the ENERGY lab

R&D FACTS

Advanced Energy Systems

Fuel Cells

The Solid State Energy Conversion Alliance (SECA) program is responsible for coordinating Federal efforts to facilitate development of a commercially relevant and robust solid oxide fuel cell (SOFC) system. Specific objectives include achieving an efficiency of greater than 60 percent, meeting a stack cost target of $175 per kW, and demonstrating lifetime performance degradation of less than 0.2 percent per 1000 hours over a 40,000 hour lifetime.

The NETL-Regional University Alliance (NETL-RUA) Fuel Cell Project performs fundamental SOFC technology evaluation, enhances existing SOFC technology, and develops advanced SOFC concepts in support of the SECA program. Research projects are designed to meet critical technology development needs that can be uniquely addressed by NETL-RUA and are broadly focused on investigation of the degradation processes of anode/electrolyte/cathode (AEC) components, cathode materials and microstructural engineering, and catalytic fuel reforming. The research approach for each component task is targeted to address SECA 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 AEC degradation rate is potentially the most influential over the total stack degradation rate. It is also perhaps the most complex in terms of the unique degradative modes, and is also the most susceptible to degradation owing to its central role in the electrochemical process. The AEC is therefore a key component targeted 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 the AEC structures and materials under commercial consideration. Results of the degradation mode investigation will be incorporated into a computational model that will include only the most prominent degradation modes. Individual degradation modes will be constituted as mathematical expressions relating dependent AEC parameters (e.g., electrode porosity) to independent operating parameters including operating temperature and local overpotential. This model will provide evolving AEC performance parameter updates on a 40 plus kilohour timescale. Model predictions will be confirmed by comparison to samples prepared in-house and also from samples obtained from industry teams.

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.

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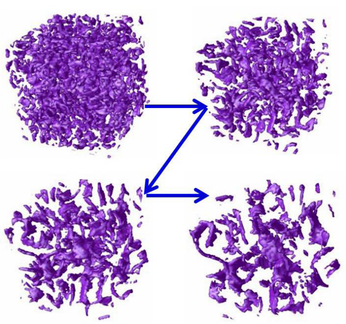
U.S. DEPARTMENT OF ENERGY

Cathode Materials and Microstructural Engineering

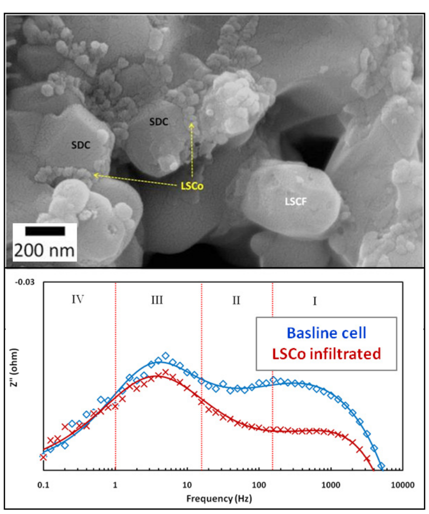
Cathodes are a primary source of the inefficiency observed in a state-of-the-art anode-supported cell operating at temperatures from 750–800 °C. Owing to the relatively high contribution of cathode overpotential to total cell inefficiency, SOFC research to improve cathode performance can help meet critical program targets for cell cost and efficiency.

Conventional cathode microstructural engineering is accomplished through careful control of precursor cathode materials. Using conventional methods, limited variability is available in the final cathode structures. New approaches focus on generation of advanced microstructures that are more conducive to species transport, or methods to apply an engineered cathode at lower cost. These research projects will result in full characterization of performance and durability of the proposed technologies at an intermediate scale. Results will be shared with SECA industrial partners, and the most promising technologies will be selected for further scale-up. Methods developed will generate more functional cathode structures to facilitate enhanced cathode performance, and will potentially allow greater tuning of the final cathode architecture.

These research efforts will improve cathode performance, thereby resulting in increased cell efficiency and, ultimately, a diminished system cost. Cathode material and structure innovations developed through these projects should be readily transferable to industry.



Theoretical degradation and collapse of active regions (triple phase boundaries) in a SOFC cathode simulated for extended operations.

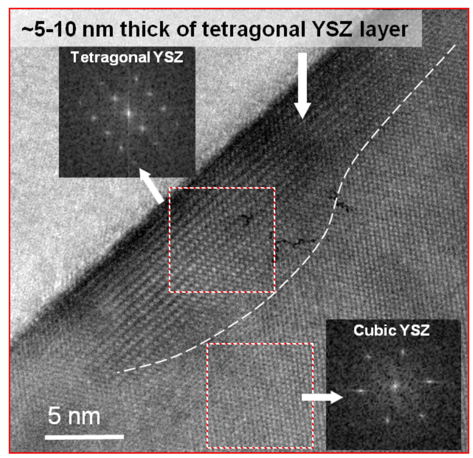


Scanning electron microscopy image of a SOFC cathode infiltrated with electrocatalytic material accompanied by an example of impedance data demonstrating improvement in electrochemical performance (reduced impedance).

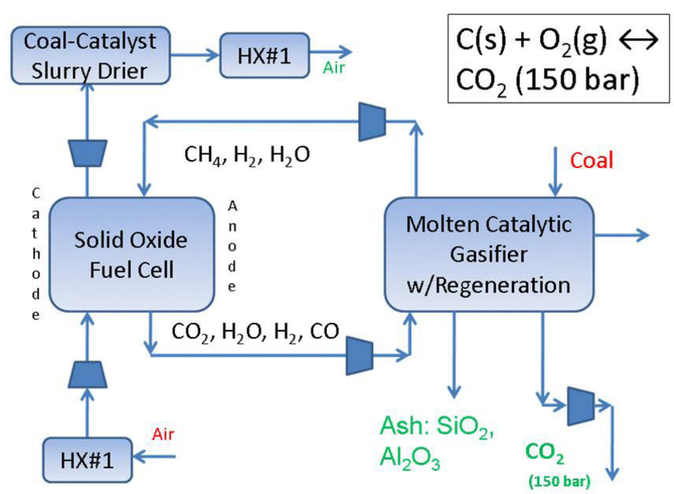
Catalytic Gasification and Fuel Reforming

Recent system studies indicate that coal-to-electricity system efficiencies can approach 60 percent while capturing CO_2, minimizing water consumption, and generating an inflation-adjusted, internal rate of return on investment of over 10 percent per year. One of the keys to achieving this target is production of a high methane synthesis gas of greater than 25 percent from coal gasification. Information collected in the molten catalytic gasification experiments will be used to calculate the gasifier's system efficiency. This project will measure the rates of reaction for the formation of methane in steam-coal gasification in the presence of molten salts as catalysts. Reaction rates and gas compositions will be integrated into gasification numerical simulations to determine the sizing and cost of developing molten catalytic gasifiers for subsequent incorporation into SOFC-based coal power plants.

This catalytic gasification work will facilitate further modeling and analysis of industrial-scale processes aiding the deployment of advanced catalytic gasification technology.



High resolution transmission electron microscopy image of ionic carrier phase breakdown at grain interfaces within a SOFC anode.



Simplified flow diagram of an integrated gasification-SOFC system featuring an advanced molten catalytic gasifier.