DEVELOPING IMPROVED MATERIALS TO SUPPORT THE HYDROGEN ECONOMY

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Objectives

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

EMTEC

- EMTEC is one of 8 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

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

Status and Budget

Status

- 3 RFP Rounds
- 125 White Papers and Proposals Reviewed
- 46 Site Visits Performed
- 37 Total Projects Funded
- 7 Phase III FY08 Projects Pending

Budget

- FY04: $2.945 M
- FY05: $2.961 M
- FY06: $2.475 M
- FY08: $ .984 M
- Contractor cost share > $8.3 million
- State of Ohio cost share: > $2.8 million

EMTEC Interactions/Collaborations

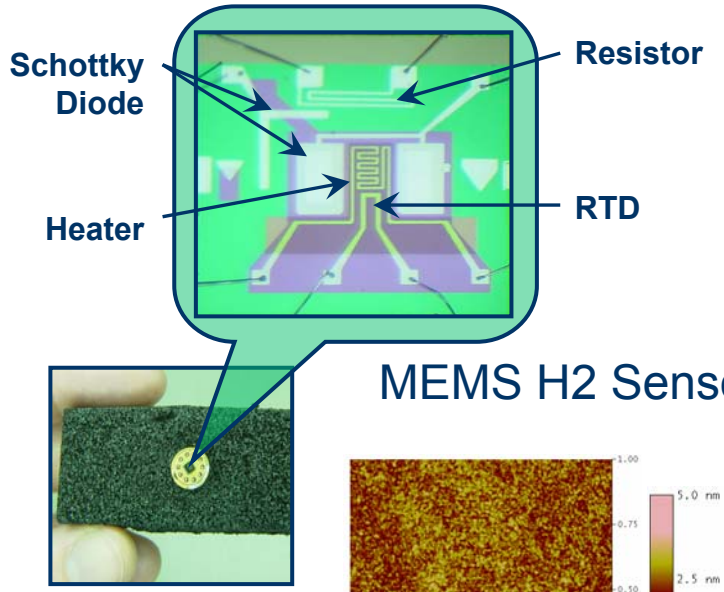
- Air Force Research Laboratory
  - Technology transfer program
  - Commercialization & business development
  - SBIR & Commercialization pilot program support
- State of Ohio
  - Department of Development Technology Division
  - Third Frontier Program
    - Multiple fuel cell projects
    - Photovoltaic 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)

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

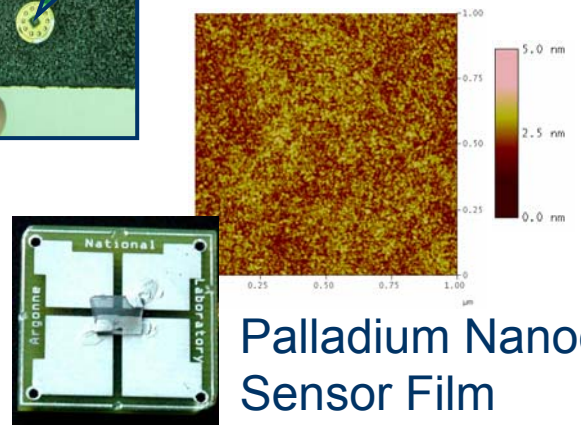
- DOE Barriers Addressed: Fuel Processor Manufacturing, Operation and Maintenance
- Total project value: $518,737*
- Drop-in replacement for the loose ceramic catalyst media in the stationary steam reforming process
- Allows 50% additional capacity from given plant size, or 10% energy savings
- Accomplishment: Lab evaluation complete, pilot manufacturing installed
- Future Work: Pilot plant planned startup: 8/1/08

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

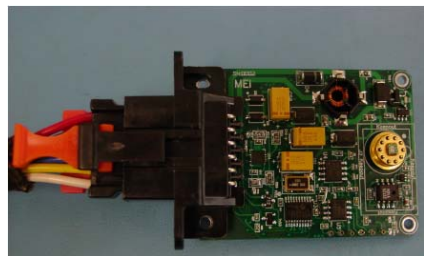
- **DOE Barriers Addressed:** Control and safety
- **Total Project Value:** $562,656*
- **Goals and Objectives:**
  - Advanced hydrogen sensor system for hydrogen powered transportation applications
  - Provides the means for low cost, compact, low power, and miniaturized systems suitable for mass production
- **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

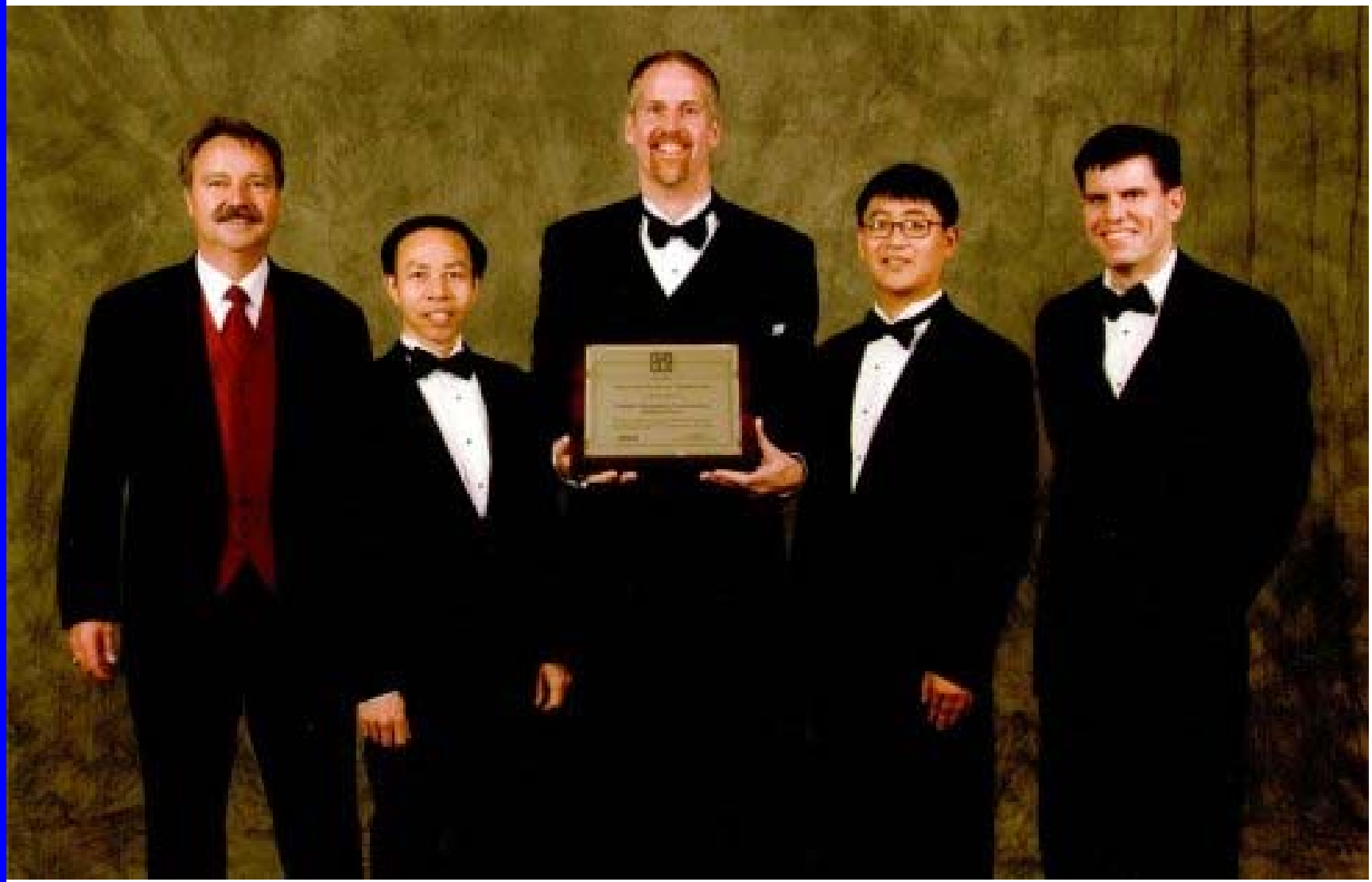


Palladium Nanocluster Sensor Film



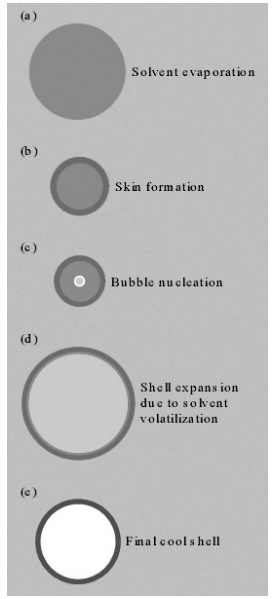
Prototype Detector Electronics

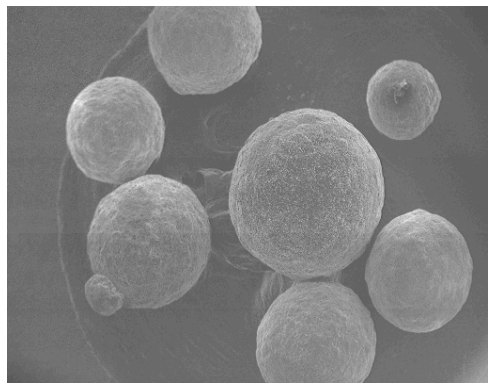
2006 R&D 100 Award
“Ultrafast Nanostructured Hydrogen Sensor”



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

- **DOE Barriers Addressed:** Weight and volume, efficiency, portability
- **Total Project Value:** $553,142*
- **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
  - Collaborators include AF Research Labs, Precision Energy and Technology, and Protonex
- **Accomplishments:** Verified microballoon H_2 storage
- **Future Work:** Design, build and test H_2 storage and delivery systems





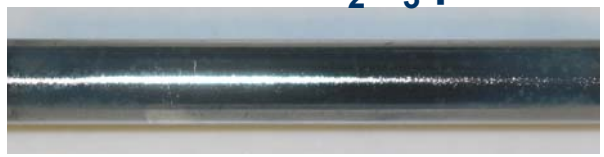
POWDERMET INC.

Preparation of Nanoscale Tubular Membrane for Hydrogen Purification/Separation

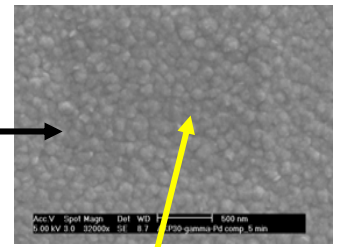
MetaMateria Partners, Columbus, OH

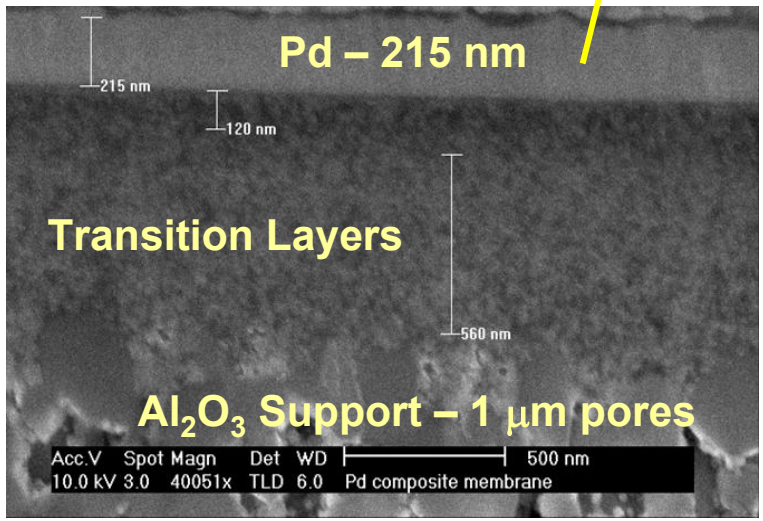
- **DOE Barriers Addressed:**
  - Efficient H_2 separation from reformed gas; CO_2 sequestration
- **Total Project Value:** $210,000
- **Goals and Objectives:**
  - Move high-flux hydrogen membrane technology from academia to industry
- **Accomplishments:**
  - Ultra-thin, nanostructured Pd membrane on high quality, multi-layer ceramic support
  - Tubular configuration demonstrated
  - H_2 flux comparable to best reported values
  - **Permeance at 320°C was 3.7×10^{-4} vs 6×10^{-4} mol/($m^2 \cdot s \cdot Pa^{1/2}$) for best Pd membrane reported in literature**
- **Future Work:**
  - Improve Pd alloy membrane & multi-layer, ceramic membranes
  - Identify partners and funding support for further development of this H_2 separation technology to demonstrate in a system

Pd membrane on Al_2O_3 porous tube



Pd surface <100 nm grains

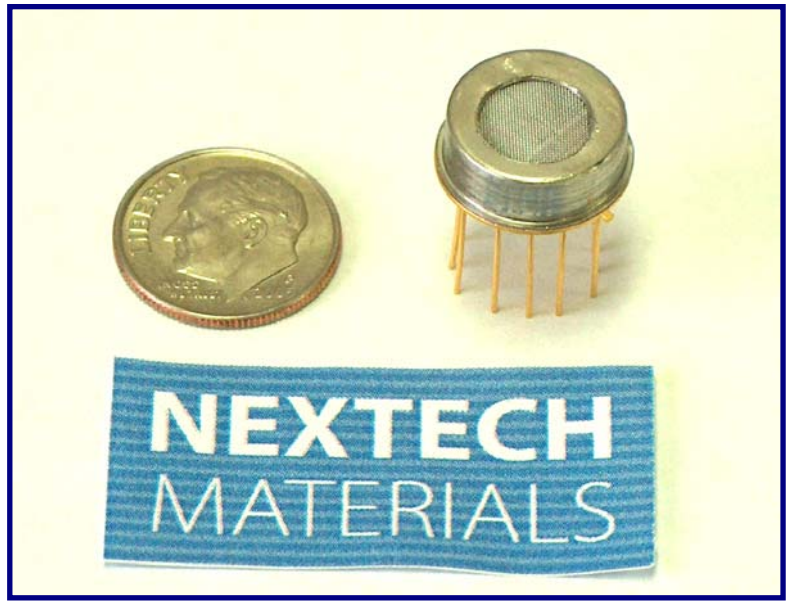


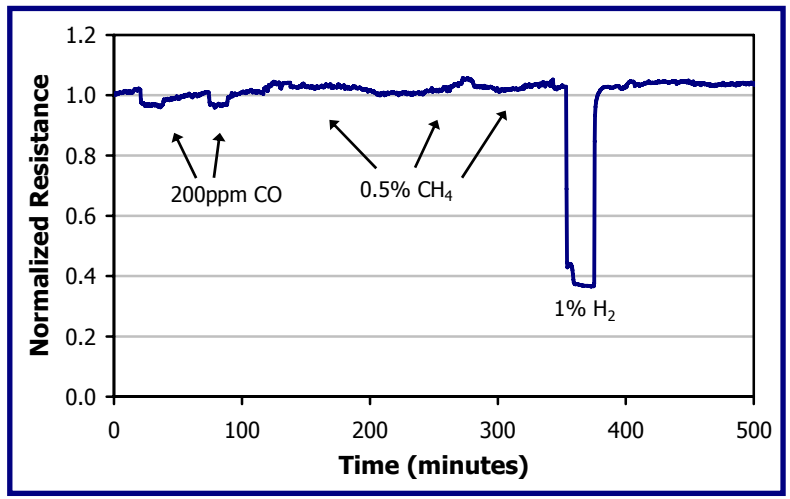


Membrane FIB cross section

Novel Ceramic Hydrogen Sensors for Fuel Cell Applications – NexTech Materials

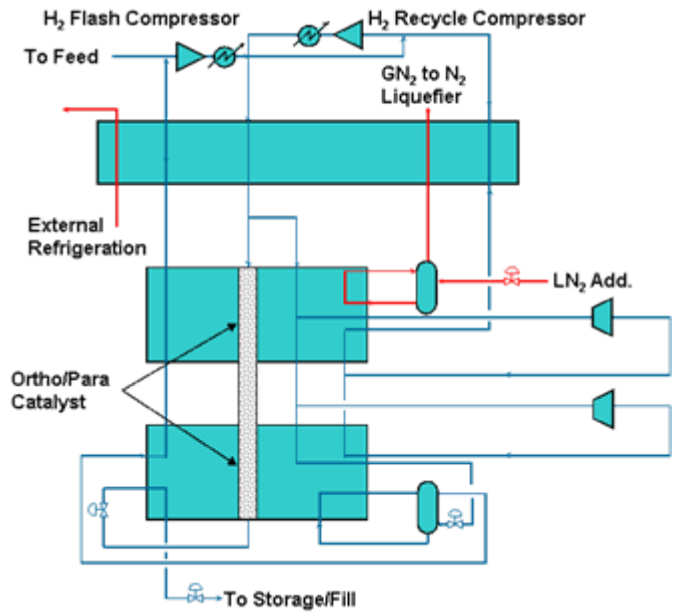
- **DOE Barriers Addressed:** Control and safety.
- **Total Project Value**: $620,602*
- **Goals and Objectives:**
  - Design low-cost hydrogen safety sensor that is highly sensitive and selective to hydrogen.
  - Take technology from bench-top to prototype level, ready for product launch to market.
- **Accomplishments:**
  - Demonstrated high selectivity to hydrogen without interference from CO, CH_4, H_2O, or silicone vapors; α-prototypes have been tested with excellent performance for 2000+ hours.
- **Future Work:** Launch of fully packaged beta-prototypes integrated on PCB followed by field testing.





Improved Hydrogen Liquefaction Process - Praxair

- **DOE Barriers Addressed:**
  - Cost of hydrogen liquefaction
  - Efficiency of hydrogen liquefaction
- **Total Project Value: $200,804**
- **Goals and Objectives:**
  - Improve hydrogen liquefaction efficiency
  - Improve ortho-para conversion process
- **Accomplishments:**
  - Developed improvement to ortho-para conversion process
- **Future Work:**
  - 3-Year DOE program for developing process further – see PDP31



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 features 37 individual, topically-related projects
- Each project targets at least one DOE technical barrier
- Successful projects generate jobs and marketable products or processes

Future Plans

- Identify and fund seven capstone projects for phase III commercialization.
  - Ultrafast Nano Sensors
  - Reel-to-Reel Membrane Processing
  - High Efficiency Catalytic Reformation
  - High Ultilization Catalyst Dispersion
  - Integrated Multi-Fuel SOFC
  - Highly Selective Hydrogen and Sulfur Sensor
  - Ultrahigh-Strength Microballoons