DE-FE0026211

Innovative, Versatile, and Cost-Effective Solid Oxide Fuel Cell Stack Concept

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Innovative, Versatile and Cost-Effective SOFC Stack Concept Project

- Project: Innovative, Versatile and Cost-Effective Solid Oxide Fuel Cell Stack Concept (DE-FE0026211)

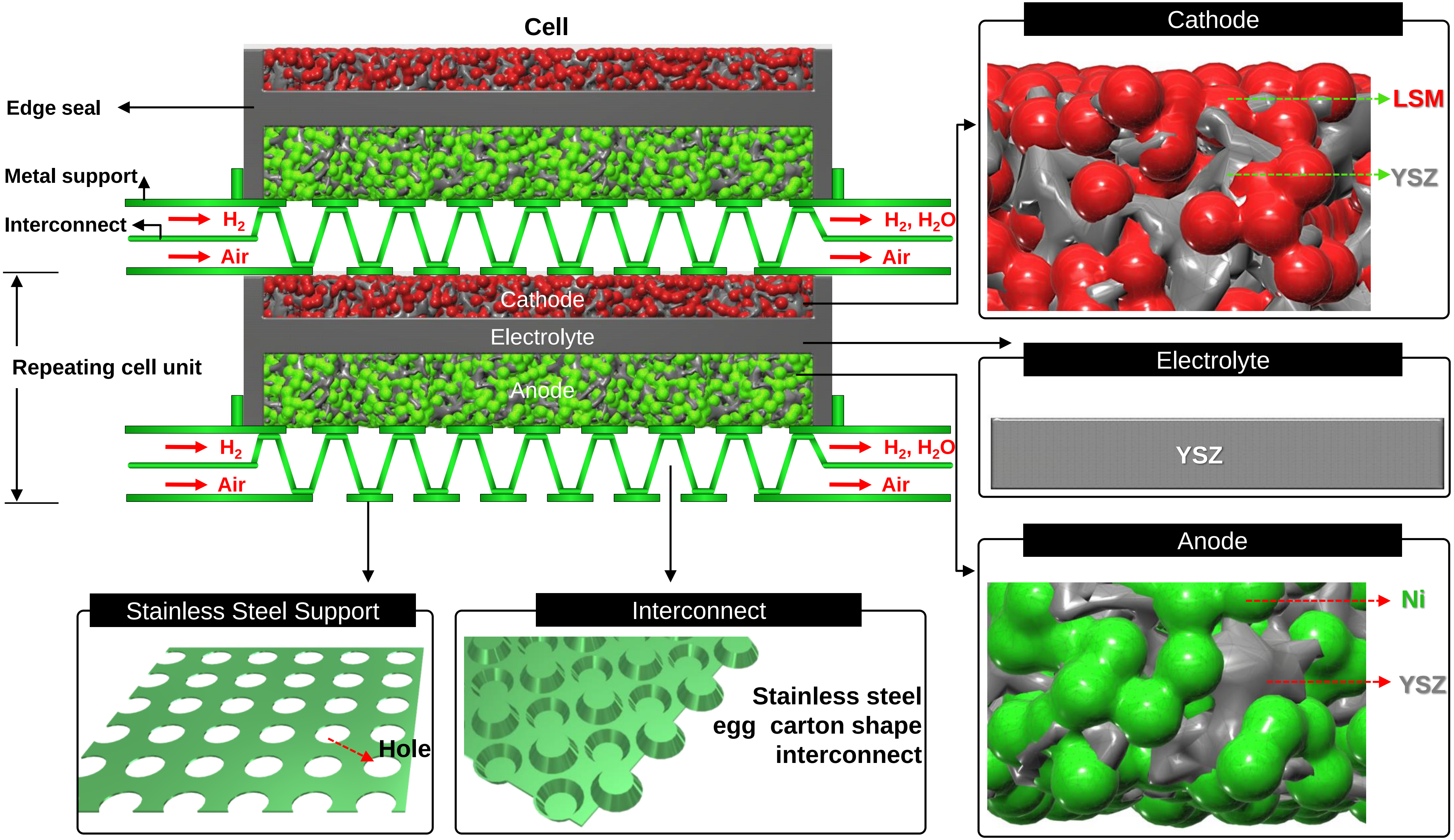
- Project Objective: Develop and evaluate a versatile stack configuration based on a prime-surface interconnect design that can incorporate different types of cell construction for a broad range of power generation applications

- DOE/NETL Project Manager: Mr. Jason Montgomery

- Project Team:
  - University of California San Diego (UCSD)
    - *Center for Energy Research*: Dr. Nguyen Minh (PI), Dr. Tuyen Tran
    - *Department of Electrical Engineering and Center for Memory and Recording Research*: Dr. Eric Fullerton
    - *Department of NanoEngineering*: Dr. Shirley Meng
  - OxEon Energy LLC (OxEon)
    - Dr. Elango Elangovan, Mr. Joe Hartvigsen

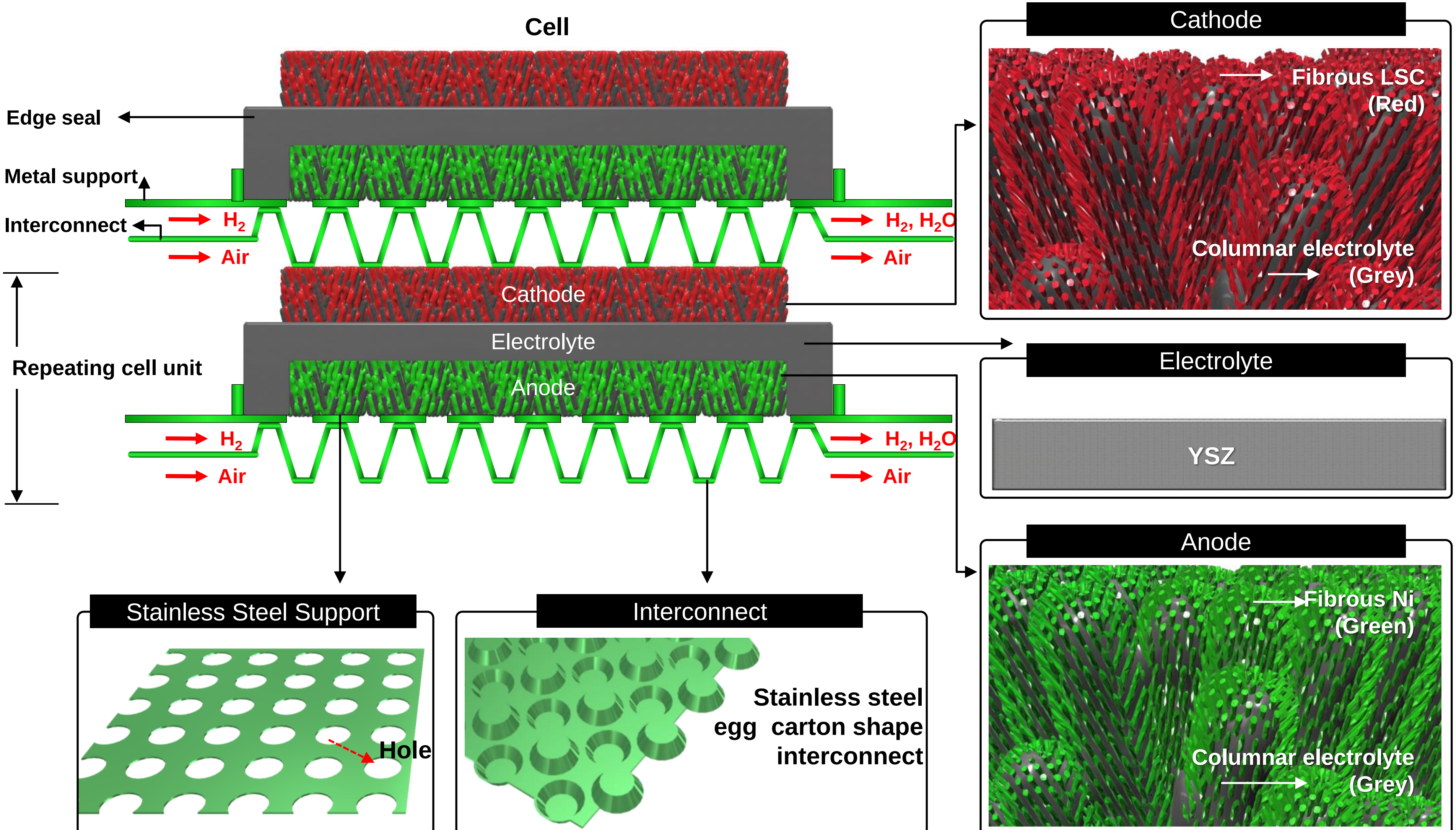
Stack Design Concept

Incorporating Conventional Cells



Stack Design Concept

Incorporating Supported Thin-film Cells



Project Technical Activities

Status/Progress/Accomplishments

- Prime surface interconnect design and fabrication development

  Prime surface interconnect design specified and fabrication process developed
- Supported thin-film cell structure development

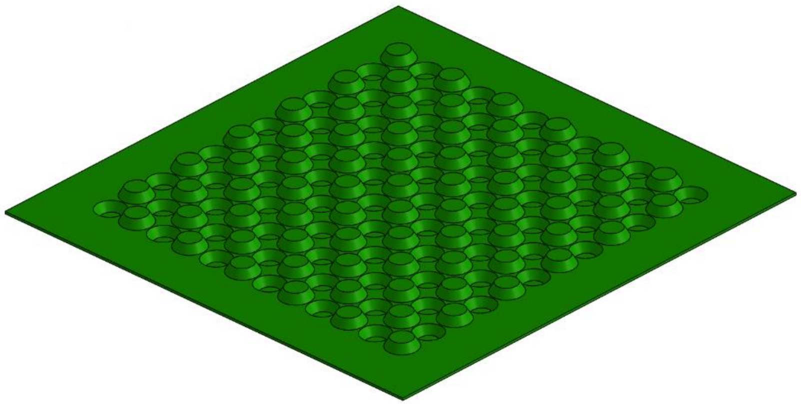
  Sputtering fabrication process developed for making thin-film cells and record cell performance demonstrated at reduced temperatures
- Stack cost assessment

  Estimated stack cost indicating potential for cost competitiveness
- Stack development

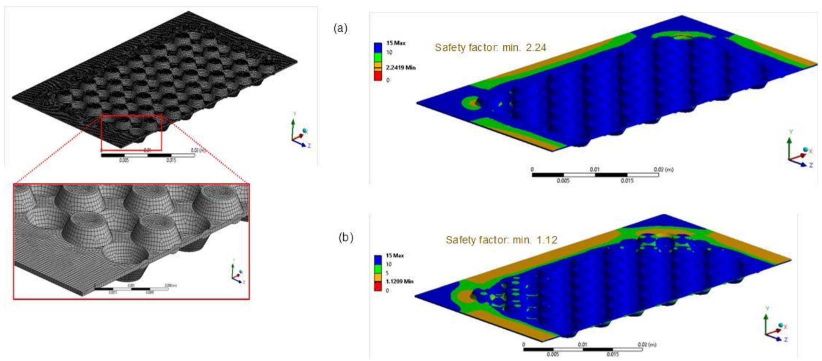
  Full scale stack design completed
- Stack operation demonstration

  Stack components being manufactured and operation demonstration to be initiated

Prime Surface Interconnect Design

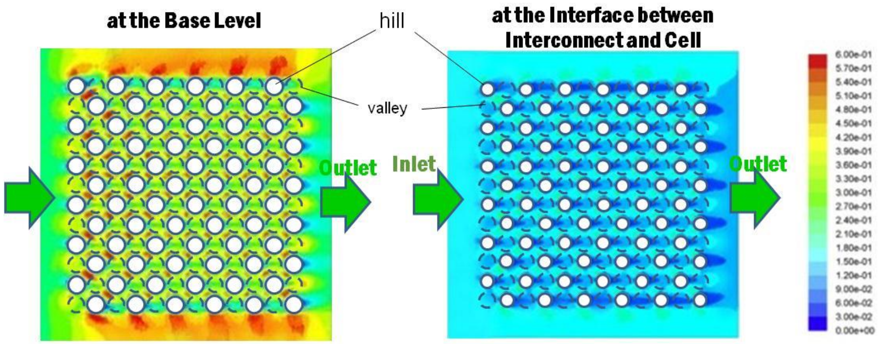


Mechanical Loading



Dimension: Length x Width x Thickness	60mm x 60mm x 2.5mm
Thickness of the interconnect plate	0.3mm
Total height of the interconnect	2.5mm
Length of the interconnect	60mm
Width of the interconnect	60mm
Diameter of the cones at the base level	4mm
Cone angle	60 degrees
Mass of the interconnect	7.66 gram

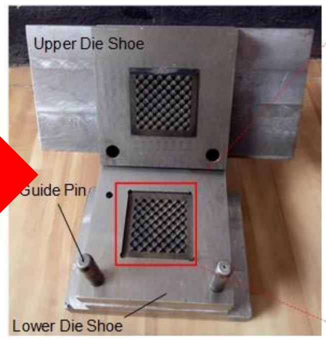
Flow Distribution

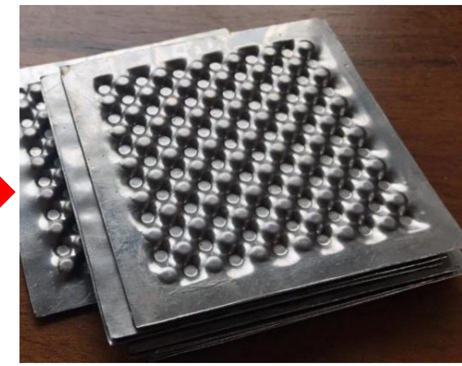


Inlet gas velocity = 0.3 m s^{-1}

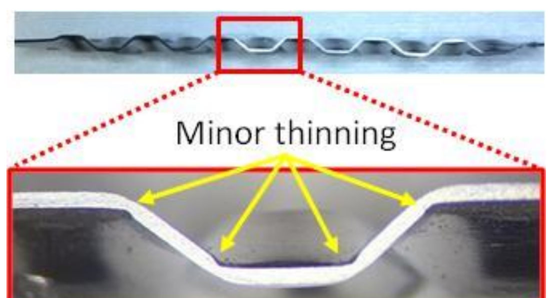
Prime Surface Interconnect Fabrication

Two-step stamping





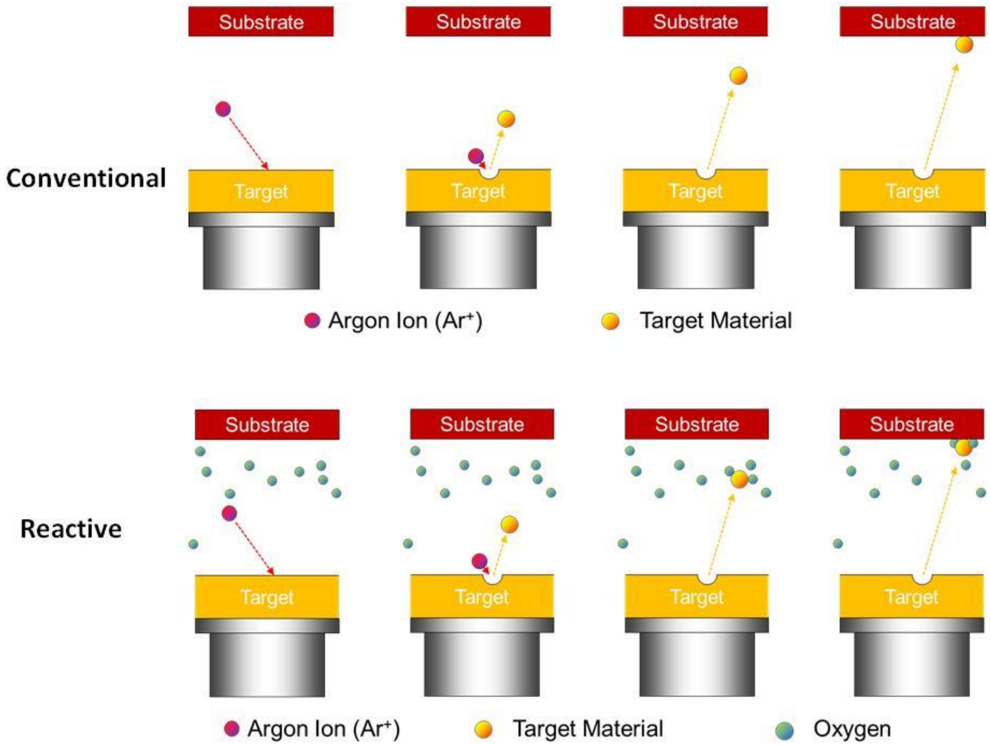
Interconnect with 2mm in height



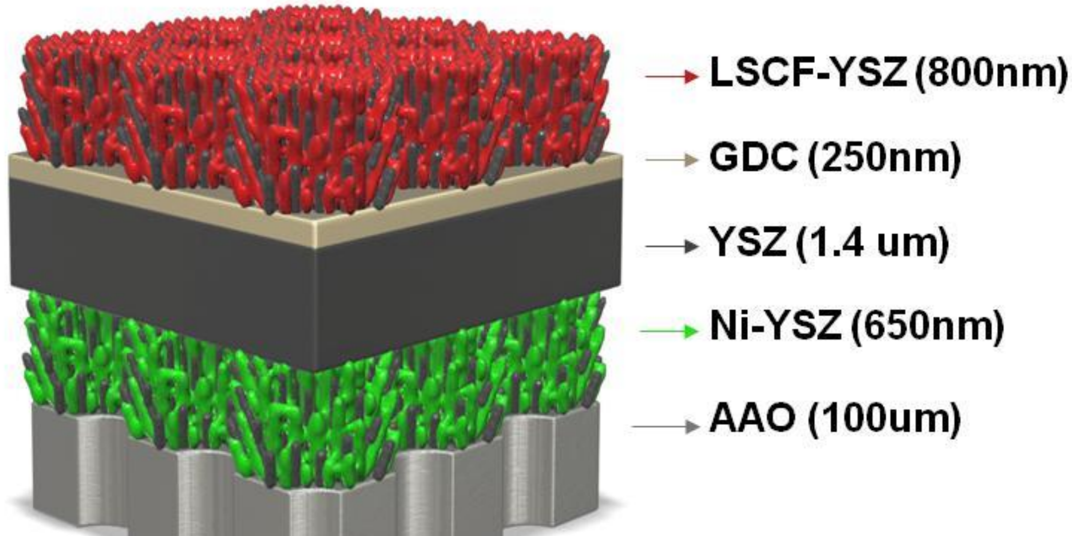
Well formed egg carton shape with minor thinning

Sputtering Process
for fabricating supported thin-film SOFCs

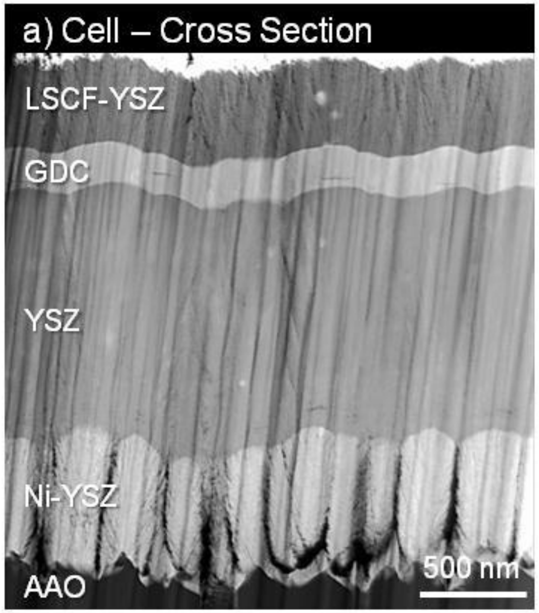
- Sputtering for making thin-film SOFCs on metal supports and other substrates
- Thin-film cells sputtered on porous anodized aluminum oxide (AAO) substrates
- Sequential sputtering of anode, electrolyte, interlayer and cathode films on porous substrates

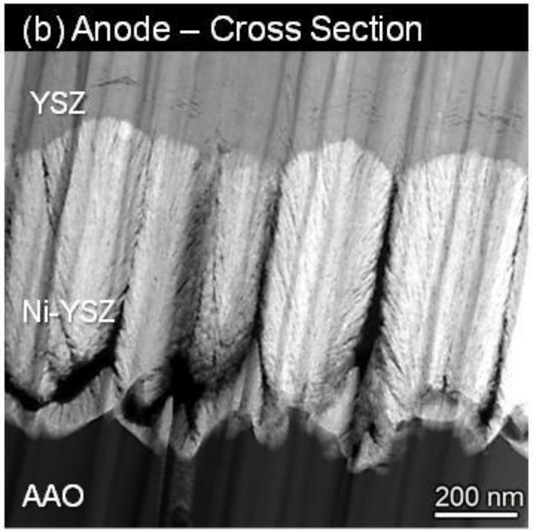


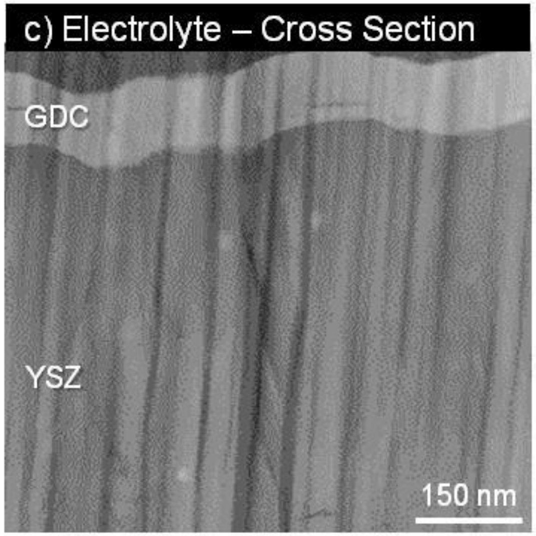
Sputtered Thin-Film Cell Microstructure

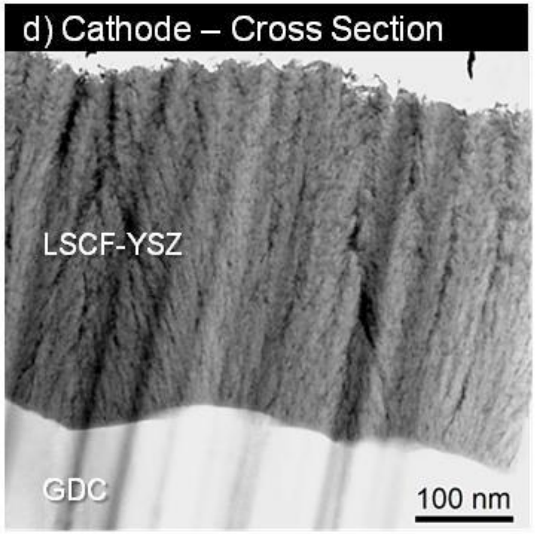


Ultra Fine Nano Structured Electrodes
and Fully Dense Electrolyte



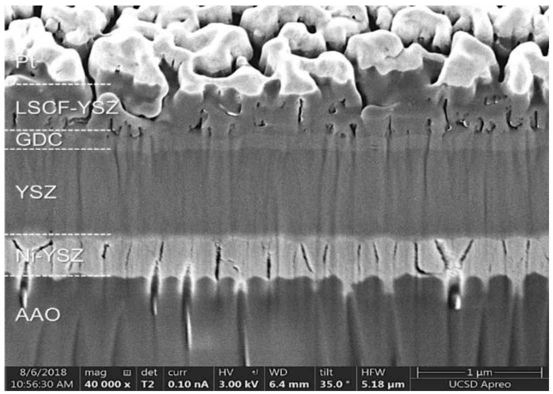




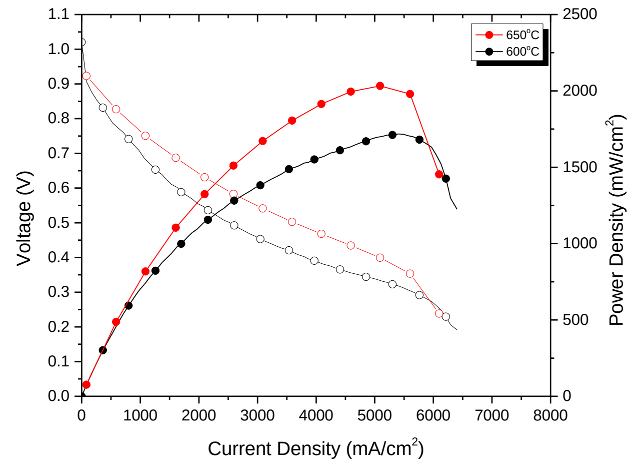


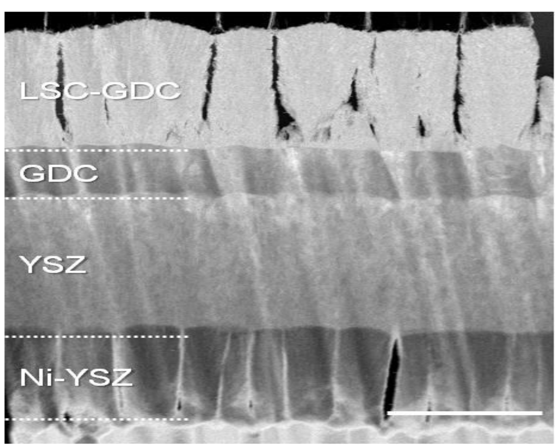
Superior Performance of Sputtered Cells

Hydrogen Fuel

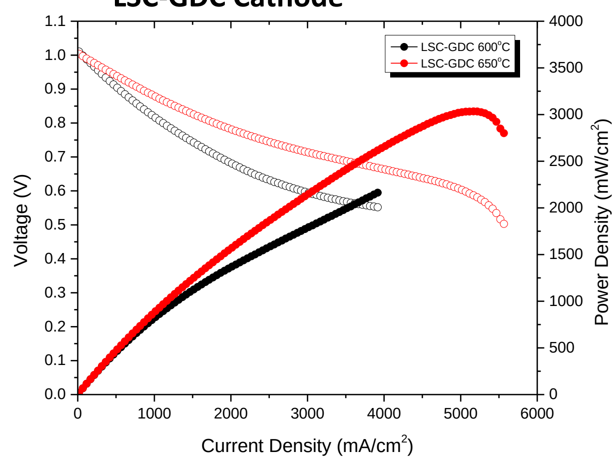


LSCF-YSZ Cathode





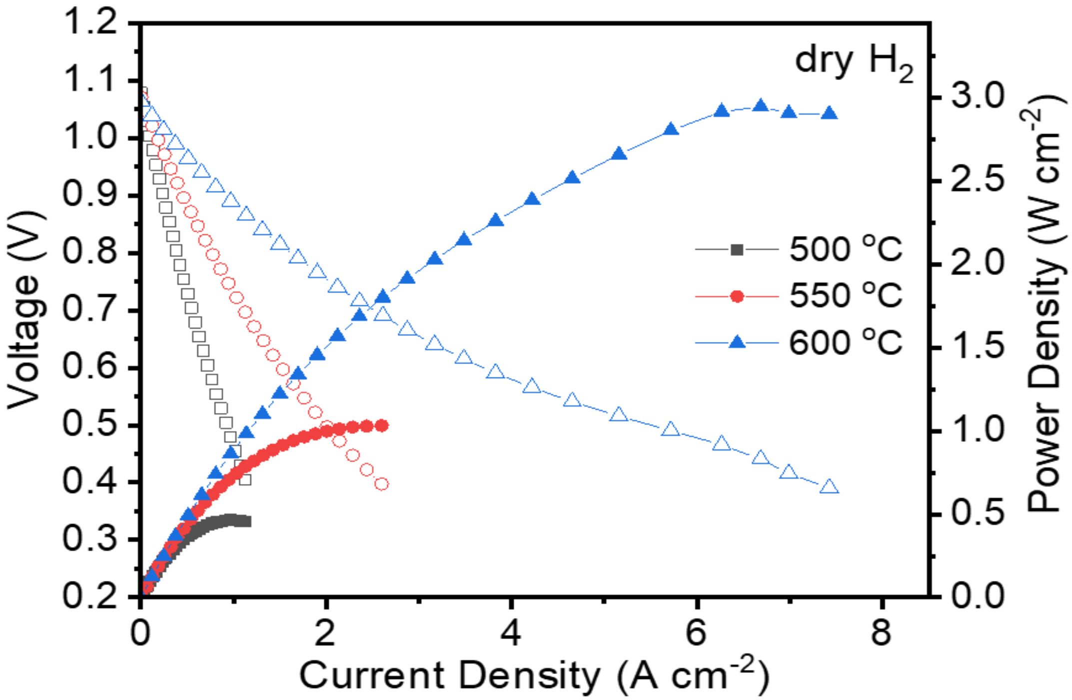
LSC-GDC Cathode



Superior cell performance reported at these reduced temperatures

Improved Sputtered Cell Performance
(Hydrogen)

LSC-GDC/GDC/YSZ/Ni-LSCF

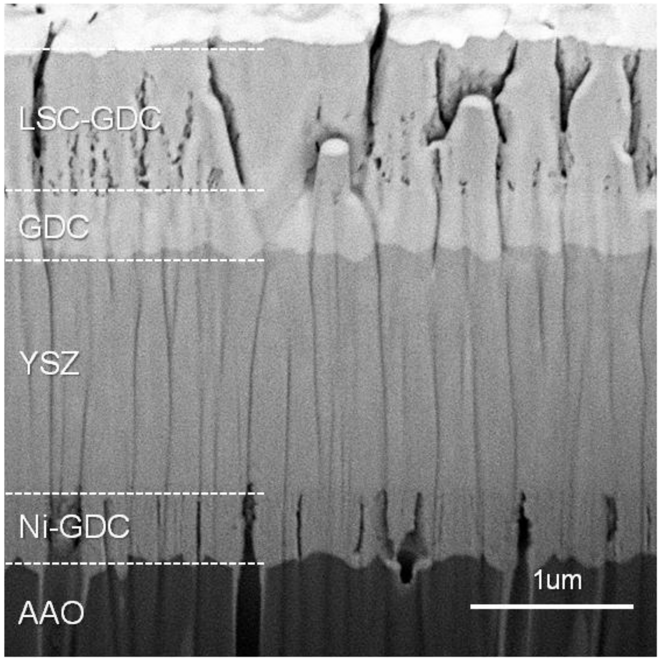


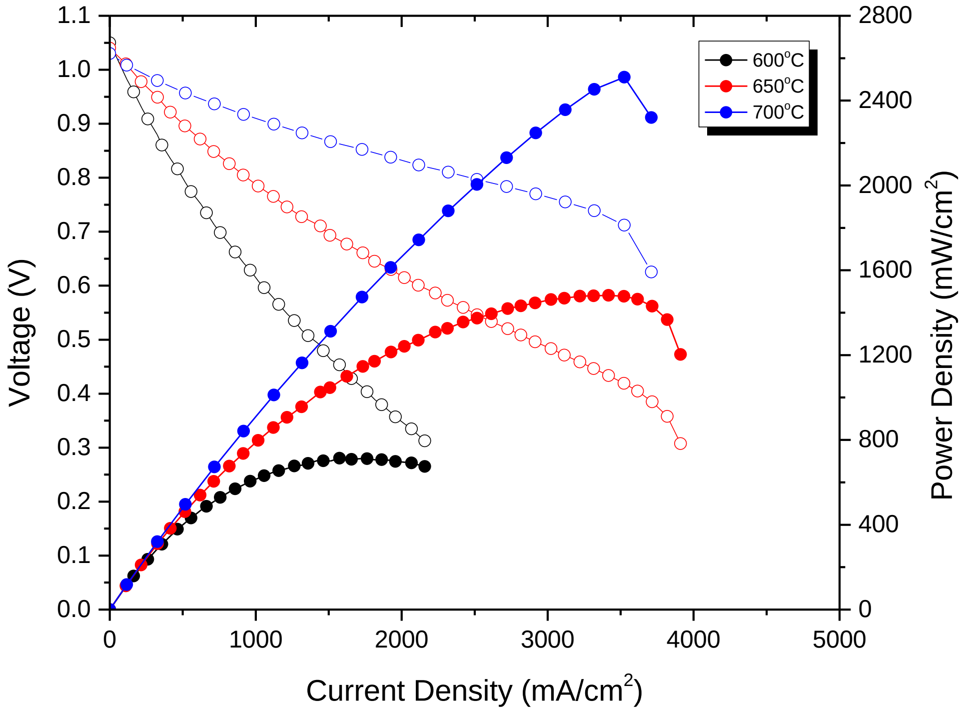
Performance improvement with Ni-LSCF anode

Best cell performance on hydrogen reported at these reduced temperatures

Superior Performance of Sputtered Cells

Dry Methane Fuel

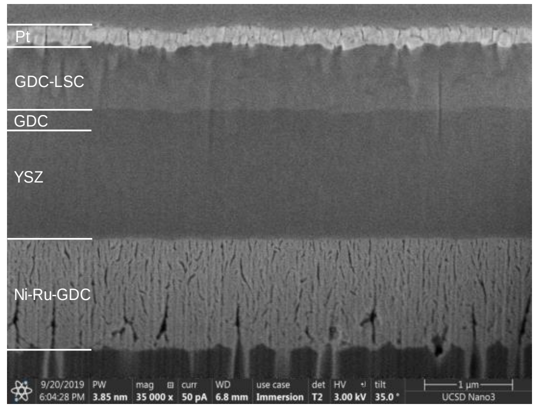


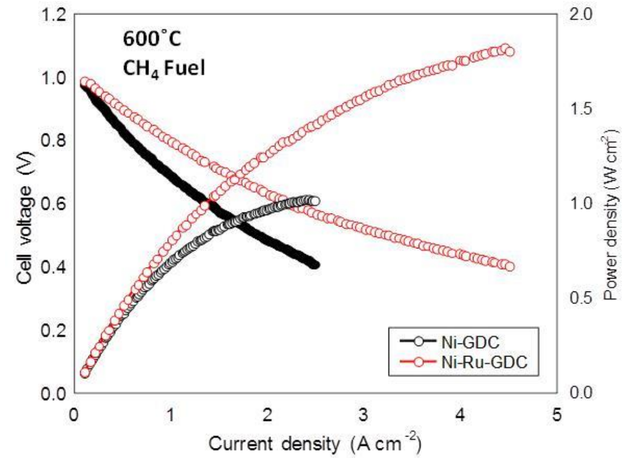


Extraordinarily high cell performance on dry methane reported at these reduced temperatures

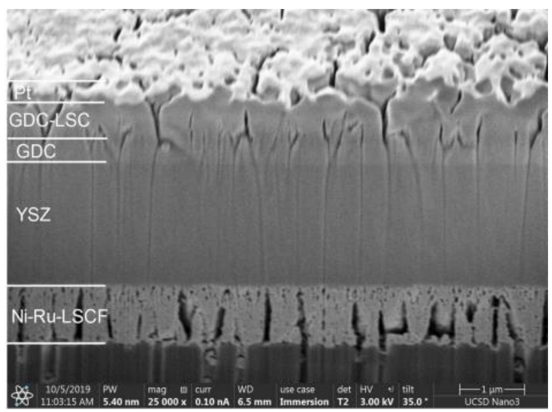
Improved Sputtered Cell Performance
(Dry Methane)

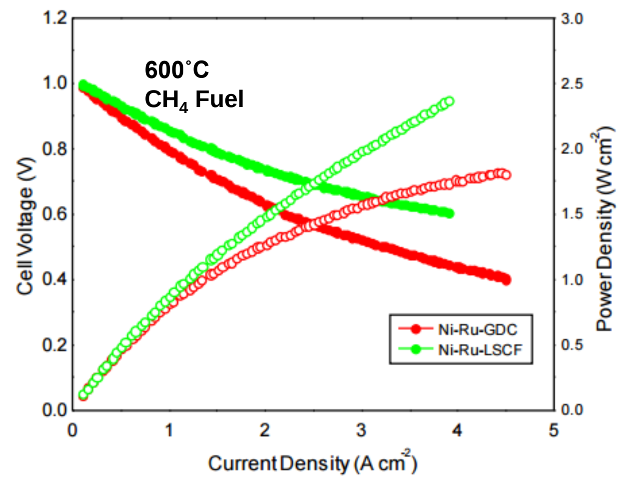
Addition of Ru in anode





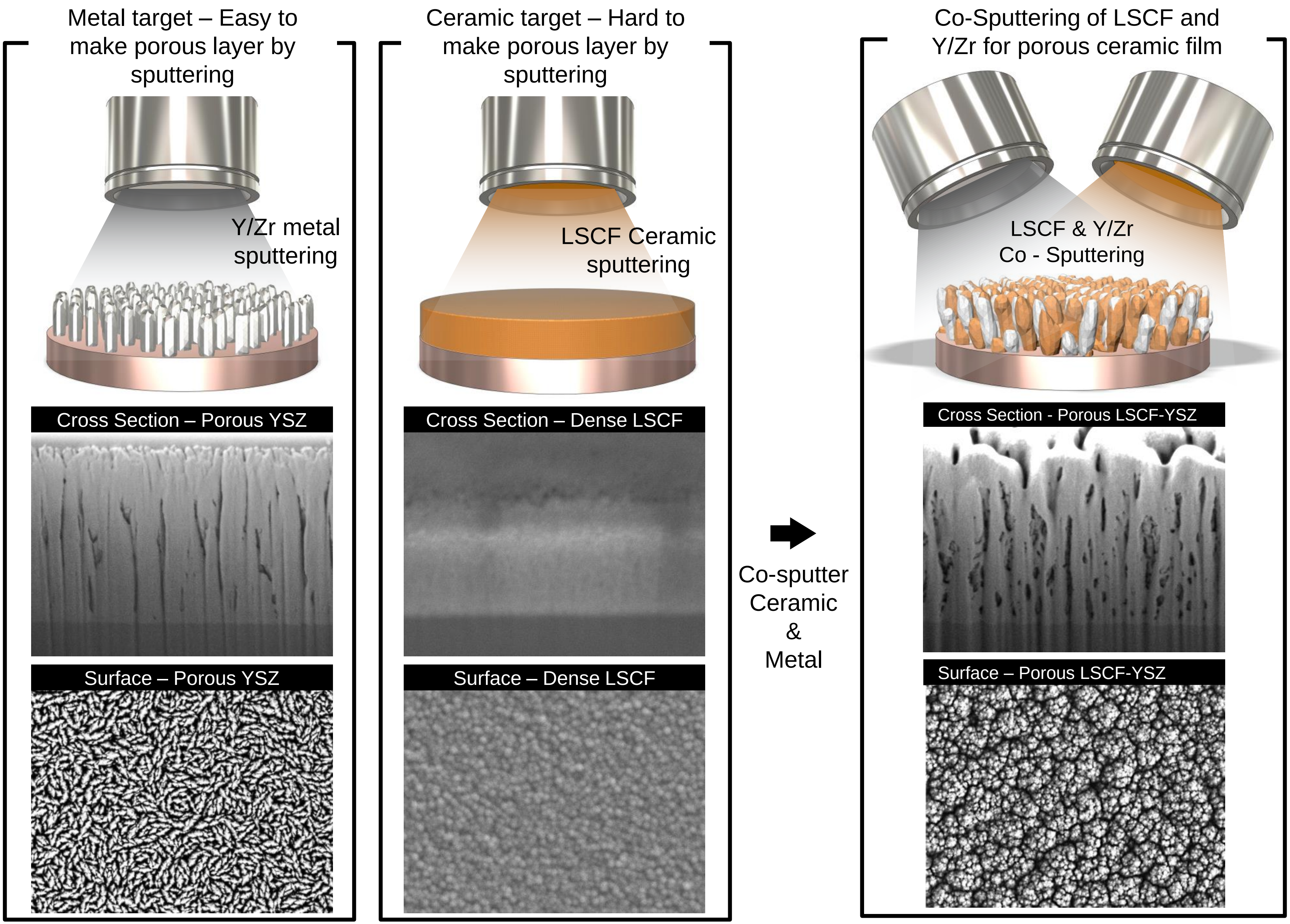
Addition of Ru-LSCF in anode





Performance Improvements with addition of Ru and Ru-LSCF in the anode

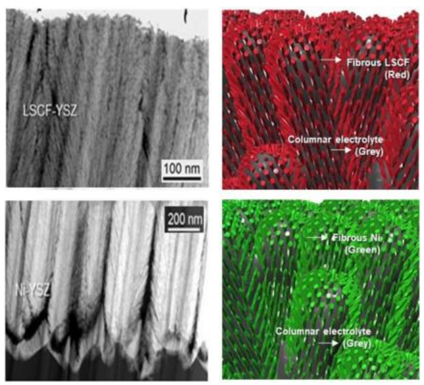
Fabrication of Porous Ceramic Composite Electrodes



Sputtered Cathode Performance

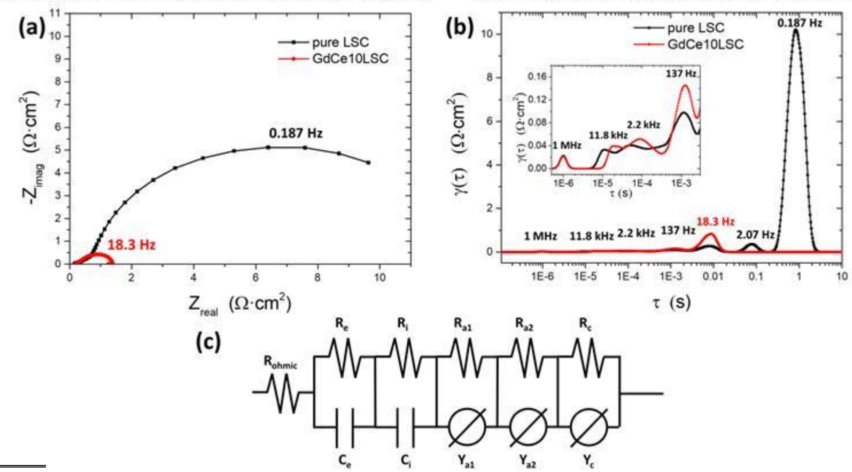
Microstructural characterization and electrochemical measurements show that the composition and nanostructure of the cathode are the two main factors that impact the power density of thin-film SOFCs

Nanostructured cathodes



Electrochemical impedance spectroscopy (EIS) measurements

Electrochemical impedance spectroscopy (EIS)   Distributed function of relaxation time (DFRT)



Equivalent circuit

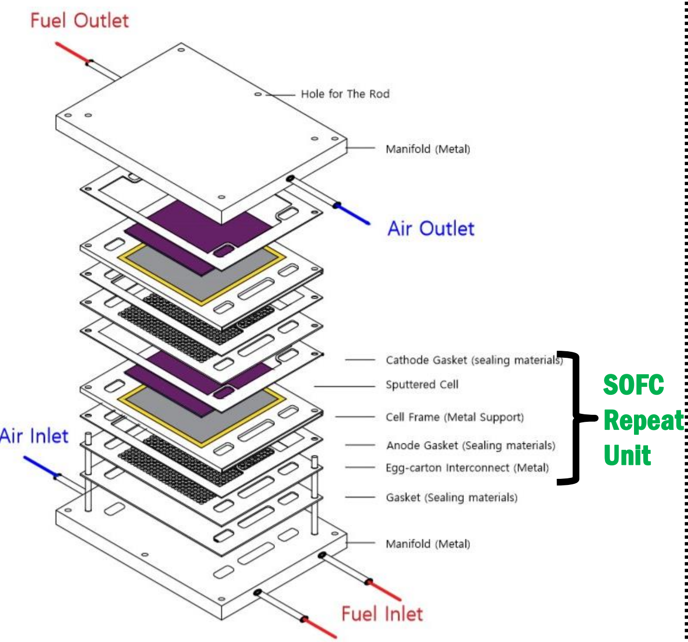
Cell performance at different cathode compositions

	OCV (V)	Peak PD (W/cm^2)				
Temperature	500°C	450°C	500°C	550°C	600°C	650°C
Pure LSC	0.92	<0.01	0.01	0.04	0.08	0.10
GdCe10LSC	1.10	0.08	0.26	0.83	1.86	2.31
GdCe20LSC	1.12	0.14	0.48	1.19	2.56	3.01
GdCe30LSC	1.10	0.12	0.32	0.81	2.16	3.37
GdCe50LSC	1.08	0.04	0.17	0.53	0.81	1.68

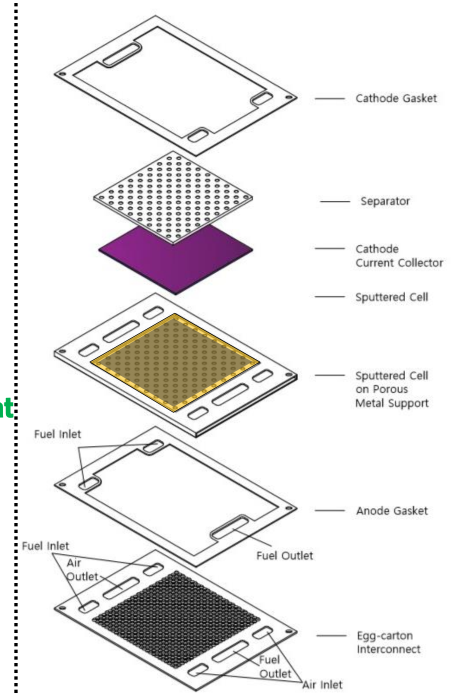
Stack Design for Cost Estimation

SOFC Repeat Unit

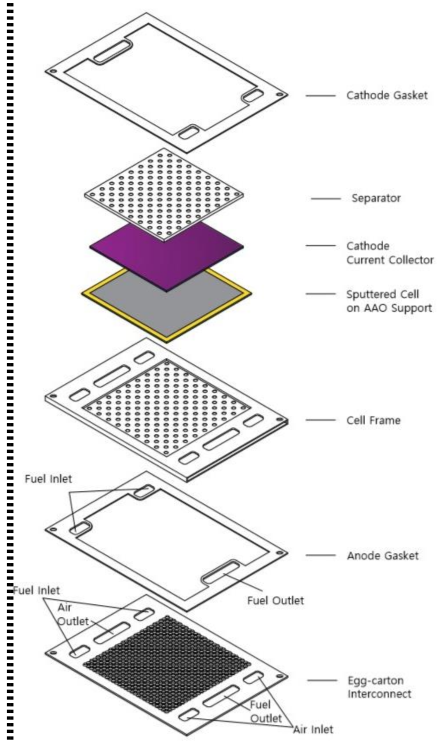
SOFC Stack



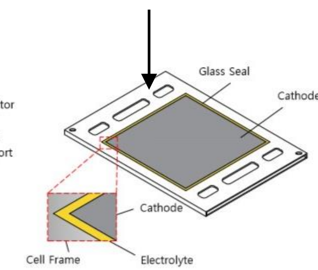
For Sputtered Cell on Porous Steel Support



For Sputtered Cell on AAO Support



Sputtered Cell on AAO Support



Stack Cost Estimation

Key Assumptions

The cost basis and key assumptions for the cost estimate:

- 5 kW SOFC stack operating on natural gas and 50,000 units per year (250 MW/yr).
- The cost is estimated based on a stack power at 0.7 V, 80% fuel utilization (U_f), 700^oC.
- The cost estimation based on sputtered cells fabricated in plant, all other components are procured from suppliers and vendors.

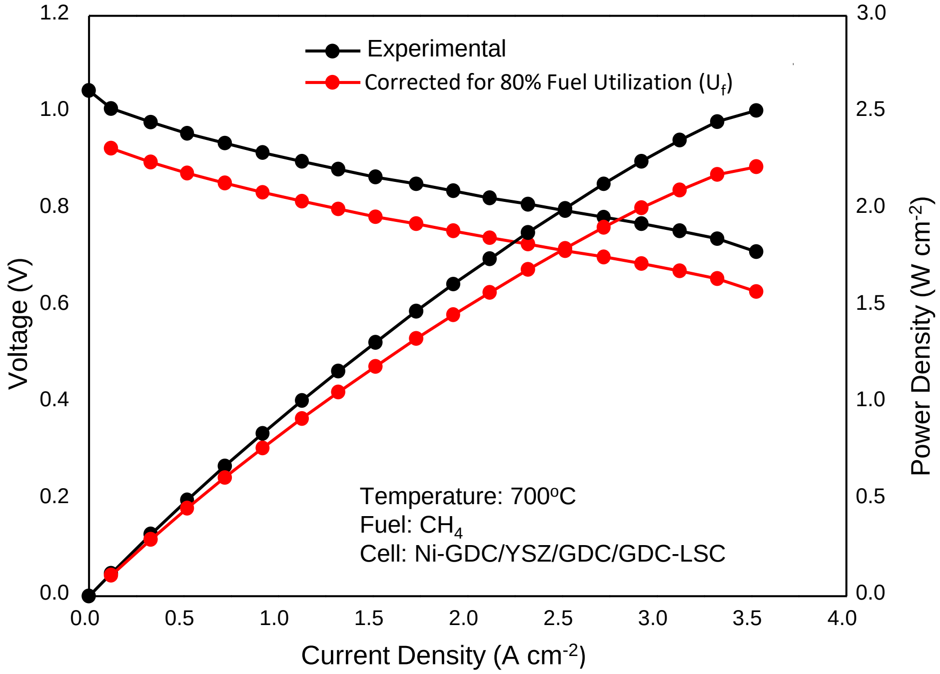
The cost estimate establishes a factory cost, which includes:

- Equipment and Plant Depreciation
- Tooling Amortization
- Facility and Equipment Maintenance
- Utilities
- Cost of Capital
- Purchased Materials
- Fabrication, Assembly and Testing Labors
- Indirect Labor and Materials

The following costs are not included in the cost estimate:

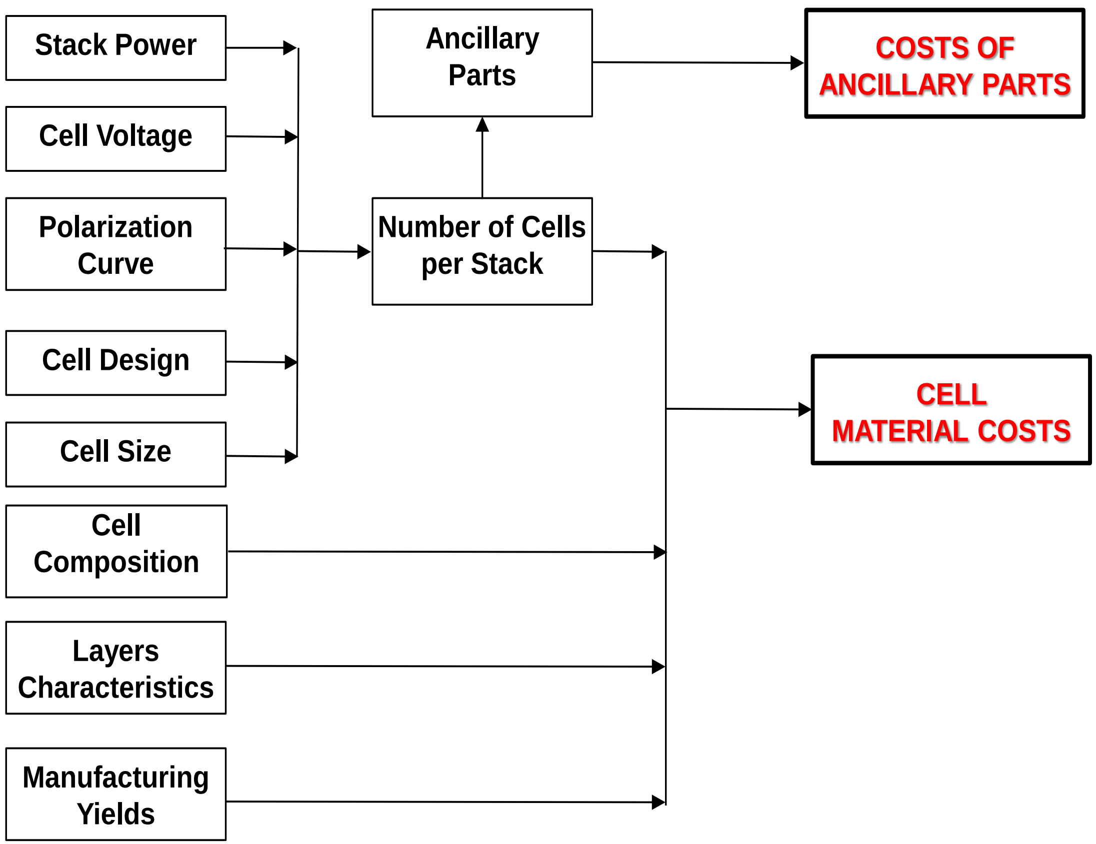
- Research and Development
- Sales and Marketing
- General and Administration
- Warranty &Taxes

Cell / Stack Performance for Cost Estimation

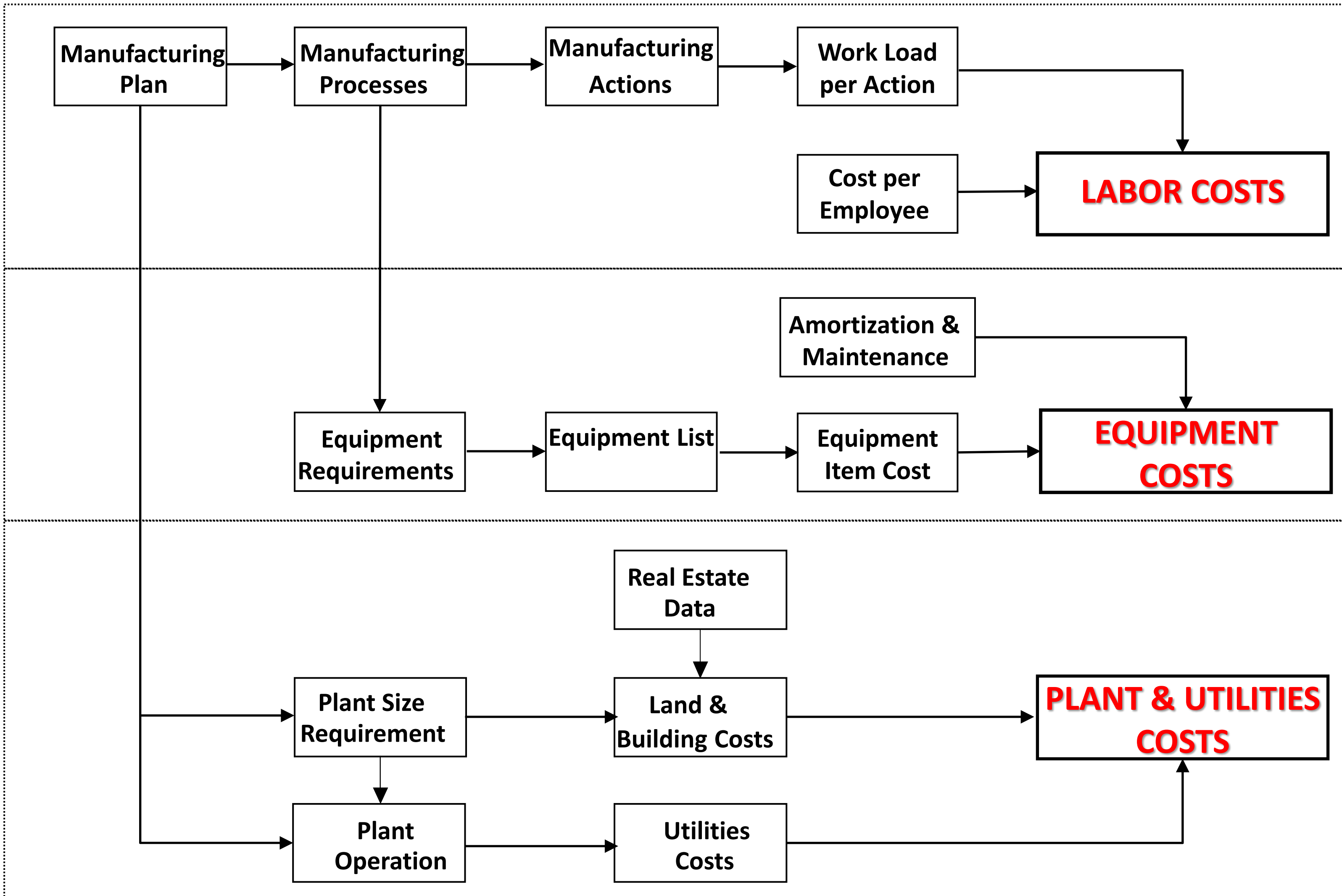


Power Output	5 kW
Temperature	700°C
Fuel	Natural Gas
Fuel Utilization	80%
Power density	1.9 W/cm^2
Current density	2.7 A/cm^2
Voltage	0.7 V
Cell size	10cm X 10cm
No. cell per 5 kW stack	32 cells

Stack Material Cost Estimation



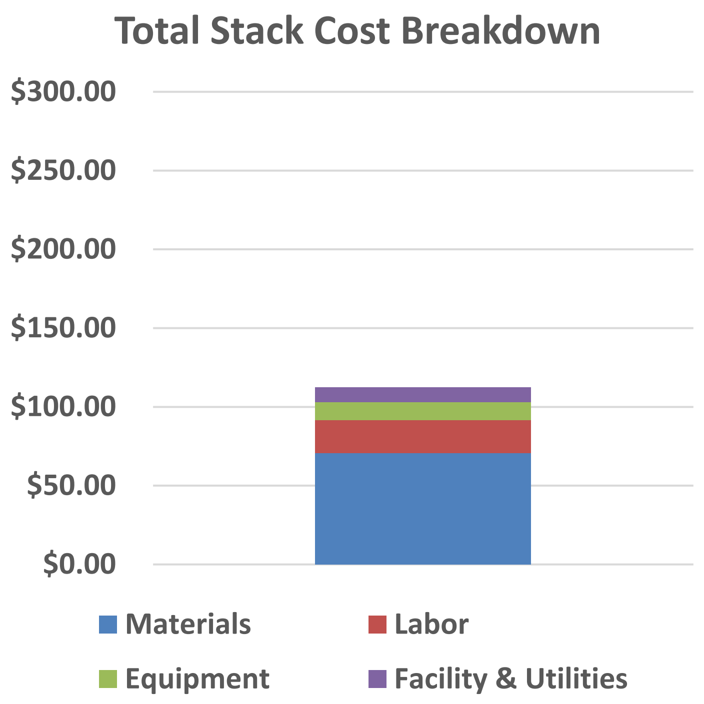
Estimation Process for Other Stack Costs



Total Stack Cost Breakdown

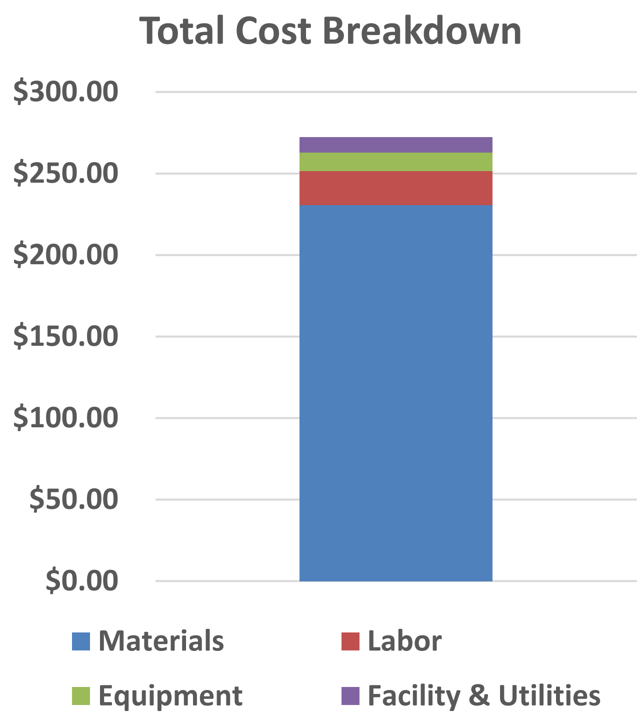
For Sputtered Cell on Metal Support

	Cost per kW
Materials	$70.7
Labor	$21.0
Equipment	$11.4
Facility & Utilities	$9.2
Total	***$112.3***



For Sputtered Cell on AAO Support

	Cost per kW
Materials	$230.7
Labor	$21.0
Equipment	$11.4
Facility & Utilities	$9.2
Total	***$272.3***



Summary of Key Achievements

- Design and fabrication process for prime-surface interconnects
- Sputter process for fabricating thin-film SOFCs and demonstration of recorded performance at reduced temperatures with hydrogen and methane fuel
- Design and specifications for full-size stacks
- Stack cost assessment

Acknowledgments

- DOE/NETL SOFC project management, especially Dr. Patcharin Burke and Mr. Jason Montgomery

- UCSD and OxEon SOFC project team