

# SOFC Development at GE Global Research

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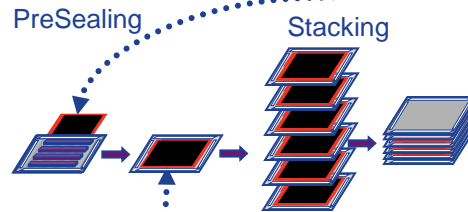
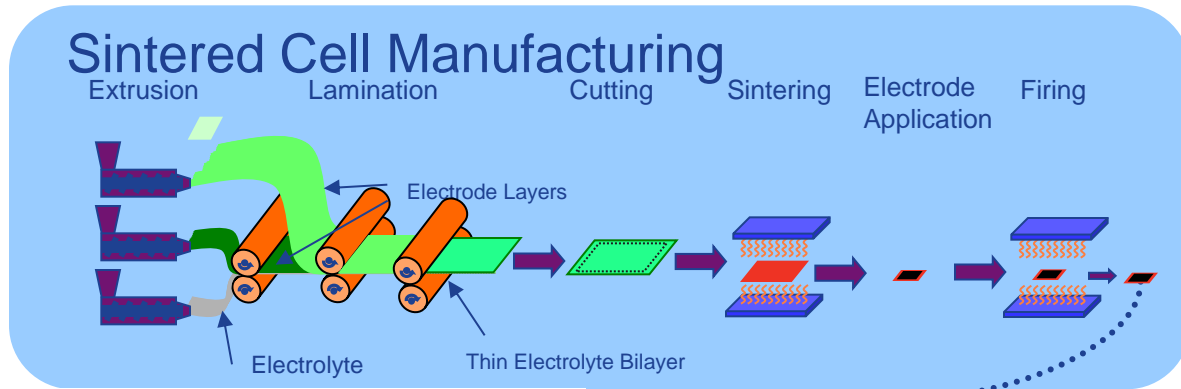


imagination at work



# Low-cost manufacturing

## Sintered Cell Manufacturing



## Advantages

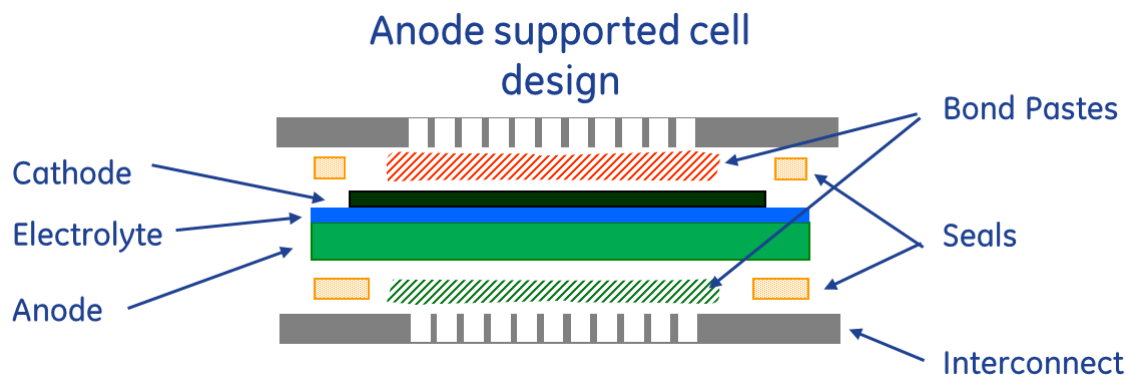
- Larger area / Scalable
- Simplified Sealing
- Low Capex / Modular
- Lean Manufacturing

## Thermal Spray



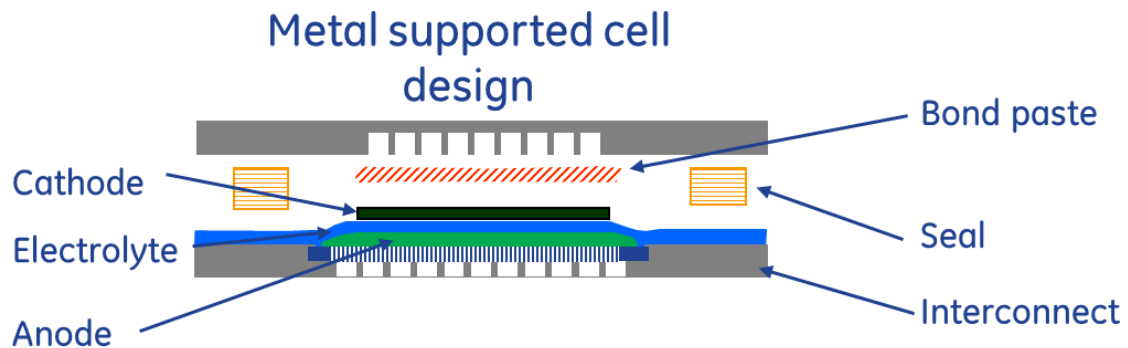
Leverage GE thermal spray expertise

# Metal supported cell



## Advantages:

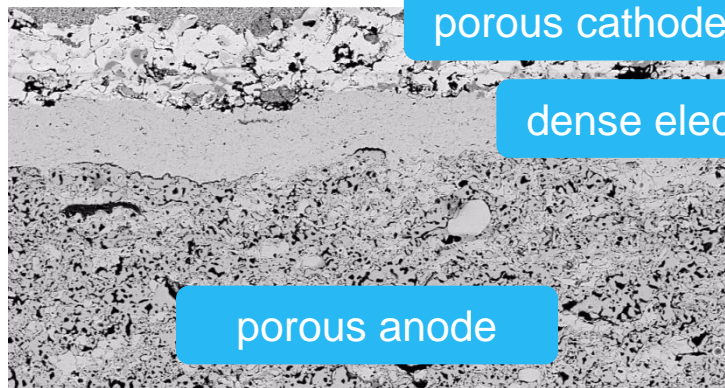
- Integrated anode seal
- Electrolyte in compression
- Improved anode electrical contact
- Increased active area
- Lower anode polarization
- Allows redesign of structures



## Challenges:

- Dense / hermetic electrolyte
- Porous metal substrate degradation

# Thermal spray manufacturing challenges



porous cathode

dense electrolyte

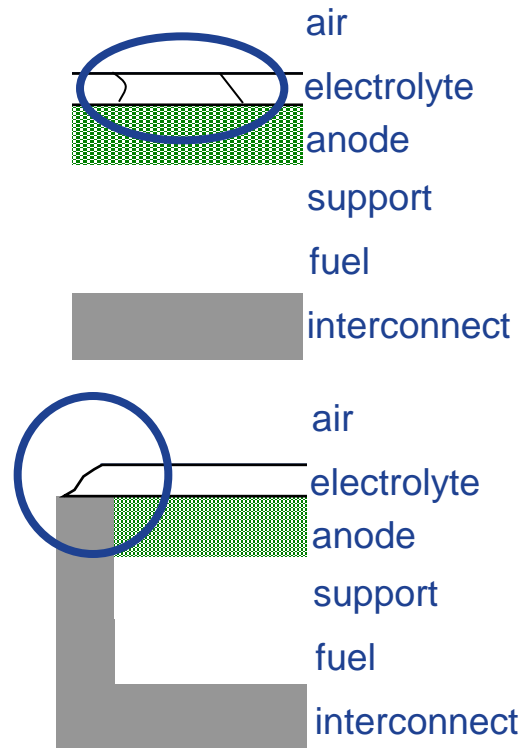
porous anode

Electrolyte functions:  
 1) Transport  $O^{2-}$  ions  
 2) Separate air/fuel

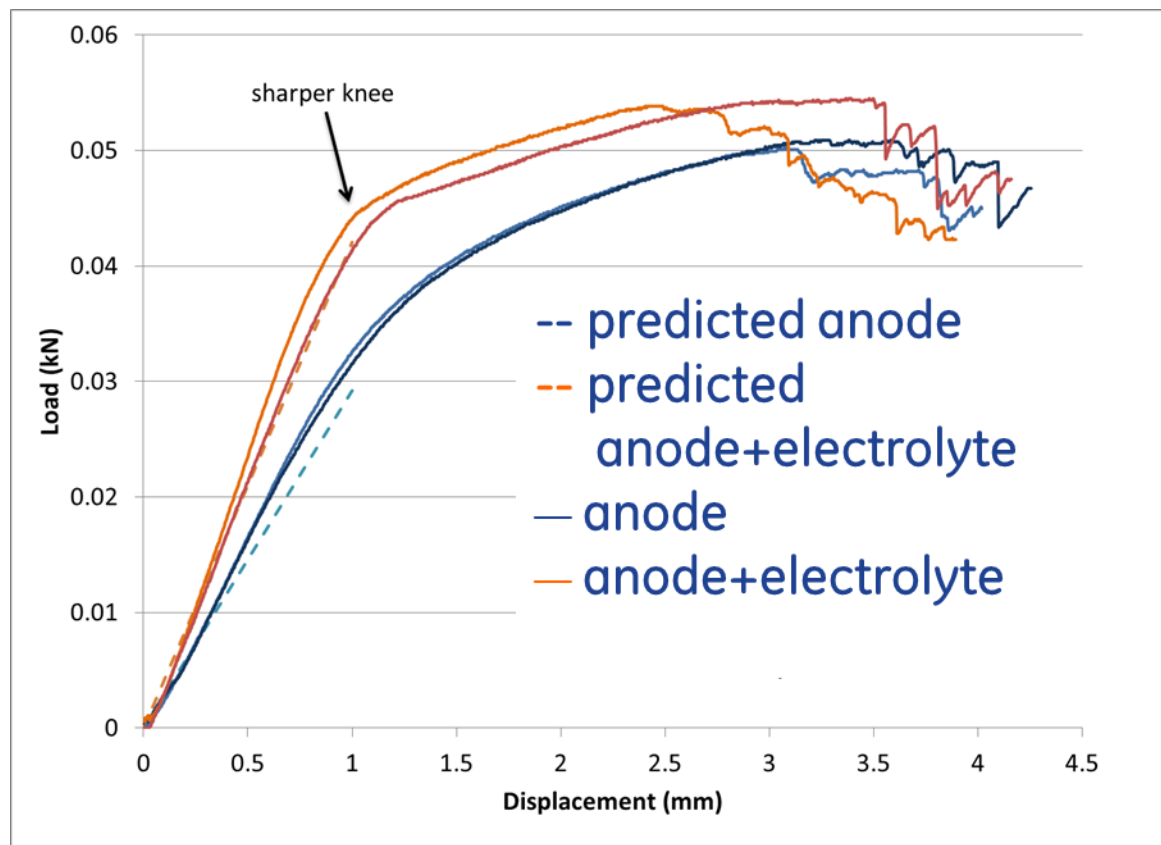
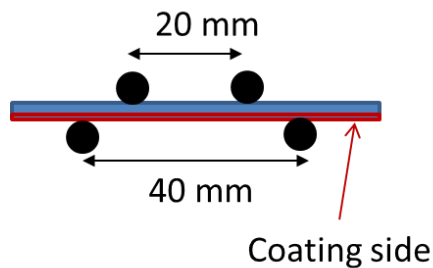
Thin & dense (on porous substrate) ✓

Crack-free / hermetic strength, residual stress ✓

Edge sealing  
 Mechanical design  
 Thermal management ✓

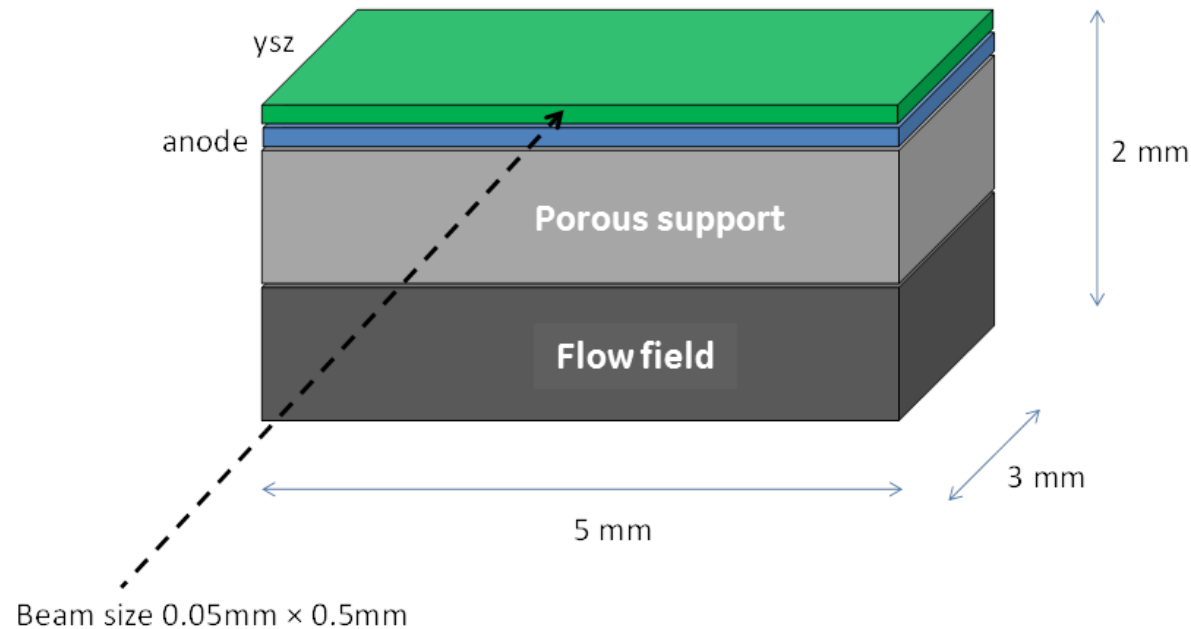


# Mechanical Properties of Thermal Sprayed Coatings



Elastic Modulus and failure stresses from 4-point bend testing

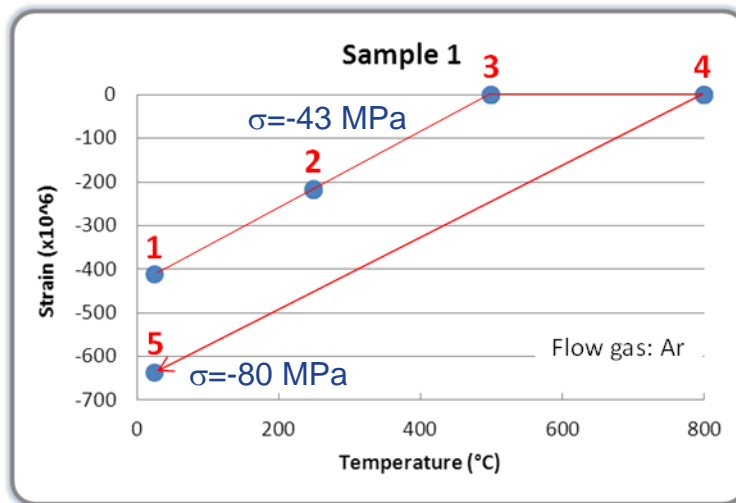
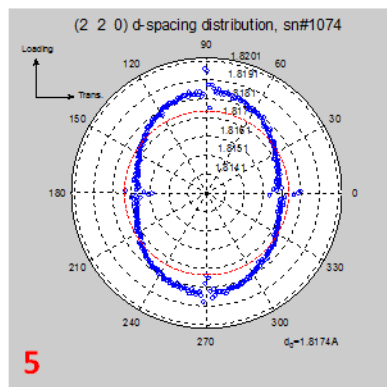
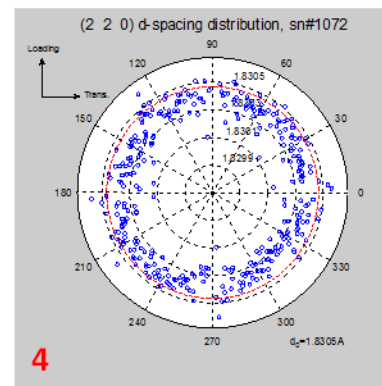
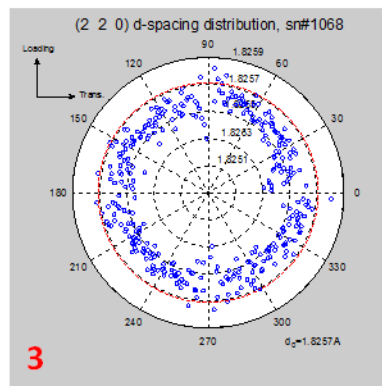
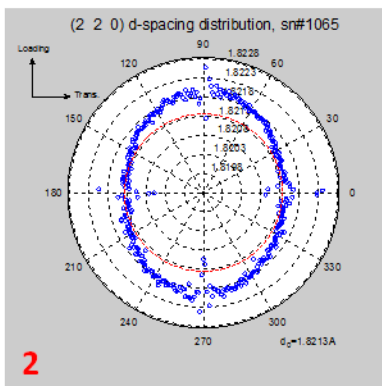
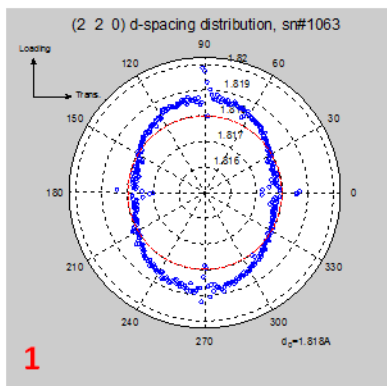
# Characterization of residual/thermal stresses in coatings



Sample dimensions for XRD  
measurements at Argonne national lab's  
APS facility

Residual stresses compound stresses during operation  
Must quantify residual stresses & thermal dependence

# XRD stress analysis - YSZ



Temp (c)	Sample 1
	e11 ( $\times 10^{-6}$ )
25	-411
250	-218
250	-219
250	-215
500	0
500	0
500	0
800	0
800	0
800	0
25	-636

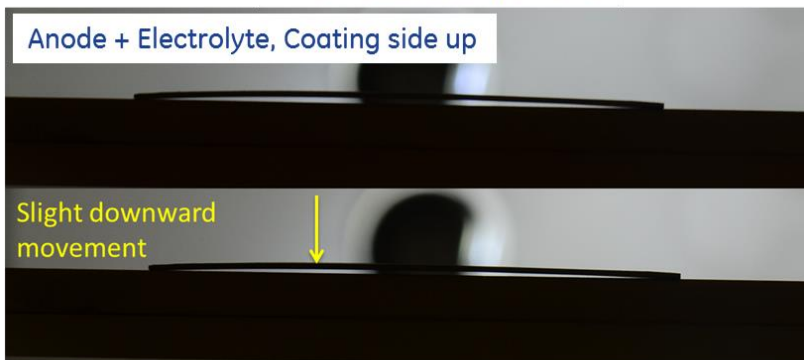
Three measurements at higher temperatures

In-plane compressive strain observed

Electrolyte stress state remains favorable

# Effect of Anode Reduction

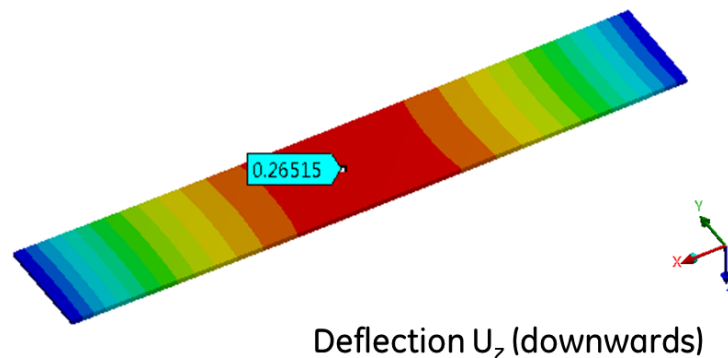
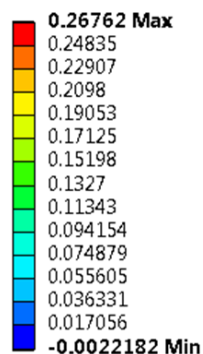
Pre-reduction, 575°C



Post-reduction, 575°C

Anode ~35 MPa tension  
YSZ ~18 MPa  
compression

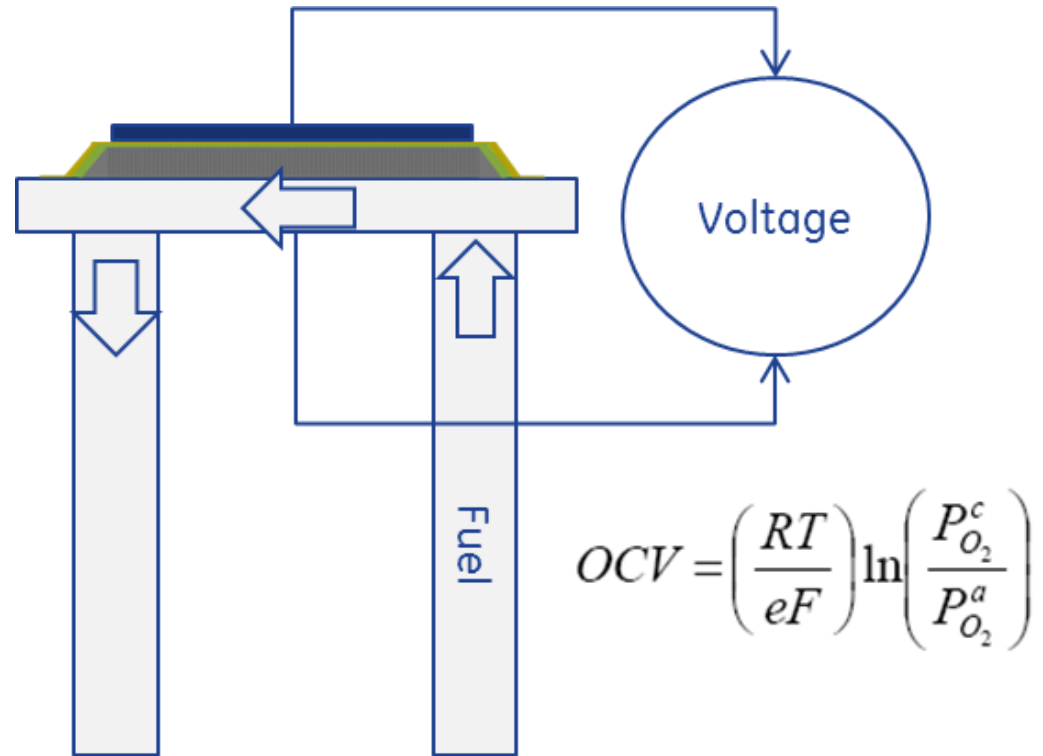
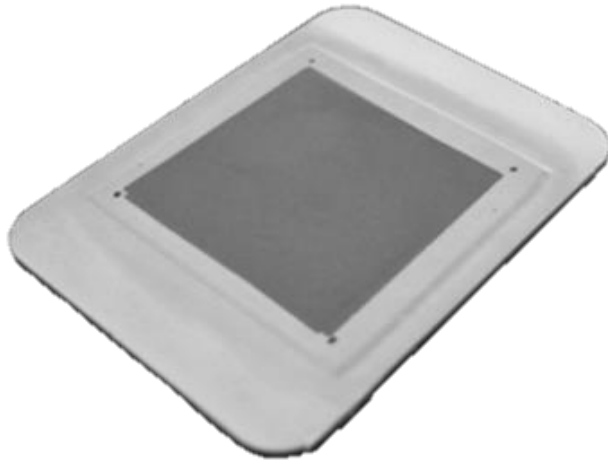
Curvature measurements are made to feed into FE model to estimate stress states



As anticipated, anode reduction imparts compressive stress state to electrolyte



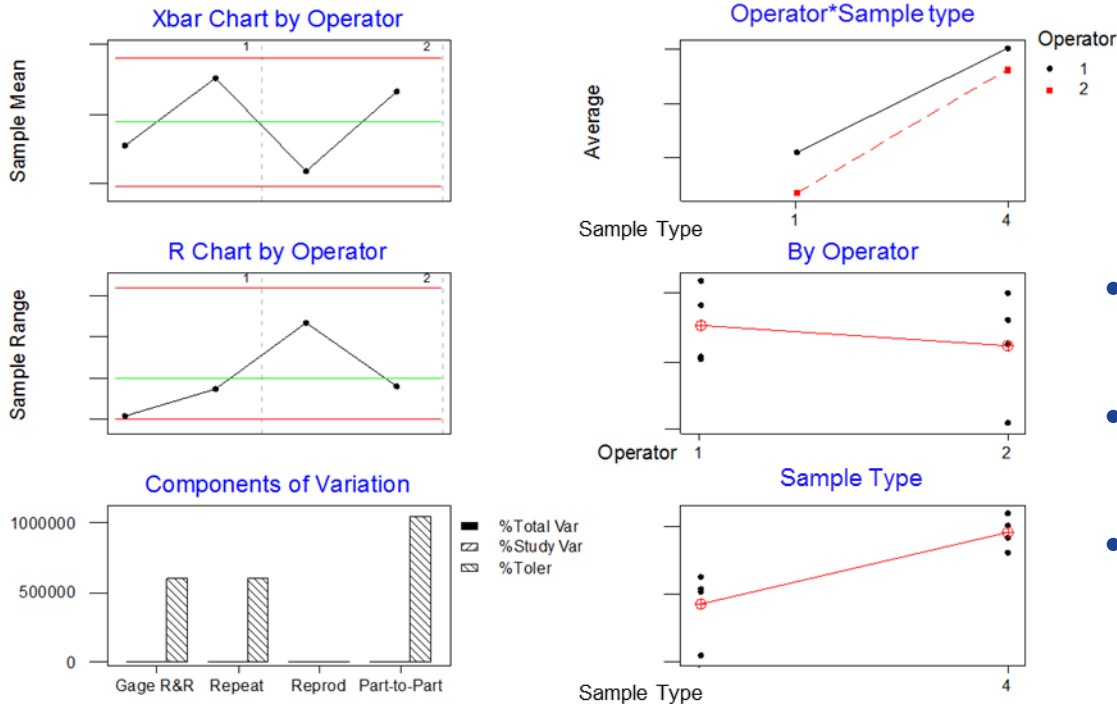
# 2" cell (25 cm<sup>2</sup>) test Set-Up



25 cm<sup>2</sup> test vehicle representative  
of stackable architecture

# Repeatability

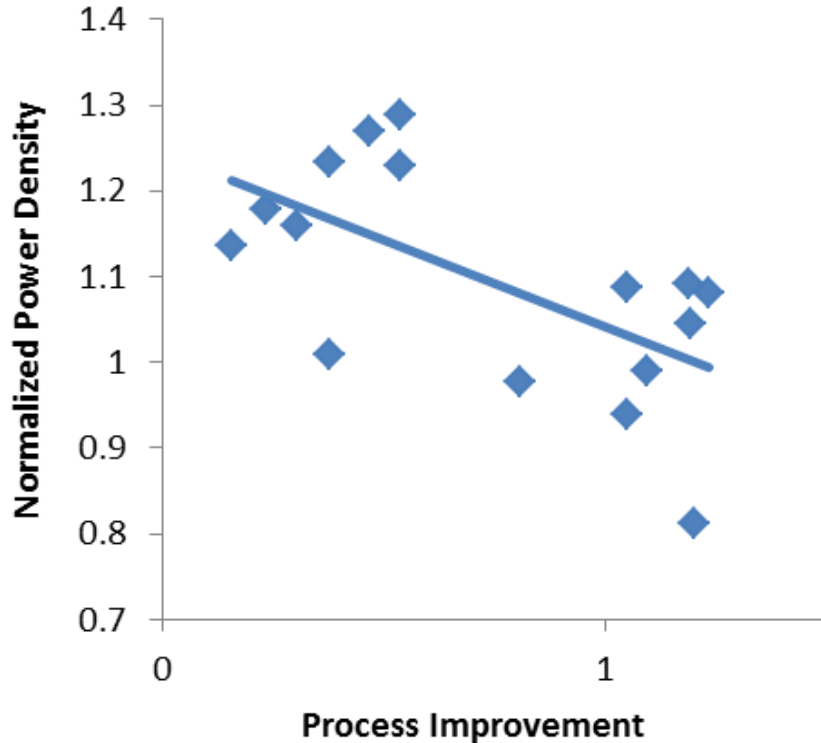
- Manufacturing and performance database allows tracking of variables for improved understanding of process-properties relationships
- Quickly screen >250 process variables/conditions



- Destructive GR&R performed using 2 typical sample types
- < 30% GR&R on testing stations
- 50 mohm-cm<sup>2</sup> resolution

25 cm<sup>2</sup> testing enables confidence in experimental design results

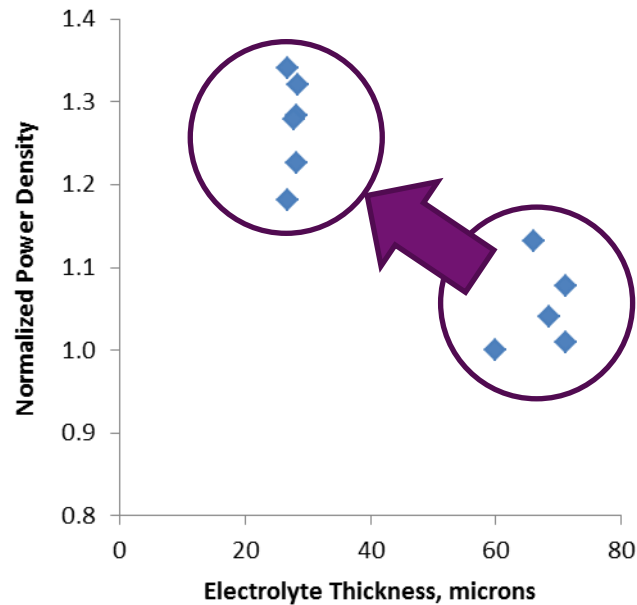
# Performance



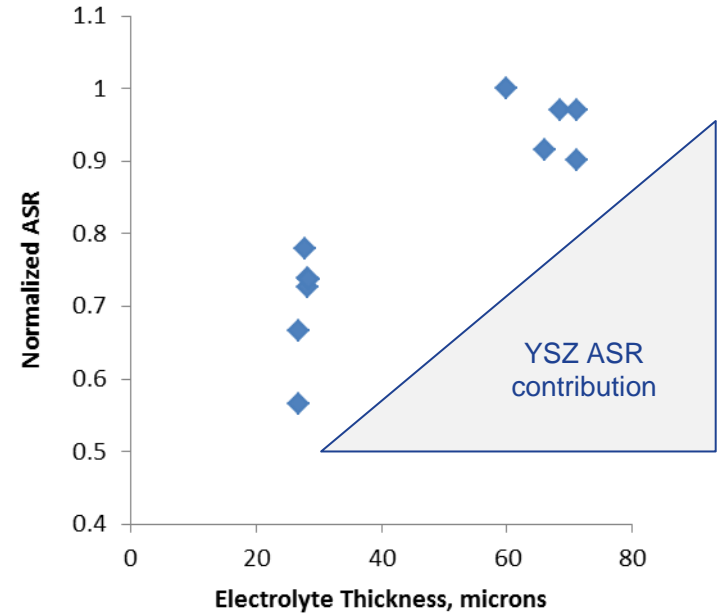
- Process shift & control increases performance

Capability to directly measure impacts of processing variables

# Performance



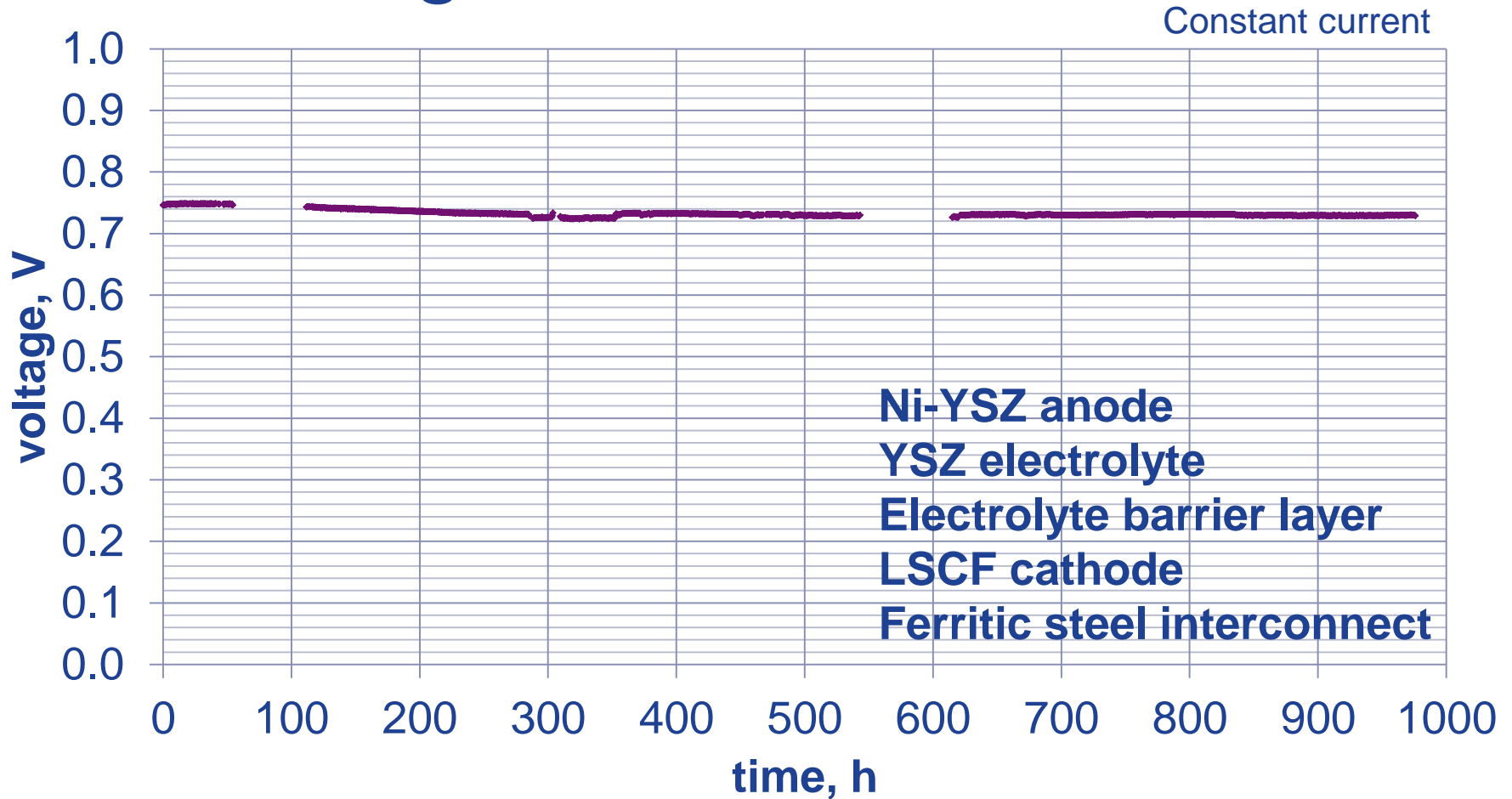
- Thinner electrolyte improves power density



- YSZ conductivity in agreement with literature values

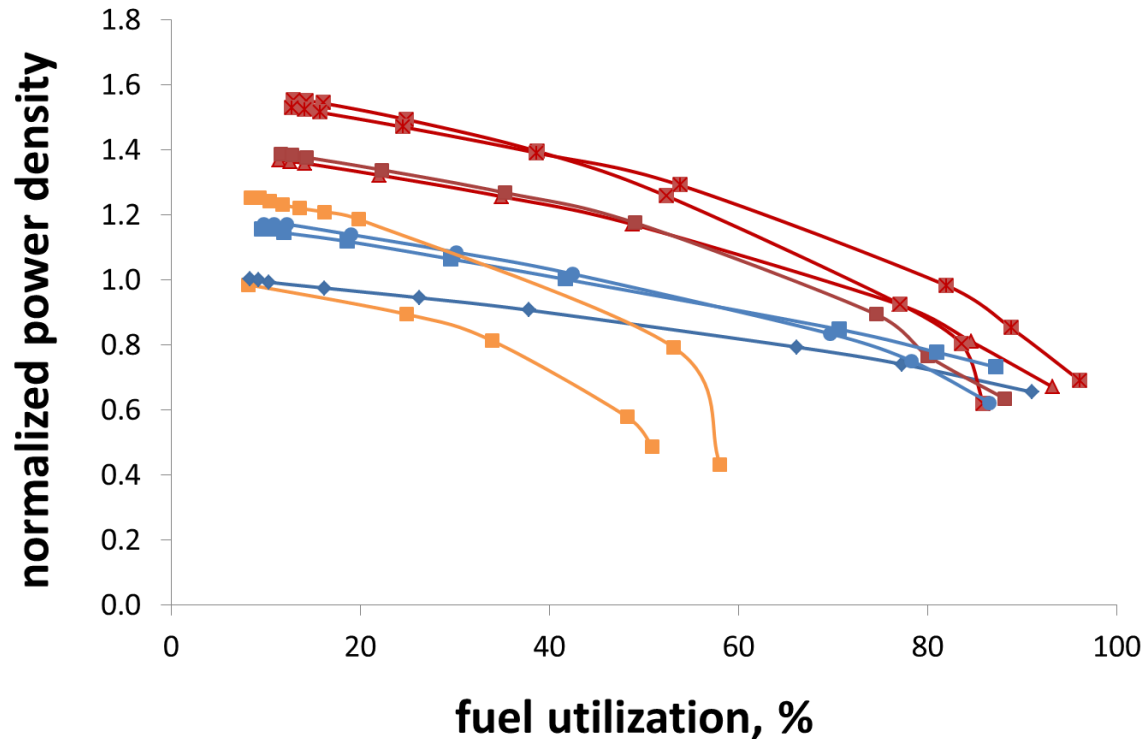
YSZ thickness dominant  
ASR contributor

# 25 cm<sup>2</sup> Degradation



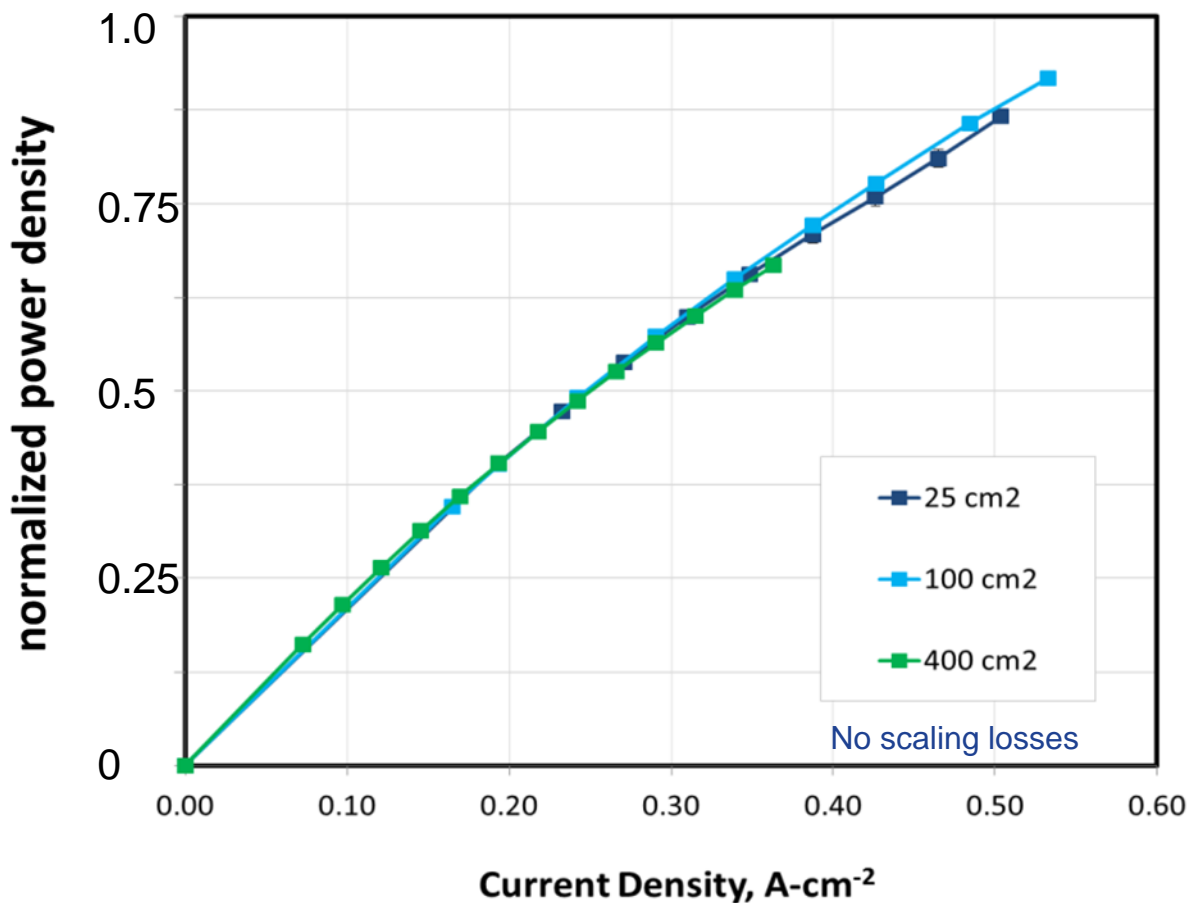
Thermal spray manufactured SOFC  
demonstrate stable operation

# Fuel Utilization on 25 cm<sup>2</sup>



Able to achieve high single-pass fuel utilization on non-optimized flow field

# Manufacturing Scale-up



Successful manufacturing scale-up:  
25 cm<sup>2</sup> to 400 cm<sup>2</sup>

# Summary

- Evolved thermo-mechanical FE models to support development and scale-up
- Developed database and 25cm<sup>2</sup> gauge to accelerate development
- Developed thermal spray conditions and suitable substrate to enable high fuel utilization
- Demonstrated thermal spray manufactured cell performance stability
- Scaled thermal spray manufacturing from 2.85 cm<sup>2</sup> to 25 cm<sup>2</sup> to 100 cm<sup>2</sup> to 400 cm<sup>2</sup>



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