National Renewable Energy Laboratory
Innovation for Our Energy Future

Fuel Cell MEA Manufacturing R&D

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Overview

Timeline

Start: July 2007
End: September 2013
% complete: N/A

Budget (incl. LBNL)

Total project funding (to date)
- $1,599,000

Funding received in FY08
- $685,000 operating
- $250,000 capital

Funding received in FY09
- $200,000 operating

Barriers

Barrier	Target
B: Cost (fuel cell)	$45/kW (2010) at 500,000 stacks/yr
F: Low levels of quality control (manufacturing)	50x stack cost reduction

Funded Partners

Lawrence Berkeley National Laboratory
Colorado School of Mines
University of Hawaii
DJW Technology

Relevance

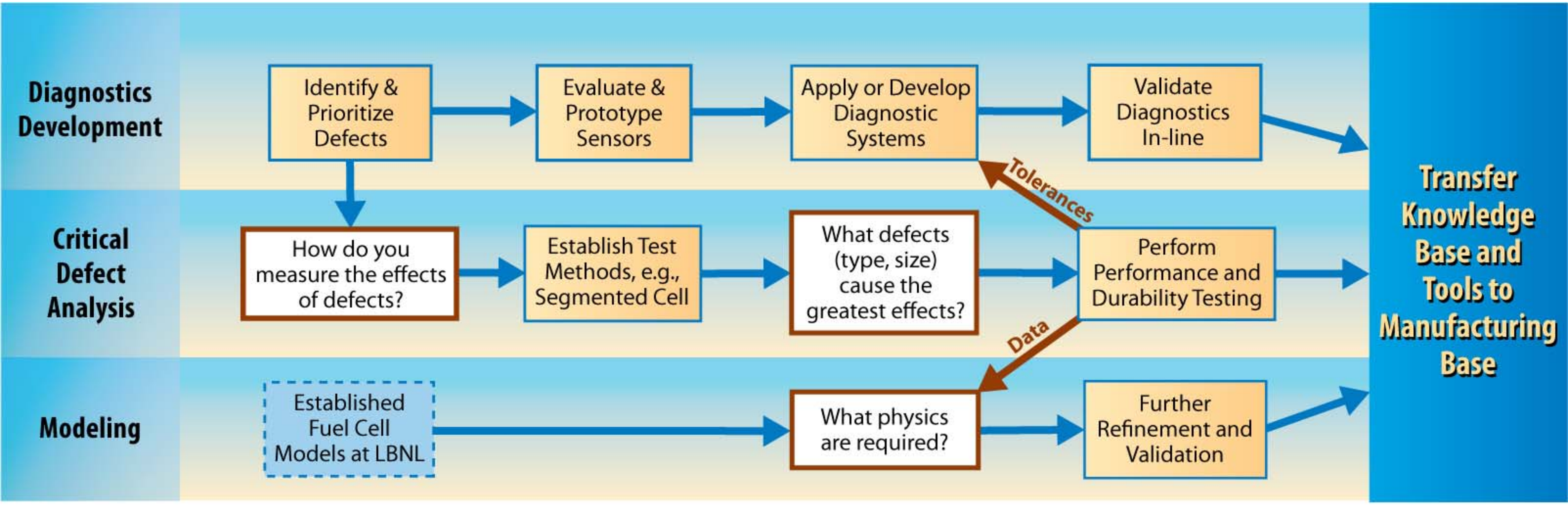
	MYPP Milestones
9/11	Develop prototype sensors for quality control of MEA manufacturing
9/12	Develop continuous in-line measurement of MEA fabrication
9/13	Demonstrate sensors in pilot-scale applications for manufacturing MEAs
9/13	Establish models to predict the effect of manufacturing variations on MEA performance

	Project Objectives
1	Evaluate and develop in-line diagnostics for <u>MEA component</u> quality control, and validate in-line
2	Investigate the effects of manufacturing defects on MEA performance and durability <u>to understand the accuracy requirements for diagnostics</u>
3	Validate and refine <u>existing LBNL MEA model</u> for new application – predictions of the effects of defects

Collaborations

- Industry partners: **3M, Arkema, Ballard Material Products, BASF, DuPont**
  - Provide guidance on critical defects and measurement needs
  - Provide material samples for testing and characterization with diagnostics
  - DOE cost-shared projects
- **NREL**: Bryan Pivovar, Michael Penev, Bhushan Sopori, Peter Rupnowski
- **LBNL** (Adam Weber): model development
- **Colorado School of Mines** (Danielle Williams, A. Herring): test method development and defect analysis
- **Hawaii Natural Energy Institute** (G. Bender, T. Reshetenko): segmented cell development and defect analysis
- **Rensselaer Polytechnic Institute** (R. Puffer): collaboration on RPI's manufacturing R&D cost-shared award
- **Georgia Tech** (T. Harris): collaboration on membrane casting process and defect detection
- Various commercial diagnostics suppliers: material evaluations, development of in-line application

Approach



KEY: Evaluation of critical defect size and type provides information for component tolerances. This enables appropriate accuracies and measurement rates to be understood in the final development of diagnostic systems.

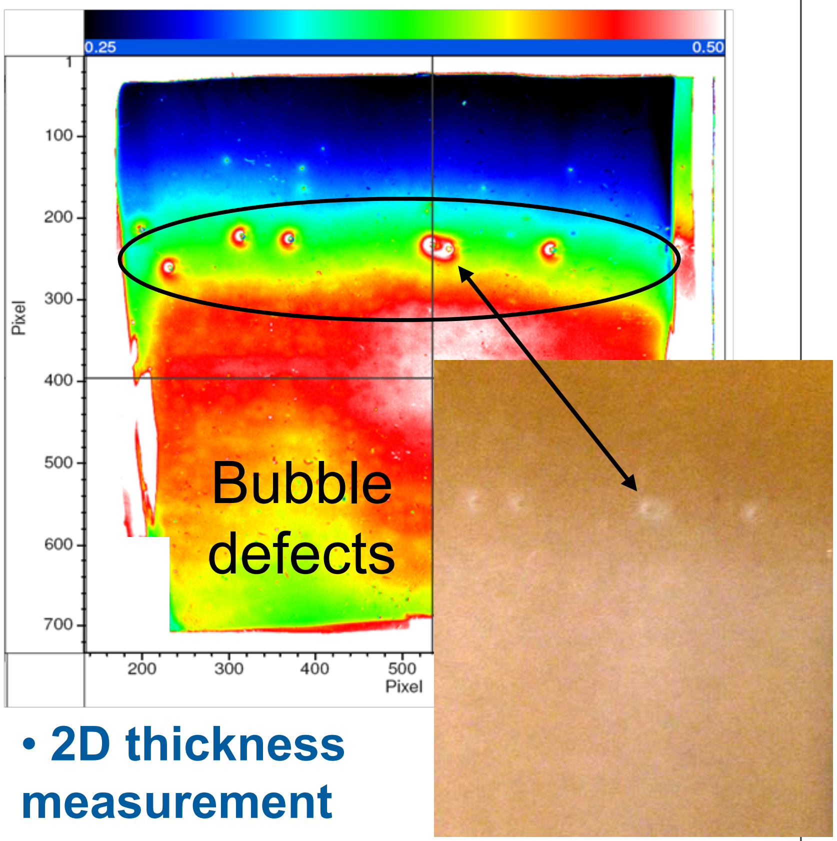
Establishing threshold sizes/extents for each type of critical defect enables specification of accuracy and precision required of diagnostic devices.

Project AOP Milestones

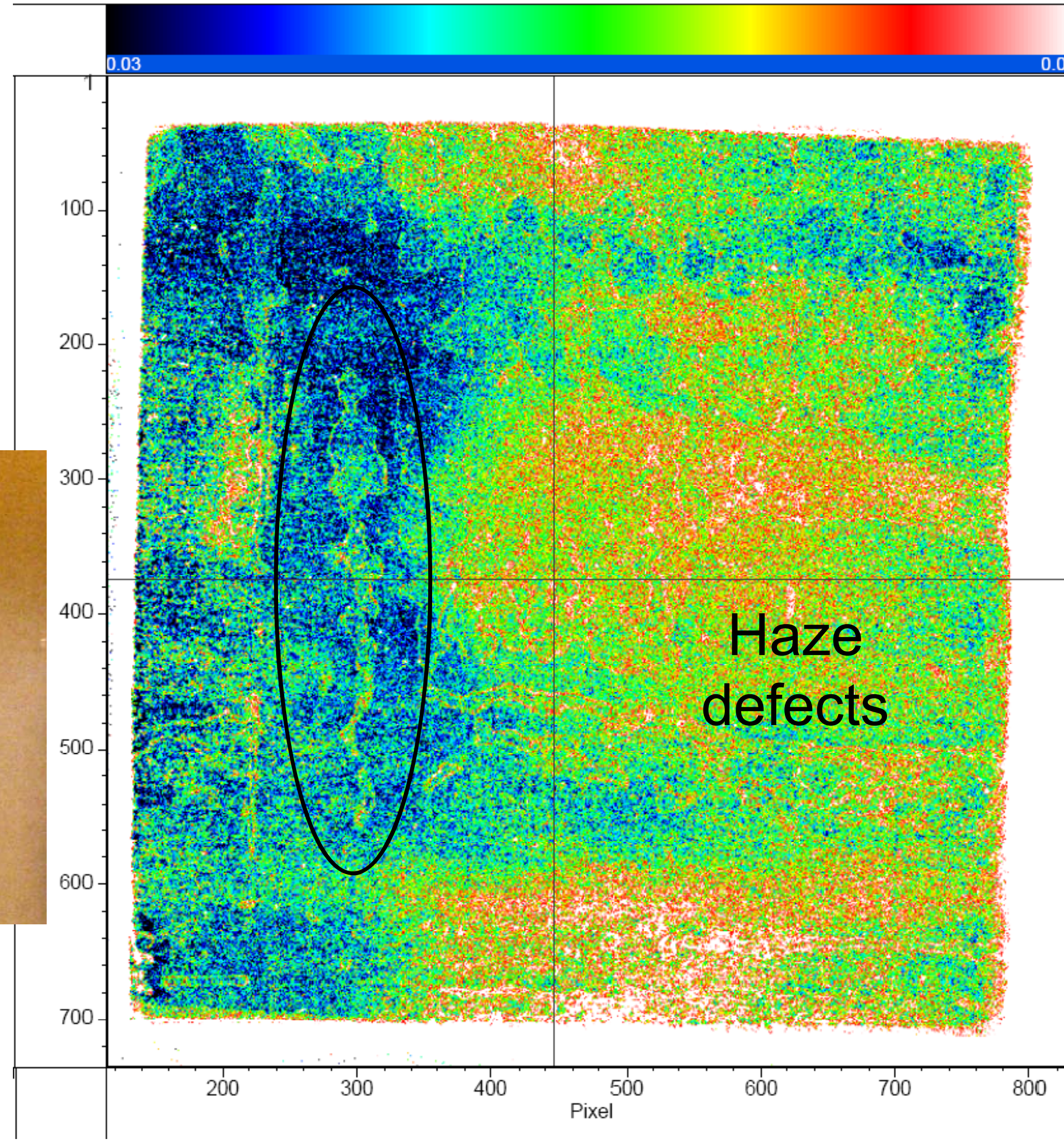
Date	Milestone/Deliverable	Complete
9/08	Initial database of performance data	100%
9/08	Demonstrate prototype thickness diagnostic	100%
12/08	Go/No-go decision on further segmented cell development	100%
6/09	Go/No-go on further development of thickness diagnostics	50%
9/09	Selection of initial non-thickness measurement(s) for further development	25%
9/09	Selection of initial critical defect(s) for further study	25%

Technical Accomplishments – Diagnostics Development

NREL Optical Device

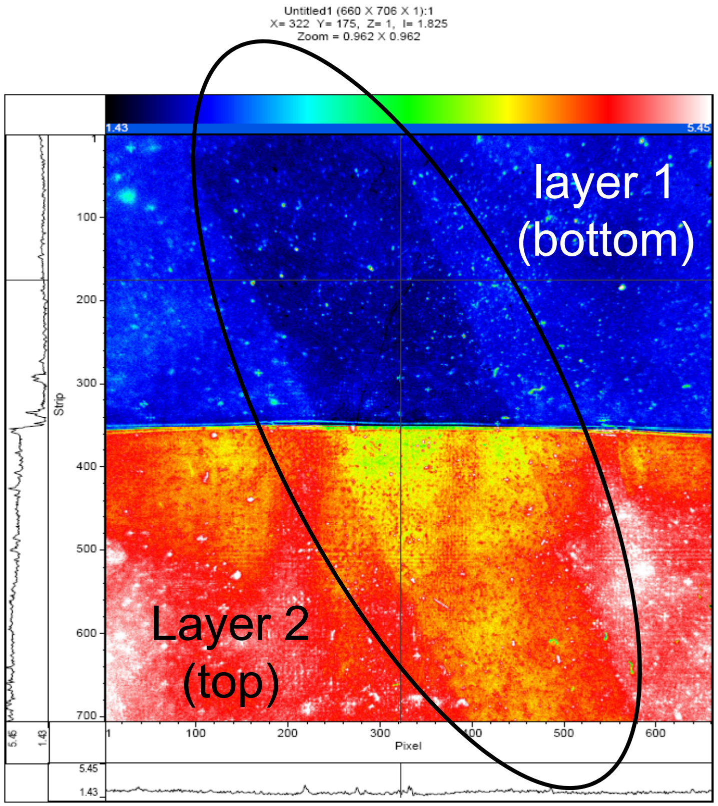


- **2D thickness measurement**
- **Identification of actual defects, not just statistical variation**

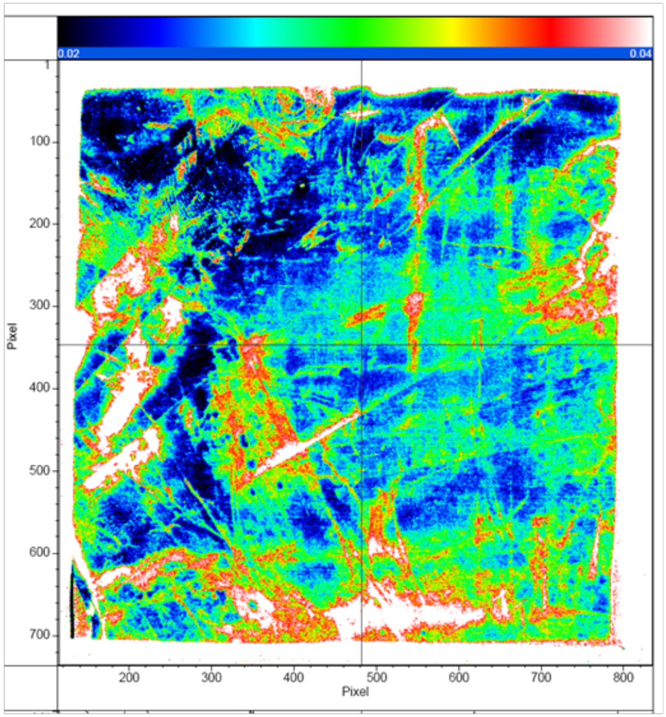


Technical Accomplishments – Diagnostics Development

NREL Optical Device



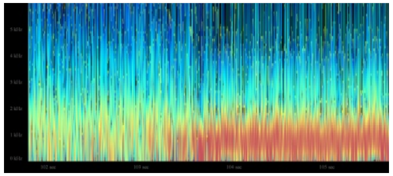
"Impression" defect in layer 1



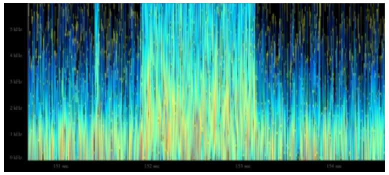
Scratches, creases and other defects

"Electron Gun"

Baseline



Pinhole



- Initial evaluation of technique
- Previously reported evaluations of x-ray, optical, capacitance, and laser techniques

Technical Accomplishments – Diagnostics Development

Summary

NREL Optical Device:

- 2D thickness measurement validated on different membranes, membranes with defects
- Optical characterization indicated potential for measurement of other properties/defects
- Initial experiments indicated potential to measure Pt

Commercial Diagnostics:

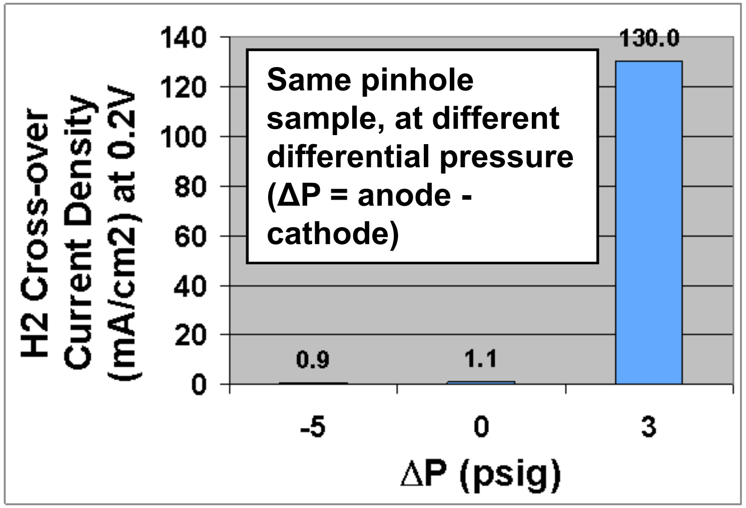
- Initial evaluation of Electron Gun diagnostic for defect identification
  - Evaluation of other techniques previously reported

Key Points

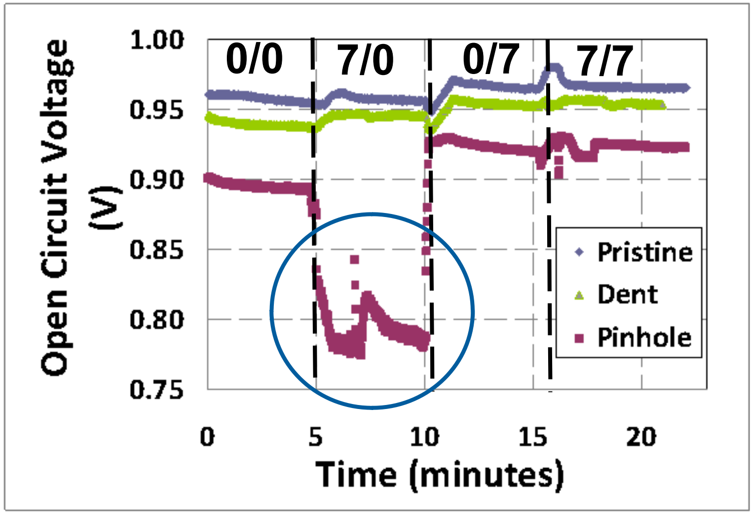
- Concentrating on capabilities not available in commercial devices
- Establishing diagnostic development platform for further exploration of NREL device
- Progressed from "idea" to demonstration of NREL diagnostic (off-line) since 2008 AMR

Technical Accomplishments – Test Method Development (Membrane Defects)

Hydrogen Cross-over (H_2/N_2)

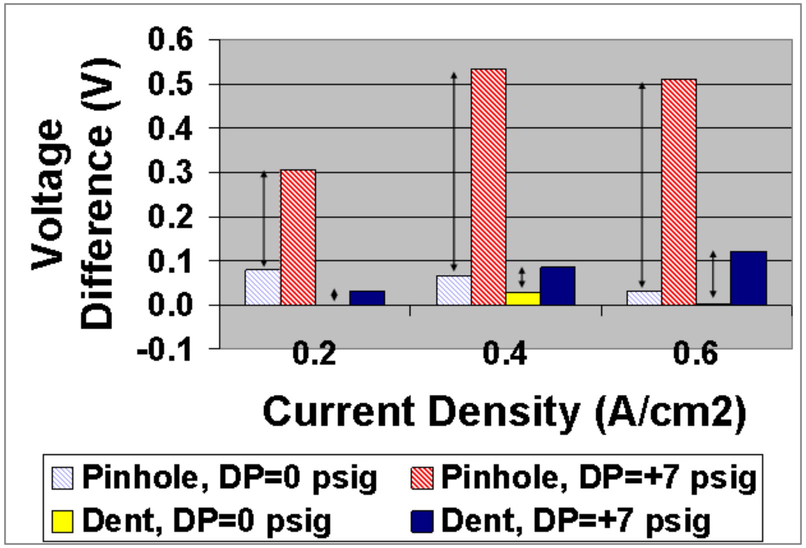


Open Circuit (H_2/Air)



Polarization

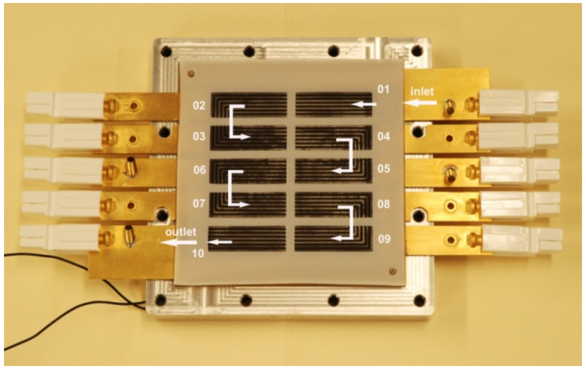
Performance comparison between Pristine MEA and MEA with either Pinhole or Dent (both ~ 1mm in dia.)



Higher pressure on anode enables detection and comparison of pinholes and thickness defects.

Technical Accomplishments – Test Method Development (Pinhole Defect)

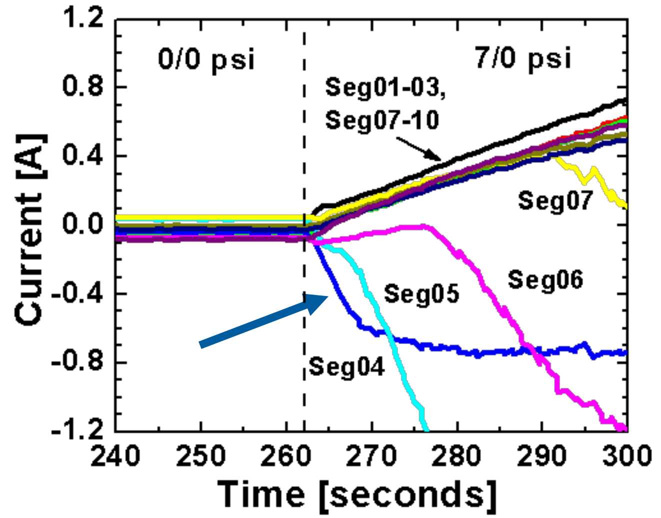
Segmented Cell



*** Defects in Seg04**

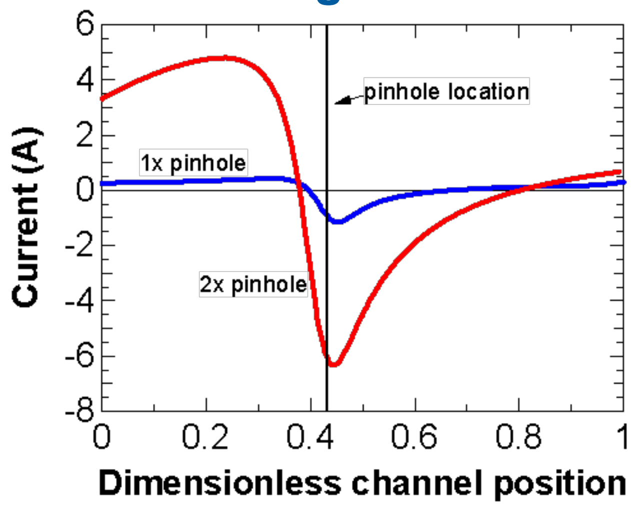
Open Circuit (H_2/Air)

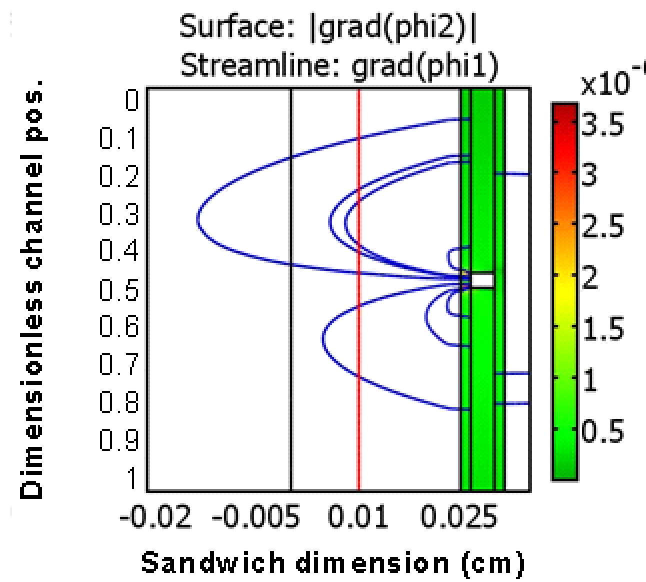
H_2 cross-over through pinhole (~ 0.1mm in dia.) in segment 4 causes "internal" currents in each segment. Sum of segment currents always equal to zero.



- **Segmented cell enables study of local effects**
- **Model corroborates "internal" current distribution**

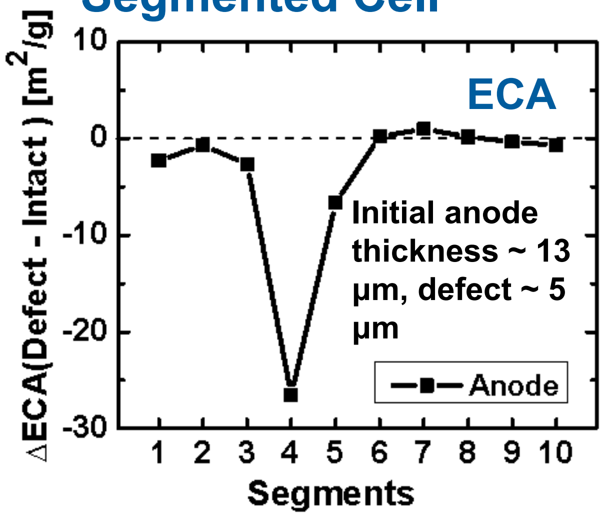
Modeling

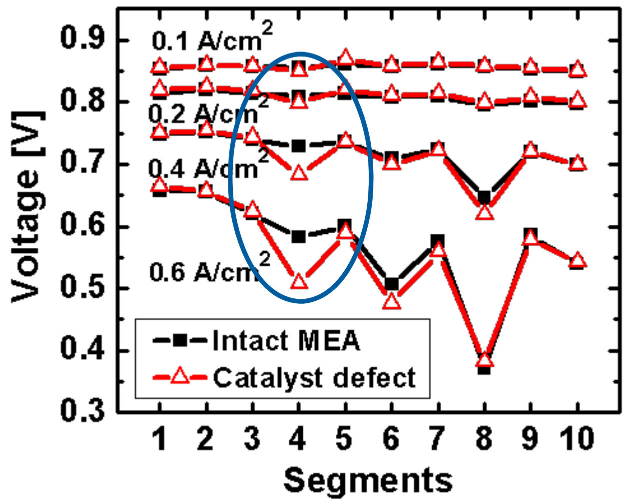




Technical Accomplishments – Test Method Development (Electrode Thickness Defect)

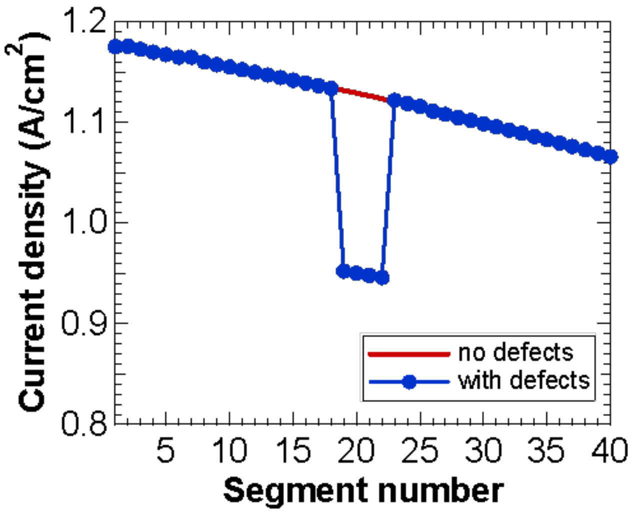
Segmented Cell

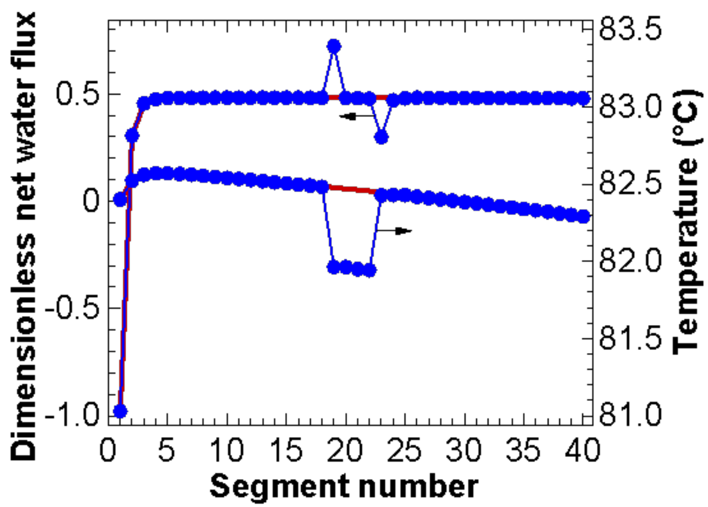




- **Measured and predicted local performance drop**
- **Model enables prediction of associated temperature and water effects**

Modeling





Model: electrode thickness defect over 10% of dimensionless flow channel

Technical Accomplishments – Test Method Development

Summary

Single Cell:

- Differential anode vs. cathode pressure during OCV, H_2 cross-over, and polarization tests enable characterization and differentiation between membrane defects

Segmented Cell:

- Demonstrated the feasibility to detect, locate, and characterize MEA defects
  - Pinholes, electrode thin spots, GDL thickness, PTFE loading, and MPL voids
- System design enables
  - Detailed diagnostics for each segment
  - Internally consistent comparison between segments with and without defects

Modeling:

- Qualitatively explains experimental findings
- Enables examination of experimental designs and defect thresholds

Key Points

- Different kinds of defects require different methodologies for evaluation
- We are making progress in developing these methodologies for critical defect types

Future Work

Diagnostics

- Validate 2D thickness imaging results and future development focus with industry partners (FY09)
- Explore wide range of material properties with NREL diagnostic (FY09/10)
  - Initial focus on Pt content
- Evaluate commercially available diagnostics (ongoing)
- Install web-line and begin to validate diagnostics (FY09/10)
  - Final validations with industry partners (FY10)

Defect Analysis and Modeling

- Establish test methodology for each critical defect type (FY09/10)
- Begin durability testing and modeling (FY09)
- Establish threshold values for critical defects using models and experiments (FY10)
- Optimize segmented cell design and methods for project objectives (FY09/10)
- Refine and extend LBNL model capabilities to address project needs-e.g., durability, transient effects (FY09/10)

Continue to be responsive to MEA manufacturers and system integrators
Support DOE cost-shared programs (RPI, Ballard)

Summary

- Demonstrated feasibility of 2D thickness imaging for membranes
- Progressed in establishing test methodologies to best measure the effects of:
  - Membrane thin spots/pinholes
  - Electrode thickness
  - GDL thickness, Teflon® content, and MPL voids
- Verified feasibility of segmented cell for obtaining spatially resolved data on effects of defects
- Utilized modeling to help explain experimental results
- Continued to expand relationships with industry