the ENERGY lab

PROJECT FACTS

Fuel Cells

Reliability and Durability of Materials and Components for SOFCs—Oak Ridge National Laboratory

Background

The U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) has a mission to advance energy options to fuel our economy, strengthen our security, and improve our environment. With the Solid State Energy Conversion Alliance (SECA), NETL is leading the research, development, and demonstration of solid oxide fuel cells (SOFCs) for coal-fueled central generation power systems that enable low cost, high efficiency, near-zero emissions and water usage, and capture carbon dioxide (CO_2).

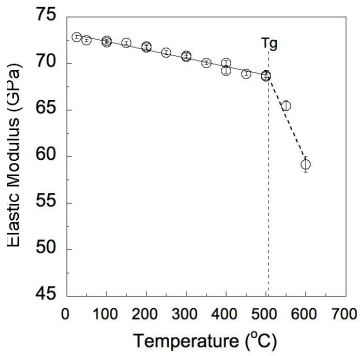
Oak Ridge National Laboratory (ORNL) is one of various SECA Core Technology Program participants working together to provide vital research and development and testing support that addresses applied technological issues common to multiple SECA Industry Teams that are developing SOFC technology for integrated gasification fuel cell (IGFC) systems.

ORNL has provided multi-year project support by conducting research on testing for reliability and durability of materials for SOFCs. The current focus of the project is thermal-mechanical property characterization of SOFC materials under conditions representative of SOFC operation (temperatures and environments). This project supports modeling efforts by developing material property characterization techniques, the collection and analysis of associated experimental data, and the development of failure criteria.

Project Description

ORNL will experimentally characterize SOFC cell and stack materials and interfaces, provide data on thermal and mechanical properties under typical operating conditions, and establish these experimental techniques required to collect this data. This information is then used to produce high-fidelity models to assess and predict SOFC cell and stack behavior.

ORNL will also identify the mechanisms that are responsible for the failure of SOFC components, in particular multilayer anode/electrolyte/cathode assemblies which constitute the building blocks of these systems. They will then develop and implement a probabilistic



Young's modulus of a barium alkali silicate determined as a function of temperature using a resonant ultrasound spectrometer.

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PARTNERS

None

PROJECT DURATION

Start Date	End Date
10/01/2000	9/30/2012

(annual continuations)

COST

Total Project Value
$5,700,000

DOE/Non-DOE Share
$5,700,000/ $0

AWARD NUMBER

FEAA066

U.S. DEPARTMENT OF ENERGY

design methodology for predicting the life and reliability of SOFCs. In addition, ORNL will characterize the thermo-mechanical properties of these materials for incorporation into state-of-the-art computer-based modeling tools. ORNL will also develop and evaluate engineered glass-based composite seals characterizing self-healing SOFC seal designs (glass seals that flow at high temperatures to heal cracks formed during thermal cycling) incorporating crystallization-resistant glasses.

Goals and Objectives

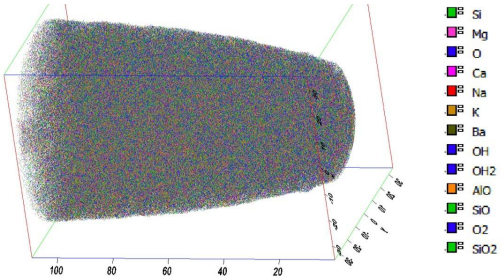
The primary goal of this project is to identify and characterize the mechanisms that are responsible for the failure of SOFC materials, components, and stacks, and in particular the multilayer anode/electrolyte/cathode/interconnect assemblies that constitute the building blocks of these systems. A second goal of this effort is to develop engineered self-healing seal systems, which includes the characterization of selected glasses after long term exposure in SOFC environments.

The project objectives include the following:

- Characterization of the various interfaces within the SOFC assembly, in particular the interfaces between metallic interconnects, their thermally-grown oxide layer, and protective coatings applied to metallic interconnects.
- Characterization of specific commercial glasses in the SECA Core Technology Program for potential use as SOFC seal materials.
- Development and design of engineered glass sealing concepts.
- Conducting experiments characterizing SOFC interfaces (cathode-interconnect and interconnect-thermally grown oxide-coating). The results are being utilized by Pacific Northwest National Laboratory (PNNL) in the modeling effort to guide stack design and interconnect coating/cathode contact aid material development aimed at reducing interfacial resistance and increasing stack robustness.
- Developing, characterizing, and testing self-healing SOFC seal systems in collaboration with PNNL.
- Development of the American Society of Mechanical Engineer (ASME) SOFC Design Basis Document.

Accomplishments

- Successfully characterized the micro-structural changes in candidate glass seals that have been exposed to SOFC environments (800 degrees Celsius in air and gas mixtures of steam, hydrogen and nitrogen) in excess of 10,000 hours.
- Developed concepts for glass sealing that will allow dimensional tolerances in the SOFC stack to be accommodated. Several concepts of engineered glass seal designs have been developed.
- Determined the uncertainty associated with the quantitative chemical compositional analysis of glass seal materials.
- Developed a test methodology based on the Brazilian disk geometry to characterize the adhesion of oxide scales on metallic interconnects.



Reconstruction of a volume of 70nm x 70nm x 109nm containing 3,997,448 atoms of a barium alkali silicate glass obtained by atom probe tomography.

- Supported the SECA Industry and Core Teams in the characterization of potential glass seal materials. Cooperative development projects have been executed with Delphi Corporation and Rolls Royce Fuel Cells (US). The ORNL team closely partners with PNNL in various areas such as seal leakage testing.
- Finalized, in cooperation with PNNL and ASME, the initial ASME Design Basis document. This document serves as a repository for SOFC mechanical design based upon the efforts of the SECA Core Technology Program since its inception.
- Used in-situ synchrotron x ray diffraction (XRD) to monitor phase evolution of the oxide scale on ferritic stainless steel interconnects. The growth stresses and residual stresses of the oxide scales were also evaluated
- Established data bases of thermomechanical properties of fuel cell materials and components (e.g., anode, electrolyte, cathode)

Benefits

This project assists the SECA program in meeting its cost and life targets by understanding the mechanisms that limit the reliability and durability of SOFC materials. Findings and inventions under the Core Technology Program are made available to all Industry Teams under unique intellectual property provisions (an exception to the Bayh-Dole Act) that serve to accelerate development. SECA will ultimately enable fuel cell-based near-zero emission coal plants with greatly reduced water requirements and the capability of capturing 99 percent of carbon at costs not exceeding the typical cost of electricity available today. Achievement of this goal will have significant impact for the nation given the size of the market, expected growth in energy demand, and the age of the existing power plant fleet. Federal funding support of this research is appropriate given the game changing nature of the technology, accompanied by risks higher than the private sector can accept.