrates. Several different nano-particle species have been attempted. Detailed transport, magnetization and microstructural characterization were performed and these results will be presented.

**The FY 2005 plans are:**

1) Continue fundamental studies of epitaxial growth of simplified buffers on textured nonmagnetic substrates, including nickel alloys, copper and copper alloys and demonstrate high $I_c$ YBCO films.
2) Perform studies aimed at an all solution route to buffers that are capable of sustaining a high quality and thick (>1 μm) YBCO layer by a scalable superconductor process, such as evaporated $BaF_2$ precursors or a TFA-derived MOD process.

- High $I_c$ of 200 A/cm on all solution buffers
- Demonstrate MOD layer on nonmagnetic Ni-W9at.% substrates.

3) Produce meter lengths of solution buffers using both slot-die coating and reel-to-reel dip-coating capable of sustaining 1-µm-thick YBCO films with $J_c$ over 1 MA/cm$^2$.
   - Optimize double-sided YBCO coating on all-solution buffers
4) Continue detailed studies on incorporation of practical pinning centers in YBCO *in-situ* and *ex-situ* films on RABiTS. Identify pinning centers using TEM studies and correlate to measured superconducting properties such as irreversibility field, $J_c$ versus field, and angle at various temperatures.

**FY 2004 Results:**

**<u>All solution buffers based $CeO_2$/LZO/Ni-W substrates</u>** - Under *ex-situ* YBCO process conditions, we have found that a 100 nm thick LZO protects the metal substrate from oxidation as well as that of the standard three-layer buffer architecture. About 80-120 nm MOD LZO provide good metal diffusion barrier, no delamination, and adequate template for growing thick YBCO films. To date, 10- to 20-cm-long LZO buffers were produced by dip coating. MOD LZO buffers were successfully grown on non-magnetic Ni-W9at.% templates for feasibility of deposition on Ni-W9at.% substrates. Highly textured MOD $CeO_2$ caps were grown on LZO-buffered Ni-W substrates and YBCO films with good properties were obtained.

**<u>Demonstration of high current density YBCO films on conductive LSMO/Ir/Ni-W substrates</u>** - Using PLD YBCO films, we have demonstrated *ideal* electrical coupling to the metal substrate. Electron microscopy shows a complete absence of unwanted insulating oxide interfaces. For 0.2-µm-thick YBCO films self-field critical current ($J_c$) values exceeding $2 \times 10^6$ A/cm$^2$ at 77 K were obtained on a Ni-W RABiTS template. Critical current ($I_c$) values for 1-µm-thick YBCO coatings exceed 100 A/cm at 77 K. Using a $CeO_2$ cap layer, a buffer layer stack was made compatible with the $BaF_2$ ex situ process, yielding $I_c$ >150 A/cm (77 K) for a 1-µm-thick YBCO coating.

**<u>Conductive buffer layer studies on copper</u>** - Feasibility of two different epitaxial buffer layer architectures, LSMO/Ir and LSMO/Ir/TiN, were explored as a conductive buffer interface on Cu templates. Preliminary results show that YBCO can be grown on these buffer architectures.

**<u>Strongly enhanced flux-pinning in YBCO films on RABiTS</u>** - We have incorporated second phase nano-particles of various kinds in YBCO films grown epitaxially on RABiTS substrates. During growth, a fine distribution of nano-particles (2-5 nm) precipitates homogeneously in the YBCO films, as determined by TEM. This produces significant enhancements in the transport behavior, including increases in self-field $J_c$, less sensitivity to field, increases in the irreversibility field, and significantly enhanced angular dependence of flux pinning at 77 K.

**Research Integration:** This project is related to the objectives of our CRADA partners that are working directly with ORNL. These teams are led by American Superconductor Corporation, MetOx, 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 Tennessee, University of Florida, University of Kansas, University of Wisconsin-Madison, University of Houston, NREL, LANL, and SNL. Numerous publications (including a Web-based posting of the FY 2003 ORNL annual report) and presentations help assure transfer of information to industry.