
Project Title:	Buffer Layer Growth and the Thickness Dependence of J_c in Coated Conductors
Organization(s):	University of Wisconsin - Madison
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FY 2004 Funding:	\$250 K

Project Purpose and FY 2004-2006 Objectives:

I. Buffer layer studies: Our primary objectives were

- 1) To understand the mechanisms of in-plane texture improvement of YBCO films on specific buffer layers such as SrRuO₃
- 2) To control the mosaic spread of both out-of-plane and in-plane texture using a single buffer layer and to identify the optimum buffer layer, deposition technique, and deposition parameters to obtain the largest improvement of in-plane texture
- 3) 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 primary objectives were:

- 1) To measure the $J_c(t)$ dependence of a baseline set of ex situ BaF₂ films converted in a variety of ways at ORNL using both RABiTS and IBAD substrates and to develop hypotheses about how the observed behavior depends on process methodology
- 2) To improve the $J_c(t)$ dependence through feedback to processing science and to decisively impact the production of >500A/cm width CC.

FY 2004 Performance and FY 2005 Plans:

I. Buffer Layer Experiments

The initial plan for IBAD-MgO buffer layer studies was to optimize the deposition parameters of various buffer layers on single crystal substrates. We have grown epitaxial SrRuO₃ (SRO), SrTiO₃ (STO), CaTiO₃ (CTO), Y₂O₃ and CeO₂ buffer layers on epitaxial Ni films by PLD with *in situ* high pressure reflection high energy electron diffraction (RHEED). A second aspect of the plan was to obtain YBCO/buffer (SrRuO₃), and SrTiO₃/IBAD-MgO seed template layer samples from Quanxi Jia at LANL and characterize by AFM and x-ray diffraction to investigate the in-plane texture improvement. Jia has fabricated five different samples: a. IBAD-MgO/Ni-alloy, b. SrRuO₃/IBAD-MgO/Ni-alloy, c. SrTiO₃/IBAD-MgO/Ni-alloy, d. YBCO/ SrRuO₃/IBAD-MgO/Ni-alloy, e. YBCO/ SrTiO₃ /IBAD-MgO/Ni-alloy. AFM images shows SRO layers grow in step flow mode with smoother surface morphology which indicates planarization during the SRO layer growth. We have also set up a high resolution x-ray optics with a four-bounce monochromator in our four-circle x-ray diffraction system in order to determine the crystalline qualities and textures of each layers. For FY2005 we plan to investigate the correlation between the textures, surface morphologies and microstructures to determine the mechanism of in-plane texture improvement. We will also measure $J_c(H)$ as a function of temperature for the YBCO samples on SRO and STO buffer layers.

Chemical Buffer Layer work focused on depositing La-Mn-O sol gel solutions to form LMO layers on Y₂O₃ seed layers on textured Ni(W) using lanthanum and manganese acetylacetonates (La-acac, Mn-acac). Because these metal acacs have low solubility in methanol and glycol, we developed, in consultation with Paranthaman (ORNL), a pyridine/propionic acid mixture as a new solvent. This dissolved much larger amounts of the acacs, allowing us to make a 0.4M solution (0.4M La and 0.4M

Mn), which was a factor of 10 higher in concentration than was possible with the methanol + glycol solvent. Studies are now being pursued by UW graduate student Kartik Venkaratam, while he spends a summer at ORNL with Paranthaman. For FY2005 we will continue depositing LMO using the sol-gel technique, experimenting with different cation concentrations and different spinning rates when depositing the solution. The LMO films will be studied using pole figure analysis to determine the phase composition and texture, and by scanning electron microscopy to investigate their microstructure.

II. Critical current density- Thickness studies of CC

We made extensive studies of $J_c(t)$ in the YBCO for BaF_2 films made by Feenstra (ORNL) using an older, “slow” and a newer, “fast” conversion process. The slow process allowed a maximum of ~ 200 A/cm at ~ 2 μ m thickness, while the faster process allowed up to ~ 300 A/cm at same t . $J_c(t)$ was approximately flat through thickness for both processes, while TEM analysis by Holesinger (LANL) showed a marked bimodal microstructure in the “fast” films. Magneto optical and EBSD analysis at UW showed that 40-50 μ m YBCO grains were growing on the template, even when the template was IBAD-YSZ with sub- μ m grain size. Thus the observed $J_c(t)$ performance is a combination of granular effects that lower overall J_c while providing higher local flux pinning from planar defects arising from the new, liquid-present route. To shed further light on these strong process-dependent results, we performed a study of $J_c(t)$ on 1 μ m-thick AMSC CC ($I_c \sim 270$ A/cm). Unlike the BaF_2 films, they appear not to develop liquid during YBCO conversion and exhibit a rising J_c at smaller t , consistent with models of a more 2D-like vortex behavior at small t . To help understand these complex behaviors, we are now modeling the flux pinning in a more real, multi-scale network. Careful growth of “uniform” PLD microstructures of YBCO will be used for model testing. For FY2005 we plan to separate the connectivity and pinning aspects of J_c and to develop a full model of flux pinning in the 2D-3D crossover regime that will allow prediction of how best to juggle the connectivity (J_c -decreasing) and flux pinning (J_c -increasing) contributions to our 500 A/cm goal.

FY2004 Results: Key results include:

- ◆ Development of controlled growth of various oxide buffer layers using *in situ* high pressure RHEED
- ◆ Development of an understanding of $J_c(t)$ in high current tapes made both by the PVD- BaF_2 and by the MOD-TFA routes
- ◆ Development of a new flux pinning model that incorporates multi-scale pinning interactions and analyses their influences on the 2D-3D crossover

Research Integration: The whole effort is strongly interactive with scientists at AMSC, LANL and ORNL. BaF_2 studies are very tightly integrated between ORNL scientist Feenstra and UW postdoc Feldmann. Gurevich (UW) takes the data developed by Feldmann and UW student Kim as input for new theory. UW student Venkataraman is working on MOD buffer layers with Paranthaman (ORNL) and spending the summer at ORNL to better learn techniques. PVD buffer layer studies are tightly integrated between UW postdoc Das and LANL scientist Jia. The global impact of the work is discussed at the trimesterly meetings of the CC-WDG.