VI.6 Cause-and-Effect: Flow Field Plate Manufacturing Variability and its Impact on Performance

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Objectives

Develop a pre-competitive knowledge base of engineering data relating fuel cell performance variation to bipolar plate manufacturing process parameters and dimensional variability.

Technical Barriers

This project addresses the following technical barriers from the Manufacturing R&D – Fuel Cells section of the Fuel Cell Technologies Program Multi-Year Research, Development and Demonstration Plan:

(B) Lack of High-Speed Bipolar Plate Manufacturing Processes

(F) Low Levels of Quality Control and Inflexible Processes

Contribution to Achievement of DOE Manufacturing Milestones

This project will contribute to achievement of the following DOE milestone from the Manufacturing R&D section of the Fuel Cell Technologies Program Multi-Year Research, Development and Demonstration Plan:

- Milestone 13 Complete development of standards for metrology of proton exchange membrane fuel cells. (4Q, 2010)

Accomplishments

- Co-developed LANL/NIST statement of work (SOW) including an initial testing protocol to facilitate an official collaborative agreement for LANL through DOE to conduct fuel cell performance testing using NIST fabricated and verified experimental plates (10/2009).
- Initiated experimental plate testing at LANL and completed preliminary testing report with protocol recommendations (4/2010).

Introduction

Based on a workshop organized by the Center of Automobile Research and NIST in December 2004; industry bipolar plate manufacturers identified a need for engineering data that relates geometric bipolar plate tolerances to fuel cell performance. This need is in response to pressure from fuel cell designers to produce lower cost plates, as such, plate manufacturers are being forced to consider potential quality related trade-offs to achieve desired cost targets. To justify these trade-offs, manufacturers are questioning the relevance of stated tolerances on dimensional features of bipolar plates; thus expressed a desire for published engineering data relating performance and dimensional quality of the plates that can be used as a reference when making these decisions. In response to the identified need, this project was conceived in 2004 and partially funded through the NIST Advanced Technology Program Intramural Competition for a period of three years (Fiscal Year [FY] 2005-FY 2007). In 2008, funding was provided through DOE in an attempt to bring this project to a successful completion by the end of FY 2008.

To date, the reference single-cell design has been selected, the fabrication and dimensional verification of all experimental plates has been completed according to a statistically based design-of-experiments, and the NIST single cell performance capability has established and verified. All that remains is the performance testing of the experimental plates. Unfortunately, progress has been delayed due to membrane degradation issues

followed by difficulties associated with obtaining the required on-site facility safety upgrades needed to permit continuous and sometimes unattended multi-day fuel cell performance operation required to reduce performance variability associated with start-up and shut-down. Due to the potential importance of the outcome of this project the deadline for completion was extended through FY 2010. The facility upgrade difficulties forced us to adopt an alternative and hopefully more efficient plan where LANL will conduct the performance testing. This activity is currently underway.

Approach

Using a statistically-based design-of-experiments (Table 1), fabricate experimental "cathode" side flow field plates (Figure 1) with various well defined combinations of flow field channel dimensional variations; then through single-cell fuel cell performance testing using a well defined protocol, quantify the performance affects, if any, and correlate these results into required dimensional fabrication tolerance levels.

Results

In the absence of a DOE Annual Merit Review Progress Presentation and Annual Progress Report submission during 2009, the following details results from October 2008 to the present.

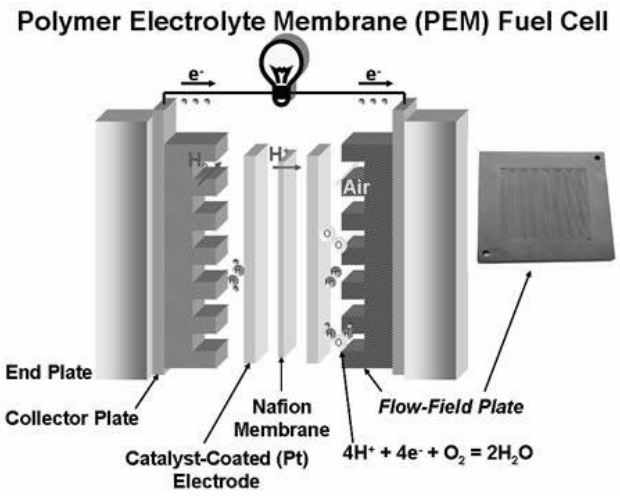

FIGURE 1. Concept - Reference Single Cell and NIST Fabricated Cathode Flow-Field Plates

- Validated NIST's single-cell testing performance proficiency to a higher level through successful participation in second single-cell performance intercomparison organized by the US Fuel Cell Council Joint Hydrogen Quality Task Force/DOE North American Hydrogen Quality (Participants included: LANL (Reference Lab), Hawaii Natural Energy Institute, University of Connecticut, University of South Carolina, Clemson/Savannah River).

TABLE 1. Design of Experiment 2^{4-1} Fractional Factorial Design…4 Parameters, 2 Levels, and Replicate Center Point

	2^{4-1} Fractional Factorial Design with replicated center point (k=4,n=10)							
	Sidewall Straightness	Sidewall Straightness	Bottom Straightness	Sidewall Taper				
	Amplitude	Phase	Amplitude			Sequence		Drawing
Part	*X1*	*X2*	*X3*	*X4*	*Machining*	*Measuring*	*Perf. Testing*	*Cross-Section* *Top*
9	0(25μm)	0(90)	0(25μm)	0(5)	1	1	1	
3	-1(0)	+1(180)	-1(0)	+1(10)	2	2	2	
2	+1(50μm)	-1(0)	-1(0)	+1(10)	3	3	3	
4	+1(50μm)	+1(180)	-1(0)	-1(0)	4	4	4	
8	+1(50μm)	+1(180)	+1(50μm)	+1(10)	5	5	5	
5	-1(0)	-1(0)	+1(50μm)	+1(10)	6	6	6	
7	-1(0)	+1(180)	+1(50μm)	-1(0)	7	7	7	
10	0(25μm)	0(90)	0(25μm)	0(5)	8	8	8	
6	+1(50μm)	-1(0)	+1(50μm)	-1(0)	9	9	9	
1	-1(0)	-1(0)	-1(0)	-1(0)	10	10	10	

- Performed long-term stability testing of the reference single-cell with chosen components and NIST fabricated anode and cathode flow-field plates. For this testing, the fabricated plates for both sides are the reference "optimal geometry" plates having dimensional variations less than 5 um.
- From this testing we concluded:
  - Performance stability can only be achieved through continuous operation during the entire testing process for each assembly of the cell with substitute experimental cathode plates. More specifically, this means that start-up and shut-down introduced variability and a typical testing cycle including a stabilization period takes approximately 2 to 3 days.
  - Although the membrane was chosen based on what were considered sound recommendations, the membrane exhibited substantial and not always predictable degradation. This was independently verified by LANL through testing we requested of the same membrane supplier.
- Facility safety upgrades needed to support unattended continuous operation encountered significant difficulties and delays therefore a SOW was developed in cooperation with LANL where the testing would be conducted by LANL to hopefully ensure a timely completion of this project.
- LANL performed initial testing of the NIST single-cell using their membrane of choice and reached the following conclusions (Figures 2 and 3):
  - Reuse of the same membrane from one single-cell configuration to the next where experimental cathode plates are swapped out between each configuration is not possible, as the disassembly and reassembly process results in significant degradation and sometimes operational failure.
  - The initial range and testing points selected in the testing procedure co-developed by NIST and LANL in the SOW did not extend far enough to show the mass-transport region and subsequently the target point for alternating current impedance investigation did not fall within this region as needed to elucidate plate-to-plate differences.

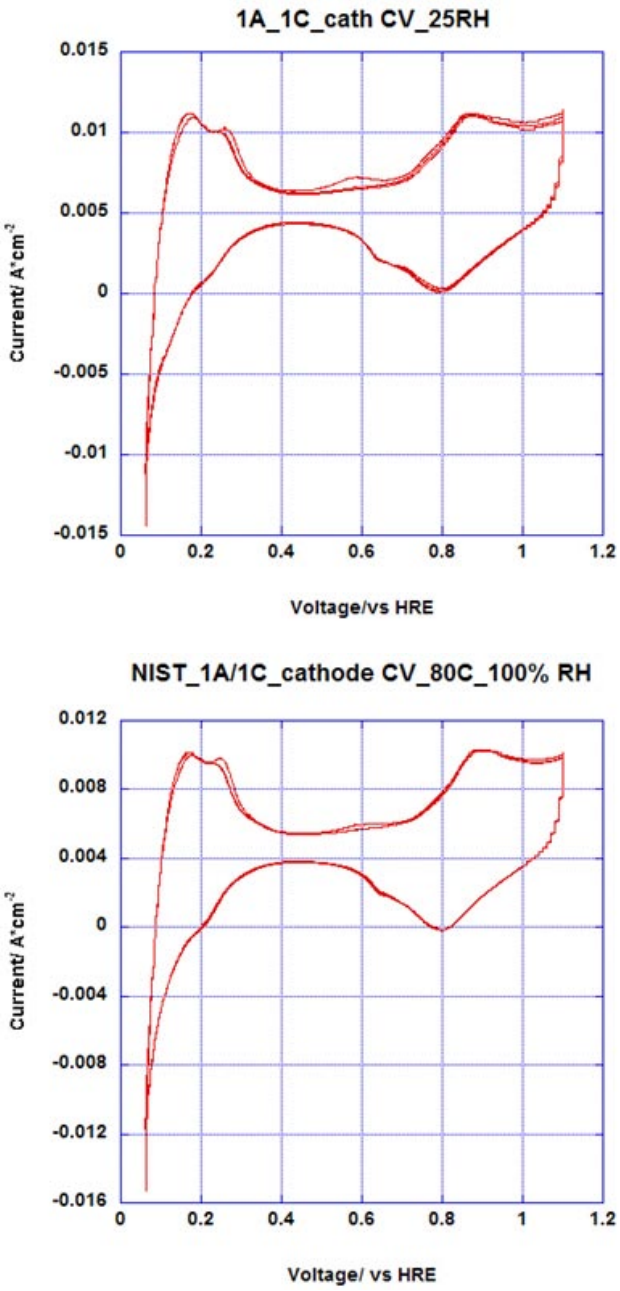

FIGURE 2. LANL preliminary testing, quality control cyclic voltammograms for electrochemical surface area as well as hydrogen crossover at 25% and 100% relative humidity using NIST reference cathode and anode plates (H_2/N_2 @ 500 sccm, 25 psig, Scan Rate: 20 mV/s, 0.1 V– 1.1 V, 3 cycles).

Conclusions

- Progress significantly delayed due to issues involving facility safety upgrades of the NIST Fuel Cell Testing Laboratory needed to support unattended and continuous fuel cell operation.
- Alternative plan formulated with the oversight and assistance of DOE program management where LANL was subcontracted to conduct performance testing thus enabling the quickest possible completion.
- Membrane and protocol weaknesses/limitations, as well as, proposed solutions were identified through NIST and LANL preliminary performance testing.

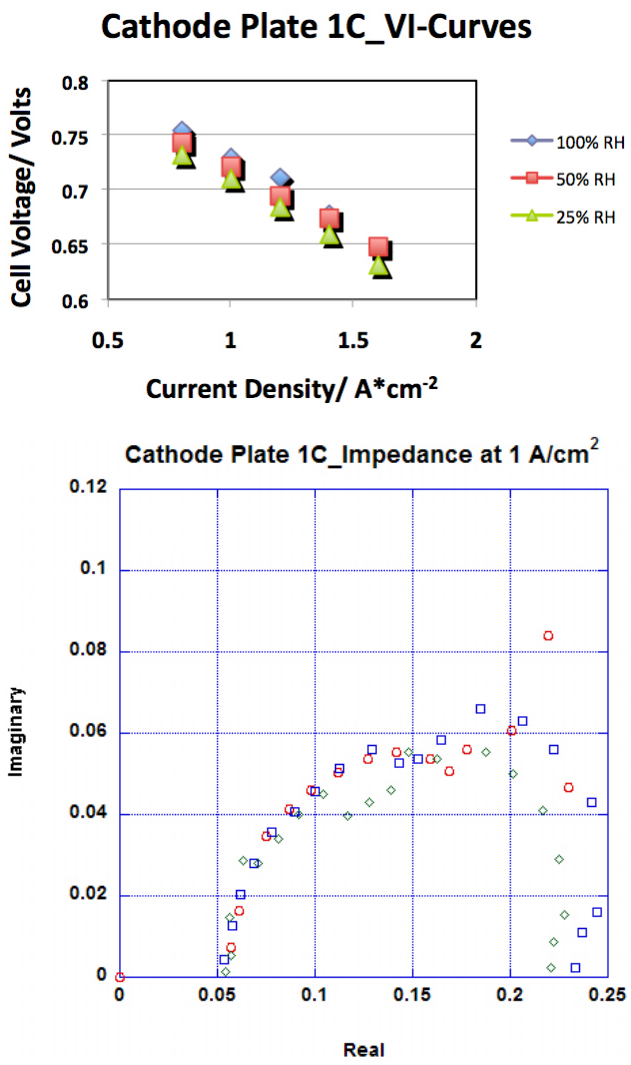

FIGURE 3. LANL preliminary testing using NIST reference cathode and anode plates indicating initial protocol limits were not appropriate for mass transport investigation.

Future Directions

- Proposed protocol and membrane solutions will be tested by LANL.
- Assuming the solutions prove adequate, LANL will perform and complete performance testing of experimental plates.
- NIST and LANL expect to complete analysis of results and publication of the conclusions by January 31, 2011.

Disclaimer

Certain commercial equipment, instruments, or materials are identified in this paper in order to specify the experimental procedure adequately. Such identification is not intended to imply recommendation or endorsement by NIST, nor is it intended to imply that the materials or equipment identified are necessarily the best available for the purpose.

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FY 2010 Publications/Presentations

1. Precision Engineering 2009 Program Technical Accomplishments, pp 42-45, 2010 http://www.nist.gov/mel/ped/index.cfm.

2. E. Stanfield, "Metrology for Fuel Cell Manufacturing," DOE Annual Merit Review Proceedings, MN006, June 11, 2010, http://www.hydrogen.energy.gov/pdfs/review10/mn006_stanfield_2010_o_web.pdf.