Validation of Novel Planar Cell Design for Megawatt-Scale SOFC Power Systems

M.J. Day, Principal Investigator

10th Annual SECA Workshop

Pittsburgh, PA

July 16, 2009

SECA

Outline

- Introduction to the *FlexCell* planar cell design concept
- Objectives of SECA Project
- Core Data (ScSZ-based *FlexCells*)
- Results of SECA Project (YSZ-based *FlexCells*)
  - Cell Fabrication and Testing
  - FEA Modeling (Ohio State)
- Conclusions and Future Work

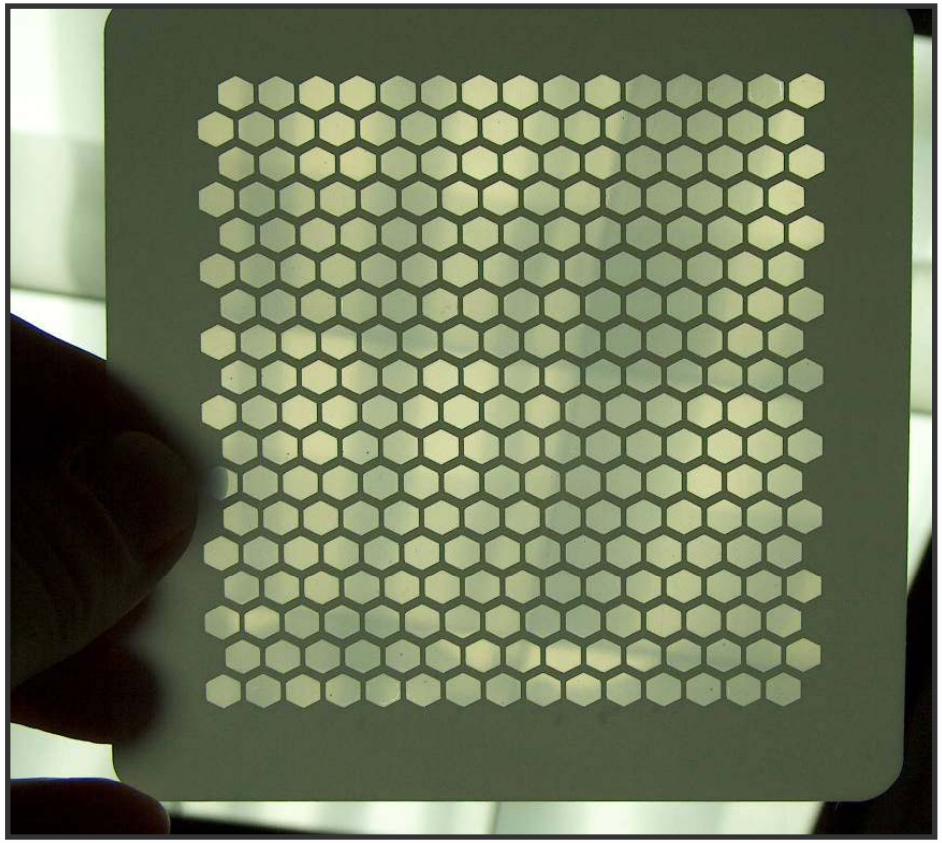
SECA

NEXTECH MATERIALS

Introduction to the FlexCell

Attributes

- Thin-electrolyte for high performance
- Small repeat units for high power density
- Dense perimeter for ease of sealing
- Thin electrodes to facilitate gas diffusion
- Thin anode for redox cycling tolerance
- Electrode material flexibility



Project Objectives

Overall Project Goal

- Validate performance, robustness, cost and scalability of NexTech's *FlexCell* planar cell design for coal-based SOFC power systems

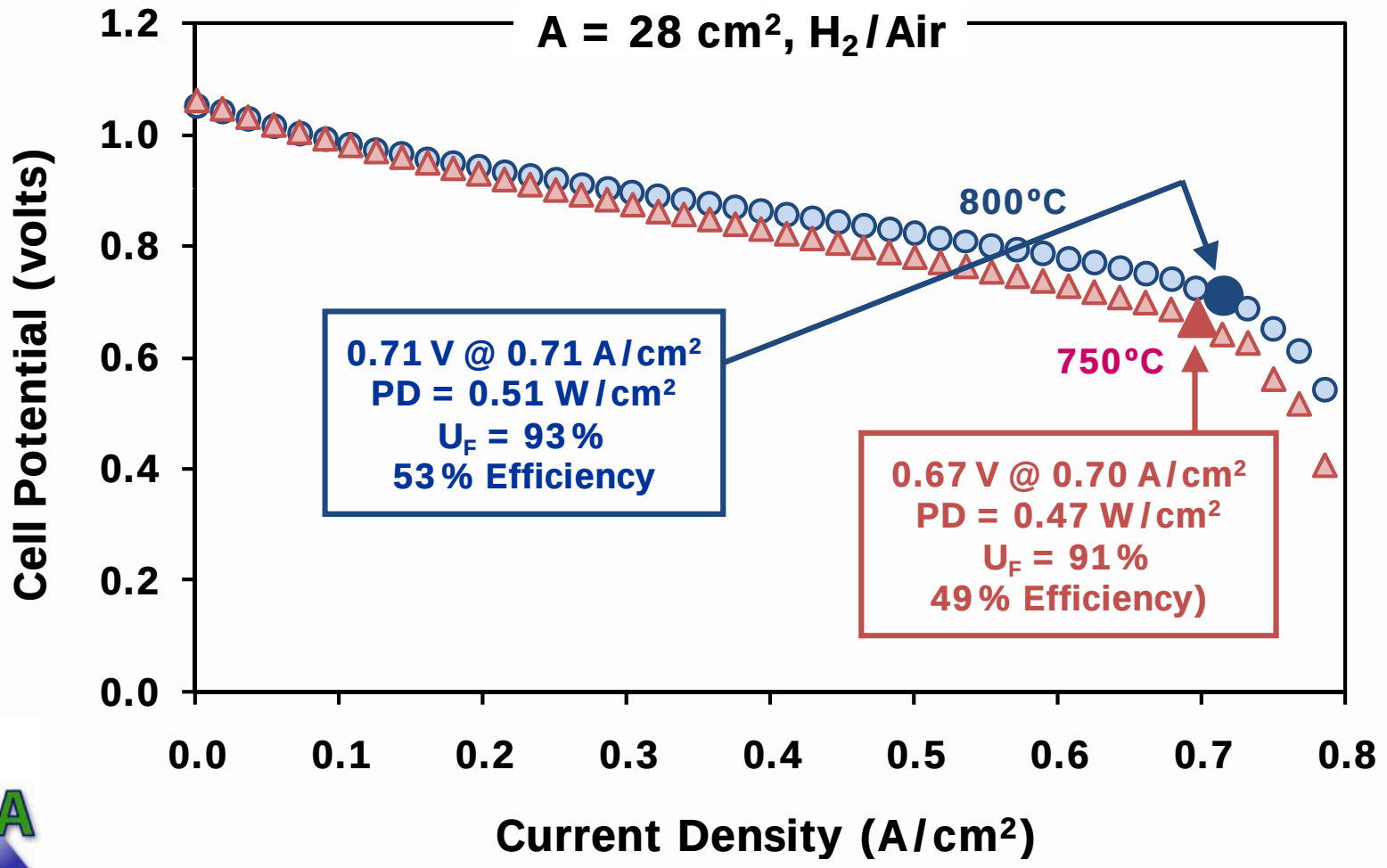
Phase I Objectives

- Demonstrate that high performance can be achieved in *FlexCells* made with YSZ as the electrolyte material
- Demonstrate that *FlexCells* have sufficient mechanical robustness for SOFC applications
- Demonstrate potential of achieving cell manufacturing cost of less than $50/kW

SECA

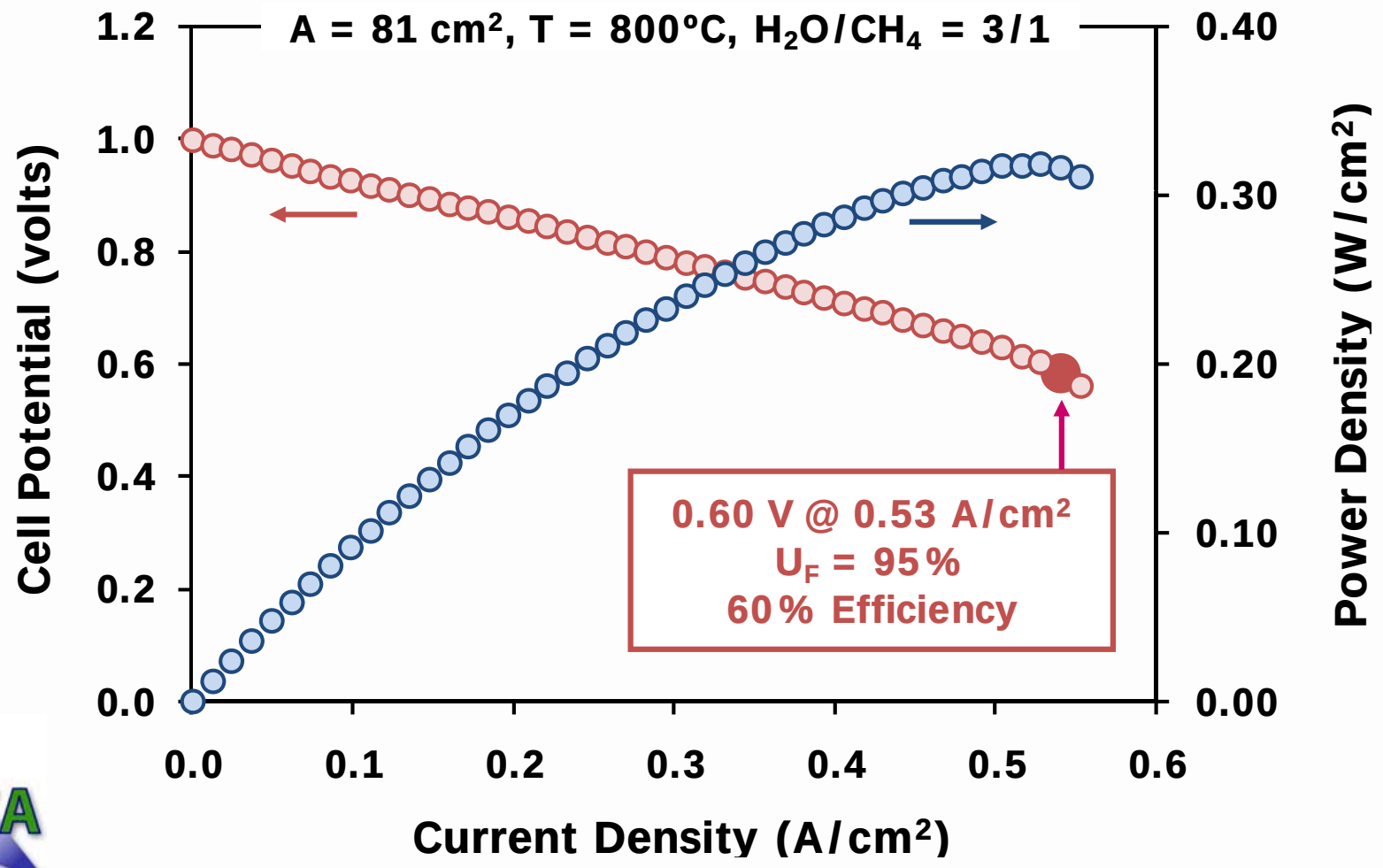
Core Data (ScSZ-Based FlexCells)

High Performance and Efficiency



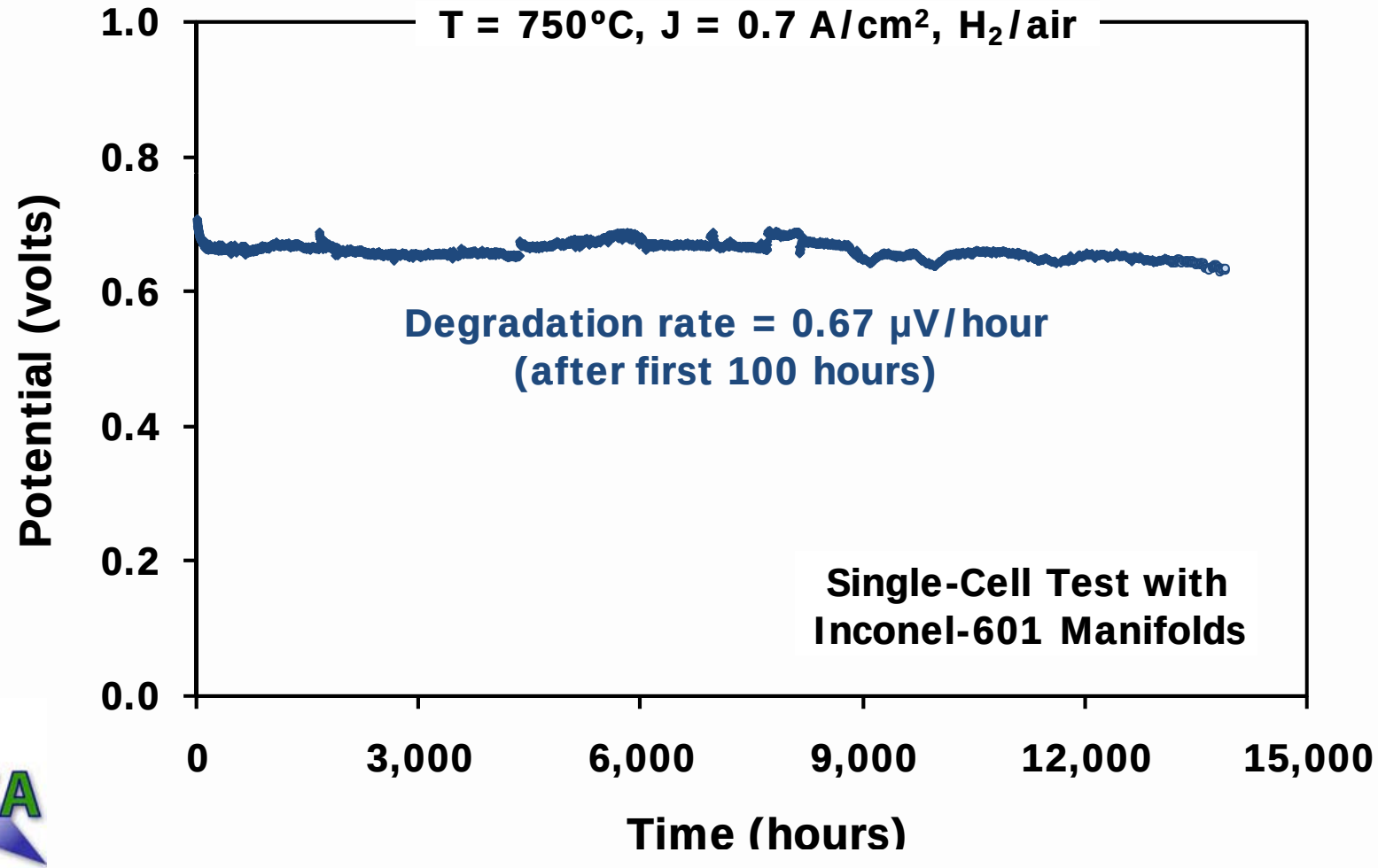
SECA

Internal Reforming of Methane



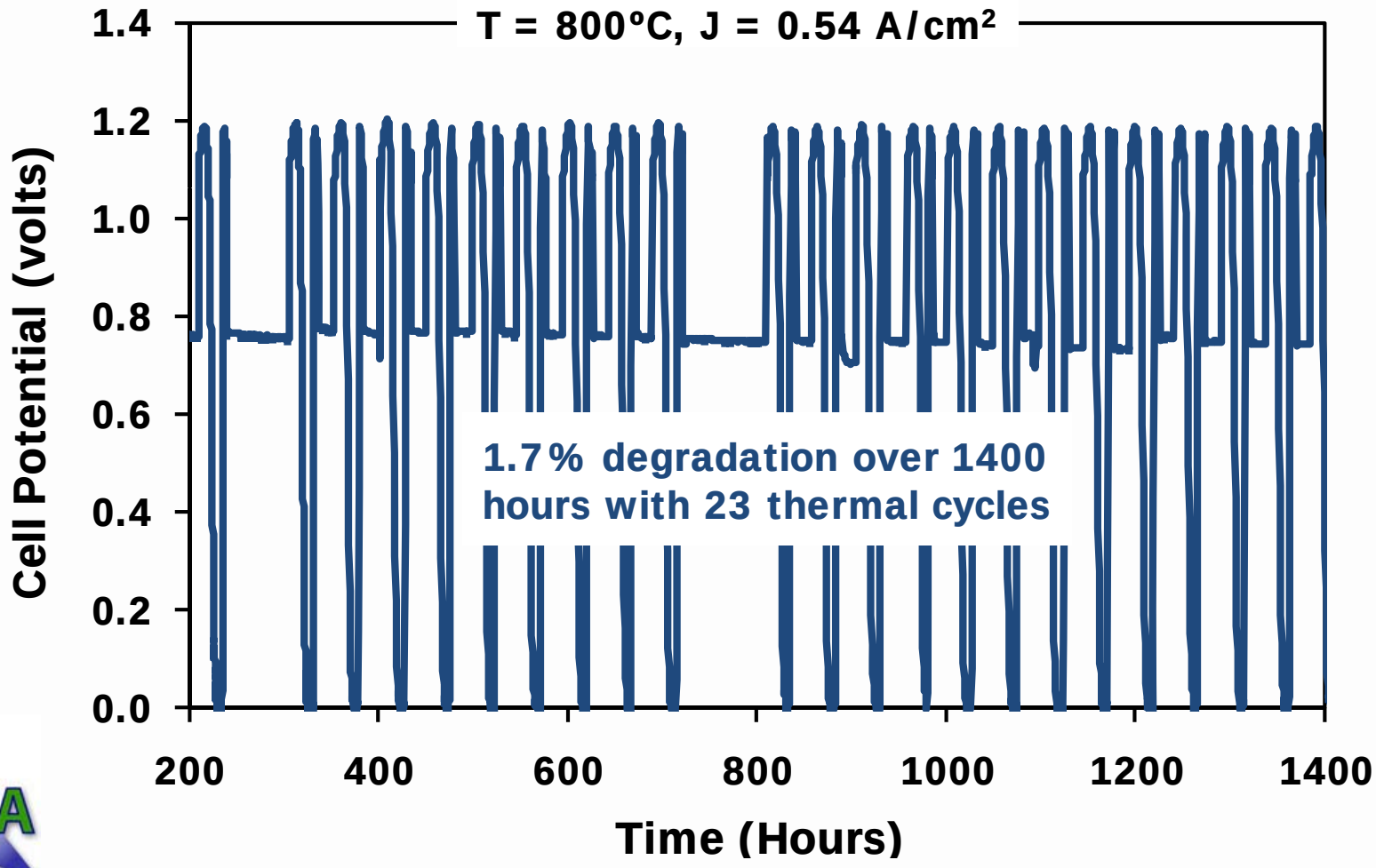
SECA

Long-Term Durability

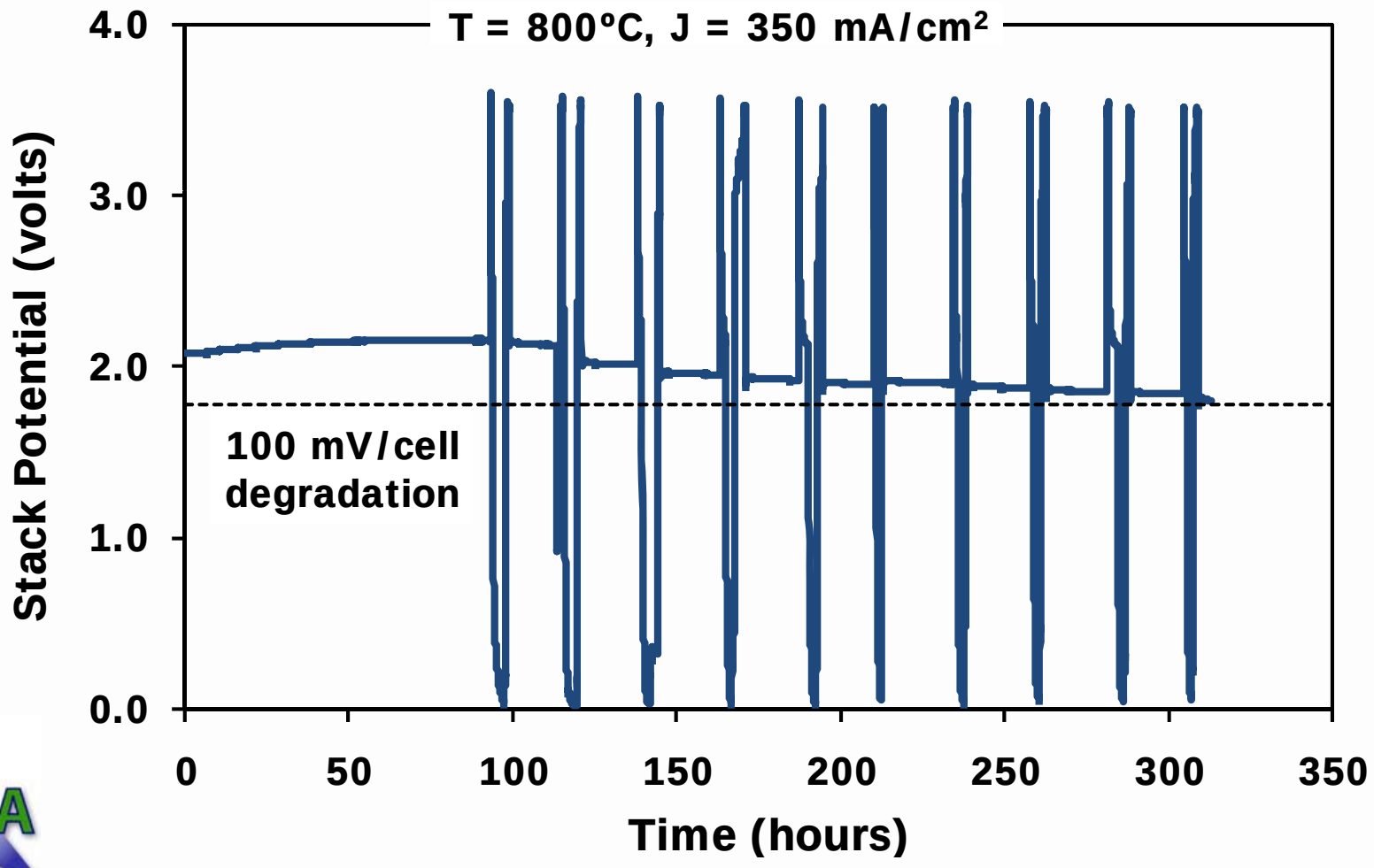


SECA

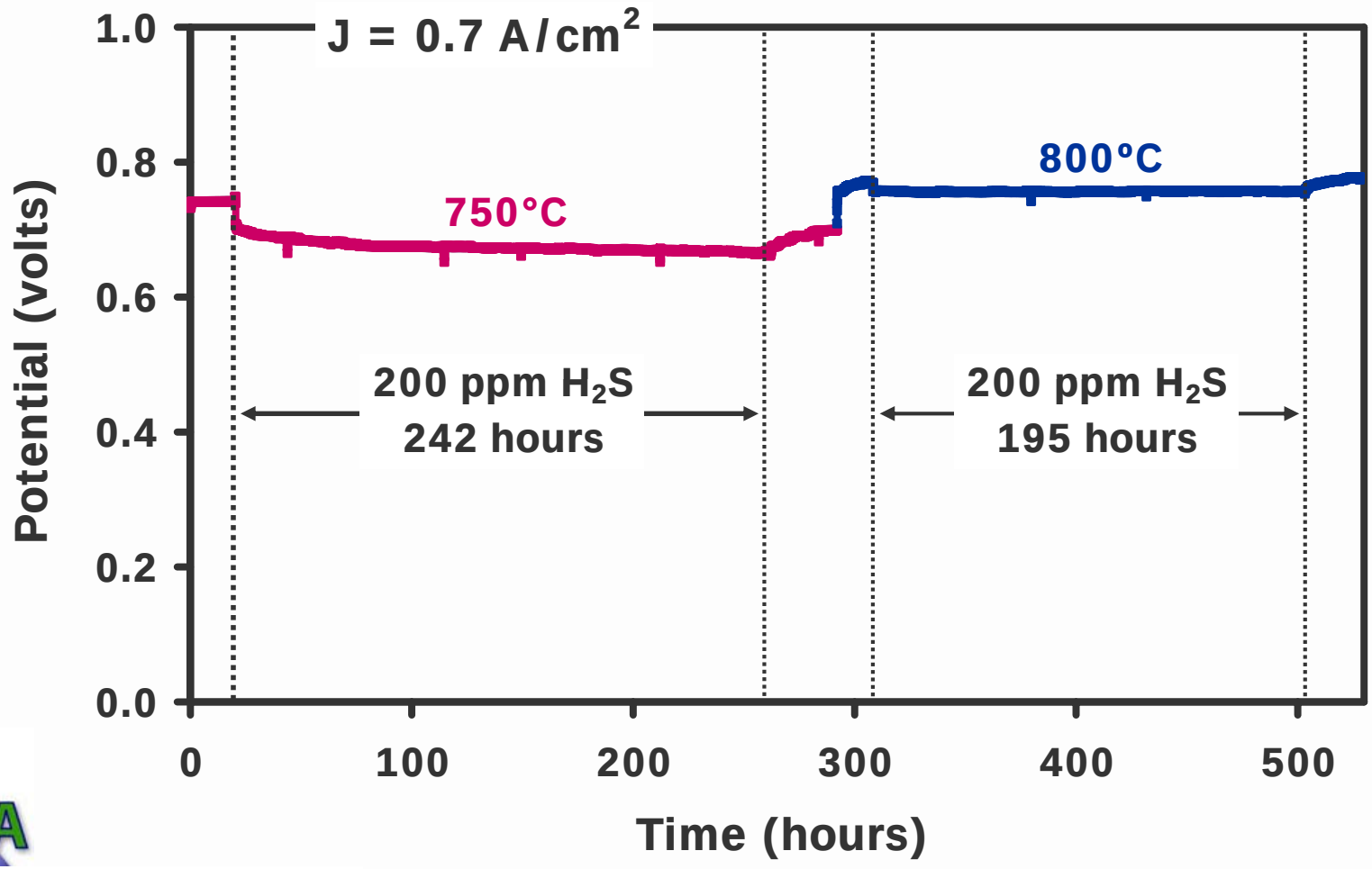
Tolerance to Thermal Cycling



Redox Cycling (3-Cell Stack)

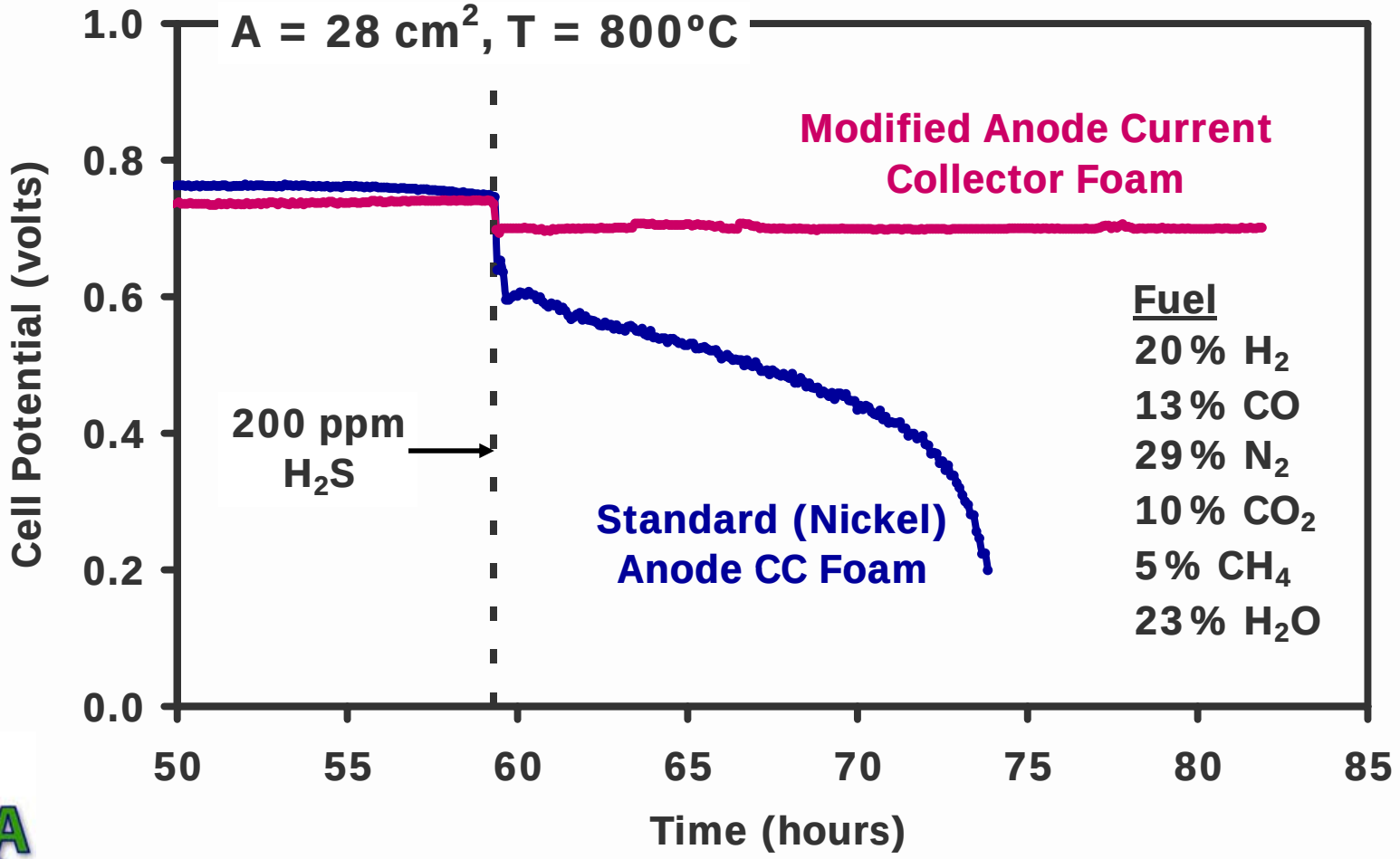


Sulfur Tolerance (Hydrogen Fuel)

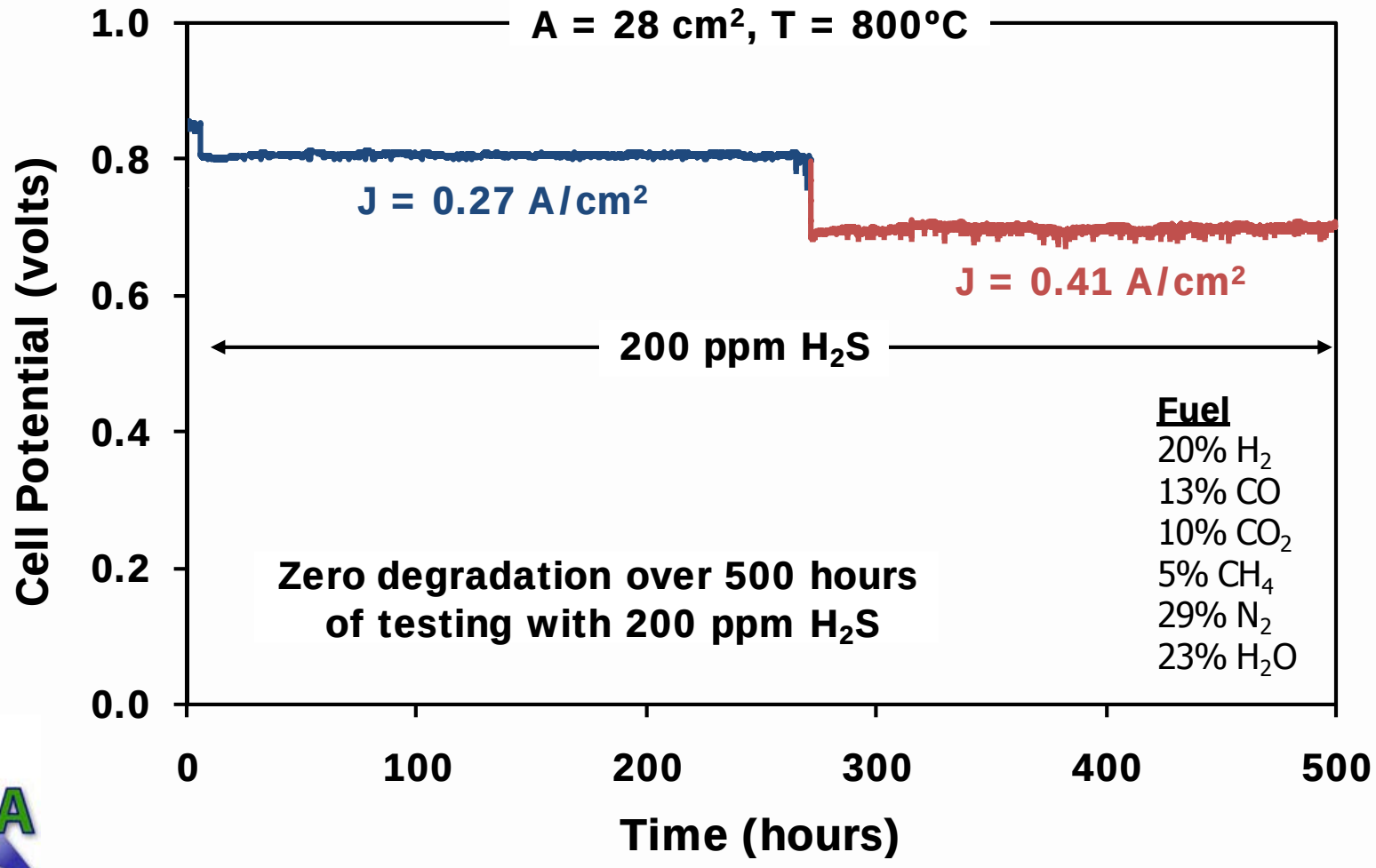


SECA

Sulfur Tolerance (Reformate Fuel)



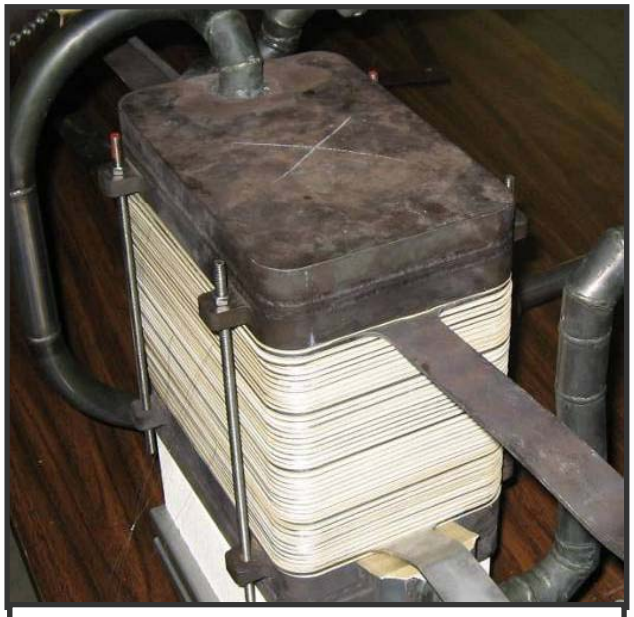
Sulfur Tolerance (Reformate Fuel)



NexTech SOFC Stacks

500-watt stack module (10 cells)

2-kW stack (40 cells)

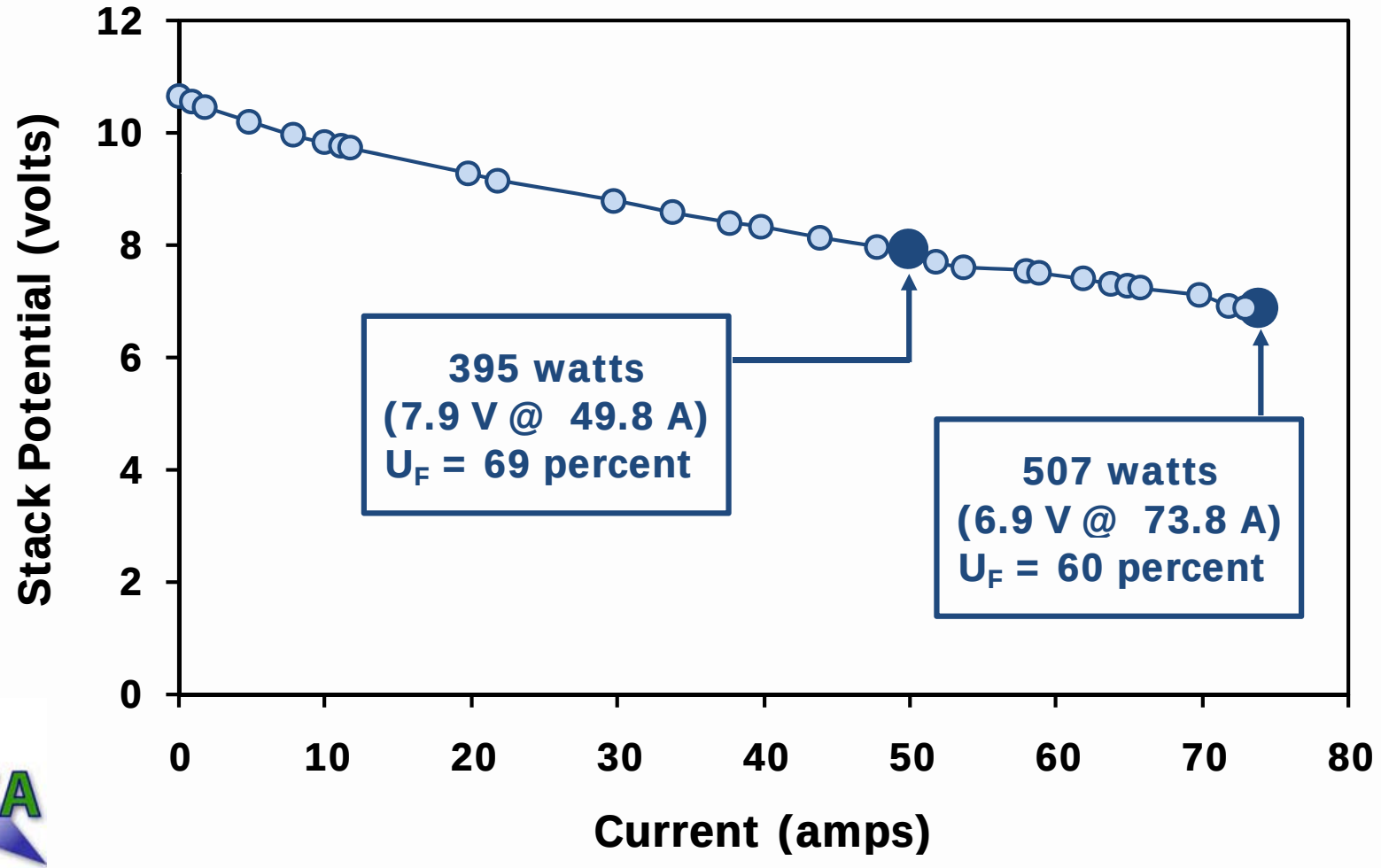


Stack Dimensions (without endplates)

- L = 22.2 cm
- W = 14.5 cm
- H = 10.6 cm

SECA

Stack Performance (10-Cell Stack)

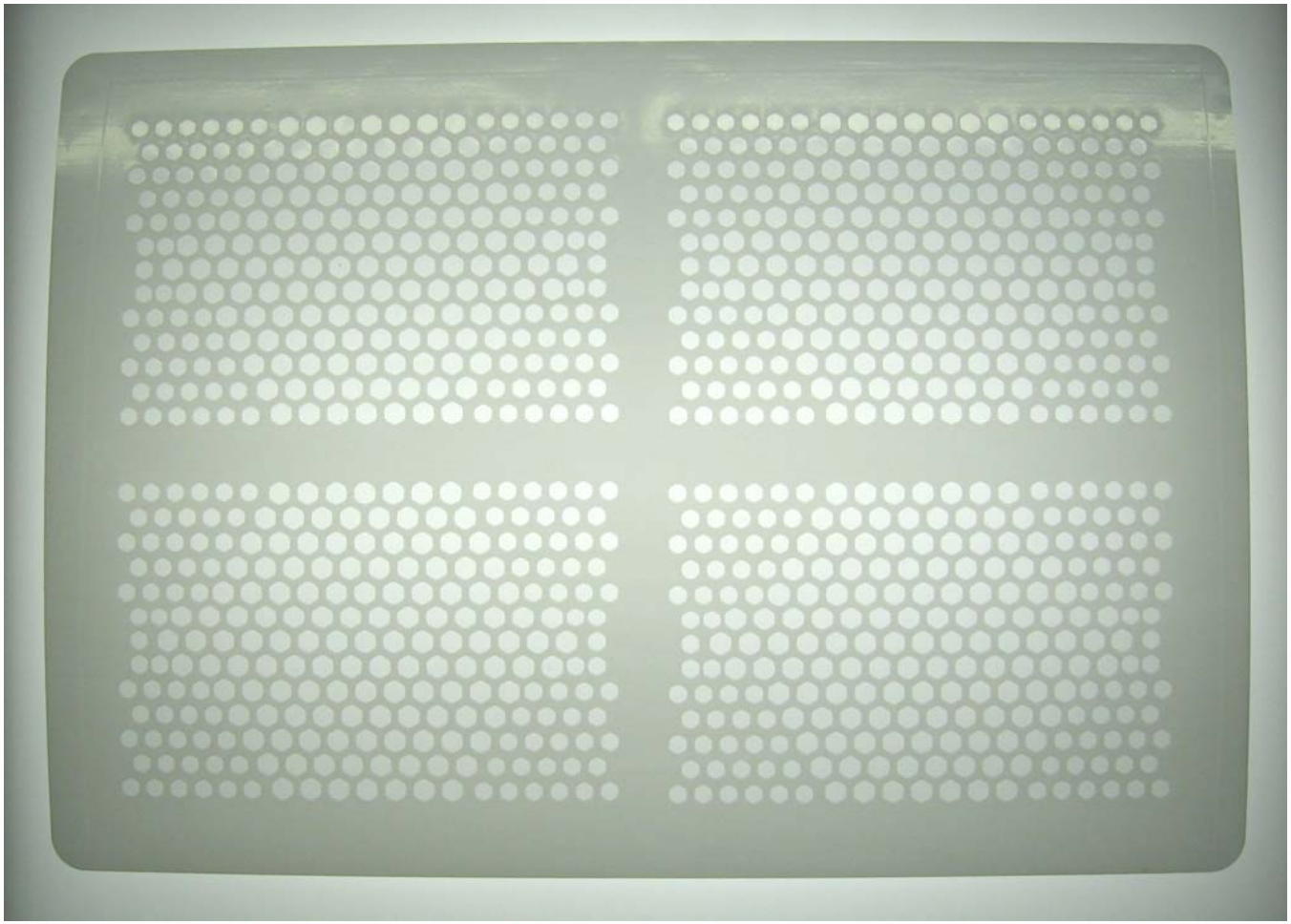


NEXTECH MATERIALS

10th Annual SECA Workshop: July 16, 2009

Large-Area FlexCell Manufacturing and Testing

470-cm² Area FlexCell

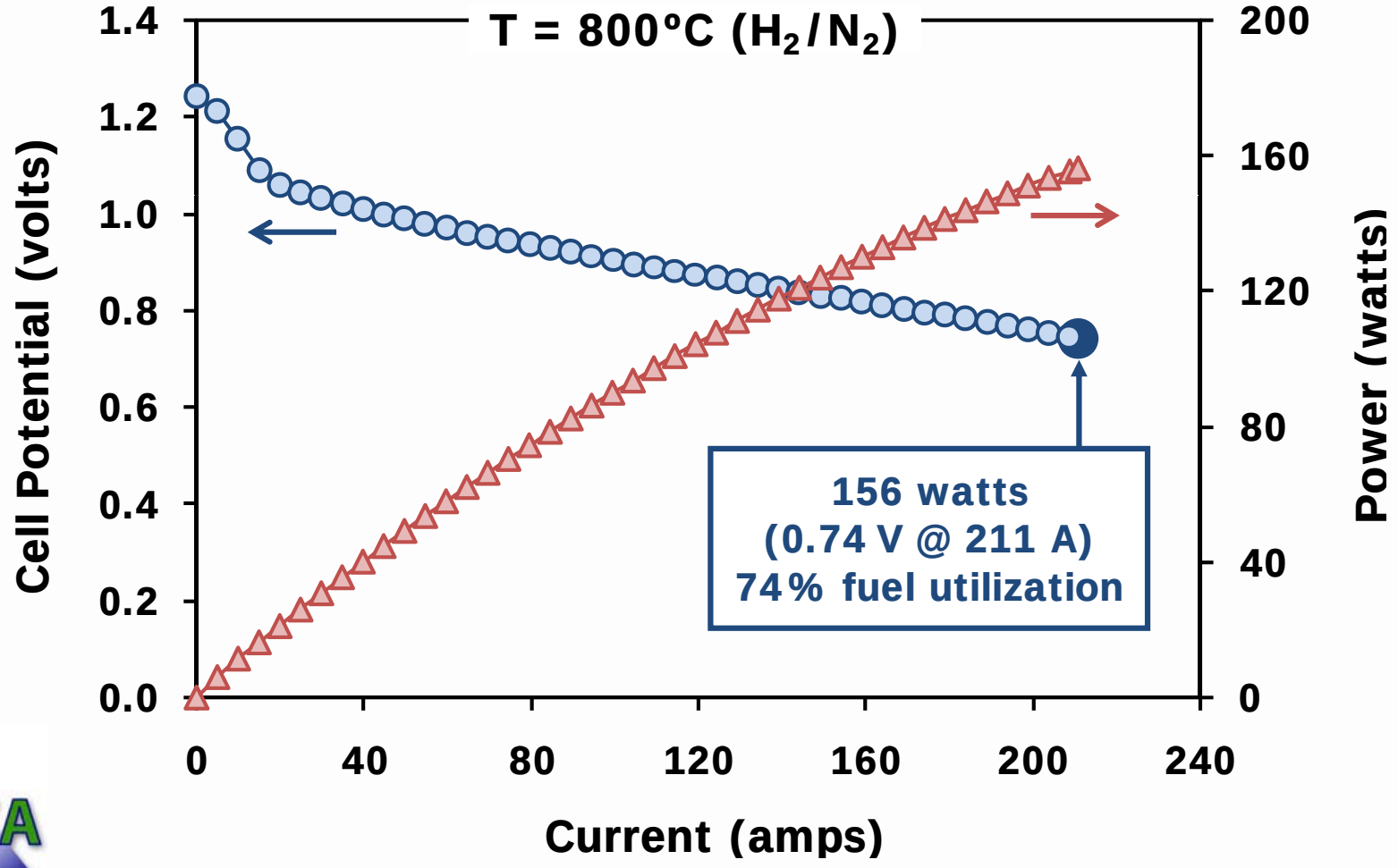


SECA

NEXTECH MATERIALS

10th Annual SECA Workshop: July 16, 2009

Testing of Large-Area FlexCells

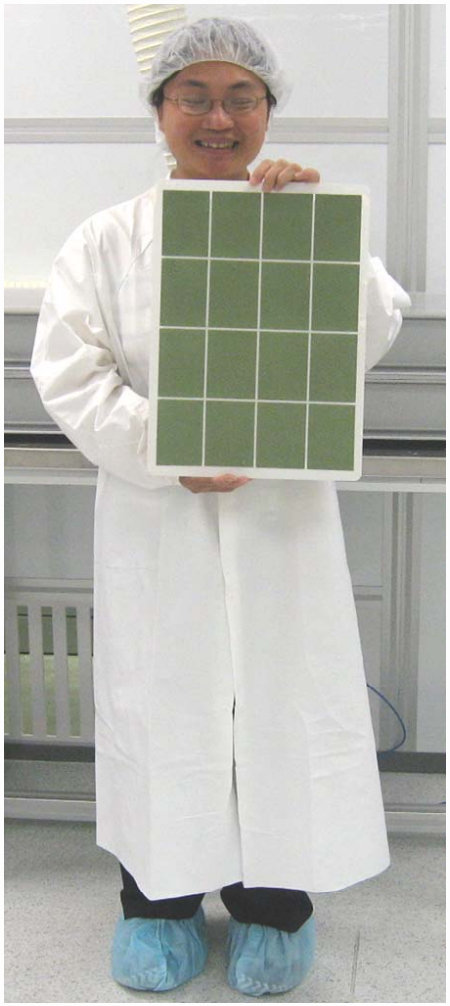


SECA

NEXTECH MATERIALS

10th Annual SECA Workshop: July 16, 2009

1200-cm² Area FlexCell



SECA

NEXTECH MATERIALS

10th Annual SECA Workshop: July 16, 2009

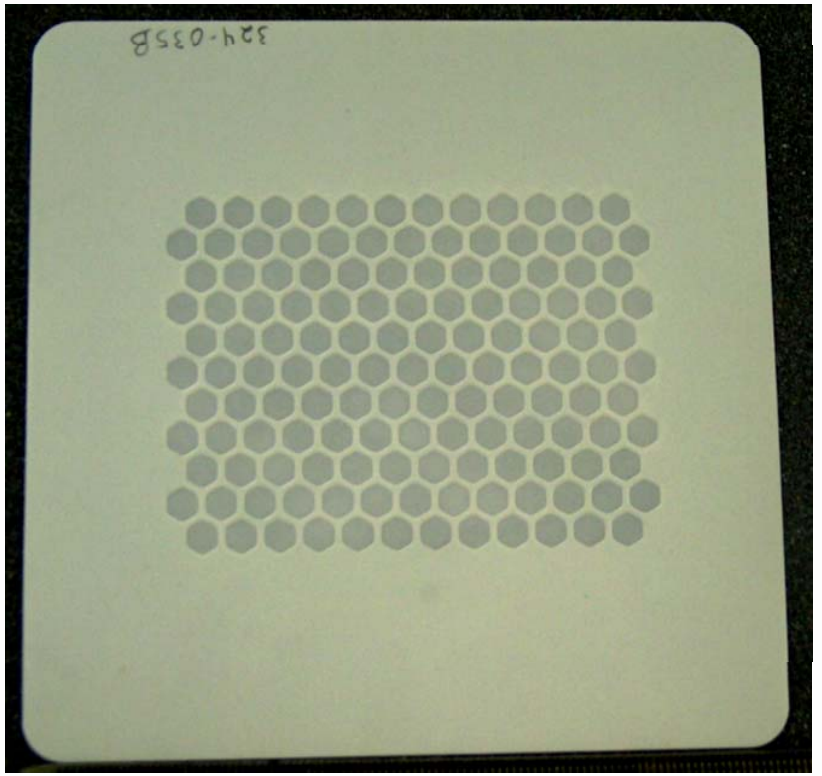
Fabrication and Testing of YSZ-Based FlexCells

SECA

Fabrication of YSZ-Based FlexCells

Architecture Variables

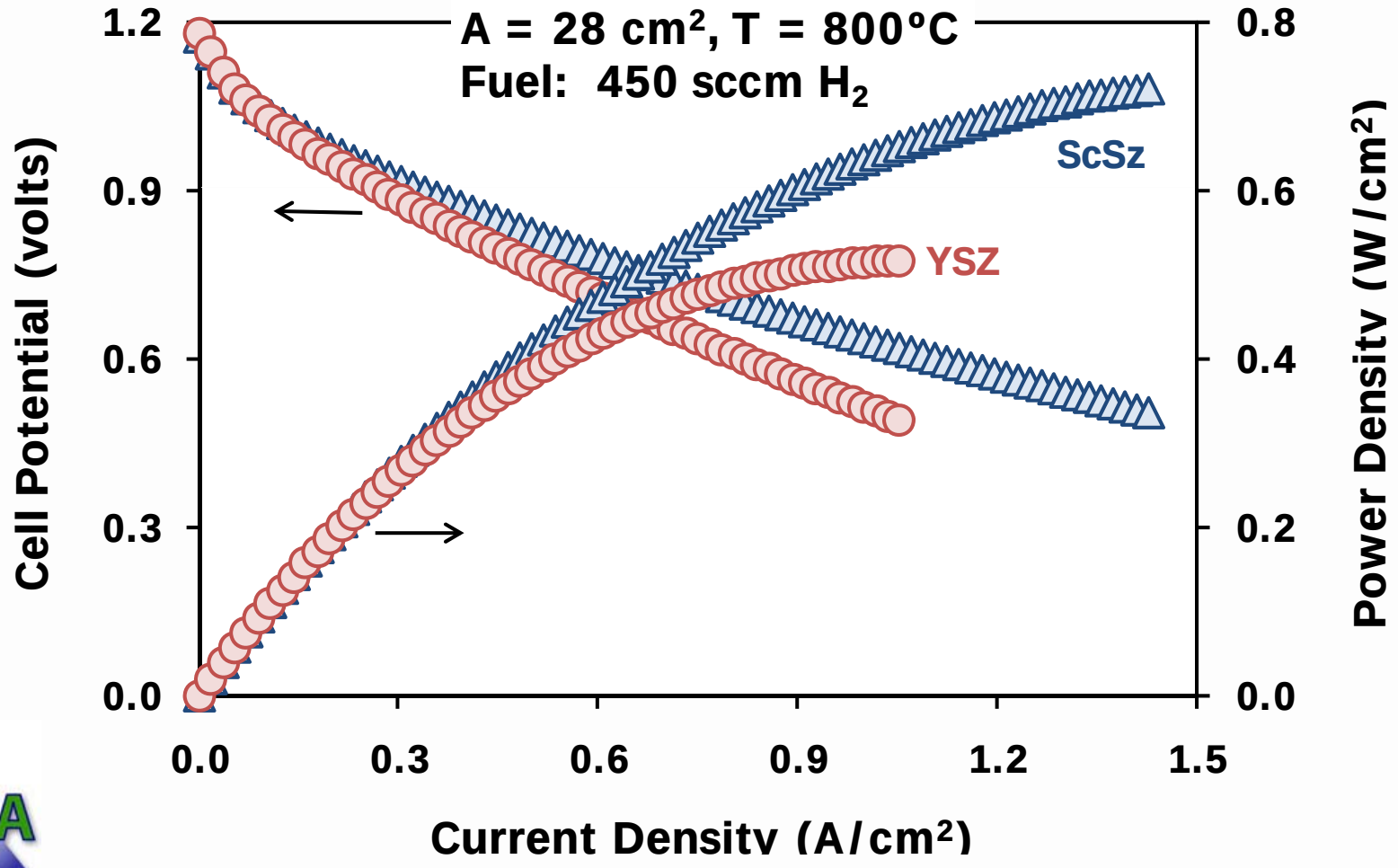
- Support thickness: 80-160 µm
- Membrane thickness: 24-32 µm
- Percent thin membrane in active region: 65-75 percent
- Support mesh pattern/geometry



SECA

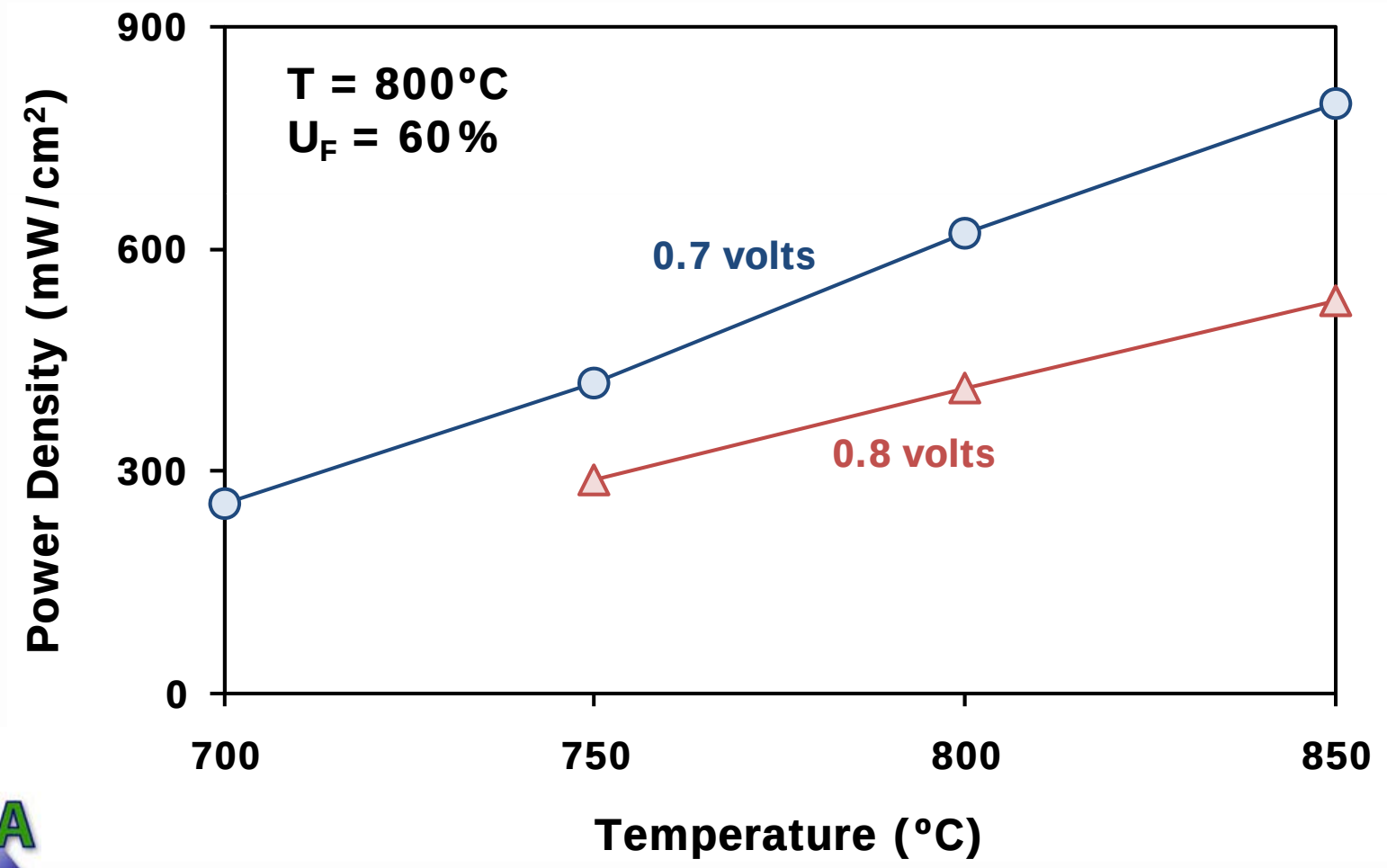
NEXTECH MATERIALS

ScSZ vs. YSZ FlexCells Standard Geometry



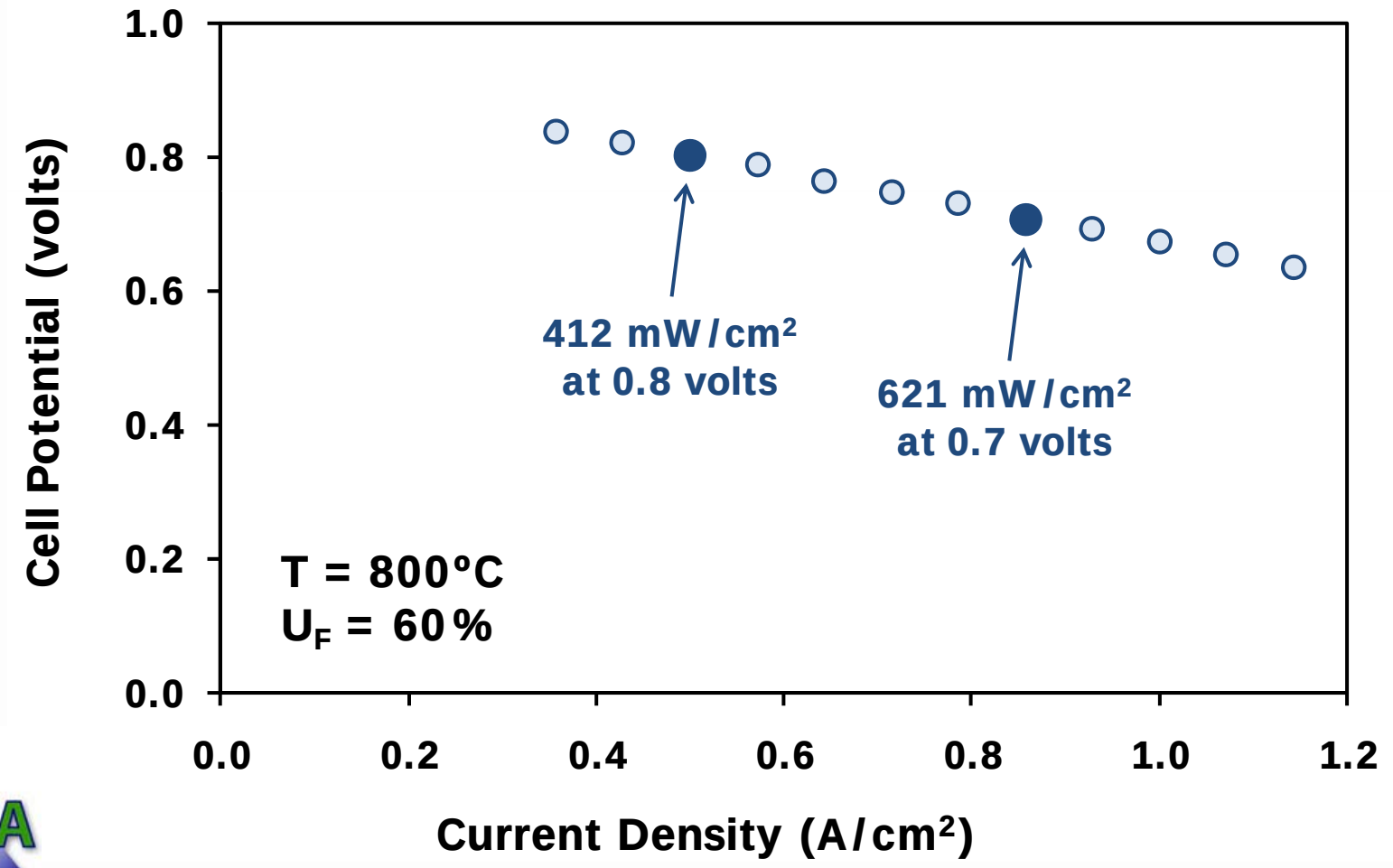
SECA

Ultra-Thin FlexCell Pole Curve Data



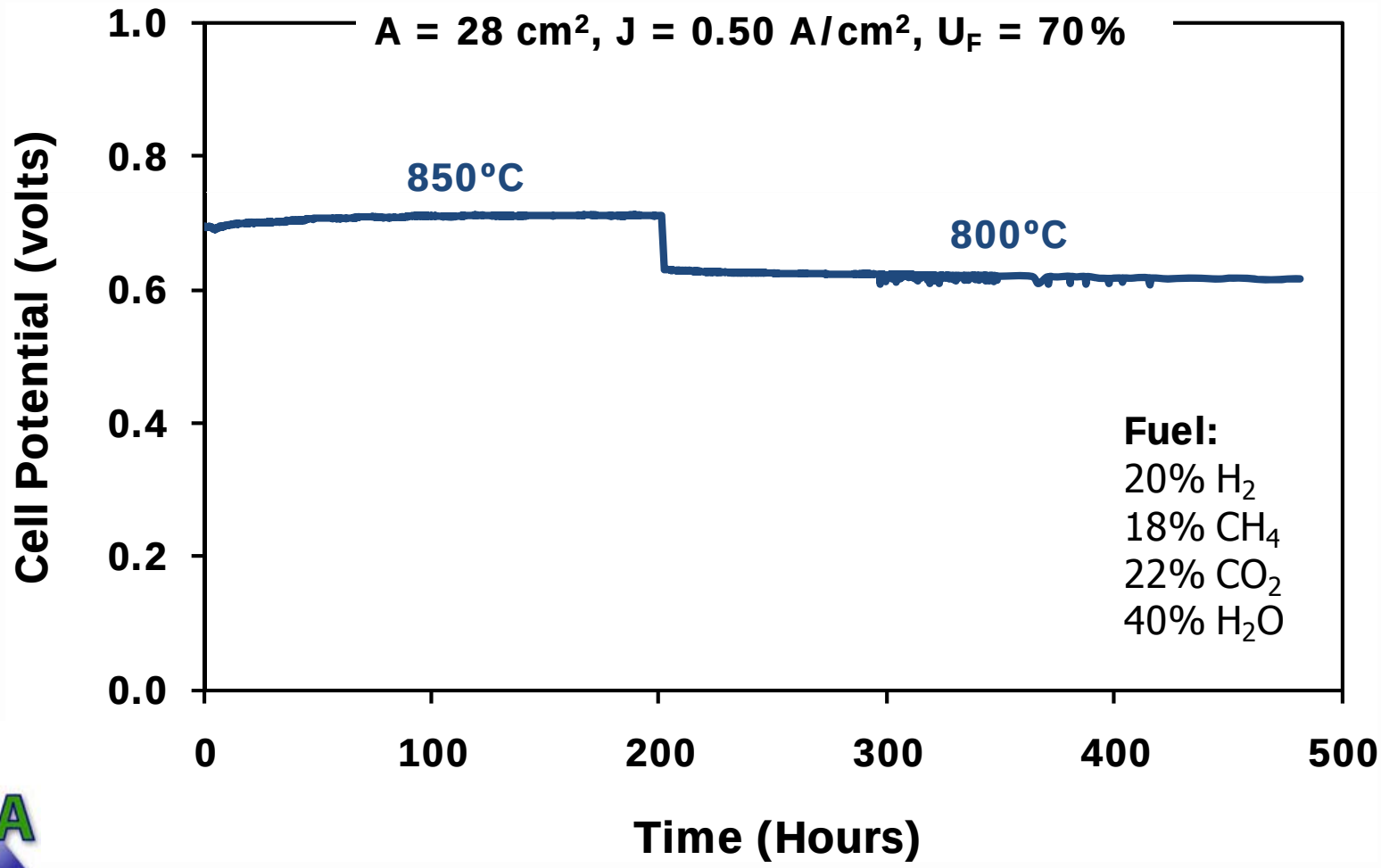
SECA

YSZ-Based FlexCell Pole Curve Data



SECA

YSZ-Based FlexCell Long-Term Data (Coal Gas)



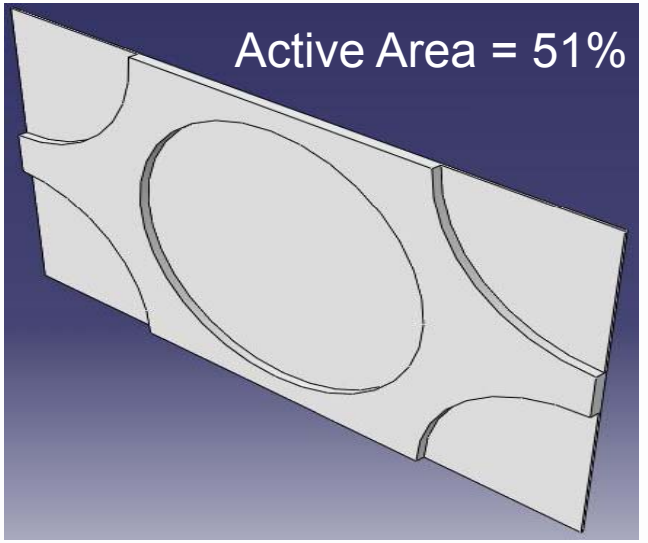
SECA

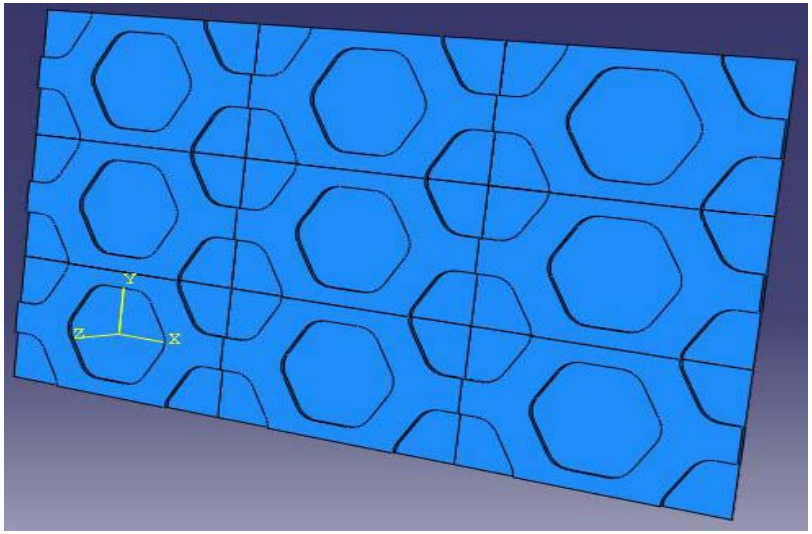
NEXTECH MATERIALS

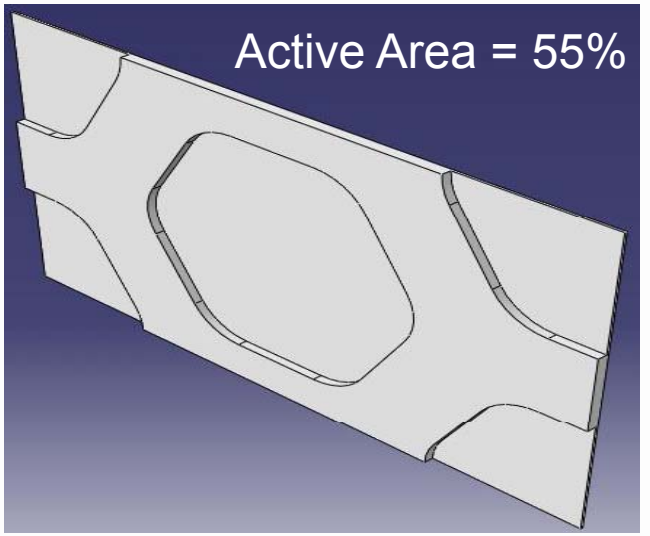
FEA Modeling of Mechanical Robustness of FlexCells (Ohio State)

FEA Models of FlexCell Active Area

- Circles (upper right)
- Rounded Corner Hexes (lower right)
- Two-dimensional *FlexCell* mesh (lower left)



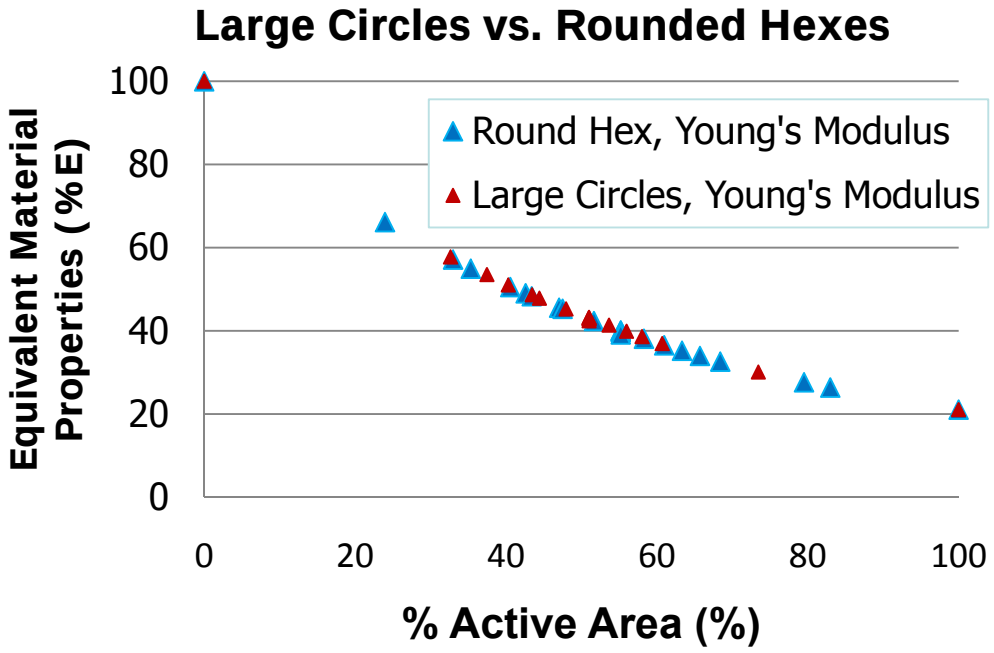


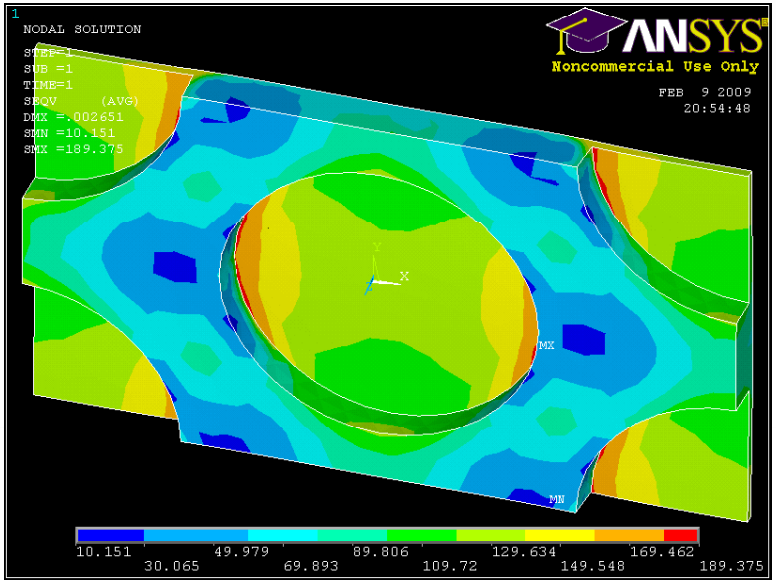


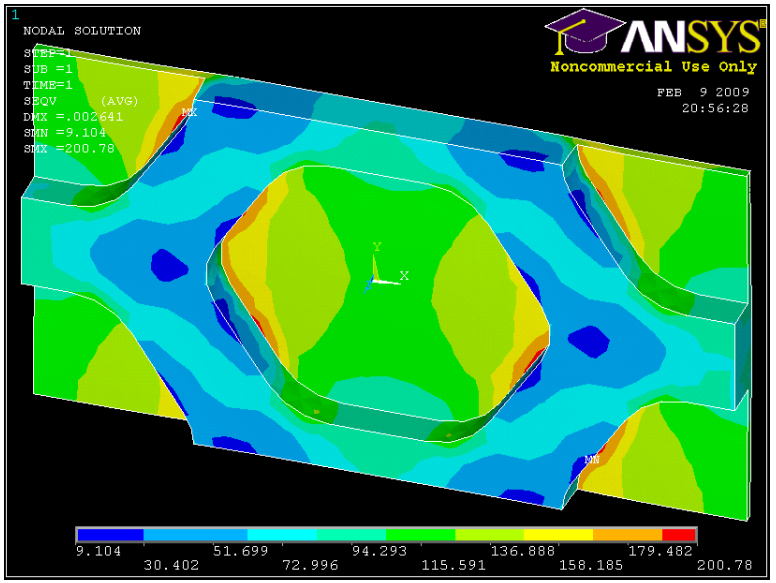
SECA

FEA Models of FlexCell Active Area

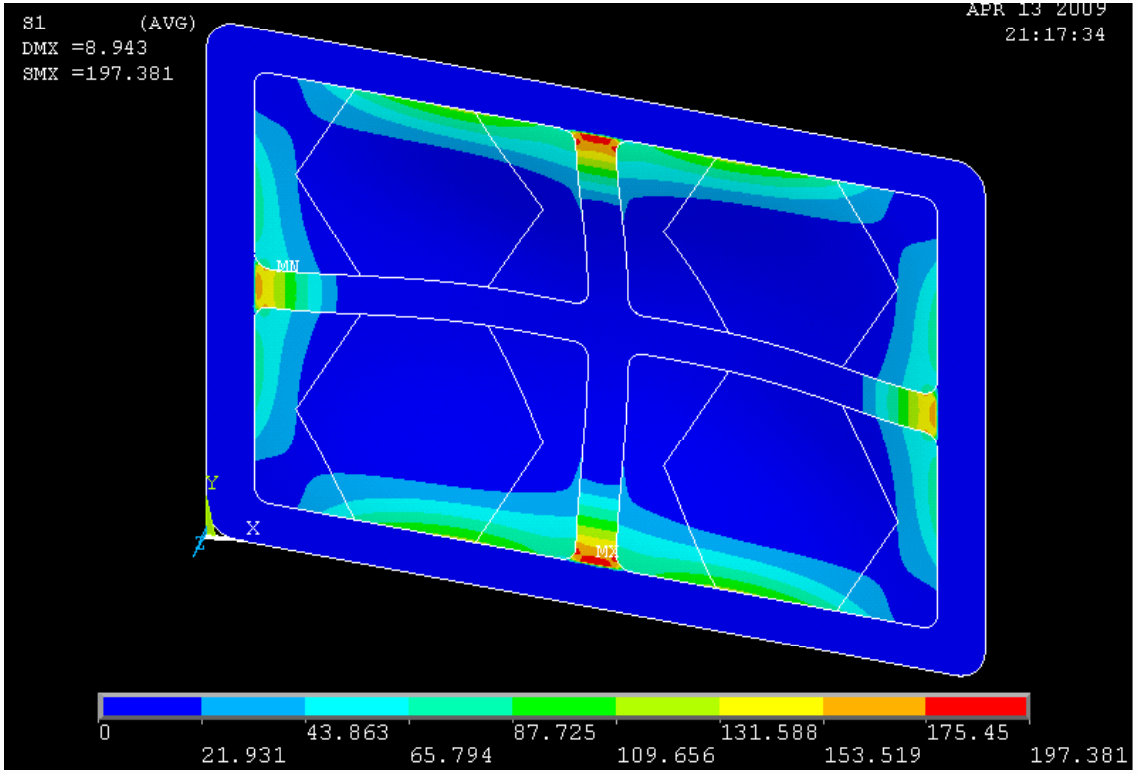
- Circles: Sample Contour (upper right).
- Rounded Hexes: Sample Contour (lower right).
- Effective properties found to rely on area, not shape (lower left).







FEA Modeling (Ohio State)



Principle stress contours for a large-area membrane with support ribs, with uniform pressure applied to the entire membrane with outer frame area being fully constrained

Conclusions and Future Work

Conclusions

- Fabrication methods for ScSZ-based *FlexCells* were successfully transferred to YSZ-based *FlexCells*.
- High performance in YSZ-based *FlexCells* has been demonstrated at the single-cell level.
- Stable performance has been achieved in testing with simulated coal gas.
- Finite element analysis is an effective design tool for mechanically robust *FlexCell* architectures.

SECA

NexTech's *FlexCell* is a promising cell design for coal-based, MW-scale SOFC power systems

Future Work

- Continued work to assess effects of *FlexCell* geometry on SOFC performance.
- Additional long-term testing on simulated coal gas
- Fabrication of YSZ-based *FlexCells* with 500-cm^2 area, and single-cell testing of large-area *FlexCells*
- Continued FEA modeling of mechanical robustness, including validation testing
- Completion of the manufacturing cost analysis

SECA

Acknowledgements

Funding

- DOE/SECA
- Ohio's Third Frontier Program
- U.S. Air Force
- Office of Naval Research

NexTech Colleagues

- Scott Swartz
- Lora Thrun
- Robin Kimbrell

Ohio State Colleagues

- Professor Mark Walter
- Angel Dharsh Suresh
- Ryan Berke