2011 DOE Hydrogen and Fuel Cells

Program Review

High Speed, Low Cost Fabrication of Gas Diffusion Electrodes for Membrane Electrode Assemblies

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MN007

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Overview

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Timeline

- Start: 1 July 2009
- End: 30 June 2012
- 55% complete

Barriers

- Manufacturing R&D
  - (A) Lack of High Volume Membrane Electrode Assembly (MEA) Processes
  - (F) Low Levels of Quality Control and Inflexible Processes.

Budget

- Total project funding: $3.06M
  - DOE share: $1.99M
  - Contractor share: $1.07M
- Fed. funding received in FY10: $700K
- Est. Fed. funding for FY11: $339K

Partners

- Case Western Reserve University
- X-Ray Optical Systems

Relevance

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Overall Objective

- Reduce cost in fabricating gas diffusion electrodes (GDEs)
  - Focus on GDEs used for combined heat and power generation (CHP).
- Relate manufacturing variations to actual fuel cell performance in order to establish a cost effective product specification within six-sigma guidelines.
- Develop advanced quality control methods to guide realization of these two objectives.

Objective(s) this reporting period

- 2X speed increase or equivalent on cloth
- Proof-of-principle coating on non-woven paper

Directly Addresses Barriers

- (A) Lack of High Volume Membrane Electrode Assembly (MEA) Processes
  - High speed or throughput coating
- (F) Low Levels of Quality Control and Inflexible Processes.
  - On-line Pt measurement.

Addresses key DOE targets

Targets: 1–10 kW_e Residential CHP FC Operating on Natural Gas

	2008 Status	2012	2015	2020
Electrical efficiency at rated power	34%	40%	42.5%	45%
CHP energy efficiency	80%	85%	87.5%	90%
Factory cost* per kW	$750	$650	$550	$450

*Cost includes materials and labor costs to produce 50k/yr stacks

Approach

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Tools → Build → Tools → Test

	Tools	Build	Test
Task	**Task 1**: On-line QC to guide the process by Y1 **Task 2**: Model impact of defects by Y1	Develop Ink and Application **Task 3**: full length coating by Y2 **Task 4**: Increase line speed by Y2 (go/no go June 2011) **Task 5**: Full width roll by Y2/Y3	Performance Defects/Uniformity Relate defects to performance
Milestone	**T1**: On-line Pt measurement **T1**: On-roll porosity measurement **T2**: Verify Model, Calculate defect limits	**T3**: >240 lin m **T4**: 2X speed improvement (go/no go): 3X final goal **T5**: full width (>100 cm full width) at higher speed	**Main Concept** Use advanced dispersion and ink formulations to make aqueous solid - binder suspensions compatible
Status	**T1**: complete, modified for full width cloth **T1**: On-roll porosity: delay due to vendor **T2**: Base model established	**T3**: cathode & GDL complete **T4**: demonstrated 2X capacity / time unit **T5**: full width GDL begun	

Technical Accomplishments and Progress

Task 2: Defects

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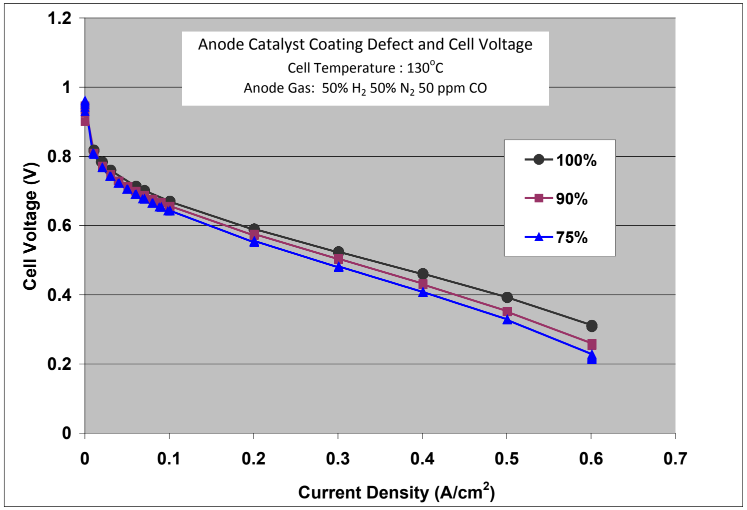
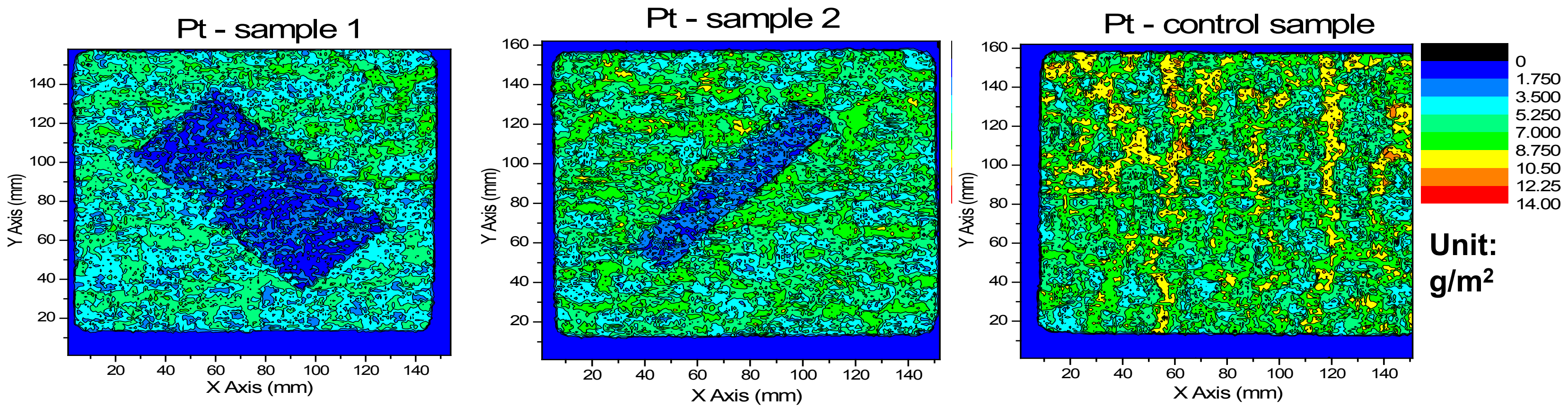
- **Objective**: 1.) What is the impact of loss-of-catalyst coating defects? 2.) Does the model accurately predict actual?
- **Experiment**: systematically introduce "coating" defect into GDE, characterize, make MEA and test. Sample 1=25% gross GDE surface area loss, 2=10% area loss.
- **New Collaboration**: X-ray Optical Systems used high-resolution XRF mapping. RPI tested under a variety of conditions.
- **Conclusion**: system is robust to catalyst loss defects. Model in good agreement with experiment at <0.4A/cm^2



Test results with 25% and 10% loss



Actual performance loss at 0.2A/cm^2 <1% power with 10% surface defect

Technical Accomplishments and Progress

Tasks 3/4: Full Length Roll Coating, 2X speed Cathode

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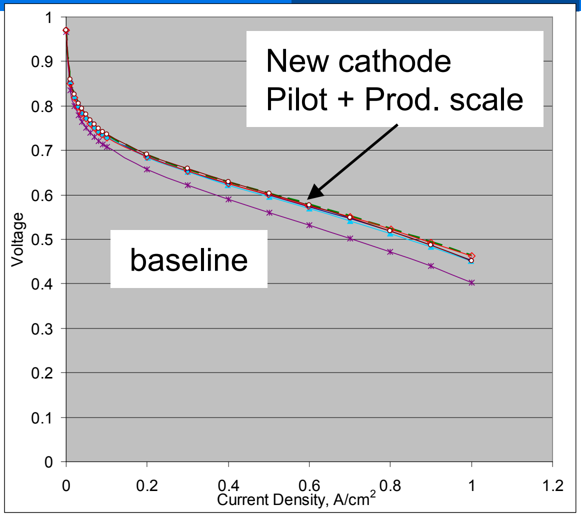
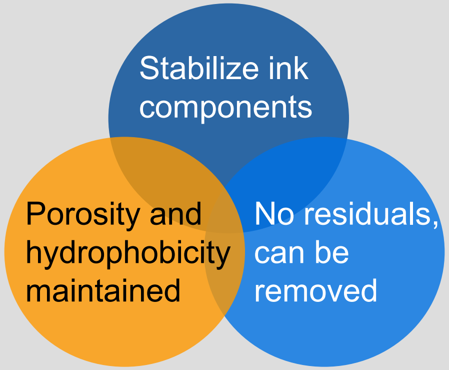
- **Accomplishments:** Extended last year's ink formulations to stabilizing catalyst suspensions that have been subject to very high energy dispersion.
- **Breakthrough:** Very fine particles tend to agglomerate. Advanced additives stabilized dispersion.
- **Results**:
  1. Decreased ink preparation time by >60%.
  2. Decreased number of application passes by >40% through higher solids in ink.
  3. Increased Pt utilization by >25%.
  4. Decreased variation from +/-20% to +/-4% g/m^2 (using on-line XRF).
- **Conclusion**: Have effectively increased capacity/unit time by 2X and reduced costs.



Baseline vs Pilot and Production (full roll)



Ink additive selection rules now combined with high energy dispersion

New cathode reduces labor by at least 50% and increases performance by 20mV over baseline!
Met go/no go with Cathode

Technical Accomplishments and Progress

Task 3/4: Full Length Roll Coating, 2X Speed
GDL (microporous layer) + Anode

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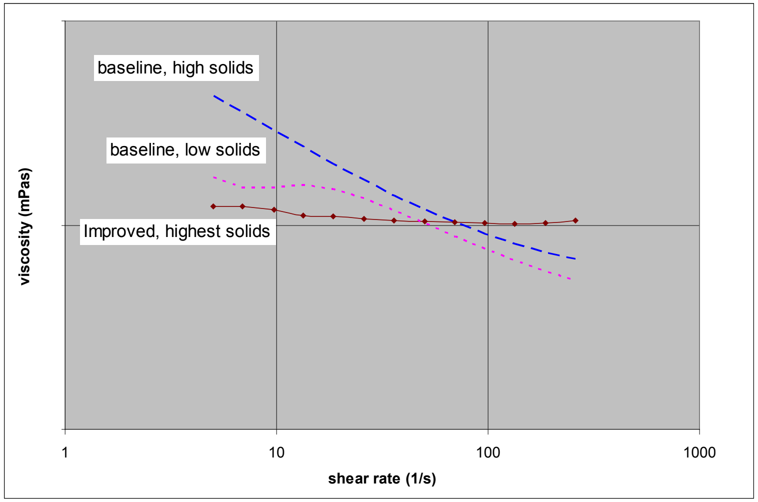
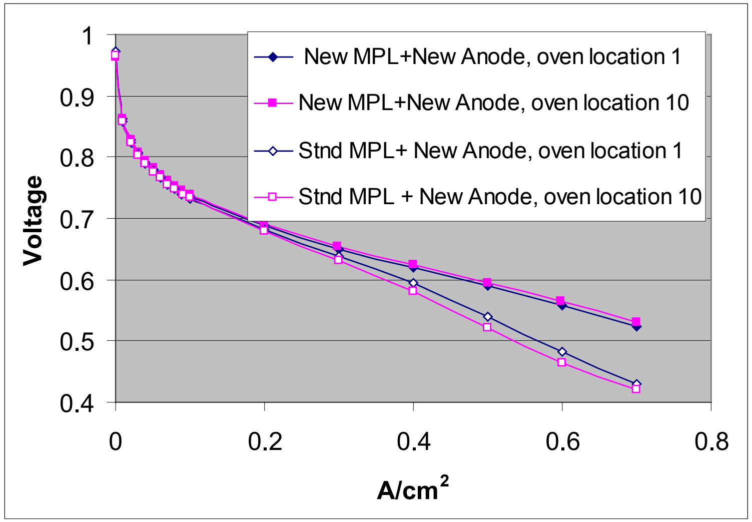
- **Observation:** baseline MPL inks are non-Newtonian. Indicates strong particle-particle interaction. Limits solid content for ink and prone to agglomeration.
- **Approach**: Identified additive and prep methodology that shields hydrophobic carbons and provides for Newtonian behavior over wide shear range.
- **Results**: Decrease ink prep time and number of coating applications by >50%. Improved performance. *Demonstrated MPL on production coater with full width cloth.*

Extended high energy dispersion and new formulation for MPL and Anode inks with >50% reduction in prep time and number of coats.



MPL ink shear vs. viscosity, baseline, high solids baseline, and new highest solids improved formulation



Performance improvement with new MPL and anode formulations. 180°C, 1.4/5 Reformate (71% H_2, 27% CO_2, 2% CO)/Air

Technical Accomplishments and Progress

Task 3/4: Full Length Roll Coating, 2X Speed
Carbon Paper (Non-Woven)

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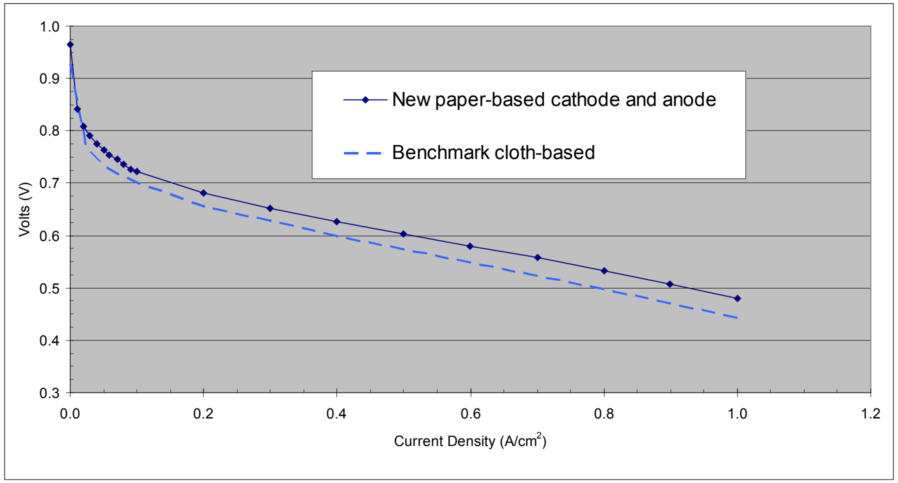
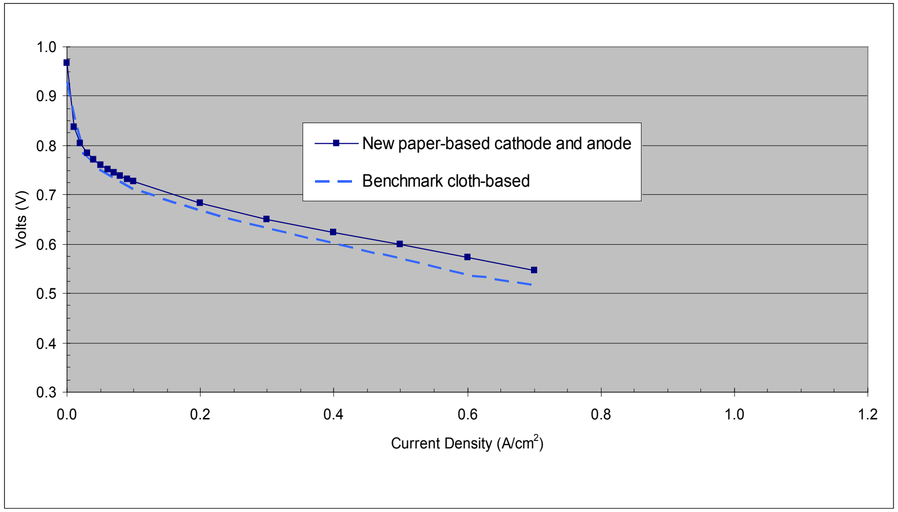
- **Observation:** Cost for paper vs. cloth is projected to be at least 30% lower in higher volume. However, inks used for cloth do not work with paper.
- **Approach**: Using established cloth approach and high energy dispersion, design new inks matched to carbon paper substrate to yield desired porosity and hydrophobicity profile.
- **Results**: Demonstrated good electrode performance at Pilot scale, and MPL at Production scale. Production scale MPL coating at >2X speed compared to cloth. In all platforms, number of application passes paper< best new cloth formulations.

New GDEs on paper vs cloth standard 160°C, H_2/air, 1.2/2



New GDEs on paper vs cloth standard, 180°C, Reformate/air 1.4/5



Paper-based materials offer great potential in performance and further reduction in process cost.

Collaborations

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Task 2 Defects

- **X-Ray Optical Systems** (XOS)
  - New collaboration for detailed XRF mapping of GDE surface
- **RPI** – Prof. Dan Lewis
  - Evaluation of MEAs with defects

Collaborations begun during this reporting period

- **RPI** – CATS Prof. Ray Puffer
  - Have sent samples of new anode and cathodes for ultrasound assembly technology
- **Customer** - Have sent MEAs made with new GDE builds to a major µCHP supplier.

These collaborations were initiated outside the original team tasks in this DOE program

Proposed Future Work

Over next year

- **Task 3: full roll coating**
  - Scale new anode ink to production coating within Q2, 2011.
  - Continue new approach to coating non-wovens (carbon paper).
- **Task 4: Increase line speed**
  - Key go/no go in Fy2011: Demonstrate 2X increase in line speed on a full roll – June 2011
  - Have elements in place: MPL, cathode, and anode – will focus on anode.
    - Demonstrated 2X reduction in cost from decreasing labor content of ink prep and significant decrease in number of coat applications across all platforms.
    - Will show an effective 2X increase in capacity when anode at production coater.
- **Task 5: Demonstrate full width (>100cm) and 3X equivalent speed (Phase II)**
  - MPL at full width and 2X equivalent capacity demonstrated.
  - First anode and cathode trials planed for Q2, 2011 (ahead of plan).

Summary Slide

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- Reduced total GDE labor costs by ~50% due to new high energy dispersion with advanced formulations.
    - Cathode utilization improvement (20 mV gain) implies potential for decrease of precious metal content by at least 25%, although this is not main focus of the program.
- Well on the path towards achieving June's go/no go.

Platform	Improved Ink	Coating Pilot	Coating Production 1/2 width	Sintering	Coating Production full width
Cloth					
MPL	>50%	>55%	>55%		
Cathode	>60%	>40%	>40%		**Q2**
Anode	>50%	>40%			**Q2**
Paper					
MPL					
Cathode					
Anode					
	← Phase I →				Phase II

% indicates reduction in labor-hours. No benchmark for paper but have achieved similar or greater results compared to cloth