DEVELOPING IMPROVED MATERIALS TO SUPPORT THE HYDROGEN ECONOMY

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This presentation does not contain any proprietary or confidential information

Overview

Timeline

- Start Date: Sep 2004
- End Date: Jun 2009
- 95% Complete

Budget

- FY04: $2.945 M
- FY05: $2.961 M
- FY06: $2.475 M
- FY08: $ .984 M

Total: $9.365 M

- Contractor cost share
  > $9.6 M
- State of Ohio cost share
  > $3.8 M

Barriers

- PD - Fuel Processor Capital Costs
- PD, MF - Renewable Integration
- MF, ST, AN - Materials Efficiency
- PD, ST, MF - Cost, Impurities
- PD, MF - Capital Cost & Efficiency
- AN - Efficiency, Cost, Wt. & Volume
- PD, ST, MF, AN - Durability, Cost

Partners

- Makel Engineering - H_2 Sensor
- Precision Energy - Membrane Proc.
- Catacel Corp. - Reformation
- Faraday Technology - Catalyst App.
- Technology Mgmt. - Multi Fuel SOFC
- NexTech Materials - H_2 Sensor
- Powdermet, Inc. - H_2 Storage
- UltraCell Corp. - Fuel Cell Power

Program Objectives

Relevance

Edison Materials Technology Center (**EMTEC**) uses goals set forth in the USDOE *Hydrogen, Fuel Cells & Infrastructure Technologies Program Plan* to find and fund projects which satisfy these criteria:

- Demonstrate feasibility with job creation potential
- Cross-cutting breakthrough materials technology
- Stimulate near term manufacturing-based commercialization
- Patterned on EMTEC Core/Commercial Technology (CT) model

Target Technologies and Barriers

Target Technology	DOE Barrier Addressed
H_2 Generation from Renewable Liquid Feedstocks	Fuel Processor Capital Costs
H_2 Generation by Water Electrolysis	Renewable Integration
H_2 Generation by Photo-electrochemical Electrolysis	Materials Efficiency, Bulk Materials Synthesis, Device Configuration Designs
H_2 Separation Materials	Cost, Impurities
H_2 Generation from Biomass and Coal	Capital Cost and Efficiency
H_2 Storage by New Materials and Concepts	Efficiency, Cost, Weight and Volume
H_2 Processing: Sensors, Delivery, Purification	Durability, Cost

Approach

- EMTEC solicited projects that:
  - Have Industry Relevance
  - Are Appropriately Resourced
  - Are Aligned with EERE Hydrogen Goals
  - Address DOE Barriers
  - Have Near Term Commercialization Viability
- EMTEC has extensive experience managing collaborative technology projects
- EMTEC has developed a business model for selection and management of core/commercial technology

EMTEC

- EMTEC is one of 7 State of Ohio Edison Centers
  - Established in 1987 by Ohio Gov. Celeste
  - 501c(3) Not-for-Profit
- Membership Based with Over 140 Industry, University, and Government Members
- Virtual – We Own no Major Capital Equipment
- Access to Over $2B in State-Of-The-Art Facilities
- Significant Experience in Ceramics, Metals, Polymers, and many Material Processes

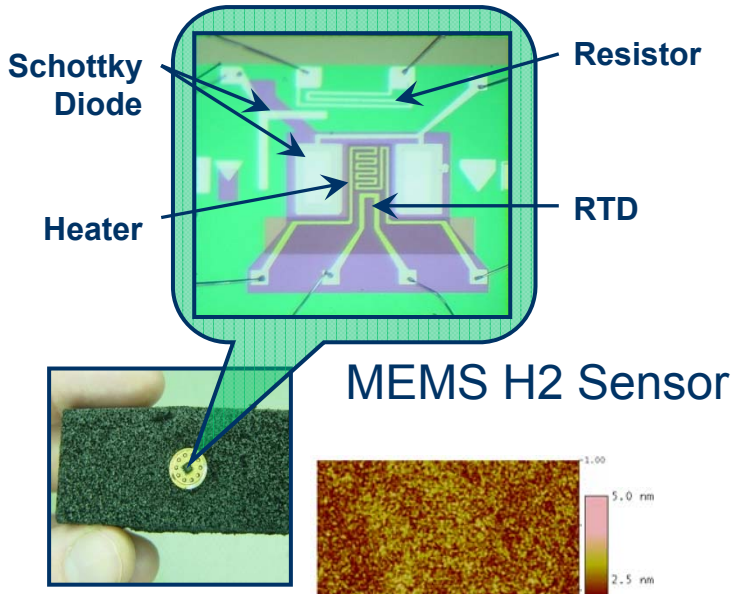
EMTEC Interactions/Collaborations

- Air Force Research Laboratory
  - Technology transfer program
  - Commercialization & business development
  - SBIR & Commercialization pilot program support
- State of Ohio
  - Department of Development Technology Division
  - Third Frontier Program
    - Multiple fuel cell projects
    - Photovoltaic Innovation Center (PVIC)
  - Ohio Fuel Cell Coalition / Wright Fuel Cell Group
- Business Outreach Services
  - Procurement Technical Assistance Center (PTAC)
  - Manufacturing Small Business Development Center (MSBDC)
- EMTEC Technical Steering Committee (TSC)

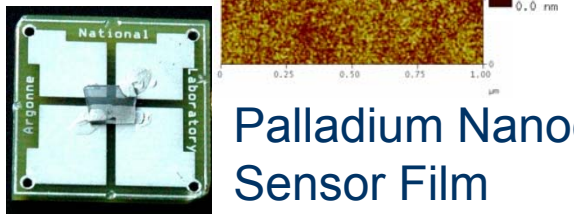
PARTNERS

Low Cost MEMS Hydrogen Sensor for Transportation Safety
Makel Engineering, Inc.

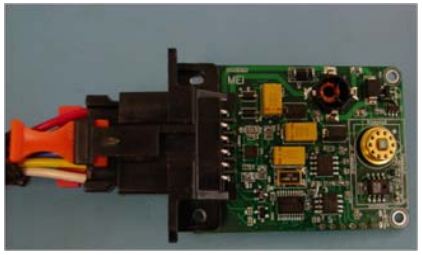
- **DOE Barriers Addressed:**
  - Control and safety
- **Total Project Value:** $736,656
- **Goals and Objectives:**
  - Advanced hydrogen sensor system for hydrogen powered transportation applications
  - Provides the means for low cost, compact, low power, and miniaturized systems suitable for mass production
- **Accomplishments:**
  - Prototype H_2 sensor developed and automotive testing initiated
- **Future Work:**
  - Nanomaterial enhancements, product testing with automotive partners, improved manufacturability at reduced cost, and market development



MEMS H2 Sensor

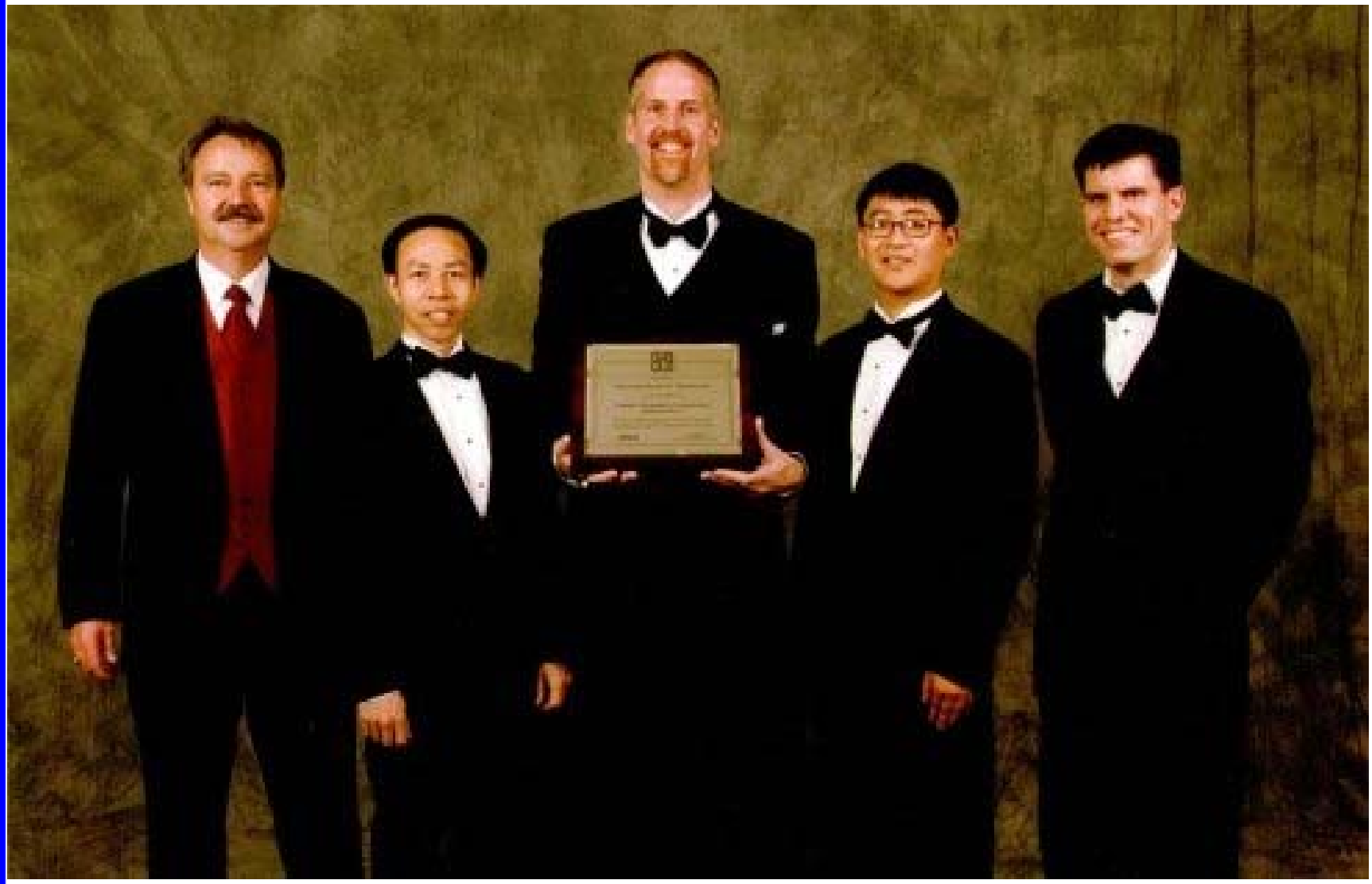


Palladium Nanocluster Sensor Film



Prototype Detector Electronics

2006 R&D 100 Award
“Ultrafast Nanostructured Hydrogen Sensor”



PARTNERS
Reel-to-Reel High Volume, Low Cost MEA Production - Precision Energy & Technology

- **DOE Barriers Addressed:**
  - Materials Efficiency, Bulk Materials Synthesis, Device Configuration Designs
- **Total Project Value**: $935,386
- **Goals and Objectives:**
  - Low cost manufacture of PEM MEAs for hydrogen and/or electric generation through reel-to-reel manufacture technology
- **Accomplishments:**
  - MEA Bonder System produced.
  - Demonstrated capability to continuously manufacture 3-layer MEAs
  - Membranes can be used to generate hydrogen
- **Future Work:**
  - Refine catalyst utilization and manufacturing processes

PARTNERS

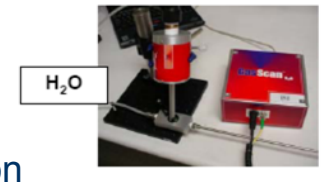
Novel Stackable Structural Reactor (SSR™) for Low-cost Hydrogen Production - Catacel Corp.

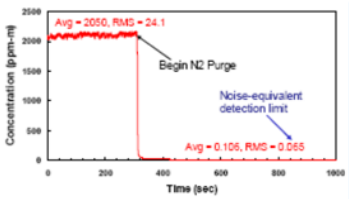
- **DOE Barriers Addressed:**
  - Fuel Processor Manufacturing, Operation and Maintenance
- **Total Project Value:** $692,737
- **Goals and Objectives:**
  - Drop-in replacement for the loose ceramic catalyst media in the stationary steam reforming process
  - Allows 50% additional capacity from given plant size, or 10% energy savings
- **Accomplishments:**
  - Lab evaluation complete, pilot manufacturing installed
- **Future Work:**
  - Pilot plant install & test
  - Market entry

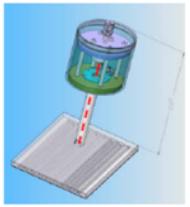
PARTNERS

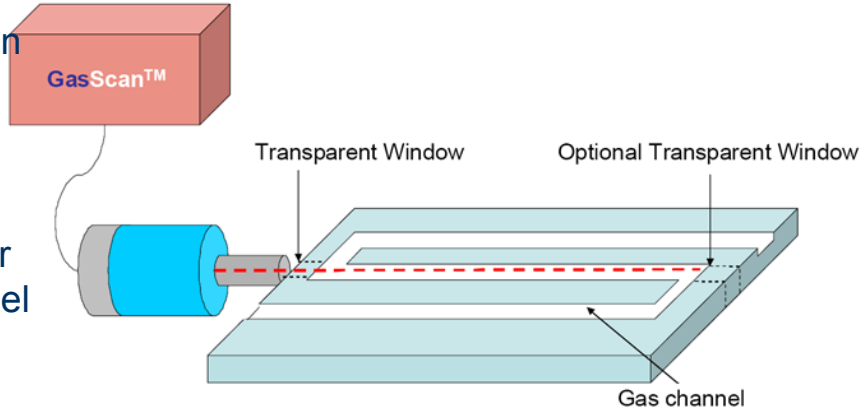
TDLAS Sensor for In-Line Continuous Monitoring of PEM Fuel Cells & Electrolyzers – Faraday Technology, Inc.

- **DOE Barriers Addressed:**
  - Efficiency, Cost, Weight and Volume.
- **Total Project Value**: $1,034,445
- **Goals and Objectives:**
  - Demonstrate technical and economic feasibility of Tunable Diode Laser Absorption Spectrometer (TDLAS) for analysis within PEM fuel cell bipolar plate channels
- **Achievements:**
  - Nanoscale catalysts for hydrogen generation
  - Bipolar plate fabrication for PEM fuel cells with integrated sensors/shunts
- **Future Work:**
  - Demonstration of the TDLAS for moisture or oxygen sensing down the length of a channel in a bipolar plate
  - Design of a TDLAS capable of continuous, sequenced in-line sensing of a fuel cell or electrolyzer stack
  - Product development and market evaluation





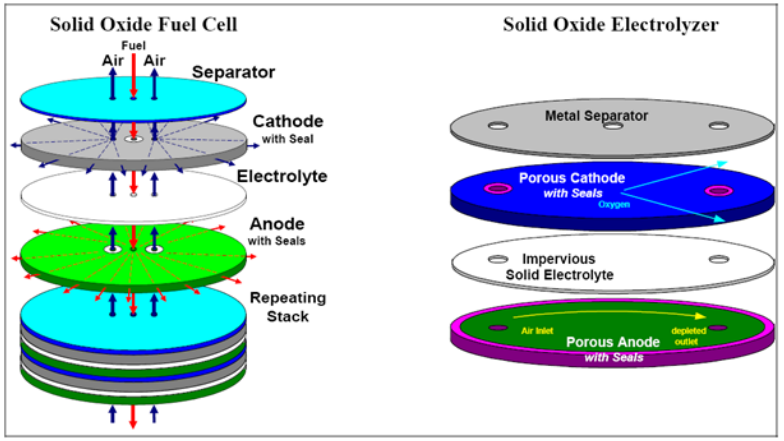


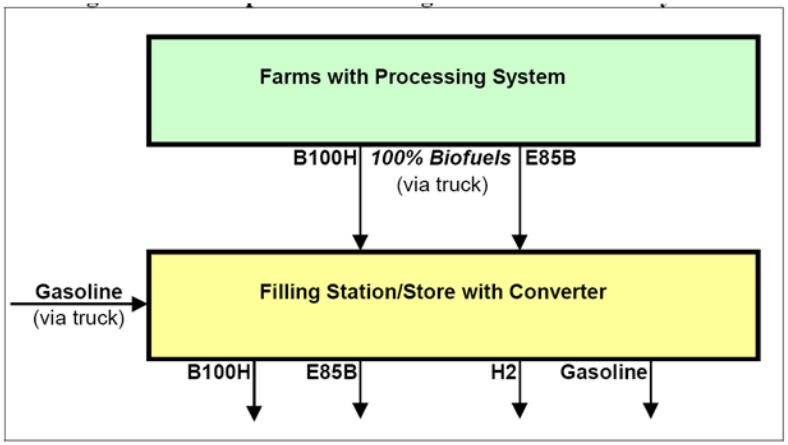


PARTNERS

On-Farm Soybean-Powered TMI SOFC System Demonstration – Technology Management, Inc.

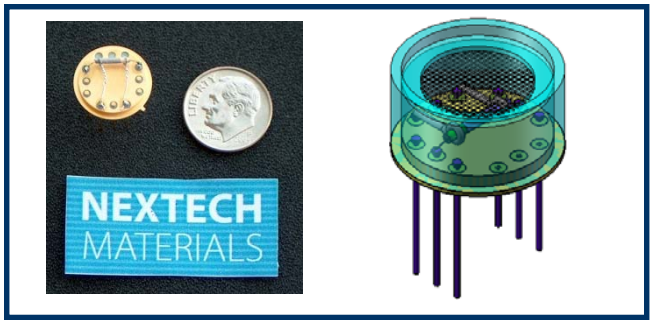
- **DOE Barriers Addressed:**
  - Efficiency, Cost, Weight and Volume.
- **Total Project Value**: $548,950
- **Goals and Objectives:**
  - Advance prototype multi-fuel SOFC system for commercialization
- **Achievements:**
  - Beta prototype demonstration in plant with soybean/vegetable oil based fuels
- **Future Work:**
  - Continue test of prototype system with multi-fuel sources – select candidate test site
  - Improve long term cell and stack component performance
  - Product development and commercialization

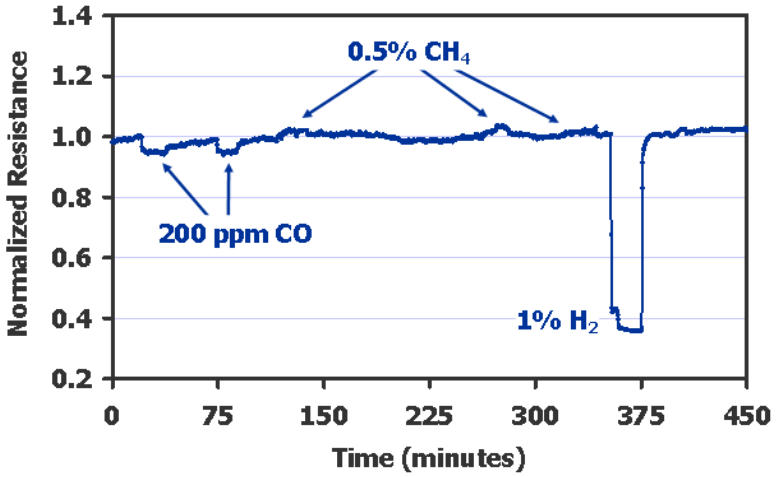


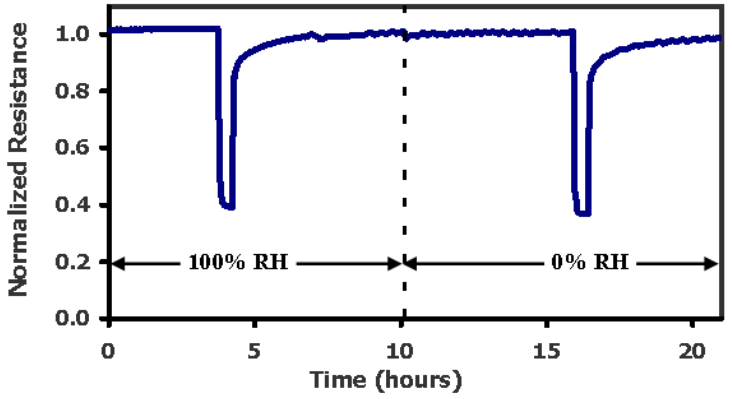


PARTNERS
Novel Ceramic Hydrogen Sensors for Fuel Cell Applications – NexTech Materials

- **DOE Barriers Addressed:**
  - Control and safety.
- **Total Project Value**: $794,602
- **Goals and Objectives:**
  - Design low-cost H_2 safety sensor that is sensitive and selective to H_2.
  - Take technology from bench-top to prototype level, ready for product launch to market.
- **Achievements:**
  - Demonstrated high selectivity to hydrogen without interference from CO, CH_4, H_2O, or silicone vapors; a-prototypes have been tested with excellent performance for 2000+ hours.
- **Future Work:**
  - Electronics for handling signal; Design for manufacturing; Pilot manufacturing; Production validation; market entry

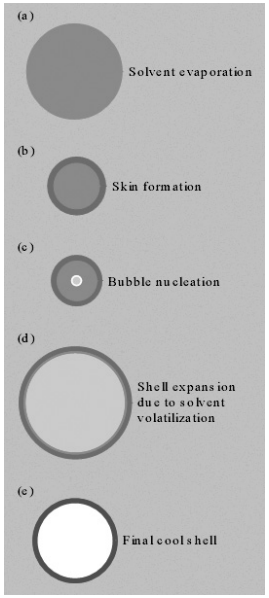


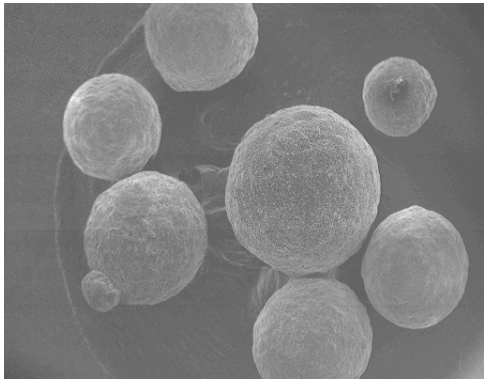




PARTNERS
High Strength, Low-Cost Microballoons for Hydrogen Storage - Powdermet Inc.

- **DOE Barriers Addressed:**
  - Weight and volume, efficiency, portability
- **Total Project Value**: $727,142
- **Goals and Objectives:**
  - High-strength microballoons by chemical vapor deposition for high volume hydrogen storage
  - Store 6 wt. % H2 in balloons, >4 wt. % in system for 2mm balloons
  - Collaborators include AF Research Labs, Precision Energy and Technology, and Protonex
- **Accomplishments:**
  - Verified microballoon extended duration H_2 storage and completed initial system design studies.
- **Future Work:**
  - Build and test prototype microballoon H_2 storage and delivery systems as well as evaluate microballoon technology for other uses.





POWDERMET INC.

PARTNERS

Manufacturing UltraCell's Reformed Methanol Micro Fuel Cells in the State of Ohio For Military and Commercial Markets

- **DOE Barriers Addressed:**
  - Efficiency, Cost, Weight and Volume
- **Total Project Value**: $425,000
- **Goals and Objectives:**
  - Develop and Demonstrate technology with potential customers to accelerate next level of funding support and purchase order generation.
- **Accomplishment:**
  - Testing at "alpha" sites such as the Federal Bureau of Investigation (FBI), U.S. Forestry Service, U.S. Marine Corp, and the Air Force Research Laboratory (AFRL).
  - Soldier Technology U.S. 2008 Conference: **"Best Soldier System Innovation & Technology" Award.**
  - JRTC Technology Readiness Level (TRL) 7 status
- **Future Work:**
  - Secure tooling for continued long-term material evaluation.
  - Field additional prototypes for feedback from Alpha sites.
  - Continue performance and form factor work for manufacturing plant outlines.

Summary

- EMTEC manages a program with a DOE cooperative agreement in Hydrogen, Fuel Cells & Infrastructure Technologies
- Program featured 38 individual, topically-related projects
  - Phased Projects - based on success
  - 7 Active Phase III Projects
- Each project targets at least one DOE technical barrier
- Successful projects generate jobs and marketable products or processes