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)
- DOE/NETL Project Manager: Dr. Patcharin Burke
- Project Team:
  - UCSD
    - Center for Energy Research: Dr. Nguyen Minh (PI), Dr. Yoon Ho Lee (Postdoctoral scholar), Dr. Eduard Ron (Postdoctoral scholar)
    - Department of Electrical Engineering and Center for Memory and Recording Research: Dr. Eric Fullerton, Haowen Ren (graduate student)
    - Department of NanoEngineering: Dr. Shirley Meng, Erik Wu (graduate student)
  - FuelCell Energy
    - Dr. Hossein Ghezel-Ayagh and Dr. Alireza Torabi

Project Objective and R&D Work

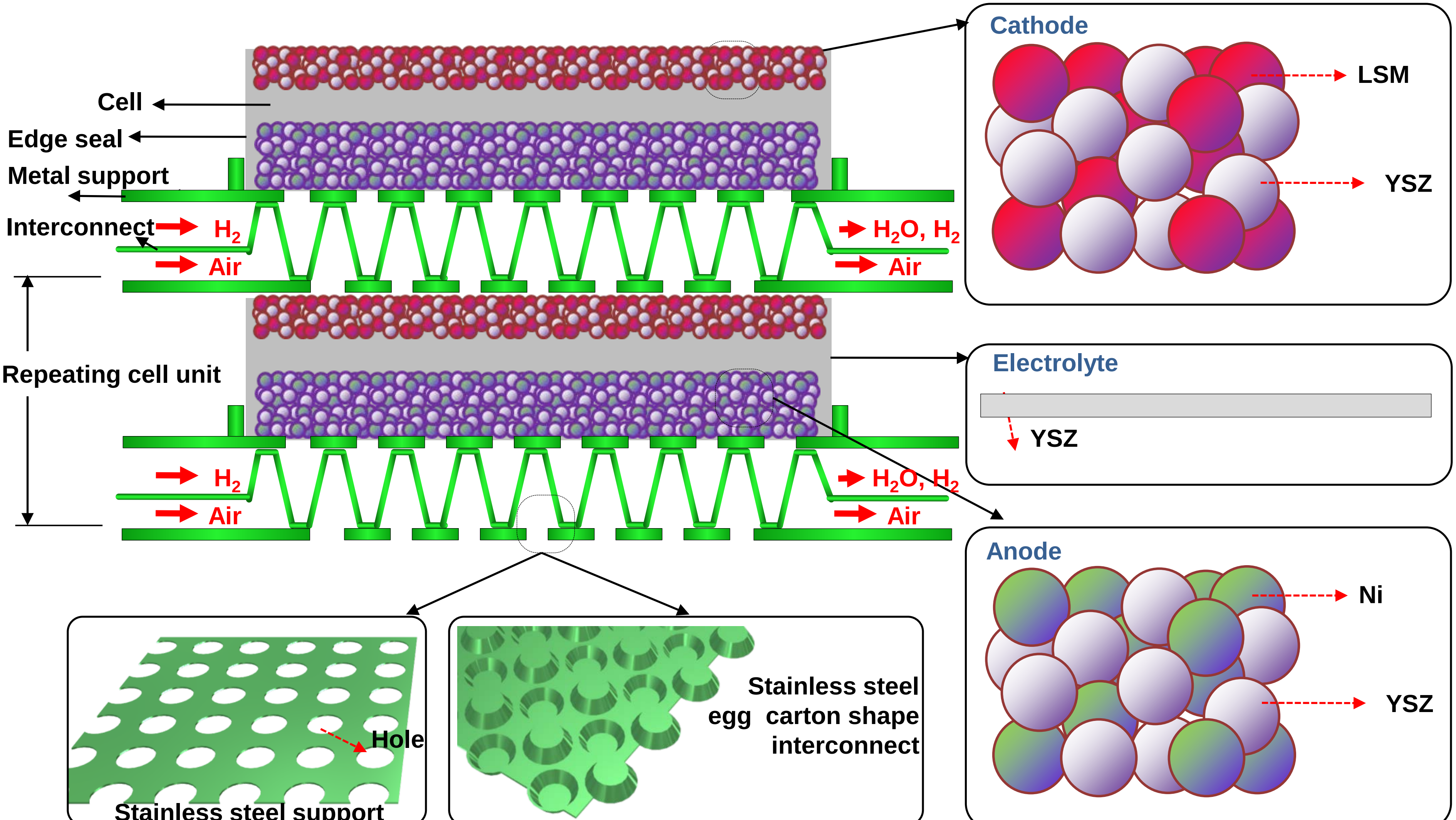
- Objective: Develop and evaluate a versatile stack configuration based on a prime-surface interconnect design for a broad range of power generation applications

- R&D Work: Involve R&D activities to demonstrate fabricability, operability and affordability of the stack design

STACK DESIGN CONCEPT

Stack Design

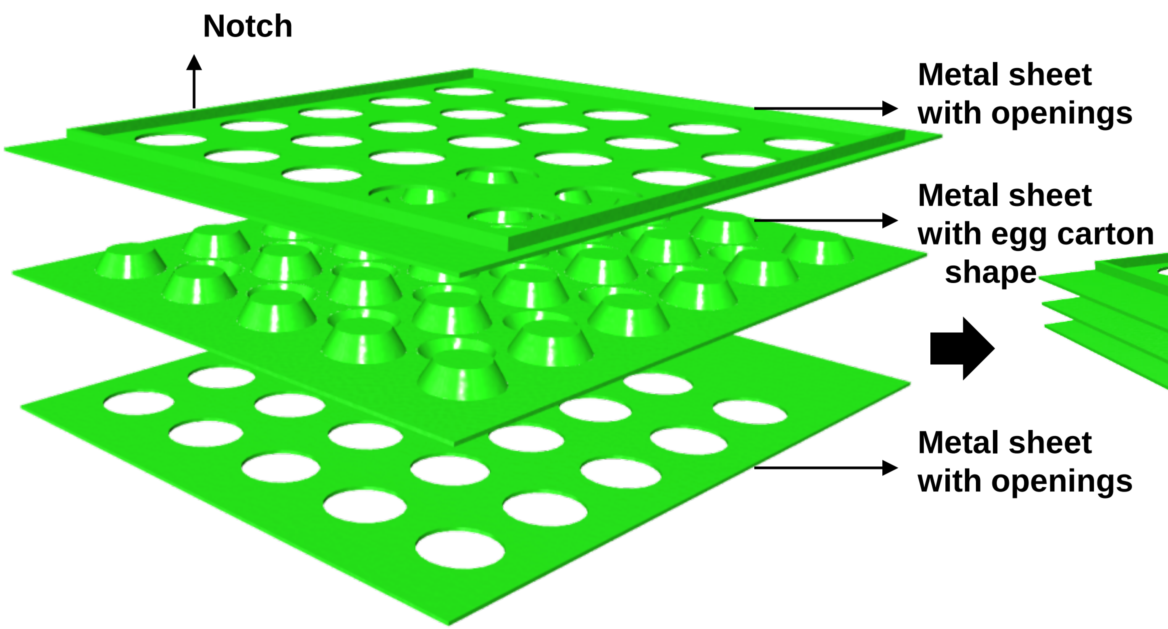
Incorporating Conventional Cells

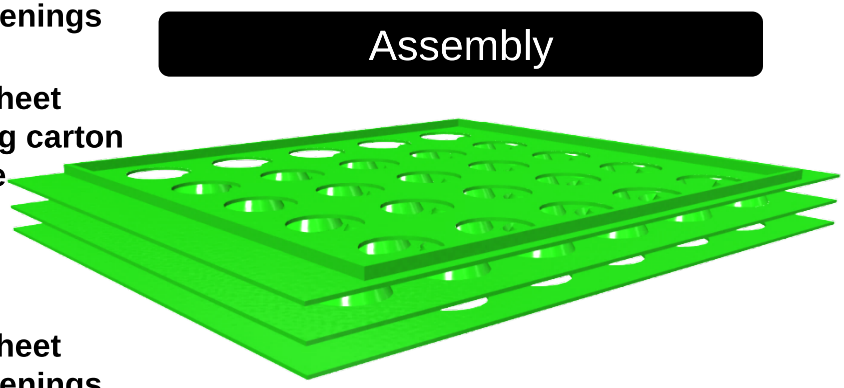


Features of Stack Concept

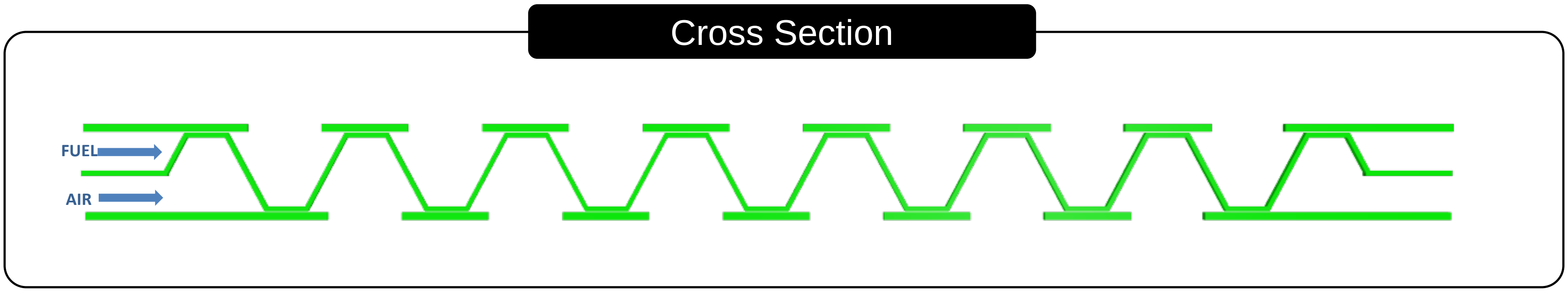
- Reduced weight and volume
- Flexibility in gas flow configuration
- Reduced stacking performance losses
- Improved sealing
- Versatility in incorporation of different types of cell construction

Prime-Surface Interconnect Design



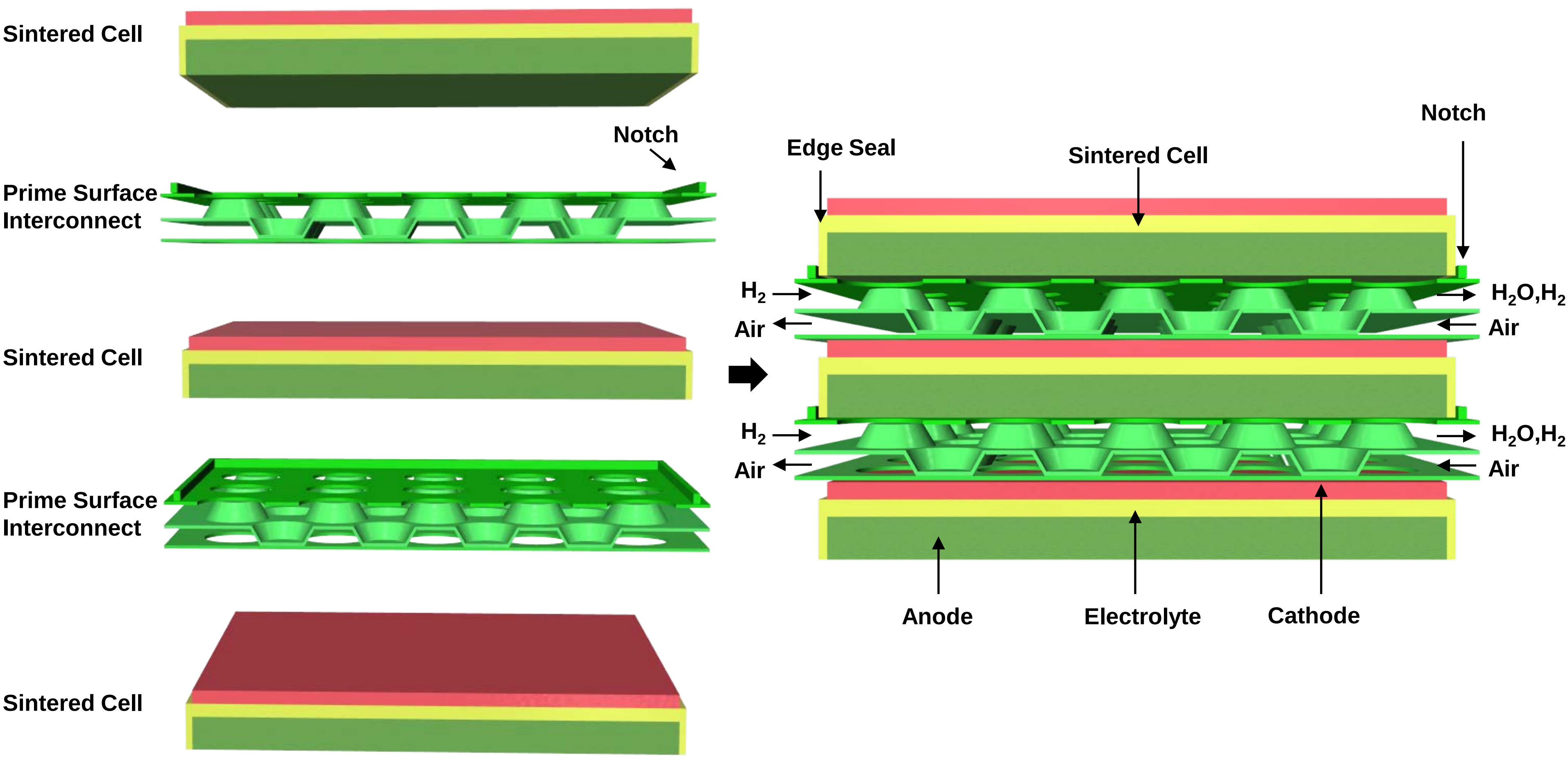


Not in Scale



Stack Design

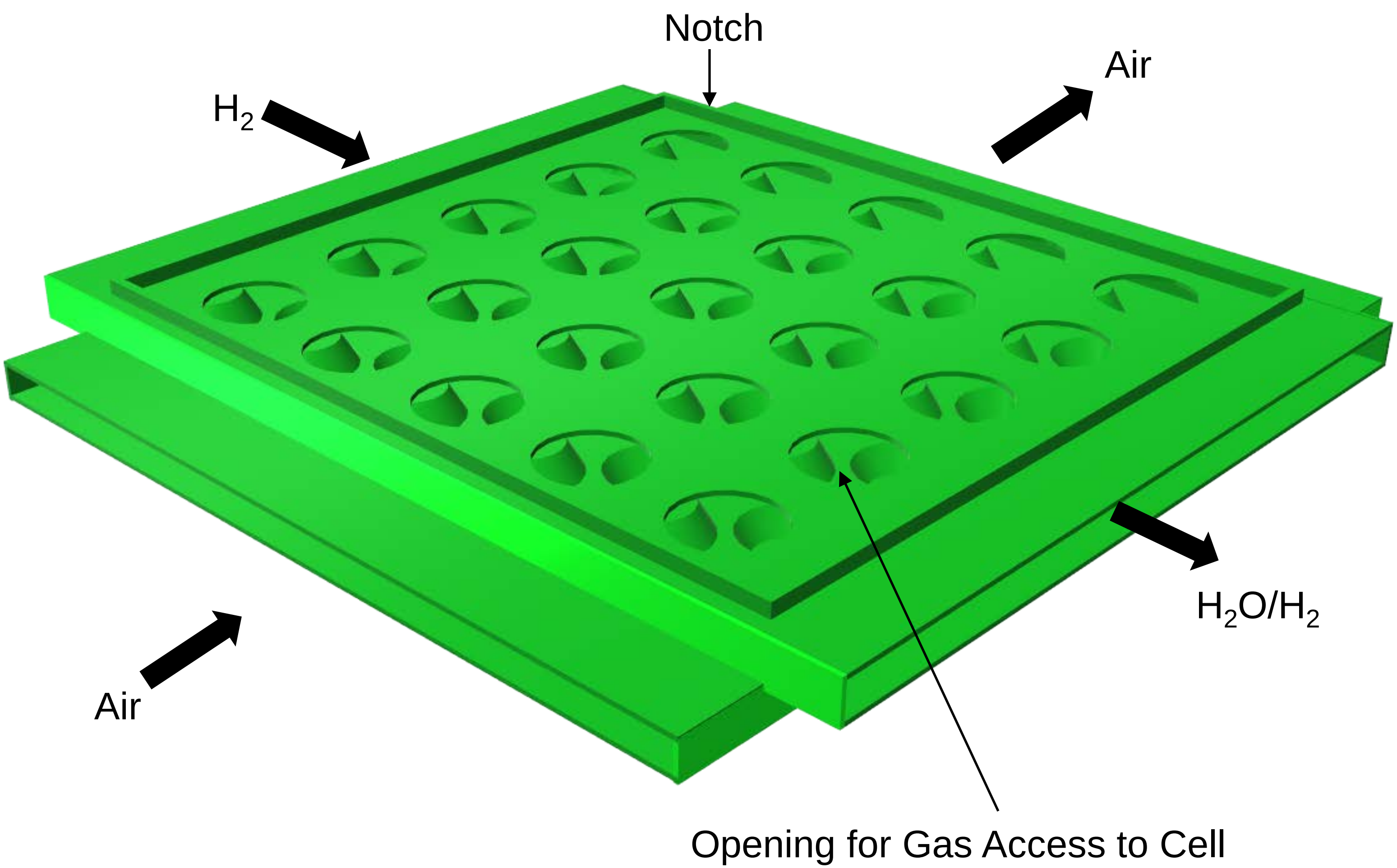
Incorporating Sintered Cells



Not in Scale

Stack Design

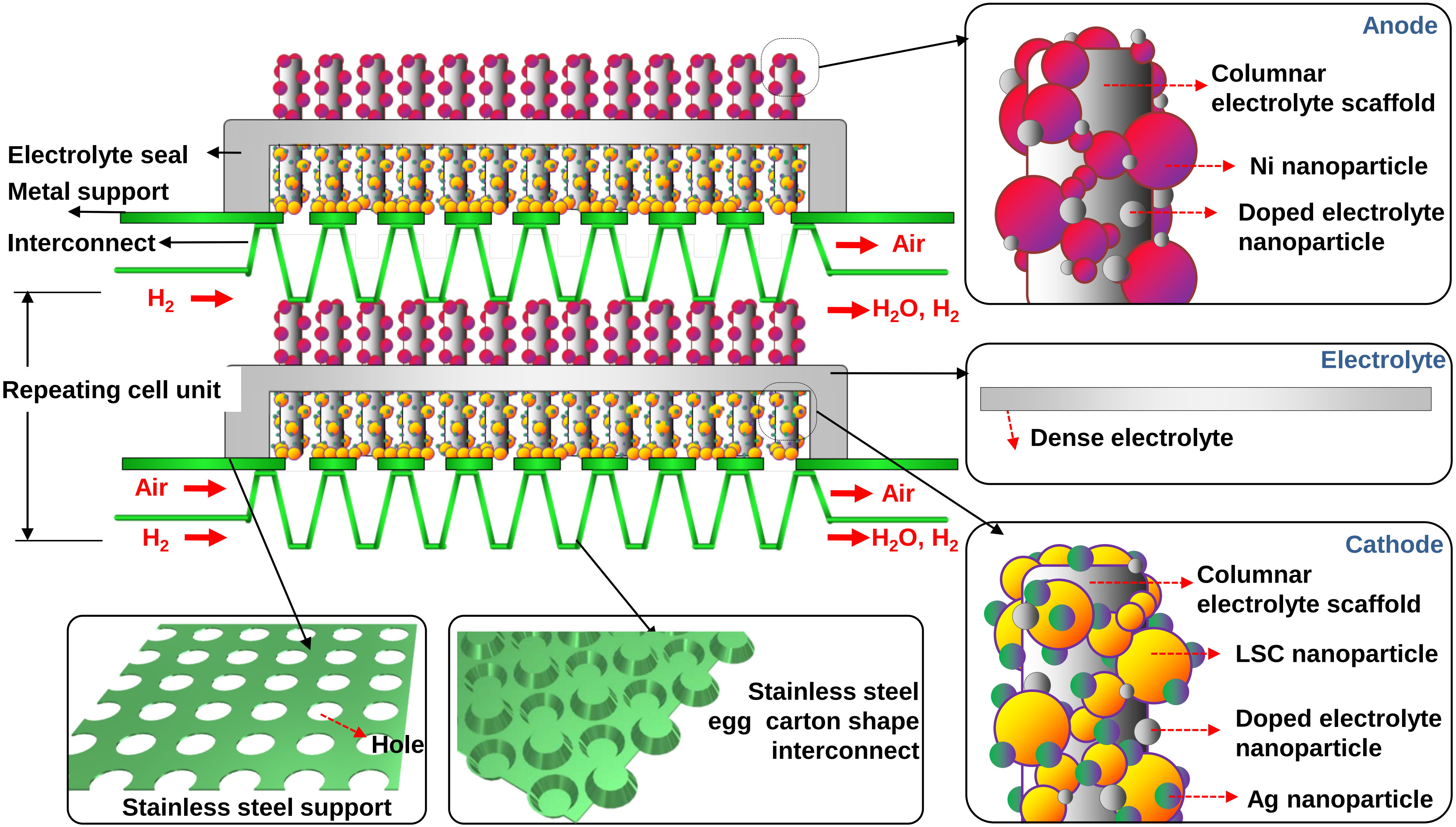
Cross Flow Gas Manifolding



Not in Scale

Stack Design

Incorporating Metal-Supported Cells



Project Technical Activities

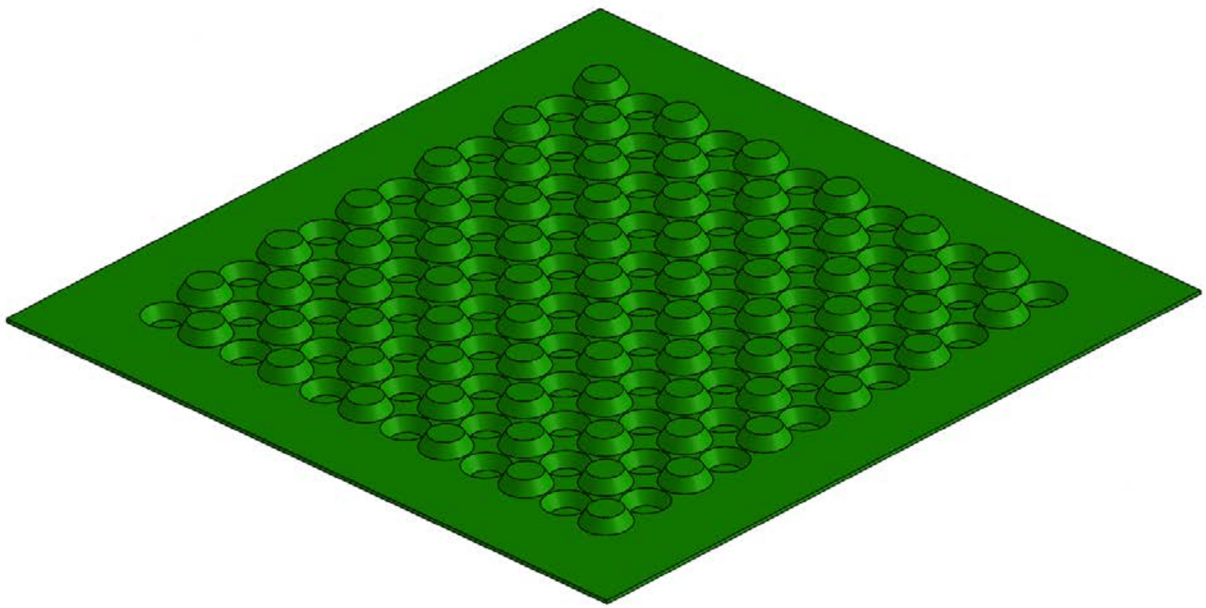
- Prime surface interconnect design and fabrication development
- Metal-supported cell structure development
- Stack development
- Stack operation demonstration
- Stack cost assessment

PRIME SURFACE INTERCONNECT DEVELOPMENT

Preliminary Interconnect Design Assessment

- Flow distribution
- Mechanical loading
- Current collection
- Formability

Prime Surface Interconnect Design



Parameter	Value
Interconnect height	2.5mm
Interconnect sheet thickness	0.3mm
Cone angle	60^{o}
Diameter of the cone	4mm
Mass of one sample (60 mm x 60 mm)	10.56 grams

Gas Flow Distribution Modeling

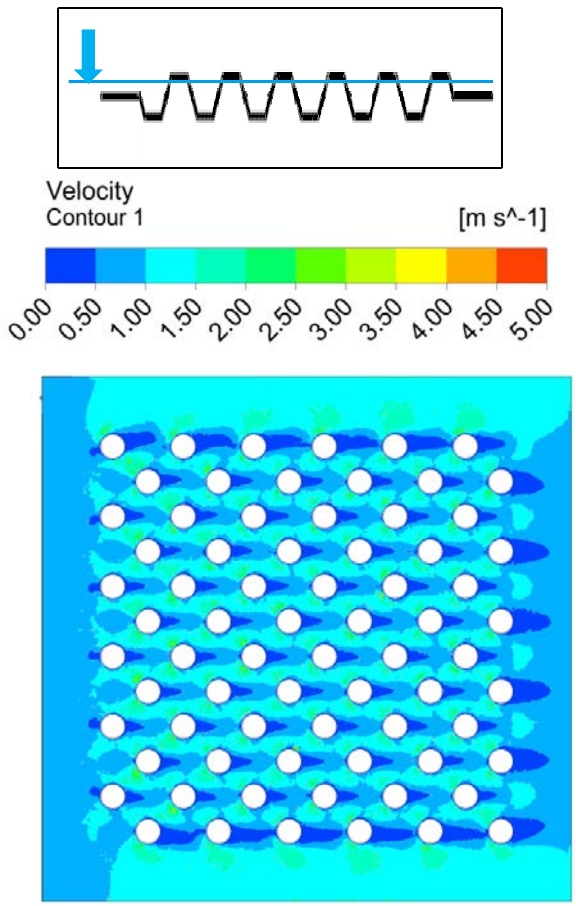
- Approach: FLUENT software, LES & URANS turbulence models

- Inlet boundary conditions:

Parameter	**Value**
Inlet velocity	2 m/s
Temperature of the flow	800°C
Interconnect design	Egg carton shape
Fuel type	Hydrogen

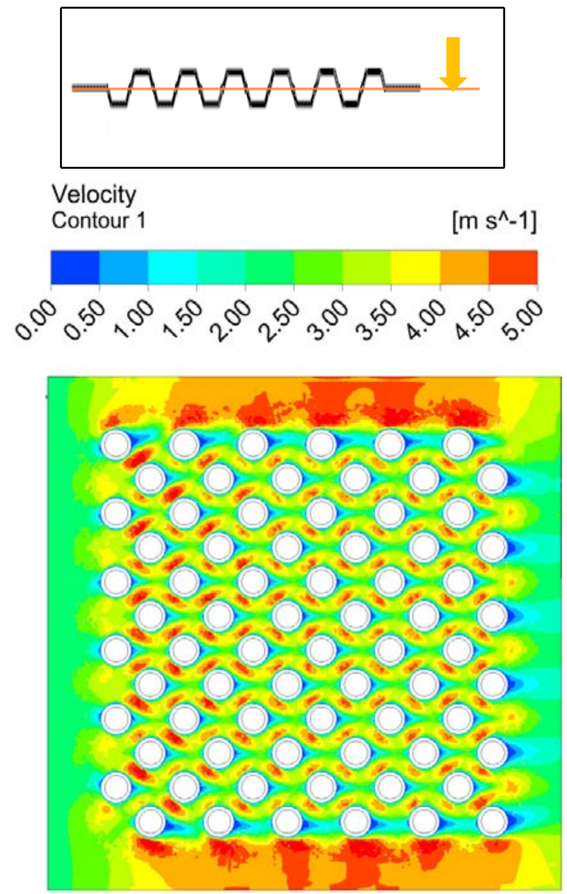
Gas Flow Patterns

Plane near interconnect/cell interface



- Flow is uniform with areas of boundary layer detachment in the wakes of the hills

Plane in interconnect center



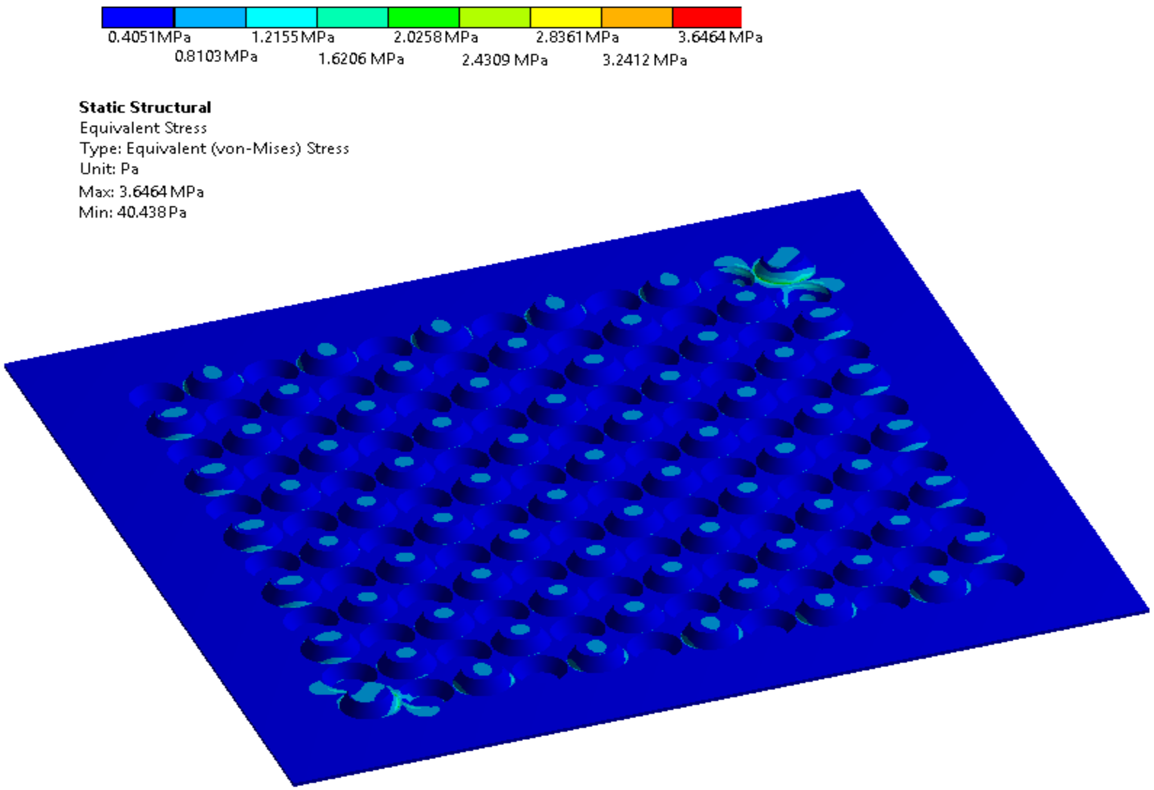
- Flow exhibits areas of acceleration
- Potentially that can be used for improved diffusion

Mechanical Loading Modeling

- Approach: ANSYS Mechanical software, modeling of loading within a stack
- Parameters:

Parameter	Value
Temperature of the cell	800ºC
Interconnect design	Egg carton shape
Cell type	Conventional anode-supported
Number of cells in the stack	100
Interconnect material	Ferritic stainless steel

Stress Analysis



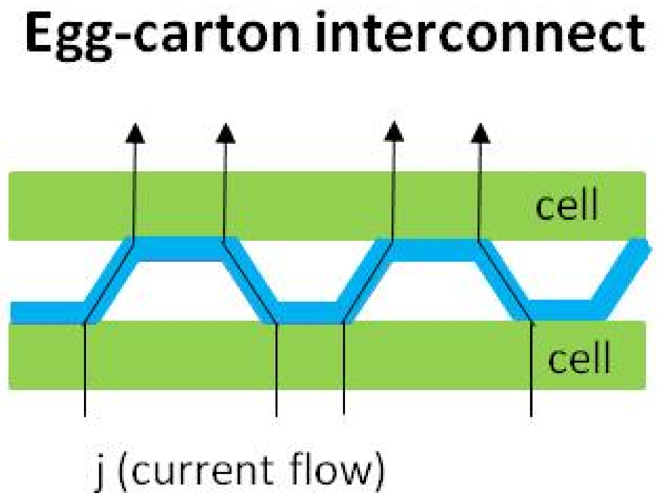
- The appeared stresses of 3.65MPa at the bottom cell are much lower than the yield strength of ferritic stainless steel (240MPa)

Current Collection Modeling

- Approach: Analytical calculations
- Parameters:

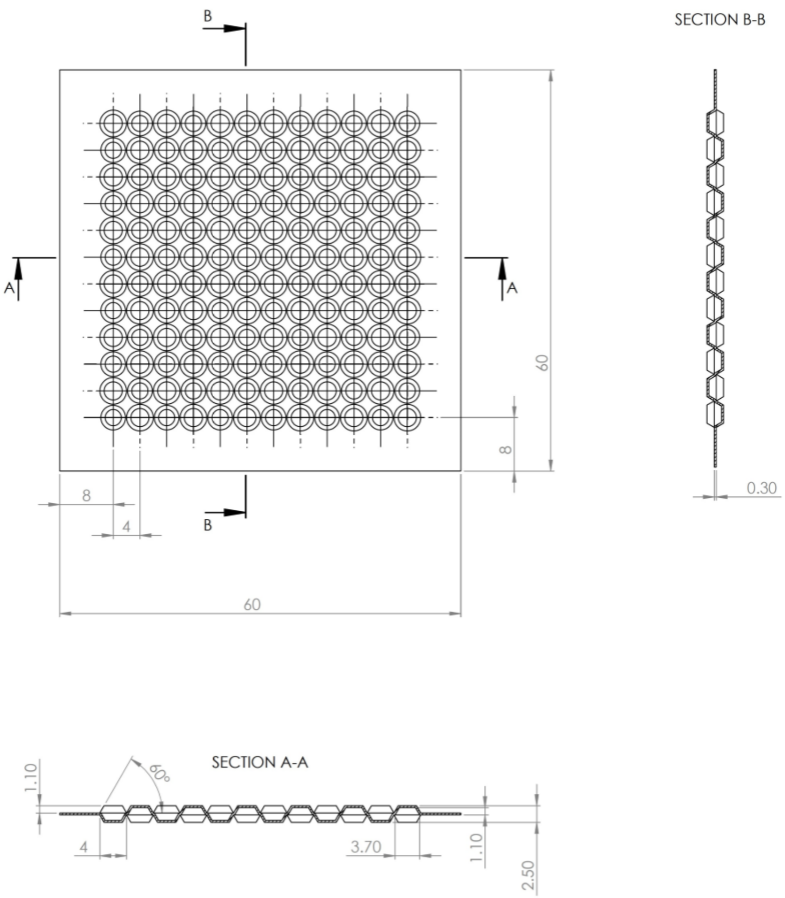
Parameter	Value
Interconnect height	2.5mm
Interconnect sheet thickness	0.3mm
Cone angle	60^{o}
Diameter of the cone	4mm

Current Collection Losses



- Evaluation was performed for a simplified interconnect design and egg carton shape
- Egg-carton shape accounts for insignificant increase in the area-specific resistance as compared to that of a cell
- Negligible current density losses with egg carton shaped interconnects

Interconnect Formability



Engineering drawing

- Engineering drawing produced
- Hydroforming method of production chosen
- The interconnect manufacturer Borit™ contacted
- Positive feedback on its manufacturability received

Prime Surface Interconnect Design

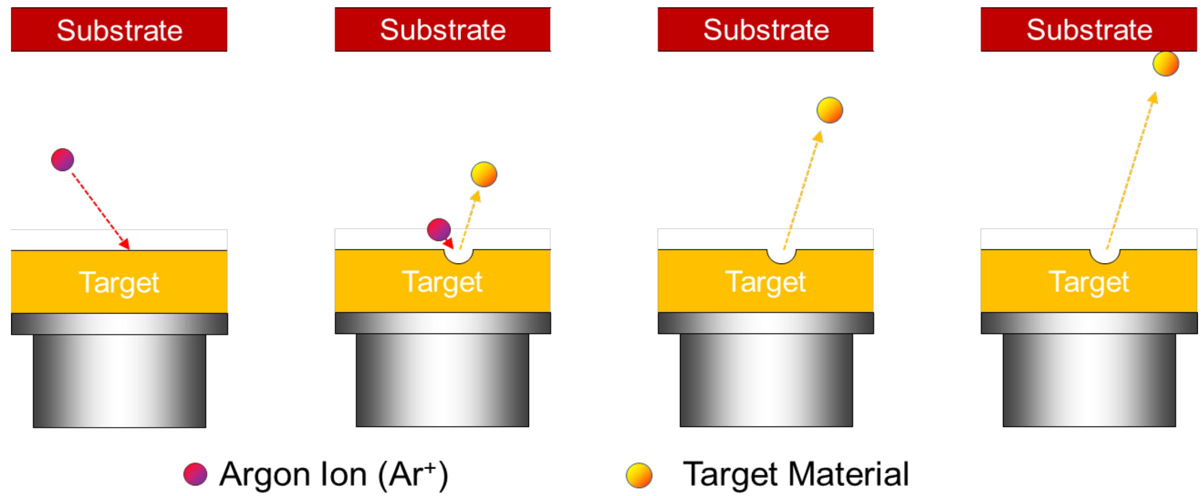
Preliminary Assessment Summary

- No flow maldistribution
- Stress estimated at interconnects well below yield strength of stainless steels
- Interconnect current collection without significant losses
- Formability possible with hydroforming

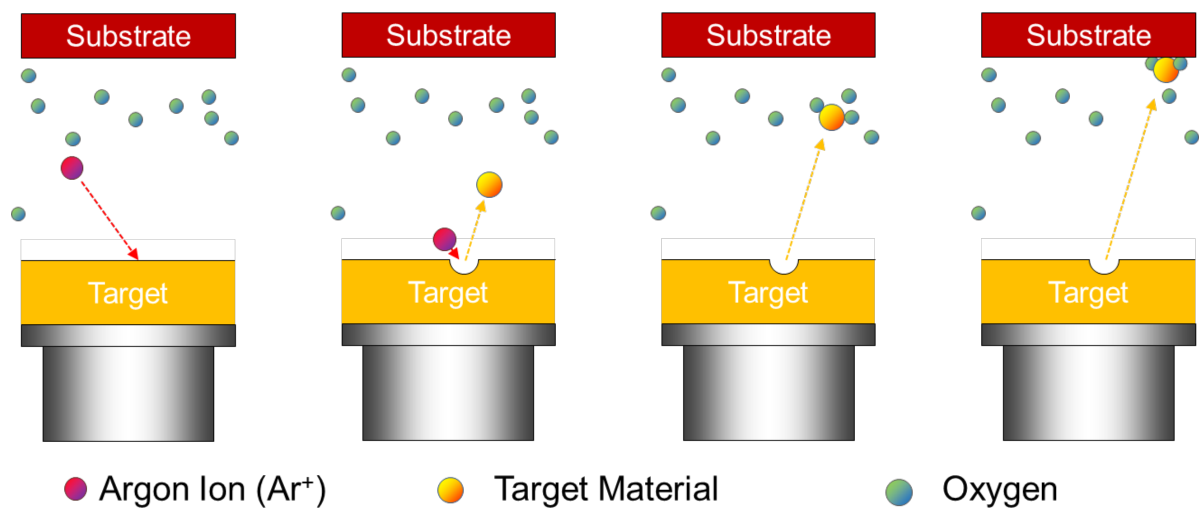
METAL-SUPPORTED CELL STRUCTURE FABRICATION

Sputtering Process

Conventional

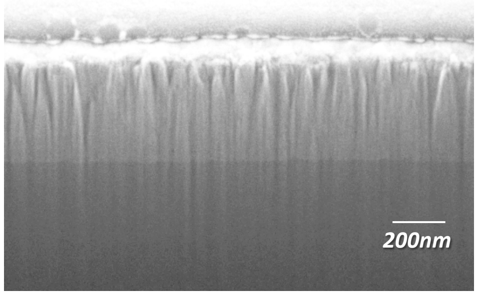


Reactive



Sputtering for SOFC Cell Fabrication

- Fabrication of dense and porous layers



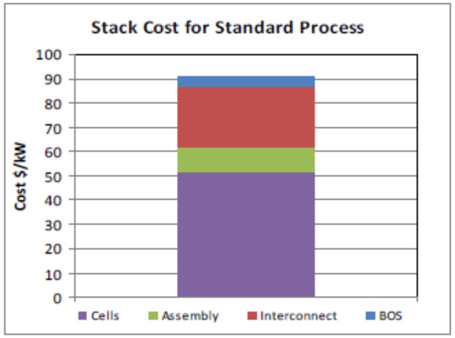
Nano-scale Dense YSZ layer

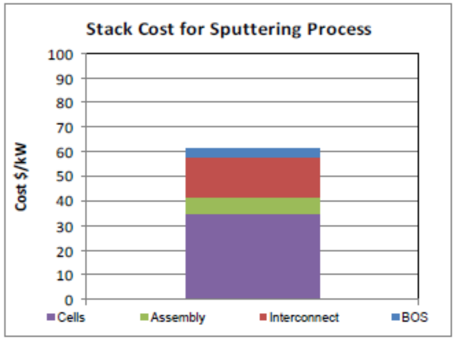
- Scalability

Goldstone Vacuum Sputter System
http://www.goldstone-group.com/

Sputtering Target by AZO Materials
http://www.azom.com/

- Potential cost effectiveness

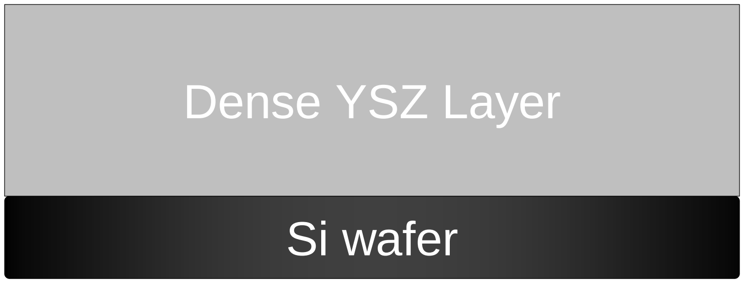




Weimar et al, PNNL Report PNNL-22732, 2013

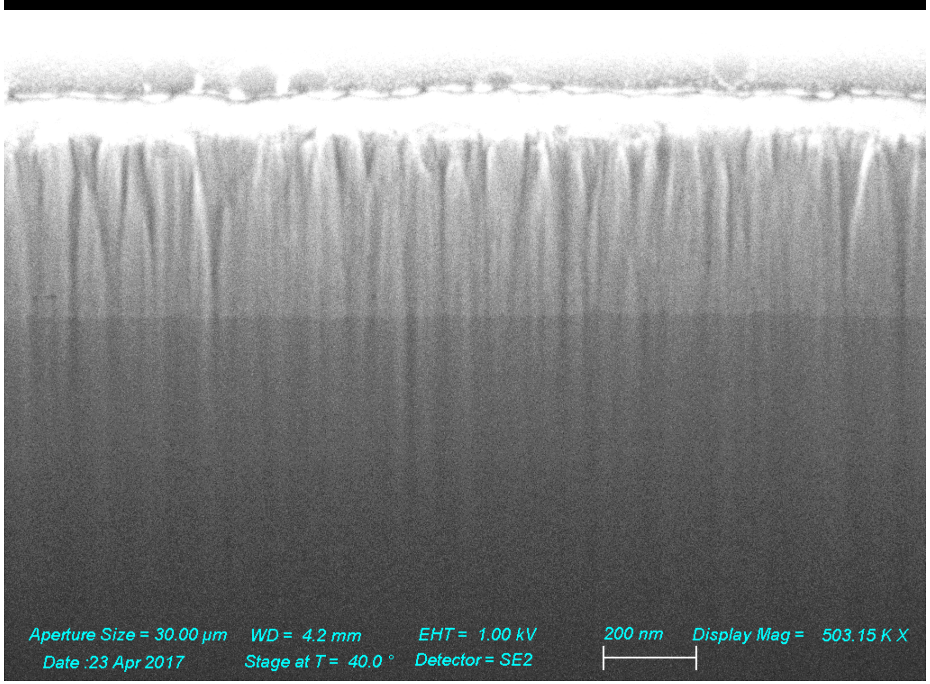
Fabrication of Dense YSZ Layers

Structure & Condition

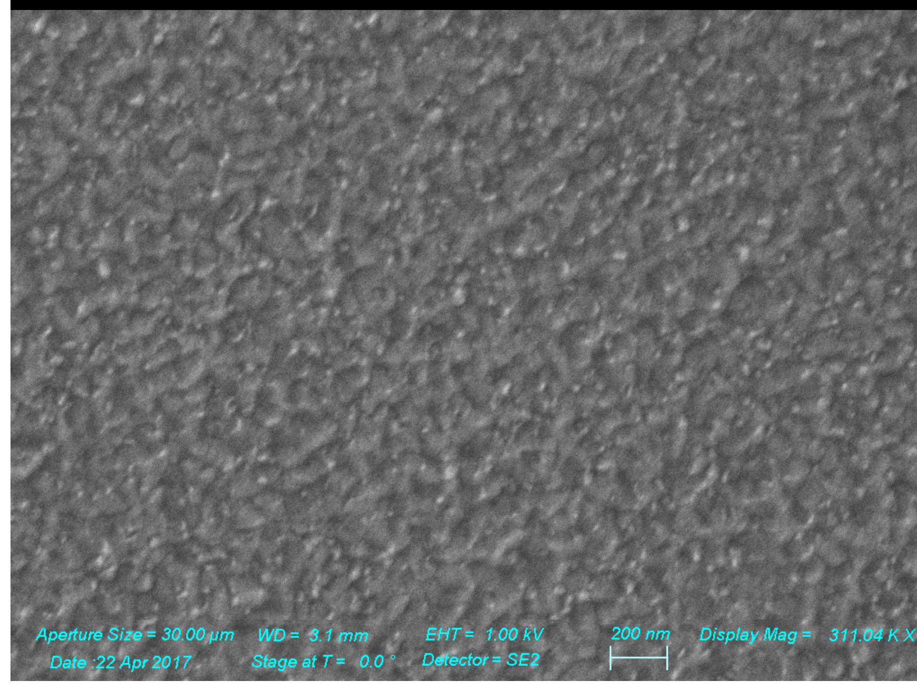


Target	Y/Zr
Pressure	5mtorr
Gas Flow	50sccm of Ar
Power	200W
T-S Distance	70mm
Time	7200sec

Cross Section

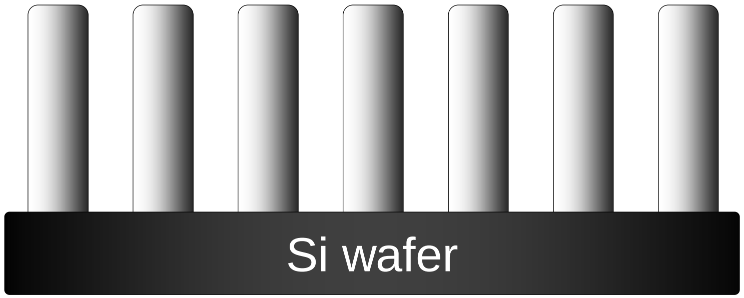


Surface



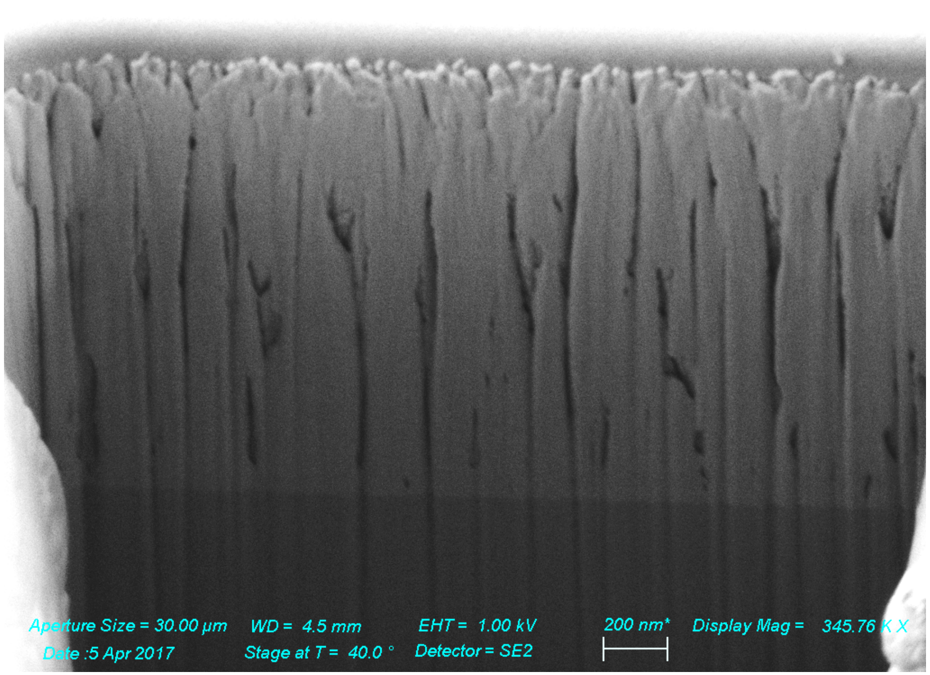
Fabrication of Porous YSZ Structures

Structure & Condition

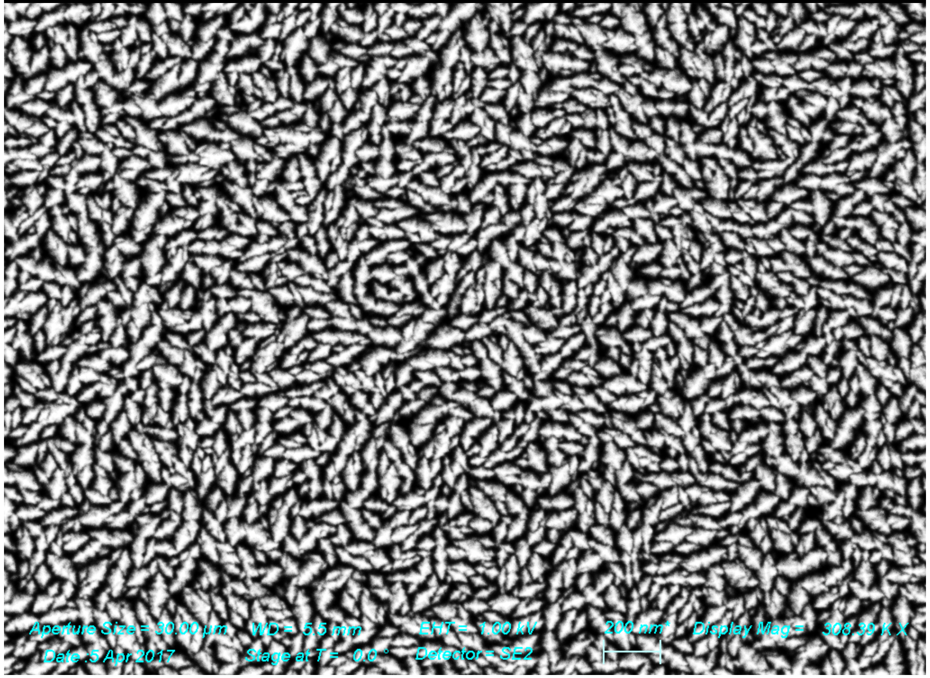


Target	Y/Zr
Pressure	30mtorr
Gas Flow	50sccm of Ar
Power	200W
T-S Distance	120mm
Time	7200sec

Cross Section

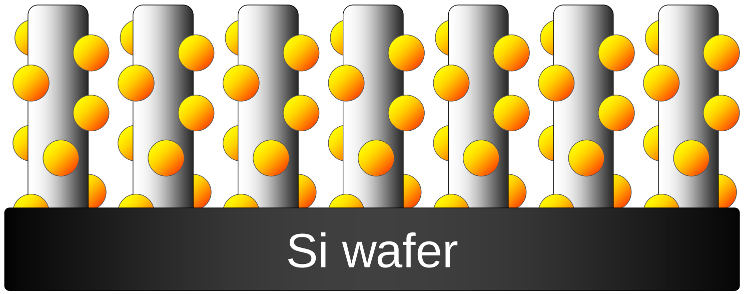


Surface



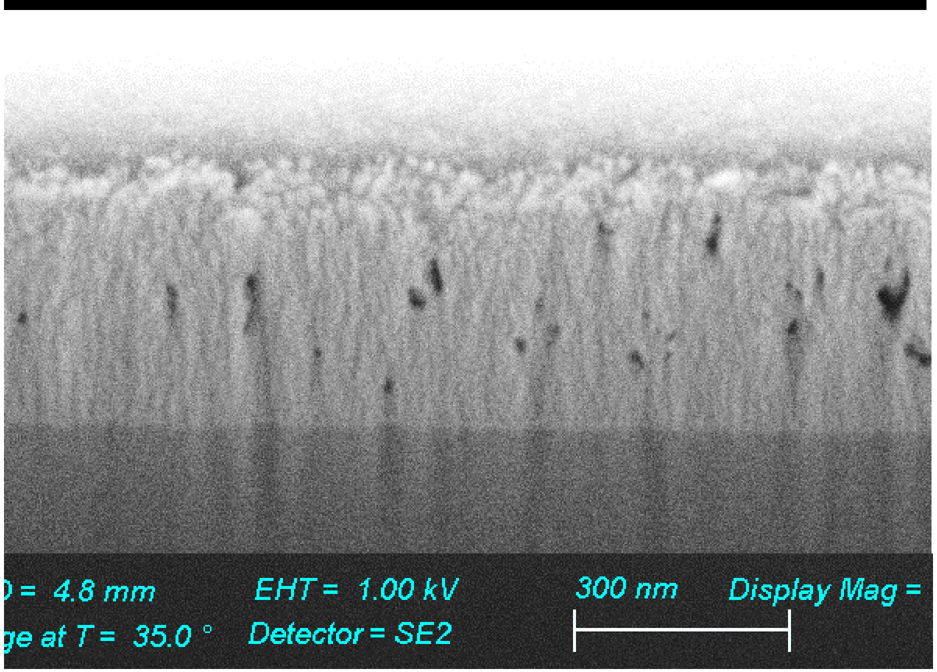
Fabrication of Porous Ni-YSZ Layers

Structure & Condition

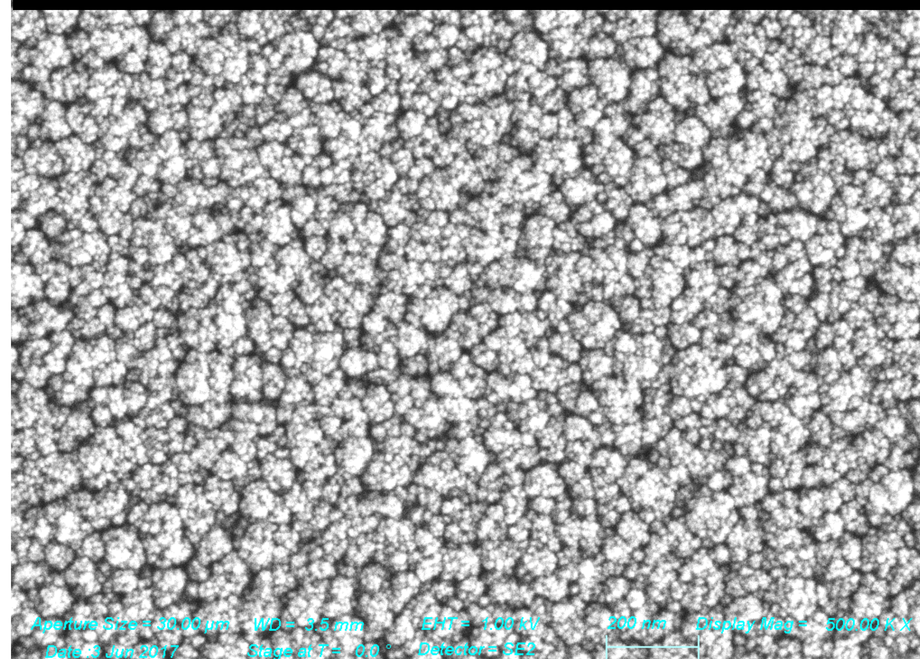


Target	Y/Zr	YSZ	Ni
Pressure	30mtorr		
Gas Flow	50sccm of Ar		
Power	25W	200W	100W
T-S Distance	120mm		
Time	7200sec		

Cross Section

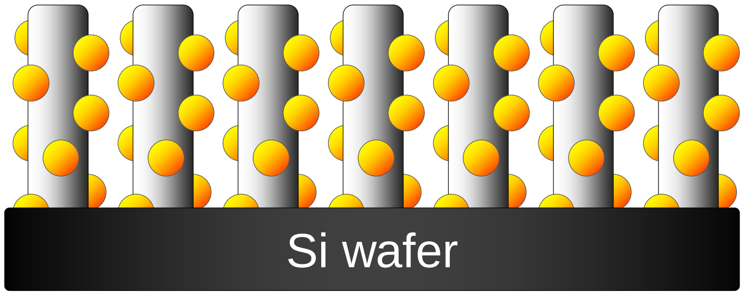


Surface

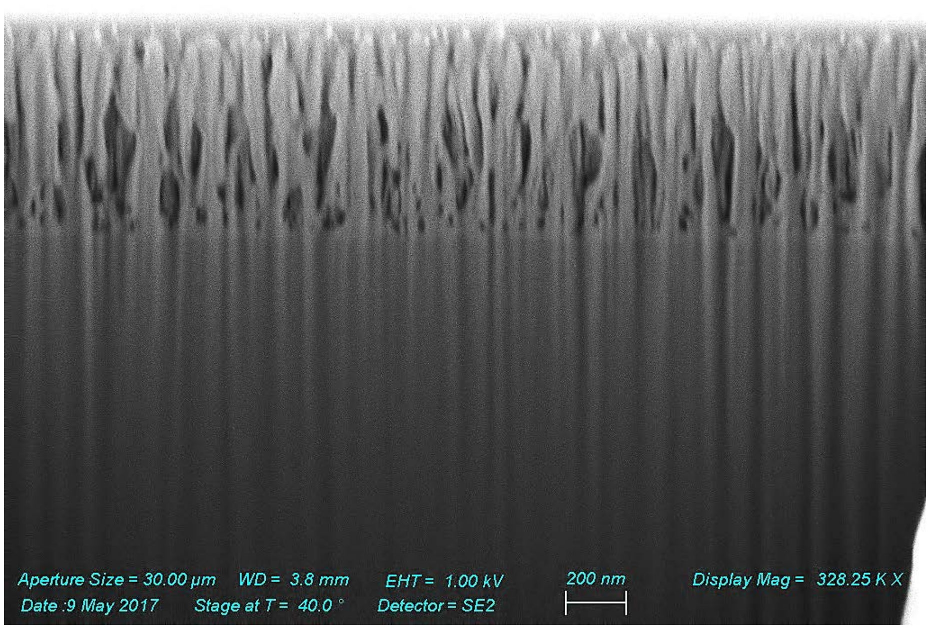


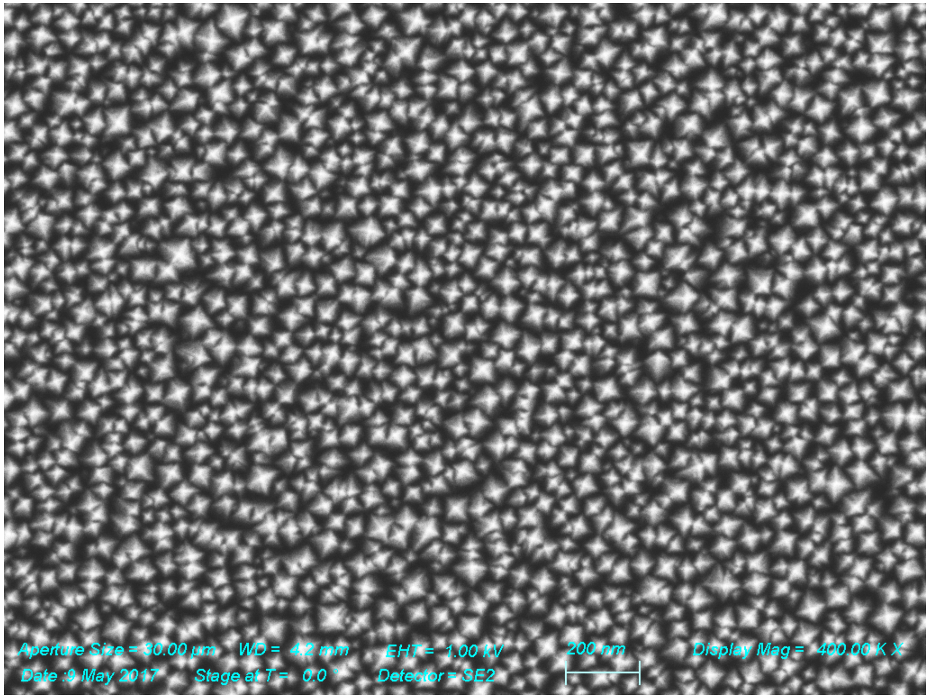
Fabrication of Porous LSC-YSZ Layers

Structure & Condition

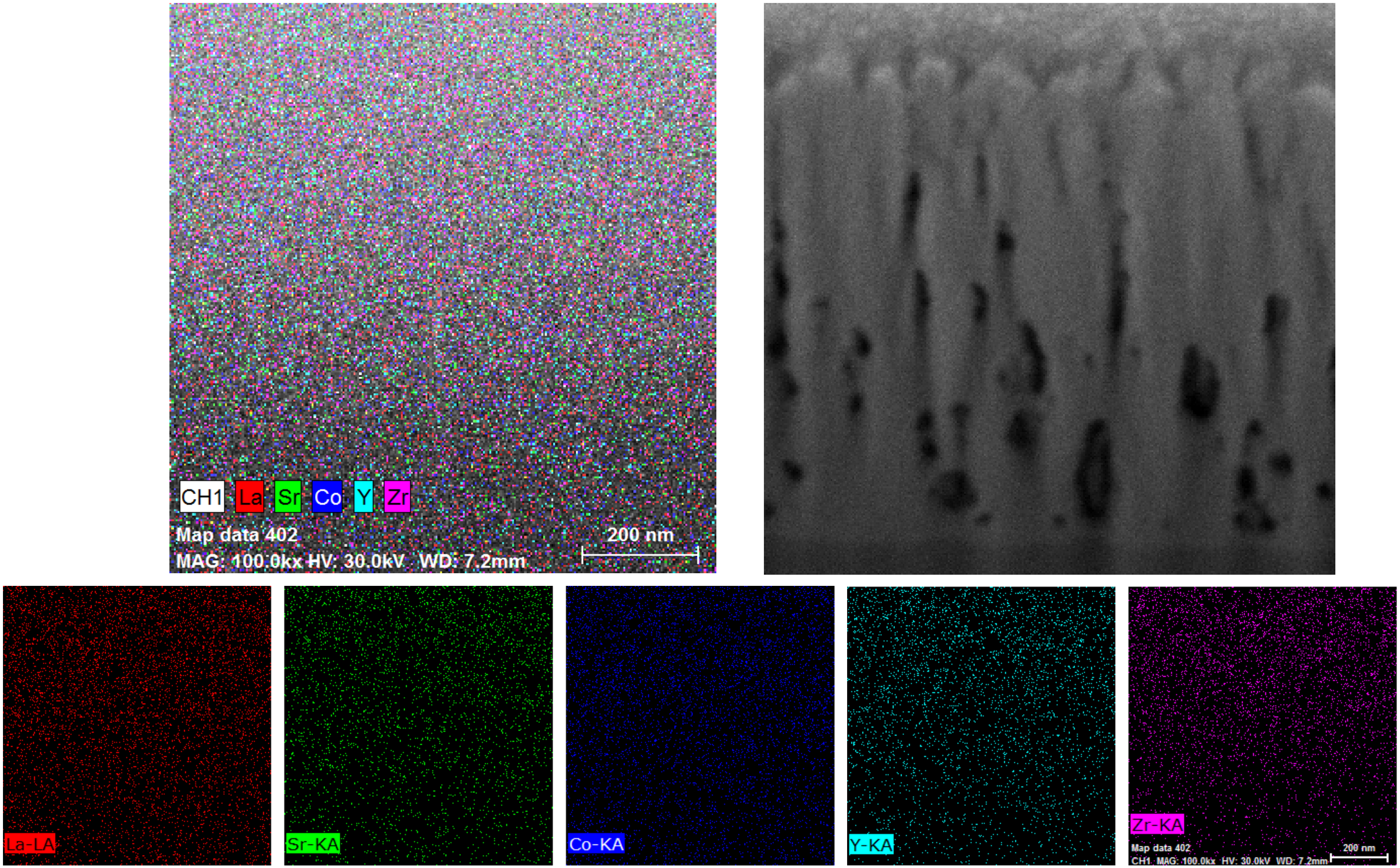


Target	Y/Zr	LSC
Pressure	30mtorr	
Gas Flow	50sccm of Ar	
Power	50W	200W
T-S Distance	120mm	
Time	7200sec	

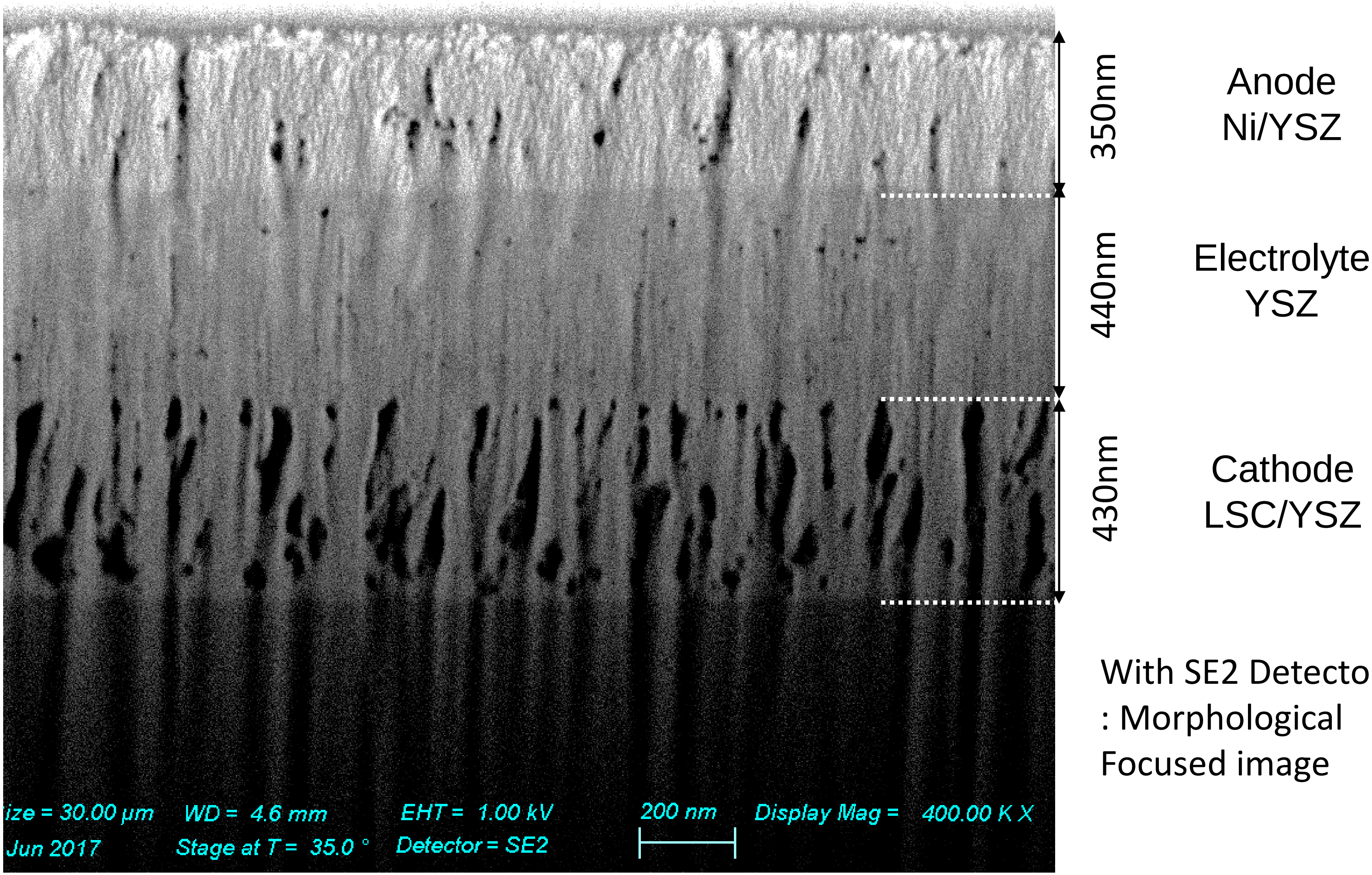




EDX Mapping of Deposited LSC- YSZ Layer

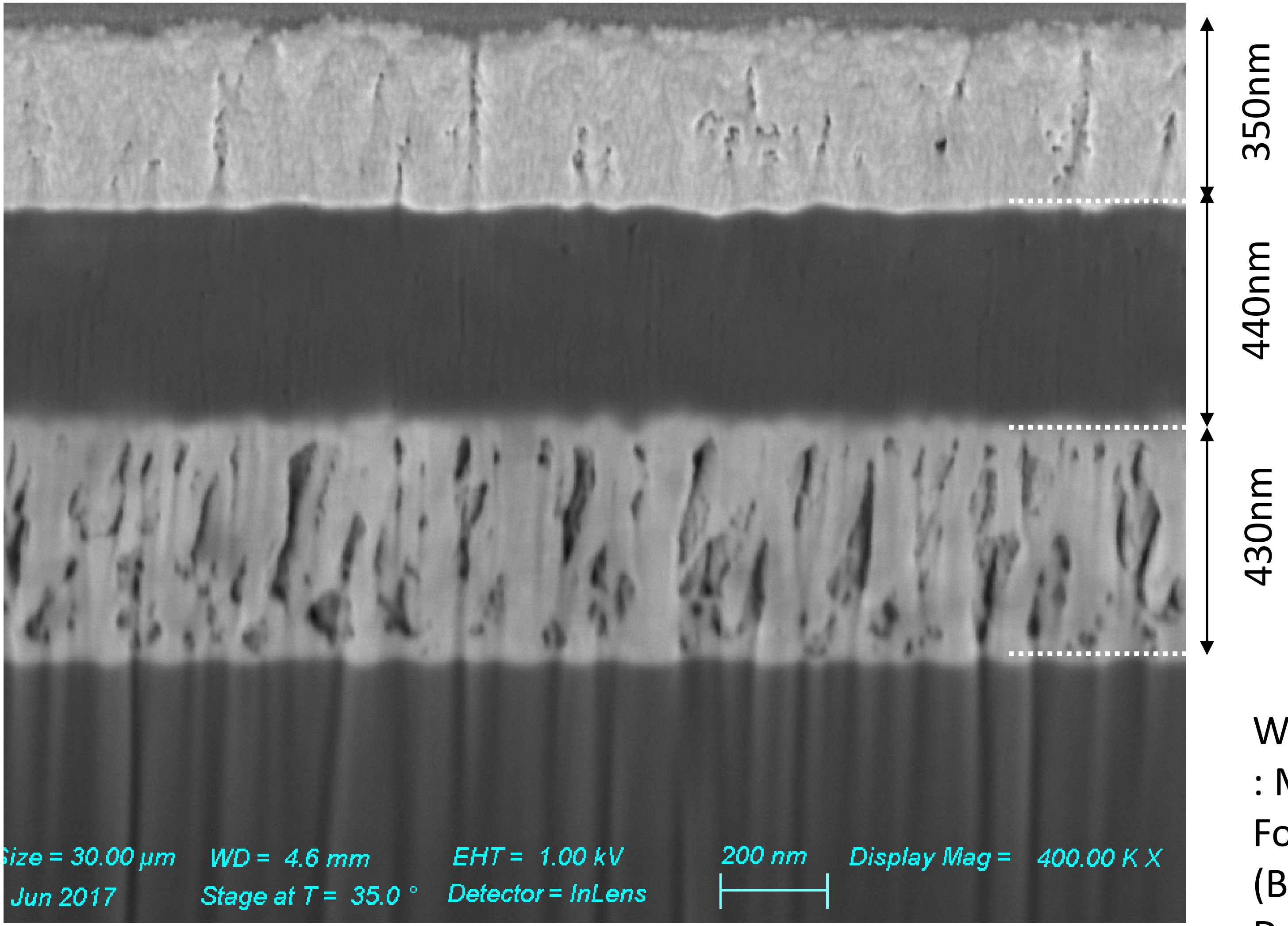


Fabrication of SOFC Cell



With SE2 Detector
: Morphological
Focused image

Fabrication of SOFC Cell



Anode
Ni/YSZ

Electrolyte
YSZ

Cathode
LSC/YSZ

With InLens Detector
: Material
Focused image
(Bright : Conductor
Dark : Insulator)

Metal-Supported Cell Development

Preliminary Fabrication Results Summary

- Fabrication feasibility demonstration by sputtering
  - Dense YSZ electrolyte layers
  - Porous YSZ structures
  - Porous Ni-YSZ layers
  - Porous LSC-YSZ layers
  - Single cell structures
- Uniform layer thickness and excellent interfaces between layers
- Electrode porosity improvements required

Near-Term Future Work

- Prime surface interconnect development
  - Initiate and evaluate hydroforming of egg carton shaped interconnect and characterize fabricated samples
  - Modify and optimize design
- Metal-supported cell structure development
  - Modify and optimize sputtering process and characterize fabricated samples
  - Fabricate and characterize single cells
  - Fabricate cell components and single cells on metal supports
- Stack development
  - Initiate assembling of stacks incorporating prime surface interconnects and sintered cells

Acknowledgments

- DOE/NETL SOFC project management, especially Dr. Patcharin Burke
- UCSD/FCE SOFC project team