NREL National Renewable Energy Laboratory
Innovation for Our Energy Future

Fuel Cell MEA Manufacturing R&D

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MN001

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Overview

Timeline

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

Budget (incl. LBNL)

Total project funding to date
- $4,001,000

Funding received in FY09
- $1,582,000 operating
- $290,000 capital

Funding received in FY10
- $730,000 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
DJW Technology

Relevance

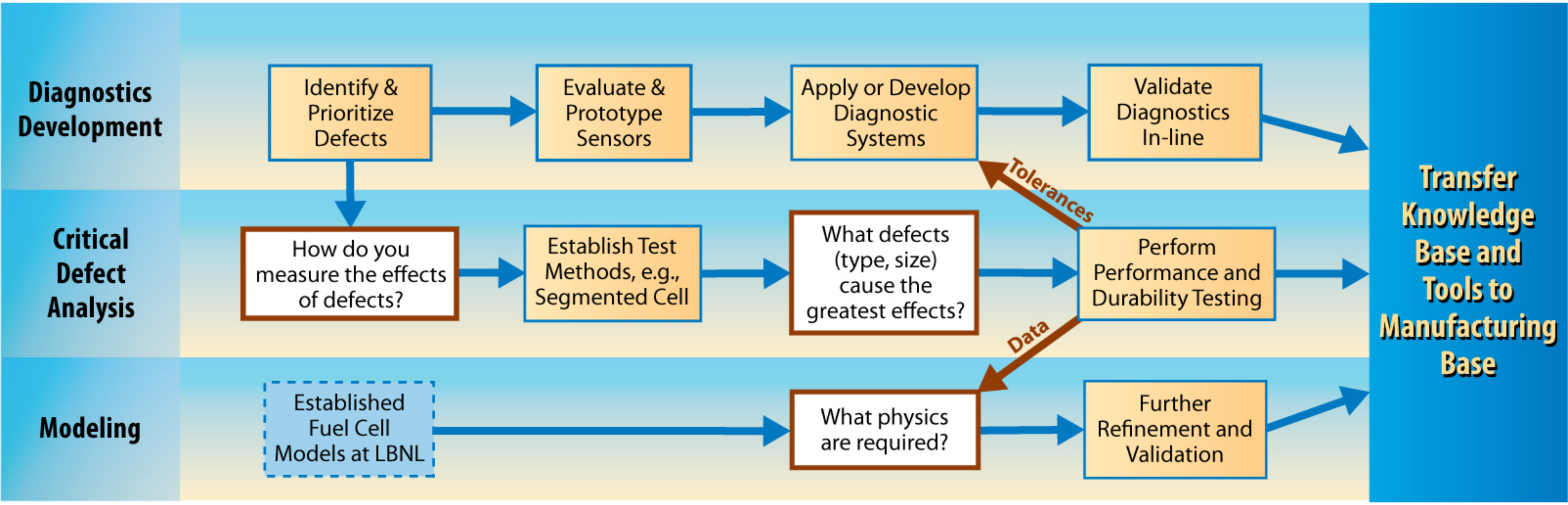
	MYPP Milestones
9/11	Develop prototype sensors for quality control of MEA manufacturing
9/12	Develop continuous in-line measurement of MEA fabrication
9/13	Demonstrate sensors in pilot-scale applications for manufacturing MEAs
9/13	Establish models to predict the effect of manufacturing variations on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

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

Collaborations

- Industry partners: **3M, Arkema, Ballard Material Products, BASF, Johnson-Matthey, W.L. Gore**
  - Guidance on critical defects and measurement needs
  - Material samples for testing and characterization
  - DOE cost-shared projects
- OEM discussions: **GM, Toyota**
- **NREL Hydrogen Center**: **Dinh, Bender, Aieta, Penev, Pivovar**
- **NREL National Center for Photovoltaics**: diagnostics development
- **LBNL**: model development
- **NIST:** project partner
- **Colorado School of Mines**: test method development and defect analysis
- **Hawaii Natural Energy Institute**: segmented cell development and defect analysis
- **Rensselaer Polytechnic Institute**: collaboration on cost-shared project
- **Proton Energy Systems**: SBIR for electrolyzer MEA QC
- **Georgia Tech**: collaboration on membrane casting process and defect detection

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 or distributions for each type of critical defect enables specification of resolution and accuracy required of diagnostic devices.

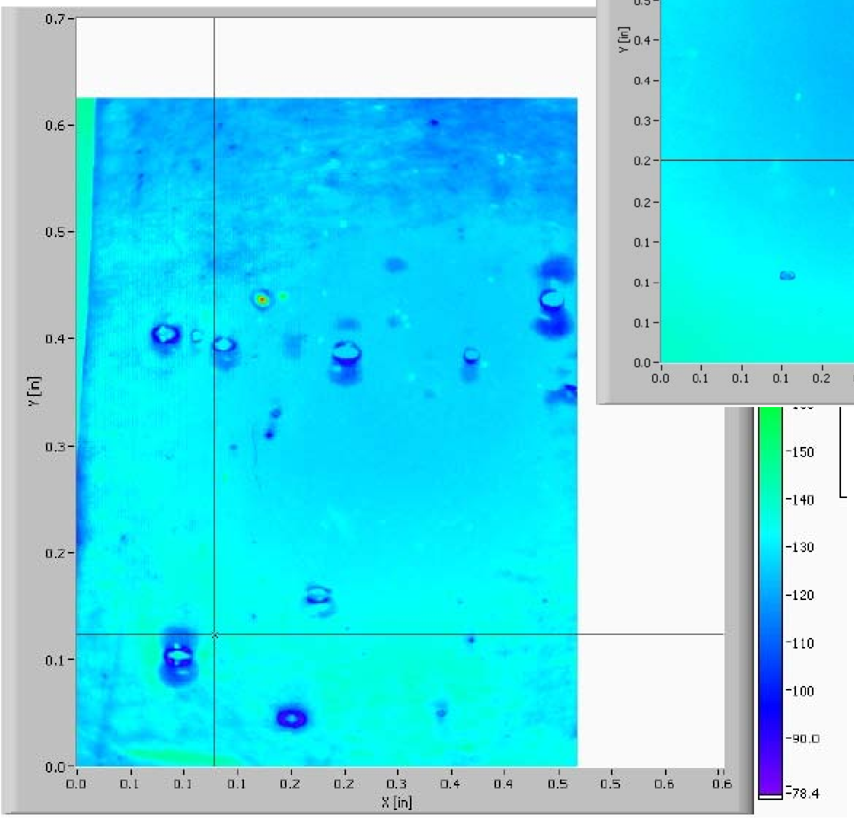
Project AOP Milestones

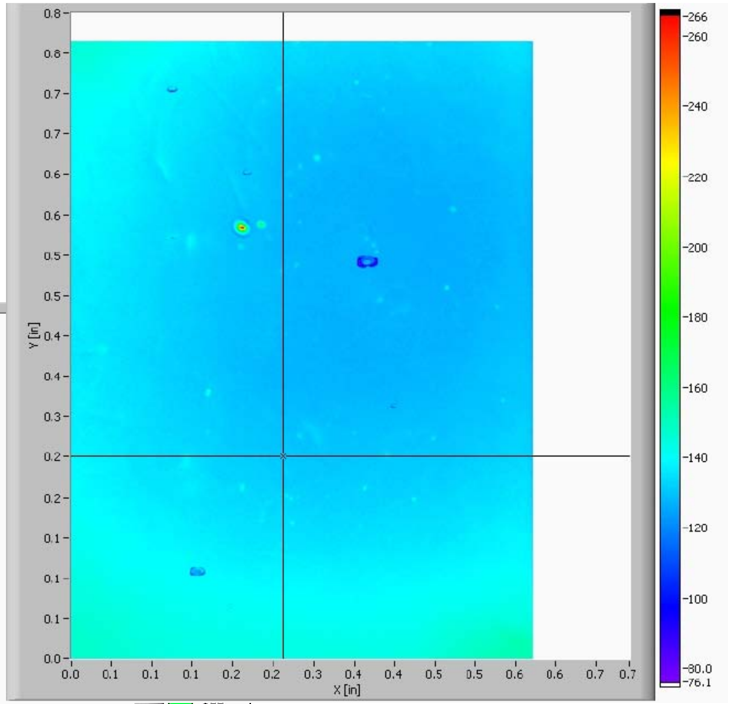
Date	Milestone/Deliverable	Complete
6/09	Go/No-go on further development of thickness diagnostics	100%
9/09	Selection of initial non-thickness measurement(s) for further development	100%
9/09	Selection of initial critical defect(s) for further study	100%
4/10	Research web-line commissioned	75%
7/10	In-line validation of XRF	10%
8/10	Bench-top validation of platinum diagnostic	80%
9/10	In-line validation of membrane diagnostic	10%

Technical Accomplishments
Diagnostics Development

NREL Optical Device – Membrane Diagnostic

- Working with industry partners to understand implementation details
- Expanding the scope of the membrane diagnostic development to other membrane types and applications



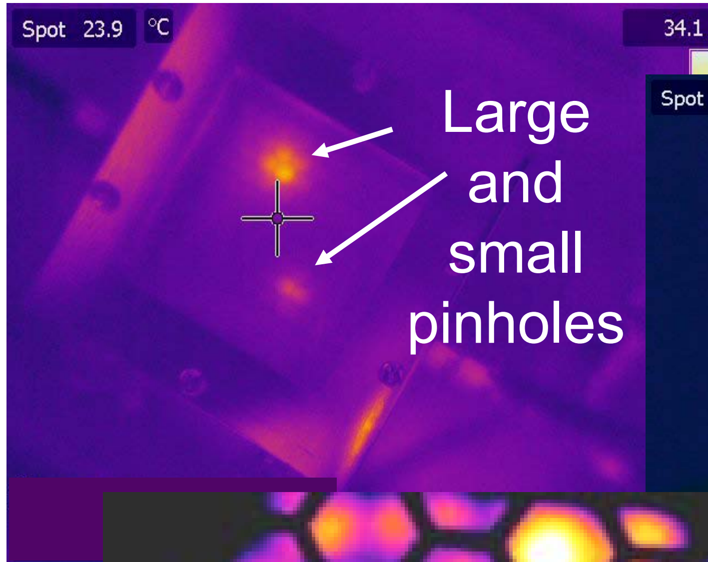


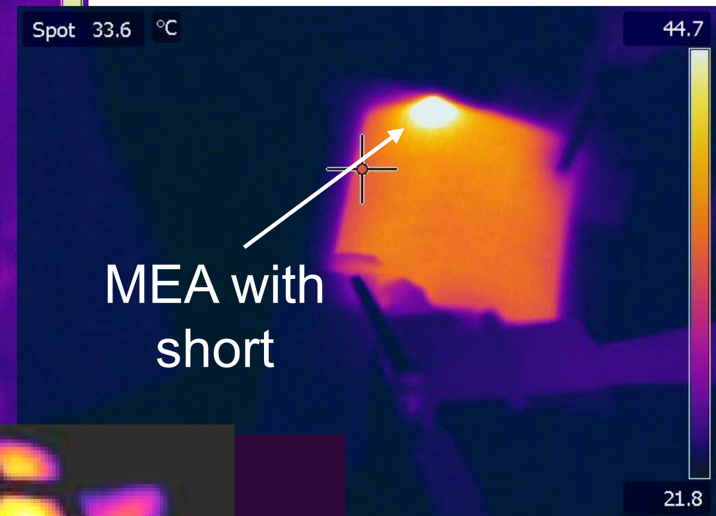
Alternative membranes supplied by industry partner with known as-manufactured defects

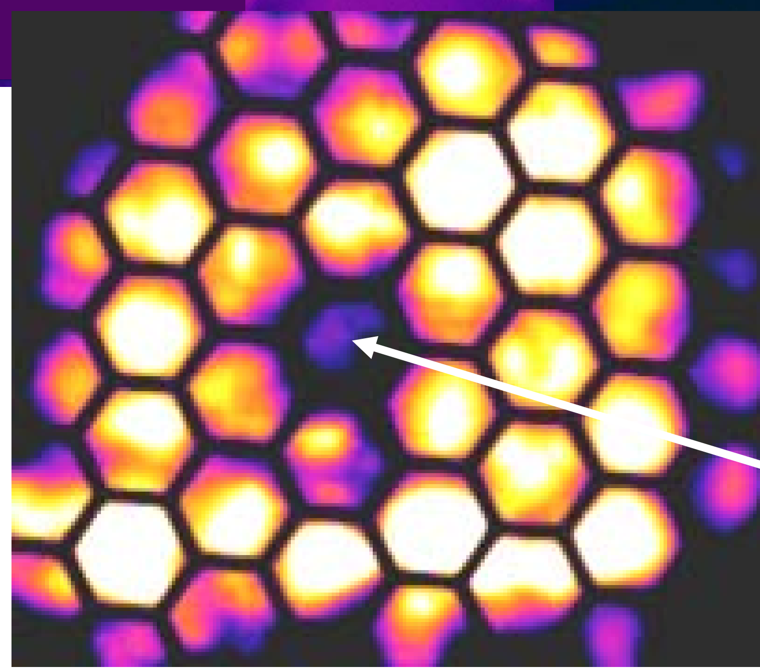
Technical Accomplishments
Diagnostics Development

NREL IR test stand

- Multi-functional
  - Characterization
  - Off-line QC
  - Potential for in-line QC
- Various methods of sample excitation
- Applications
  - Pinholes/defects
  - Thickness variation
  - Shorting
  - Leaks
  - Delamination
- Rapid detection: <1s

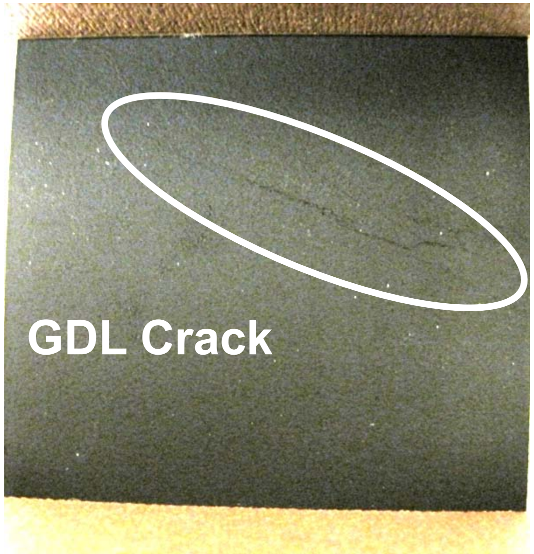


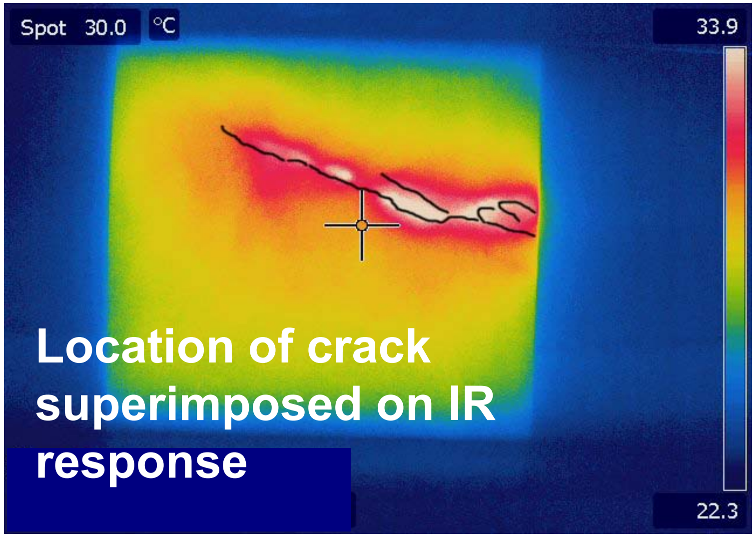


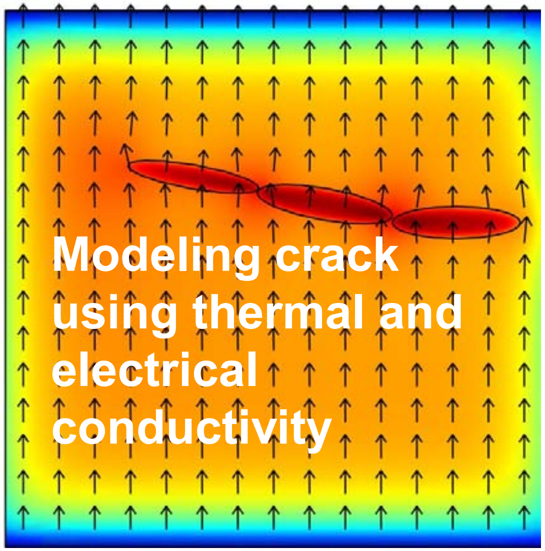


Electrode with thickness variation

Technical Accomplishments
Diagnostics Development







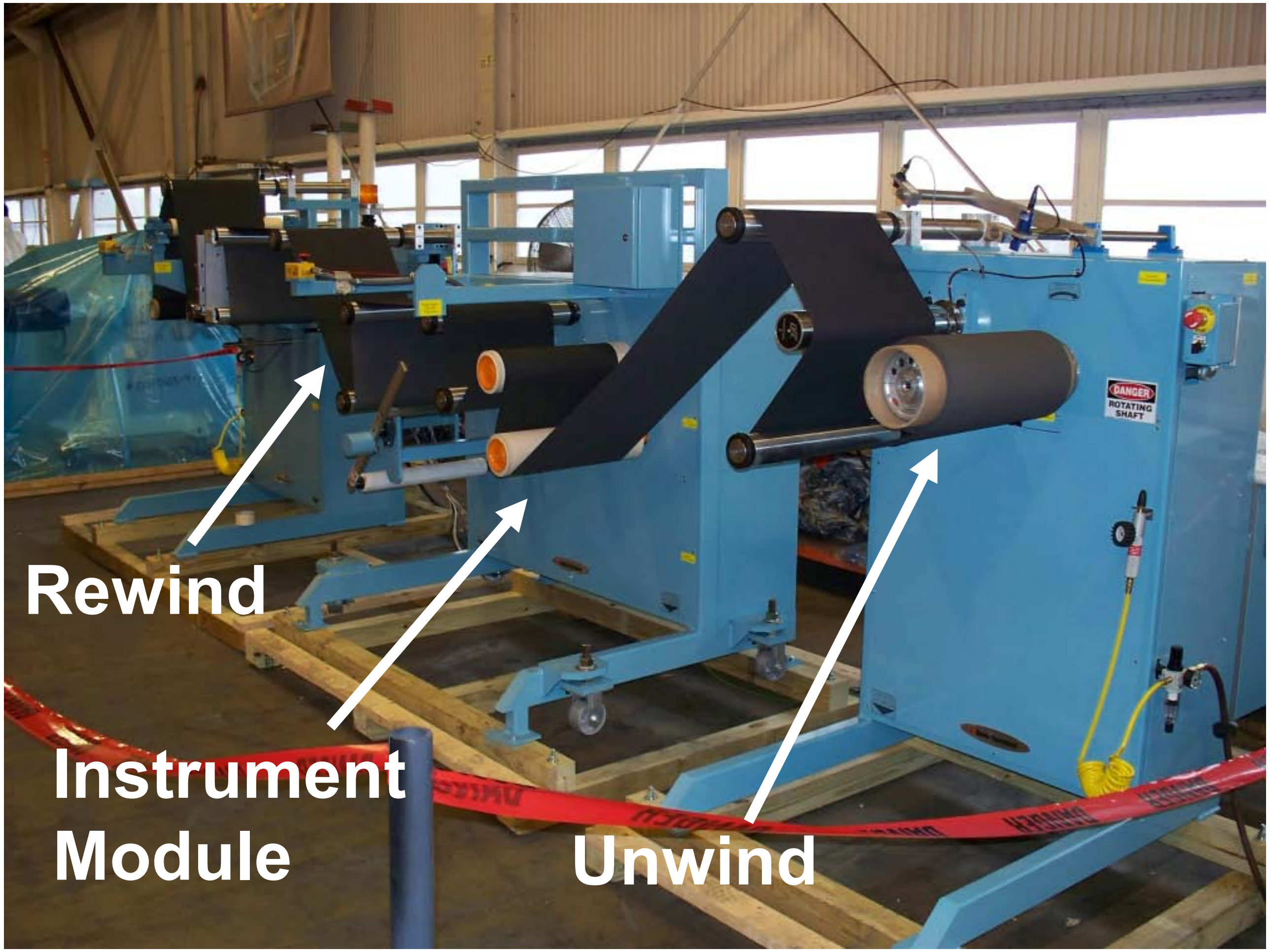
‘Case study’: GDL Defect

- Several cracks in MPL
- Excitation creates thermal response in <1s
- Detection of not visible defects demonstrated
- Modeling verifies and enhances understanding of IR response
- Modeling indicates correlation between temperature rise, crack location, and crack geometry

Technical Accomplishments
Diagnostics Development

NREL Research Web-line

- Closes gap between research and industry scale operations
- Use MEA component roll-goods from industry partners
- Mount diagnostics on instrument module
- Test diagnostics under different speed and tension conditions, with membrane and GDL based webs



Technical Accomplishments Diagnostics Development

Summary

Optical Device:

- Signed additional NDAs and held discussions with industry partners on further development of in-line QC system based on membrane thickness imaging
- Continue to assess the feasibility of measuring Pt content in electrodes

IR Test Stand:

- Proof of concept studies for membrane, GDL, and MEA defect/failure QC
- Test bed for in-line QC concepts

Research Web-line:

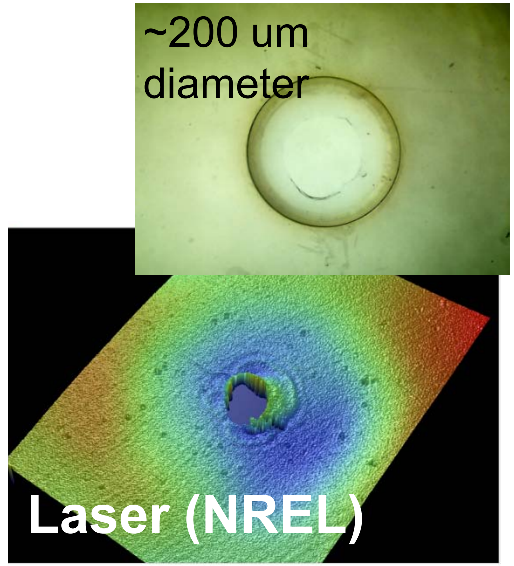
- Installed and operating
- Discussed in-line XRF with suppliers: off-the-shelf vs. development

Expanding studies to materials for applications other than low temperature PEMFC

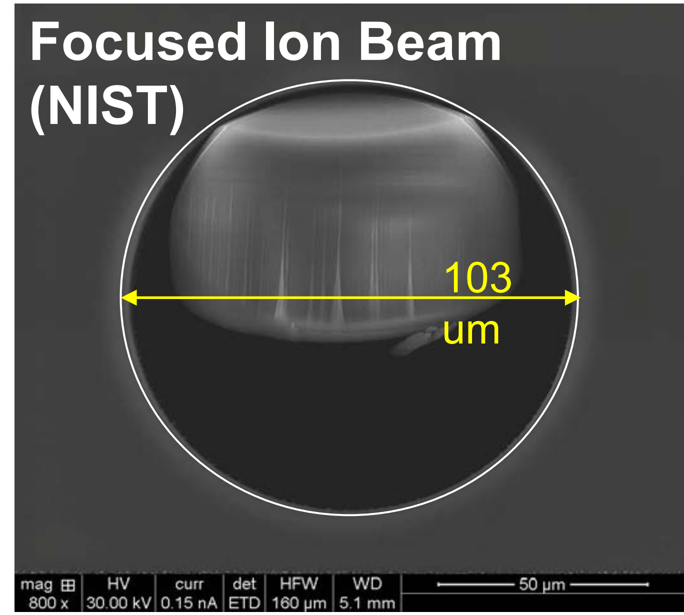
Technical Accomplishments
Test Method Development: Defect Fabrication

Membrane Defect Fabrication

- Objective: replication of ‘real’ defects
- New methods enable hole sizes <150 um
- Nd:YAG laser, Ga FIB

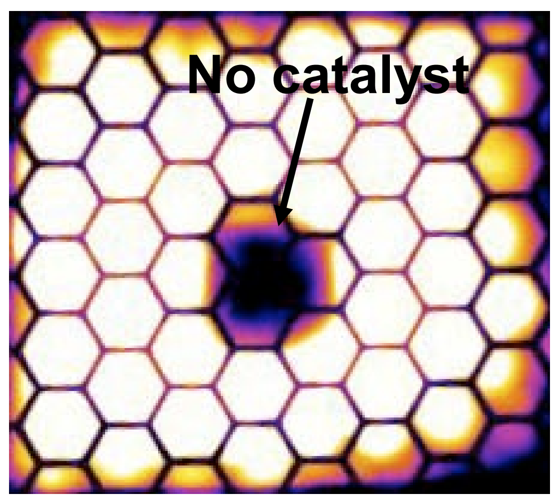


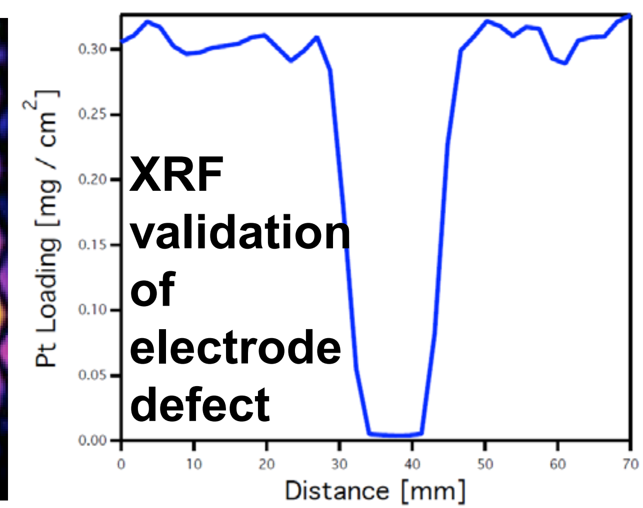
50 um hole



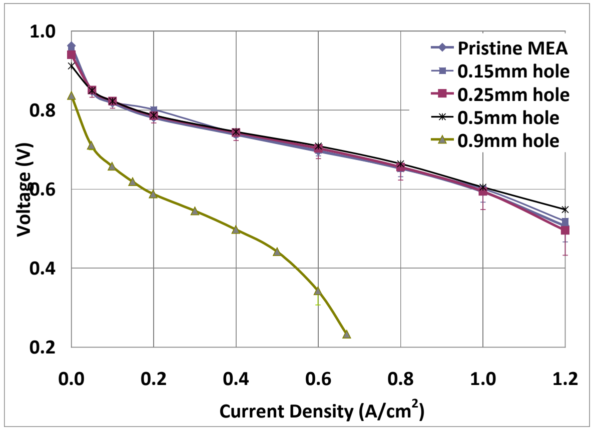
Electrode Defect Fabrication

- Ultrasonic spraying
- Creation of thin spots and areas of loading variation
- Size limitation under investigation

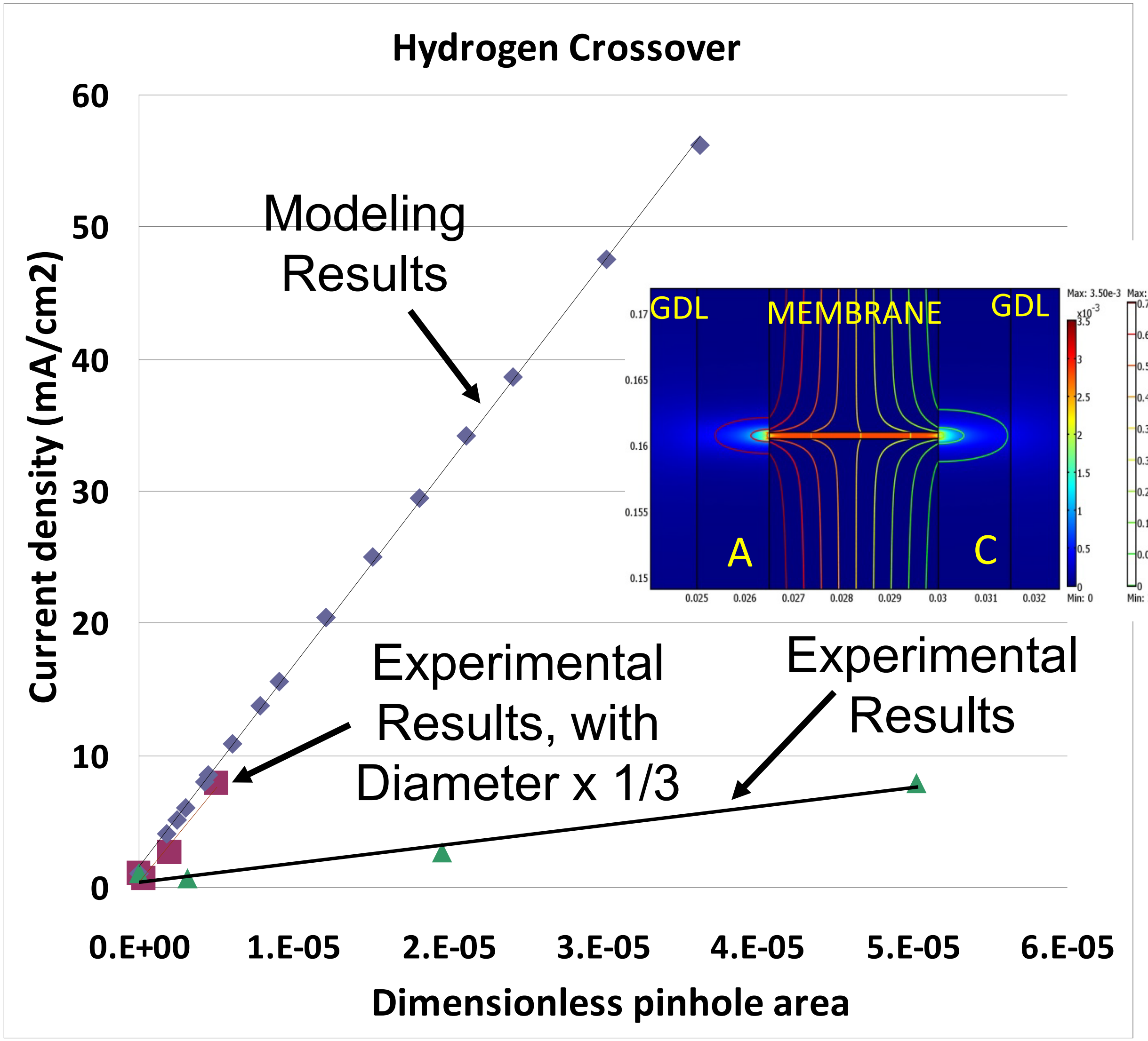




Technical Accomplishments
Test Method Development: Pinhole Defect



- Objective: determine threshold for pinholes
- Pol curves are insensitive to small pinholes
- H2 cross-over:
  - sensitive
  - enables study of threshold
- Model indicates importance of swelling



Technical Accomplishments
Test Method Development

Summary

- Developed and utilized multiple methods to detect and characterize defects
  - Beneficial for development of in-line diagnostics
- Successful fabrication of membrane defects down to 50 um diameter via laser and FIB method
- Ongoing threshold studies for membrane pinhole indicate swelling may control threshold size
  - Single cell testing and modeling
  - Swelling experiments formulated
- Successful fabrication of electrode defects via ultrasonic spraying
  - Thin spots/uncoated areas
  - Catalyst non-uniformity

Future Work

Diagnostics

- Work with industry partners to transition membrane diagnostic from technique to system; validate on web-line
- Begin diagnostic validation on web-line
- Complete assessment of areal platinum content diagnostic technique
- Develop IR-based QC concepts and validate with industry partners
- Explore other MEA material properties with NREL diagnostic
- Evaluate commercially available diagnostics (ongoing)

Defect Analysis and Modeling

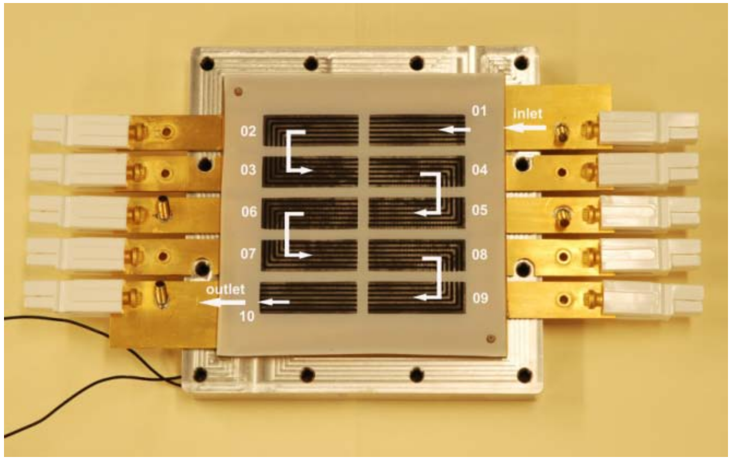
- Study effects of electrode defects
- Develop techniques to replicate other electrode defects
- Study growth rates of defects
- Establish threshold values for critical defects using models and experiments
- Continue segmented cell development and studies
  - Install (3M design) high-spatial resolution system at NREL
  - Optimize segmented cell hardware for defect studies in collaboration with HNEI
- Refine and extend LBNL model capabilities to address project needs
  - Growth rates and transient effects
  - Extend modeling to IR diagnostics development

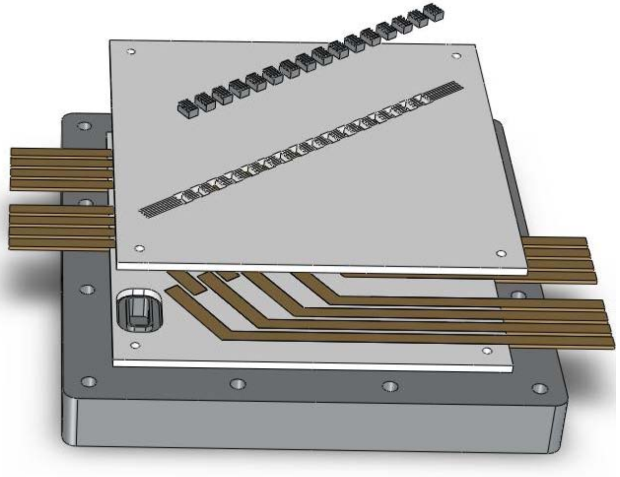
Summary

- Project continues to support MYPP milestones that enable transition to high-volume production of MEAs and MEA components
- Dual approach of developing diagnostics and contributing to the understanding of how defects impact fuel cell functionality
- Working with industry partners on how to implement the optical diagnostic for in-line membrane thickness imaging
- Installed and commissioned research web-line for in-line validation of diagnostics
- Developed IR-based platform to address low volume (off-line) and potentially high volume (in-line) QC needs
- Increased understanding of membrane pinhole threshold value, with key insights from LBNL model
- Expanded capabilities to fabricate and characterize membrane and electrode defects for threshold studies
- Expanded pool of industry partnerships
  - Program partnership with NIST
  - Detailed discussions with automotive OEMs
- Expanded efforts to include materials for applications other than low-temperature PEMFC

Supplemental Slides

Additional Information: Optimizing Segmented Cell for Defect Analysis





- Segmented cell system was shown to be a very valuable tool to study the effect of defects
- Lessons learned with current segmented cell system are applied to optimize segmented cell system for defect analysis
- Path forward includes improvement of defect sensitivity by reduction of segment area from 7.6 to 0.25 cm^2
- Future design envisioned that allows the study of the growth rates of multiple defects simultaneously