

**2010 Advanced Cables and Conductors Peer Review  
Project Summary**

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<b>Project Title:</b>	<b>Materials development and nano-engineered pinning landscapes for coated conductors</b>
<b>Organization:</b>	Los Alamos National Laboratory
<b>Presenters:</b>	Terry Holesinger, Boris Maiorov and Leonardo Civale
<b>FY 2010 Funding:</b>	\$1.2 M

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**Overall Project Purpose and Objectives:**

HTS coated conductor wire technology requires microstructural control across multiple length scales. Wires based on  $Y_1Ba_2Cu_3O_y$  (YBCO) or, more generally,  $RE_1Ba_2Cu_3O_y$  (REBCO: RE = Y, Sm, Eu, Gd, Nd, etc.), must contain engineered nanoscale inhomogeneities (within the grain structure), while maintaining a homogeneous macroscale structure (phase purity, grain-to-grain alignment, minimal manufacturing defects). This work strategically targets materials and vortex pinning issues in REBCO films for coated conductors, covering new materials development, nanoscopic defect development, and thick-film growth processes. Coupled with the materials work is an emphasis on technique development for measurements of the superconducting and material properties, identifying structure-property-processing-chemistry relationships as they pertain to specific applications and the development of predictive capabilities for coated conductor performance.

The **Control Milestone** for this project was to:

- Systematically develop a materials system in which the pinning landscape, determined by REBCO film chemistry and additions to form nano-rods, nano-particles, and stacking faults can be independently controlled. (Due Date: Sept. 30, 2010)

Additional **Milestones** for FY2010 were:

1. Develop additional processes for controllably producing a nano-engineered defect / second phase structures (density, morphology, alignment, and assembly) within the REBCO films for the purpose of understanding the combined effects of multiple defect types in an optimized pinning microstructure landscape. (Due Date: July 31, 2010)
2. Expanding upon LANL recent success with double-perovskite, phase-separable materials, we will further optimize and understand the incorporation of this class of additives to expand the performance limits of REBCO films for coated conductors. (Due Date: September 30, 2010)
3. We will examine the relationships between growth processes - defect formation - pinning properties via expanded superconducting property characterizations in the temperature range of 20-50 K and as a function of field and orientation, conditions considered relevant to applications such as motors. (Due Date: July 31, 2010)
4. We will explore at high fields and relevant temperatures (65 – 85 K), the influence of different pinning centers and grain misalignment in realistic cable configurations. (Due Date: July 31, 2010)
5. We will compare, via flux creep studies, REBCO films and CC having different, deposition-dependent microstructures in order to understand the commonalities underlying REBCO film microstructure and its effects on flux creep. Samples will be produced at LANL by methods other than PLD (such as co-evaporation) and obtained from our industrial partners (MOCVD and MOD) and collaborators (Cambridge, AFRL). (Due Date: September 30, 2010)
6. We will perform angular and field studies in pulsed fields up to 65T to study the influence of different types of defects in the pinning landscape. The data will be analyzed within the context of existing vortex pinning models to quantify the effectiveness of various combinations of pinning defects. (Due Date: July 31, 2010)

**2010 Approach and Results:**

Our approach was to coordinate activities in advanced materials development with detailed investigation of the superconducting properties as outlined in the LANL 2010 AOP subtask 1.1

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*Materials development and nano-engineered pinning landscapes for coated conductors.* Synergistic combinations of extrinsic additions, such as the double-perovskites  $\text{YBa}_2\text{NbO}_6$  or  $\text{YBa}_2\text{RuO}_6$ , rare-earth oxides, and others, rare-earth substitutions into YBCO films, template effects, and process variations were quantified for improvements in connectivity and flux pinning (**milestones 1-3**). Detailed characterizations by STEM/TEM, XRD, and  $J_c(\Theta, T, H)$  were carried out on MOD (ISTEC), MOCVD (SuperPower), and PLD YBCO films (LANL, Cambridge) containing different nanoparticle and nanorod sizes and densities allowing for the separation of intrinsic and extrinsic factors affecting performance. Identification of processing dependencies, substrate effects, and synergistic combinations of additions have translated into some of the highest performance thick-film ( $> 2 \mu\text{m}$ ) conductors reported to date.

Measurements of  $J_c$  in maximum and variable Lorentz force configurations (**Milestone 4**) were performed on both MOCVD/IBAD-MgO (SuperPower, ORNL) and MOD/(IBAD-MgO) (ISTEC-Japan) coated conductors. We found an overall increase in  $J_c$  in the variable Lorentz configuration and report the first observation of an *in-field* critical current **higher** than self-field.

We measured creep rates over broad ranges of temperatures and fields (**Milestone 5**) for films from LANL and several collaborators and industrial partners. The samples were grown by a variety of methods (PLD, MOCVD, Co-Evap, and MOD) and contained different types of pinning landscapes (correlated, nanoparticles and mixtures) produced by self-assembled second phase inclusions (BZO, BNO, tantalates) and by particle irradiation. The data was used to draw  $S(T, H)$  contour maps that allow us to distinguish various types of depinning excitations, including kinks from columnar defects, collective regimes, and the slow creep regime at low  $H$  and intermediate  $T$  that we identified in FY 2009.

Comparative analyses were made of different pinning landscapes (**Milestone 6**) comprised of  $\text{BZO}+\text{Y}_2\text{O}_3$  and  $\text{RETaO}_y$  ( $\text{RE} = \text{rare earth, RTO}$ ) additions (mostly correlated and mixed) to YBCO films. It had been argued that BZO and RTO additions affect YBCO's electronic structure, leading to pinning improvements. We have analyzed the influence of different pinning centers and found that mixed landscapes lead to a higher and more isotropic irreversibility line ( $H_{\text{irr}}$ ), both with RTO and  $\text{BZO}+\text{Y}_2\text{O}_3$  additions. However, the upper critical field ( $H_{c2}$ ) angular dependence is not affected within the experimental error. The same conclusion was reached regarding MOD YBCO and  $(\text{Y, Gd})\text{BCO} + \text{BZO}$  coated conductors (ISTEC).

### 2011 Plans and Expectations:

In 2011 we will continue to utilize our film growth and characterization capabilities to investigate the specific microstructural and chemical features that result in higher YBCO performance, publish our results in the open literature, and help our industrial partners incorporate appropriate technologies into their production lines. Focus on priorities for cable application such as enabling measurements and characterization techniques.

### Technology Transfer, Collaboration, Partnerships:

Industry collaborations are listed separately in the CRADA reports. External collaborations with the Univ. of Cambridge, UK (Driscoll/Kursunovic/ Harrington/Wimbush), Texas A & M University (Wang), and ISTEC (Japan) ensure a wide variety of samples that allow us to separate process and intrinsic properties. One team member (Maiorov) visited Univ. of Cambridge and Dr. Driscoll visited Los Alamos at different occasions during FY10. ISTEC collaborations focused on pulsed high field (up to 65T) measurements of coated conductors as well as the exploration of strong pinning by randomly dispersed nanoparticles in MOD YBCO films. We continued our internal collaboration with the NHMFL at LANL. These collaborations resulted in several manuscripts accepted for publication during this period.