the ENERGY lab

R&D FACTS

Energy Conversion Engineering

Fuel Cells

The Solid Oxide Fuel Cell (SOFC) Program is responsible for coordinating Federal efforts to facilitate development of a commercially relevant and robust SOFC system. Specific objectives include achieving an efficiency of greater than 60 percent, meeting a stack cost target of $225 per kW, and demonstrating lifetime performance degradation of less than 0.2 percent per 1,000 hours over a 40,000 hour lifetime.

The Fuel Cell Team performs fundamental SOFC technology evaluation, enhances existing SOFC technology, and develops advanced SOFC concepts in support of the SOFC Program. Research projects are designed to meet critical technology development needs that can be uniquely addressed and are broadly focused on investigation of the degradation, of cell and stack and electrode engineering. The research approach for each component task is targeted to address SOFC program technology development goals, especially with regard to reducing stack costs, increasing cell efficiency, and increasing stack longevity. The ultimate goal of these research and development efforts is to transfer technology that facilitates commercial acceptance of SOFC technology.

Advanced Fuel Cell Research at NETL

Cell and Stack Degradation

Among stack components, the anode/electrolyte/cathode (AEC) degradation rate heavily influences the overall system degradation rate. It is also perhaps the most complex in terms of the amount of unique degradation modes and the most susceptible to degradation, owing to its central role in the electrochemical process. The AEC contains multiple complex oxides that are operating at high temperatures under reducing or oxidizing conditions and under polarization, making it a key component for degradation investigation.

Comprehensive models predicting SOFC stack degradation do not exist or are not sufficiently descriptive to consider all of the primary degradative modes. Due to the complexity and sheer number of degradation processes occurring in the SOFC stack, the present effort to evaluate degradation is initially confined to AEC structures and materials under commercial consideration. Experimental and theoretical results from degradation mode investigations will be incorporated into a computational framework model that will include the most prominent degradation modes. Individual degradation modes will be constituted as mathematical expressions relating microstructural (e.g., porosity, particle size) and kinetic parameters (e.g., oxygen exchange coefficient, conductivity) to operating parameters, including operating temperature and local overpotential. This model will provide evolving AEC performance parameter updates on a 40,000+ h timescale. Model predictions will be confirmed by comparison to samples manufactured by industry teams.

CONTACTS

Gregory A. Hackett
Principal Investigator, General Engineer
304-285-5279
gregory.hackett@netl.doe.gov

David Berry
Associate Director for
Energy Conversion Engineering
304-285-4430
david.berry@netl.doe.gov

George Richards
Senior Fellow
Energy Conversion Engineering
304-285-4458
george.richards@netl.doe.gov

RESEARCH PARTNERS

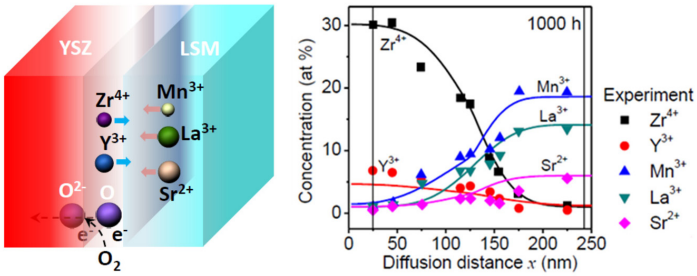
AECOM

Carnegie Mellon University

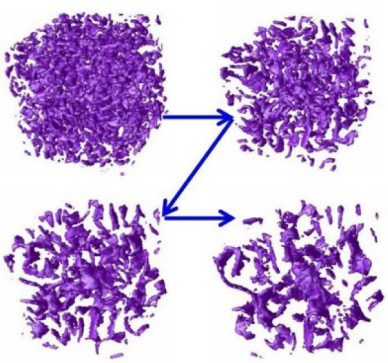
The Pennsylvania State University

University of Wisconsin-Madison

West Virginia University



Simulation of the interdiffusion of atomic species between the LSM cathode and YSZ electrolyte after 1,000 h at 1,000 °C. The change in interfacial composition changes the catalytic and transport properties around the interface.



Simulated degradation and collapse of active regions (triple phase boundaries) in a SOFC cathode caused by coarsening of the cathode particles during long-term operation.

The current long-term degradation modes under study include coarsening of particles within the anode and cathode, the electrochemical diffusion of species across anode/electrolyte and cathode/electrolyte interfaces, and the formation of secondary phases in the anode and cathode due to the operating conditions. A detailed investigation of the degradation modes in the AEC will facilitate targeted efforts to improve fuel cell longevity, ultimately resulting in decreased system costs. Development of a world-class modeling tool will accelerate AEC materials and structure innovation, leading to more commercially relevant SOFC technology.

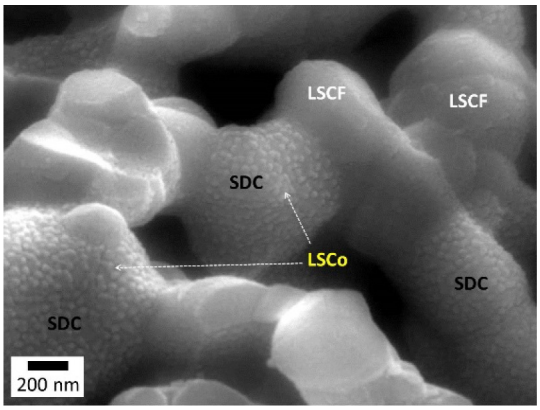
Electrode Structure and Materials Engineering

Electrode engineering is accomplished through careful control of catalytic modifiers, surface chemistry, and synthetic process parameters to produce electrode nanostructure that improves cell power output, while maintaining other critical performance metrics of cost and durability.

The electrode engineering process permits diversity in the selection of active components, or electrocatalysts, and engenders the tailoring of fine electrode microstructure, specifically by enabling microstructure design that is superior to those achievable via conventional fabrication processes at lower cost. Full-scale cell tests at SOFC program industrial partners have demonstrated that the materials and nanostructure of cathodes generated using the engineering process induced an increase in initial power density, reduction in degradation rate, and doubling of cell lifetime.

The approach further focuses on the development of active electrocatalyst and nanostructure engineering for high performance anodes. Tailored materials and methods for electrode modification will be developed to mitigate degradation modes induced by intrinsic and extrinsic sources.

These research efforts will improve overall electrode performance, thereby resulting in increased cell efficiency and, ultimately, a diminished system cost and extended lifetime, which are touchstones of commercialization of SOFC.



Scanning electron microscopy image of a SOFC cathode that was surface-modified with nano-electrocatalysts.

Demonstration of electrode engineering process through solution chemistry control and spraying infiltration technique.