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

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Annual SOFC Project Review

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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)

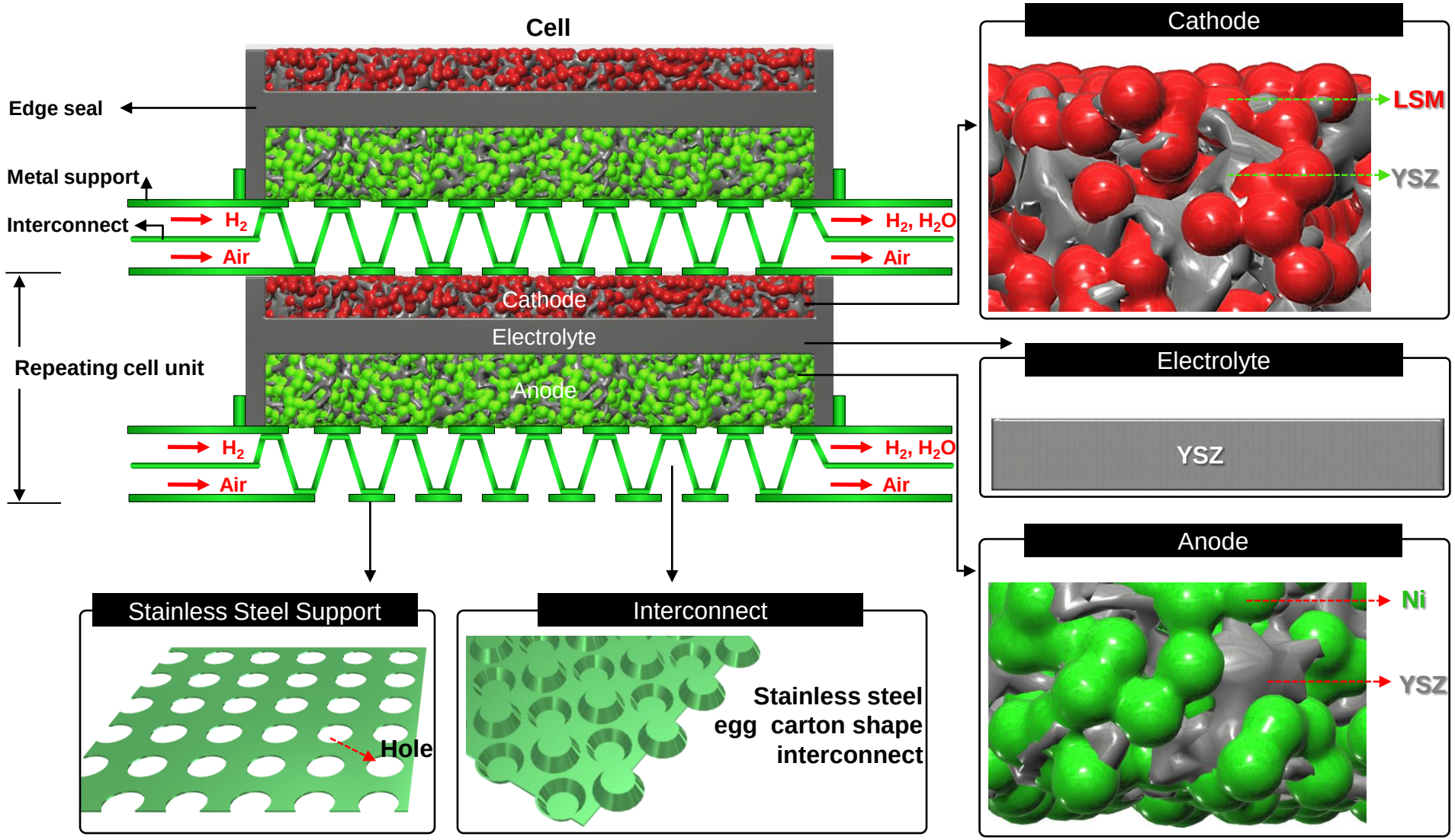
- Project Objective: Develop and evaluate a versatile stack configuration based on a prime-surface interconnect design that can incorporate different types of cell construction for a broad range of power generation applications

- DOE/NETL Project Manager: Mr. Jason Montgomery

- Project Team:
  - ❑ UCSD
    - *Center for Energy Research*: Dr. Nguyen Minh (PI), Dr. Tuyen Tran (Assistant Project Scientist), Dr. He Qi (Postdoctoral Scholar)
    - *Department of Electrical Engineering and Center for Memory and Recording Research*: Dr. Eric Fullerton (Professor), Haowen Ren (Graduate Student)
    - *Department of NanoEngineering*: Dr. Shirley Meng (Professor), Erik Wu (Graduate Student)
  - ❑ OxEon
    - Dr. Elango Elangovan, Mr. Joe Hartvigsen

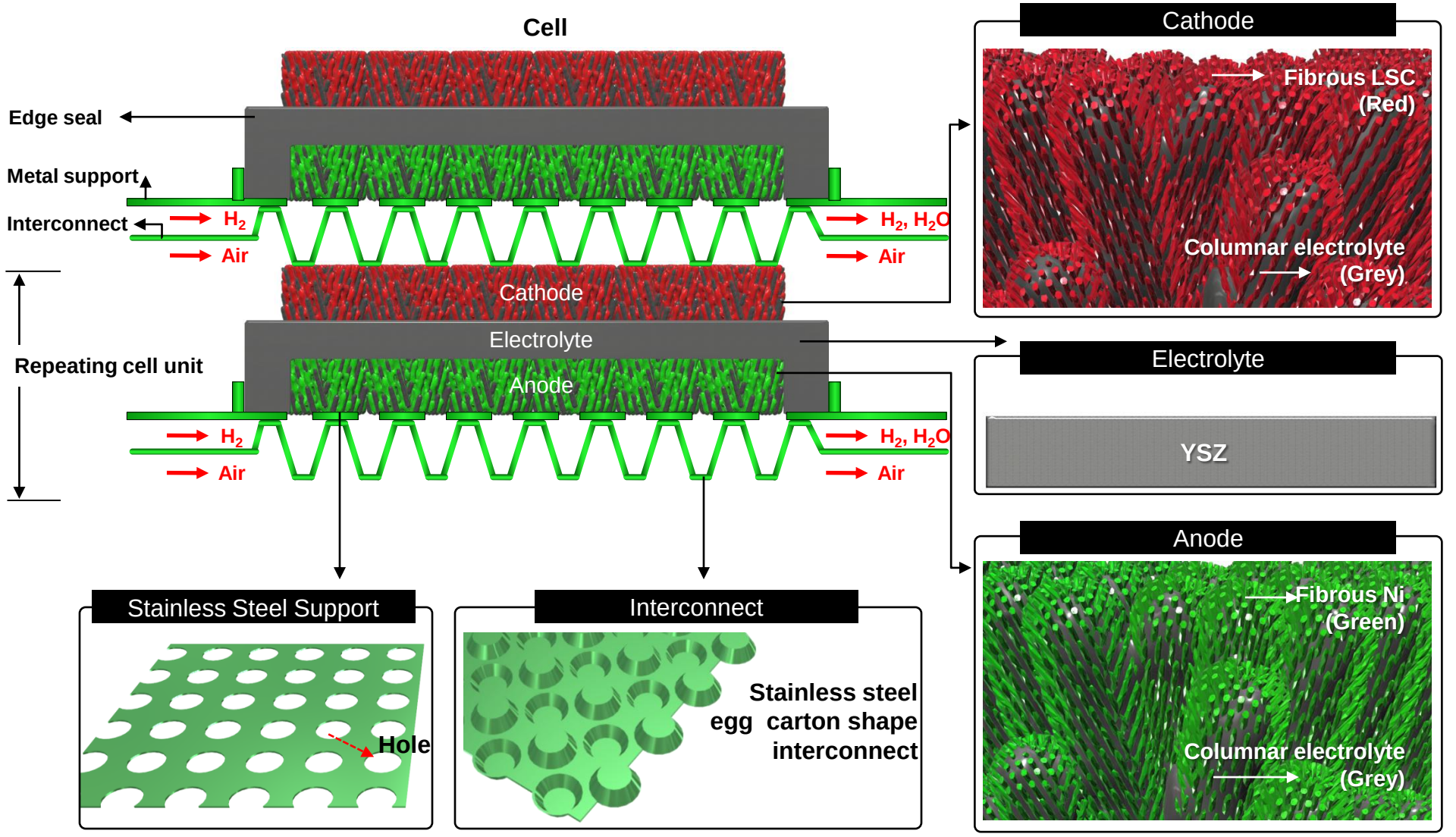
Stack Design Concept

Incorporating Conventional Cells



Stack Design Concept

Incorporating Metal-Supported Cells



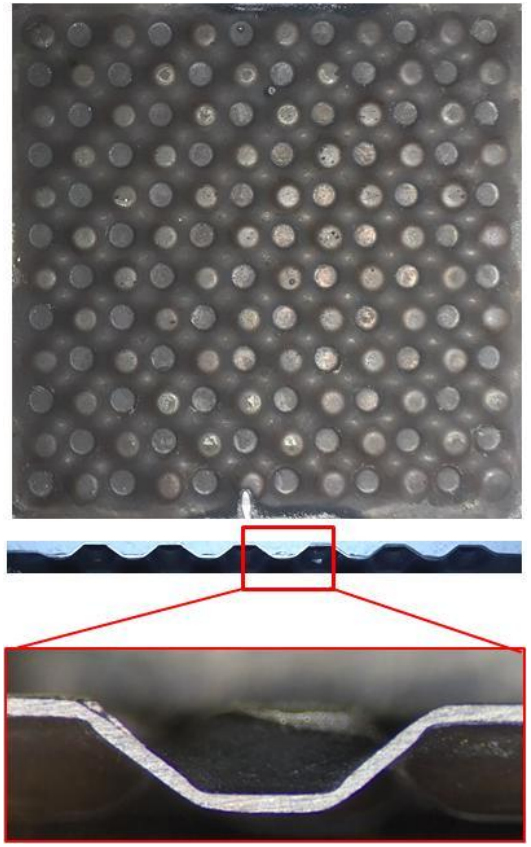
Project Technical Activities

- Prime surface interconnect design and fabrication development
- Metal-supported cell structure development
- Stack development
- Stack operation demonstration (to be initiated)
- Stack cost assessment

PRIME-SURFACE INTERCONNECT DESIGN AND FABRICATION DEVELOPMENT

Prime-Surface Interconnect

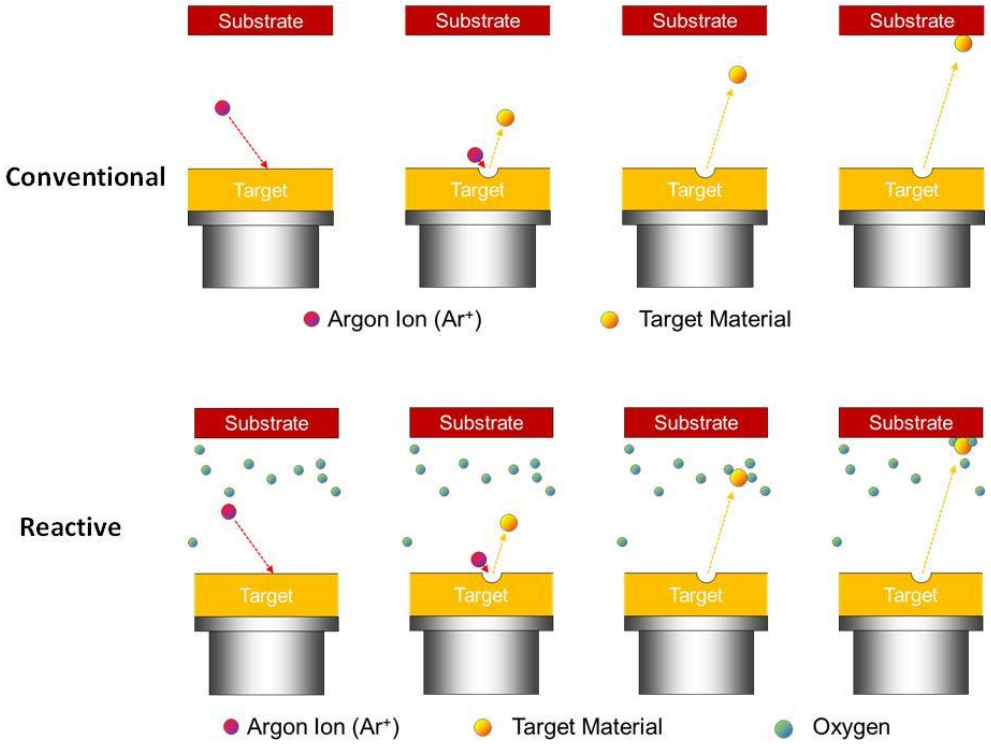
- Egg-carton shaped prime-surface interconnect design
- Two-step pressing fabrication process
- Full-size interconnects being fabricated



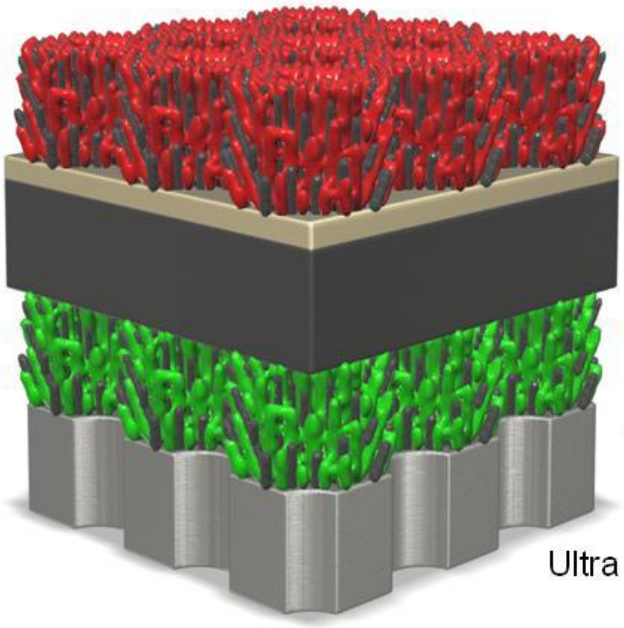
METAL SUPPORTED CELL STRUCTURE DEVELOPMENT

Sputtering Process

- Sputtering for making thin-film SOFCs on metal supports and other substrates
- Thin-film cells sputtered on porous anodized aluminum oxide (AAO) substrates for cell performance testing and evaluation



Sputtered Thin-Film Cell Microstructure



LSCF-YSZ (800nm)

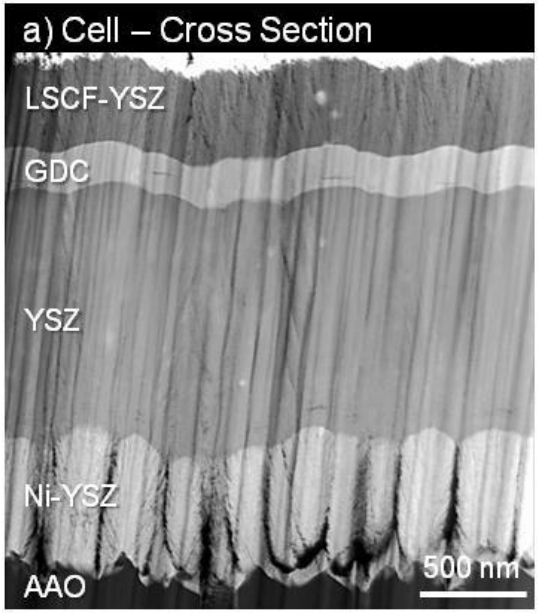
GDC (250nm)

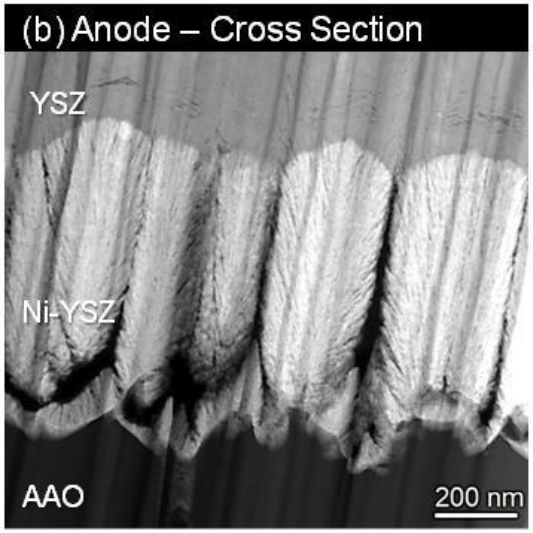
YSZ (1.4 um)

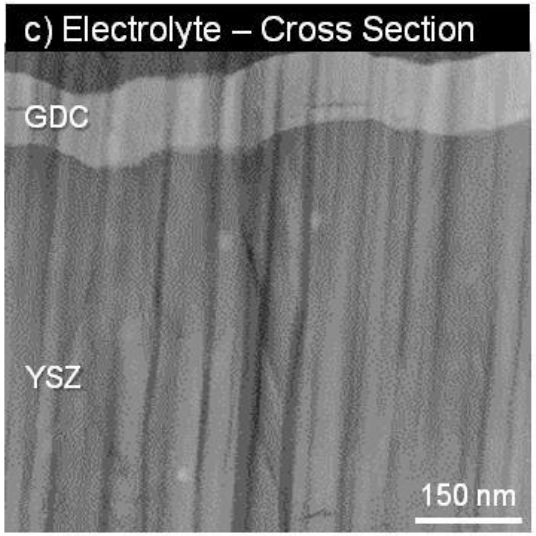
Ni-YSZ (650nm)

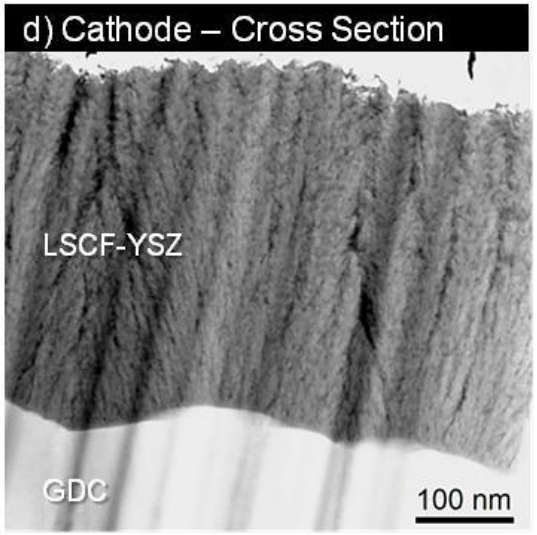
AAO (100um)

Ultra Fine Nano Structured Electrodes
and Fully Dense Electrolyte



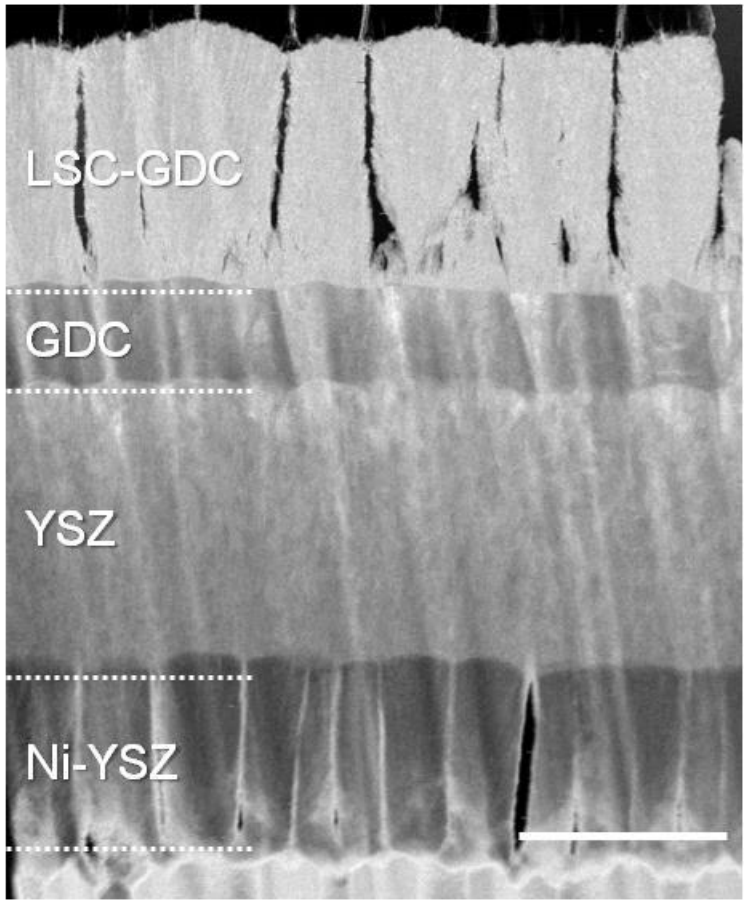


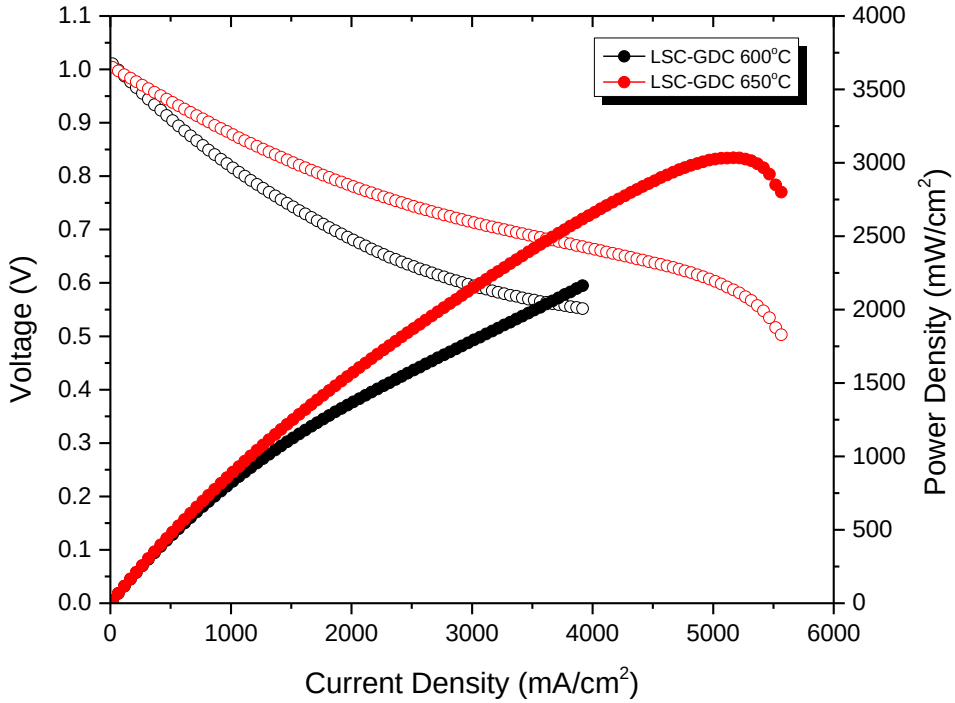




Superior Performance of Sputtered Thin-Film Cell at Reduced Temperatures

LSC-GDC / GDC / YSZ / Ni-YSZ , Hydrogen Fuel

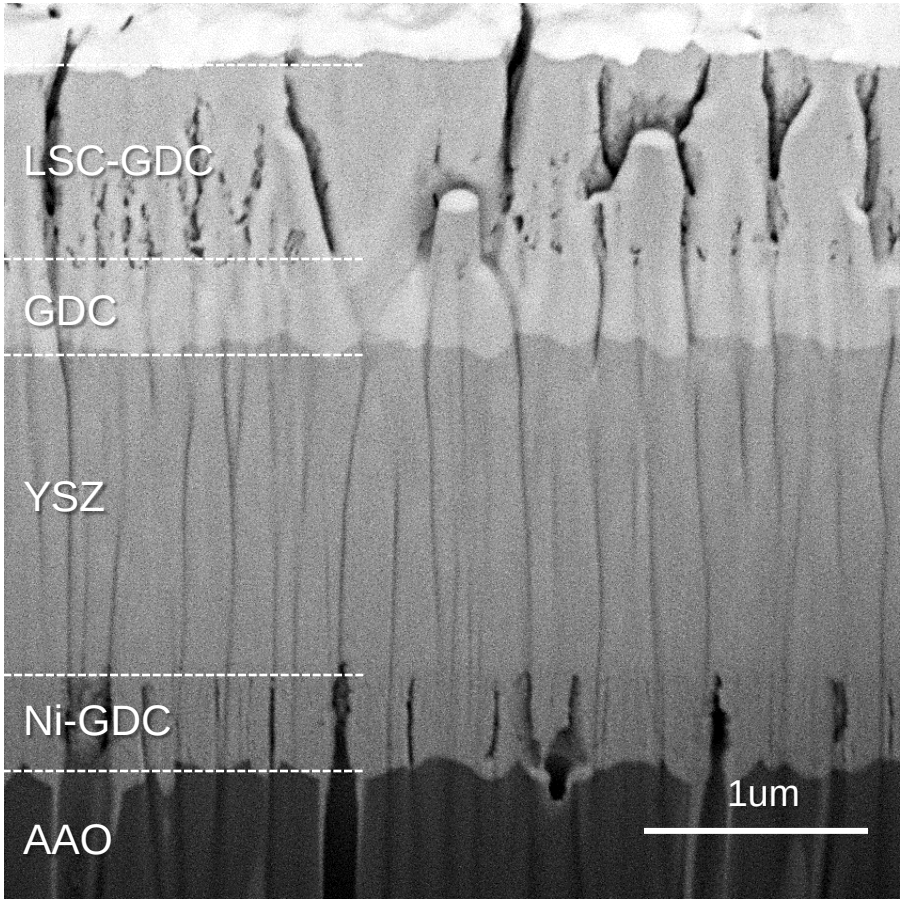


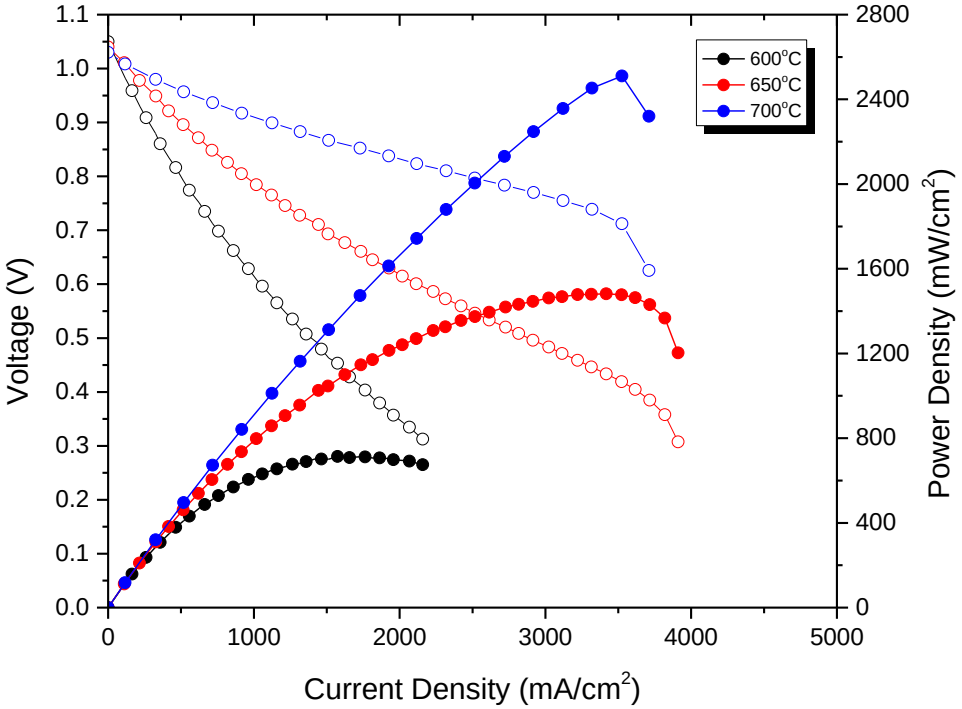


Best cell performance reported at these reduced temperatures

Thin-Film Cell Performance on Dry Methane

LSC-GDC/GDC/YSZ/Ni-GDC, Dry Methane



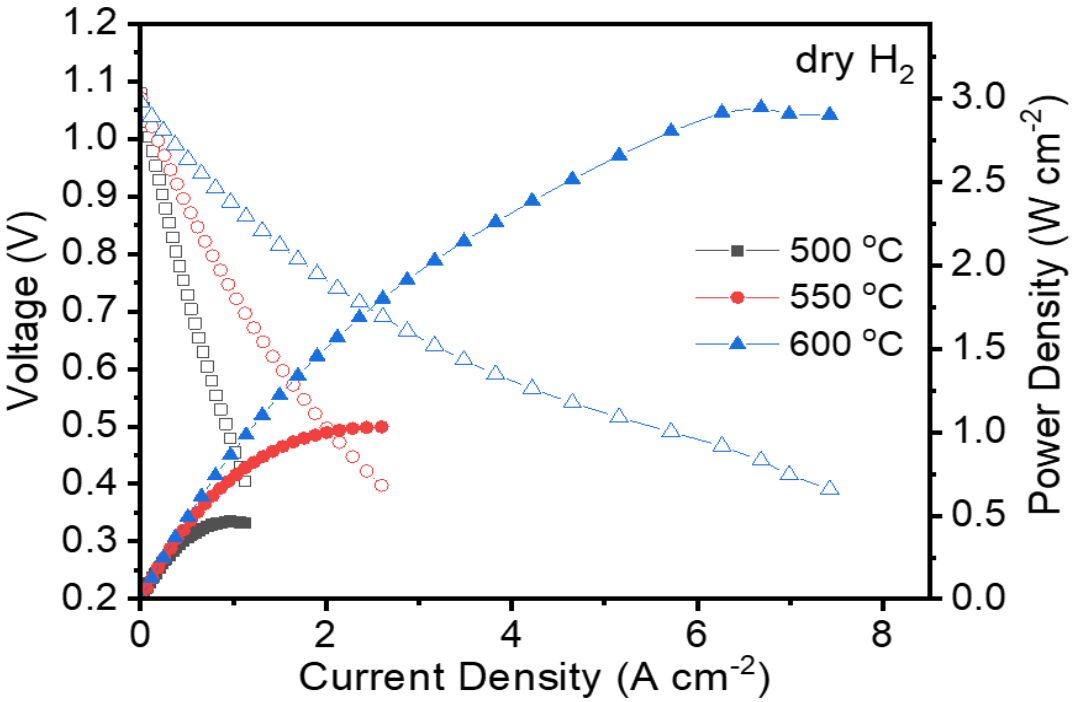


Pure Dry Methane 100sccm

Best cell performance on dry methane reported at these reduced temperatures

Improved Cell Performance (Hydrogen)

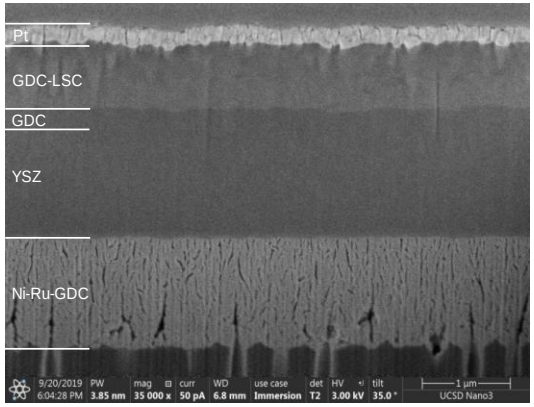
LSC-GDC/GDC/YSZ/Ni-LSCF

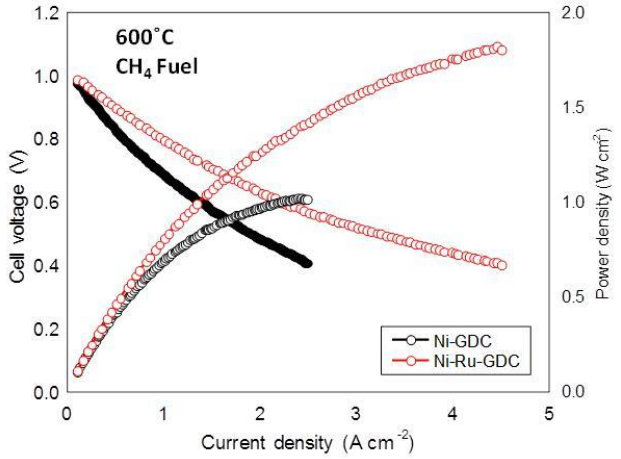


Performance improvement with Ni-LSCF anode

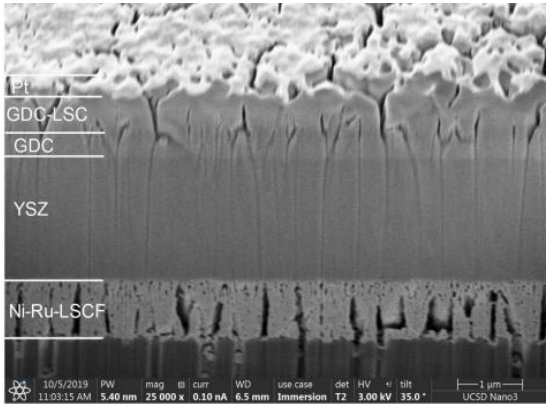
Improved Cell Performance (Dry Methane)

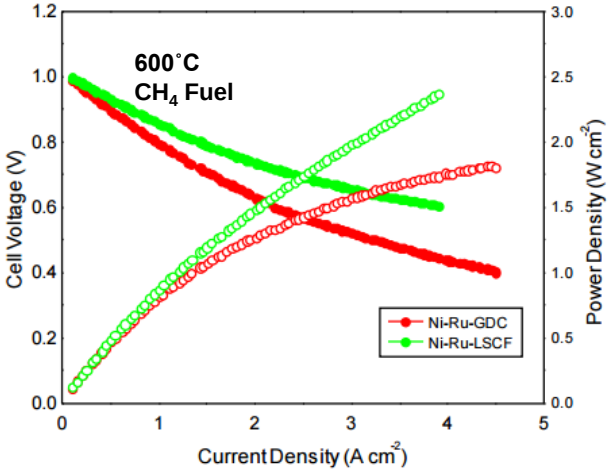
Addition of Ru in anode





Addition of Ru-LSCF in anode



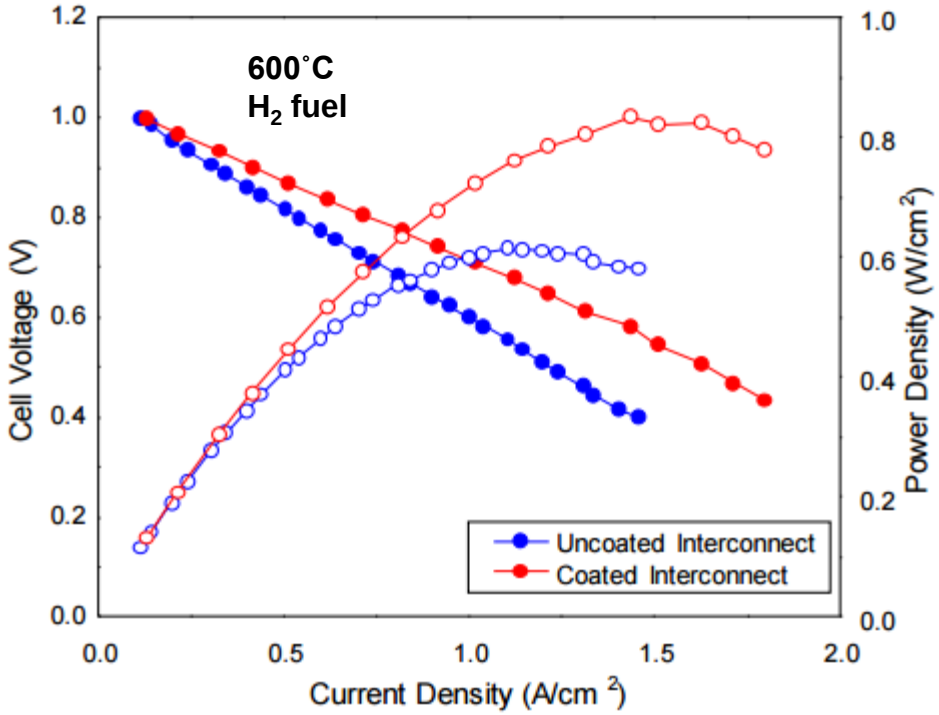


Performance Improvements with addition of Ru and Ru-LSCF in the anode

STACK DEVELOPMENT

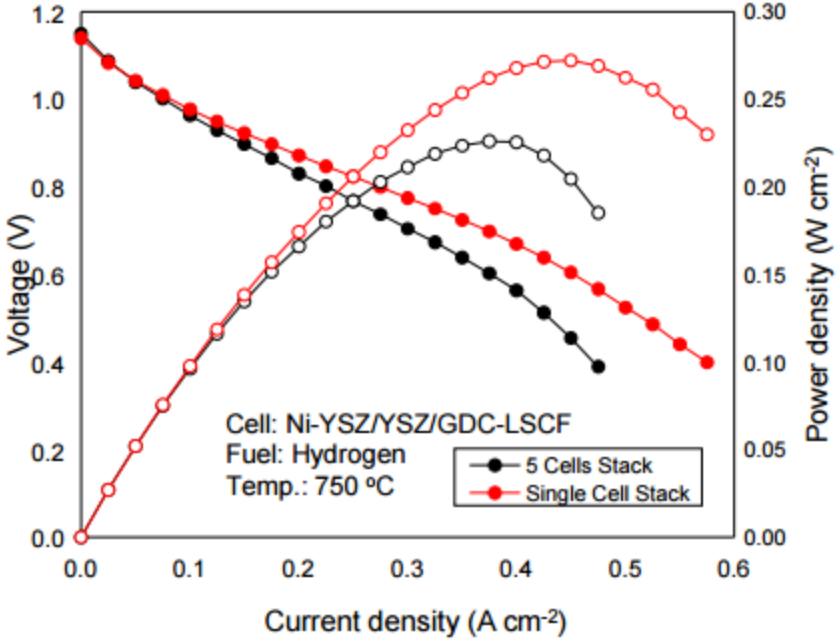
Testing of Laboratory-Scale Stack

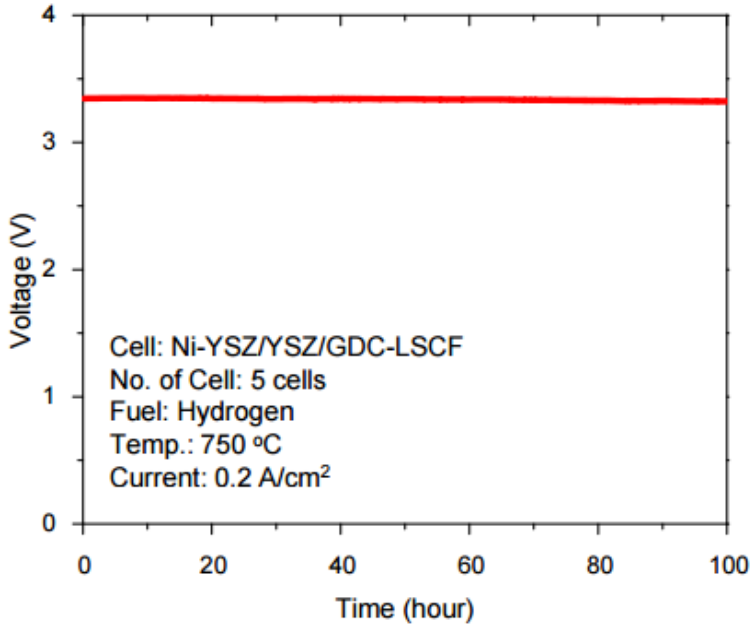
Incorporating Thin-Film Cell



Testing of Laboratory-Scale Stack

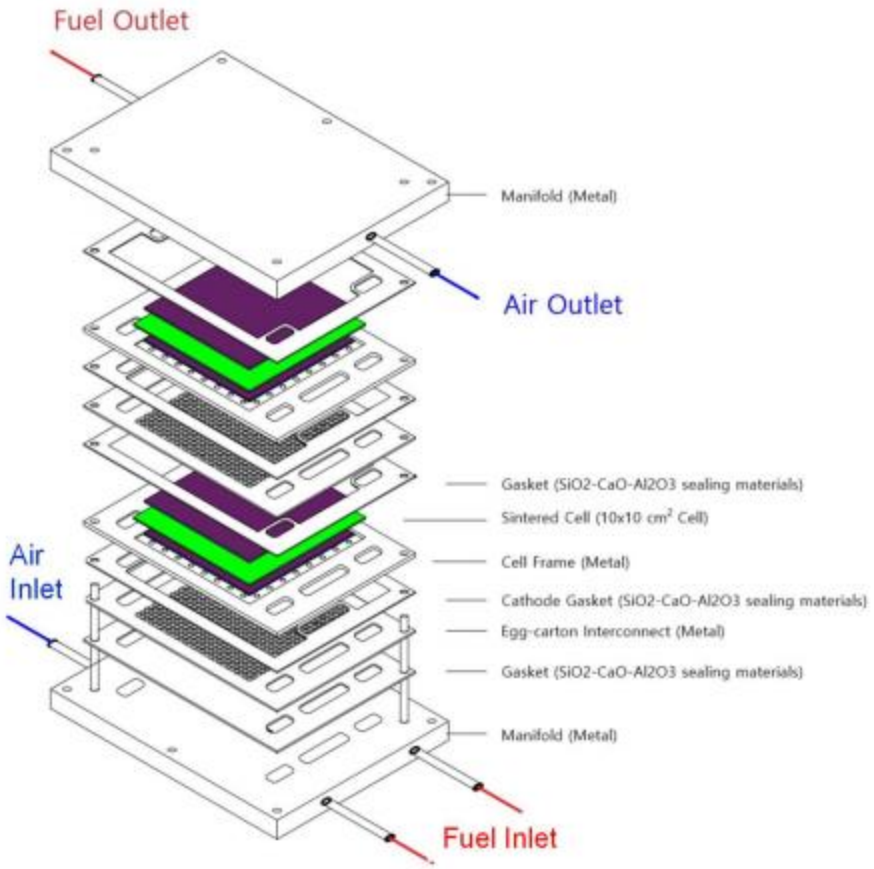
Incorporating Sintered Anode-Supported Cell



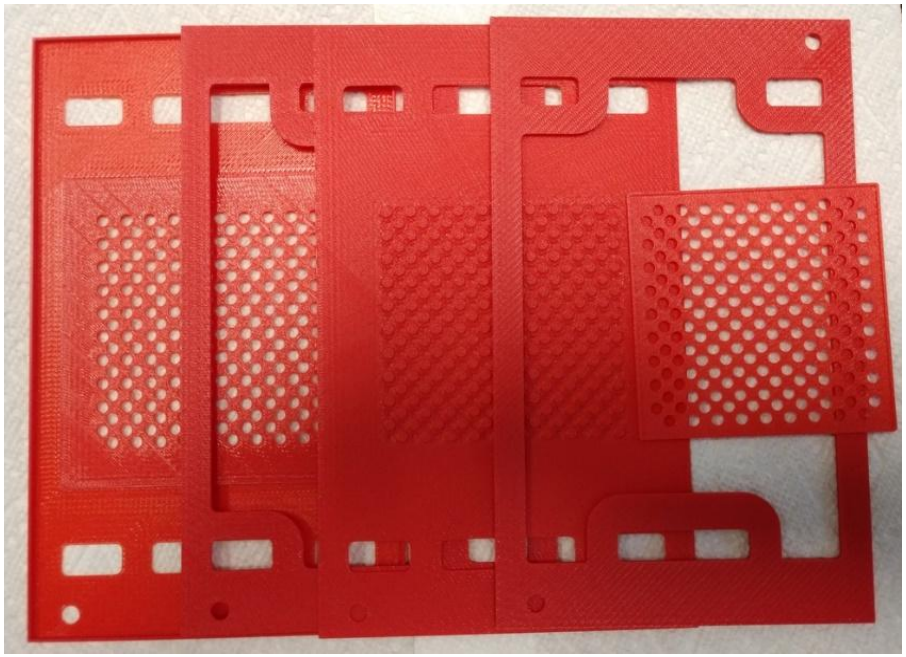


Full-Size Stack Design

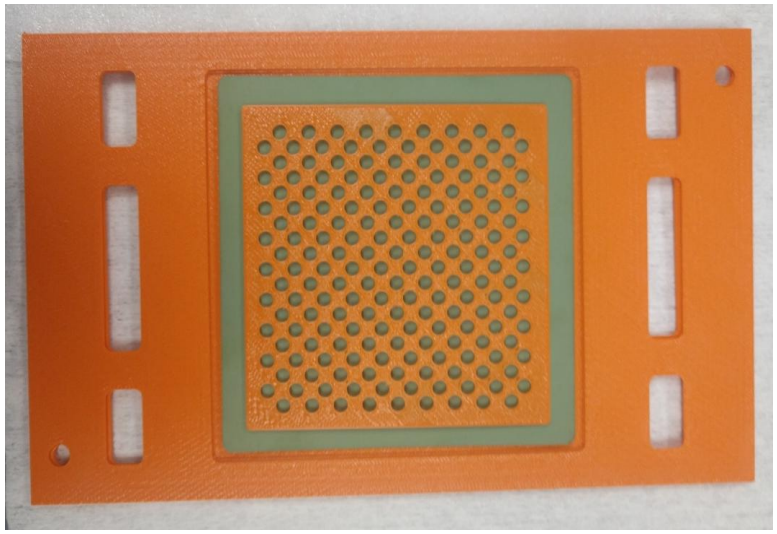
Incorporating Prime-Surface Interconnects and Conventional Sintered Cells



3D Printing Evaluation - Interconnect Layer



A set of 3D printed interconnect layers

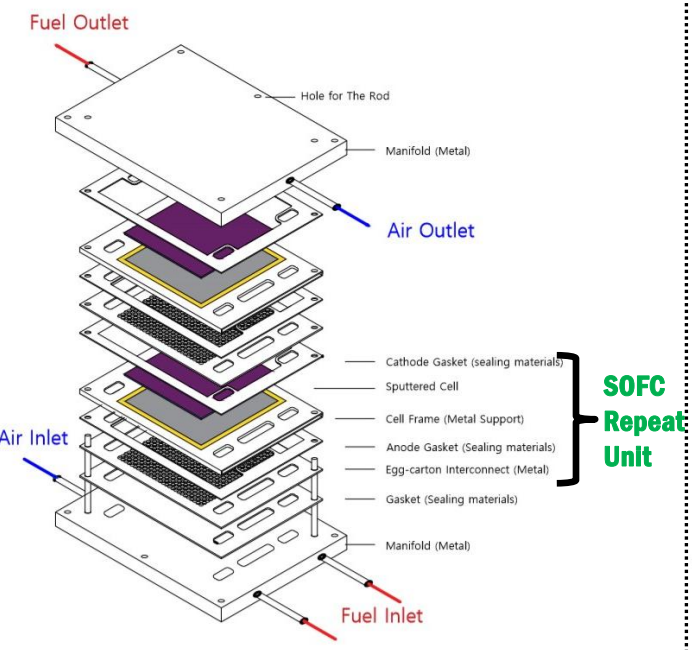


A 3D printed interconnect overlaid with a cell

STACK COST ASSESSMENT

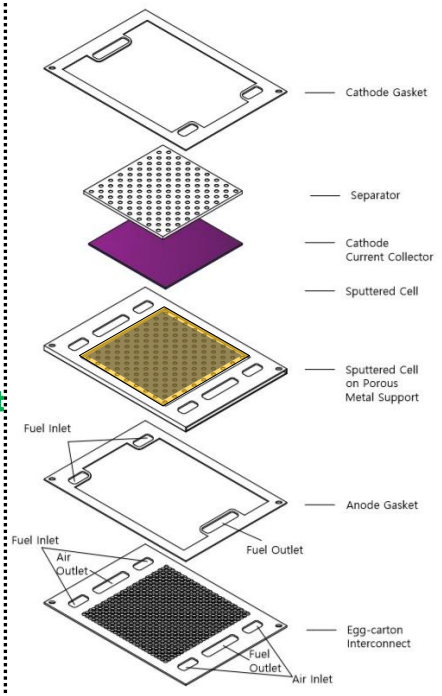
Stack Components for Cost Estimation

SOFC Stack

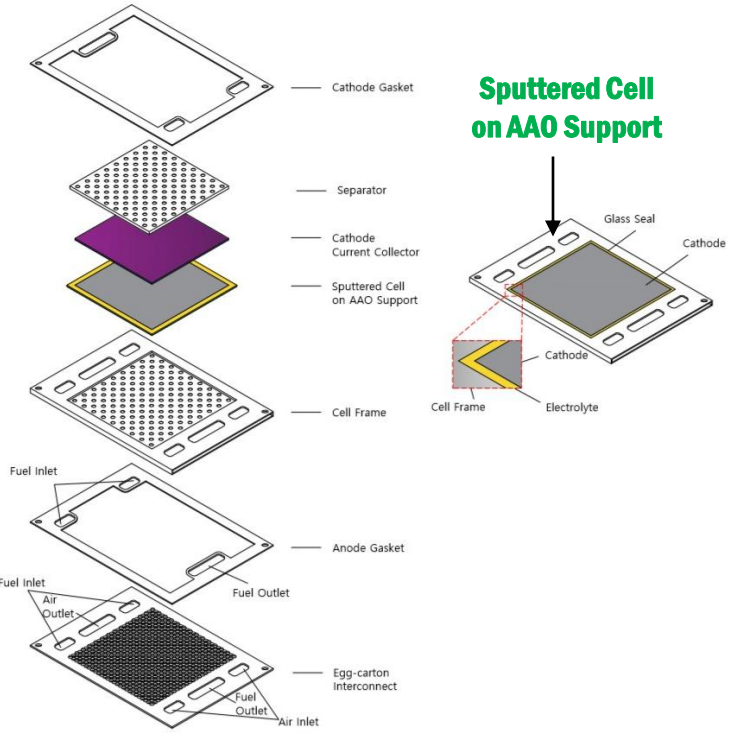


SOFC Repeat Unit

For Sputtered Cell on Porous Steel Support



For Sputtered Cell on AAO Support



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^{o}C.
- The cost estimation based on sputtered cells fabricated in plant, all other components are procured from suppliers and vendors.

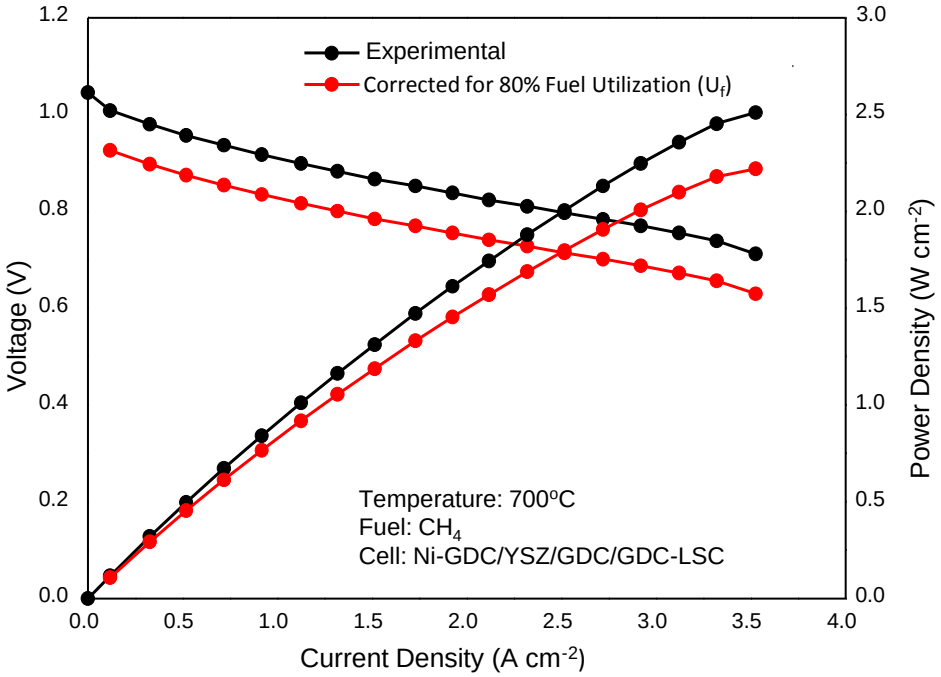
The cost estimate establishes a factory cost, which includes:

- 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:

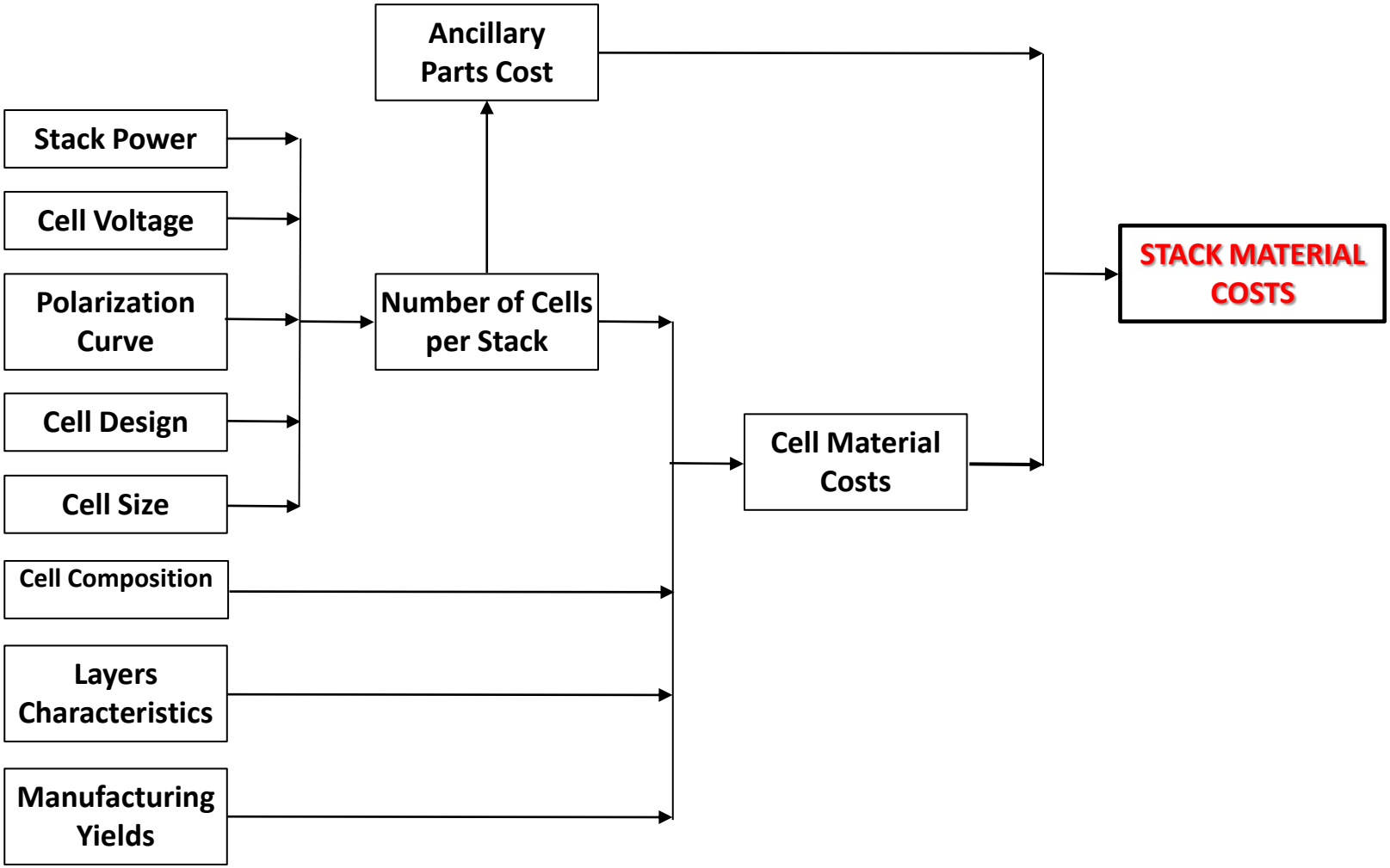
- Research and Development
- Sales and Marketing
- General and Administration
- Warranty &Taxes

Cell /Stack Performance for Cost Estimation

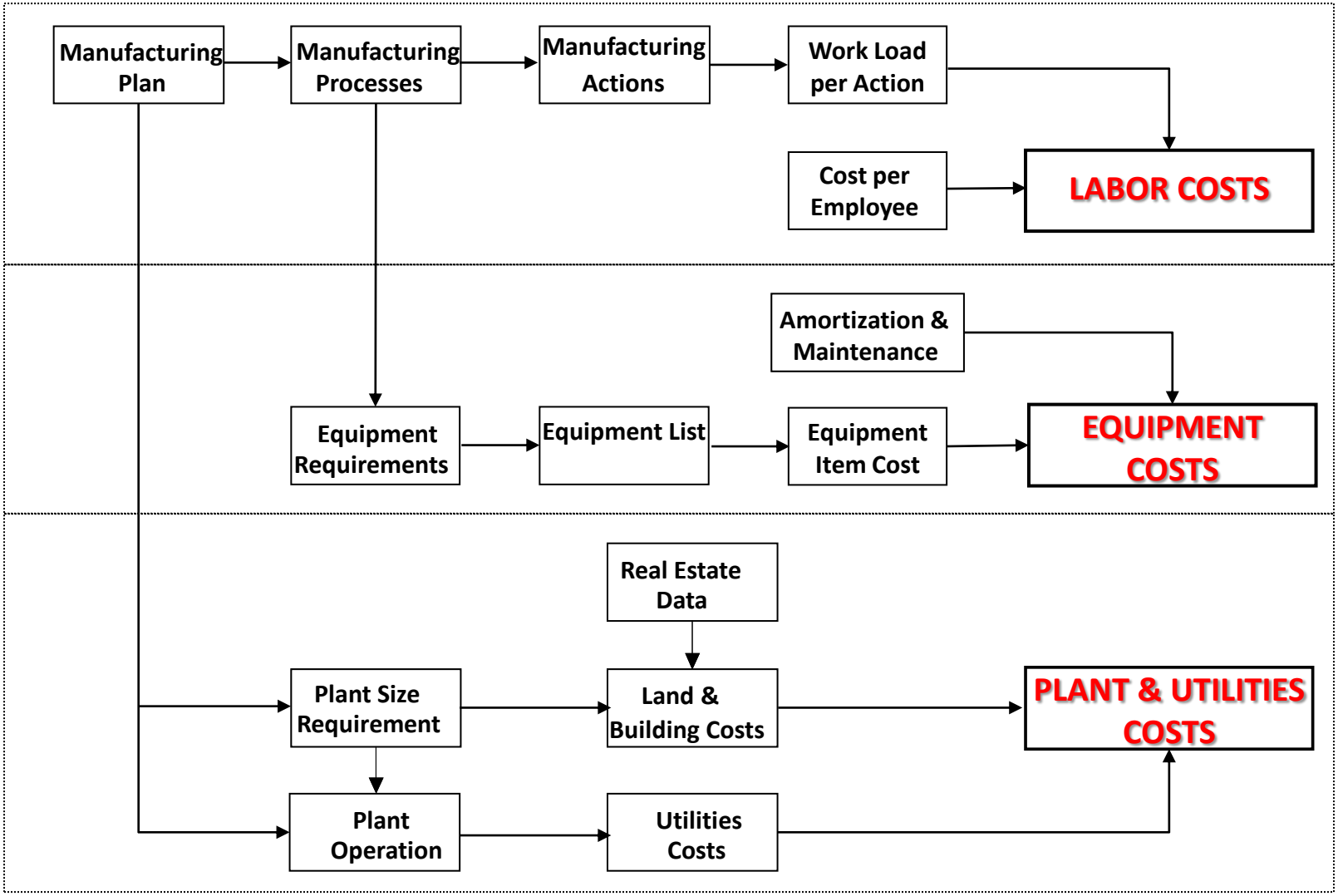


Power Output	5 kW
Temperature	700°C
Fuel	Natural Gas
Fuel Utilization	80%
Power density	1.9 W/cm^2
Current density	2.7 A/cm^2
Voltage	0.7 V
Cell size	10cm X 10cm
No. cell per 5 kW stack	32 cells

Stack Material Cost Estimation



Estimation Process for Other Stack Costs

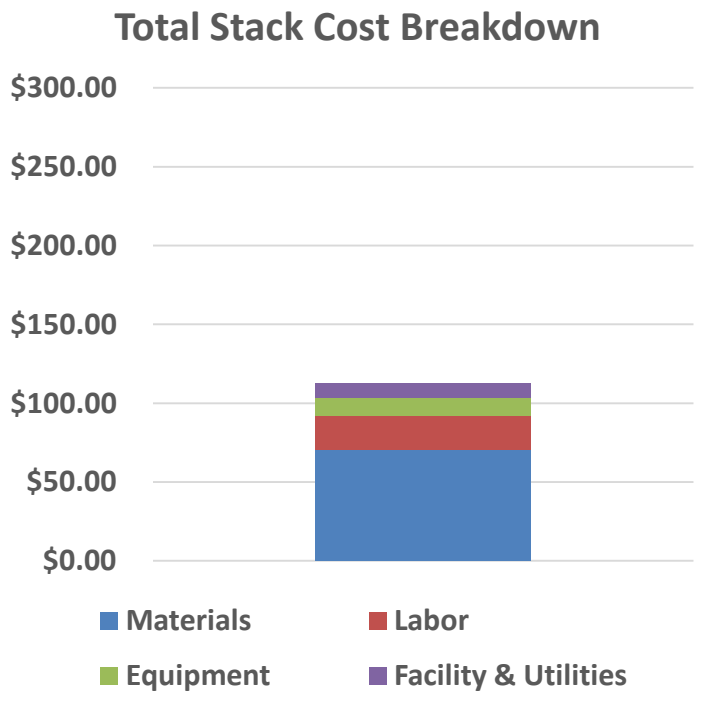


Total Stack Stack Cost Breakdown

Preliminary Results

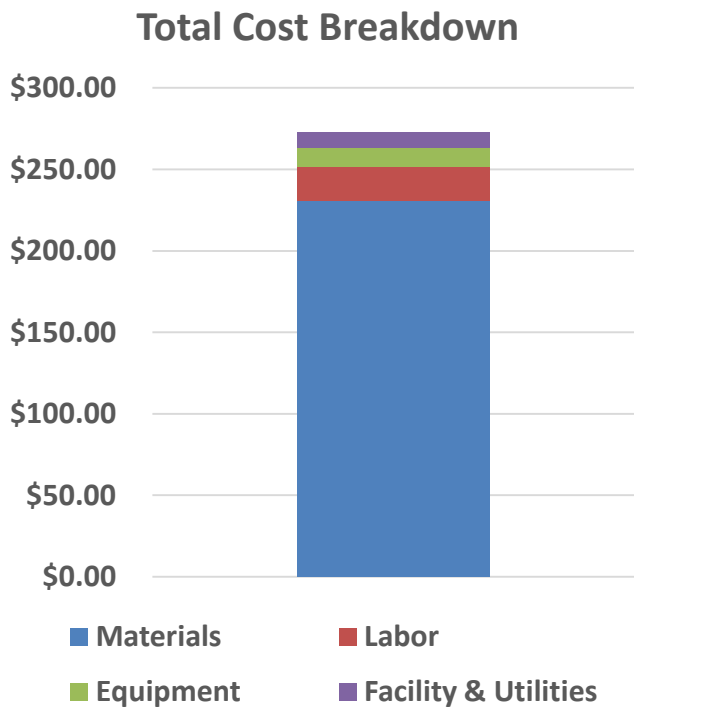
For Sputtered Cell on Metal Support

	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

Key achievements since last project review:

- Fabrication process for prime-surface interconnects
- Cell performance improvements and recorded performance at reduced temperatures with 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