Florida Solar Energy Center

Creating Energy Independence Since 1975

Florida Hydrogen Initiative (FHI)

DOE Contract # DE-FC36-04GO14225

Dr. David Block, Director Emeritus
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May 2012

Project ID#: TV012

Overview

Timeline

- Project Start Date: 10/1/04
- Project End Date: 6/30/12 (12/31/12)
- Percent Complete: 85%

Barriers

- Barriers addressed
  - Research and Development
  - Creating Partnership
  - Facilitating Technology Transfer

Budget

- Total project funding
  - DOE share: $3,946,155
  - Cost Share: $1,512,604
  - Total Project: $5,458,759
- Funding for FY09-FY12: None

Partners

- Florida Solar Energy Center
- EnerFuel, Inc., Florida Atlantic University
- SRT Group, Inc., Electrolitic Technology Corp., University of Florida
- Florida State University, Bing Energy, Inc.
- Florida Institute of Technology
- University of South Florida
- EnerFuels, Inc., University of Florida

Project Objectives/Relevance

- Develop hydrogen and fuel cell infrastructure
- Create partnerships
- Sponsor fuel cell and hydrogen R & D
- Facilitate technology transfers
- Develop industry support
- Develop unique education programs

Approach and Progress

Key Results – Very Successful Year!

- **Project solicited competitive proposals – 12 projects conducted**
- **Six projects are completed**
- **Six projects are active with completion scheduled for December 31, 2012**
- **Poster presents nine active projects for the past year**

Project Breakdown by Technology

Fuel Cells:

- *Methanol Fuel Cell Evaluation at FAU – EnerFuel, Inc./Florida Atlantic University – Completed*
- **Low Cost/High Efficiency of PEMFC System – Florida State University/Bing Energy, Inc.**
- **Advanced HiFoil™ Bipolar Plates – EnerFuel, Inc./University of Florida**
- *Mechanical and Chemical Durability of MEAs – FSEC – Completed*

Hydrogen:

- **Hydrogen Leak Detection – FSEC**
- *Production of Hydrogen from Biowaste – SRT Group, Inc./Electrolytic Technologies Corp./University of Florida – Completed*
- **Advanced Hydrogen Storage System – University of South Florida**

Hydrogen and Fuel Cells:

- **Low Cost Electrocatalysts – FSEC**
- **Hydrogen and Fuel Cell Technology Academic Program – Florida Institute of Technology**

Collaborations – Went from 5 to 12

Past Collaborations:

Chevron Technology Ventures, FSEC, Rollins College, Orlando Science Center, EnerFuel, Inc.

New Collaborations:

- **EnerFuel, Inc., Florida Atlantic University**
- **Florida Solar Energy Center**
- **SRT Group, Inc., Electrolytic Technologies Corp., Miami, and University of Florida**
- **Florida State University and Bing Energy, Inc.**
- **Florida Institute of Technology**
- **University of South Florida**
- **EnerFuel, Inc. and University of Florida**

Proposed Future Work

- Continue project monitoring and reporting
- Complete remaining six projects
- See individual projects for each sub-project status report and future activity

Summary

Relevance: Conduct R & D, create partnerships, facilitate technology transfer

Approach: Complete projects to accomplish goals

Technical Accomplishments and Progress: Six projects completed. Six active projects scheduled for completion 12/31/12

Technology Transfer/Collaboration: Continue 12 active partnerships

Proposed Future Research: Continue active projects, conduct project reviews, complete projects.

*

Task 2: Hydrogen Technology (HyTech) Rest Area

Michel Fuchs

EnerFuel, Inc.

1501 Northpoint Parkway, Suite 101

West Palm Beach, FL 33407

3/5/2012

DOE Contract #DE-FC36-04GO14225

Sales@enerfuel.com

Project Overview

Timeline

- Project start date: Oct 2006
- Project end date: June 2012
- Percent complete: 98%

Budget

- Total project funding
  - DOE - $607K
  - Contractor - $632K
- Funding received in FY11: $0
- Funding for FY12: $:0

Barriers

- **Barriers**
  - **C**. Performance
  - **G**. Startup and shut-down time and Energy/Transient Operation

Partners

- Collaboration/Interaction: Florida Atlantic University (FAU)
- Project Lead: EnerFuel, Inc.

EnerFuel

Objectives

Overall	• Design, construct and demonstrate a 10kW$_{net}$ PEMFC stationary power plant operating on methanol • Achieve an electrical energy efficiency >32% • Demonstrate transient response time <3ms
2010	• Changed demonstration scope and location from rest area demo to electrical vehicle charge station due to budget constraints
2011	• Constructed fuel cell, electric vehicle charging station at Florida Atlantic University
2012	• Commission charging station • Evaluate fuel cell power plant and charging station performance • Present results of project

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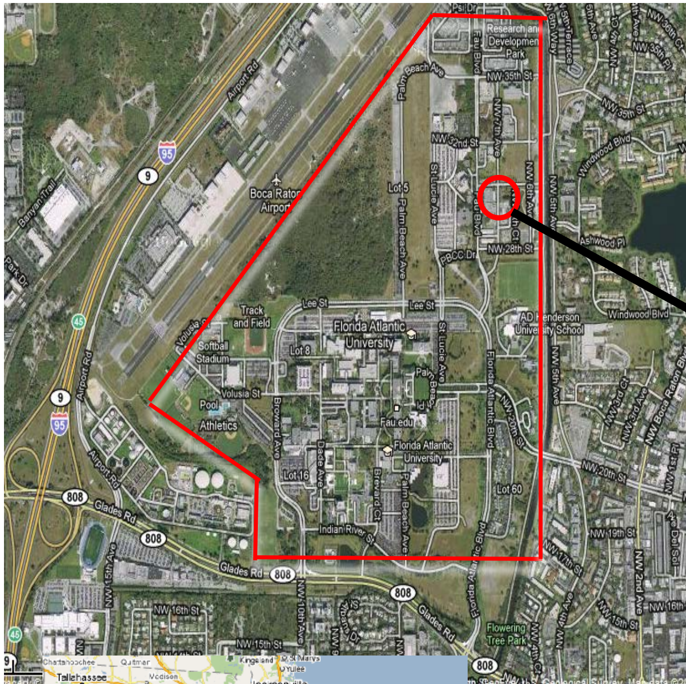
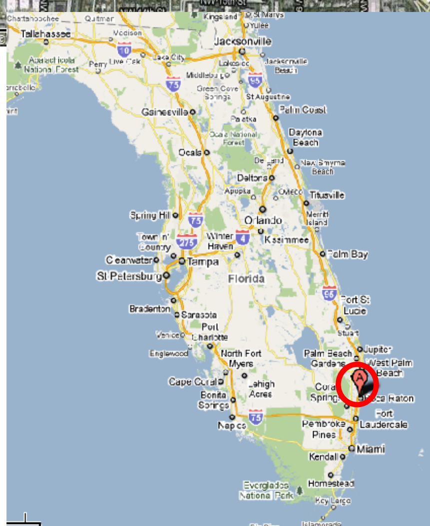
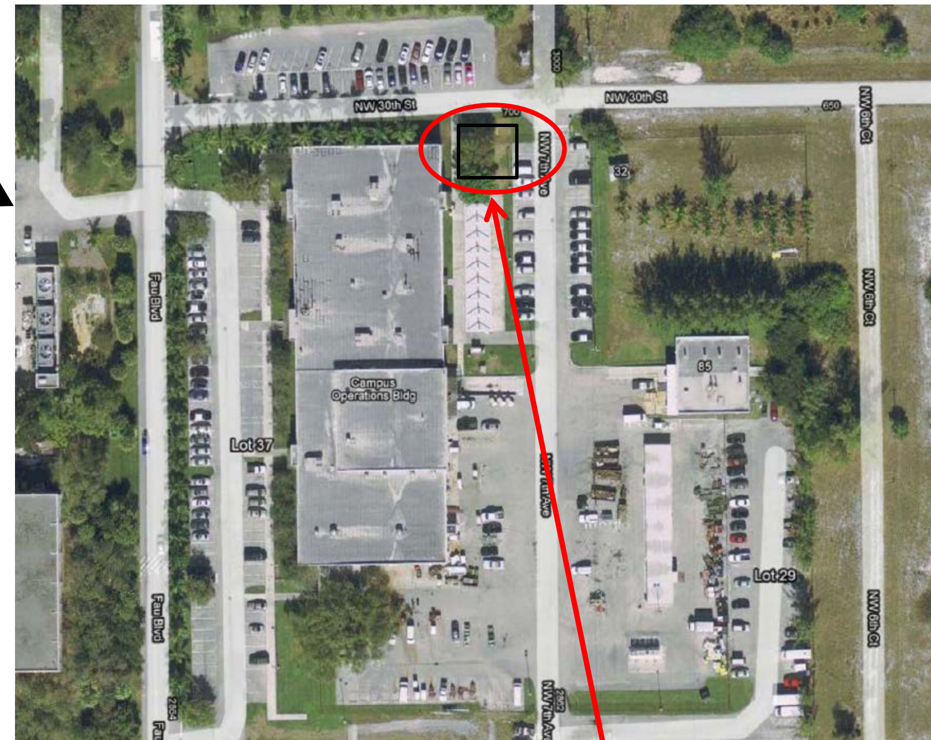
EnerFuel

Demonstration Site







Vehicle charging station location

FAU
FLORIDA ATLANTIC UNIVERSITY

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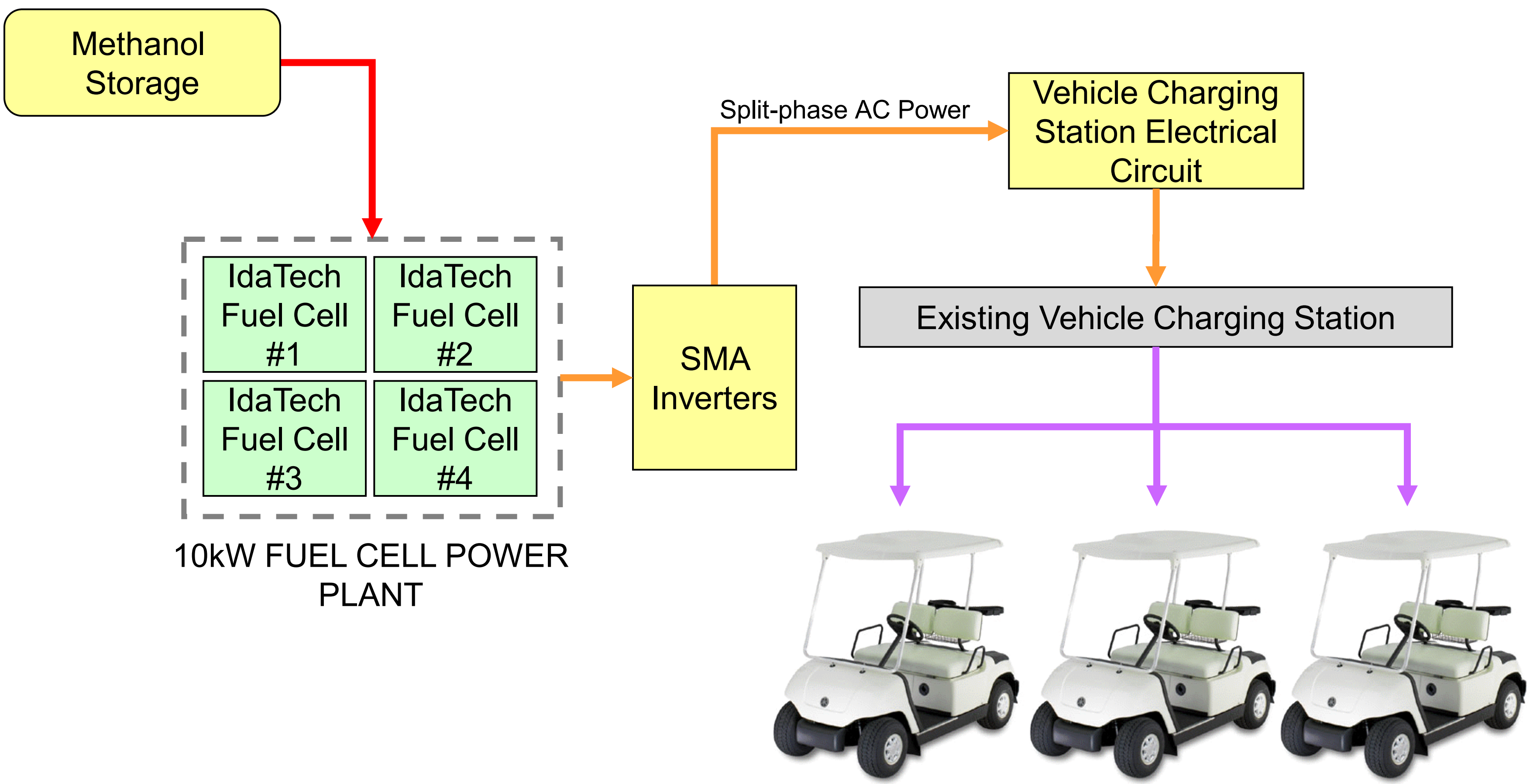
EV Charging Station Design



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Accomplishments

- Obtained all necessary permits for construction of charging station
- Installed all fuel cells, batteries and inverters at FAU
- Wired all fuel cells, batteries, breakers, disconnects and inverters together
- Wired fuel cell charging station to exiting FAU electric vehicle charging complex.

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Remaining Work

- **Qtr 1, 2012**
  - Commission station
- **Qtr 2, 2012**
  - Operate charge station
  - Collect operational data
  - Complete final report

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Task 7: Chemochromatic Hydrogen Leak Detectors for Safety Monitoring

Drs. Nahid Mohajeri and Nazim Muradov
Florida Solar Energy Center
1679 Clearlake Road
Cocoa, FL 32922

Overview

Timeline

- Start date: April 8, 2010
- End date: June 30, 2012
- Percent complete: 92%

Barriers

- Visual H_2 sensors

Budget

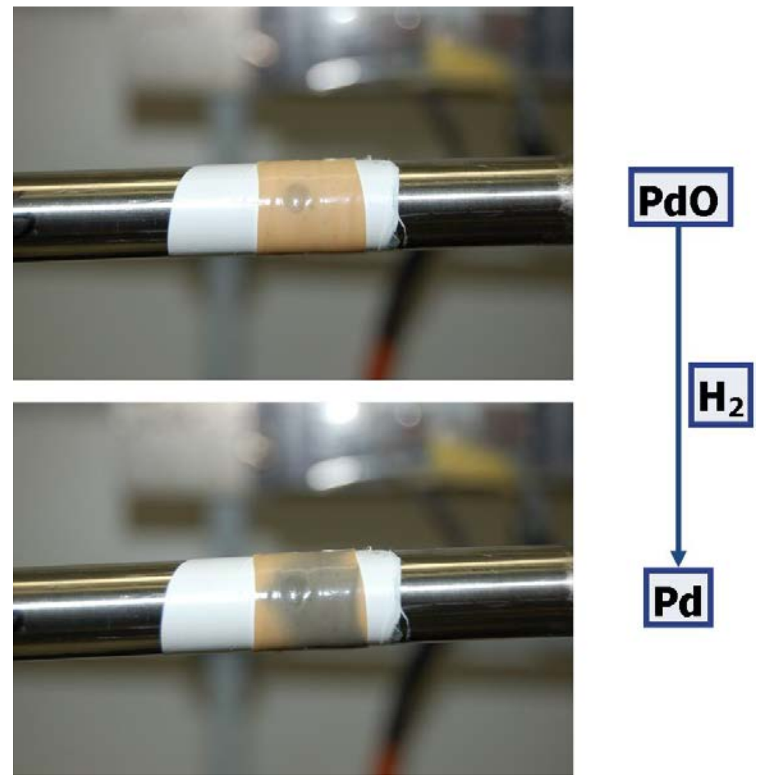
- Total project funding
  - DOE share: $281,547
  - Contractor share: $70,387
- Funding received in FY11: $0
- Funding received in FY12: $0

Objectives

- To develop irreversible and reversible chemochromic hydrogen leak detector with better reliability, superior field worthiness, and lower cost.

Chemochromic Sensors

- Goals:
  - Increasing hydrogen sensing kinetics
  - Determining the sensitivity and selectivity toward hydrogen detection in the presence of other reducing gases
  - Optimizing the encapsulation methods
  - Studying the effect of environmental parameters such as UV, temperature, and water exposure.
  - Improving the worthiness and shelf life of the chemochromic H_2 sensors

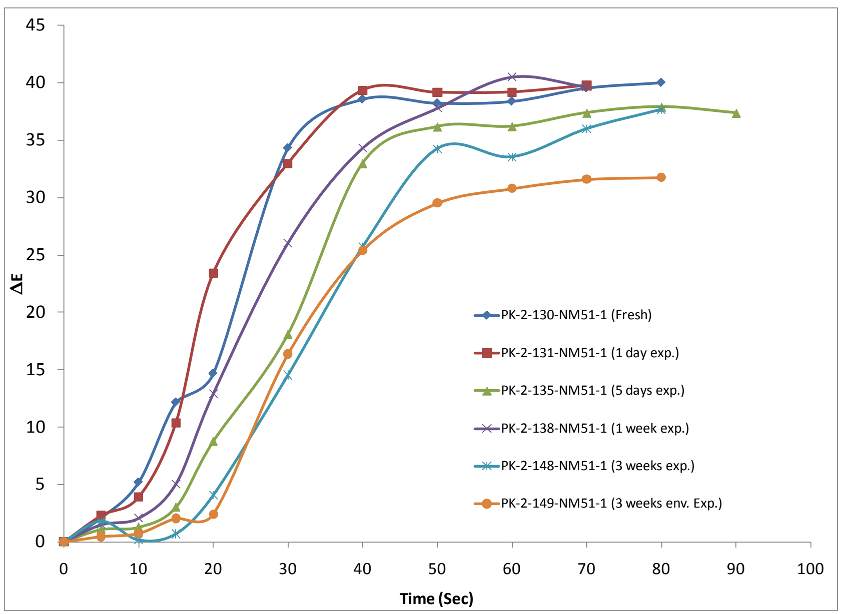


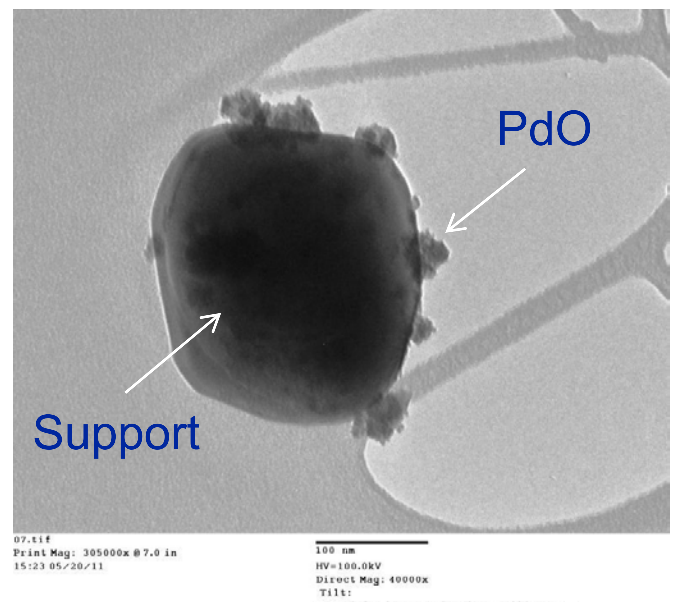
Irreversible – 3rd Generation

- Fast response time (visible color change after 20 seconds of being exposed to H_2 gas; 5 times faster than 1st Generation)
- Lower cost support compared to TiO_2 (pigment's materials cost reduction by ~13%)
- Comparable color change to 1st Generation
- Great Sensitivity toward low hydrogen concentrations (visible color change in less than 3 minutes when exposed to 1% hydrogen gas)
- No reaction with other reducing gases such as CH_4 and CO after one hour of exposure at room temperature, when encapsulated

Irreversible UV Exposure

- Minimal change in pigment's color change kinetics after three weeks of UV exposure





Irreversible Accomplishments

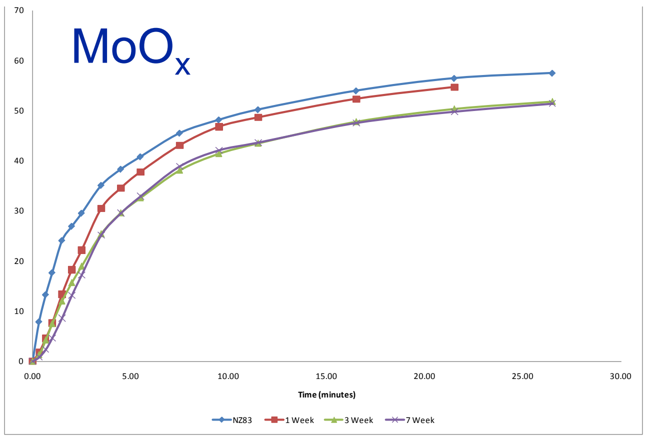
- Physico-chemical characterization of 3rd generation chemochromic pigment using SEM, TEM, TG-DTA, and UV-VIS
- Demonstrated pigments stability after being exposed to UV rays for 21days
- Two patent disclosures:
  - N. Mohajeri "Doped palladium containing oxidation catalysts", UCF-10380P
  - P. Brooker, N. Mohajeri "Chemochromic membranes for membrane defect detection", UCF 10390P

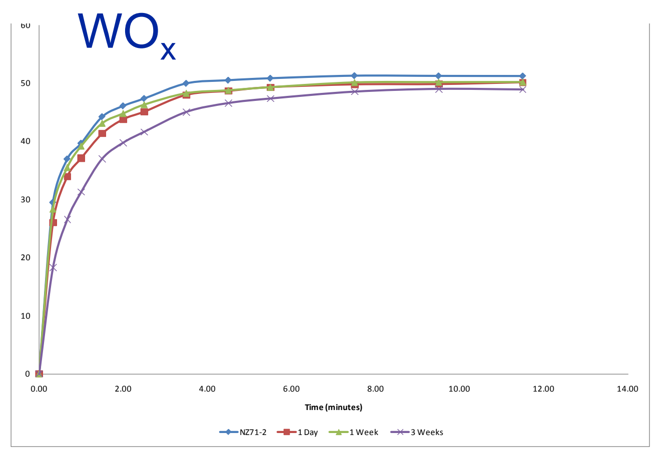
Reversible -- Sensors

Definition:
Reversible H_2 sensors are based on transition metal (Mo, W, V) compounds with tunable redox properties. Upon exposure to H_2 they are converted to a reduced (blue-colored) state (e.g., $Mo^{+6} \rightarrow Mo^{+5} \rightarrow Mo^{+4}$),and after the exposure they bleach and return to their original state.

Reversible Sensor Accomplishments:
- Synthesized and tested 60 new Mo- and W-based chemochromic formulations using different pigment precursors, activators, dopants and supports
- Conducted environmental testing of Mo- and W-based reversible pigments (exposure to sunlight, humidity, ran tests for 5 months)
- Determined the effect of long-term UV radiation (360 nm wavelength) exposure on reversible H_2 sensors performance
- Conducted analysis and characterization of Mo- and W-based pigments using XPS, SEM, EDS, TEM, and XRD methods.

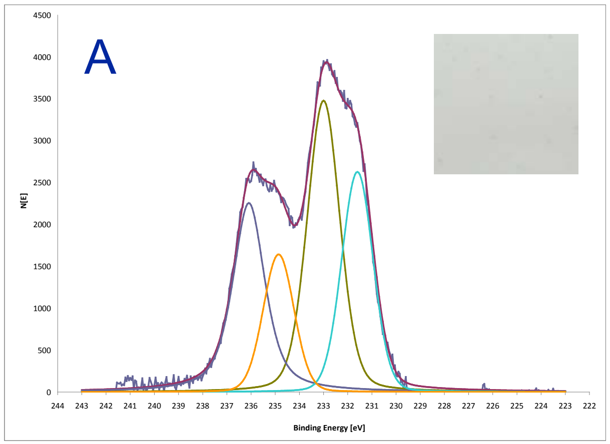
Comparison of MoO_x vs. WO_x Pigments

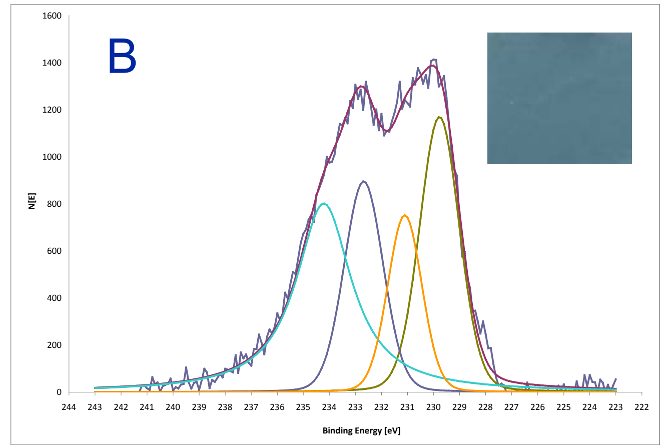




Effect of UV radiation (360 nm wavelength) on the performance of reversible Mo- and W-based hydrogen sensors. Exposure time: up to 7 weeks. Both sensors have good UV stability. WO_x shows faster response time.

Mo-Based Pigment Exposures





XPS spectra of Mo-based pigment before (A) and after (B) exposure to hydrogen

Future Work

Irreversible:

- Long term environmental stability and reliability
- Develop scaled-up synthetic procedure

Reversible:

- Complete long-term field testing of reversible H_2 sensors

Task 8: High Efficiency, Low Cost Electrocatalysts for Hydrogen Production and Fuel Cell Applications

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Cocoa, FL 32922

Overview

Timeline

- Start date: April 8, 2010
- End date: June 30, 2012
- Percent complete: 78%

Barriers

- Improve electrode performance
- Reduce PGM loading

Budget

- Total project funding
  - DOE share: $351,862
  - Contractor share: $87,965
- Funding received in FY11: $0
- Funding received in FY12: $0

Objectives

- Reduce Pt loading while maintaining high performance by increasing Pt activity

Methods of Increasing Pt Activity

- Increasing available surface area by optimizing Pt size and shape
- Enhancing electronic interactions by alloying Pt with other metals
- Improving utilization by depositing catalyst particles only where the electrocatalytic reaction takes place (i.e. triple phase boundary)

Approach

- Spray catalyst layer containing Nafion® and carbon powder onto carbon paper loaded with a microporous layer
  - Catalyst layer is hydrophilic due to Nafion®
  - Carbon paper and microporous layer is hydrophobic due to Teflon®
- Predeposit nanosized Pt and Pt alloy particles using a colloidal method
  - Serve as nucleation sites (i.e. "seeds") for catalyst growth
  - Target deposition to hydrophilic layer
  - Pulse electrodeposition carried out using a rotating disk electrode (RDE)
    - Modify electrodeposition parameters to maximize activity
- Determine catalyst activity using RDE

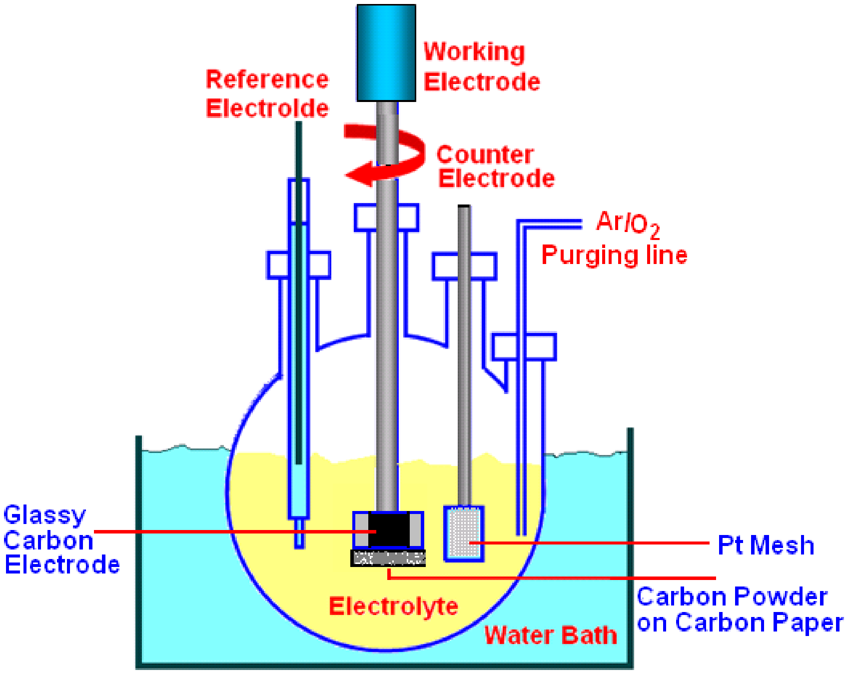


Figure 1 – Pulse electrodeposition and oxygen reduction reaction setup

Technical Accomplishments

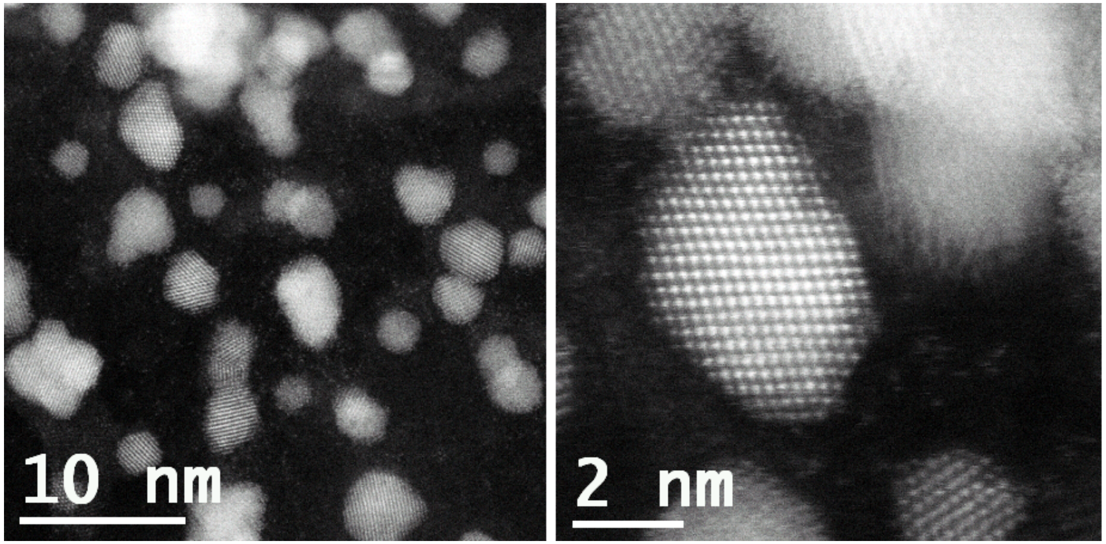
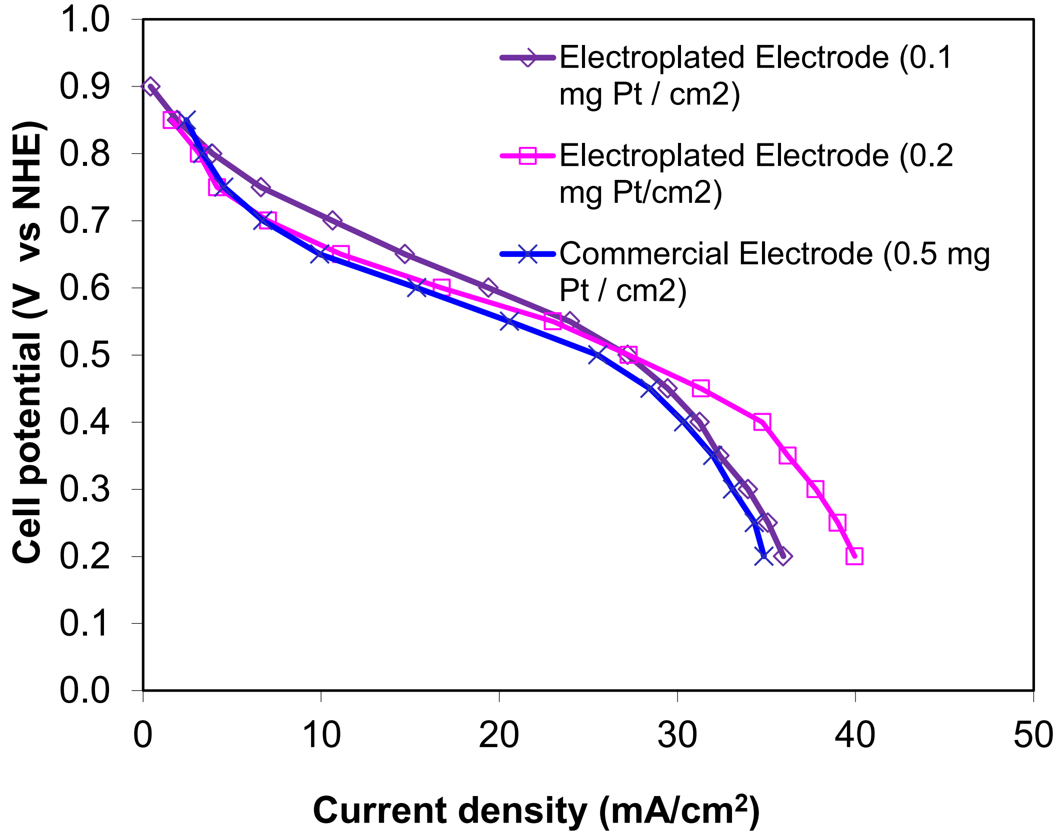


Figure 2 – Atomic level STEM of Nanosized Pt colloidal particles

Pt particles with an average size of 3 nm were fabricated and were used to “seed” the carbon paper for electrodeposition

Technical Accomplishments



Comparison of ORR activity for electroplated electrode vs. commercial electrode

Pulse electrodepositing onto the seeded electrode results in higher performance than commercial catalyst with 5x greater Pt loading

Summary and Future Work

Summary

- Optimized pulse electrodeposition can be used to prepare low Pt loading, giving higher performing electrocatalysts for use in PEM fuel cells
  - An electrocatalyst prepared with 0.1 mg/cm^2 Pt loading shows higher performance than that of a commercial catalyst with 0.5 mg/cm^2 Pt loading

Future Work

- Further validate the performance, morphology, and fundamental understanding of pulse electrodeposition technology by:
  - Examining the morphology of the catalysts with a SEM
  - Modifying electrodeposition techniques on alternate catalysts
  - Scaling up for use in 5 cm^2 fuel cell

Task 9: Understanding Mechanical and Chemical Durability of Fuel Cell Membrane Electrode Assembly

PI: Dr. D. Slattery and L. Bonville
Florida Solar Energy Center
1679 Clearlake Road
Cocoa, FL 32922

Overview

Timeline

- Start date: April 8, 2010
- End date: June 30, 2012
- Percent complete: 99%

Barriers

- A. Fuel cell durability

Budget

- Total project funding
  - DOE share: $351,862
  - Contractor share: $87,965
- Funding received in FY11: $0
- Funding received in FY12: $0

Relevance

- Understanding degradation mechanisms will lead to greater durability

Objectives

- Improve fuel cell durability by understanding mechanical and chemical degradation mechanism.

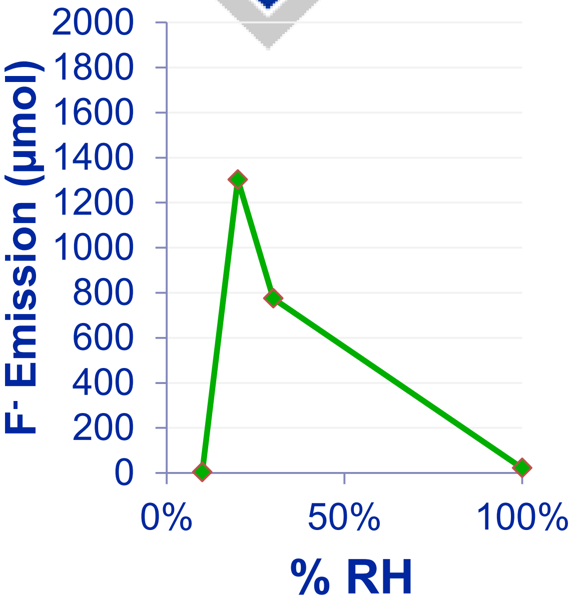
Approach

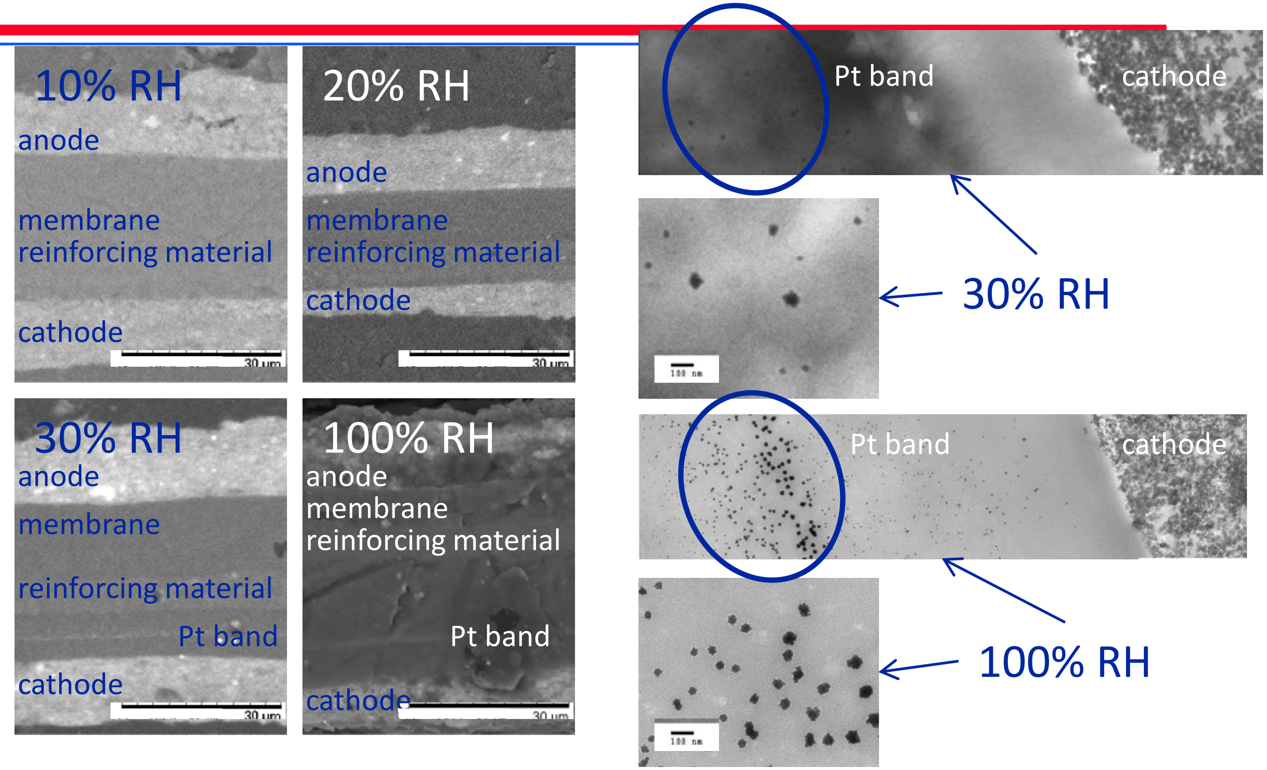
- Investigate chemical mitigation of membrane degradation
- Evaluate platinum band formation and develop Pt band formation mitigation strategy
- Combine chemical mitigation results and Pt band reduction for overall durability strategy

Chemical Mitigation by Cerium Oxide Addition

- Addition of cerium oxide to PFSA membranes shows a concentration-dependent improvement in durability when subjected to liquid and gas Fenton testing.
- In accelerated OCV degradation experiments, a two-fold decrease in the OCV decay is observed as well as a one order of magnitude reduction in the fluoride emission, due to the presence of ceria. These improvements were found to be independent of both ceria concentration and formulation.
- Ceria is an effective radical scavenging additive for PEMs that greatly improves durability without significantly impacting performance or mechanical stability.

Evaluation of Pt Band Formation





- Cells containing Pt/C in the electrode and 1100 EW membrane were OCV tested for 100 h under H_2/air and 10 to 100% RH
- Degradation is highest at 20% and 30% RH and lowest at 0% and 100% RH
- Pt bands are only visible with higher RH
- Reduced degradation at 10% RH may be due to less Pt band formation
- At 100% RH, the membrane experiences less stress and therefore lower degradation

Results for Understanding Pt Band Formation

- Fluoride emission provides a direct measure of membrane degradation
- Using PtCo/C rather than Pt/C greatly reduces degradation
- Using 1100 EW membranes reduces degradation compared to 950 and 750 EW
- Degradation at 20% and 30% RH is much larger than that at 10% and 100% RH
- Loading 10 mol% Pt into the membrane resulted in much larger degradation than 10, 30, or 50 mol%

Results from Ceria and Sublayer Combination

- The presence of ceria in the membrane of sublayer-containing cells resulted in a 5-fold reduction in the fluoride emission and a 1.5-fold reduction in the OCV decay
- PTA in the sublayer further reduced the fluoride emission by a factor of 3, and the OCV decay by a factor of 1.3
- For membranes without ceria, fluoride emission increased by a factor of 2-3 for the XC-72R sublayer over the non-sublayer case

Summary and Conclusions

- Ceria is an effective radical scavenging additive for PEMs
- Using PtCo/C instead of Pt/C greatly reduces degradation
- Although PTA was shown to effectively reduce membrane degradation, its incorporation into a cell as a sublayer is detrimental to cell performance and durability
- Combination of ceria and sublayer results in more degradation than ceria without sublayer

Future Work

- Conduct 500 hrs fuel cell test with Ceria containing membrane
- Probe and investigate physico-chemical characteristics of cerium oxide during and after fuel cell tests
- Perform TEM analysis to identify Pt size, shape and distribution
- Determine influence of incorporating PTA within the electrode only

Task 10: Florida Hydrogen Initiative
SRT Group Inc. (SRT)

Production of Low-Cost Hydrogen from Biowaste

POC: Robin Z. Parker
(305) 321-3677
rzpsrt@thesrtgroup.com

Overview:

Timeline

- Project start date: 12/1/10
- Project end date: 6/30/12
- Percent complete: 90%

Budget

- Total project funding:
  - DOE share: $ 203,184
  - SRT share: $ 50,796
- Funds received in FY11: $0
- Funds allocated to FY12: $0

Barriers

- Reduce energy to produce renewable electrolytic-grade H_2 by 60%
- Modeled cost of H_2 from renewable sources <$3.00/gge
- Process scalable from kg to tonnes H_2/day
- Distributed and centralized applications
- Minimize feedstock pre-treatment

Subcontractor

- Electrolytic Technologies Corporation

Relevance :

- Conventional Biowaste-to-Fuel processing:
  - Anaerobic Digester
    - requires biological microorganisms ('bugs')…temperature dependent, large-volume, low-yields, H_2S contamination
  - Fermentation/Distillation
    - slow-processing 'bugs' (yeast) & requires heat for distillation
    - questionable economics, even with $0.45/gal tax credit
  - Gasification
    - not developed for small scale, requires oxygen plant
    - complex gas clean-up >700^{o} C
  - Pyrolysis
    - feedstock pretreatment & large footprint for upgrade of oil
    - temperature sensitive 200-300^{o} C – waste stream disposal

Process Advantages:

- Exploits two thermochemical advantages that reduce the cost and energy of converting waste-to-fuel:
  - elevated temperature and pressure provides high product rates & yields minimizing the size of equipment
    - improves the relationship between fuel production and consumption
  - the chemical bonds requiring energy to release hydrogen are weak, requiring less energy that what hydrogen will produce when burned with oxygen (air)

Approach:

- Bromination[1]
  - Produces hydrogen bromide (HBr) from wet-cellulosic waste
  - Co-produces carbon dioxide (CO_2) & thermal energy (exothermic)

[1]Bromination is analogous to combustion (burning) wood (cellulose) with oxygen from air, only bromine is the oxidizer, consequently HBr is formed instead or H_2O.

- Electrolysis
  - Dissociates hydrogen bromide ($E^o = 0.555V$) producing recyclable bromine and hydrogen (endothermic)

- Combustion
  - React hydrogen with the more energetic oxygen ($E^o = 1.229V$), affording a *theoretical process efficiency* >100%[2]

[2]Waste-to-fuel efficiency of 70%; >160% if omitting the energy content of waste.

What Happens to Contaminants?

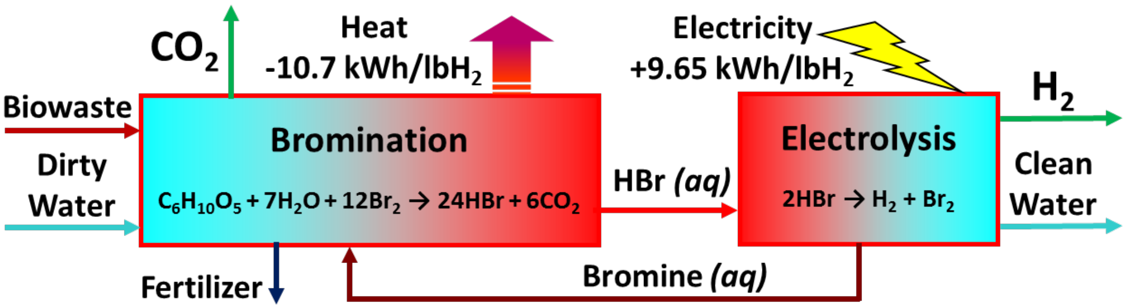
- Pathogens and organisms are killed by bromination
- Sulfur and nitrates are converted into sulfates and nitrogen in exothermic reactions that produce additional HBr
- Metals and other impurities that react with Br_2 to form metal bromides that are treated with dilute sulfuric acid to form metal sulfates and additional HBr
- Sulfates and unreacted carbon are removed with the ash, which is sterile and safe for use as fertilizer

Accomplishments:

- Designed & operated reactor/electrolysis vessel
- Collected data from bromination/hydrogen experiments with favorable results
- Assembled prototype development team

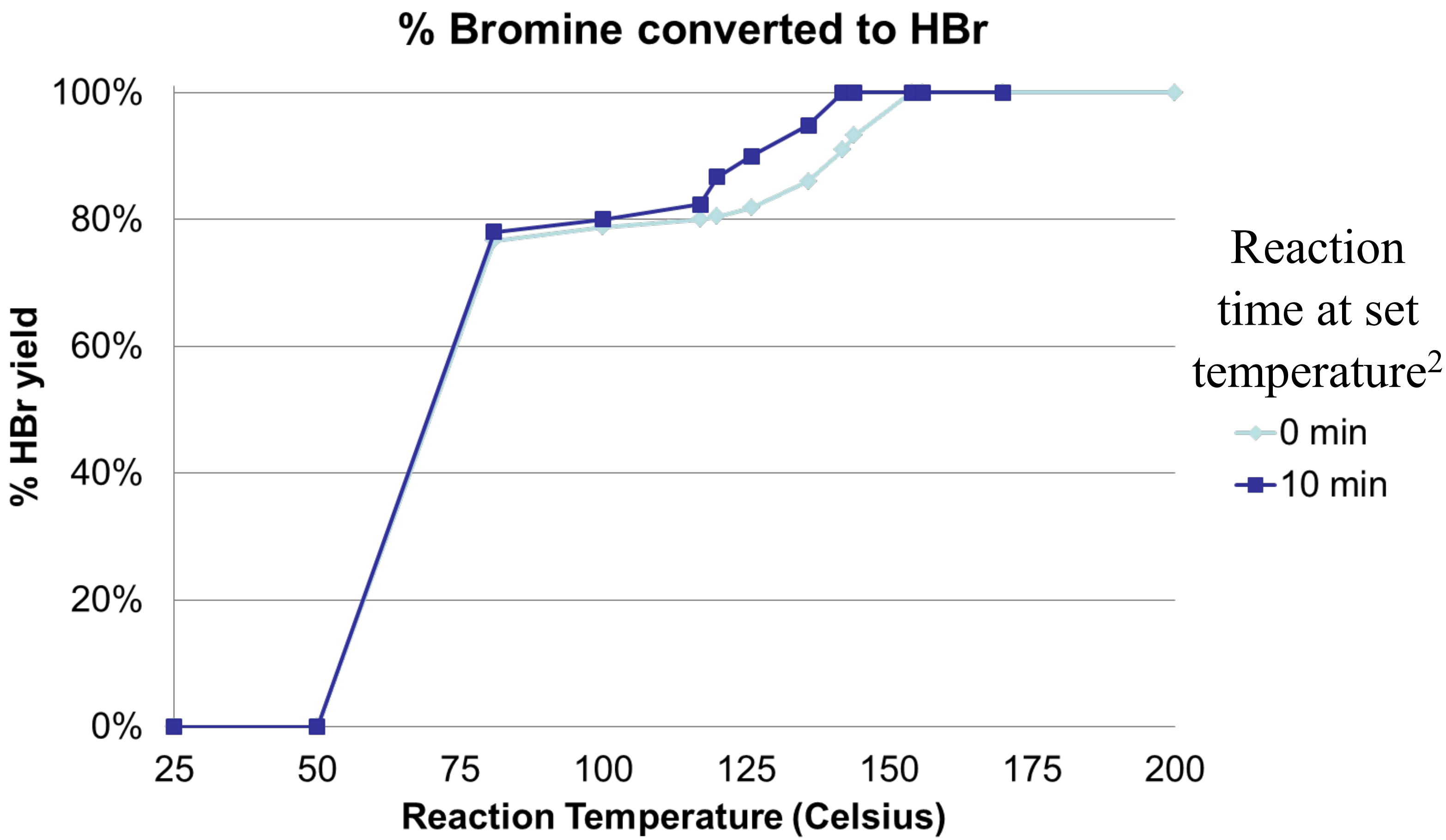
Process and Apparatus:

Setup allows investigation to 300 Celsius and 3000 psi



Bromination Results:

Full conversion of Br_2 and cellulose to HBr and CO_2 at 120 psi & 150° C [1]

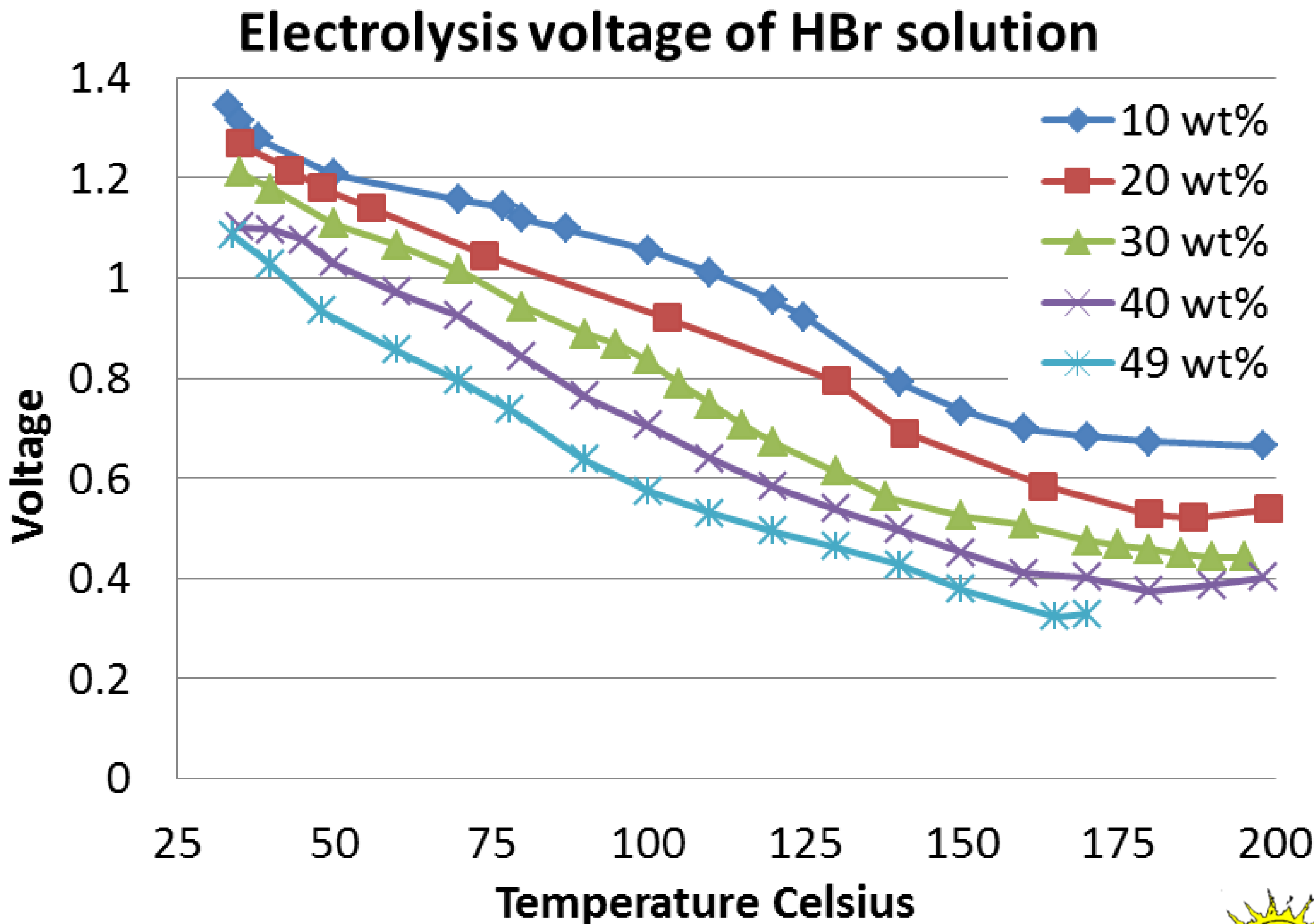


[1] 100% conversion of Br_2 to HBr; no brominated carbonaceous species.

[2] Reaction time does not include ~10 mins to ramp temp up and ~5 mins to quench it down

Electrolysis Results:

Shows strong dependence on HBr concentration and temperature[1]



[1] **Measured open circuit voltage**

Future Work:

- Continue high temperature HBr electrolysis experiments
- Develop integrated bromination and electrolysis system
- Determine optimum temperatures and pressures for integrated system
- Continue analysis of byproducts
- Conduct economic analysis
- Begin product commercialization

Task 11: Development of a Low-Cost and High-Efficiency 500 W Portable PEMFC System

Jim P. Zheng, Wei Zhu, Richard Liang
Florida A&M University-Florida State University College of Engineering
Tallahassee, FL 32310
Harry Chen
Bing Energy Inc., Chino, California 91708

Overview

Timeline

- Project start date: 12/01/2010
- Project end date: 12/31/2012
- Percent complete: 66%

Budget

- Total project funding
  - DOE share: $306,888
  - Contractor share: $76,722
- Funding received in FY11: $0
- Fund for FY12: $0

Barriers

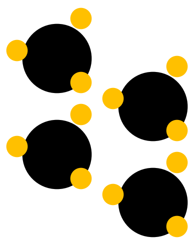
- Ultralow Pt loading: using 3D nano-structural catalytic electrode to maximize Pt usage.
- Durability: using surface stable carbon nanotubes to replace carbon blacks as support.

Partners

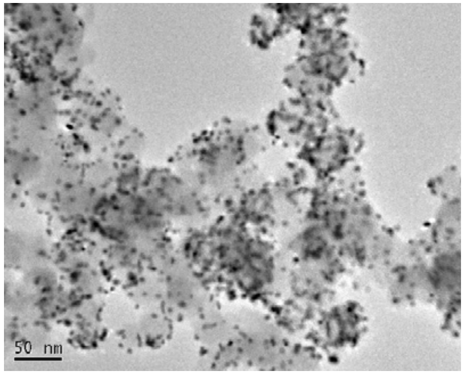
- Bing Energy Inc. (BEI) - A fuel cell company
- Project lead: Harry Chen (CTO of BEI)

Advantages of Buckypapers in Fuel Cells Assembly

Conventional method



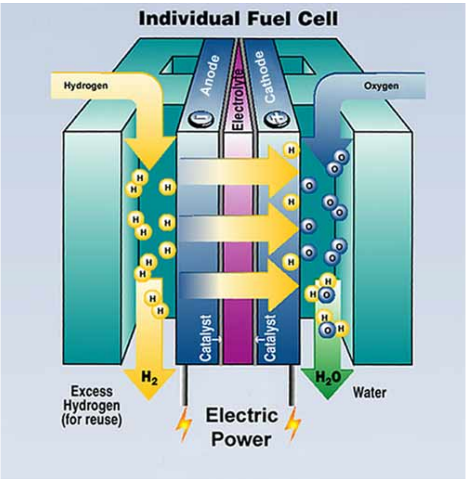
Pt/carbon coating



Catalytic electrode film

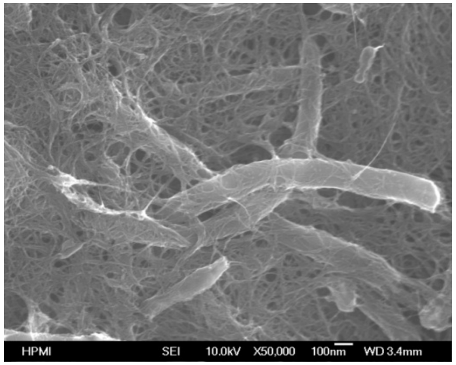
Disadvantages:

- Low Pt usage: due to Pt blocking by support materials and micropores
- Poor durability: carbon surface corroded under the severe condition

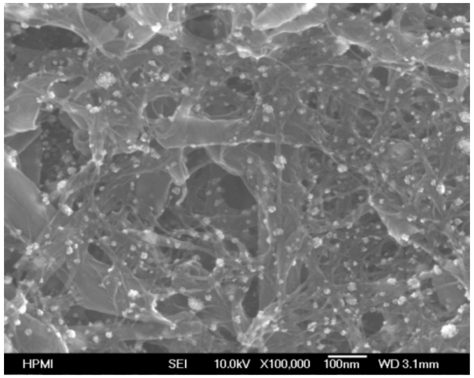


MEA & fuel cell assembly

Our method



Buckypaper



Pt/buckypaper coating

Advantages:

- High Pt usage: no Pt blocking
- Good durability: stable CNT surface

Fuel Cell Power Performance

Date	July 2008	October 2010	December 2011
Electrode structure	Single-layer SWNT buckypaper	Double-layer SWNT buckypaper	Double-layer MWNT buckypaper
Rated power density (mW/cm^2)	494	990 (540)	1500 (800)
Pt loading (mg_{Pt}/cm^2)	0.19	0.19	0.25
Pt utilization (g_{Pt}/kW)	0.38	0.19 (0.35)	0.167(0.31)

DOE's 2015 Old Goal: 1000 mW/cm^2; 0.2 g_{Pt}/kW

DOE's 2015 New Goal: 1000 mW/cm^2; 0.125 g_{Pt}/kW

Oxygen (Air)

Long-term Stability

	Characteristic	Units	DOE's 2015 target	BEI's MEA
Electrocatalyst Cycle 0.6 to 1.0V 30k cycles	Catalytic Mass Activity	% loss of initial activity after 30K cycles	<40	33
	Polarization Curve	mV loss at 0.8 A/cm^2 after 30K cycles	<30	0
	Electrochemical surface area	% loss of initial ECSA after 30K cycles	<40	24

Tasks and Deliverables

- Completion of Task #1: The modeling and simulation work - Completed
- Completion of Task #2: Delivery of buckypapers with optimal gradient structure - Completed
- Completion of Task #3: Delivery of catalytic electrodes (4”×4”) with electrochemical surface area greater than 50 m^2/g and Pt loading at 0.1-0.2 mg/cm^2 – Completed
- Completion of Task #4: Delivery of MEAs with following characteristics (1) Pt utilization better than 0.2 g_{Pt}/kW, (2) power density greater than 1,000 mW/cm^2 at rated voltage 0.65 V - Completed
- Completion of Task #5: Demonstration of a 5-cell short stack based on the optimized single cells with buckypaper supported catalyst and completion of 3,000 hour test – In Progress
- Completion of Task #6: Delivery of a 500 W stack prototype based on the optimized Pt/buckypaper electrode
- Completion of project: Summary of other project outcomes including publications, conference presentations and proceedings, new research grants, and student graduation.

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Task 12: Interdisciplinary Hydrogen & Fuel Cell Technology Academic Program

Drs. Mary McCay and Kurt Winkelman
150 West University Boulevard
Melbourne, FL 32901-6975

March 2012

Timeline

- Project Start Date: Dec. 1, 2010
- Project End Date: Dec. 31, 2012
- Percent Complete: 55%

Budget

- Total Project Funding: $300,000

Barriers

- Lack of Readily Available, Objective, and Technically Accurate Information
- Disconnect Between Hydrogen Information and Dissemination Networks
- Difficulty Measuring Success

Objectives

- Provide hydrogen and fuel cell researchers by developing an interdisciplinary education program of undergraduate modules, of enquiry-based laboratory experiments and by offering a specialized graduate program.

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Hydrogen-Themed General Chemistry Laboratory Course

Relevance

Improve students' views about chemistry and their knowledge and opinion of hydrogen as an alternative energy source

Approach

- Create a General Chemistry II lab course with the theme of hydrogen technology
- All experiments involve properties, uses and production of hydrogen
- Experiments adapted and improved from literature
- Experiments published in easy-to-use lab manual

- Measure effect of experiments on students' views and knowledge about hydrogen (Hydrogen Knowledge and Opinion Survey, HKOS)
- Measure changes in students' perspectives about chemistry (in-house survey)

Hydrogen Experiments

- Chemical and physical properties of hydrogen
- Absorption and storage of H_2 in metals
- Detection of reaction intermediate of H_2 combustion
- Construction of solar powered H_2 electrolysis cell
- Measure kinetics of hydrogen production
- Construct an H_2 fuel cell

Accomplishments and Progress

- Collected student survey data prior to adding new experiments (baseline student response)
- Implemented new experiments, collected student survey data
- Analyzing data now (summer 2012)

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Graduate Hydrogen Curricula
Department of Mechanical and Aerospace Engineering
Department of Chemical Engineering

Graduate Specializations

MSME – Hydrogen and Fuel Cell Tech.
MS CHE – Hydrogen and Fuel Cell Tech.

Hydrogen Technology is the application of engineering principles to the analysis, design and development of hydrogen-based systems, components, and vehicles. The current focus on hydrogen as an alternative fuel has brought increased attention to the fuel cell, the electrochemical device of choice for recovering and using the energy carried by the gas. These specializations provide the students with a strong background in hydrogen technology, including an in-depth study of the fuel cell and electrochemical engineering principles, thus preparing them to serve the challenging demands of a growing hydrogen economy.

New Courses

MAE 5330 Principles of Fuel Cells
CHE 5240 Electrochemical Engineering
CHE 5250 Hydrogen Technology

Status

MAE 5330 and CHE 5250 have been approved and will be offered beginning Fall 2012.

The program specializations and CHE 5240 have been approved by the Florida Tech College of Engineering Council and are approved by Florida Tech Graduate Council.

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Hydrogen Related Student Projects

Webpage
Brochure

Life cycle cost estimation of conversion of the Airport ground equipment to hydrogen fuel cells

Cost analysis of a hydrogen emergency power supply.

Future Work

- Publish project results showing impact of hydrogen-themed course on chemistry student knowledge and opinion of hydrogen technology
- Begin offering specialized new hydrogen and fuel cell programs beginning Fall 2012
- Develop student projects on the design of an unmanned VSTOL vehicle powered by a fuel cell and design a fuel cell that uses the airflow over the wing for cooling.

Task 13: Design and Development of an Advanced Hydrogen Storage System using Novel Materials

E.K. Stefanakos, D. Yogi Goswami, A. Kumar
CERC, University of South Florida
4202 E. Fowler Avenue, Tampa, FL 33620

CERC
Clean Energy Research Center

USF UNIVERSITY OF SOUTH FLORIDA

Overview

Timeline

- Project start date: 12/01/2010
- Project end date: 06/30/2012
- Percent complete: 55%

Barriers

•Meet DOE's 2015 technical targets for storage system of gravimetric at 0.055 kg H_2/kg and volumetric at 0.040 kg H_2/L.

Budget

•Total Project funding

- DOE share $248,000
- Contractor share $62,019

•Funding received in FY11: $0

•Funding for FY12: $0

Objectives

Design and develop novel conducting polymeric nanomaterials for on-board hydrogen storage with a system gravimetric capacity of 5.5 wt.% or greater and have completely reversible hydrogen storage characteristics at moderate temperatures (<100^oC).

CERC Clean Energy Research Center

USF UNIVERSITY OF SOUTH FLORIDA

Specific Tasks

Task 1: Fabrication of polymer nanostructures for reversible hydrogen storage

Task 2: Modification of polymer nanostructures by, for example, CNT, Graphene and transition metal catalyst doping.

Task 3: Engineering system design, development and testing

Task 4 Education and Outreach

Proposed Approach

- Synthesis of polyaniline (PANI) and its composites - a solid state hydrogen storage material.
- Modification of synthesis parameters for optimized storage capabilities.

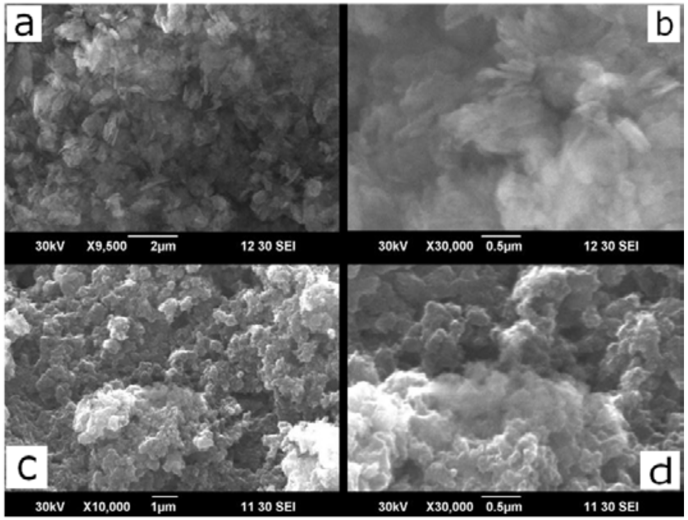
Results

- **System Gravimetric Capacity (5.5 wt.%):** Achieved 1.5 wt.% H_2 storage, at room temperature.

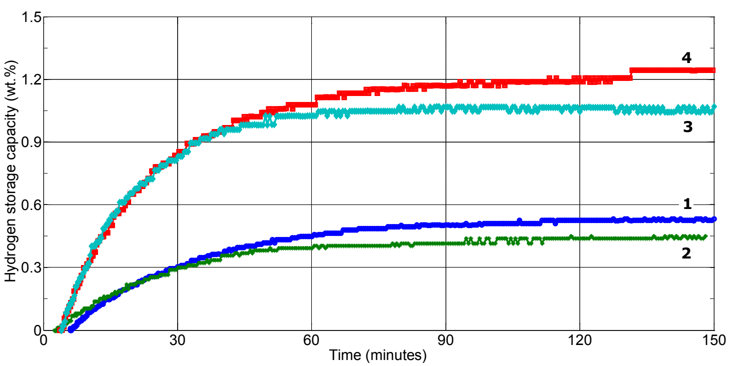
- **Reproducibility of the Material:** Presently, not achieved in electrospun polyaniline materials.

- **Reproducibility of Performance:** Presently, not able to sustain H_2 recyclability in electrospun polymers.

Polyaniline CSA doped

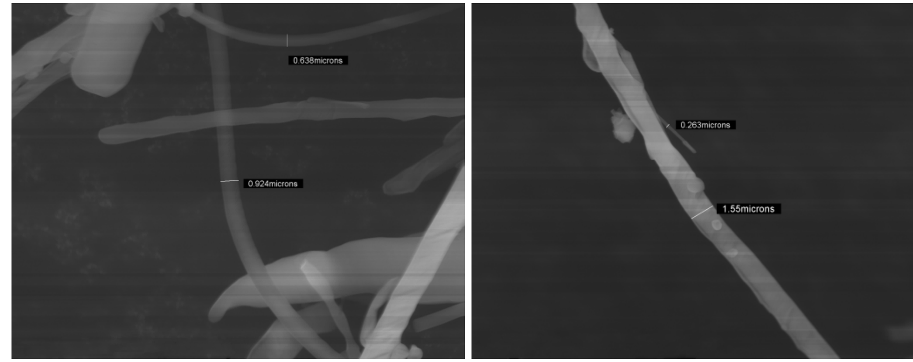


SEM images of PANI; (a&b) 0.1M aniline:1M CSA and (c&d) 1M aniline:0.1M CSA.

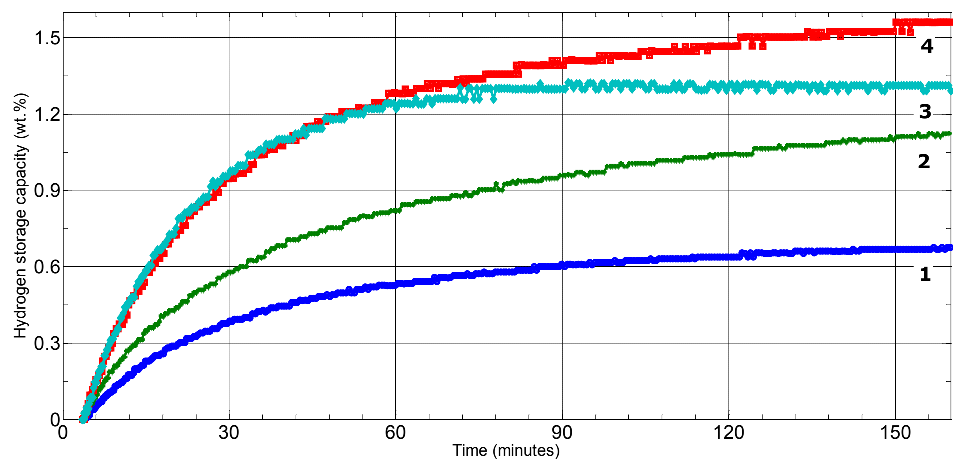


Absorption kinetics and storage capacity of different PANI samples at 70°C. (1 – 1M Aniline-1M CSA, 2 – 1M Aniline-0.5M CSA, 3 – 1M Aniline-0.05M CSA, 4 – 1M Aniline-0.01M CSA

Polyaniline electrospun fiber



SEM Images of Electrospun Fibers

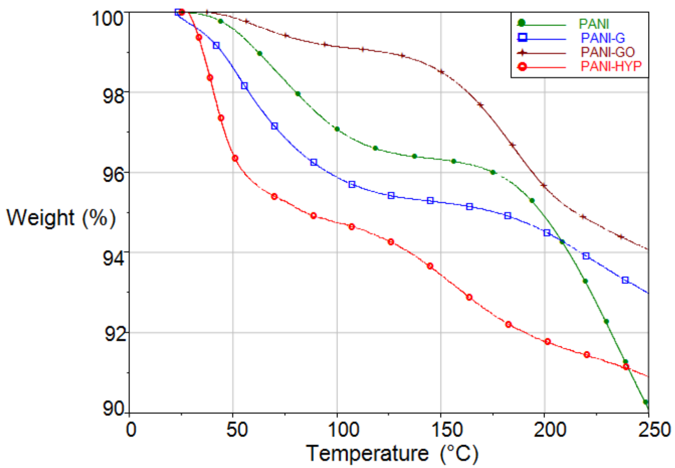


Absorption kinetics and storage capacity of different PANI samples at 25°C. (1 – 1M Aniline-1M CSA, 2 – 1M Aniline-0.5M CSA, 3 – 1M Aniline-0.05M CSA, 4 – 1M Aniline-0.01M CSA)

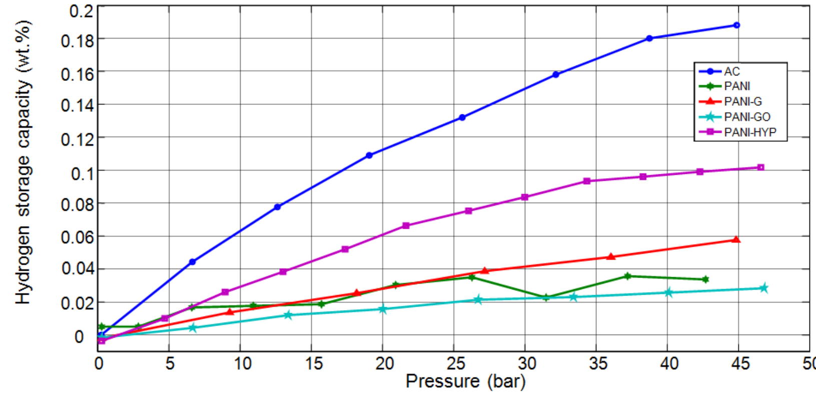
CERC Clean Energy Research Center

USF UNIVERSITY OF SOUTH FLORIDA

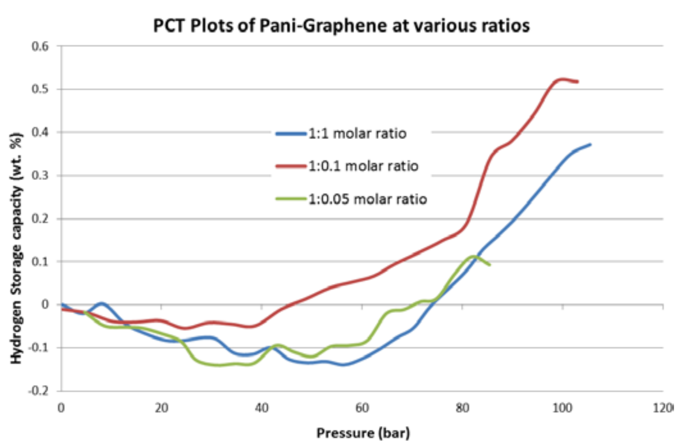
Modification of conducting polyaniline nanostructures by graphene and polymer /or transition metal catalyst doping



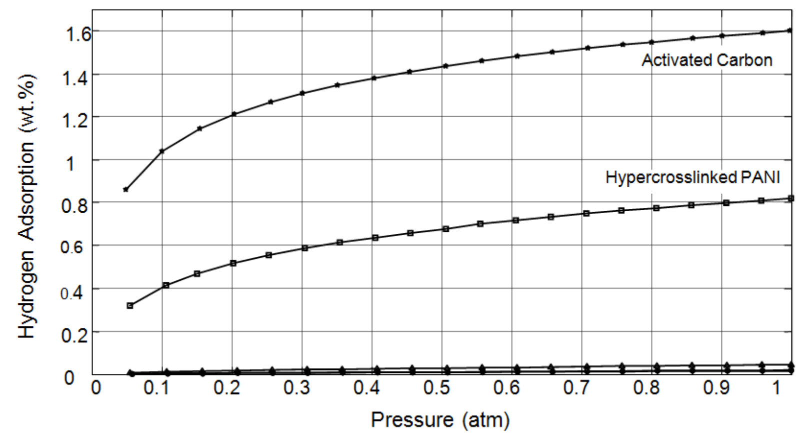
TGA analysis of PANI, PANI-G, PANI-GO and PANI-HYP.



PCT (pressure-concentration-temperature) absorption isotherms of PANI, PANI-G, PANI-GO, PANI-HYP and AC at 298K



Hydrogen Adsorption Isotherms of Pani-G (various molar ratios) at 298K



Hydrogen adsorption isotherms of PANI¥, PANI-G¥, PANI-GO¥, PANI-HYP and AC at 77.3K. ¥ Since PANI, PANI-G and PANI-GO performed almost identical they were not labeled but shown for comparison

Future Work

- Continue R & D on nanocomposite conducting polymer materials for increased storage capacities, temperature, reproducibility, durability and recycling.

- Continue testing to understand the hydrogen storage physisorption and chemisorption processes in a conducting polymer (PANI)

Task 14: Advanced HiFoil™ Bipolar Plates

PI: James Braun
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DOE Contract #DE-FC36-04GO14225

Sales@enerfuel.com

Advanced HiFoil™ Bipolar Plates

Overview

Timeline
- Project start date: 4-1-11
- Project end date: 12-31-12
- Percent complete: 48%

Barriers
- A, B and E (MYPP Section 3.4 Task 11)

Budget
- Total Project Funding
  - DOE share: $344,684
  - Contractor share: $147,722
- Funding received in FY11: $0
- Funding for FY12: $:0

Partners
- Interactions/ collaborations: The University of Florida
- Project lead: EnerFuel, Inc.

Objectives/ Approach

1. **Moldable Plate** – Develop a multi-layer bipolar plate configuration that permits molding of the reactant flow field channels <u>and enables edge heat conduction</u>

2. **Integral Seal** - Achieve a robust seal against porosity around fluid ports and plate edges using a dispensed sealant or coating

3. **Stack Validation** - Obtain performance data in a liquid-cooled, reformate capable HTPEM fuel cell stack with $1kW_e$ output

4. **Meet DOE Targets** - Meet or exceed DOE bipolar plate technical targets

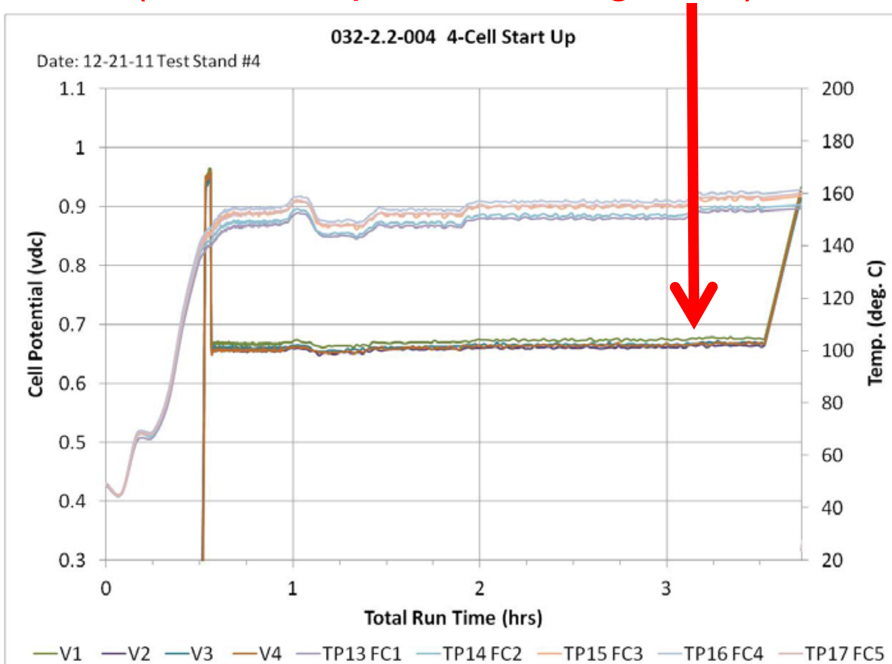
EnerFuel

Advanced HiFoil™ Bipolar Plates

Accomplishments

New low cost plates performed better in 4-cell testing at 32 Amps!

Pre-HiFoil™ (High Cost) Bipolar Plates
(~14 mV spread among cells)



Gen 2 HiFoil™ (Low Cost) Bipolar Plates
(~1 mV spread among cells)

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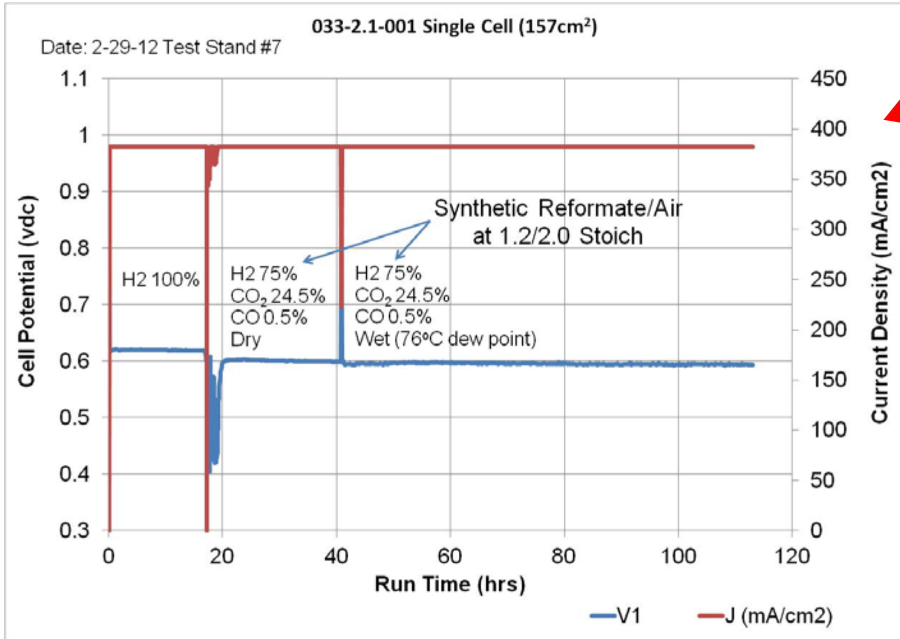
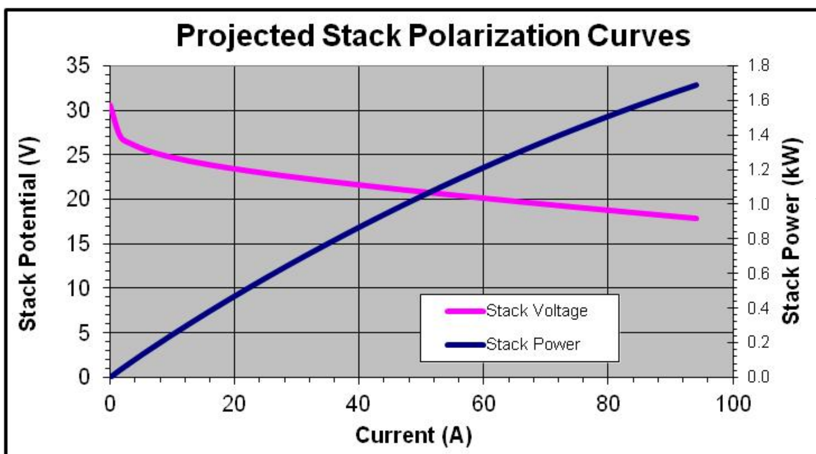
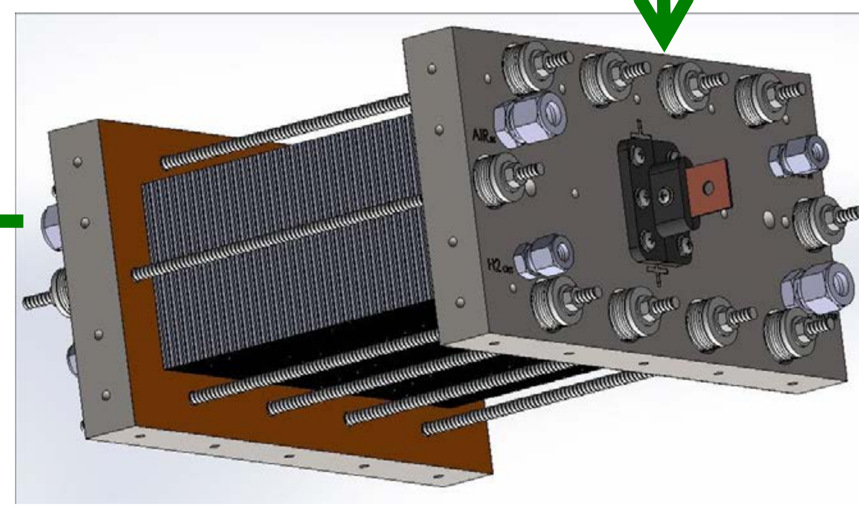
Advanced HiFoil™ Bipolar Plates



Initial Test Results Look Good with Synthetic Reformate at Low Stoich

Next Steps: Validate Plates in 1kW$_e$ Edge-Cooled microCHP Stack





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Future Work

- Develop molding process for flow channels
- Use conventional material suppliers for plates
- Develop process for sealing ports of internal plate
- Validate plates in 1kWe edge-cooled micro CHP stack

EnerFuel

Future Commercial Applications

Transportation


Car


Materials Handling


Buses

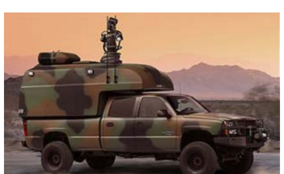

Scooters


Trains

Planes


Boats


APU – Trucks


APU – Military


APU – Police

Stationary


Home Power


Office Building


Telecom Power

Facility Power

Remote Locations


Yachts

Cruise Ships


Space Shuttle


Submarine

Additional Uses

- Backup Power
- Base load power plants
- Off-grid power supply