the ENERGY lab

PROJECT FACTS

Fuel Cells

Theory, Investigation, and Stability of Cathode Electro-catalytic Activity—Georgia Institute of Technology

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 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).

Georgia Institute of Technology (Georgia Tech) 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 developing SOFC technology for integrated gasification fuel cell (IGFC) systems.

SOFC cathodes are responsible for a reaction in which oxygen from incoming air is converted into ions, which then migrate across the solid electrolyte membrane to react with fuel to form water or CO_2. This reaction can be accelerated through the use of cathodes with improved catalytic activity. This project will characterize properties of some novel catalytic cathode material sets to understand how and why some materials work better than others as SOFC cathodes.

Project Description

The reactivity, and thus the performance, of catalysts are directly linked to the kinds and arrangement of atoms on their surfaces. In this project, a base cathode material, such as lanthanum strontium cobalt iron oxide (LSCF), will be coated with a second cathode material (e.g., lanthanum strontium manganite - LSM) in an attempt to improve overall cathode activity. The surface properties of the materials will be characterized with a variety of advanced analytical techniques. The results will be compared with the known reactivity of these materials to understand how and why some materials work better than others as SOFC cathodes. The samples will also be tested under SOFC conditions to determine their performance.

A semi-empirical method based on continuum modeling was developed for interpretation of electrochemical testing results regarding the performance enhancement of the LSM-coated LSCF cathode. Two kinds of infiltration solutions—non-aqueous- and water-based—are used for deposition of LSM films on LSCF pellets to optimize the infiltration process and to examine the microstructure evolution during annealing at high temperatures. The optimized LSM infiltration process is applied to porous LSCF cathodes, which are electrochemically examined under steady-state polarization using symmetrical cells with three-electrode configuration. The praseodymium strontium manganite (PSM) infiltration process is the same as that of the LSM infiltration. The effects of LSM and PSM

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PARTNERS

None

PROJECT DURATION

Start Date	End Date
09/01/2008	09/30/2012

COST

Total Project Value
$875,000

DOE/Non-DOE Share
$700,000/$175,000

AWARD NUMBER

NT0006557

U.S. DEPARTMENT OF ENERGY

coatings on performance of the LSCF cathode are determined using symmetrical and anode-supported button cells. The detailed structure, composition, and morphology of the LSCF surface, and the LSM/LSCF interfaces in LSM-coated LSCF, are characterized using electron microscopy and spectroscopy. The microscopic details of the cathodes will be correlated directly with their electrochemical performance.

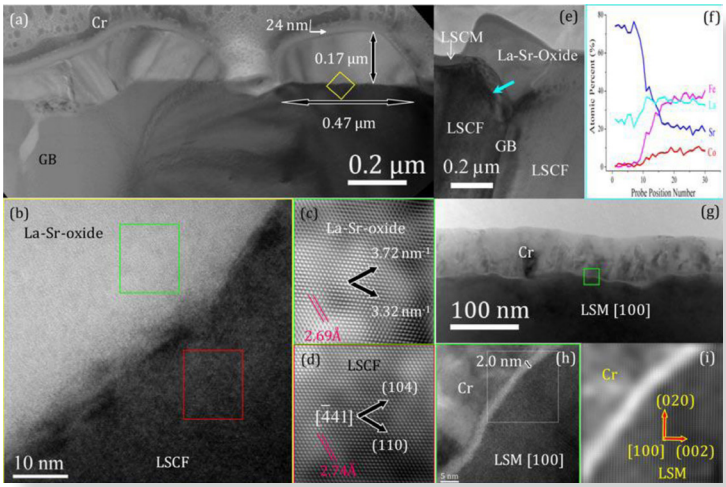

Figure 1. Transmission electron microscopy (TEM) image of surface of LSCF pellet annealed at 850 degrees Celsius (°C) for 900 hours. A thin layer of chromium (Cr) coating was used to delineate the sample surface. (b) High resolution TEM (HRTEM) image of the interface between an oxide particle and the underlying LSCF pellet in the yellow square marked in (a). (c) and (d) Fourier-filtered images of the green and red rectangles marked in the surface oxide and the LSCF in (b). (e) TEM image of LSCF grain boundary of LSM-coated LSCF pellet after annealing at 850 °C for 900 hours. (f) Profiles of atomic percents along the line marked by the blue arrow in (e). (g) TEM image of LSM-coated LSM pellet after annealing at 850 °C for 900 hours. The sample received sequential depositions of C and Cr for the purpose of protection and delineation of the surface. (h) HRTEM image of the green rectangular area highlighted in (g). (i) Fourier-filtered image of the white rectangular area marked in (h).

Goals and Objectives

The goal of this project is to understand the role of cathode surface properties on SOFC performance.

Current project objectives are:

- Characterize the surface composition, morphology, and electro-catalytic properties of a catalyst infiltrated LSCF cathode.
- Establish the scientific basis for rational design of high-performance cathodes by combining a porous backbone (such as LSCF) with a thin catalyst coating.

Accomplishments

Accomplishments for fiscal year 2011:

- Developed a semi-empirical phenomenological model for studying the mechanism of performance enhancement of the LSM-coated LSCF cathode.
- Optimized the LSM solution infiltration process further on LSCF pellets for a variety of parameters including solution pH value, surfactant addition, and thermal treatment conditions as well as ambient humidity.
- Quantified the correlation among performance, infiltration concentration, and operation condition (polarization current density) of the LSM-coated LSCF cathode. Characterized porous LSCF and LSM-coated LSCF cathodes electrochemically as a function of the time of polarization and relaxation under different oxygen partial pressures.
- Characterized the detailed structure, composition, and morphology of pure LSCF surfaces, the LSM/LSCF interfaces in LSM-coated LSCF, at 850 degrees Celsius annealed for 900 hours.
- Fabricated dense, continuous LSM films with desired structure, composition, morphology, and thickness on the LSCF surface by two kinds of infiltration solutions: non-aqueous and water-based.

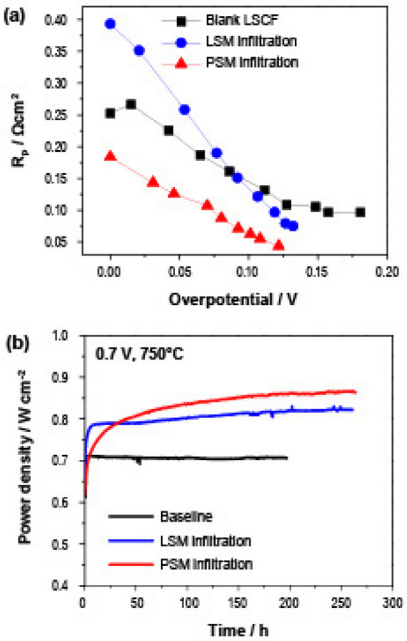

Figure 2. (a) Interfacial polarization resistance versus overpotential for LSCF cathodes without/with 0.1 M of PSM and LSM infiltration measured at 750 °C. (b) Typical power out-puts of the homemade button cells with PSM and LSM infiltrated LSCF cathodes (compared with baseline LSCF cathode) at a constant voltage of 0.7 V at 750 °C.

Benefits

Findings and inventions under the SECA Core Technology Program are made available to all SECA 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. 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. 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. It is expected that the knowledge gained from this research will guide future cathode development such that SOFC-based power generation systems will become more efficient and cost-effective.