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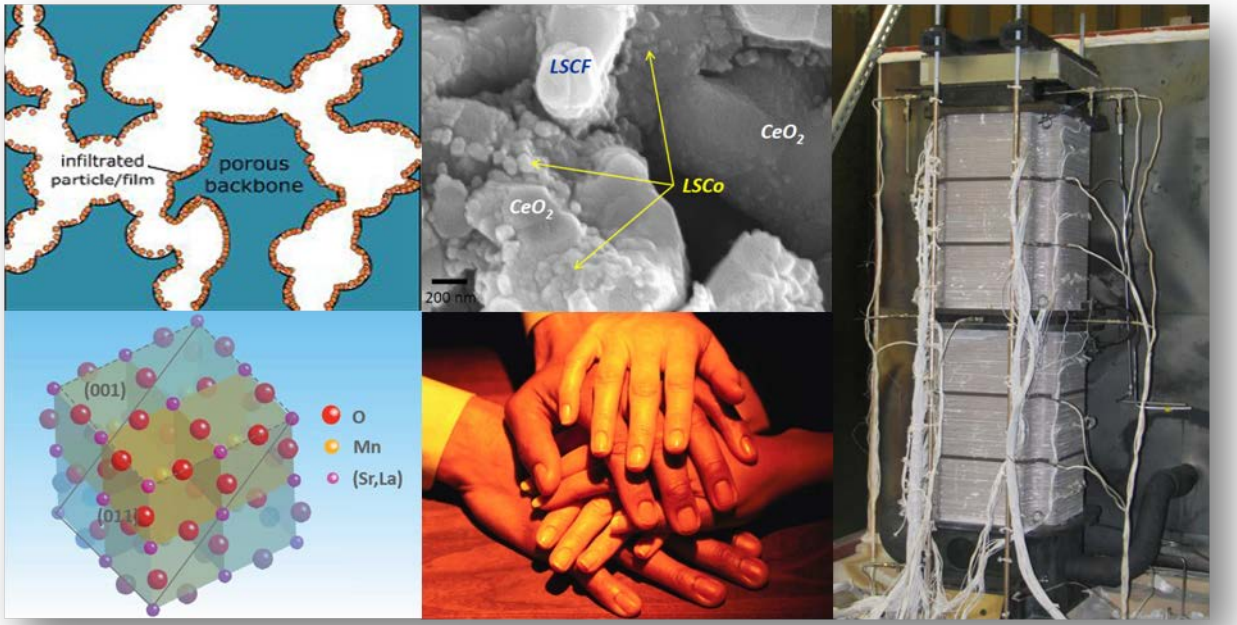

Recent Cathode Studies

Novel Concepts, Tools, and Results to Make Better Cells

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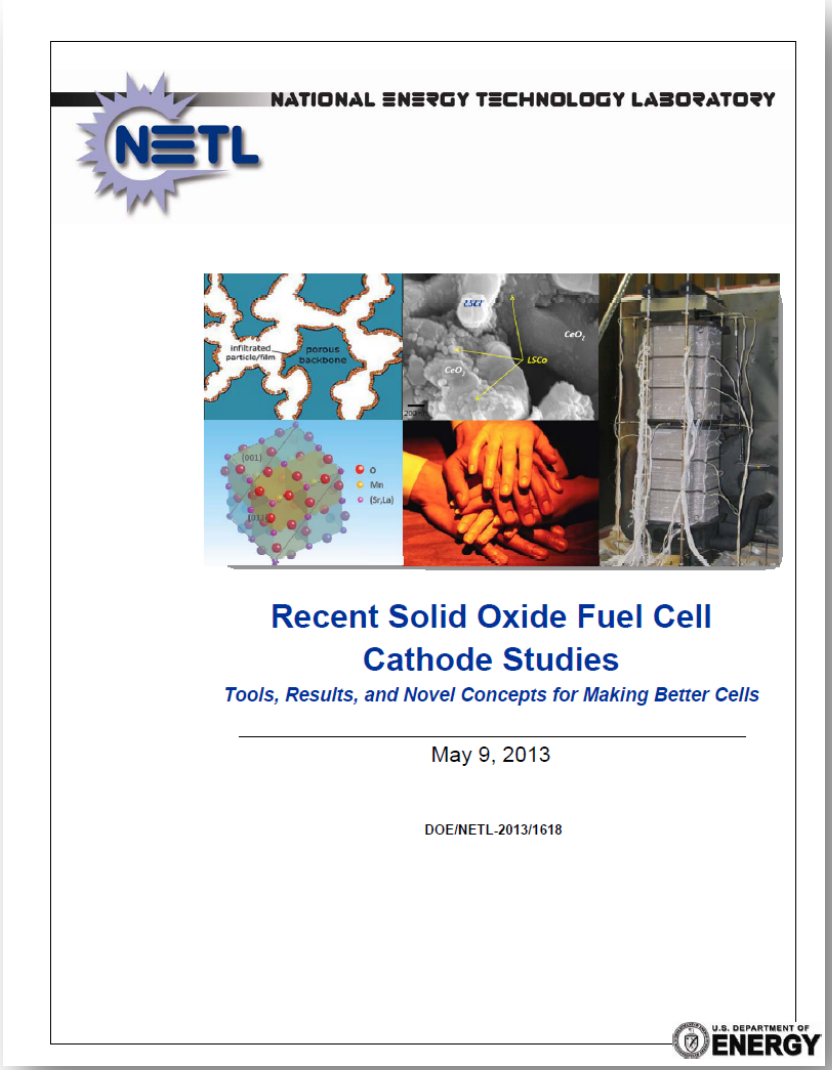
Advanced Energy Systems Division

National Energy Technology Laboratory

U.S. DEPARTMENT OF ENERGY

Outline

- **Introduction**
- **Documenting Recent Progress**
  - Purpose
  - Process
- **Report Highlights**



Cathode Performance - Status and Objectives

State-Of-The-Art

- Cathode overpotential adequate
- Total degradation 1-2 %/1000 hrs
- Bulk microstructures established
- Operate at 650-900°C

Technical Objectives

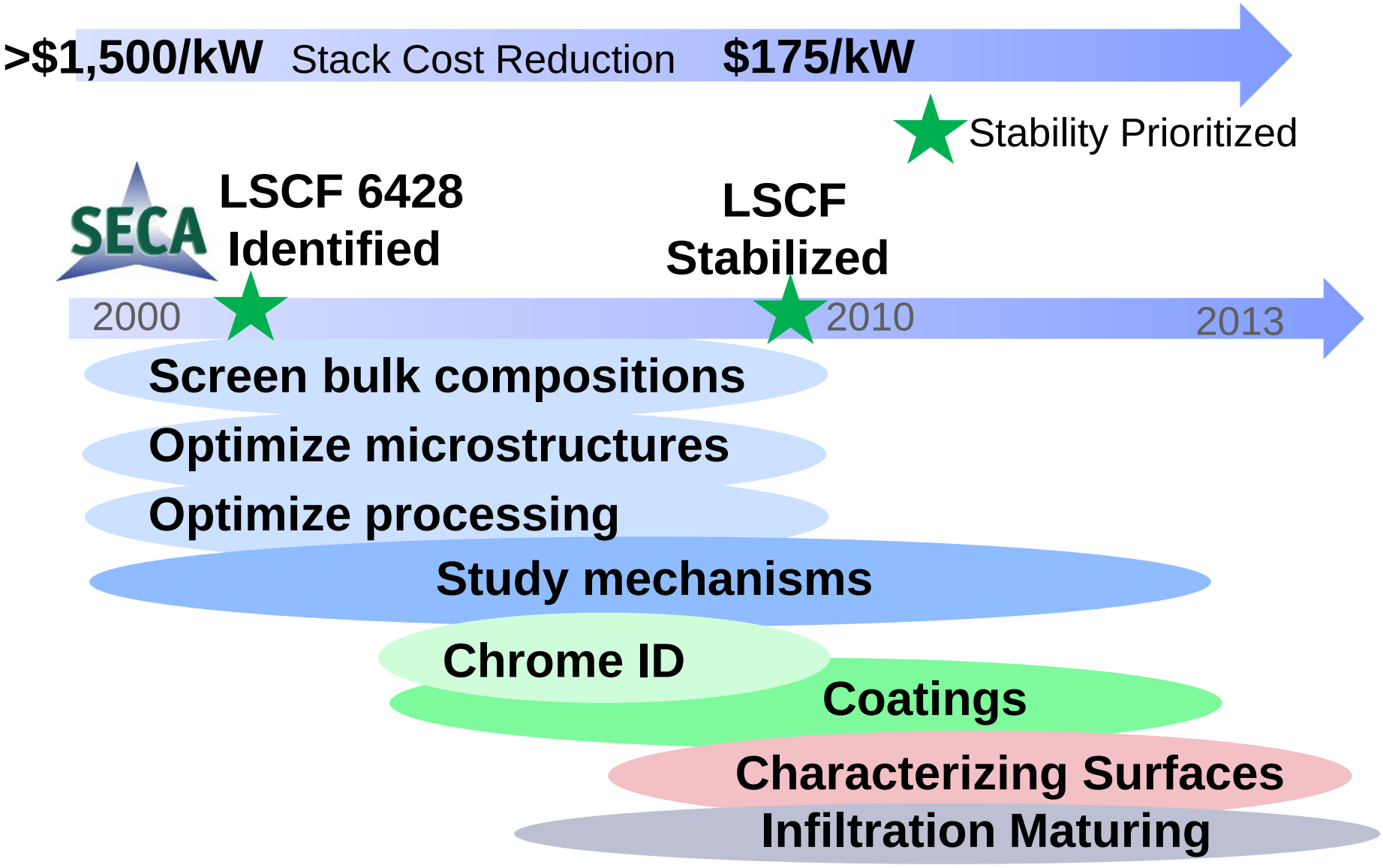
- 100 mV cathode overpotential
- Overall degradation = 0.2 %/1000 hrs
  - Key Industry Focus

Benefits

+ Capital cost ($ / kW)
+ System efficiency (%)
+ Environmental impacts (emissions, carbon & H_2O)
+ Service lifetime (>40,000 hrs)

Cost Of Electricity ($ / kW*hr)

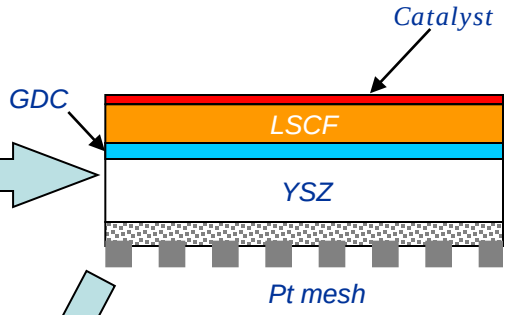
Cathode Development - Historical Perspective



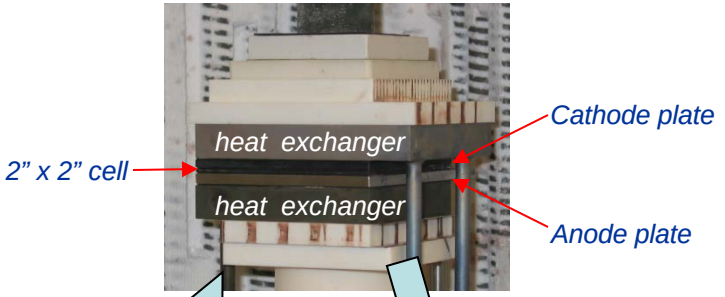
Validation of Concepts

Generate
Idea

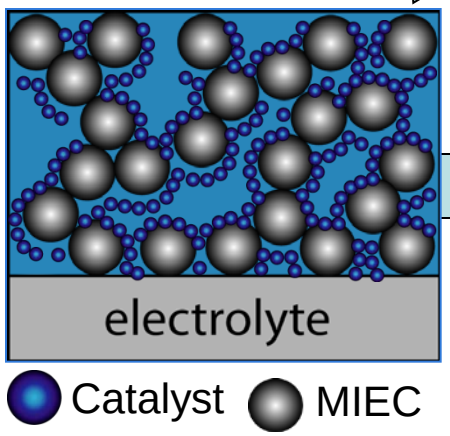
Optimize
Catalyst Morphology



Validate
SECA Stack Fixture

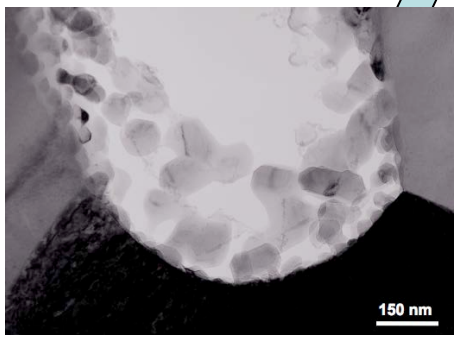


Infiltrate
Button Cells

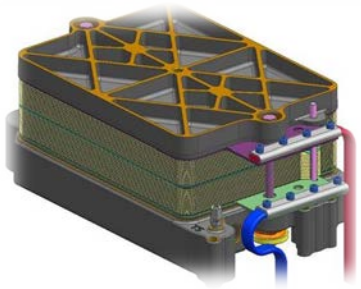


Test Cells

Confirm
Coating Stability



Transfer
to Industry



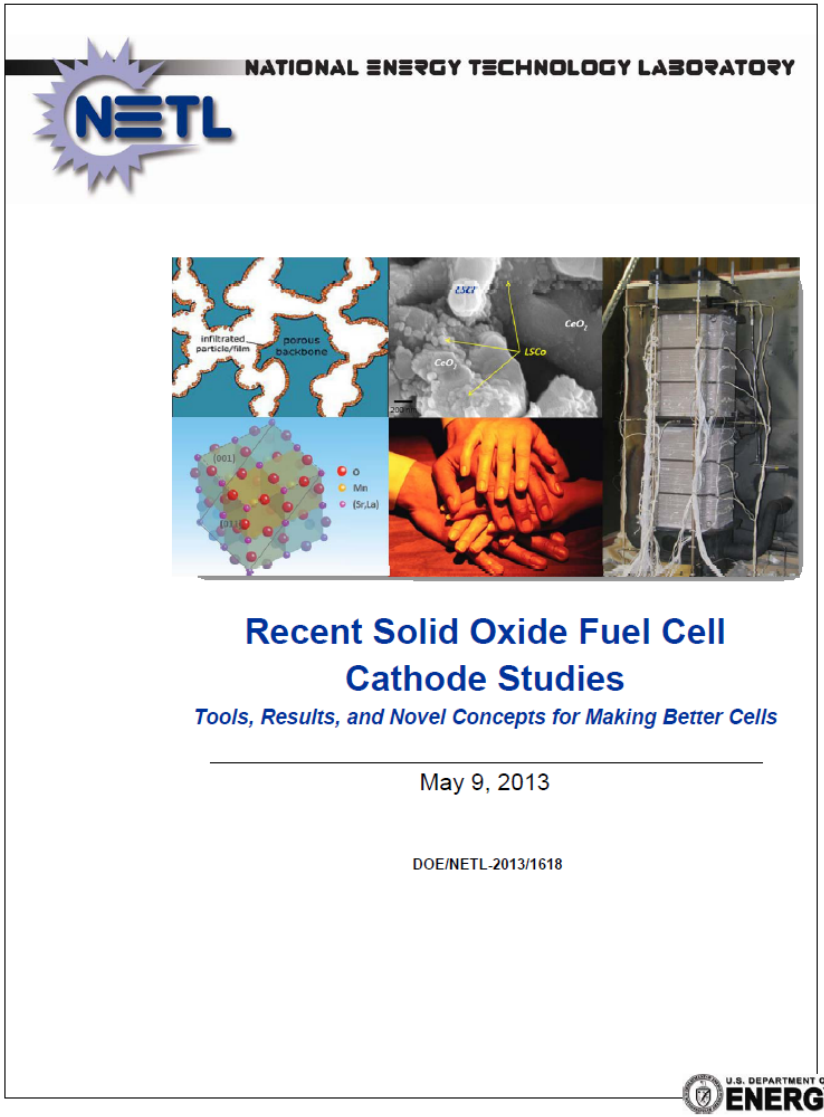
**Graphics courtesy of LBNL, Georgia Tech, PNNL, and Delphi.*

Documenting Recent Progress

Goal - Improve tech transfer

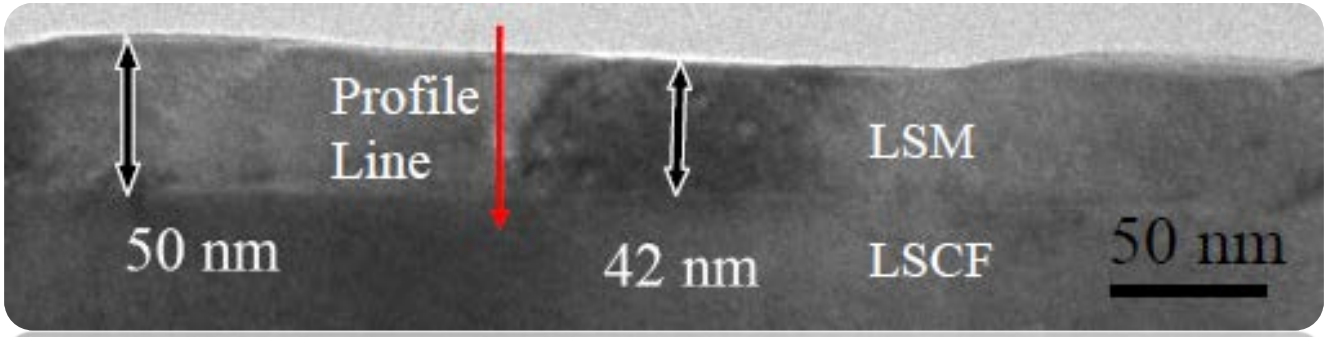
Process & Contents

- Succinct reporting with key takeaways for industry
- SECA Core Technology Program authors
- 3 integrated reports
- 5 topical reports
- 2007-2013
- Surface Science, Infiltration, Degradation, and Mechanisms



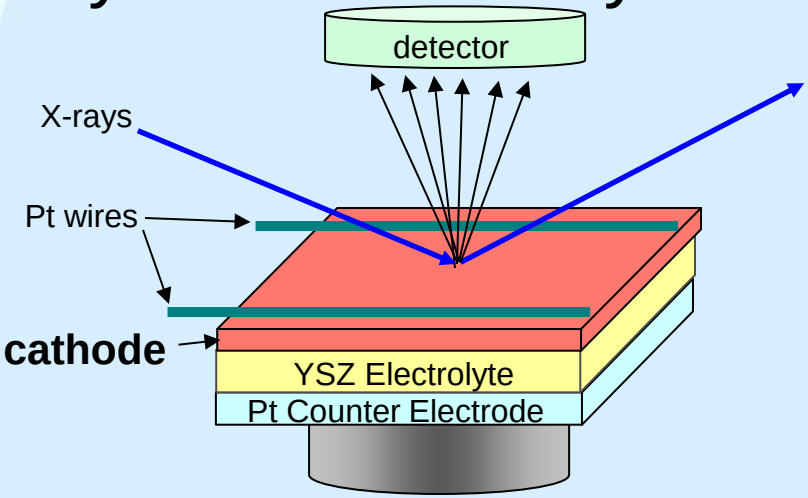
Report Highlights

1. **New In situ Characterization Tools**
2. **New Surface Property Data**
3. **In situ / Ex situ Correlations**
4. **Surface Chemistry Manipulation**
5. **Catalyst Thickness**
6. **Interface Effects**
7. **Infiltration Developments**



New In situ Characterization Tools

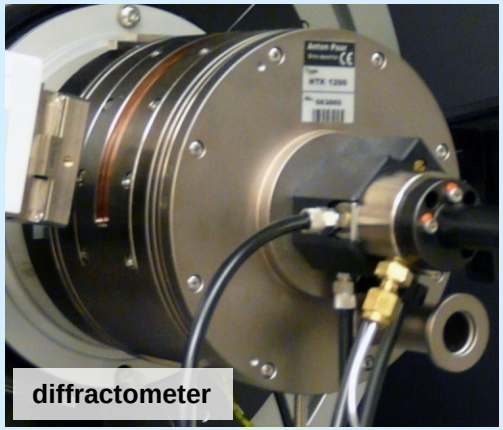
Synchrotron X-ray Tools

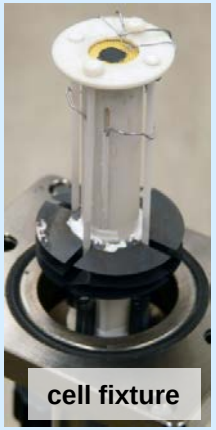


Test Attributes

- High-temperature, applied bias, controlled atmosphere
- Thin-film samples
- Surface sensitive crystal structure
- Variable-depth composition
- Valence state

Lab X-ray Tool





Test Attributes

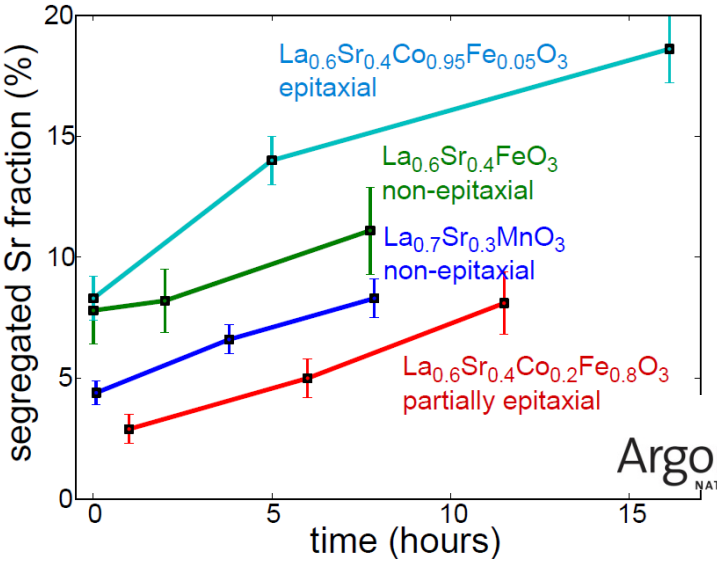
- High-temperature, applied bias, controlled atmosphere
- Porous cathode microstructures
- Phase analysis (secondary phases)
- Bulk sensitive
- High throughput

New Surface Property Data

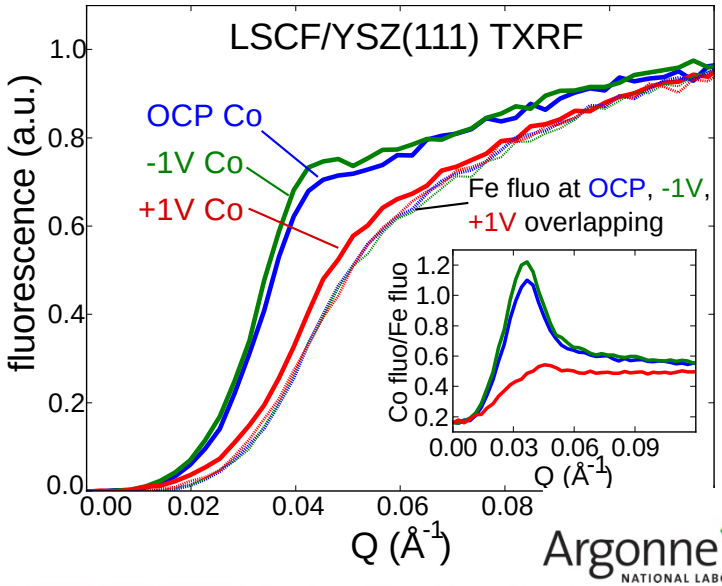
Takeaways

- Surfaces of cathodes are significantly different than the bulk
  - Most have strontium segregation
- Surfaces change rapidly with time and bias

Surface Composition



Valance States



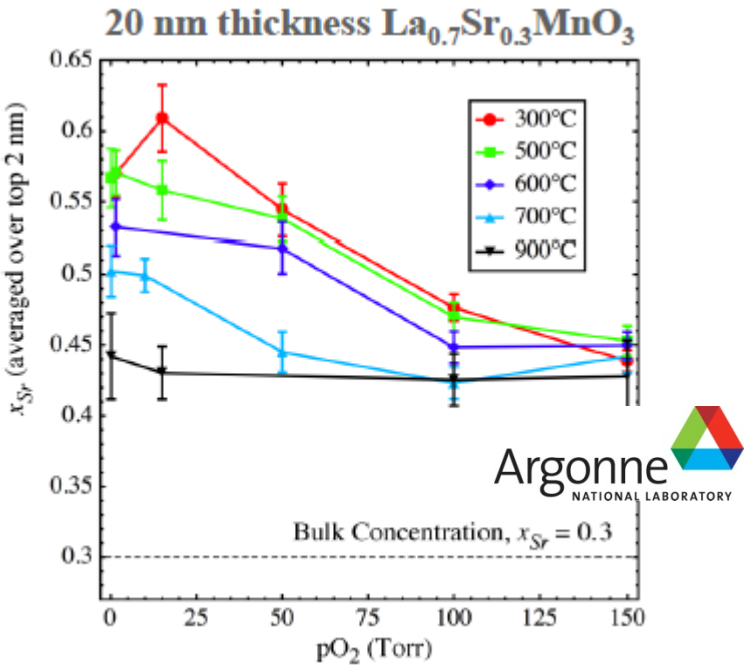
Data Collection & Results

- Results obtained primarily from synchrotron x-ray techniques
- Additional data available for La and Mn
- LSCF surface reconstructs, LSM does not

In situ / Ex situ Correlations

Takeaways

- LSM surface has similar Sr segregation in air at all temperatures
- Ex situ tools reasonably appropriate for characterizing surface composition of LSM
- Additional data available for LSFC and LSC



In situ Tools
SOFC Operating Conditions

→

Ex Situ Tools
Room Temperature

Change in Sr concentration from bulk

	Operating T (700-1000 C)	Low T (300 C)
Low pO_2 (mTorr)	+35%	+50%
Operating pO_2 (atmospheric)	+21%	+25%

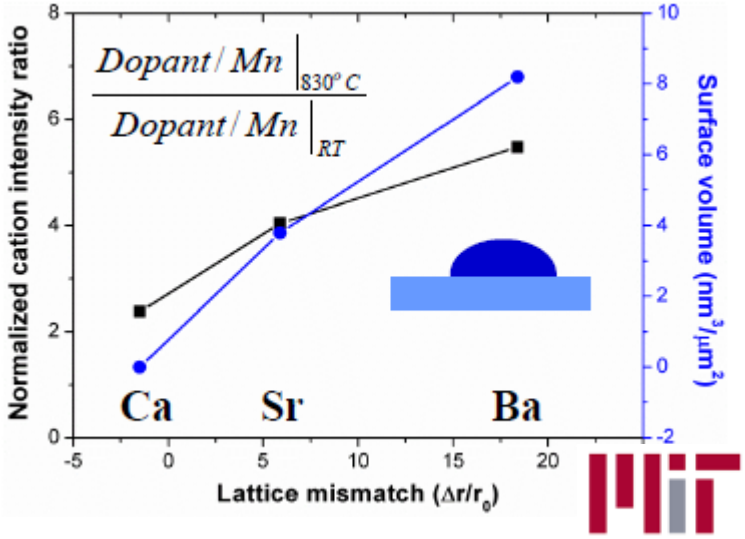
Surface Chemistry Manipulation

Takeaways

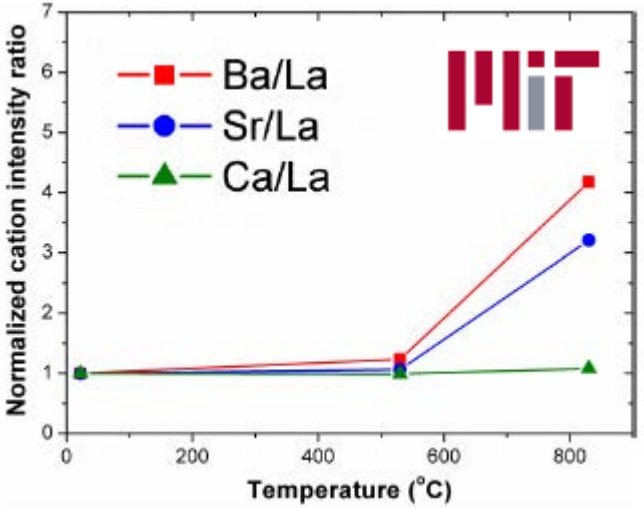
Dopant size mismatch can drive surface segregation

- Smaller mismatch, less segregation
- Larger mismatch, more segregation

Doped LaMnOx Thin Films



Doped LaMnOx Thin Films



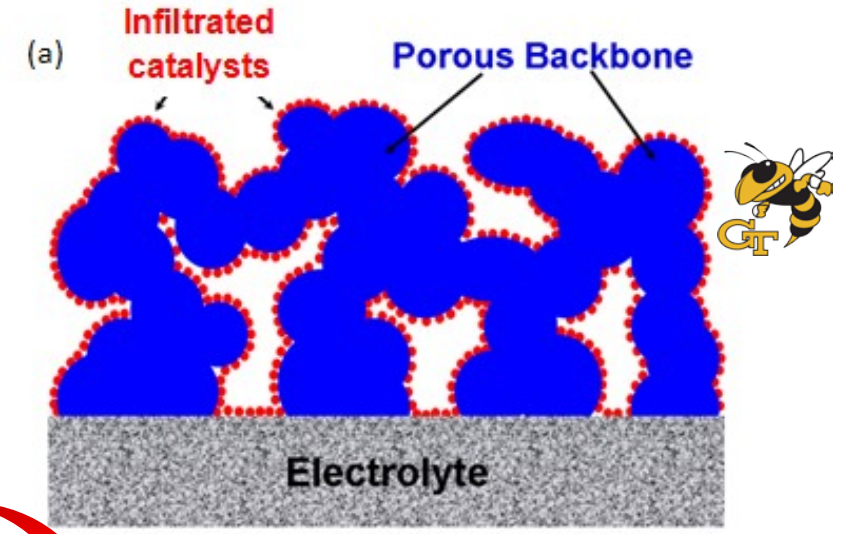
Performance Implications

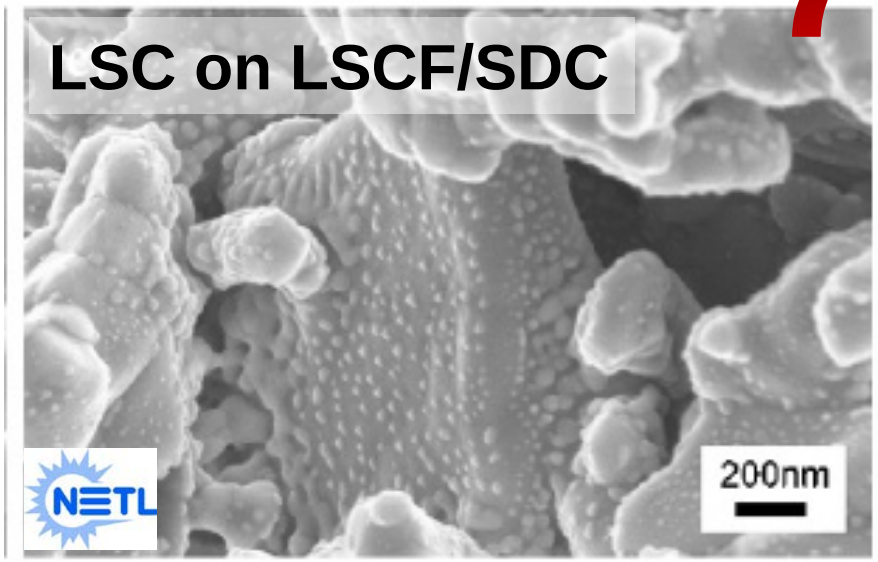
- Now possible to tune surface composition using dopants
- New projects will guide future cathode architectures with stable performance
  - surfaces stable in real-world air (chrome, CO_2, moisture)

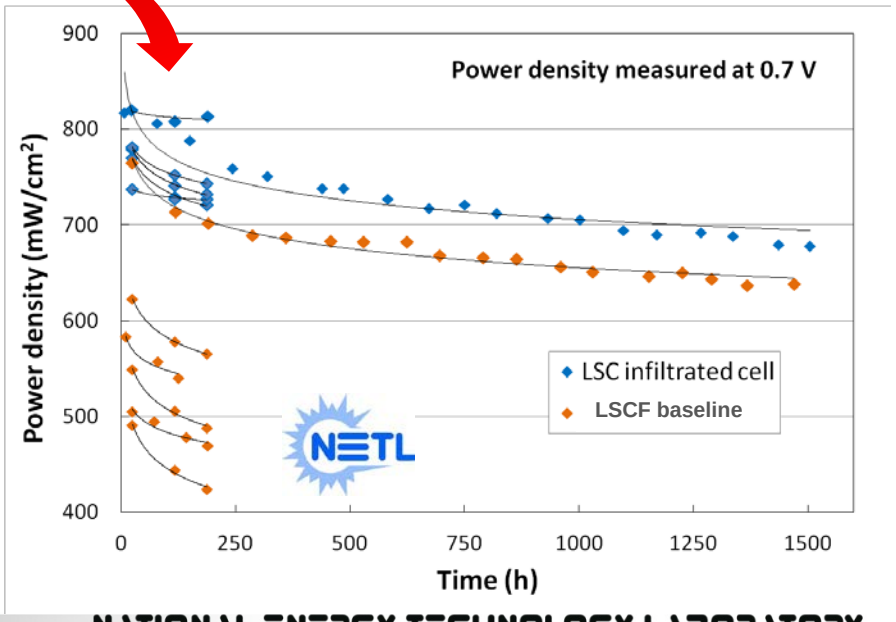
Infiltration

Takeaways

- Many materials improve performance (e.g. LSM, LSC, SSC, LCC)
- Processes in place
- Promising stability at button-cell scale – 1,500 hrs

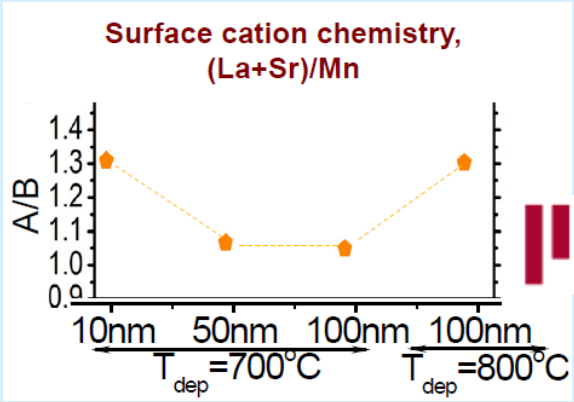






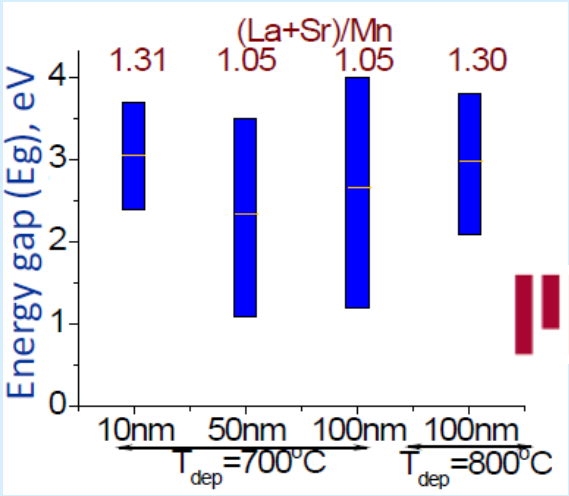
Catalyst Layer Thickness Effects

- Layer thickness controls surface composition
- A/B-site ratio
- A-site dopants can segregate
- Depends on materials, processing, and operating conditions



- Layer thickness controls surface electronic structure
- Surface band gap affected
- May control oxygen reaction rates

Informs design of infiltrated microstructure for high performance



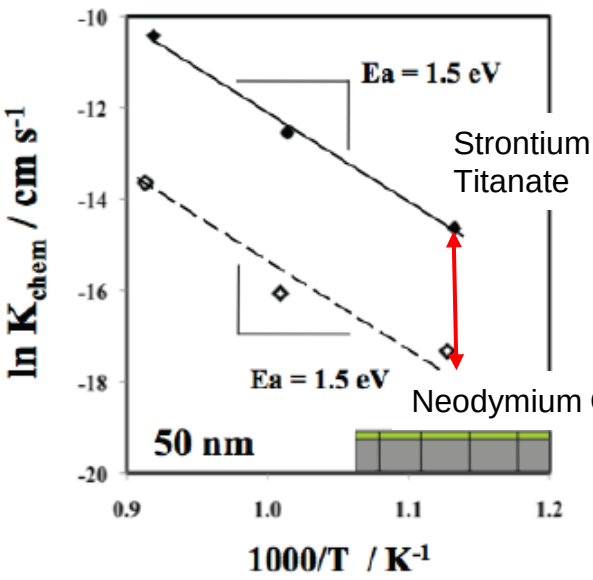
Interface Effects

Interfaces strongly influence:

- Surface exchange kinetics
- Electrical resistances

Surface Exchange Coefficients

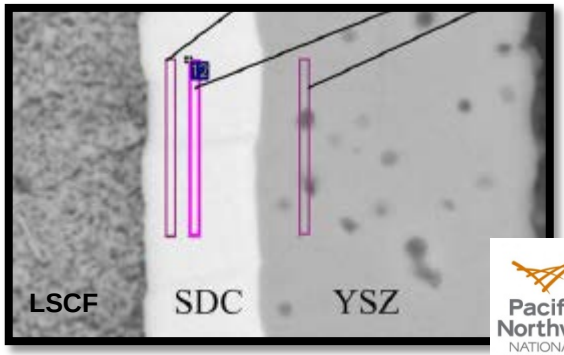
LSM thin films on 2 substrates



Carnegie Mellon University

2 orders of magnitude

Dense SDC barrier layer fabricated with Pulsed Laser Deposition



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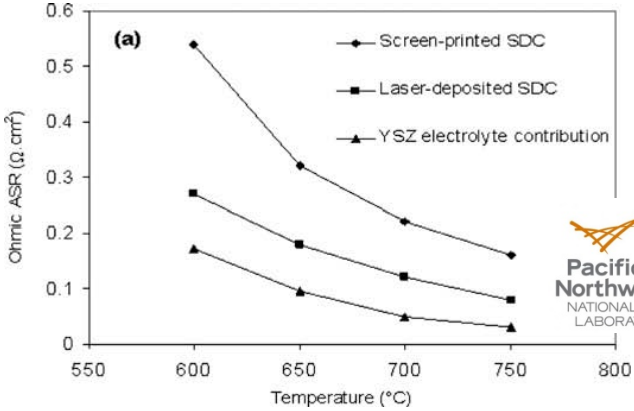
Substantial reduction in cell resistance



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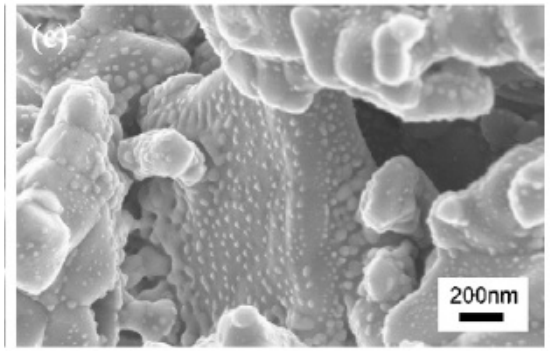
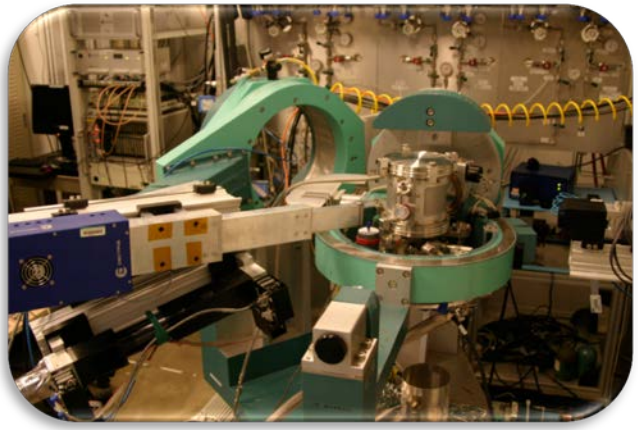
Summary

1. **SECA has come a long way**
2. **Compilation of Recent Cathode R&D available**



Highlights

- **New Surface Property Data**
- **New In situ Characterization Tools**
- **In situ / Ex situ Correlations**
- **New Concepts:**
  - Surface chemistry manipulation
  - Catalyst thickness effects
  - Interface effects
- **Review of Infiltration**



Acknowledgements

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Thank You!

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DOE-NETL's SECA Reference Shelf

http://www.netl.doe.gov/technologies/coalpower/fuelcells/seca/refshelf.html