the ENERGY lab

PROJECT FACTS

Fuel Cells

Solid Oxide Fuel Cell Cathodes: Unraveling the Relationship among Structure, Surface Chemistry, and Oxygen Reduction—Boston University

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

The Boston University (BU) project was competitively selected to acquire the fundamental knowledge and understanding that will facilitate research and development to enhance electrochemical performance under a diversified portfolio for anode-electrolyte-cathode development. This project is providing vital support that addresses applied technological issues common to multiple SECA Industry Teams developing SOFC systems.

Many of the specific details of the oxygen reduction reaction in a SOFC cathode are not completely understood. Surface chemistry directly influences the nature of oxygen reduction reaction pathways and the rates at which the individual processes proceed. This project will attempt to clarify the cause and effect relationships in oxygen reduction processes through correlations between the chemistry and structure of oxide surfaces to provide valuable guidance in improving cathode performance.

Project Description

In this cathode surface science project, BU will study deposition of epitaxial thin-film cathodes, heteroepitaxial thin film layers of selected cathode materials, and polycrystalline thin-film cathodes. The chemical, crystallographic, and electronic structure of cathode surface materials will be characterized. Epitaxial methods grow one layer of crystals on another of the same structure. Heteroepitaxial technology is a single-crystal layer grown on a different material and is often used to grow crystalline films of materials for which crystals cannot otherwise be obtained and to fabricate integrated crystalline layers of different materials.

BU will acquire surface-specific chemical and structural data on heteroepitaxial thin films of lanthanum strontium manganite (LSM) and lanthanum strontium cobalt ferrite (LSCF) cathodes on single crystals of yttria-stabilized zirconia (YSZ) and YSZ coated with a barrier layer of rare-earth doped ceria such as yttrium oxide (Y_2O_3)-doped cerium dioxide (CeO_2) (YDC) electrolytes. This is being accomplished using a combination of analytical spectroscopic techniques and transmission electron microscopy (TEM). BU will also employ soft X-ray spectroscopies (X-ray emission spectroscopy [XES]/ X-ray

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PARTNERS

None

PROJECT DURATION

Start Date	End Date
10/01/2008	03/31/2013

COST

Total Project Value
$856,014

DOE/Non-DOE Share
$675,001/$181,013

AWARD NUMBER

NT0004104

U.S. DEPARTMENT OF ENERGY

absorption spectroscopy [XAS]) to correlate the surface chemical composition and the charge state of the manganese ion to changes in the thin film polarization resistance. The overall goal is to understand the role of surface atomic and electronic structure in the oxygen reduction reaction.

Goals and Objectives

The goal of this project is to understand the role of surface atomic and electronic structure in the oxygen reduction reaction of SOFC cathodes. Project objectives are as follows:

- Continue deposition of high quality epitaxial and poly-crystalline cathodic thin films.
- Use in situ x ray chamber to obtain high-temperature surface structure and composition analysis.
- Obtain kinetics data on oxygen exchange on cathode thin films using impedance spectroscopy.

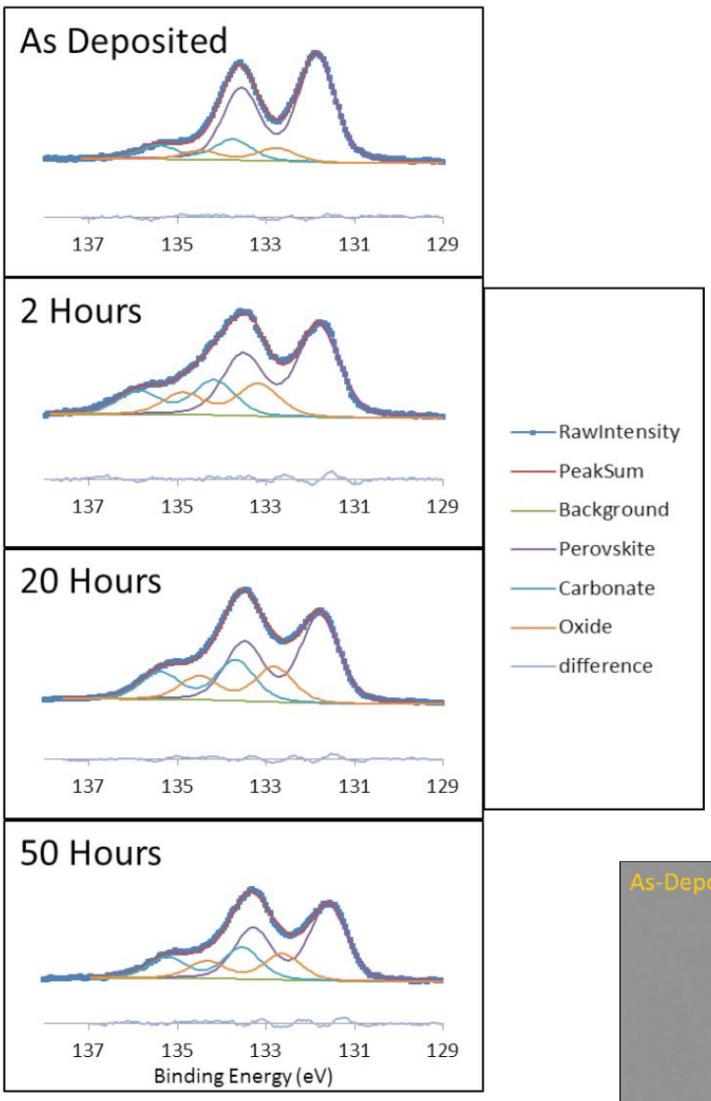

Figure 1. *Curve fitted Sr 3D regions of the HAXPES spectra of LSCF 7328.*

Accomplishments

- Total reflection X-ray fluorescence data clearly show diminished A/B ratios at the surface of LSM thin films.
- Oxygen adsorption, surface diffusivity, and incorporation reaction rate coefficients have been measured for polycrystalline thin films.
- Hard X-ray photoelectron spectroscopy (HAXPES) technique was employed to clarify the cation segregation and surface evolutions effects in LSCF including the formation of surface strontium carbonate.
- Impedance spectroscopy has been used to separate the relative importance of surface and bulk diffusion in LSCF cathodes.

Benefits

The BU 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 and natural gas power 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, the 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.
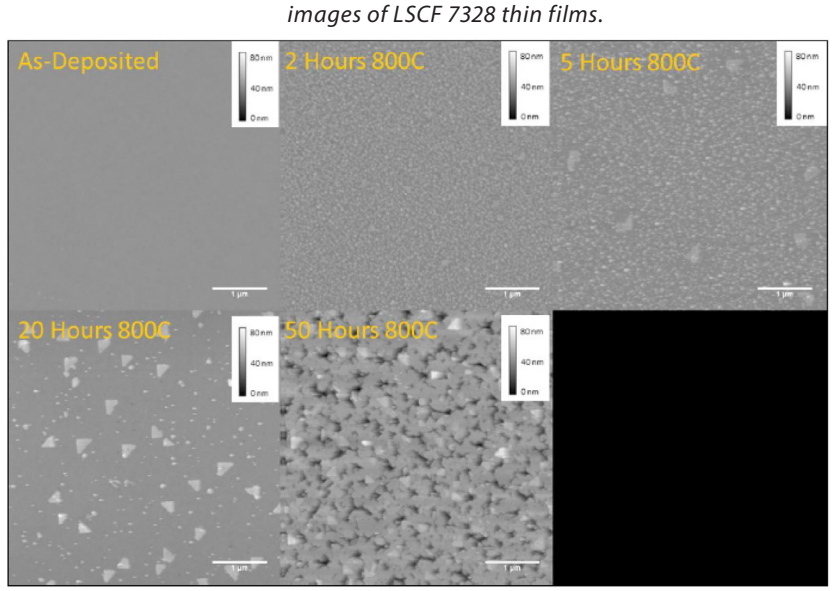
Figure 2. *Atomic force microscopy images of LSCF 7328 thin films.*