# IV.A.16 SECA Core Technology Program Activities—PNNL

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## Objectives

- Direct Solid State Energy Conversion Alliance (SECA) core technology programs.
- Identify and prioritize technology development needs that meet the cost and performance targets of SECA.
- Develop and execute experimental plans, summarize technical findings, and prepare topical reports; disseminate technical information and assist in technology transfer to SECA industrial teams.
- Develop materials, design and fuel processing technologies for large coal-based solid oxide fuel cell (SOFC) systems.
- Participate, organize technical and topical meetings and workshops, and exchange technical information with industrial and academic experts.
- Hold technical and program reviews and meetings to present the results of on-going technical work.
- Provide leadership and organization to technical societies and outreach programs.

## Accomplishments

- Identified key cell component materials cost reduction, thermal management, design scale-up approaches, and methodologies. Established a collaborative program with Allegheny Technologies, Inc. (ATI) for the development and testing of low-cost, bulk interconnect materials produced, using conventional melt and ladle metallurgical processes.
- Initiated a low-cost surface coatings development program to mitigate multi-step heat treatment process.
- Conducted modeling workshop and provided simulation tools to SECA industrial teams.
- Provided technical reports and materials samples of advanced coatings and seals to facilitate technology transfer.
- Published quarterly progress and topical reports. Peer reviewed journal papers were also published.
- Presented invited technical lectures at technical societies, universities, and industries.
- Organized American Society for Metals and Materials Science & Technology 2007, and American Ceramic Society, Cocoa Beach meetings on SOFC technology.

## Introduction

The SECA Core Technology Program (CTP) at PNNL conducts, and coordinates research towards the development and implementation of advanced cell and stack materials, systems design, simulation and performance optimization, along with the utilization of hydrocarbons and coal-derived fuels, in SOFC power systems. The PNNL program also collaborates with academic institutions, national laboratories, and industries towards the identification of technology gaps and prioritization of development needs. Research programs are focused on the development of cost effective materials and fabrication processes, electrical performance optimization and long-term stability, stack and systems design, and optimization along with thermal and structural analysis, and utilization of hydrocarbons and coal-derived fuels.

The CTP facilitates the exchange and dissemination of technical information to SECA participants in a timely manner. Technical workshops, topical reports, peer reviewed publications in technical journals, and presentations at technical meetings facilitate the information exchange. Quarterly and topical progress reports are prepared, and provided to SECA participants. The CTP also interacts with other government agencies, to gather and disseminate technical information related to SOFCs.

## Approach

The CTP conducts and coordinates research to meet the cost and performance targets of SECA. The program disseminates the research findings through workshops, technical and topical reports, and journal publications.

- Meet with SECA industrial participants, discuss technology status, and identify technology needs.
- Hold technical and program reviews and meetings to present the results of on-going technical work.
- Organize topical area workshops and exchange technical information with industrial and academic experts.

- Identify and transfer key technologies to industries.
- Publish technical findings in quarterly, annual, and topical technical reports, after completion of the task.
- Provide leadership and organization to technical societies and outreach programs.
- Organize and participate in the Annual SECA Program Review Meeting.
- Co-ordinate with the National Energy Technology Laboratory (NETL) on all aspects of the SECA-CTP.
- Organize technical society meetings.
- Foster university interactions, student exchange and training.

## Results

The SECA CTP has developed low-cost, interconnect materials and coatings, and provided the technical details to industrial teams. Mechanistic understanding of corrosion processes has also been developed. Advanced refractory glass formulations were developed, and are currently being tested, under SOFC exposure conditions. Thermal and structural models for large cell stacks were developed. The role of on anode reforming on temperature distribution was studied. Technical meetings with industrial teams were held and technical information related to cell materials, design and performance, were provided. Technical findings were presented at technical society meetings (MST 06-Cincinnatti and ACerSoc Cocoa Beach meeting). Numerous peer-reviewed journal articles were published, based on the core technology research.

Cell and stack component materials development activity focused on the development of lower cost, bulk interconnect alloy and surface coatings for improved corrosion resistance under bi-polar exposure conditions and mitigation of chromia poisoning of cathode electrodes exposed to ambient air. Evaluation of glass formulations also continued for applications in seals. Alloy metallurgy developed utilizing conventional melt processing, and ladle metallurgy techniques are currently being investigated, in collaboration with Allegheny Technologies Inc., for the development of modified ferritic stainless steels. This approach eliminates the use of expensive vacuum melt treatment techniques. Use of selected alloy additives to the melt also allow for localized segregation of Si. Although the spinel-based coatings have proven successful in reducing the alloy scaling, elimination of chromia evaporation and poisoning of the cathode electrode, the coating technique requires multiples of controlled heat treatment steps. Our current focus is on the development of low-cost electroplating or electrophoretic deposition processes for the fabrication of near net shape surface coating on stamped or formed interconnects. Several glass modifications were developed for seal applications, and are currently being examined for structural and chemical stability. Issues related to glass interaction with adjoining chromia scale, resulting in the dissolution of chromia and interface separation, have been studied. An aluminizing surface treatment of the steel has been developed for the elimination of chromia interaction with the glass. The aluminizing process is a commercial, low-cost process and can be scaled-up for coating large volume and large area current collectors. Another advantage of the aluminizing process is that it results in the formation of electrically insulating surface oxide.

Cell and stack design, performance simulation and long-term reliability studies at PNNL have focused on in-depth structural and thermal analysis of SOFC stacks. Glass seals stability, metal interconnection deformation, electrode-electrolyte interface stability, on-anode reforming, etc. have been investigated using computational simulation tools developed at PNNL. Training was conducted for the efficient utilization of modeling tools to SECA industrial partners. Utilization of hydrocarbon on the anode was found highly effective in controlling the stack temperature distribution more effectively for large size cells and stacks. We found that the reformation rate for methane remained very high, resulting in significant endotherm and cooling, at the cell inlet. Anode modification was developed and found to be effective in controlling the reformation rate and inlet cooling. We studied morphological changes in the bulk anode, due to subsequent reduction during the initial reduction or long-term operation. Phase changes in the zirconia present in the anode bulk were investigated, and results were disseminated to all SECA industry teams and to appropriate CTP participants. Topical reports covering the results and mechanistic understanding has been prepared and provided to SECA participants. Technical specifications, materials formulations, processing techniques, etc. have been documented in technical reports and provided to industrial partners as part of the technology transfer. PNNL provides topical and technology development status reports to SECA participants.

Topical and technical workshops to gather and disseminate technical information were conducted. PNNL participated in a joint meeting with ATI and NETL to develop a low-cost interconnection bulk alloy utilizing conventional metallurgical processes. A seal workshop was held at NETL to develop and test refractory glass seals. Use of refractory glass in the cell stack has the potential to reduce interactions with interconnect scale, along with increasing the glass sealing operational window. PNNL, along with the University of Cincinnati, is developing a comparative assessment of rigid and viscoelastic glass seals during nominal and transient cell operating conditions. The core technology management interacted with

Delphi, Siemens, General Electric and Fuel Cell Energy, and presented the technical status of research conducted in cell materials, simulation and fuel processing. A technical meeting with Delphi was held in Rochester to present the results of on-going work on interconnection corrosion, coatings, seal, anode reforming and simulation and modeling. Issues related to performance and performance stability, materials interaction, cell to cell interconnection and processing of liquid and gaseous hydrocarbons were identified and approaches for mitigation were developed. Because of the workshop, white papers in the areas of liquid fuel processing and catalyst stability have been prepared. Meetings with SECA industrial teams help identify and prioritize technical issues and promote technology transfer. PNNL works closely with the NETL Project Management Team and provides technology status reports.

## Conclusions

The SECA CTP at PNNL conducts research to meet the cost, performance and performance stability requirements of SECA. PNNL also coordinates the research activities with universities, national laboratories and industries for the development of advanced materials, electrodes, fuels and fuel processing, and modeling and design tools. Technical findings are presented at workshops and technical society meetings, as well as published in technical journals.

## Future Directions

- Continue technology development and collaborative programs with industries. Identify technology gaps and development needs at the stack and systems levels to meet the cost and performance targets.
- Prioritize technology needs for SOFC operation on coal-derived fuels. Assist industries in developing and optimizing cell, stack and systems design and configurations for scale-up.
- Develop and implement cost effective materials and fabrication processes to meet the SECA cost and life targets.
- Identify long-term performance degradation mechanisms.
- Accelerate technology transfer to industries.
- Provide technical and topical progress reports to SECA participants.
- Organize technical society meetings to exchange technical information.
- Conduct CTP meetings and topical workshops.

## Publications/Presentations

**1.** P. Singh and Z. Gary Yang “Corrosion in Fuel cells” ASM Handbook, Volume 13C.

**2.** Xiaodong Zhou and Prabhakar Singh, “Electrolytes for solid Oxide Fuel cells” Book Chapter.

**3.** J.W. Stevenson, L. A. Chick, M. A. Khaleel, D. L. King, L. R. Pederson, and P. Singh, “Recent Advances in Solid Oxide Fuel Cell Technology at Pacific Northwest National Laboratory” Fuel Cell Seminar, 2006.