Cathode R&D Introduction

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SOFC Operating Conditions for Coal Plants

High system efficiency is a key target
- High performance required over wide design space
  - Temperature, cell potential, fuel utilization

Stack Operation Parameters

Temperature
- Upper limit - interconnect oxidation
- Lower limit - cathode activity (overpotential)
- Upstream integration - gasification & gas cleaning
- Downstream integration - heat recovery devices & CO₂ capture

Overpotential
- Apparent correlation w/ degradation
- Typically 100-200 mV
Cathode Performance - Status and Objectives

State-Of-The-Art
- Cathode voltage loss substantial
- Industry team progress
  - bulk materials identified
  - microstructures optimized
- Industry cathodes established
- Total degradation 1-2 %/1000 hrs

Technical Objectives
- Cathode overpotential reduction
- Overall degradation 0.2 %/1000 hrs

Benefits
- Higher power density = reduced capital cost ($ / kW)
- Higher power block efficiency = higher system efficiency (%)
  - Environmental impact (Coal contaminants, Carbon & H₂O / kW*hr)
- Minimize degradation = longer service lifetime (>40,000 hrs)

All benefit Cost Of Electricity ($ / MW*hr)
Cathode Catalyst Development

1. Correlate Properties/Performance
2. Generate Ideas

Theorists Determine Energy Structure

Collect Data

Optimize Catalyst Morphology

1. Infiltrate & Test Button Cells
2. Validate - SECA Stack Fixture
Cathode Catalyst Development Approach

1. Collect data
   • Generate a database
     • Chemical, crystallographic, and electronic structure data
     • Focused on common compositions: LSM, LSF, LSC, LSCF
   • Collect in-situ data relevant to SOFCs
     • At temperature, under overpotentials representing operating voltages of 0.7 V to 0.9 V, in air
   • Compare with industrial experience

2. Draw in-situ/ex-situ correlations
   • Enable ex-situ techniques (especially for electronic structure)
   • Improve sample throughput
   • Validate in-situ measurements
Key Correlations - Surface Characteristics and Performance Properties

Collecting Surface Characteristics Data
- MIT
- UNLV
- ANL
- CMU
- Georgia Tech
- MSU
- Boston
- NETL

Generating Performance Property Data
- MIT
- CMU
- Georgia Tech
- MSU
- Boston
- PNNL

Advancing Theory / Interpreting Data
- ANL
- Stanford
- NETL
Translating Understanding – model thin-films to infiltrated catalysts

Sample Complexity

Perfect Epitaxial Films
- Boston
- MIT
- ANL
- CMU
- MSU
- UNLV

Imperfect Epitaxial & Sputtered Films
- Boston
- MIT
- ANL
- CMU
- MSU
- UNLV
- Georgia Tech

Infiltrated Cell Testing Capability
- Georgia Tech
- NETL
- PNNL
Validation of Candidate Catalysts

Generate Idea

Optimize Catalyst Morphology

Validate SECA Stack Fixture

Infiltrate Button Cells

Confirm Coating Stability

Transfer to Industry

*Graphics courtesy of LBNL, Georgia Tech, PNNL, and VPS.*