Project Title:	**Improvement of 2G wires by solid-state catalysis**
Organization:	Brookhaven National Laboratory
Presenters:	Vyacheslav Solovyov
FY 2010 Funding:	$350 K

Overall Project Purpose and Objectives:

The purpose of the project is significant improvement of properties of the second-generation superconducting wires through structure refinement and development of new ways to pin magnetic flux. In FY2010 we concentrated our effort on utilizing metastable cuprate phases to achieve higher irreversibility field and lower magnetic flux creep value in YBCO wires. In FY2011 we plan to continue studies of metastable cuprate formation and will apply the "pinning through low-temperature transformation" concept to the production tapes. An important aspect of our work is connecting industrial and academic participants of OE-funded projects with large BES facilities such as National Synchrotron Light Source. In FY2009 we established a new CRADA with SuperPower Inc. on development of high-performance superconducting wires by utilizing the synchrotron radiation at the NSLS. The FY2011 CRADA work will also focus on understanding mechanisms of epitaxial phase formation during the early stages of MOCVD growth. The goal is to design a substrate that would reduce density of copper-rich phases and a-axis oriented grains at least by an order of magnitude.

2010 Approach and Results:

1. CRADA with SuperPower, study of YBCO nucleation during MOCVD growth:

In The CRADA collaboration will concentrate on developing the scientific understanding of nucleation of YBCO material deposited by metal-organic chemical vapor deposition (MOCVD) on a metallic substrate buffered by ion-assisted beam deposition (IBAD) with MgO-La-Mn-O (LMO) epitaxial stack. The knowledge will allow developing a technology for treatment of the buffered tapes which would improve properties of the YBCO layer and enhance critical current density through higher nucleation rate. In FY2010 we have performed a series of synchrotron based experiments. Local structure of YBCO in thin stripes of low-AC loss tape has been determined by microprobe X-ray (beamline X-13B). It is shown that the inter-stripe region still contained epitaxial YBCO which was separated from the stripe by a thin strip comprised of random grains. Nucleation studies on a cross-over sample included atomic force microscopy and synchrotron X-ray diffraction of a cross-over tape sample passed through a MOCVD deposition zone. The nucleation event was detected by the synchrotron X-ray diffraction, after that the sample was investigated by AFM to determine size and density of YBCO nuclei. It is shown that YBCO nucleates on LMO grain periphery as a strongly disordered perovskite. The local nuclei density is determined to be inversely proportional to the LMO grain size.

2. Metastable cuprates by substrate catalysis, synthesis of new cuprate compounds.

This is a continuation of 2010 effort in solid-state catalysis of metastable cuprates. Utilization of metastable phases opens new possibilities in the design of superconducting materials. In FY2010 we have shown that catalytically active, small-grain strained ceria buffers catalyze two new metastable cuprate phases in the proximity of the Bormann-Hammond stability line. One phase appears to structurally identical to $Y_2Ba_4Cu_8O_{16}$ however, unlike $Y_2Ba_4Cu_8O_{16}$ which is a superconductor with T_c = 80 K, the phase is insulating. This phase is shown to be the source of stacking faults in YBCO films. The most interesting is the second metastable YBCO derivative, the previously unknown long-period (3.5 nm) phase, which has a

remarkable effect on J_c and H_{irr}. The unique features of YBCO films intercalated with the new phase include strong pinning at the $H||c$ orientation along with apparent absence of T_c degradation even at a very high volume fraction.

3. Strain - pinning – carrier density diagram project

The project goal is to build a diagram that ties internal stain of the YBCO matrix with the pinning and the critical current density. The diagram will be used to tailor properties of 2G wires for specific applications and to develop new pinning strategies that maximize the flux retention without compromising T_c. In the project we use high-flux synchrotron radiation (single crystal X-18A beamline of NSLS) to accurately measure (00*l*) YBCO line position and line profiles in the normal scattering geometry and (*l*00) lines in the in-plane scattering geometry. The project participants are Air Force Lab (Tim Haughan), Los Alamos Nat. Lab. (Boris Mayorov), SuperPower, and Oak Ridge Nat. Lab (Eliot Specht). In FY2010 we used a set of 25 well-characterized samples with variable doping of $BaZrO_3$, Y_2O_3, grown in the deposition temperature range from 750 to 850^{o}C. The first XRD experiments were performed at X-18A beamline in May 2010. It was found that the in-field performance of Y_2O_3 and $BaZrO_3$ doped films strongly correlates with the ratio of intensities of (100) and (200) in-plane reflections. This implies that the precipitates introduce an in-plane disorder which might be responsible for the strong in-field pinning of these samples. Comparison of AFL and LANL samples with similar levels of $BaZrO_3$ doping but different T_c showed that T_c suppression by rod-like $BaZrO_3$ inclusions (LANL samples) occurs due to the formation of high amount of $Y_2Ba_4Cu_8O_{16}$ phase.

2011 Plans and Expectations:

1. Metastable phase formation through catalysis by distributed nano-particles

In FY2010 we established that strained planar surfaces cab be used to catalyze formation of cuprate phases with enhanced properties. In FY 2011 we plan to extend this approach and achieve more uniform catalysis in thick films. For the purpose we will pursue two directions: (i) reduction of the substrate grain size to increase the substrate activity, (ii) use of distributed nano-particles as the catalyst. The nano-particles will be synthesized at the Center for Functional Nanomaterials, BNL and optimized for the activity with respect to nucleation. The goal is to determine whether distributed nano-particles can be as effective as planar substrates.

2. Strain-pinning-carrier density diagram completion

In 2011 we plan to finish the strain-pinning diagram project, which would require additional beamtime on the X-ray beamline. We plan to support the X-ray data by the carrier density measurements (oxygen K-edge) that will be performed on U-7A beamline. The structural and carrier density information will allow building a consistent model of the artificial pinning center influence on both electronic and cation structure of HTS conductors.

3. CRADA with SuperPower

In FY2011 we plan to perform nucleation studies on substrates with various lateral grain size *R*. Since density of YBCO nuclei changes as *1/R*, we expect that smaller grain substrates would deliver denser arrays of YBCO nuclei and less non-superconducting grains.

Technology Transfer, Collaboration, Partnerships:

1. After the first year CRADA with SuperPower we performed characterization of low-AC loss tapes and delivered the first results on nucleation of YBCO on IBAD tapes.

2. A multi-lab collaboration on establishing a correlation between internal strain and the pinning in thick YBCO films with artificial nano-structures.

3. Collaboration with ICMAB Barcelona on strain analysis in ceria nano-islands.

Publications and invited presentations in FY2010:

1. Solovyov V F, Develos-Bagarinao K, Li Q, Qing J, and Zhou J, "Nature of $YBa_2Cu_3O_7$ nucleation centers on ceria buffers", *Superconductor Science and Technology,* **23** (2010)**,** pp: 014008.
2. Solovyov V F, Develos-Bagarinao K, and Nykypanchuk D, "Nanoscale abnormal grain growth in (001) epitaxial ceria", *Physical Review B,* **80** (2009)**,** pp: 104102-104112.
3. *Invited talk:* Materials Research Society Meeting, San Francisco, CA, April 5-8 2010, "Epitaxy of textured YBCO on technical oxide buffers"
4. *Invited talk:* International Conference on Coated Conductors Applications CCA09, Barcelona, Spain, November 22-25, 2009." Optimization of YBCO Nucleation on Technical Buffers".