New MEA Materials for Improved DMFC Performance, Durability, and Cost

Dr. Jim Fletcher

Dr. Philip Cox

University of North Florida

School of Engineering

June, 2010

Project ID FC064

This presentation does not contain any proprietary, confidential, or otherwise restricted information

Northeastern University

Johnson Matthey Fuel Cells the power within

University of North Florida

Overview

Timeline

- Start date: January 1, 2010
- End date: June 30, 2012
- Percent complete: 16%

Budget

- Total project budget $3,112,850
  - DOE share $2,490,078
  - Contractor share $622,772
- Funding for FY10 $1.4 M (awarded incrementally)

Barriers

- Barriers addressed
  - Power and energy density
    - 100 W/kg and 1000 Wh/L
  - Cost
    - <$3/W at the system level
  - Lifetime
    - 2000 hours

Partners

- University of Florida (UF)
- Johnson Matthey Fuel Cells (JM)
- Northeastern University (NEU)

Northeastern University

Johnson Matthey Fuel Cells the power within

University of North Florida

Relevance

Increased MEA functionality and internal water recovery facilitates system simplicity increasing power and energy density and lowers cost to address DOE's Consumer electronics goals.

- Project Objectives
  - Improve the performance and durability of the UNF MEA design to
    - Increase power and energy density
    - Lower the cost
  - Development of commercial production capabilities
    - Improve performance
    - Lower cost
  - Increase catalyst stability and lower loading
    - Lower MEA cost

Status and System Level Targets for passive water recovery MEAs

Characteristic	Units	UNF 15 W DP3 2008 Status	DOE 2010 Target
Specific Power [a]	W / kg	35	100
Power Density [a]	W / L	48	100
Energy Density	W-hr / L	250 (1 x 100ml)[b] 396 (1 x 200ml)[b]	1000
	W-hr/kg	155 (1 x 100ml)[b] 247 (1 x 200ml)[b]	N/A
Lifetime [c]	Operating Hours	1,000 hrs in single cell	5,000
Cost	$ / Watt	11 (est. in volume)	<3

[a] Beginning of life, 30°C, sea level, 50% R.H., excluding hybrid battery, power module alone
[b] Normalized from DP3 data from 150 ml cartridge to either 100ml or 200ml for comparison purposes
[c] Lifetime measured to 80% of rated power

Approach

Development of optimized DMFC MEA with internal water recovery to simplify system design and optimize energy and power density and reduce cost

Overall Program Tasks

- Membrane Optimization
  - Improve the balance between water transport and methanol crossover to optimize efficiency
  - Improve energy density and durability
- Barrier Layer Process Development
  - Optimize the passive water recovery barrier layer for manufacturing and performance
  - Provide improved reliability and lower cost
- Catalyst Development
  - Improve catalyst durability to lower cost and increase operating lifetime
- MEA Development
  - Optimize passive water recovery MEA for performance, durability, and cost
  - Increase power density and energy density
  - Lower system cost
- MEA Short Stack Performance and Durability Testing
  - Durability and performance validation at the stack level

Northeastern University

Johnson Matthey Fuel Cells — the power within

University of North Florida

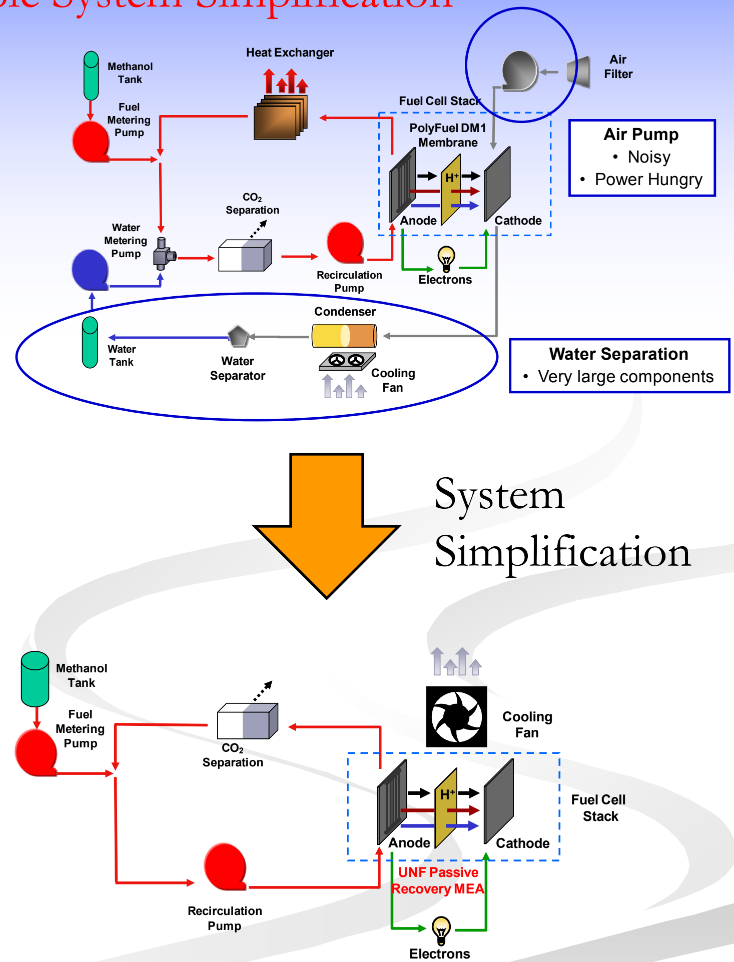
Technical Accomplishments and Progress

MEA Design Developed to Enable System Simplification

- UNF Baseline Membrane Electrode Assembly (MEA) provides path to system simplification and increased power and energy density, and lower system cost

MEA Design Characteristics

- Membrane has engineered porosity with low methanol cross-over and low electro-osmotic drag
- Incorporates a cathode liquid barrier layer (LBL) which blocks liquid transport but allows gas transport
- Incorporates a cathode liquid distribution layer (LDL) to distribute the water to the low pressure drop paths through the membrane back to the anode
- Typical catalyst and gas distribution layers on the anode and cathode



Northeastern University

Johnson Matthey Fuel Cells the power within

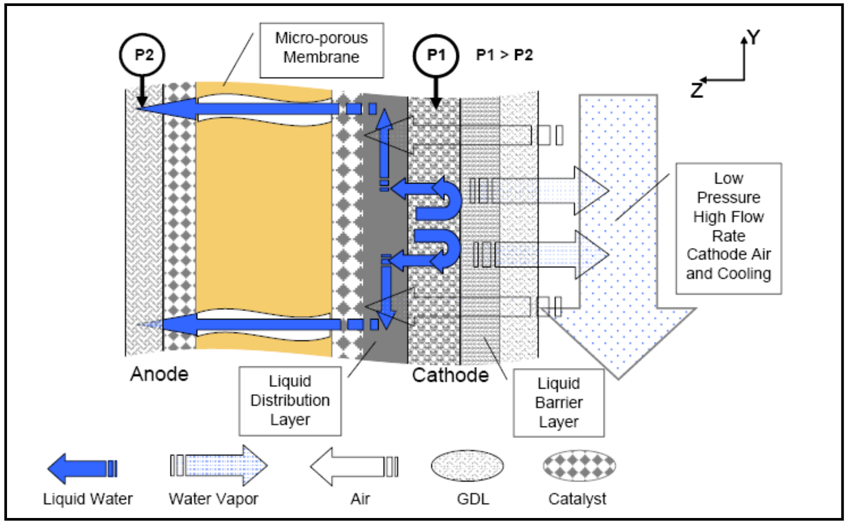
University of North Florida

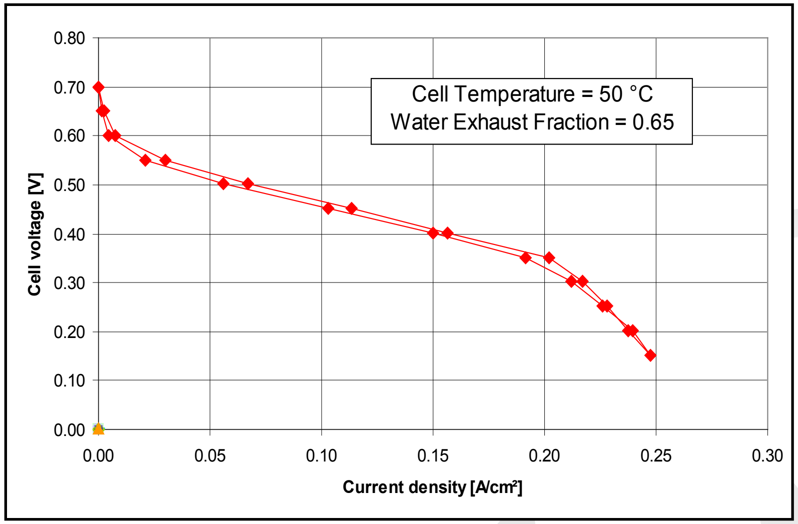
Technical Accomplishments and Progress

MEA Design Developed to Enable System Simplification

- MEA Water Transport characteristics optimized to internally recycle water to anode compartment

- Baseline MEA Performance with passive water recovery enables system simplification and recovery of both product water and electro-osmotic drag water in MEA





Northeastern University

Johnson Matthey Fuel Cells
the power within

University of North Florida

Technical Accomplishments and Progress

MEA Design Developed to Enable System Simplification

Baseline MEA developed enabled a smaller compact system

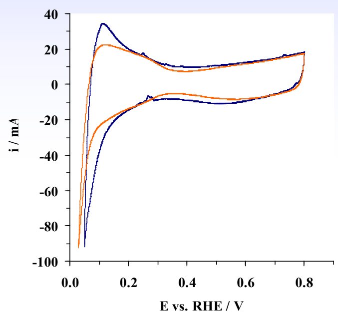
Fuel cartridge and power section

DP3 System with comparable battery energy

Technical Accomplishments and Progress

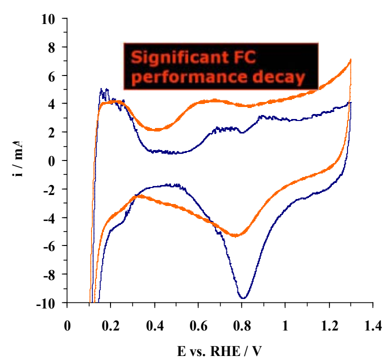
Catalyst Modification to improve lifetime

- Ru dissolution from DMFC anodes can cross the membrane and deposit on cathode[1]
- This Ru deposits spontaneously at open circuit causing significant cathodic overpotential losses



Anode (3 mg/cm² A PtRu)

	Before test [at.%]	After Test [at.%]
Pt	55.1	75.9
Ru	44.9	24.1

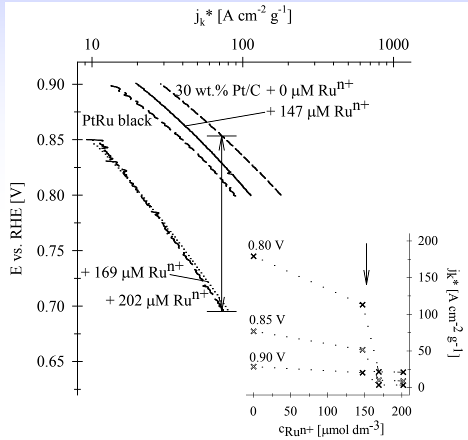


Conditions:

- 12 hs at E_c=0.02V
- 1 M MeOH in 0.5 M H_2SO_4
- Room T, 100% RH of O_2
- Internal REF

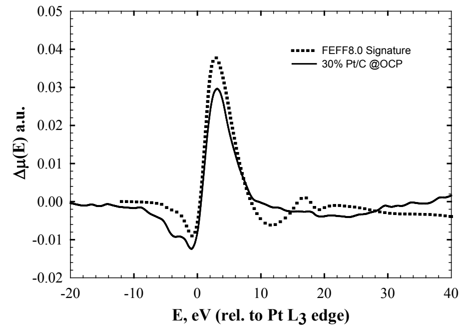
Cathode (0.5 mg/cm² Pt)

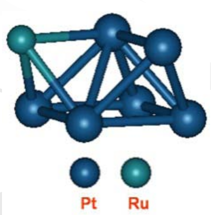
	Before test [at.%]	After Test [at.%]
Pt	100	93.7
Ru	0	6.3



Effect on Cathode Electrode

Significant lowering of Tafel Kinetics with micro-molar Ru in Cathode stream





Northeastern University

Johnson Matthey Fuel Cells the power within

University of North Florida

1. Piela *et al.*, *J. Electrochem. Soc*, **151**, A2053, (2004)

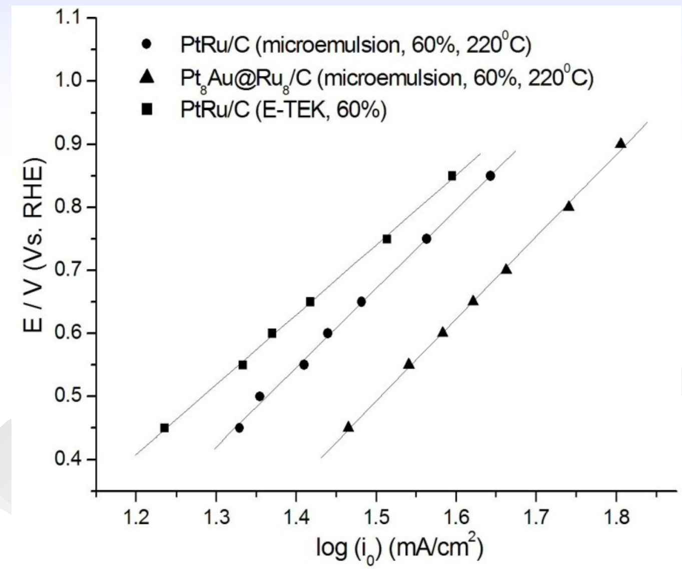
Technical Accomplishments and Progress

Ultra-stable Pt-Ru Electrocatalyst

	Pt coverage (%)		Surface area
	before test	after test	remained (%)
PtRu/C (60%, E-TEK), room T, *24* hours	69.4	72.3	**88.1**
PtRu/C (60%, E-TEK), at 50 , *4* hours	69.4	76.7	**88.7**
$Pt_8Au@Ru/C$ (60% 220), room T, *24* hours	74.4	76.9	**98.3**
$Pt_8Au@Ru/C$ (60% 220) , at 50 , *4* hours	74.4	76.1	**99.5**

Surface Coverage of PtRu/C (E-TEK, 60%) and Northeastern University $Ru_8@Pt_8Au/C$(60%, by microemulsion method, heated at 220 ^{0}C under H_2/Ar),before and after long term chronoamperometry test.

Surface area measured by Cu-upd method



Results of anode polarization measurements in 0.5 M MeOH in 0.1 M $HClO_4$ at room temperature

Collaborations

Subcontractors

- University of Florida
  - Catalyst development and MEA optimization
- Northeastern University
  - Catalyst Development and Fuel Cell Testing
- Johnson Matthey Fuel Cells
  - MEA scale up and optimization

Proposed Future Work

FY10

- Catalyst development and Characterization (UF, UNF)
- Development of improved manufacturing techniques for the liquid barrier layer (JM, UNF, UF)
  - Improve durability
- Scale up and MEA testing of high stability anode catalyst (NEU, UNF)
  - Improve lifetime

FY 11

- Development of improved manufacturing techniques for the liquid barrier layer (JM, UNF, UF)
  - Improve MEA reproducibility and yield
  - Improve durability
- Scale up and Testing of high stability anode catalyst (NEU, UNF)
  - Improved lifetime
- Catalyst development and Characterization (UF, UNF)
- MEA development (UNF, JM, UF)
  - Improve performance to increase power density and energy density
  - Improve lifetime
- Single cell and Stack testing
  - Measurement of performance and durability under system type operating conditions

Northeastern University

Johnson Matthey Fuel Cells — the power within

University of North Florida

Summary Slide

- Project leverages the UNF MEA technology and system technology to improve
  - Power and energy density performance by optimizing manufacturing technology
  - Durability by improving manufacturing processes and increasing catalyst stability
  - Lower cost by increasing yield and lowering catalyst loading
- The project will develop an MEA that is commercially available and enables significant simplification of DMFC systems to address the DOE consumer electronics system targets.

Northeastern University

Johnson Matthey Fuel Cells
the power within

University of North Florida