National Renewable Energy Laboratory
Innovation for Our Energy Future

A Study of the Effects of Polymer Electrolyte Membrane Thickness Defects on Cell Performance

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Project Background

- For high volume manufacturing, membrane electrode assemblies (MEA) components will be made using continuous processes, such as web-lines
- At high processing rates (100-1000 ft/min or more) and wide widths (24”-72” or more), in-line quality control is required

Courtesy Ballard Power Systems

Project Background

- DOE's automotive fuel cell system cost targets are based on a projection of 500,000 units/year[1]
- The supplier base needs high speed manufacturing methods – and quality control methods to support them – to achieve these volumes
- To support these cross-cutting needs, NREL, with DOE support, initiated a Membrane Electrode Assembly (MEA) Manufacturing R&D project in 4Q FY07

1 DOE Hydrogen, Fuel Cells & Infrastructure Technologies Program, Multi-Year Research, Development and Demonstration Plan, 2007

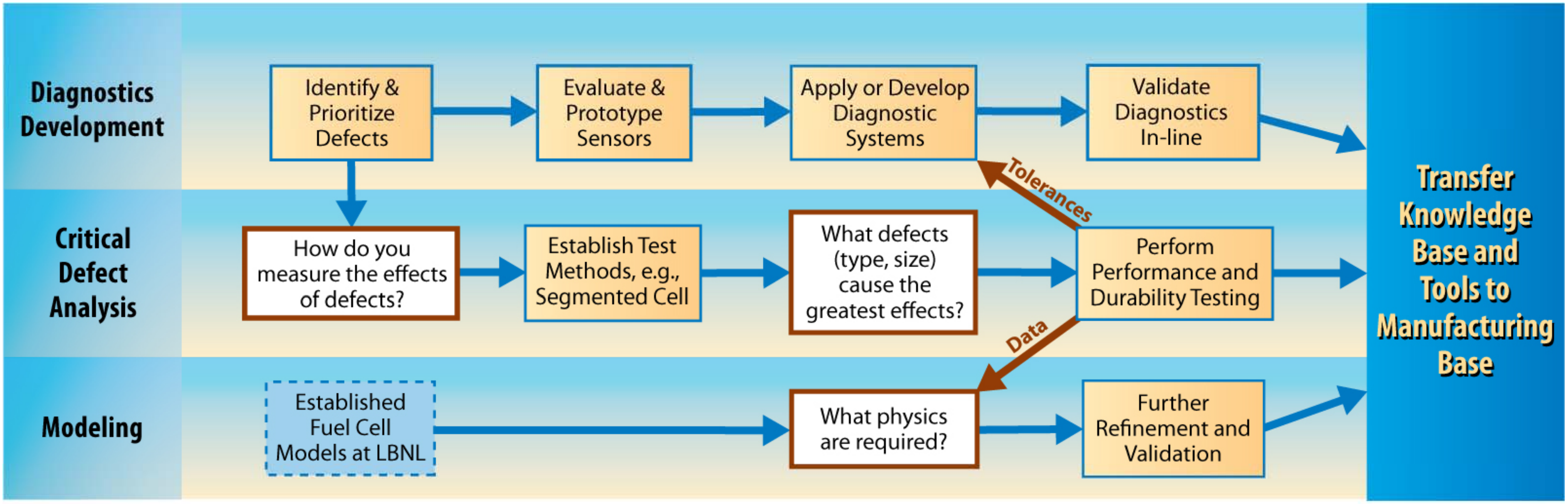
Project Tasks

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, DuPont, W.L. Gore, Johnson-Matthey**
  - Provide guidance on critical defects and measurement needs
  - Provide material samples for testing and characterization with diagnostics
  - DOE cost-shared projects
- **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

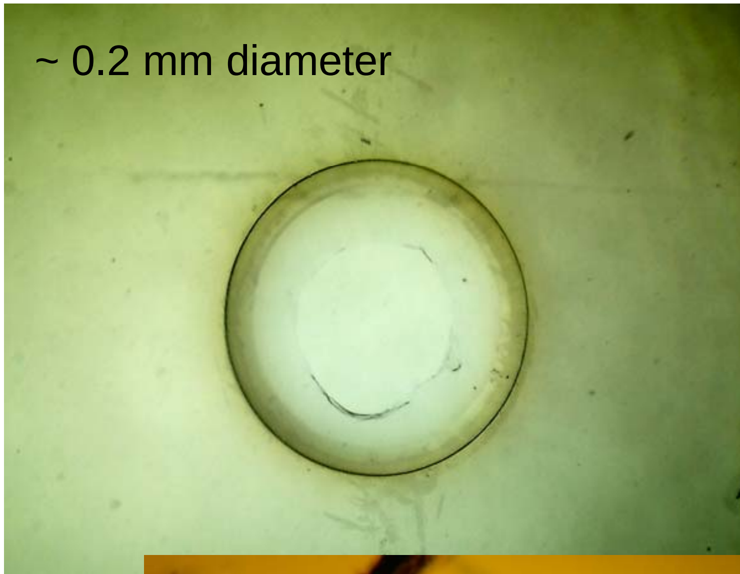
Approach

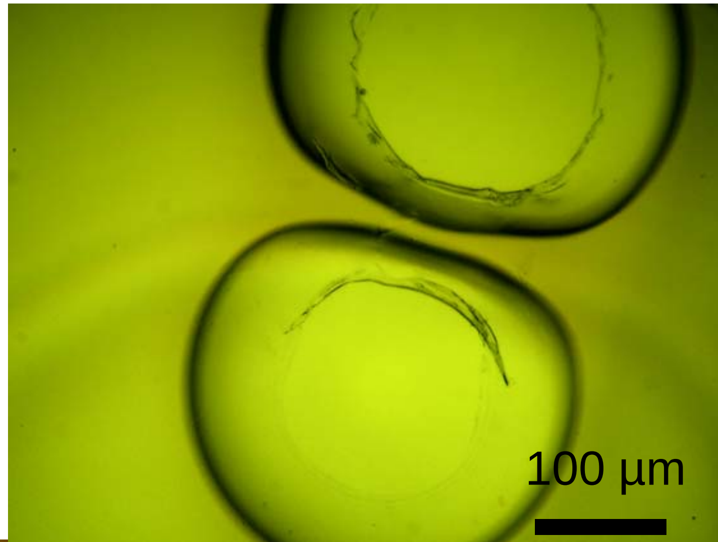


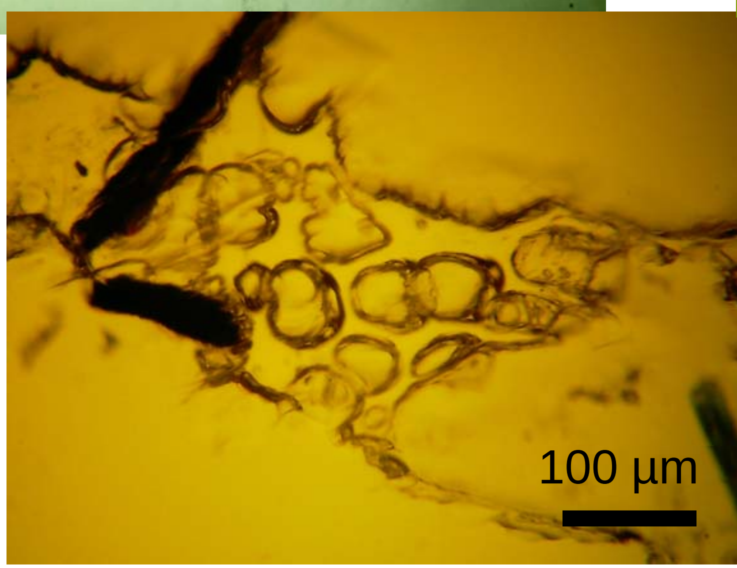
KEY: Evaluation of critical defect size and type provides information for component tolerances. This enables appropriate accuracies and measurement rates to be understood in the final development of diagnostic systems.

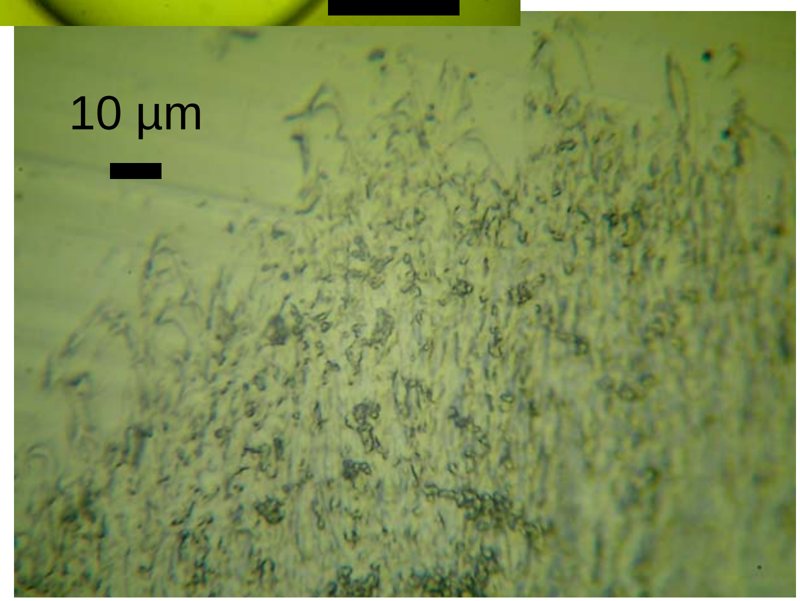
Establishing threshold sizes/extents for each type of critical defect enables specification of accuracy and precision required of diagnostic devices.

Actual Membrane Defects

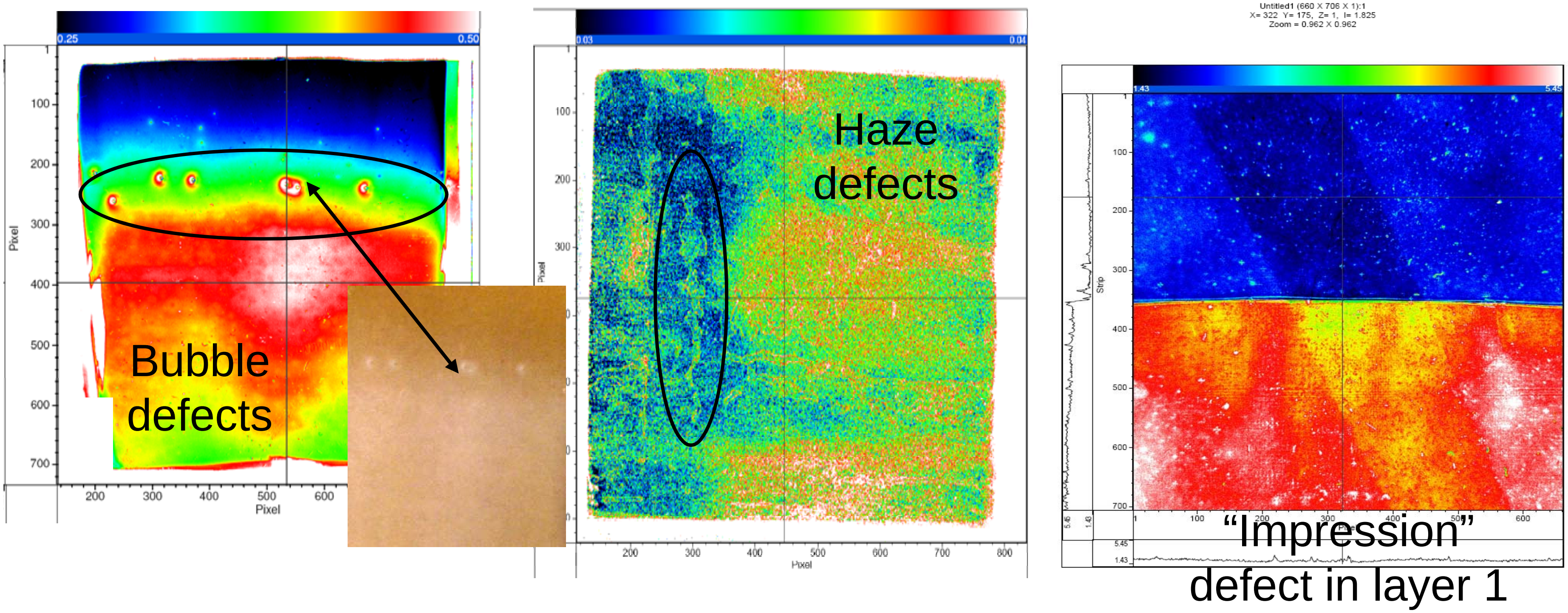








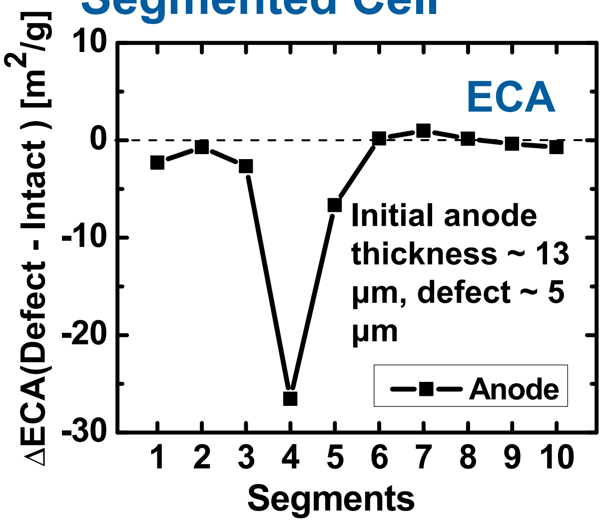
Diagnostics Development - NREL Optical Device

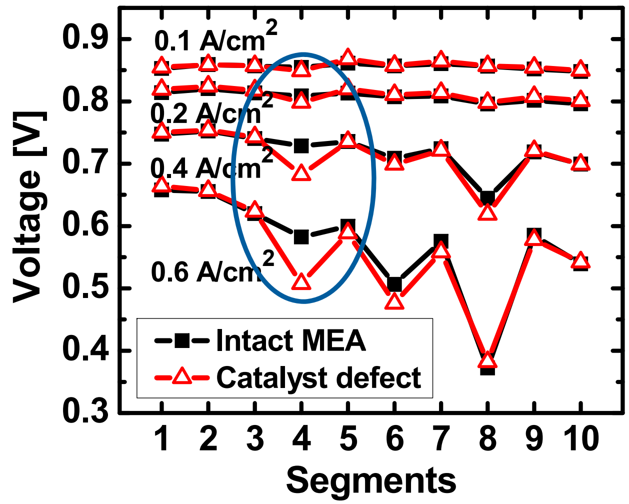


- Developed and currently used for in-line measurement of PV cells
- Data acquisition and processing already exists
- Modifying technique for materials/properties for fuel cell MEA components
- Initial focus: membrane thickness imaging and defect identification
- Expected applicability: platinum, porosity, surface structure, others
- 2D thickness measurement
- Identification of actual defects, not just statistical variation

Electrode Thickness Defect: Segmented Cell and Modeling

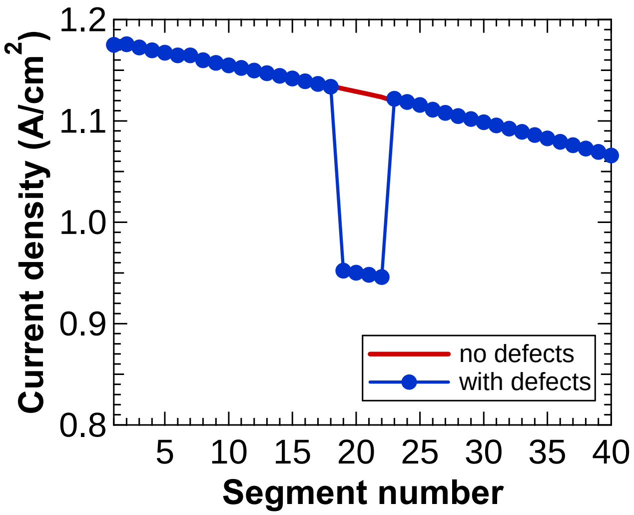
Segmented Cell

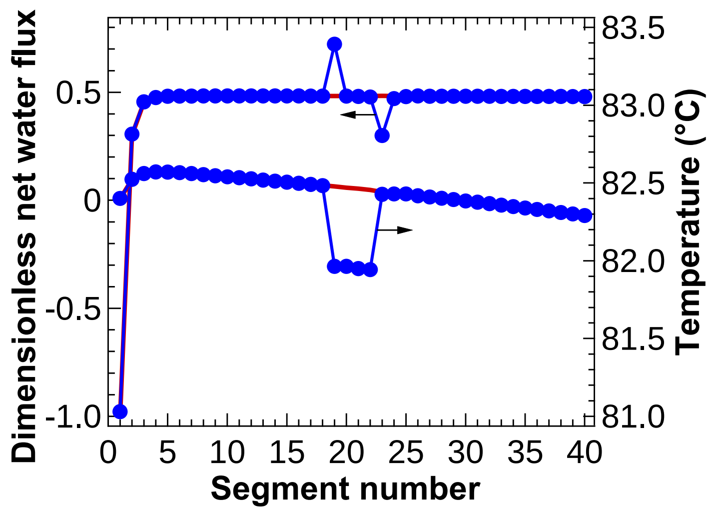




- Measured and predicted local performance drop
- Model enables prediction of associated temperature and water effects

Modeling





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

Focus of this presentation

1. Effect of pinhole size
2. Effect of pinhole location relative to flow field

Experimental Approach

Develop methods to simulate as-manufactured defects of realistic size

- Create "designed" defects (pinholes) in membranes using laser techniques
- Prepare MEAs from the modified membranes and commercially available GDEs for fuel cell testing

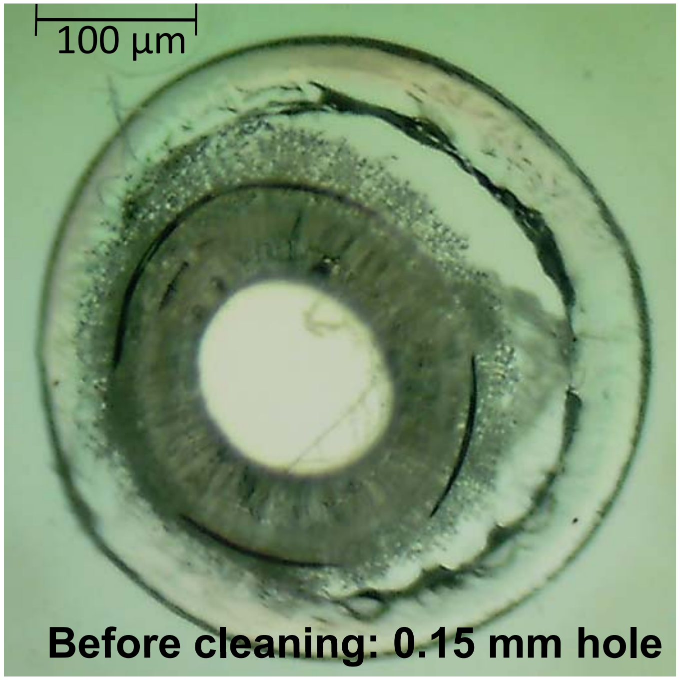
Establish test methodologies to understand the effects of defects on fuel cell performance

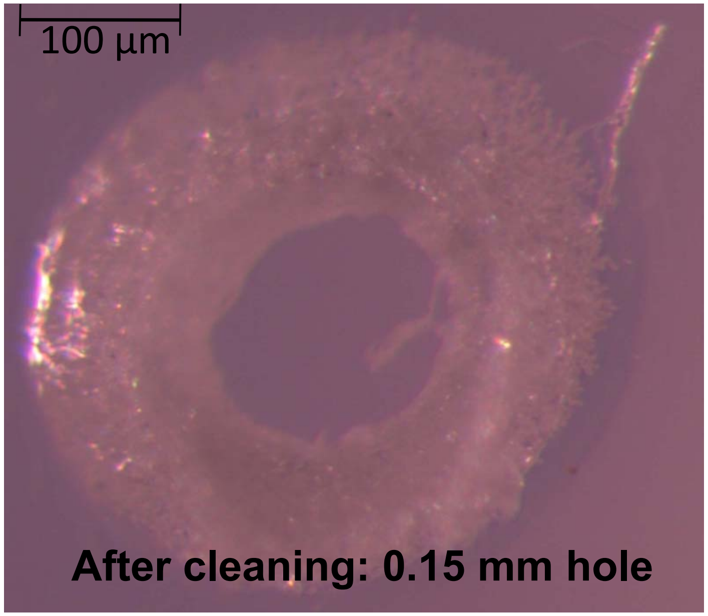
- Differential pressure performance
- Differential open circuit voltage (OCV)
- Differential hydrogen cross-over (H_2 XO)

Determine "critical" defect size

- To establish appropriate specifications for diagnostics that will identify and measure these defects during continuous processing

Creating pinholes in membranes

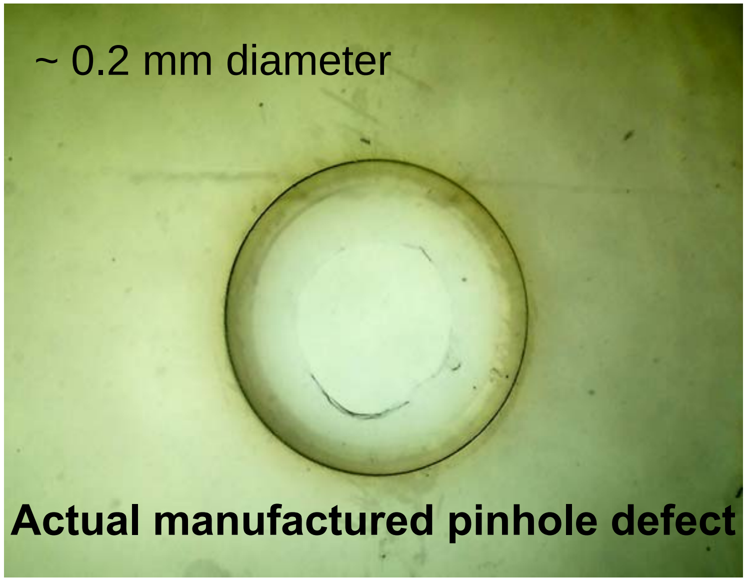




Different sized pinholes were constructed using a 30W Epilog Radius CO_2 CNC Laser Cutter

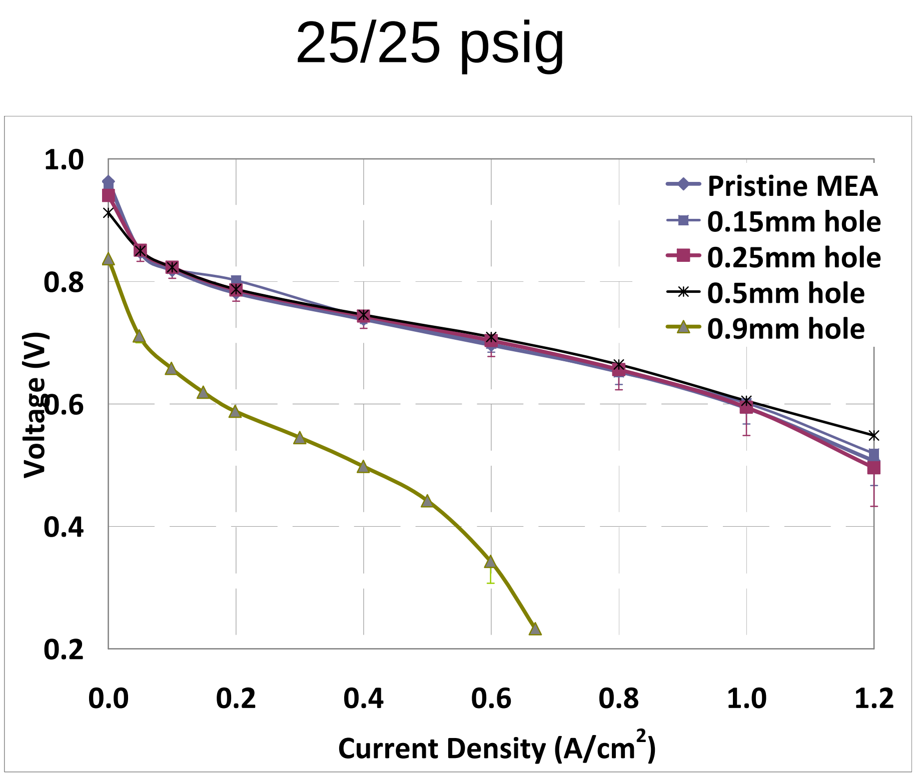
Cutting conditions: 7% power at 30% speed and 100% frequency rate

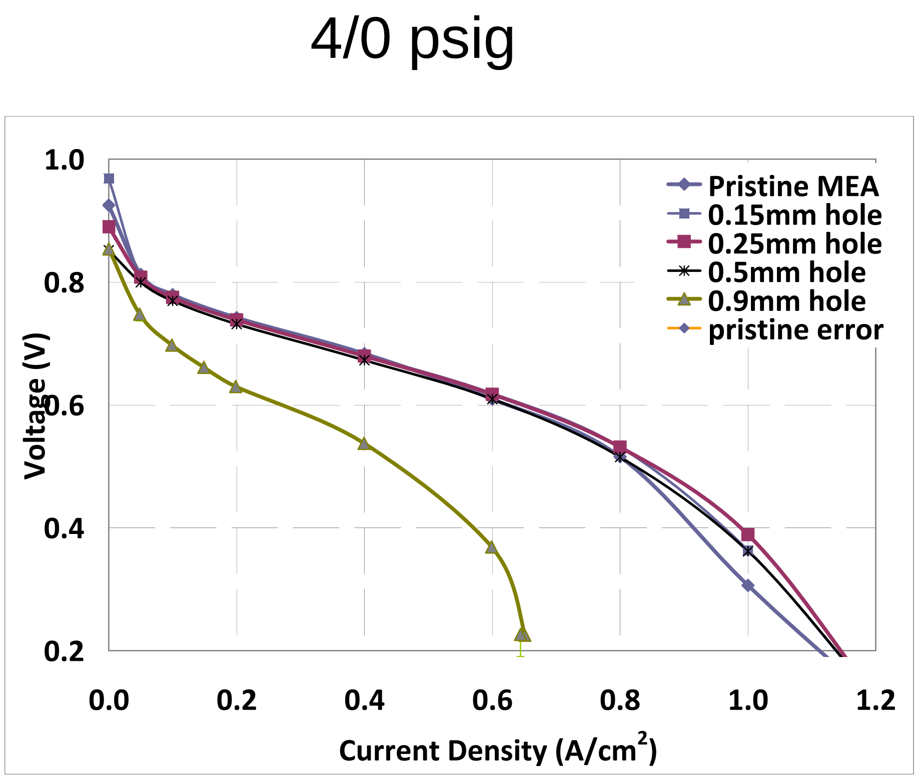
0.15 mm hole is the lower limit of the technique.



Effect of membrane pinhole size

Effects of small defects not easily observed using performance curves.

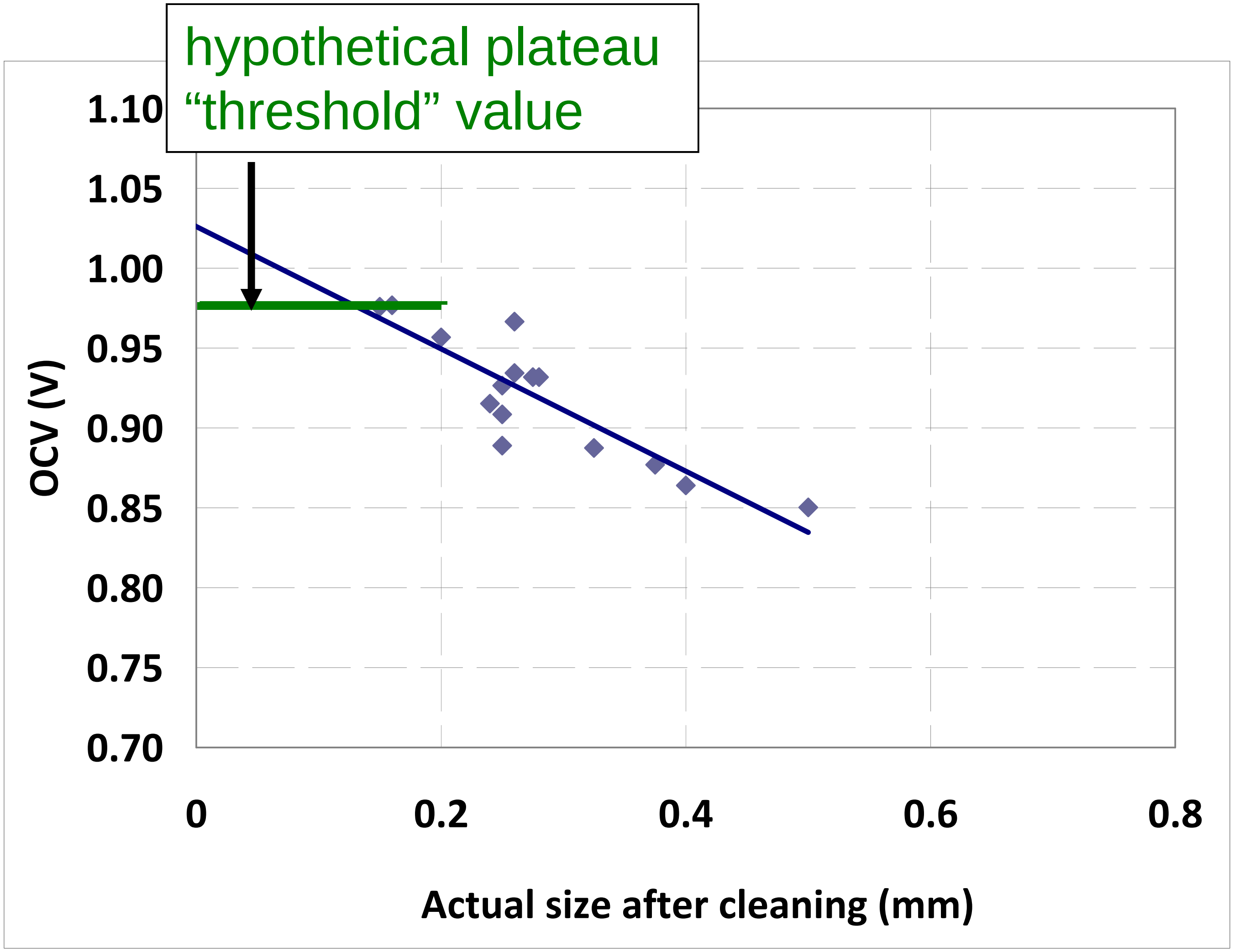




T_{cell} = 80°C, 1.2 stoich H_2 and 1.5 stoich air, 100% relative humidity

Effect of pinhole size – OCV

OCV method can measure the effect of pinholes less than 0.5 mm.



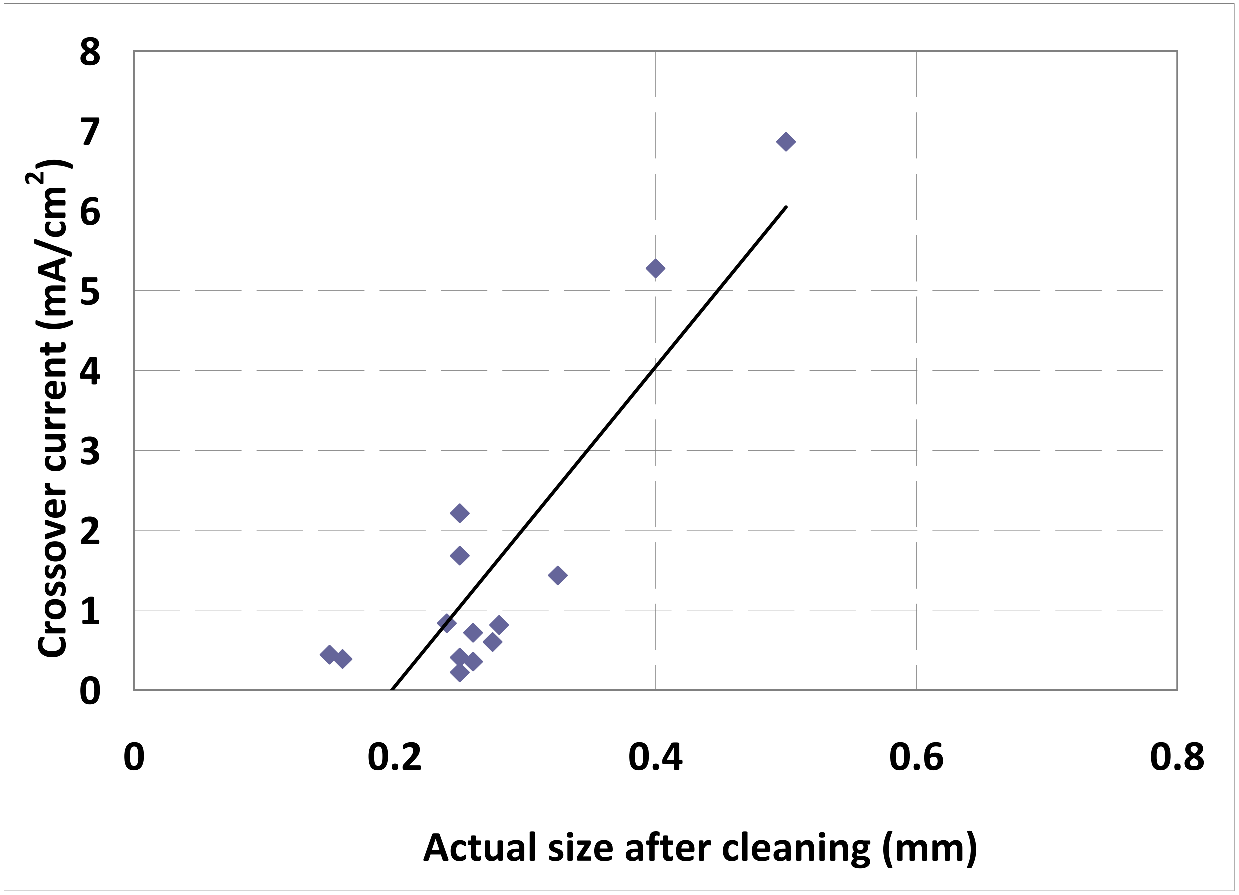
OCV decreases linearly with pinhole size.

80°C, 7/7 psig back pressure and 500/500 sccm hydrogen/air on the anode/cathode

Effect of pinhole size – H_2 XO

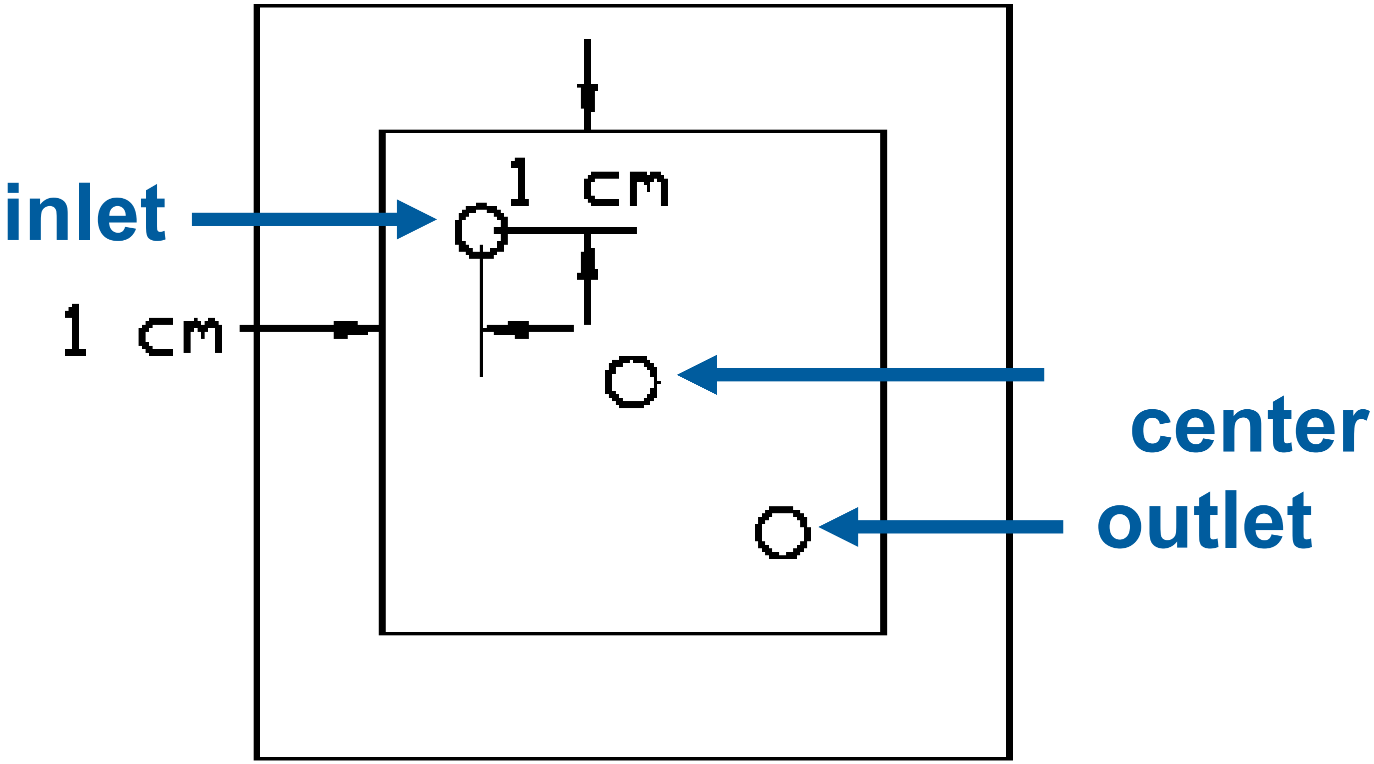
H_2 crossover method can measure the effect of pinholes.

H_2 crossover current density increases linearly with pinhole size.



0.4 V; 80°C; 500/500 sccm of H_2/N_2 on anode/cathode

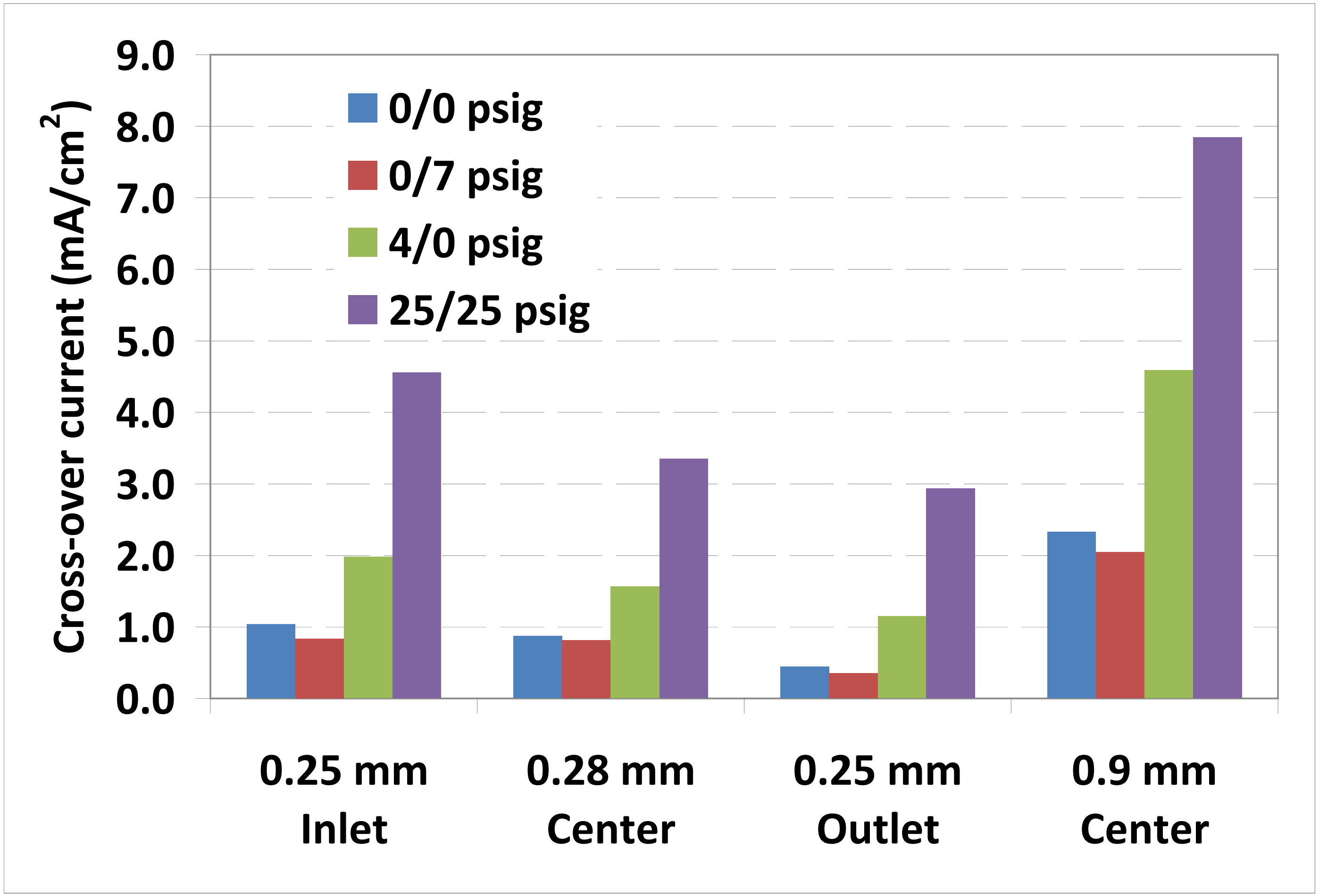
Effect of pinhole location



MEA Active area = 25 cm^2

Effect of pinhole location

Pinholes near the flow field inlet can have the most effect on fuel cell performance.



Hydrogen crossover data obtained at 0.4 V; 80°C; 500/500 sccm of H_2/N_2 on anode/cathode

Conclusions

- Pinholes of reasonably repeatable size were able to be produced, down to ca. 0.15 mm diameter, using the Epilog Radius laser system
- While it is difficult to ascertain the effects of pinholes using performance curves, OCV and hydrogen crossover can be used, in conjunction with differential pressure operating conditions, to understand and quantify effects
- The effects of pinhole size are seen to correlate relatively linearly with OCV and hydrogen crossover
- While performance curves do not show an impact of pinhole location, hydrogen crossover does appear to indicate that the detrimental effect of the pinhole is reduced if it is located near the flow field outlet

Future Work

Establish a method to make holes/defects at smaller than 0.15mm to resolve the plateau/threshold

Extend these studies to thin spots in membranes (as opposed to pinholes)

Study other critical types of defects

Effect of defects on durability

Acknowledgements

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Jason Roadman at the University of Colorado, Boulder, for assistance in using the laser system.

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