the ENERGY lab
PROJECT FACTS
Fuel Cells

Performance Degradation of LSCF Cathodes—GE Global Research

Background

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

GE Global Research (GEGR) will focus on the investigation of SOFC degradation mechanisms and the development and implementation of mitigation strategies, as well as the research and development (R&D) of alternative cell manufacturing techniques. The scope of the effort focuses on fundamental cell R&D issues—primarily power density enhancement and materials stability (degradation) under a portfolio for alternative anode-electrolyte-cathode development.

Project Description

The project will investigate, characterize, and develop mitigation strategies for SOFC degradation mechanisms. This effort encompasses cell and test fixture design, fabrication, and testing to characterize performance, and substantial microanalysis to investigate fundamental degradation mechanisms. It is focused on cathode side materials stability and degradation mechanisms. These mechanisms may include area specific resistance (ASR) increases due to interconnect oxidation; fundamental material instability as a function of time at temperature; and/or chemical and electrochemical solid state interactions between interconnects, interconnect coatings, contact aids, cathodes, and cathode interlayers. The project also includes an investigation of alternative cell manufacturing techniques, applying a thermal spray manufacturing approach to overcome the high costs of producing SOFCs at lower volumes.

Goals and Objectives

The primary project goal is to reduce power density degradation rates to less than one percent per 1,000 hours (<1%/1,000 h), while maintaining high initial power densities (greater than 0.75 watt per square centimeter [>0.75W/cm^2]). To support this goal, the dominant degradation mechanisms must be identified and cost-effective mitigation strategies developed and implemented. The focus is to retain high electrochemical activity in lanthanum strontium cobalt ferrite (LSCF)-based cathodes over the operational lifetime of an SOFC stack (>40,000 h). LSCF-based cathodes have sufficient activity to produce increased power densities in cells at higher operating voltages, which is important for system efficiency and stack and system cost. Primary project objectives are:

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PARTNERS

None

PROJECT DURATION

Start Date	End Date
10/01/2008	09/30/2013

COST

Total Project Value
$9,066,707

DOE/Non-DOE Share
$6,800,030 / $2,266,677

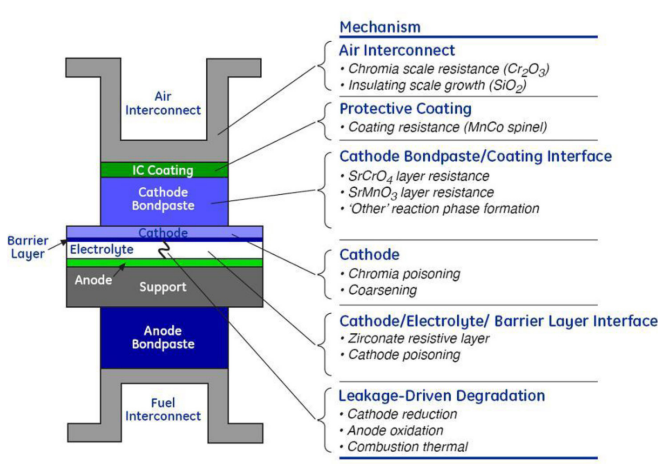
AWARD NUMBER

NT0004109

- Identify fundamental cathode degradation mechanisms and validate cost-effective mitigation strategies.
- Evaluate operational condition-specific (temperature, voltage, current) performance degradation.
- Investigate interconnect chromium evaporation to optimize coating structure to mitigate chromium transport.
- Validate degradation mitigation strategies on planar cells.
- Develop kinetic oxidation models for GE-13L and 441SS at relevant operating temperatures.
- Determine the effect of interconnect contact geometry on contact resistance.
- Develop processing method to increase cathode interconnect coating density to minimize chromium volatilization.
- Identify and mitigate potential anode degradation mechanisms.
- Evaluate alternative cell manufacturing approaches.
- Apply alternative manufacturing approaches to produce larger area planar cells.
- Build a three cell stack using larger area planar cells.

Accomplishments

- Identified high-impact fundamental degradation mechanisms and developed cost-effective mitigation solutions.
- Demonstrated stable high performance of LSCF-based cathode SOFCs with gold current collectors.
- Demonstrated parabolic power density degradation behavior with ferritic stainless steel current collectors, which is indicative of chromia scale growth.
- Validated 441HP stainless steel as a viable, low-cost current collector alloy during a 1,500 h electrochemical test.
- Designed, constructed, and validated a novel approach to real-time measurements of chromium volatilization from interconnect alloys using solution conductivity.

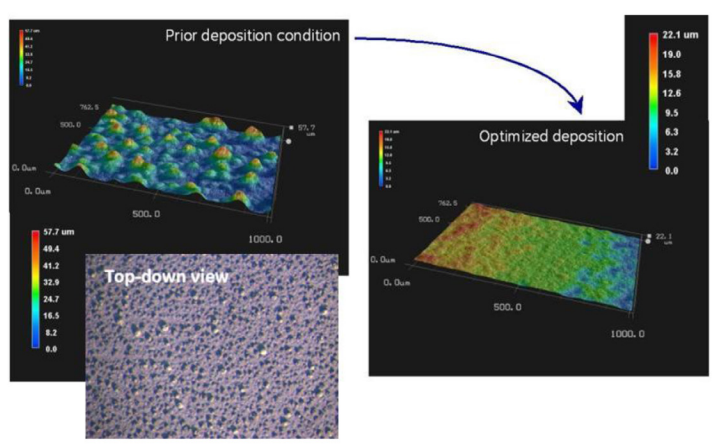


Schematic of a SOFC highlighting potential degradation mechanisms.

- Demonstrated that interconnect geometry does not influence contact resistance degradation.
- Validated that the power density degradation behavior using AL441 stainless steel current collectors decreases with time from approximately (~) 3%/1,000 h for the initial 1,000 h and ~0.5%/1.000 h for subsequent testing (~600 h).
- Identified the anode contact layer as a degradation mechanism responsible for ASR increases of 5–15 milliohms (mΩ)-cm^2/1,000 h and developed mitigation strategy.
- Optimized processing to create a dense current collector chromium barrier coating to prevent chromium volatilization in support of 40,000 h fuel cell interconnect life.
- Developed thermal spray conditions to produce a smooth fuel electrode (anode) on a porous metal support.
- Developed thermal spray conditions to produce a dense, crack-free and hermetic electrolyte (>95% open circuit voltage theoretical sufficient to enable high-efficiency commercially feasible SOFC stacks).
- Achieved repeatable SOFC performances of 0.25 W/cm^2 at 0.7V on 25 cm^2 thermal spray manufactured cells operating at 800 °C at high fuel utilizations (>90%).

Accomplishments

The GEGR project assists the SOFCs program in meeting its cost and performance targets by ensuring that SOFCs can achieve reliable operation over an extended operating life. The program will ultimately enable fuel cell-based near-zero emission coal plants with greatly reduced water requirements and the capability of capturing 97 percent or greater of carbon at costs not exceeding the typical cost of electricity available today. Achieving this goal will significantly impact the nation given the size of the market, expected growth in energy demand, and the age of the existing power plant fleet. It will also provide the technology base to enable grid-independent distributed generation applications. Federal funding support of this research is appropriate given the game changing nature of the technology accompanied by risks higher than the private sector initially can accept.



Development of a smooth thermal sprayed anode to enable thin thermal sprayed electrolytes.