

PROJECT TITLE:	Understanding and pushing the limits of critical current in coated conductors
ORGANIZATION:	LANL-STC
PRESENTERS:	Steve Foltyn, Leonardo Civale
FY 2006 FUNDING:	\$500 K

Project Purpose and FY 2006 Objectives:

With an overall objective of improving the performance of and commercial prospects for coated conductors, this project has been focused on raising the J_c and I_c of YBCO both in self-field and in an external applied magnetic field. A large portion of our effort has been devoted to increasing our general understanding of flux pinning in YBCO coated conductors (CC). Complementary results from the same project will be presented by B. Maiorov (next talk).

While the self-field J_c of sub-micron thick YBCO films is very high, this performance cannot be maintained in thick films or in strong magnetic fields. Last year we reported substantial advances in understanding and overcoming the limitations in both areas. Using a variety of experimental tools and ad-hoc designed samples, we validated our incremental j_c model and narrowed the possibilities for explaining thickness dependence. We found a “smoking gun” for interfacial effects in misfit dislocations. We also demonstrated that multilayers retain high J_c performance in applied fields, and found record low values for the decrease of J_c with magnetic field in BaZrO₃-doped films.

To expand on these advances, our 2006 goals included achieving 1000 A/cm-width at 75K and self-field in a multilayer of only 2 μ m thickness, determining which properties are significant in achieving high interfacial j_c and why the interfacial enhancement extends into the YBCO, and combining multilayers with an in-field pinning enhancement method. We also planned to continue working with interested industrial partners to implement multilayers and different pinning enhancement routes appropriate to their deposition technologies.

FY 2006 Performance and FY 2007 Plans:

In the thickness dependence area, we were successful in getting high critical current in thinner multilayers, as proposed. Our primary focus was to investigate the cause(s) for the rapid drop in J_c with thickness t . We conducted several experiments and analyses that led us to establish a definite link between misfit dislocations and strong thickness dependence. We devised methods to tune the interface-related pinning, which allowed us to strongly reduce or even suppress the thickness dependence of J_c . To obtain additional information about the structural features responsible for the bulk and interface-related pinning, we applied our toolkit of J_c characterization as a function of temperature, field and angle to perform a comparative analysis in films of different thickness and with different amount of interface-related pinning. We found in particular that some methods for in-field J_c enhancement, such as incorporation of BZO nanoparticles, suppress the thickness dependence, a result that has important implications for the design of multilayers. From a broader perspective, we combined a number of these and previous results to explore the fundamental and practical limits of the J_c s achievable in CC.

As an important part of our mission, we continued supporting in several ways the efforts at American Superconductor and SuperPower for enhancing pinning and improving the performance of their CC.

In 2007 we propose to build on our findings regarding the importance of interfacial effects with a long-term goal of finding a general approach for extending high thin-film J_c s to the thick film regime. We will use our characterization tools to continue investigating the specific microstructural features producing the interfacial enhancement, and we will search for engineering methods to optimize their effects. Specifically, we will endeavor to develop a collaboration to provide theoretical support to help model stresses and stress-relieving mechanisms in YBCO films. We will pursue additional experiments to reveal the roles of lattice misfit and mismatch of the thermal expansion coefficient between film and substrate. With regards to the

improvement of in-field J_c and I_c , we will investigate the interplay of artificially introduced pinning centers, such as BZO nanoparticles, and the microstructural features responsible for the interface-induced pinning.

We will also continue our work with SuperPower to develop an optimized continuous multilayer process. We will continue supporting American Superconductor through our participation in the Wire Development Group (American Superconductor, Oak Ridge National Lab., Univ. of Wisconsin-Madison, Argonne National Lab.). We plan to maintain the collaborations with our other partners by performing temperature, field and angular dependent J_c measurements and analysis on their samples.

FY 2006 Results:

- Produced multilayers with $I_c \sim 1000$ A/cm-width at a thickness of 2.2 μm .
- Designed and conducted a series of experiments to determine the source of high J_c in thin films, and the way that multilayers extend the thickness range of high J_c .
- Established a definite link between misfit dislocations and strong thickness dependence.
- Determined the thickness dependence in films engineered for in-field J_c enhancement.
- Measured the field, angle and temperature dependence of J_c in families of films with and without thickness dependence.
- Explored the fundamental and practical limits of J_c achievable in CC.

Research Integration: During FY2006 we continued the transfer of multilayer technology to SuperPower. We continued to work with Argonne National Laboratory to use Raman spectroscopy in the investigation of thickness dependence. We continued our collaboration with American Superconductor in the investigation of pinning mechanisms in their baseline and doped MOD CC, in particular we participated in the Wire Development Group (American Superconductor, Oak Ridge National Laboratory, University of Wisconsin-Madison, Argonne National Laboratory). We continued our collaborations with University of Cambridge, the Air Force Research Laboratory and began new collaborations with Brookhaven National Laboratory and the ICMAB (Barcelona, Spain). These collaborations resulted in joint publications and conference presentations. The information learned from these collaborations is critical for studying and understanding the pinning mechanisms arising from different routes for pinning enhancement.