

2007 DOE HFCIT Kick-off Meeting

Advanced Cathode Catalysts and Supports for PEM Fuel Cells

DE-FG36-07GO17007

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3M Company

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Overview

Timeline

- Project start 1/1/07
- Project end 12/30/10

Budget

- Total Project funding **\$10.43MM**
 - \$8.34 MM DOE
 - \$2.09 MM Contractor share
- Received in FY07: \$0 million

Partners

- Dalhousie University (J. Dahn)
- JPL (S. R. Narayanan)
- ANL (N. Markovic)

Barriers

- A. Electrode and MEA Durability
- B. Stack Material & Mfg Cost
- C. Electrode and MEA Performance

DOE Technical Targets

Electrocatalyst (2010, 2015)

- Durability w/cycling: hrs
 - < 80°C - (5000, 5000)
 - > 80°C - (2000, 5000)
- Cost: \$/kW (5,4)
- Mass activity: A/mg (0.44, 0.44)
- PGM Total, g/ kW rated: (0.3, 0.2)

MEA (2010, 2015)

- Cost: \$/kW (10,5)
- Performance: W/cm² at
Rated Pwr. (1,1) ; 0.8V (0.25, 0.25)

Overall Contract Objectives

The objectives of this project are development of a durable, low cost [both precious group metal (PGM) content and manufacturability], high performance cathode electrode (catalyst and support), that is fully integrated into a proton exchange membrane electrode assembly characterized by:

- a) total Pt group metal loading per MEA of ≤ 0.25 mg/cm²,
- b) short-stack specific power density of < 0.5 g/kW at rated power,
- c) durability sufficient to operate at $> 80^{\circ}\text{C}$ for 2000 hours, $\leq 80^{\circ}\text{C}$ for 5000 hours, with cycling for transportation applications,
- d) high prospects for 40,000 hours durability under operating conditions or stationary applications, and
- e) high volume manufacturability.

Project Focus and Scope

The focus of this project is:

Development of advanced cathode catalysts and supports based on 3M's nanostructured thin film (NSTF) catalyst technology platform, which has already demonstrated catalyst specific activity and durability significantly higher than conventional carbon supported Pt catalysts.

The scope of work includes:

- a) fundamentals of inherent catalyst activity enhancement (with ANL),
- b) high throughput fabrication and characterization of new multi-element Pt alloys (ternaries and quaternaries) to obtain enhanced activity and stability (with Dalhousie University and JPL)
- c) new NSTF catalyst support structures for optimized ECSA
- d) extensive fuel cell performance and durability testing
- e) integrated MEA development using advanced 3M membranes and GDL's specific to the new NSTF catalysts.

Project Approach

Task 1.0 Catalyst Activity and Utilization Improvements

- 1.1 NSTF surface area increase – NSTF support optimization
- 1.2 Fundamentals of NSTF catalytic activity
- 1.3 New multi-element catalysts to increase activity

Task 2.0 Catalyst Durability Improvements

- 2.1 NSTF catalyst stabilization against dissolution
- 2.2 NSTF catalyst grain size stabilization

Task 3.0 Full Size (> 250 cm²) Single Cell Performance and Durability Tests

Task 4.0 Durability of Advanced Support Structures

- 4.1 Durability tests of new NSTF supports
- 4.2 Durability tests of new commercial catalyst supports
- 4.3 Development of support degradation model

Task 5.0 Stack Testing and Optimized NSTF MEA Roll-good

- 5.1 NSTF catalyst / low EW membrane interface optimization
- 5.2 Optimized anode and cathode GDL's
- 5.3 Short stack testing (> 10 cells, > 250 cm²)

Organizations Responsible for Work

TASK	1.1.1	1.1.2	1.2	1.3	2.1	2.2	3	4.1	4.2	4.3	5
Organiz.											
3M	X	X	X	X	X	X	X	X	X	X	X
Dalhousie University (1)		X		X	X	X		X			
JPL (2)				X		X					
ANL (3)			X								

(1) Prof. J. Dahn

(2) S. R. Narayanan

(3) Nenad Markovic

Relevant Prior Work

- 3M/DOE Cooperative Agreement No. DE-FC02-97EE50473
“High Performance, Low Cost Membrane Electrode Assemblies for PEM Fuel Cells”
- 3M/DOE Cooperative Agreement No. DE-FC02-99EE50582
“High Performance, Matching PEM Fuel Cell Components and Integrated Pilot Manufacturing Processes”
- 3M/DOE Cooperative Agreement No. DE-FC36-02AL67621
“Advanced MEA’s for Enhanced Operating Conditions”

Recent Publications

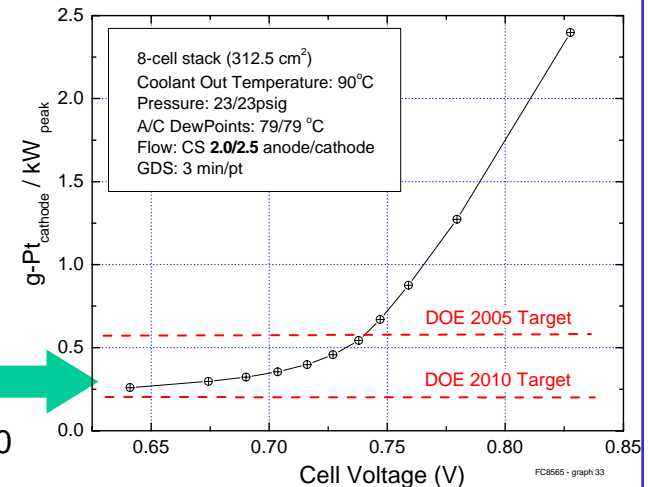
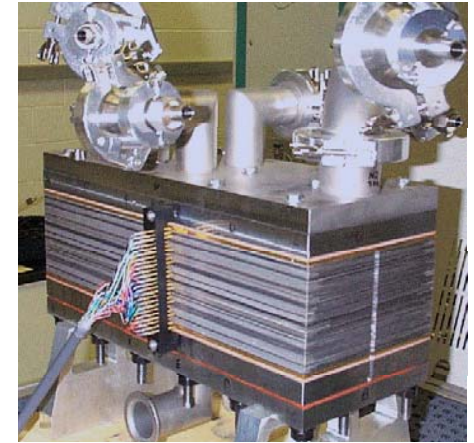
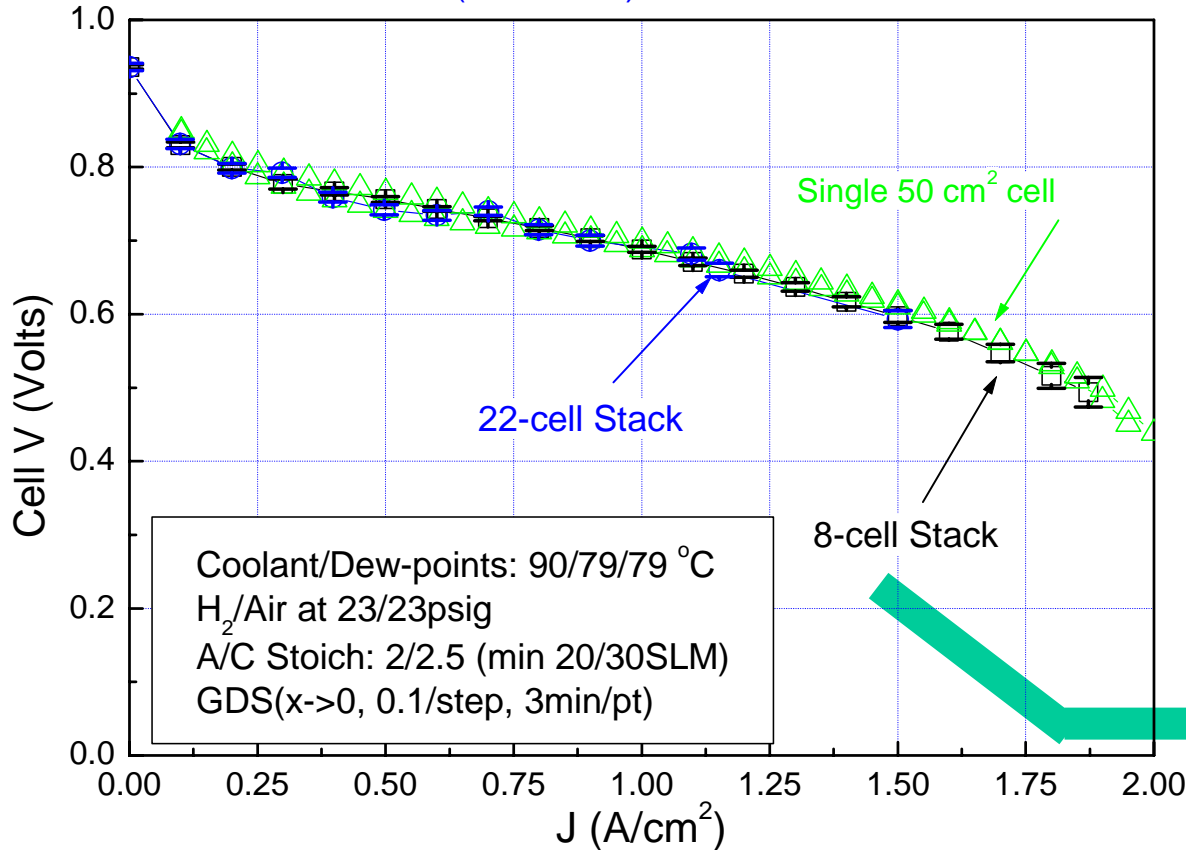
- Debe, M. K.; Schmoeckel, A.; Hendricks, S.; Vernstrom, G.; Haugen, G.; Atanasoski, R., *ECS Transactions* **1**(1), 51 (2006).
- Debe, M. K.; Schmoeckel, A. K.; Vernstrom, G. D.; Atanasoski, R., *Journal of Power Sources* **161**, 1002 (2006).
- Steinbach, A.J.; Noda, K.; Debe, M. K., *ECS Transactions* **3**(1) 835 (2006).
- Bonakdarpour, A.; Lobel, R.; Atanasoski, R. T.; Vernstrom, G. D.; Schmoeckel, A. K.; Debe, M. K.; Dahn, J. R., *Journal of The Electrochemical Society* **153**, A1835 (2006).
- Bonakdarpour, A.; Wenzel, J.; Stevens, D. A.; Sheng, S.; Monchesky, T. L.; Lobel, R.; Atanasoski, R. T.; Schmoeckel, A. K.; Vernstrom, G. D.; Debe, M. K.; Dahn, J. R., *Journal of The Electrochemical Society* **152**, A61(2005).

Relevant Prior Work

2006 Short Stack Performances with 312 cm², 7 layer NSTFC MEA

- NSTFC CCM Roll-good: Cathode , anode – PtCoMn w/ 0.2 mg/cm² ; 3M PEM
- Same performance achieved in 2kW, 5kW short stacks as in 50cm² single cell.

Comparison of NSTF Single Cell (50cm²), 8-cell (312cm²), and 22-cell (312.5cm²) Stacks @ 270 kPaa.

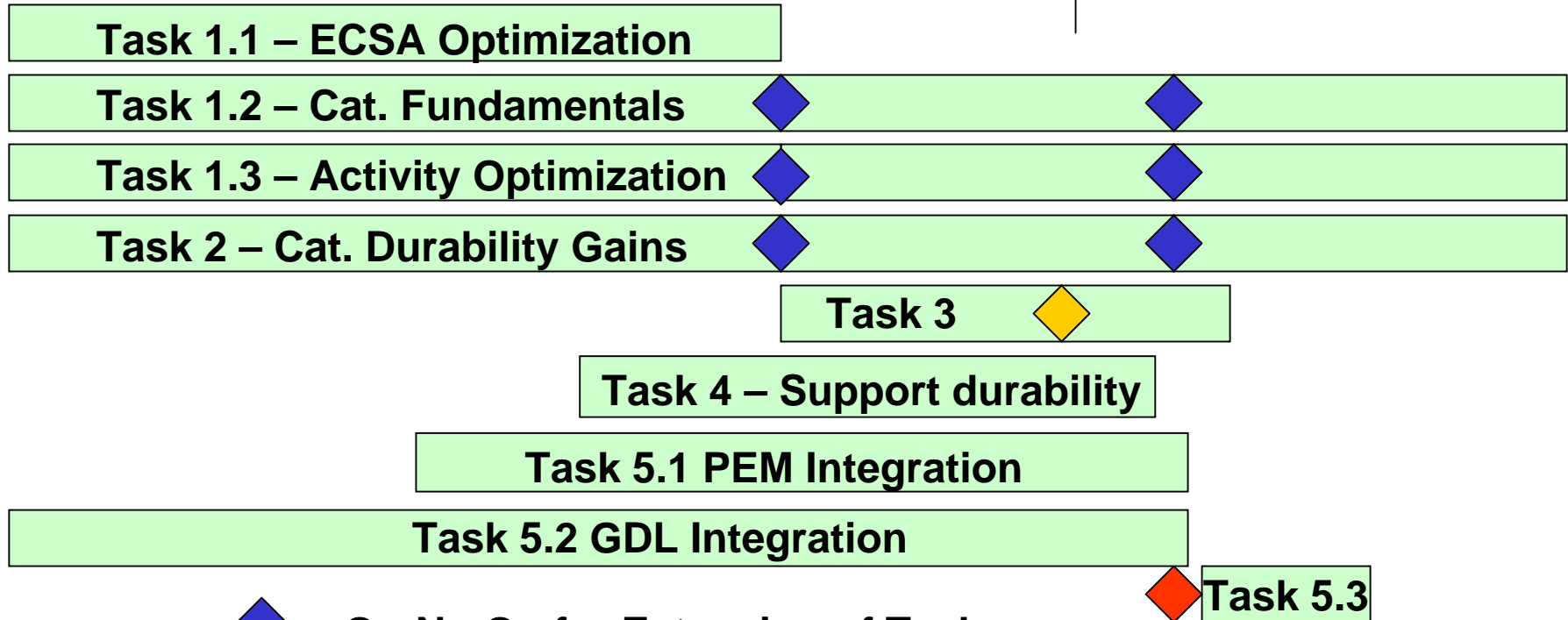
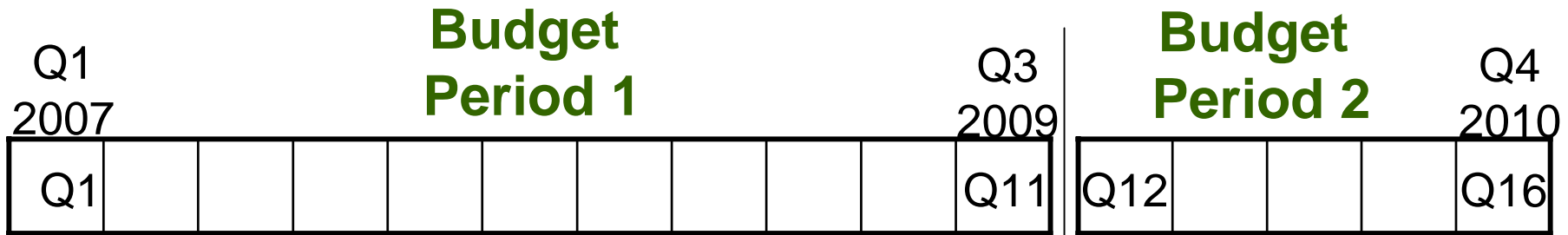





NSTF Catalyst Characteristics vs DOE Targets

Table 3.4.12. Technical Targets: Electrocatalysts for Transportation Applications

Characteristic	Units	2010/2015 Stack Targets	3M 2007 Status (volume mfg'd roll-good)	Project Goal
PGM Total Content	g/kW rated in stack	0.3 / 0.2	0.47 (in 22 cell stack)	0.25
PGM Total Loading	mg PGM/cm ² electrode area	0.3 / 0.2	0.25 – 0.4	0.25
Durability with cycling At operating T ≤ 80°C At operating T > 80°C	Hours	5000 / 5000 2000 / 5000	> 3500 hrs (single cell load cycling, 80°C)	> 5000
Mass Activity (150kPa H ₂ /O ₂ 80°C. 100% RH)	A/mg-Pt @ 900 mV	0.44 / 0.44	0.18 – 0.25 (≤ 0.2 mg/cm ²)	> 0.5
Specific Activity (150 kPa H ₂ /O ₂ at 80°C, 100% RH)	μA/cm ² -Pt @ 900 mV	720 / 720	2,930 (0.2 mg/cm ²)	> 5000
ECSA loss by Stop/Start	% ECSA loss	< 40 / 40	< 30	< 10
Electrochemical support loss at high potentials	mV after 100 hrs @ 1.2 V	< 30 / 30	< 10	~ 0

Project Time-line



-  = Go-No Go for Extension of Task
-  = Go-No Go for Large Area, Single Cell Durability Tests
-  = Go-No Go for Stack Testing

Budget by Fiscal Year

DE-FG36-07GO17007

\$MM	FY07	FY08	FY09	FY10	FY11
Cost Share	0.459	0.639	0.544	0.370	0.074
Funding	1.837	2.556	2.175	1.480	0.295
Total	2.296	3.195	2.719	1.850	0.369
	Budget Period 1			Budget Period 2	