DOE Hydrogen Program

Fuel Cell MEA Manufacturing R&D

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Project ID # MF2

Berkeley Lab

Overview

Timeline

- Start: July, 2007
- End: December, 2009
- 25% complete

Budget

- Total project funding
  - $2,585,000 (AOP project)
- Funding received in FY07
  - $414,242
- Funding for FY08
  - $485,000 operating
  - $250,000 capital

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

Partners

- NREL – Lead
- LBNL – Modeling
- DJW Technology – Consulting
- DuPont, BASF, Arkema, 3M – Guidance, Test Materials
- Colorado School of Mines – Fuel cell testing
- University of Hawaii – Segmented cell development

Objectives

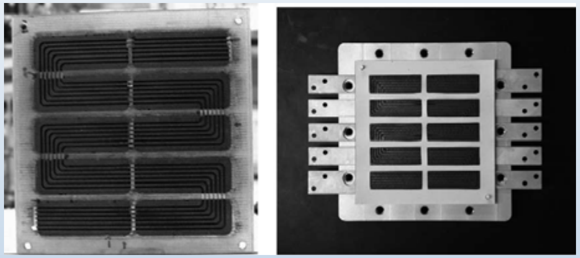
- ***Background:***
  - *Fuel cell system cost targets are based on a **projection of 500,000 units/year***
  - ***The supplier base needs high speed manufacturing methods – and quality control methods to support them – to achieve these volumes***
- **Project objectives**:
  - **Evaluate and develop in-line diagnostics for MEA component quality control, and validate in-line**
  - **Investigate the effects of manufacturing defects on MEA performance and durability**
  - **Further develop and validate models to predict the effects of local variations in MEA component properties**

Milestones

Month/year	Deliverable
9/07	Initial report on thickness measurement for MEA components
9/08	Interim database of performance and durability data, and model
9/08	Demonstrate prototype diagnostics
9/08	Go/No-go decision on segmented cell development
12/09	Validated diagnostics with database
12/09	Refined model
9/11	***MYPP: Develop prototype sensors for quality control of MEA manufacturing***
9/12	***MYPP: Develop continuous in-line measurement of MEA fabrication***
9/13	***MYPP: Demonstrate sensors in pilot-scale applications for manufacturing MEAs***
9/13	***MYPP: Establish models to predict the effect of manufacturing variations on MEA performance***

Approach

- **Diagnostic development:**
  - **Evaluate commercially available in-line diagnostics as a baseline**
  - **Focus initially on thickness as a "proto-measurement" for continuous processing**
  - **Identify (industry input) and address critical parameters for each component**
  - **Utilize NREL diagnostic-development capabilities relative to photovoltaics manufacturing**
  - **Refine techniques and systems based on understanding of critical defect size**
  - **Validate systems using research web-line**
- **Fuel cell testing:**
  - **Use standard performance tests and accelerated aging**
  - **Develop project-specific testing capabilities**
    - **Segmented cell development at HNEI**
  - **Investigate critical defect size**
    - **"Design" MEAs with defects to study effects**
    - **Input to diagnostics system requirements (resolution/accuracy)**



G. Bender et al. / Journal of Power Sources 123 (2003) 163–171

- **Modeling:**
  - **Use and refine existing LBNL pseudo 2-D performance model and development roadmap**
  - **Validate model with experimental results**
  - **Refine and simplify model based on industry input and results**
    - **Assist in creation of transfer functions**
  - **Incorporate transient (degradation) phenomena as necessary to model durability**

Progress

- **Strong support from industry**
  - **Non-disclosure agreements in place**
  - **Identified MEA component critical parameters**
    - **e.g., Pt content & distribution, electrode and GDL porosity, caliper, GDL and microlayer surface structure, hydrophobicity and conductivity of GDL, extent of ionomer cure**
  - **Defining and making MEA samples with component defects**
- **Outfitting manufacturing R&D labs**
- **Initiated collaboration with University of Hawaii for segmented cell development**
- **Initial model development and roadmap complete**
- **Working to specify web-line**

Technical Accomplishments

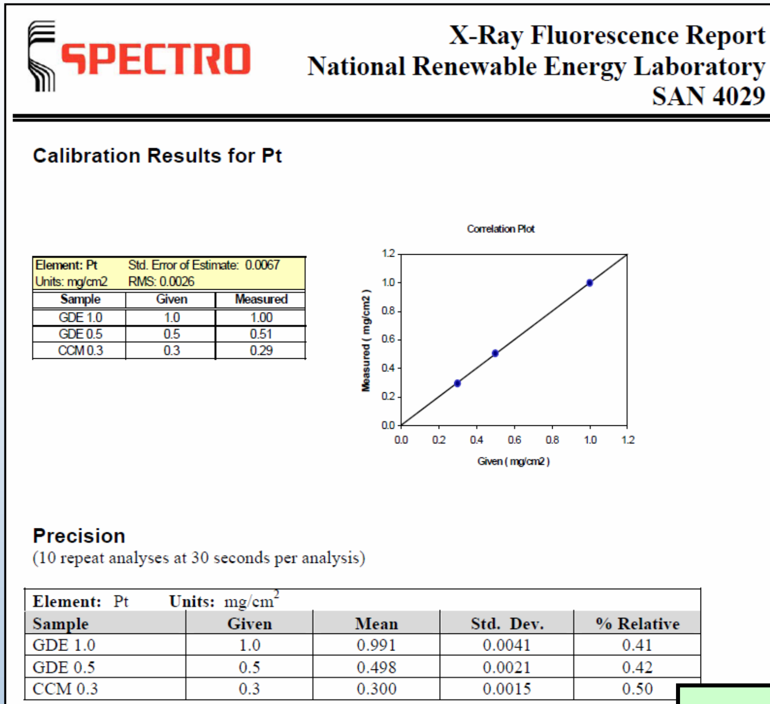
- **Submitted report, "Preliminary assessment of measurement techniques," in September**
  - **Reported on techniques relevant to in-line thickness measurement of MEA components**
  - **Suppliers evaluated small samples (not in-line) of commercially available MEA components**
    - **Also included developmental systems at NREL and LBNL**
  - ***Input from industry partners: Limitations of most commercial systems lead to either averaging over large areas or measuring at only one location***
    - ***Spot (measurement) size***
    - ***Data acquisition speed***
    - ***Techniques often not optimized for specific materials***
    - ***Resolution, repeatability***

Technical Accomplishments

Technique	Vendor	Status	Applicability
Optical/IR Reflection	Lumetrics, Infocus	Complete	Membrane
Laser Triangulation	Infocus	Complete	GDE, GDL, possibly CCM
Low-force Contact	Infocus	Complete	All, but in-line implementation may be difficult
Beta- / Gamma- / X-ray	Thermo Fisher, NDC, Mahlo	Need larger samples	Possibly all
X-ray Fluorescence	Fischer, Spectro	Complete	Catalyst, possibly membrane
Capacitance	Infocus	Complete	Questionable, but could measure conductance

Techniques applicable to MEA components

Technical Accomplishments


X-Ray Fluorescence Report
National Renewable Energy Laboratory
SAN 4029

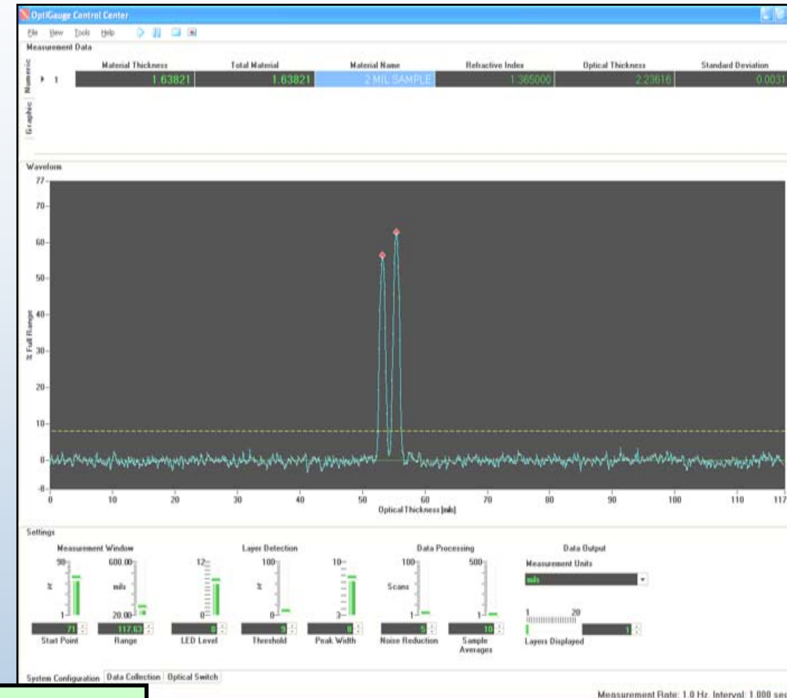
Calibration Results for Pt

Element: Pt	Std. Error of Estimate: 0.0067	
Units: mg/cm2	RMS: 0.0026	
Sample	Given	Measured
GDE 1.0	1.0	1.00
GDE 0.5	0.5	0.51
CCM 0.3	0.3	0.29

Precision
(10 repeat analyses at 30 seconds per analysis)

Element: Pt Units: mg/cm^2

Sample	Given	Mean	Std. Dev.	% Relative
GDE 1.0	1.0	0.991	0.0041	0.41
GDE 0.5	0.5	0.498	0.0021	0.42
CCM 0.3	0.3	0.300	0.0015	0.50



XRF:

- Fischer Technology and Spectro
- Coatings with 0.3, 0.5, and 1.0 mg/cm^2 Pt

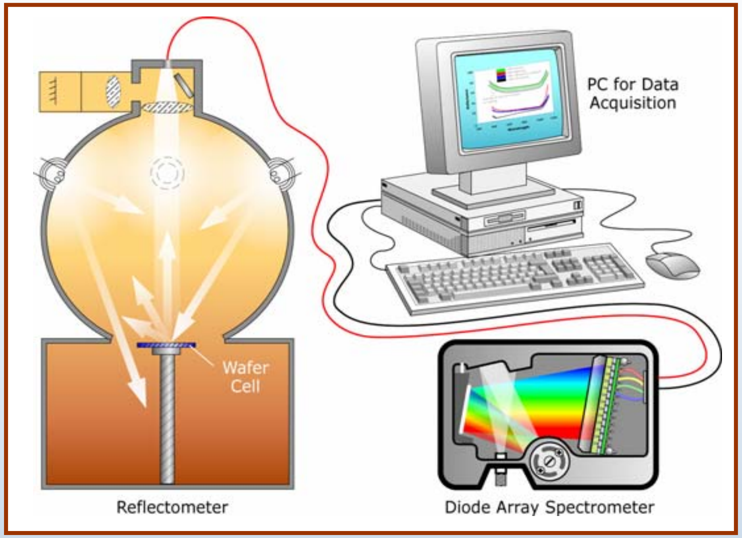
MEA components can be measured on the bench-top

Optical:

- Lumetrics and Infocus
- 1, 2 and 5 mil Nafion membranes

Technical Accomplishments

- **Completed initial assessment of NREL-developed Optical Reflectometer**
  - **Used in PV continuous manufacturing**
    - **Data acquisition and signal processing exists**
  - **Optical characterization of all MEA components**
    - **Potential for measurement of thickness, composition, porosity, surface structure, conductivity…**
  - **Demonstrated simultaneous measurements indicative of membrane thickness and composition**



Technology has potential to address:

- Multiple critical parameters
- Multiple MEA component materials
- Rapid, large area measurement

Technical Accomplishments

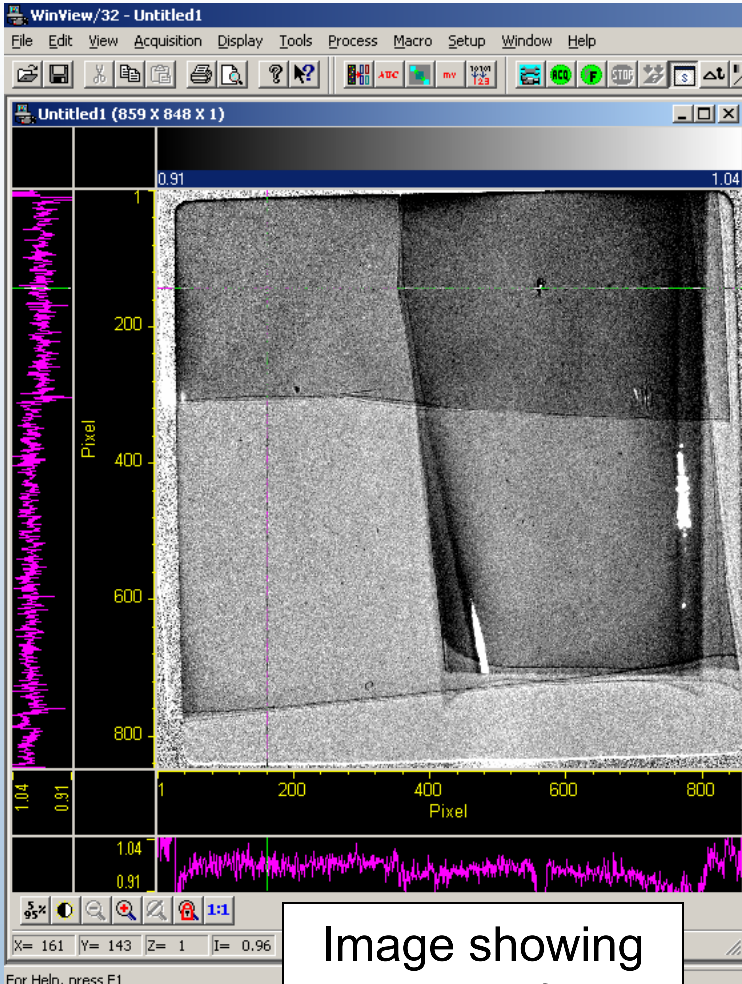
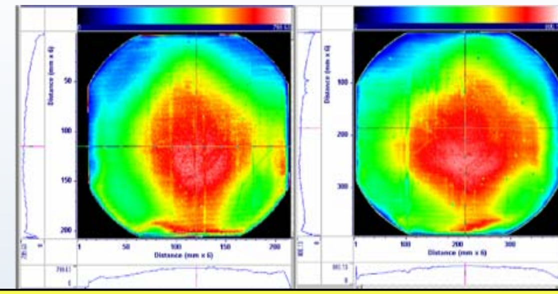


Image showing multiples of 1 mil membrane thickness



~ 25 sq-in area single measurement of silicon wafer anti-reflective coating

- **Proof of concept for 2D membrane thickness imaging**
  - **Wide angle illumination; normal reflection**
  - **In continuous processing, area measurement (vs. point measurement) enables identification of discrete defects in addition to point-to-point variation**

Future Work

FY08:

- Continue evaluation of optical reflectometer
  - Membrane thickness imaging
  - Improved signal
  - Other materials and parameters
- Initiate single cell testing (NREL, CSM)
- Begin transfer of data and model validation (LBNL)
- Complete segmented cell feasibility study (HNEI)
- Order research web-line

FY09:

- Install web-line
- Modify optical reflectometer and validate in-line
  - Optics and sensors for other materials and parameters
  - Configuration for web measurement
- Assess other diagnostic technologies for development
- Evaluate commercial diagnostics, e.g., XRF, in-line
- Develop segmented cell hardware and methods (HNEI, NREL)
- Investigate critical defect size (NREL, CSM, HNEI)
- Refine and simplify model (LBNL)

Continue to get input on priorities and directions from industry partners

Summary

Objectives: Strong industry buy-in

Approach:

- Develop in-line quality control diagnostics
- Study critical defect size
- Develop model and transfer functions for effects of defects

Progress:

- Established collaborations with industry and academia
- Completed initial report on thickness measurement techniques
- Establishing protocols and methodologies for manufacturing R&D
- Ongoing evaluation of NREL optical reflectometer
- Initial model development and roadmap complete

Future Work:

- Evaluation and development of diagnostics for a range of MEA component critical parameters
- In-line validation of diagnostics with partners
- Segmented cell and other test capabilities specific to evaluation of defects
- Model validation and refinement