

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

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<b>Project Title:</b>	<b>Engineered Defects for Coated Conductors</b>
<b>Organization:</b>	Oak Ridge National Laboratory
<b>Presenters:</b>	Amit Goyal and Sung Hun Wee (ORNL)
<b>FY 2010 Funding:</b>	\$400 K (DOE to ORNL)

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**Overall Project Purpose and Objectives:**

To develop a basic understanding of introducing controlled nanoscale defects within the superconductor to result in enhanced properties of superconductors on coated conductors. U.S. HTS wire manufacturers are now in a position to produce reasonable quality coated conductors in “pilot-scale” mode. In meeting the DOE cost target, however, it is necessary to further improve the HTS transport properties, especially in the presence of high applied magnetic fields. Improvements in the properties of the HTS coating require a thorough understanding of the pinning mechanisms and control of various combination of nanostructures, in order to further improve the in-field and angular dependent properties in REBCO.

FY 2010 objectives were:

- Further understand the mechanisms of 3D self-assembly of insulating nanodots of various compositions and other crystal structures, resulting in engineered columnar defects, to enable still better control of defect structures
- Determine properties of YBCO films with BaZrO<sub>3</sub> (BZO) nanocolumns at low temperatures and high, applied magnetic fields
- Technology transfer to companies to enable creation of “double perovskite” based tantalate and niobate columnar defects in HTS wires using techniques such as MOCVD
- Optimize the pinning characteristics in PLD films via incorporation of Ba<sub>2</sub>RETaO<sub>6</sub> and Ba<sub>2</sub>RENbO<sub>6</sub> to compare with optimized pinning by BZO incorporated films
- Explore methods and techniques which allow for creation of controlled, nanoscale, columnar defects in an ex-situ manner so that the process is amenable to ex-situ YBCO films such as MOD and BaF<sub>2</sub> processed films

**2010 Approach and Results:**

This project aims to establish a fundamental understanding of the self-assembly process in multicomponent superconductors such as YBCO via synergistic efforts in fundamental theoretical formulations, simulations and experiments. The ultimate goal of the research is to develop ways in order to introduce controlled, engineered defect structures within the superconductor layer to optimize flux-pinning in thick epitaxial superconducting films on coated conductors. Close interaction with companies to transfer the knowledge base from the base program to the companies is ongoing.

**2010 Results:**

We have shown in previous years that vertically ordered arrays of BZO nanostructures within a YBCO matrix using PLD, result from a process referred to as simultaneous phase separation and ordering (SPSO) during the growth of embedded nanostructures in heterogeneous ceramic materials. BZO and YBCO phases separate during the initial growth stage and BZO forms crystalline nanodots surrounded by YBCO epitaxial layer. Nanoscale BZO patterns form to minimize the combined free energy of mixing, phase boundary, and elasticity. Massive improvements in superconductor performance in high fields and in a broad temperature regime are obtained by incorporation of these columnar defects. In FY2009, we showed for the first time columnar defects can also be formed with double perovskite tantalates and niobates phases

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( $\text{Ba}_2\text{RETaO}_6$  and  $\text{Ba}_2\text{RENbO}_6$  respectively). We also determined the effect of out-of-plane macrostrain and microstrain on  $T_c$ . We also correlated strain as a function of BZO doping to understand decrease in  $T_c$  in PLD YBCO films with BZO columnar defects and related it to the observed pinning in these films. We also determined the effect of lattice mismatch on self-assembly of columnar defects in YBCO films with  $\text{BaMO}_3$ -type additions and found that a certain range of lattice mismatch gives the best results. This year we have made significant strides and essentially all the FY2010 goals have been fully met. In particular, the following results have been obtained:

- We have extended our work on microstrain issues dictating the self-assembly of columnar defects.
- We have in collaboration with Florida State University / High-field Magnet Laboratory, characterized films at low temperatures and high, applied magnetic fields.
- We have examined local structural and chemical properties of the interfaces between self-assembled nanocolumns and superconductive matrix at the atomic scale.
- We have clearly established the thermodynamic stability of double perovskite, tantalates ( $\text{Ba}_2\text{RETaO}_6$ ) over the corresponding pyrochlore structured tantalates ( $\text{RE}_3\text{TaO}_7$ ). Similar considerations are expected for the niobate phases.
- We have fabricated films with high-performance by additions of the double perovskite,  $\text{Ba}_2\text{RETaO}_6$ . These thick films show the highest pinning force reported to date at 65K.
- We have developed methods and techniques which allow for creation of controlled, nanoscale, columnar defects in ex-situ YBCO films such as MOD and  $\text{BaF}_2$  processed films.
- We have successfully transferred the knowledge generated from this project to SuperPower to result in massive enhancements in commercial wire performance.

**2011 Plans and Expectations:**

1. Further understand the mechanisms of 3D self-assembly of insulating nanodots of various compositions and crystal structures, resulting in engineered columnar defects, to enable still better control of defect structures.
2. Further optimize the overall defect structures within the superconductor films on coated conductors to yield an improvement in the pinning at all field orientations. Fabricate designer materials with controlled defect structures which show what properties are possible to obtain and to guide work in CRADAs.
3. Conduct detailed studies to compare the flux-pinning in optimized double perovskite tantalates-based and niobates-based, and perovskite zirconate incorporated films over a wide range of field and operating temperature.
4. Mature the methods and techniques which allow for creation of controlled, nanoscale, columnar defects in ex-situ YBCO films such as MOD and  $\text{BaF}_2$  processed films.
5. Transfer knowledge gained in the project to companies to enable creation of engineered defects in commercial wires

**Technology Transfer, Collaboration, Partnerships:**

Technology transfer to SuperPower resulted in self-assembled, columnar defects in production MOCVD films. This project was performed in close collaboration with The University of Tennessee. Prof. Yanfei Gao, has been closely involved in this work through a close collaboration and partnership. Collaborative work was also done with Florida State University / High-field Magnet Laboratory for characterization of BZO incorporated films at low-temperatures and high, applied magnetic fields. Some collaborative work was also done with S. Solovyov, Brookhaven National Laboratory with respect to ex-situ films. During the course of

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this FY, several invited talks, and few contributed talks and several book chapters and papers have been published or submitted for publication.