
Organization:	University of Wisconsin – Madison
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Project Title:	Buffer Layer Growth and the Thickness Dependence of J_c in Coated Conductors
Presenters:	Chang-Beom Eom, Eric Hellstrom, David Larbalestier
FY 2006 Funding:	\$250K foreseen, awarded so far \$50K. AFOSR-MURI matching support of \$200K and an AFOSR \$80K equipment grant.

Project Purpose and FY 2006 Objectives:

I. Buffer layer studies: Our primary objectives are:

1. To understand the mechanisms of in-plane texture improvement of YBCO films on buffer layers such as SrRuO₃, to control the mosaic spread of out-of-plane and in-plane texture using a single buffer layer and to identify the optimum buffer layer deposition technique and parameters required to obtain the largest improvement of in-plane texture.

2. To use MOD routes to deposit buffer layers on Ni(W) RABiTS and identify and understand the origin of and develop methods to eliminate buffer-layer defects by tracking individual buffer defects into the YBCO to determine how they affect the superconducting properties of the YBCO.

II. $J_c(t)$ Experiments: Our objective is to understand the thickness dependence of the J_c in CC and thin films made by both *ex situ* and *in situ* processes with a view to separating materials and physics effects so as to improve or remove the commonly observed strong $J_c(t)$ dependence.

FY 2006 Performance and FY 2007 Plans:

I. Buffer Layer Experiments

Project 1 on PVD Buffers (Eom): We studied the thickness dependence of the in- and out-of plane textures of YBCO grown on buffered SrRuO₃/IBAD-MgO. We varied the thickness of the YBCO from 0.1 to 0.4 μm and found that the texture improves more in the YBCO than through the buffer layer. Both in- and out-of-plane mosaic spreads for 0.4 μm thick YBCO are significantly smaller than for 0.1 μm thick YBCO. We have also started to study the mechanism of in-plane texture improvement in YBCO by sequential ion milling in 250 nm steps, followed by high-resolution x-ray diffraction. The FWHM of the YBCO 005 reflection increased from 1.23° to 1.36° after ion milling. The in-plane texture of YBCO increased from 3.6° to 4°.

For FY07 we will continue the ion milling HRXRD experiment. The mosaic spreads of YBCO layers from 1 μm to 250 nm will be correlated with the local EBSD grain boundary mapping and transport properties (J_c) of the YBCO at each stage of ion-milling. We also plan to grow epitaxial YBCO/CeO₂ on LSAT substrates by pulsed laser deposition to study flux pinning and the thickness dependence of J_c . We will also investigate the effect of deposition temperature of YBCO to control the defects in the YBCO layers.

Project 2 on MOD Buffers (Hellstrom): In Aug. '05 we discovered that our epitaxial LaMnO₃ (LMO) on Ni(W) was actually epitaxial La₂O₃: the Mn had been lost during firing. We were fooled because the epitaxial La₂O₃ film has a different structure than bulk La₂O₃, and it has an x-ray peak at the same position as epitaxial LMO. We consulted our partners at AMSC and ORNL and decided to continue investigating MOD LMO on Ni(W) because LMO remains a potentially important buffer for AMSC because it is one of only a few buffer materials on which AMSC can directly grow TFA-MOD YBCO and because of its excellent barrier properties. In FY06, we shifted our focus to investigate the thermodynamic and kinetic conditions underlying the formation of LMO as a function of T and pO₂ on different metallic and single crystal substrates. We found that metallic Mn evaporates at 1100°C at low pO₂ where Mn is thermodynamically stable, while on Ni(W), Mn evaporates at a higher pO₂ than given by the Mn/MnO equilibrium. We have determined the T-pO₂ window where LMO should form on Ni(W); however, in this window, W from Ni(W) reacts with the LMO precursors forming tungstates.

In FY07 we will form MOD LMO buffers using excimer laser heating. AMSC (Rupich) will deposit CeO₂ and TFA-MOD YBCO on our LMO layers. We plan to investigate the local J_c using magneto-optic imaging and low-temperature scanning laser microscopy to identify local regions with low J_c . We will use a FIB to cut local cross sections down to the substrate in these regions and SEM will be used to image the local through-thickness microstructure. We will measure metal diffusion through the LMO using SIMS in conjunction with ORNL.

II. Critical current density-thickness ($J_c(t)$) studies of CC (Larbalestier):

Performance: a. We made extensive studies to clarify the competing effects of microstructural and physics variables in determining $J_c(t)$ in single and double layer MOD CC and in purpose-grown PLD films with and without strong pinning defects. **b.** We made explicit determination of the intragrain and intergrain J_c values in MOD and PLD films grown on the same RABiTS template and were able to conclusively demonstrate the vital role that grain boundary meandering plays in making MOD-RABiTS a leading CC technology contender. We completed assembly of our Low Temperature scanning Laser Microscope (LTLSM) with a 5 Tesla magnet supported by AFOSR and used it to directly visible the crossover from highly localized grain boundary dissipation at low fields to much more uniform intra- and inter-grain dissipation at higher fields.

In FY07 we plan to delineate the conflicting roles that materials defects (current-blocking – bad and vortex pinning – good) play in thicker coated conductors. Our goal is to enable breakouts well beyond the just achieved 500A/cm. To do this we will unite ion milling, $J_c(H,T,\theta)$ measurements with FIB cross-sections and TEM so as to better understand the local J_c and the best means of approaching even higher I_c and J_c in thick films. This work will be done in collaboration with WDG partners and with Gurevich. We will address the local sources of dissipation by direct visualization using the LTLSM and will enhance our present capability which works only in perpendicular fields (H parallel to c) with a right angle mirror that should permit H parallel to ab study. In this way we will broadly map out the T, H domain in which GBs are current blocking. As films get thicker we expect that the FWHM of the YBCO will grow too and will study the extent to which GB effects are enhanced or reduced in such a scenario.

FY2006 Results:

- Studied the thickness dependence of in-plane and out-of-plane textures of YBCO films grown on buffered SrRuO₃/IBAD-MgO substrates.
- Mn was found to evaporate from LMO precursors on Ni(W) at higher pO₂ than set by Mn/MnO equilibrium. W from Ni(W) reacts with LMO constituents forming tungstates in the LMO T-pO₂ processing window.
- We found that standard MOD RABiTS films are in the strong 3D pinning limit and that multi-scale porosity strongly enhances vortex pinning in low fields, though not at high fields.
- We showed that single MOD GBs have substantially higher J_c values than PLD films grown on the same RABiTS template, sometimes 6 times as high.
- The 5T magnet for the LTLSM was brought on line and used to show that GB effects indeed become much smaller as the field increases.

Research Integration:

The UW effort is strongly interactive internally and externally. Buffer layer project 1 is carried out in collaboration with LANL, Buffer layer project 2 with AMSC and ORNL and the thickness dependence of J_c with AMSC, LANL, ORNL, SuperPower and internally with Eom. Gurevich's theoretical guidance and interactions under MURI support vitally influences the thickness dependent work. Collectively we have been highly interactive with each other. We run weekly collaborative meetings at UW which bind the groups together and Hellstrom and Larbalestier participate in the Wire Development Group, which met 3 times in FY06 and several times by Webex. We are also highly interactive with colleagues at AFRL and the AFOSR-supported CC community.