

**NEXTECH**  
MATERIALS

11<sup>th</sup> Annual SECA Workshop: July 29, 2010

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

**M.J. Day, Principal Investigator**

**10<sup>th</sup> Annual SECA Workshop  
Pittsburgh, PA  
July 29, 2010**



**NEXTECH**  
MATERIALS

11<sup>th</sup> Annual SECA Workshop: July 29, 2010

***Outline***

- Introduction to *FlexCell* planar cell design concept
- Project Details, Objectives, Conclusions
- Core Data (ScSZ-based *FlexCells*)
- Large-Area *FlexCell* Manufacturing and Testing
- Status of NexTech's SOFC Stack Technology
- Results of SECA Project (YSZ-based *FlexCells*)
- Future Work



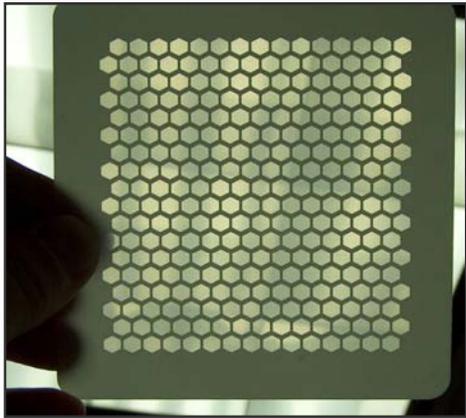
**NEXTECH**  
MATERIALS

11<sup>th</sup> Annual SECA Workshop: July 29, 2010

***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



**NEXTECH**  
MATERIALS

11<sup>th</sup> Annual SECA Workshop: July 29, 2010

***Project Details***

**U.S. Department of Energy (SECA)**

- DOE Contract Number: DE-NT0004113
- Project Monitor: Briggs White
- Phase I: 1-Oct-08 to 31-Mar-10
- Phase II: 1-Apr-10 to 30-Sep-11

**State of Ohio (Third Frontier Program)**

- *Cell Manufacturing for 100+ kW SOFC Power Generation Systems*
- ODOD Contract Number: TECH 08-057

**NexTech's Team**

- Principal Investigator: Mick Day
- NexTech Contributors: Scott Swartz, Lora Thrun, Robin Kimbrell
- Subcontractor: Ohio State University (Professor Mark Walter)

**NEXTECH**  
MATERIALS

11<sup>th</sup> Annual SECA Workshop: July 29, 2010

## *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



**NEXTECH**  
MATERIALS

11<sup>th</sup> Annual SECA Workshop: July 29, 2010

## *Conclusions*

- Fabrication methods for ScSZ-based *FlexCells* were successfully transferred to YSZ-based *FlexCells*.
- YSZ-based *FlexCells* successfully scaled to 500-cm<sup>2</sup> area.
- High performance in YSZ-based *FlexCells* has been demonstrated at the single-cell (and stack) level.
- Finite element analysis is an effective design tool for mechanically robust *FlexCell* architectures.

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

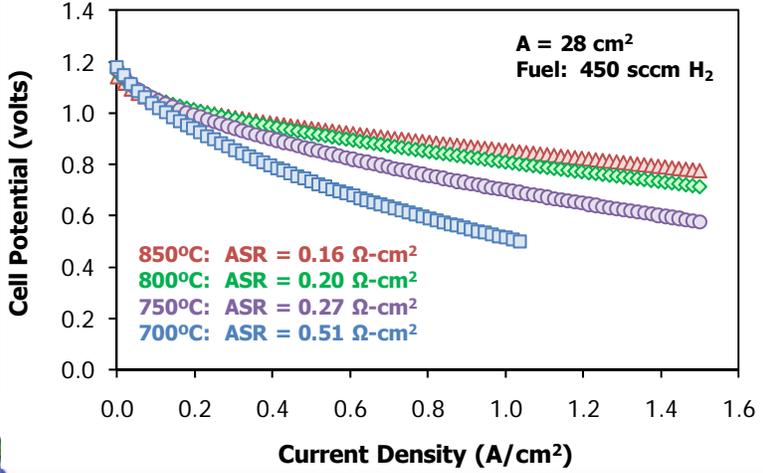
**NEXTECH MATERIALS** 11<sup>th</sup> Annual SECA Workshop: July 29, 2010

**Core Data**  
**(ScSZ-Based FlexCells)**



**NEXTECH MATERIALS** 11<sup>th</sup> Annual SECA Workshop: July 29, 2010

**State-of-the-Art Performance**



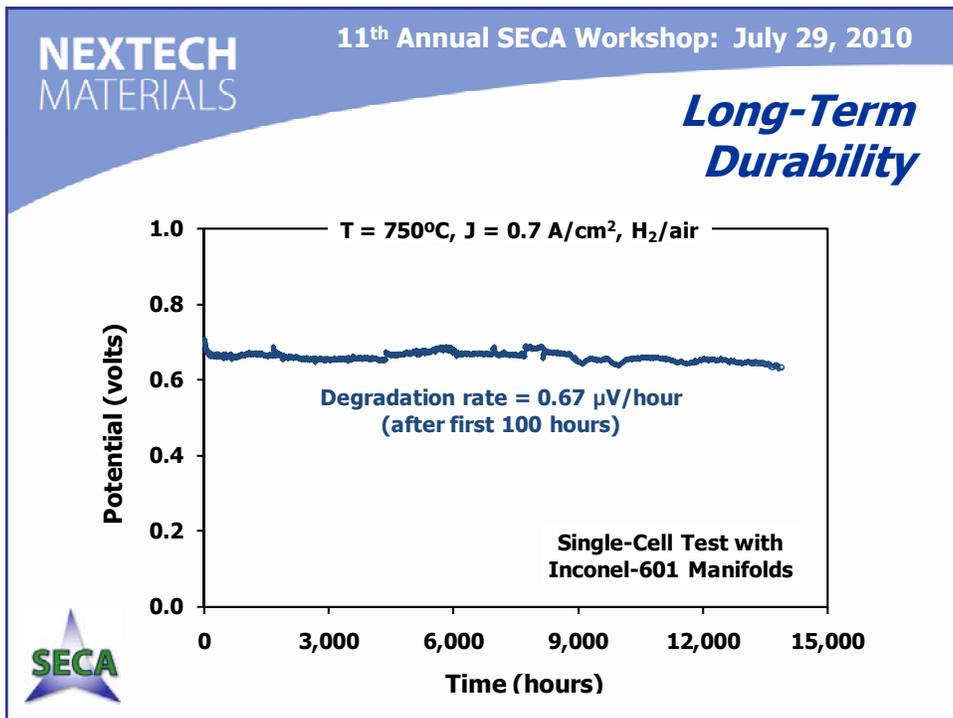
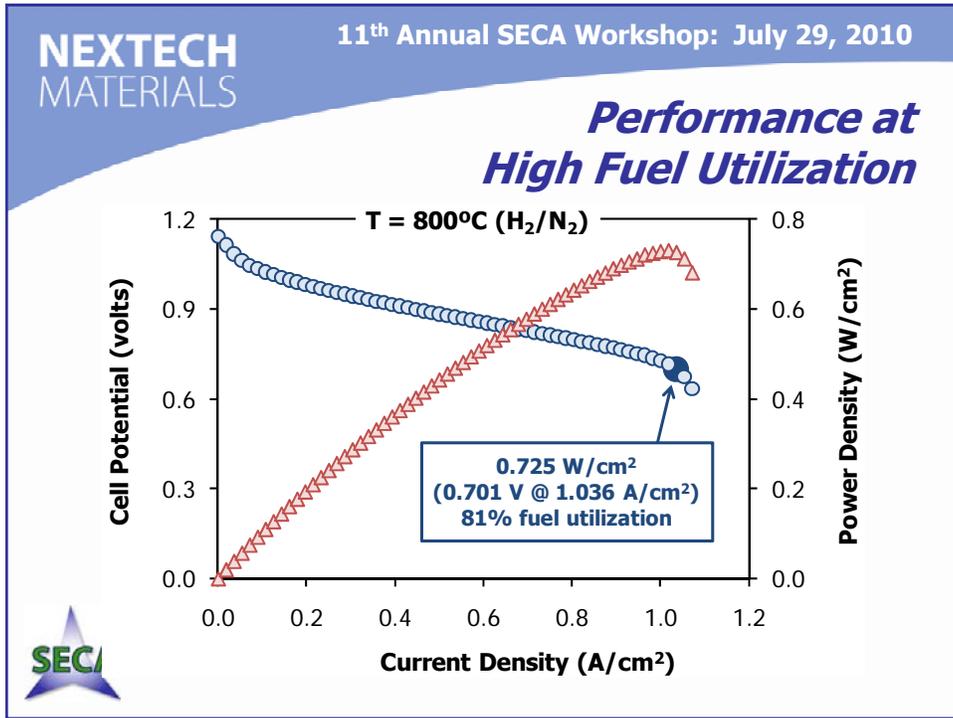
**Cell Potential (volts)**

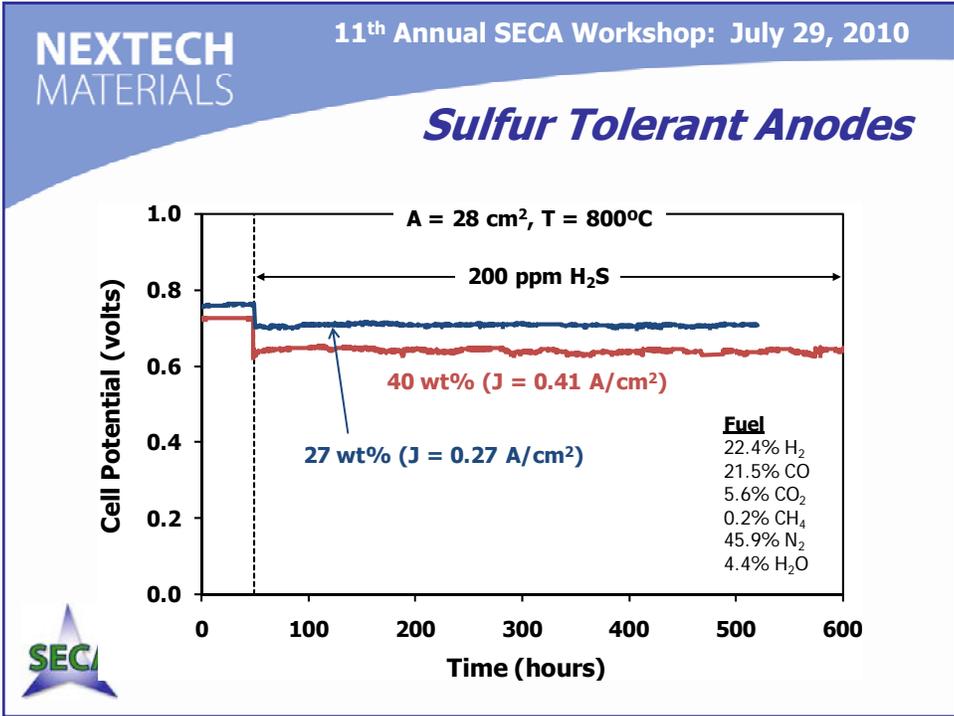
**Current Density (A/cm<sup>2</sup>)**

**A = 28 cm<sup>2</sup>**  
**Fuel: 450 sccm H<sub>2</sub>**

**850°C: ASR = 0.16 Ω-cm<sup>2</sup>**  
**800°C: ASR = 0.20 Ω-cm<sup>2</sup>**  
**750°C: ASR = 0.27 Ω-cm<sup>2</sup>**  
**700°C: ASR = 0.51 Ω-cm<sup>2</sup>**



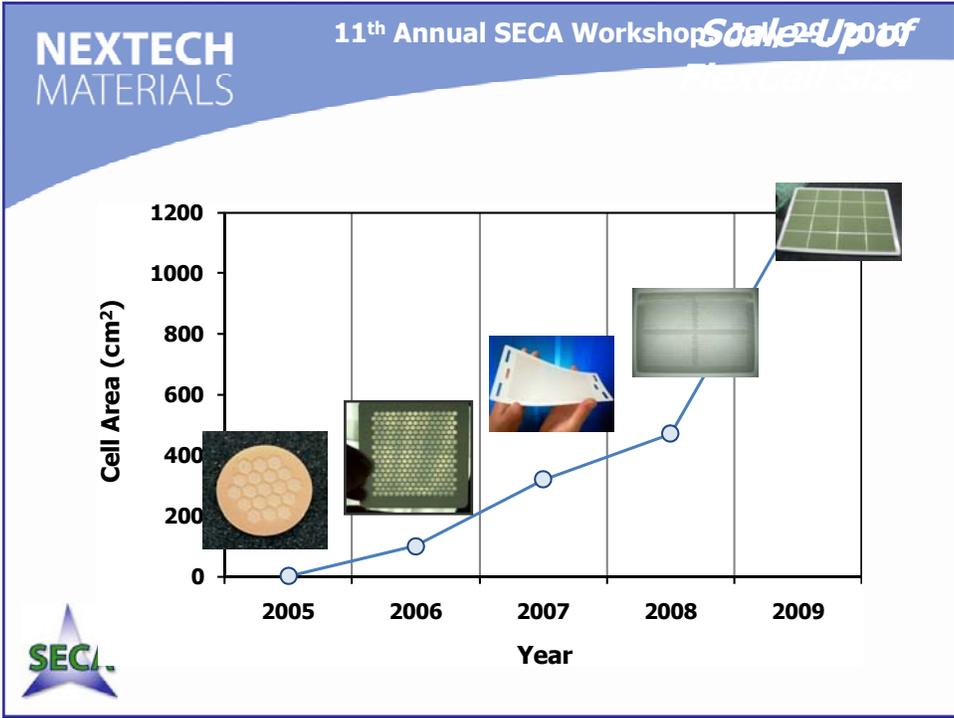




**NEXTECH MATERIALS** 11<sup>th</sup> Annual SECA Workshop: July 29, 2010

### Large-Area FlexCell Manufacturing and Testing





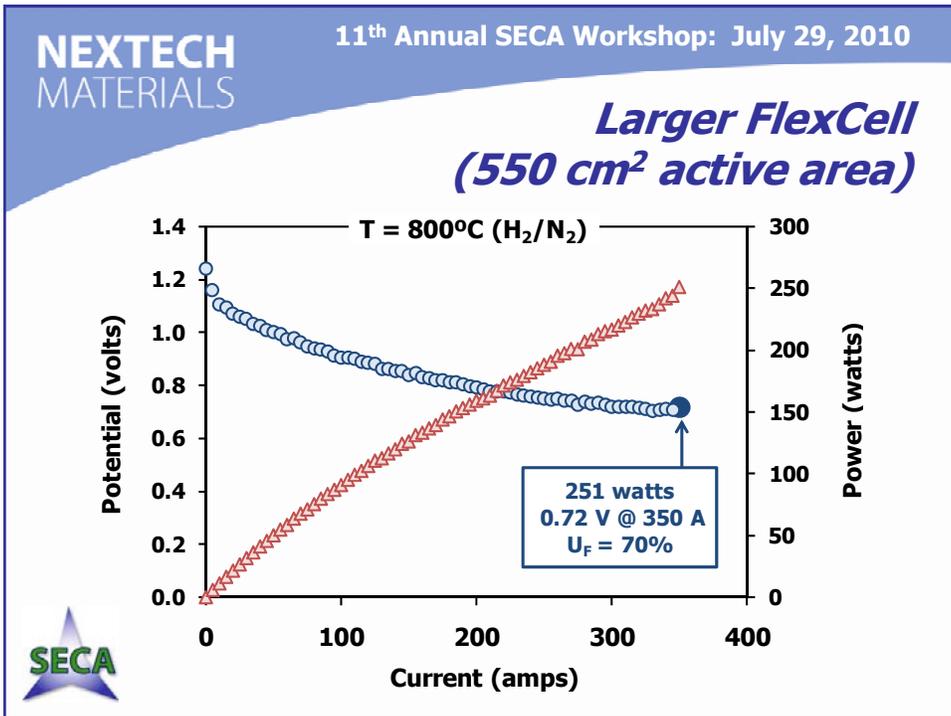
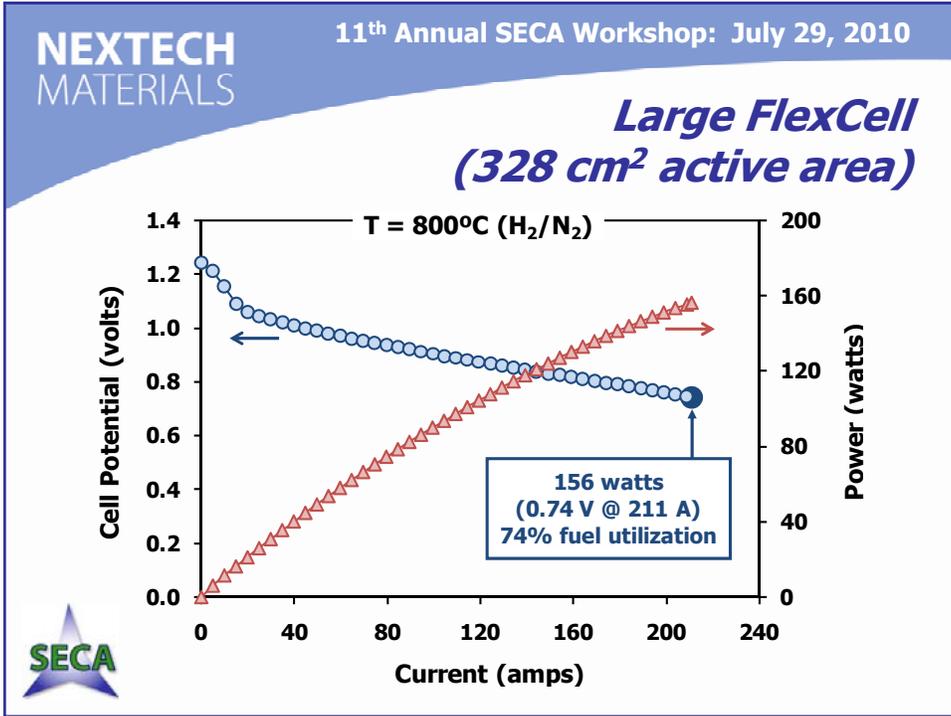
**NEXTECH MATERIALS** 11<sup>th</sup> Annual SECA Workshop: July 29, 2010

*Large-Area FlexCells*

Stack	Total area (cm <sup>2</sup> )	Active area (cm <sup>2</sup> )
Left (3 cells)	476	328
Right (4 cells)	702	550

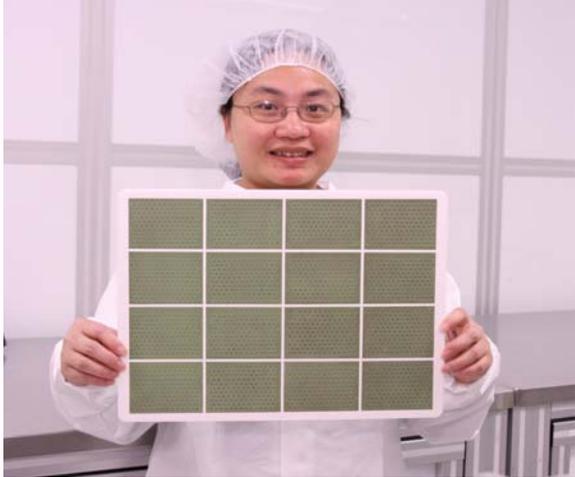
Total area = 476 cm<sup>2</sup>  
Active area = 328 cm<sup>2</sup>

Total area = 702 cm<sup>2</sup>  
Active area = 550 cm<sup>2</sup>



**NEXTECH MATERIALS** 11<sup>th</sup> Annual SECA Workshop: July 29, 2010

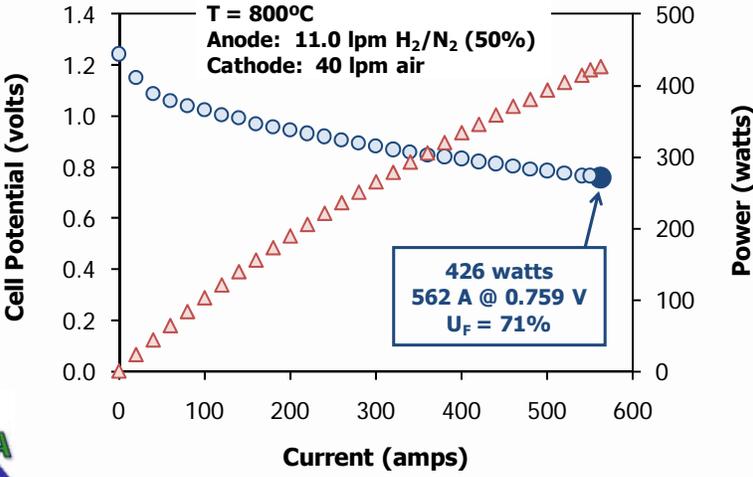
### 1200-cm<sup>2</sup> Area FlexCell



**SECA**

**NEXTECH MATERIALS** 11<sup>th</sup> Annual SECA Workshop: July 29, 2010

### Largest FlexCell (800 cm<sup>2</sup> active area)



**SECA**

**Cell Potential (volts)** vs **Current (amps)** vs **Power (watts)**

**T = 800°C**  
**Anode: 11.0 lpm H<sub>2</sub>/N<sub>2</sub> (50%)**  
**Cathode: 40 lpm air**

**426 watts**  
**562 A @ 0.759 V**  
**U<sub>F</sub> = 71%**

**NEXTECH**  
MATERIALS

11<sup>th</sup> Annual SECA Workshop: July 29, 2010

***Status of NexTech's  
SOFC Stack Technology***

**SECA**

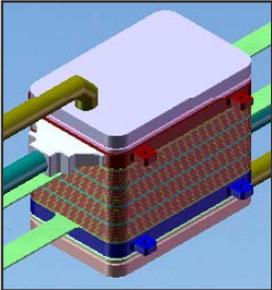
**NEXTECH**  
MATERIALS

11<sup>th</sup> Annual SECA Workshop: July 29, 2010

***SOFC Stack Design***

**SOFC Stack Design Principles**

- Maximize power density to facilitate thermal management
- Thin-foil interconnects – reduced cost, compatibility with compressive sealing approaches
- Gasket sealing, enabled by dense cell periphery
- Internal reforming for high efficiency (when possible)
- Modular stack design



**SECA**

### 2-kW Stack Platform



500-watt stack module (10 cells)

2-kW stack (40 cells)

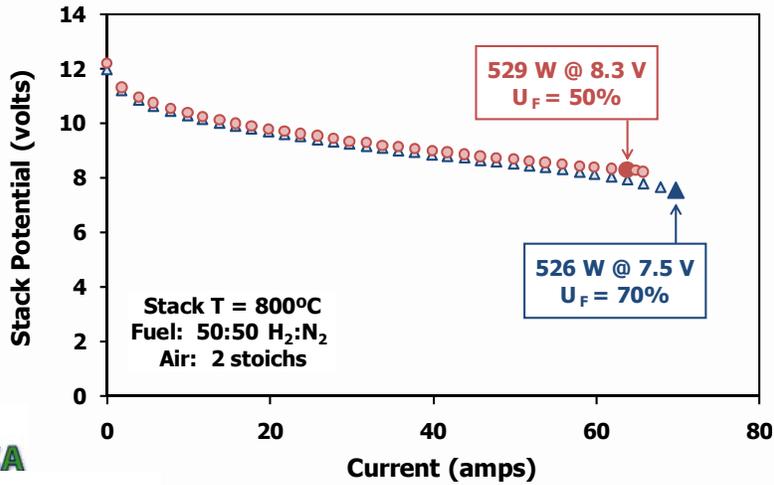


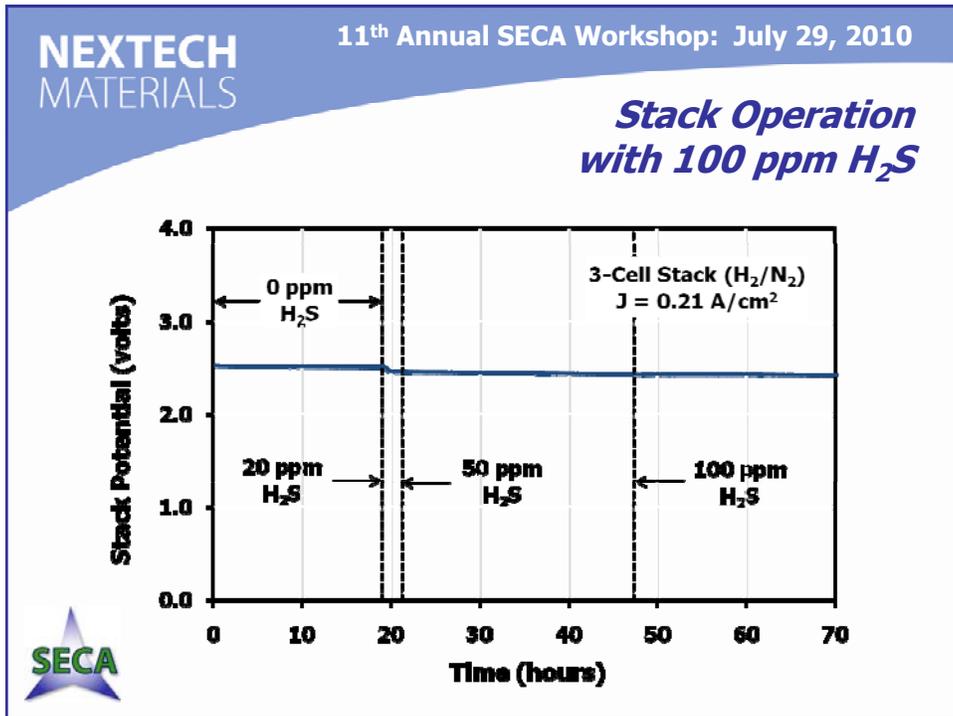
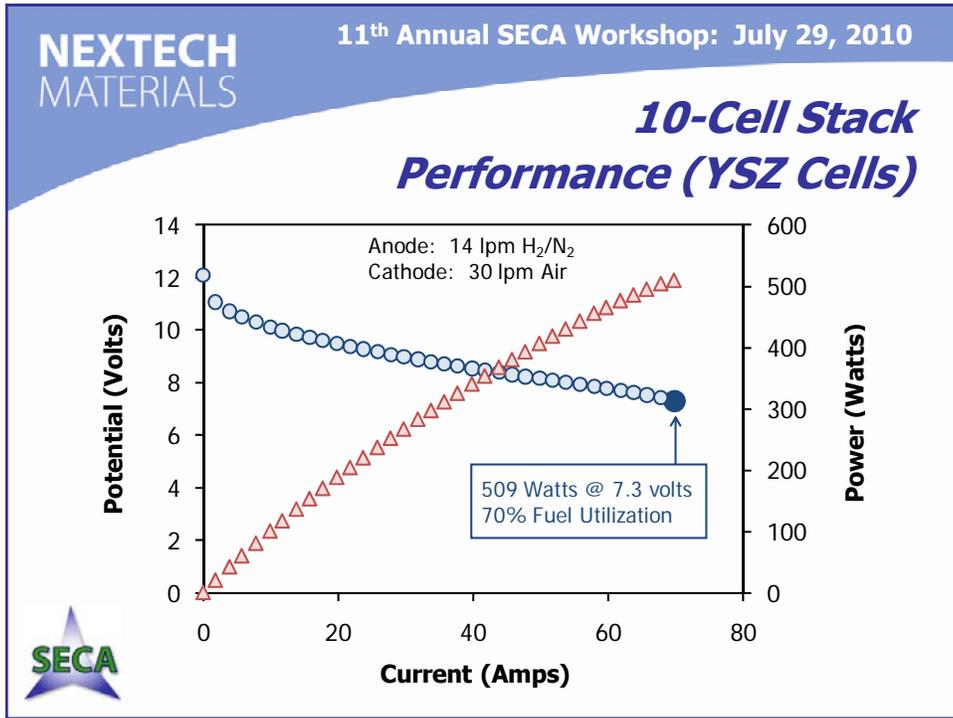
#### Stack Dimensions (without endplates)

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



### 10-Cell Stack Performance (ScSZ Cells)





**NEXTECH**  
MATERIALS

11<sup>th</sup> Annual SECA Workshop: July 29, 2010

***Fabrication and Testing  
of YSZ-Based FlexCells  
(SECA Project)***

**SECA**

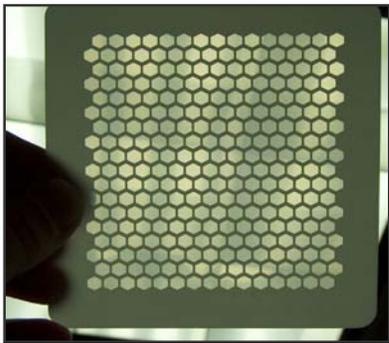
**NEXTECH**  
MATERIALS

11<sup>th</sup> Annual SECA Workshop: July 29, 2010

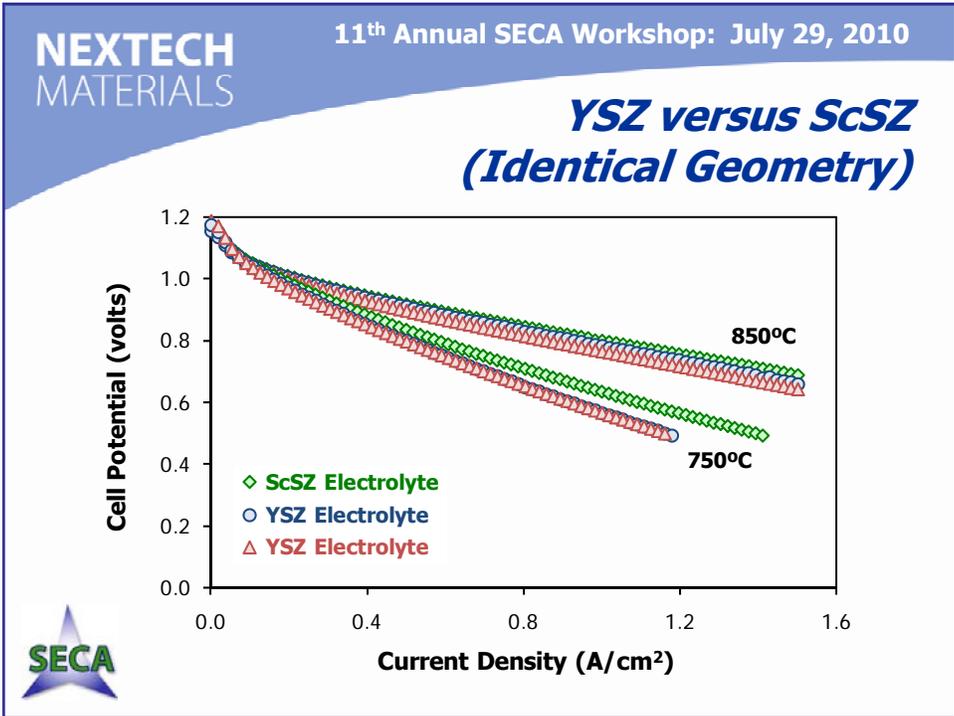
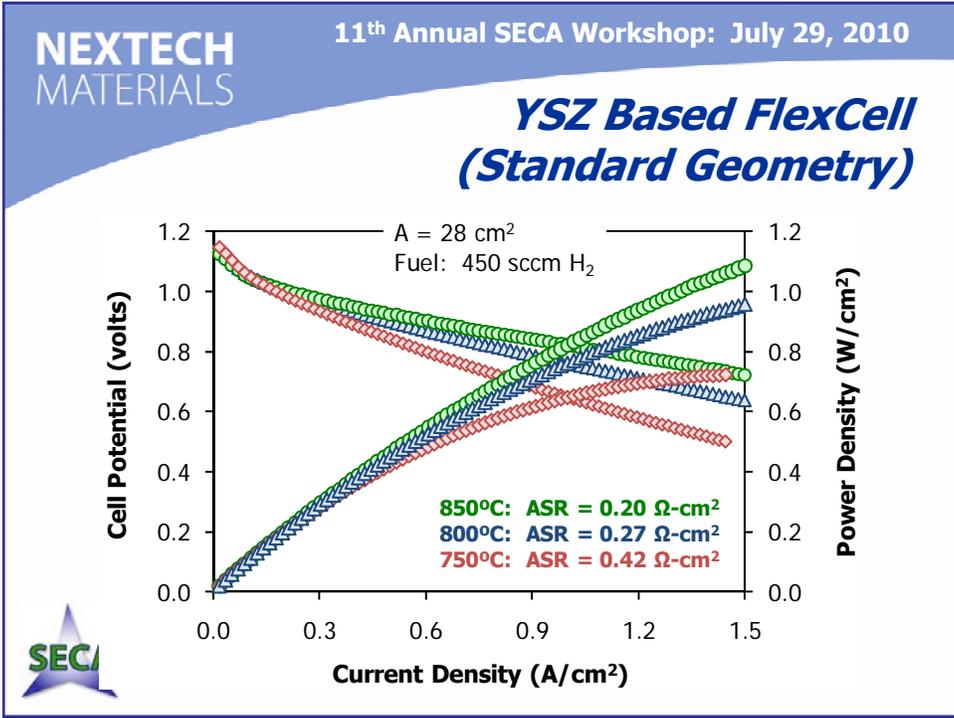
***Fabrication of  
YSZ-Based FlexCells***

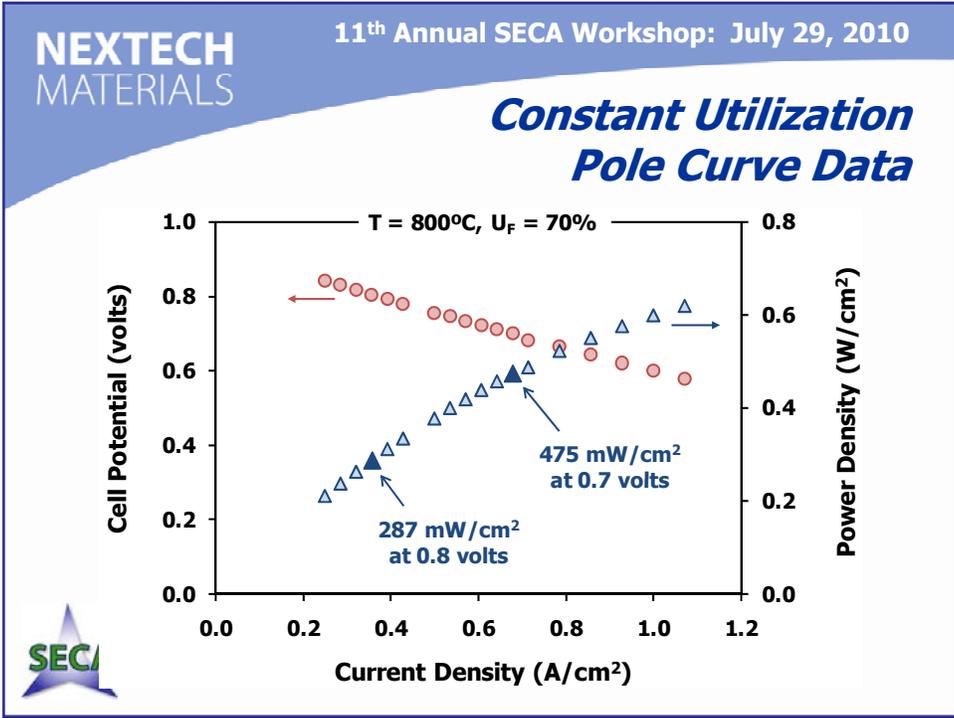
**Architecture Variables**

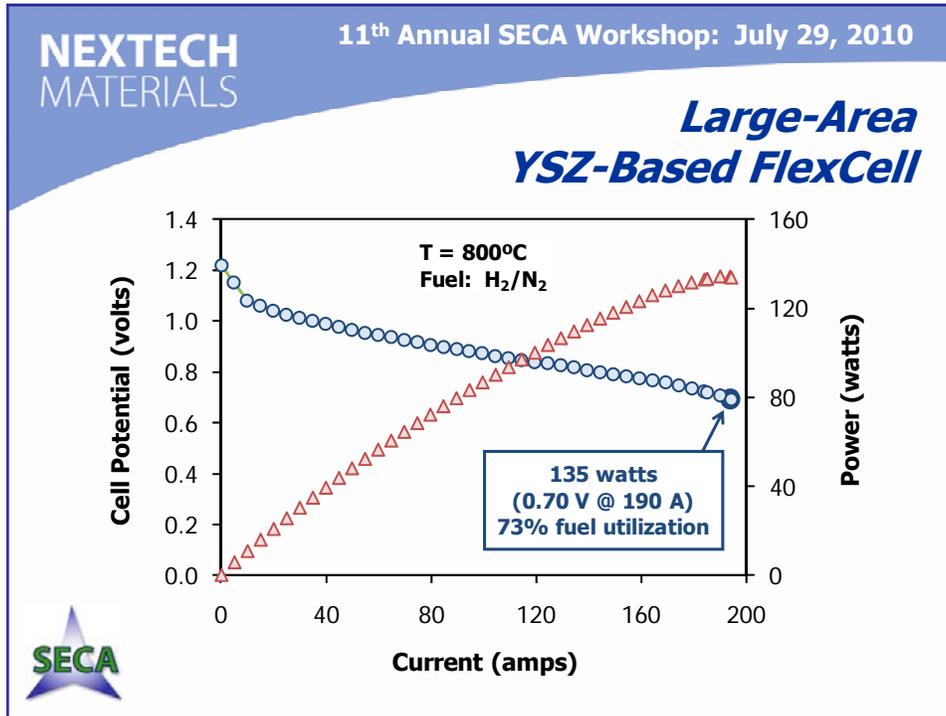
- Support thickness: 80-160  $\mu\text{m}$
- Membrane thickness: 24-32  $\mu\text{m}$
- Percent thin membrane in active region: 65-75 percent
- Support mesh pattern/geometry



**SECA**







## *Manufacturing Cost Estimation*

<b><i>FlexCell</i> production costs (250 MW/year)</b>			
<b>Cost Category</b>	<b>Yearly Cost</b>	<b>Cost Per Cell</b>	<b>Cost Per kW</b>
Raw Materials	\$3,389,653	\$1.69	\$13.56
Depreciation	\$3,032,925	\$1.52	\$12.13
Operating Labor	\$1,833,930	\$0.92	\$7.34
Utilities	\$1,146,435	\$0.57	\$4.59
Operating Supplies	\$677,931	\$0.34	\$2.71
Local Taxes	\$808,780	\$0.40	\$3.24
Maintenance & Repairs	\$67,793	\$0.03	\$0.27
Insurance	\$323,512	\$0.16	\$1.29
<b>Total</b>	<b>\$11,280,958</b>	<b>\$5.64</b>	<b>\$45.12</b>



## *Future Work*

- Continued work on fabrication of large-area, YSZ-based *FlexCells*
- Additional large-area cell testing, including long-term testing with simulated coal gas
- Updates to the manufacturing cost analysis
- Testing of SOFC stacks made with YSZ-Based *FlexCells*

