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

(DE-EE0000384)

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MN007

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Overview

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Timeline

- Start: 1 July 2009
- End: 30 June 2012
- 25% complete

Budget

- Total project funding: $3.06M
  - DOE share: $1.99M
  - Contractor share: $1.07M
- Funding received in FY09: $500K
- Funding for FY10: $500k

Barriers

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

Partners

- Case Western Reserve University
- X-Ray Optical Systems

Relevance

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

- Full length roll coating
- On-line measurement of platinum level and distribution (advanced QC)

Directly Addresses Barriers:

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

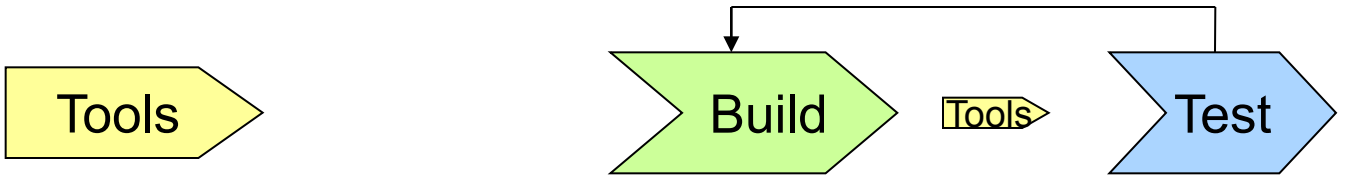
Addresses key DOE targets:

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

	2008 Status	2012	2015	2020
Electrical efficiency at rated power[2]	34%	40%	42.5%	45%
CHP energy efficiency[3]	80%	85%	87.5%	90%
Factory cost[1] Per Kw	$750	$650	$550	$450

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

Approach



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) **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 cloth or wide paper); full width at higher speed	
Status	**T1**: Ahead of plan, meeting goals **T1**: On-roll porosity : on plan **T2**: Base model established	**T3**: new ink meeting interim goals **T4**: just beginning **T5**: not begun	

Technical Accomplishments and Progress
Task 1:On-line platinum analysis
Design

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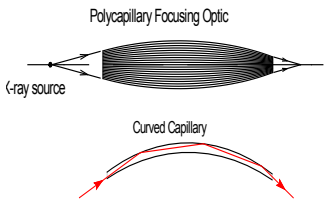
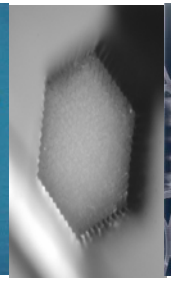
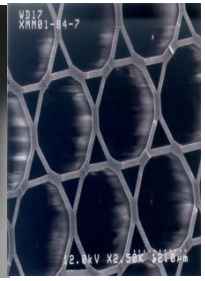
- **Problem**: commercial XRF units do not have enough power to collect a platinum signal in a short period of time
- **Solution**: Through XOS's polycapillary optics, we are able to use a low power source and obtain amplified signals in a short period of time



Capillary Optic



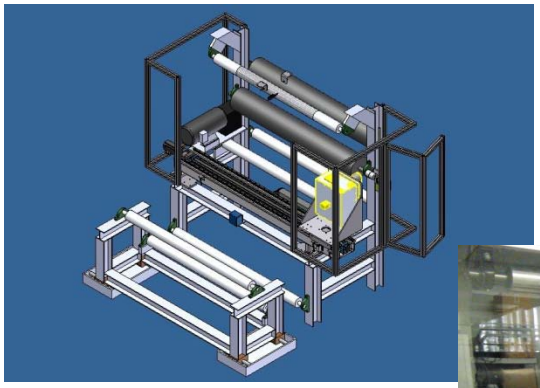
Alignment Jig



Single Elements

Design Goals

- Safely used by production staff
- 25ms accumulation: 10ms achieved
- Rail scan 10m/s: 20m/s achieved
- Instrument variation +/-2.5%: <+/-1% preliminary achieved
- Minimum level <1g/m^2 Pt: initially achieved 1.7g/m^2 but believe can exceed minimum with parameter optimization



Design Phase

Actual

This is the first time a scanning XRF has been used on GDEs
We have exceeded design specifications

Technical Accomplishments and Progress
Task 1:On-line platinum analysis
Results

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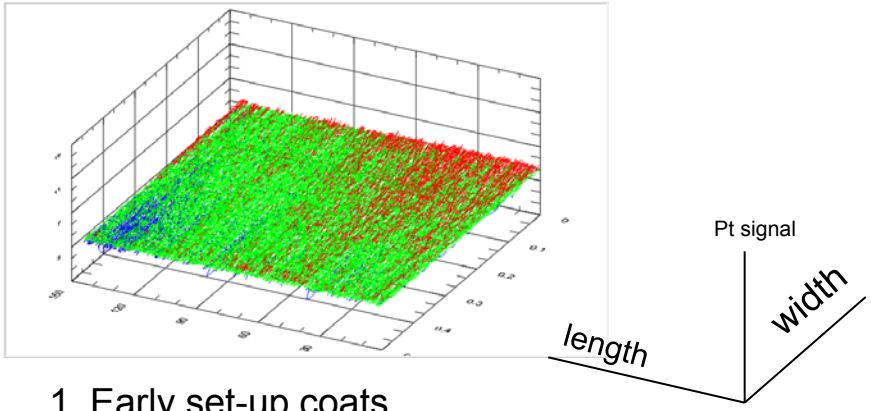
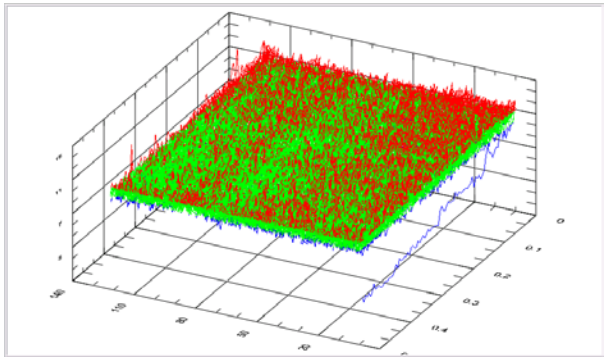
- We are able to correlate adjustments of applicator with platinum distribution and detect anomalies

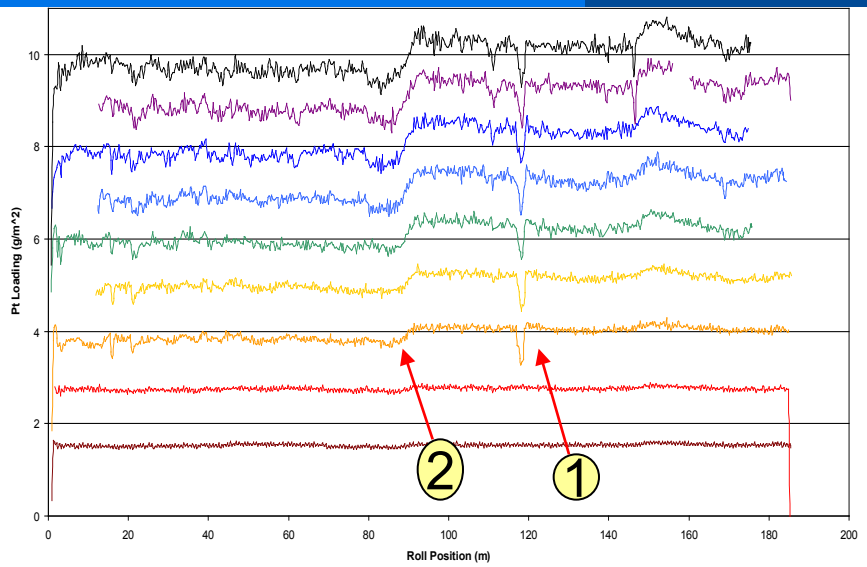


1. Early set-up coats



Green =1σ
Red >1σ
Blue <1σ

2. Adjust applicator



Roll coating anode with on-line XRF

1 = disengage applicator (one time)
2 = anomaly

XRF tool is anticipated to be a capable guide during higher speed and full width coating

Technical Accomplishments and Progress
Task 2: Model Impact of manufacturing variation & defects (Case Western University)

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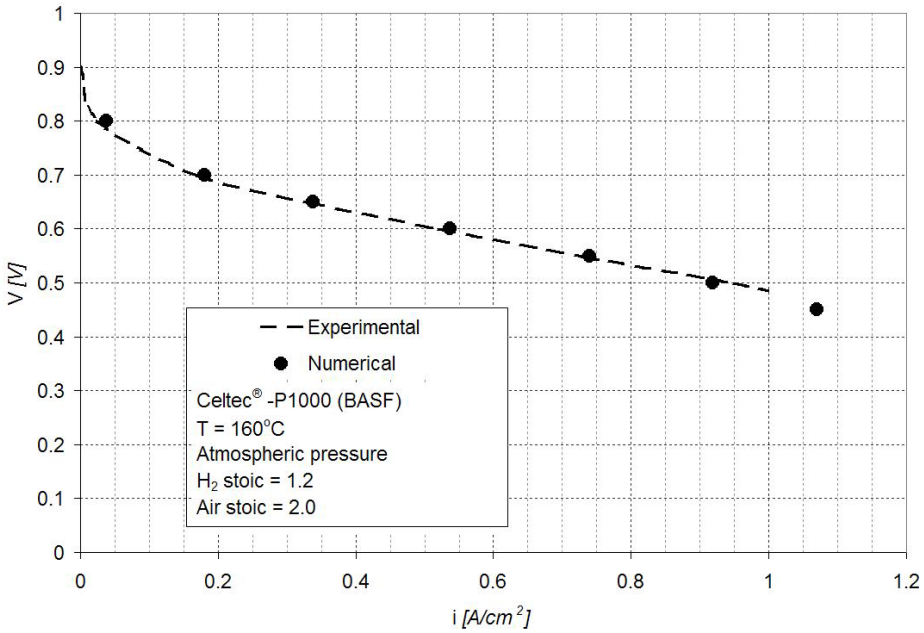
- Use model to predict impact of platinum and porosity variation.
- Use model to predict impact of “spot” defects such as GDE surface defects
- Confirm model with testing

Agglomerate

Uncoated sections



CFD modeling by Dr. V. Gurau
vladimir.gurau@case.edu

Have established baseline
Will model impact of defects

Technical Accomplishments and Progress
Task 3: Full Length Roll Coating Cathode

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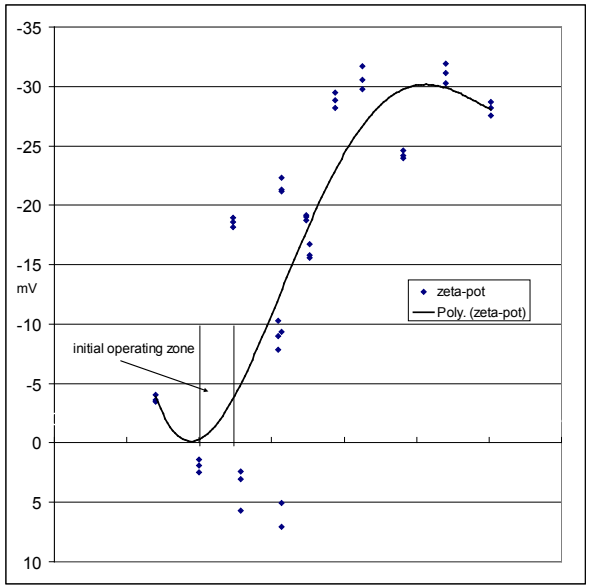
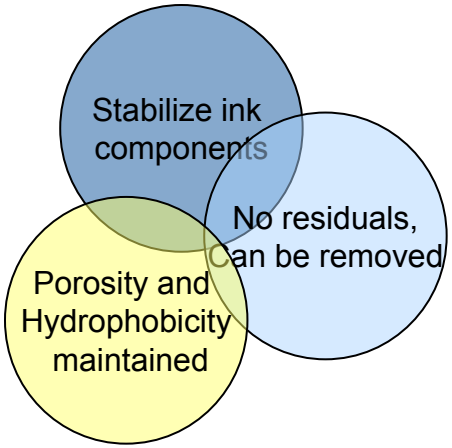
- **Challenge:** GDEs for high temperature PEM consist of catalyst/binder aqueous coatings. Binder (fluorocarbon) and catalyst are not stable in water and are shear-sensitive.
- **Approach:** focus on surface agglomerates as an indicator of ink instability, identify ink properties leading to agglomerates, use advanced dispersion and additives to improve
- **Results**: demonstrated relationship between zeta potential and agglomerate formation. Discovered additive that met all selection rules. Agglomerates for 240 linear meter roll coating reduced by at least 6-fold



zeta potential (mV) vs pH of cathode ink



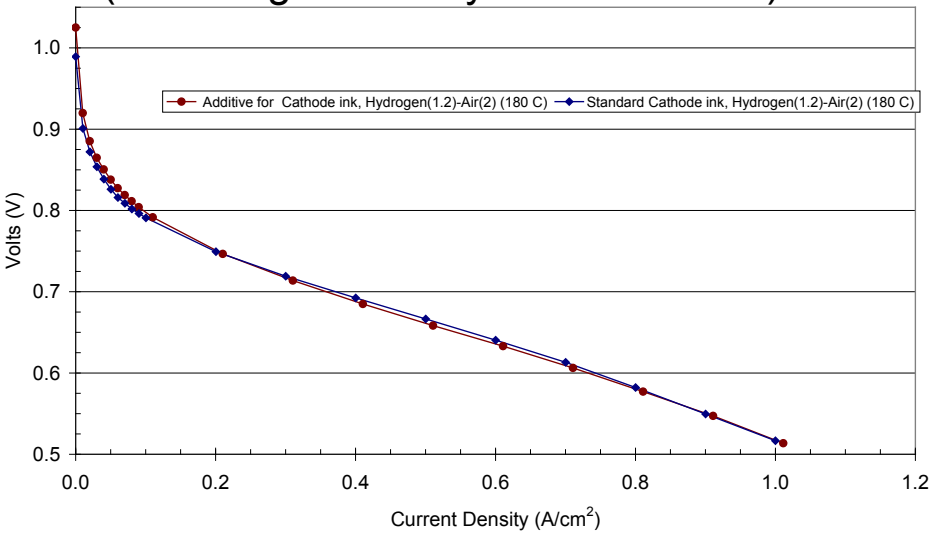
Ink additive selection rules

Zeta-potential is a function of particle size, surface state (carbon vs. catalyst), and surface charge

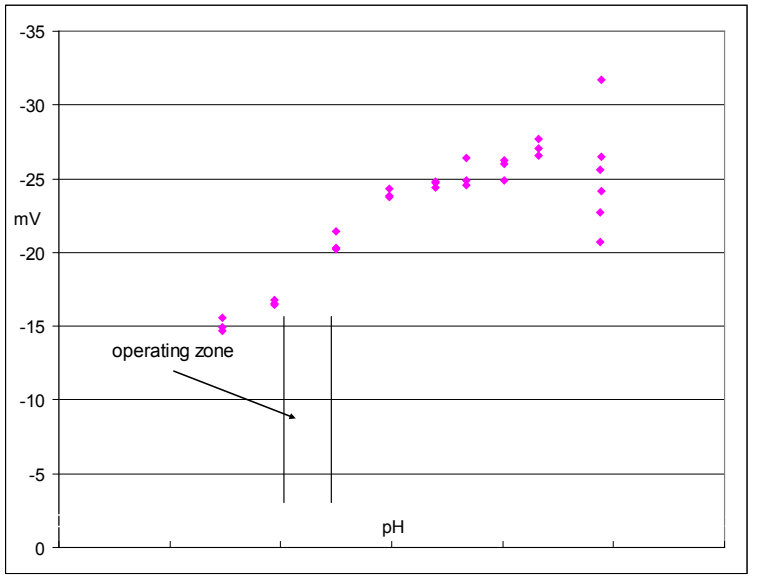
Identified additive that stabilized cathode ink and reduced agglomerates at least 6-fold

Technical Accomplishments and Progress
Task 3: Full Length Roll Coating
Anode

- **Observation:** Different internal sources of anode catalyst lead to inks that were not stable during full length anode coatings
- **Discovery**: Zeta-potential relationship does not hold! Surface states of anode catalysts – due to synthesis methods – lead to destabilizing interactions beyond zeta-potential.
- **Results**: pretreatment of catalyst stabilizes ink (no change of catalyst:binder ratios)



Polarization curve demonstrating no loss of performance with anode/cathode ink changes



zeta potential (mV) vs pH of anode ink

Identified catalyst pretreatment that stabilized anode ink without loss of performance and the surface quality is equal to best cathode coatings

Collaborations

Partners for Task 1 on-line XRF

- RPI Center for Automation Technologies and Systems (CATS)
  - System Design
  - Invited to assist, not part of original plan
- X-Ray Optical Systems (XOS)
  - XRF Engine
  - Subcontractor
- Progressive Machine and Design (PMD)
  - Translational Slide
  - Software
  - Won design bid / subcontractor

Collaborations begun during this reporting period

- NREL, Michael Ulsh
  - In discussions for additional on-line based systems

Proposed Future Work

Over next year

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- Task 1 On-Line QC
  - On-line XRF: establish instrumental variance, guide higher speed coating trials (Task 4)
  - On-the-roll porosity: demonstrate proof of principle and profile rolls using capillary flow in stop-start mode
- Task 2 Model for variation sensitivity
  - Model impact of Pt and porosity variation: compare with actual
  - Model impact of various defects (agglomerates, undercoated sections)
- Task 3: full roll coating
  - Evaluate new inks on carbon paper substrates for performance and quality
- Task 4: Increase line speed
  - Key go/no go in Fy2011: Demonstrate 2X increase in line speed on a full roll

Summary Slide

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- Program developed an innovative on-line XRF ahead of plan.
  - Challenges included extensive safety considerations, integration into a production coater, and web edge and splice detection
- Team has established a framework for understanding ink stability issues
  - For cathode, identified an additive that significantly improved key quality indicator (agglomerates) and established new GDE post-processing conditions to retain electrode porosity and hydrophobicity functionality
  - For anode, identified alternate contribution to ink instability (catalyst surface state) and a solution to address this variability
- Established first critical task-milestone: full length coating on carbon cloth