



# ***Development of Low Cost PEMFC Metal Bipolar Plate***

***Fuel Cell Seminar***

***October 31 –November 3, 2011***

***Walt Disney World Swan and Dolphin Resort***

***Orlando, FL***

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***TreadStone Technologies, Inc.***

***201 Washington Road***

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## Corporate Background

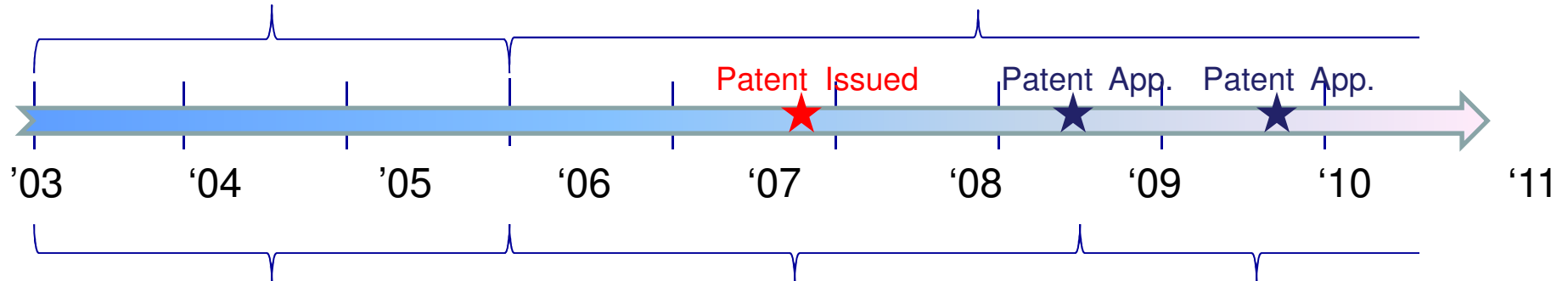
- *TreadStone is a small business technology spin-out of SRI-Sarnoff (Former RCA) in March 2006*
- *The core technology (metal corrosion protection) was developed over the last 7 years*
- *The technology is being sold and demonstrated in commercial markets for dual-use applications*



## Corporate Mission

*Achieving continuous growth in revenue, profits and net worth through the commercialization of new technologies for the alternative energy market.*

# Metal Plate Technology Development History



- Plate Design Invention
- Demonstration using Titanium w/gold
- Funded by:
  - Sarnoff
  - A DoD Project

- Processing Invention
- Demonstration using SS w/gold
- Funded by:
  - Private Investors
  - NJ CST


- Processing Improvement
- Development of Gold-free, C-steel and Aluminum plates
- Commercial sales since '09
- Funded by:
  - Private Investors
  - DOE EERE
  - DoD SBIR

## Market Applications for TreadStone's LiteCell Technology


### Fuel Cell Market

**Commercial Applications**


**Back-up Power**



**Materials Handling**




**Combined Heat & Power**




**Military Applications**


**Shipboard Power**




**UAV & UUV**



**Specialty Applications - NASA**



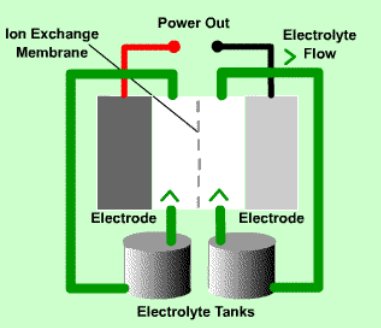
### Automotive



**Long runtime & Short refueling time**

### Energy Storage Applications

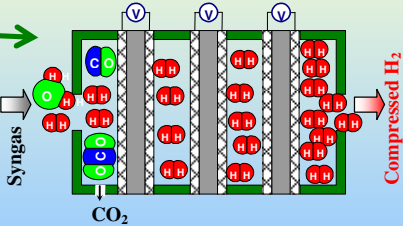
**Flow Batteries**



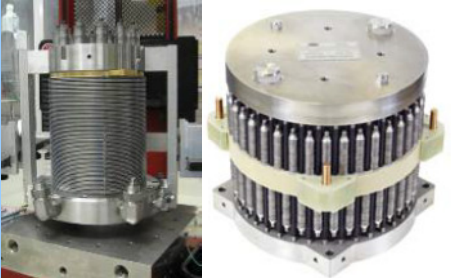
**High energy efficiency and independence**

**Long lived - low maintenance power**

**Electrochemical Compression**



**Hydrogen Generation & Delivery**



**Electrolyzers**

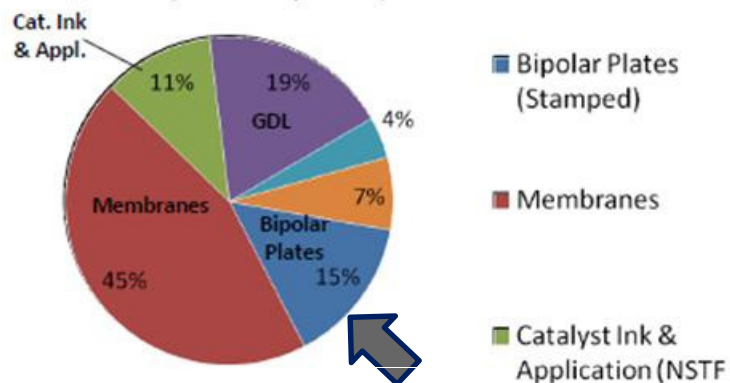
**Safe, low-emissions power**

**High Energy Density**

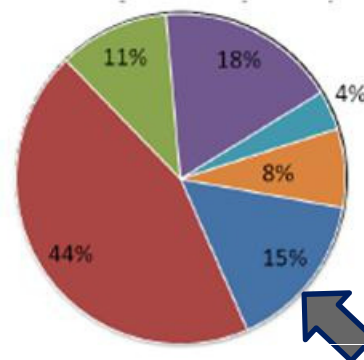
# LiteCell Technology... Why do we need it?

## Bipolar Plates are a Major Portion of Fuel Cell Stack Costs

1,000 systems (2010)



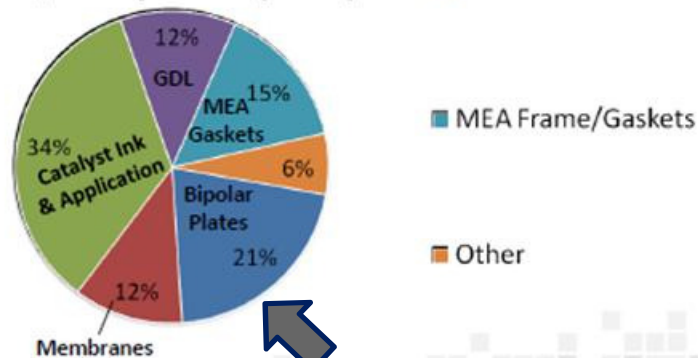
1,000 systems (2015)



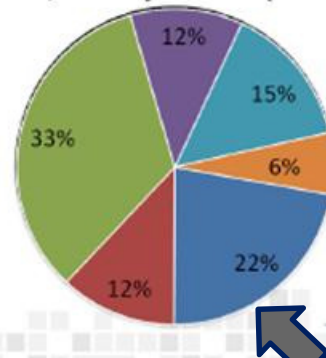
*Bipolar plates cost more than catalyst in small volume*

- Membrane dominates cost at low production
- Catalyst Ink dominates cost at high production

500,000 systems (2010)



500,000 systems (2015)



*Bipolar plates cost more than membrane in large volume*

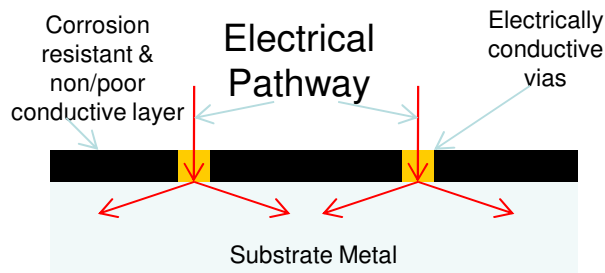
page 21

2010 DOE H<sub>2</sub> Program  
AMR Presentation

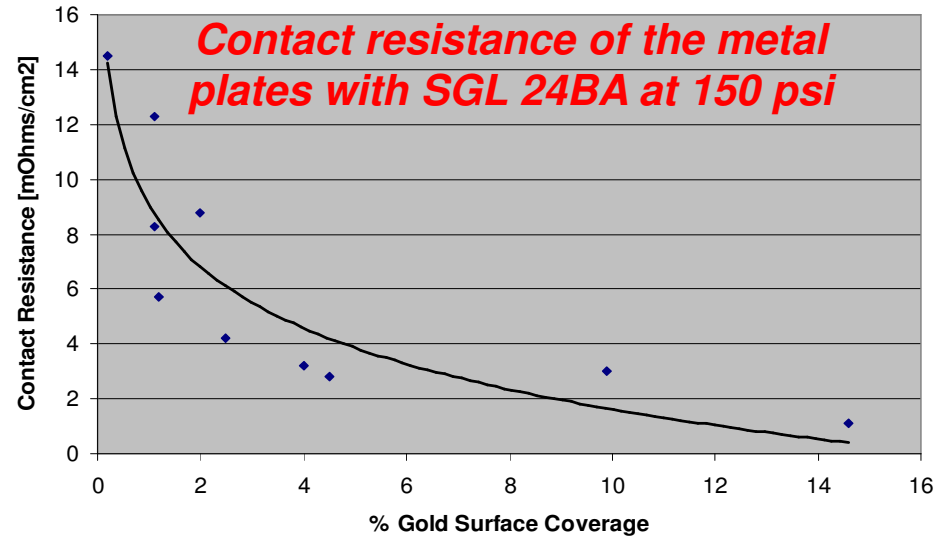
DIRECTED  
TECHNOLOGIES, INC.

# TreadStone's Metal Plate Surface Structure

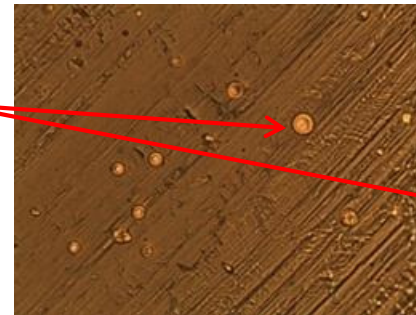
## TreadStone's Design



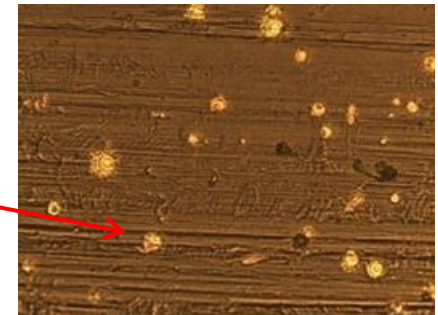
US 7,309,540, Dec. 18, 2007



- Deposit & use small conductive, corrosion resistant materials as conductive points (conductive vias) to cover a small portion of metal surface
- Use non-conductive, corrosion resistant materials to cover majority surface of the metal plates



2% surface covered by Au

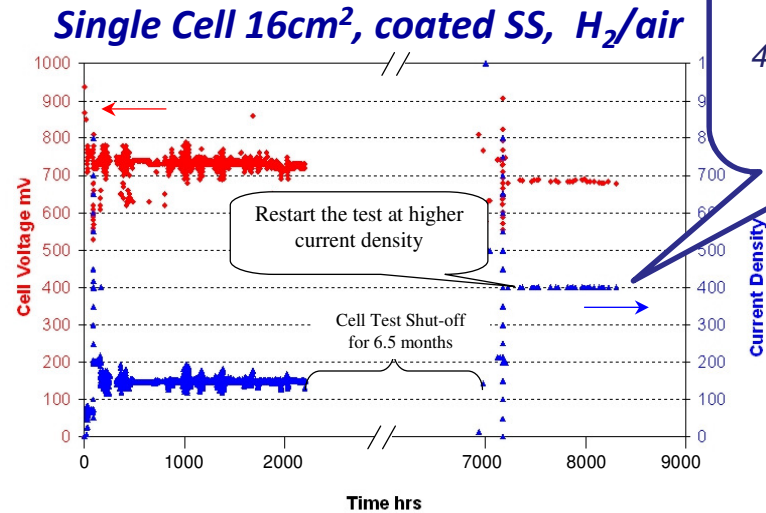


4% surface covered by Au

## Proof of Concept Demonstration

- Proved the concept of TreadStone's metal plate technology
- Demonstrated in small single cell long-term operation
- Developed a low cost fabrication process for corrosion resistant metal plates

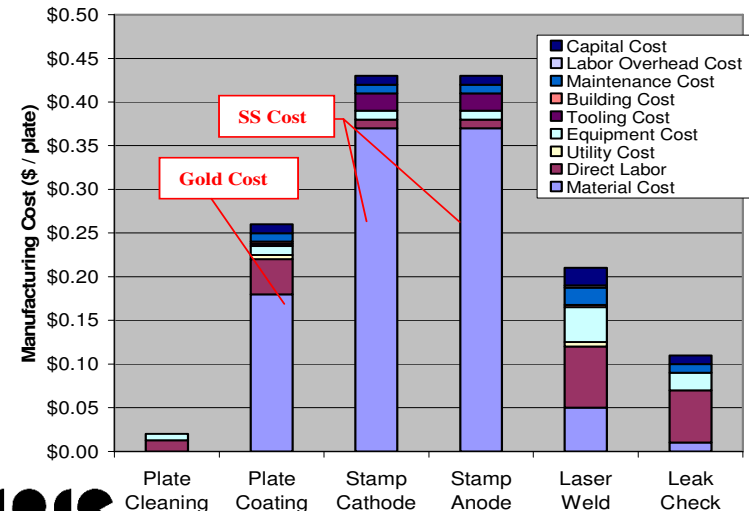
Achieved 8200 hrs (3500 hrs operation + 4700 hrs stand-by) long term stability test



gti®

- Bipolar plate cost: \$1.41/plate  
-- \$3.53/kW (based on 1000mW/cm<sup>2</sup>)
- Meet DOE 2010 Target < \$6/kW
- Need Improvements to meet DOE 2015 Target < \$3/kW

### Cost Breakdown of SS Based Plates



**IBIS**

# Outside Evaluations

## TreadStone SS Plate w/Au-Dots Evaluation at Ford <sup>1</sup>

Attribute	Metric	Unit	2015 DOE Target	Ford Data on Au-Dots
Corrosion anode	Current density at active peak in CV	$\mu\text{A}/\text{cm}^2$	<1	No active peak
Corrosion cathode	Current density at 0.8 $V_{\text{NHE}}$ in potentiostatic experiment	$\mu\text{A}/\text{cm}^2$	<1	~0.1
Area Specific Resistance	ASR (measured through plane) at 6 bar contact pressure (includes both side surface; doesn't include carbon paper contribution)	mOhm.cm <sup>2</sup>	<20	8.70 (as-recd flat samples)
Electrical Conductivity	In-plane electrical conductivity (4-point probe)	S/cm	>100	34 kS/cm
Formability	% elongation (ASTM E8M-01)	%	>40%	53(   to RD*)/ 64 (⊥ to RD)
Weight	Weight per unit net power (80 kWnet system)	Kg/kW	<0.4	<0.30

1) 2011 DOE AMR Meeting, May, 2011



\*RD: Rolling Direction

### Short Stack in-situ Testing at Ford\*

- TreadStone SS plates w/ Au dots were tested in-situ for durability at Ford Motor Company.
- Ford designed metallic bipolar plate w/SS316L as base substrate,
  - 300 cm<sup>2</sup> active area, with TreadStone's coating
  - A 10-cell, 2.5 kW short stack was assembled
- Durability Cycle:
  - The stack is being tested for durability utilizing durability cycle (which includes FTP cycle along with others) mimicking real world driving conditions.
- Results
  - To date stack has achieved 1000 hrs.
  - Next test regime starting soon



*Ford short stack with metal bipolar plates*



\* 2011 DOE AMR Meeting, May, 2011






# LiteCell Solves Cost & Durability Obstacles

## Reducing Current Obstacles

- **Graphite Separator Plates = Industry Standard**
- **Graphite Challenges:**
  - **Lower Electrical Conductivity**
  - **Fragility and Durability**
  - **Limit Overall System Efficiency**
  - **Higher Costs**

## TreadStone's LiteCell Solution

- **Uses "off-the-shelf" metal plates**
- **Improves system conductivity and efficiency**
- **Eliminates stack corrosion and associated maintenance costs**
- **Creates durable components for high efficiency systems**

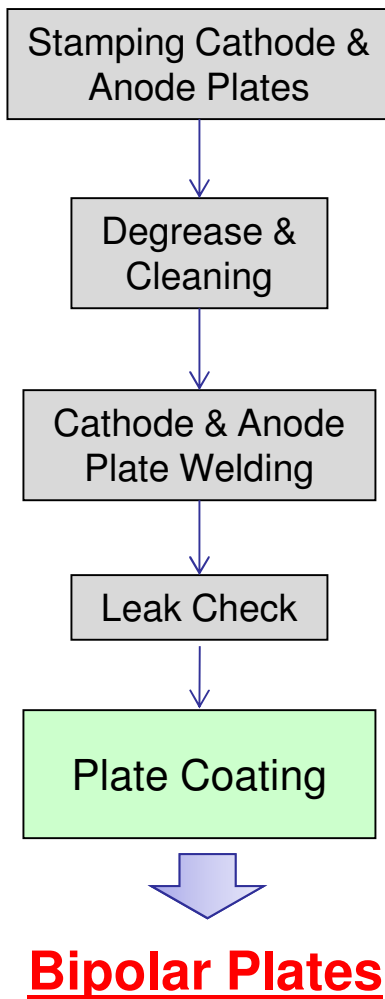
Fuel Cell Market	Durability	Weight	Form Factor	Manufacturing Cost (High Volume)
<b>Automotive</b>	5,000 hrs..	Lightweight	Cell/stack design customization desired	<\$6.00/kW
<b>Portable</b> (e.g. military)		<b>X</b>	<b>X</b>	<b>X</b>
<b>Graphite</b>				
<b>LiteCell</b>	8,200+ hrs..	>50% weight reduction	Highly customizable	\$3.53/kW

*Reported Results by Clients and Government Contractors*

**LiteCell meets the performance requirements at low cost**

# Technology Cost Improvements are Possible

## Plate Fabrication Process:



Material & Forming Costs  
**316 SS material cost accounts over 65% of the plate cost:**

- At \$2.00/lb. (historical average)  
 - SS material cost: \$1.05/plate
- At \$3.92/lb. (Aug. 2010)  
 - SS material cost is \$2.06/plate

## TreadStone LiteCell Process

Baseline Au-dots: \$0.33/plate  
 Alternative 1: \$0.31/plate  
 Alternative 2: \$0.79/plate  
 Alternative 3: \$0.30/plate

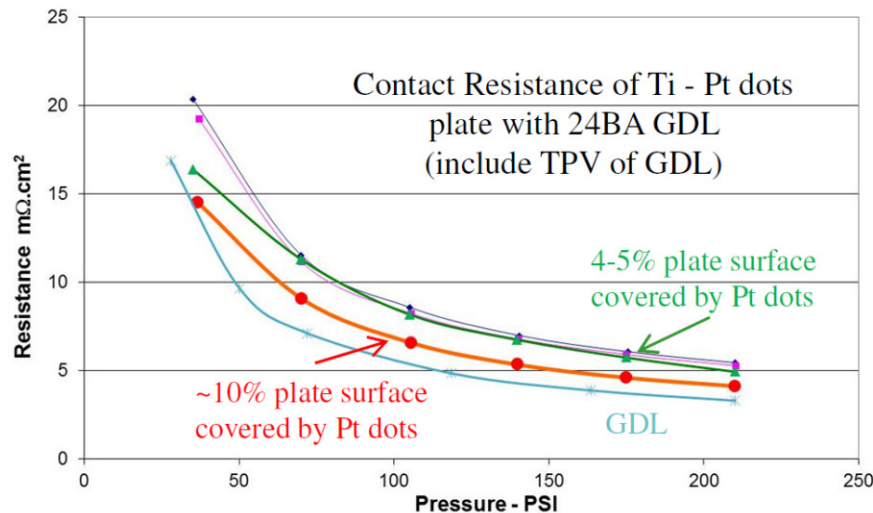


Coating Cost: (based on \$1,000/oz. Au)

# Applications in Electrolyzers

- Current focus on the Ti separator plates
  - Current Standard Plate: Ti Substrate with 100% Pt Surface Coverage
  - TreadStone's approach: Ti Substrate with Pt-dots
    - Lower Pt loading...lower cost
    - Simple fabrication process...lower cost
  - Long term operation stability testing is on-going

## Electrical Resistance



## Hydrogen Embrittlement

Sample #	H <sub>2</sub> concentration in Ti strip (after 1000 hrs. in high pressure H <sub>2</sub> )
#1	760 ppm
#2	250 ppm
#3	73 ppm*

\* Similar to original concentration in Ti Strip

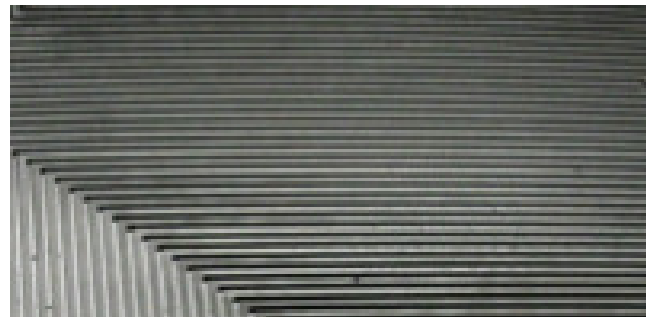
- Future applications on other metallic stack components
  - Ti mesh flow field

## Applications in Flow Batteries

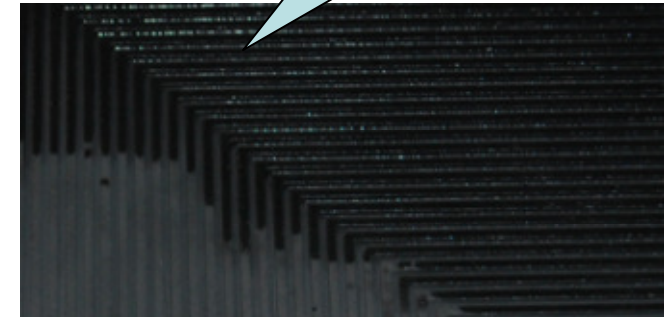
### Market Needs:

- *Highly corrosive chemicals*
  - *Requirements varies with chemical systems.*
  - *More aggressive at charge stage (high voltage)*
- *Large dimension (meters) for grid scale storage*
- *Thermal cycling stability (during charge/discharge)*

**Graphite plates  
before and after the  
test in VRB flow  
battery**



**Before**



**After**

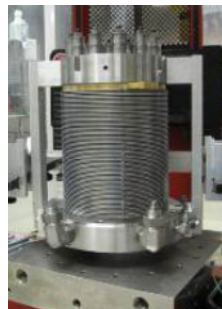
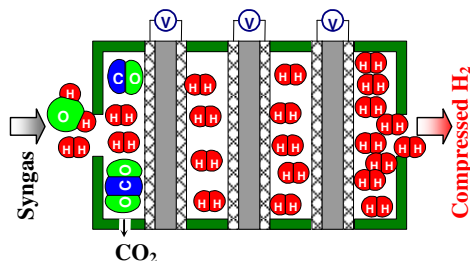
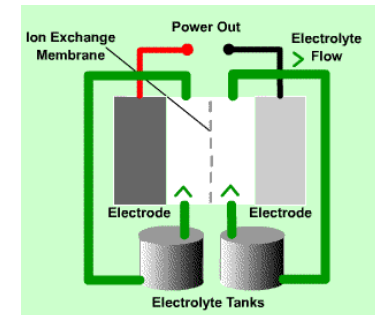
### Current Activity:

- *Electrochemical corrosion test of the selected materials in  $Br_2$ -HBr environment*
- *Conducting durability tests for additional flow battery chemistries*

# Summary

## TreadStone's LiteCell Technology....

- **Addresses key technology barriers for the electrochemical stack applications...**
  - **Durability, Corrosion Resistance & Cost...**
- **Meets the performance requirements of several applications and can be manufactured at low costs**
  - **Demonstrated by 3<sup>rd</sup> Party Evaluators...**
- **Can be applied to Fuel Cells, Electrolyzers, Flow Batteries...**
  - **Promising new application potential in Electrochemical Compressors...**
- **Can be customized for specific electrochemical systems**



# Acknowledgments

- NJ state Commission on Science & Technology
- DOE EERE Hydrogen and Fuel Cell Program
- DoD SBIR Program
- Partners
  - Gas Technology Institute
  - Ford Motor
  - Oak Ridge National Lab.
  - Center for Thermal Spray, Stony Brook University
  - IBIS Associates