

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

Project Title:	All-Solution Deposited Coated Conductors for Superconducting Utility Devices
Organization:	Sandia National Laboratories
Presenters:	Paul Clem and Daniel Wesolowski
FY 2010 Funding:	\$500K

Overall Project Purpose and Objectives:

Sandia's superconductivity program aims to commercialize and technology transfer manufacturable, high speed methods of coated conductor fabrication based on solution deposition technologies. In 2002, Sandia demonstrated the first all-solution route to a 1 MA/cm² coated conductor, using a single composition solution-deposited buffer layer (SrTiO₃ on NiW). Since then, Sandia has worked to increase the manufacturability of both the YBCO and buffer layer processes, and collaborated with industrial and national laboratory partners to leverage the modest size of our research program (\$300K in FY09, \$400-450K in prior years). Currently, the process is being scaled up to produce 10m-1km lengths of YBCO-based superconducting wire for use in Zenergy Power Systems Inc.-designed utility fault current controllers, energy-efficient induction heaters, and compact green power (wind power, hydroelectric) applications. In addition, a joint Sandia-Los Alamos process, solution deposition planarization, SDP, enables IBAD coated conductor processing on arbitrary composition and roughness substrates, and is of great interest to both Superpower and STI; CRADAs with these two companies would be pursued if enhanced funding of an additional \$200K (total \$500K) were available in FY10.

2010 Approach and Results:

The goal of this work is to develop low cost (~\$40/kA-m) coated conductors based on all-solution deposition. The solution deposition method developed is from 8-60 times faster than presently reported coated conductor processes, which may ultimately enable very low cost production. Our work is currently focused on pre-pilot plant scale-up for 10-100 meter length of our all-solution YBCO/SrTiO₃/NiW coated conductor process, with a route toward technology transfer, pilot-plant production and commercialization.

A two year CRADA was signed with Zenergy Power Systems in fall 2006 with the goal of demonstrating 10-100 meter production and pilot plant design for low-cost (< \$100 kA-m) all-solution deposited coated conductors. This CRADA currently has been extended through February 2011 (Q2 FY 11). Low cost is viewed as critical by Zenergy Power Systems for widespread adoption of fault current limiters and other superconducting industrial equipment, and Sandia technology is very promising approach for much faster deposition, pyrolysis and crystallization than in current practice.

A 1 km capacity dip coating deposition unit was designed by Sandia and supplied by SC Power Systems for scale-up of buffer layer and superconductor deposition in June 2007. A second unit, for 1 km capacity buffer layer crystallization, was set up in June 2009. 10 meter lengths of 2G superconducting wire have been deposited and converted via high rate (> 10 Å/s) ex-situ processing. Zenergy Power Systems has supplied textured NiW substrates for 2G wire manufacturing, with $\Delta\phi$ values of 5.3°. YBCO and SrTiO₃ buffer layers deposited atop these substrates displayed $\Delta\phi$ values of 5.7°, and 1.4 MA/cm² performance. Multi-pyrolysis films of up to 1µm were demonstrated this FY. Significant personnel exchange and joint experiments have been conducted with Zenergy Power to technology transfer Sandia's process to the private sector to enable low cost industrial devices for fault current limiting, advanced motors, and other applications.

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The collaboration with Zenergy allows us to perform analytical comparisons between multiple solution chemistries and conversion techniques. Zenergy scaled up a vacuum crystallization furnace this FY based on a Sandia laboratory scale design. This has become their standard R2R pilot production furnace. Zenergy provided Sandia with numerous samples for evaluation, including samples of ink-jet printed YBCO. TEM comparison of high-rate and standard pyrolysis YBCO precursors led to a number of refinements in pyrolysis conditions. At Zenergy's request we also evaluated ink-jet printable silver deposition processes to further reduce the cost of coated conductor fabrication.

Solution deposition planarization has been developed jointly between Sandia (solution chemistry) and Los Alamos (industrial scale up at the LANL research park), and prototype systems exist both at LANL and Superpower using Sandia solution recipes. A nondisclosure agreement has been signed with Superpower, and STI (Brian Moeckley) has indicated interest in developing the technique as well. SDP is attractive because it (i) eliminates the need for procuring or electropolishing smooth substrates (oxide films planarize the substrate), (ii) avoids the costs of disposal of electropolishing acid waste with metallic ion contamination (a significant cost and ES&H burden to Superpower), and (iii) enables use of IBAD many alloy substrates (i.e. Hastelloy, Inconel, stainless steel) without process changes.

2011 Plans and Expectations:

Sandia will continue the CRADA collaboration with Zenergy Power next year. Zenergy feels Sandia is their best resource for TEM evaluation of their samples. Analytical comparisons between the Zenergy processes and the Sandia developed processes will be a core feature of next year's work. Both Zenergy and Sandia are pursuing multi-pyrolysis techniques for producing thick, high- I_c films. We will help Zenergy adopt aspects of the Sandia process into their production process to solve problems common to conventional multi-layer schemes, such as copper segregation. We anticipate ink-jet printable Ag-coating technology to be transferred to Zenergy in FY11. Completion of a CRADA with Superpower or STI will significantly enhance our efforts to improve SDP production rates.

Technology Transfer, Collaboration, Partnerships:

Zenergy Power Systems: three year CRADA, all-solution deposition pre-pilot plant production, pilot plant specification design, materials evaluation, development of next generation products and processes

Los Alamos National Laboratory: tech transfer of Sandia solution deposition planarization (SDP) and joint optimization of LANL reel-to-reel continuous planarization equipment, development of new planarization chemistries and processes to decrease the substrate cost for ion beam assisted deposition (IBAD) substrates for coated conductors

Superpower: NDA in place and joint technical development of SDP prototype coating units at Schenectady and Houston locations; CRADA under consideration pending availability of enhanced funding

STI: Initial research demonstration of 590 A/cm co-evaporated YBCO on LANL/SNL IBAD/SDP substrates. Would pursue CRADA to enable STI pre-pilot plant SDP and IBAD scale-up pending availability of enhanced funding.