2004 DOE Hydrogen, Fuel Cells and Infrastructure Technologies Program Review

MEA & Stack Durability for PEM Fuel Cells

3M/DOE Cooperative Agreement

No. DE-FC36-03GO13098

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Fuel Cell Components Program

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Objectives

Overall

- Determine root causes of MEA failure modes
- Develop an MEA with enhanced durability and maintain performance
  - Manufacturable in a high volume process
  - Meets market required targets for lifetime and cost
  - Optimized for field ready systems
- System demonstration >2000 hrs

Work to Date Focus

- MEA component development
- MEA characterization and diagnostics
- Defining system operating window

Budget

	Total $	DOE $	Contractor $
Total	10,100,000	8,080,000	2,020,000
FY ’04 Project Management Plan (12/03)	4,340,000	3,480,000	860,000
FY ’04 Projected Allocation	2,690,000	2,150,000	540,000

Technical Barriers and Targets

- DOE Technical Barriers for Distributed Systems
  - E. Durability
- DOE Technical Barriers for Fuel Cell Components
  - O. Stack Material and Manufacturing Cost
  - P. Durability
- DOE Technical Target for Fuel Cell Stack System for 2010
  - Cost $750 - $1,000/kW
  - Durability 40,000 hours

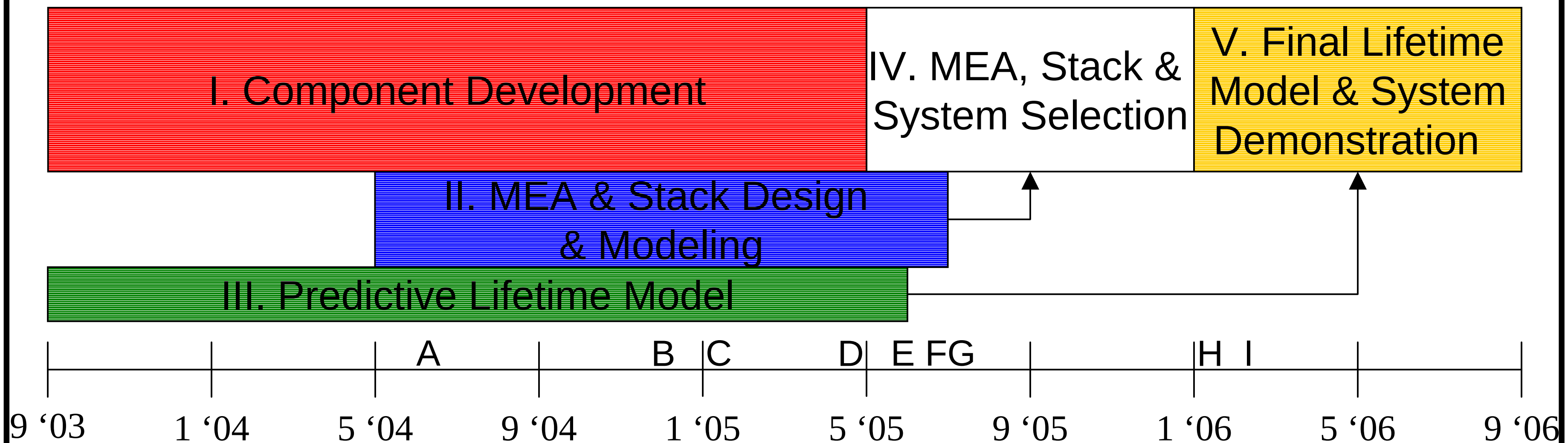
Approach

- Develop MEA utilizing 3M proprietary perfluorinated sulfonic acid ionomer which has demonstrated improved oxidative stability over baseline
- Develop and validate individual component aging tests and characterization methods
- Correlate single-cell test data and characterization data on virgin and aged components and MEAs leading to a more focused materials development strategy
- Optimize stack and/or MEA structure based upon modeling and experimentation
- Selectively test MEA and stack designs for enhanced system durability

Project Safety

- Corporate Policy and Procedures
  - Hazard review for new/modified facilities, equipment and processes
  - Risk assessment process for design and production of products
  - New Product Introduction system
    - Life Cycle Management
    - Change Management
- Test Station Safety
  - Emergency stop capabilities
  - Alarms
  - Over temperature and pressure protection
- No unusual safety issues have been encountered to-date on this project.

Timeline



Milestones

A. Accelerated tests and characterization methods defined (**I**)
B. Working lifetime model (**III**)
C. MEA components selected (**I**)
D. Component integration complete (**I**)
E. Model refined and verified (**III**)
F. Incorporate stack and/or MEA modifications from modeling and experiments (**II**)
G. Single cell testing completed (**IV**)
H. Select MEA, stack, and system design (**IV**)
I. Begin 2000 hr testing (**V**)

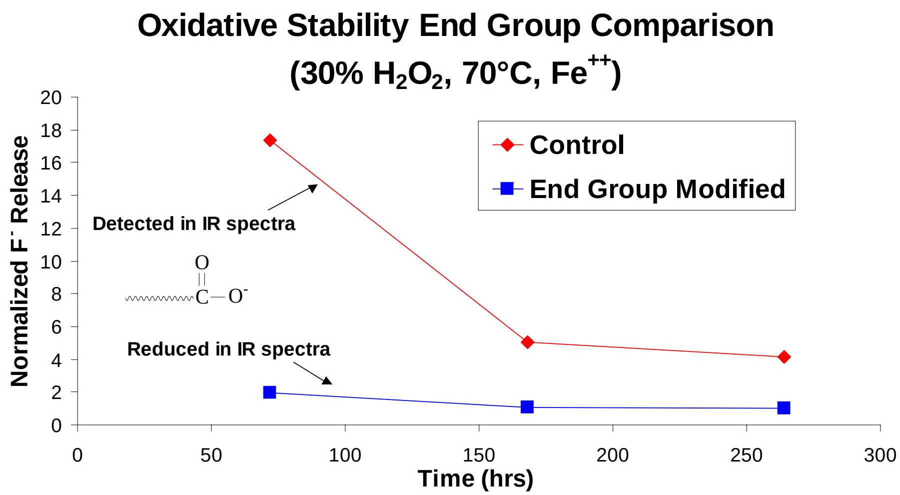
- Timeline assumes PMP planned funding
- Timeline subject to change depending on allocated funding

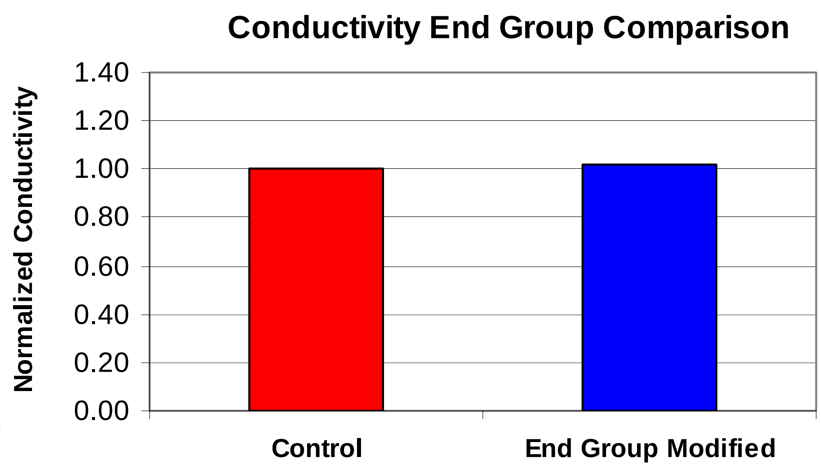
Accomplishments

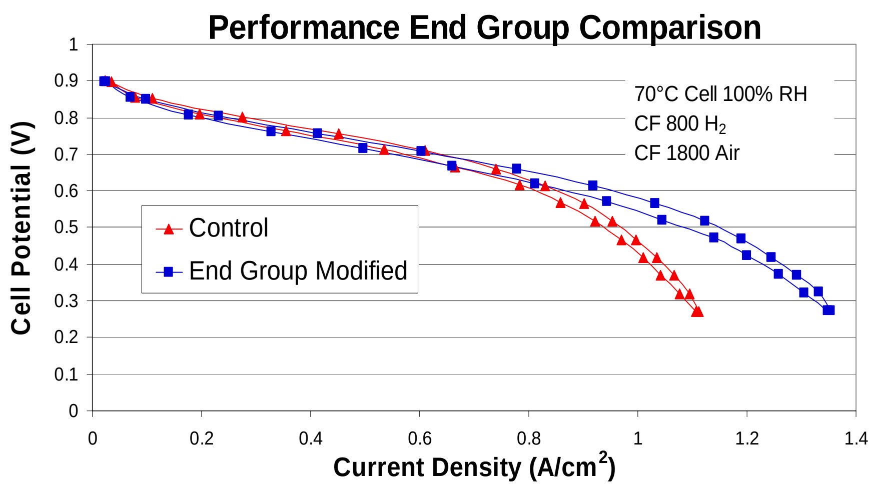
- Component Development
  - Membrane
  - GDL

  } Improved oxidative stability
  - Cathode catalyst – test to select the most stable material
- MEA Diagnostics
  - Peroxide measurements – key to understanding peroxide kinetics and impact on MEA durability
- System operating window
  - Defining operating window – investigated dew point, cell temperature, current density

3M Membrane Oxidative Stability







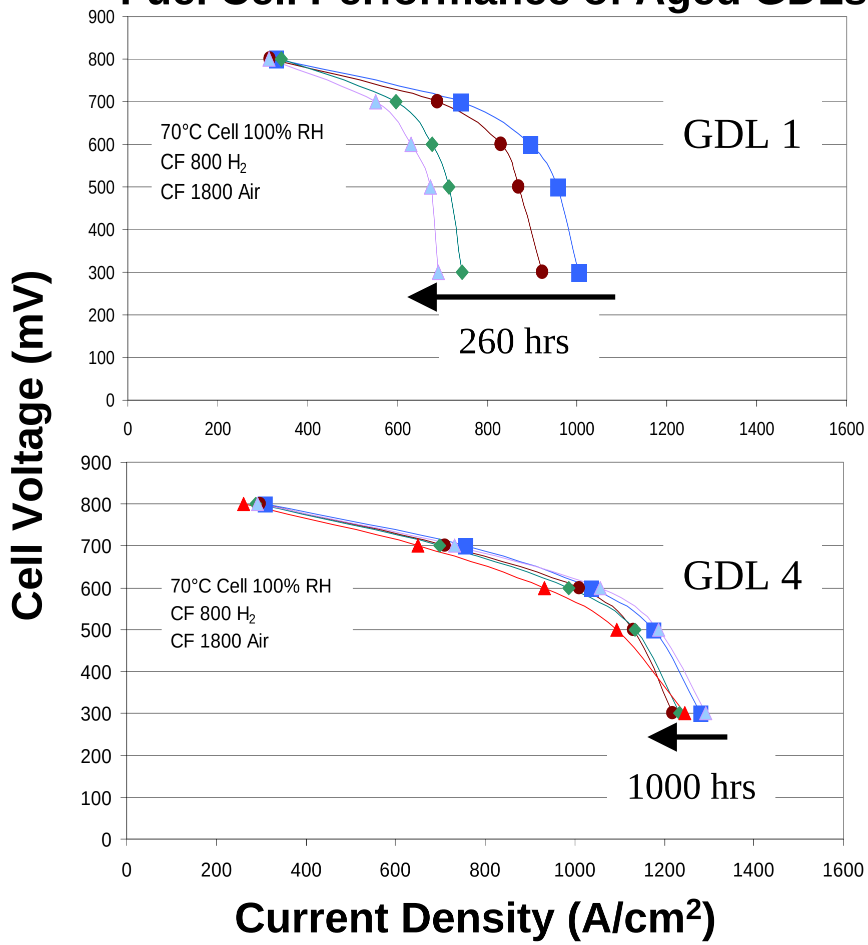
End Group Modified 3M Membrane

- More oxidatively stable
- Equal fuel cell performance
- Equal conductivity

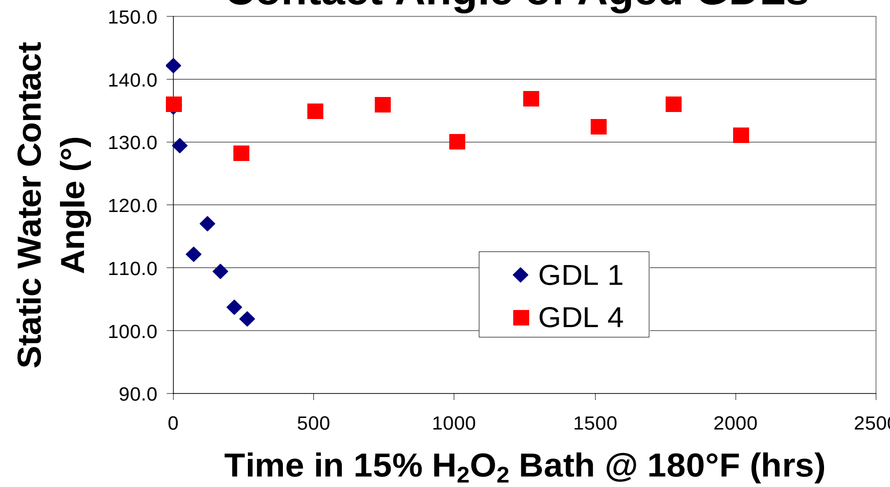
GDL Chemical Oxidative Stability

GDLs Aged in 15% H_2O_2 @ 180°F

Fuel Cell Performance of Aged GDLs

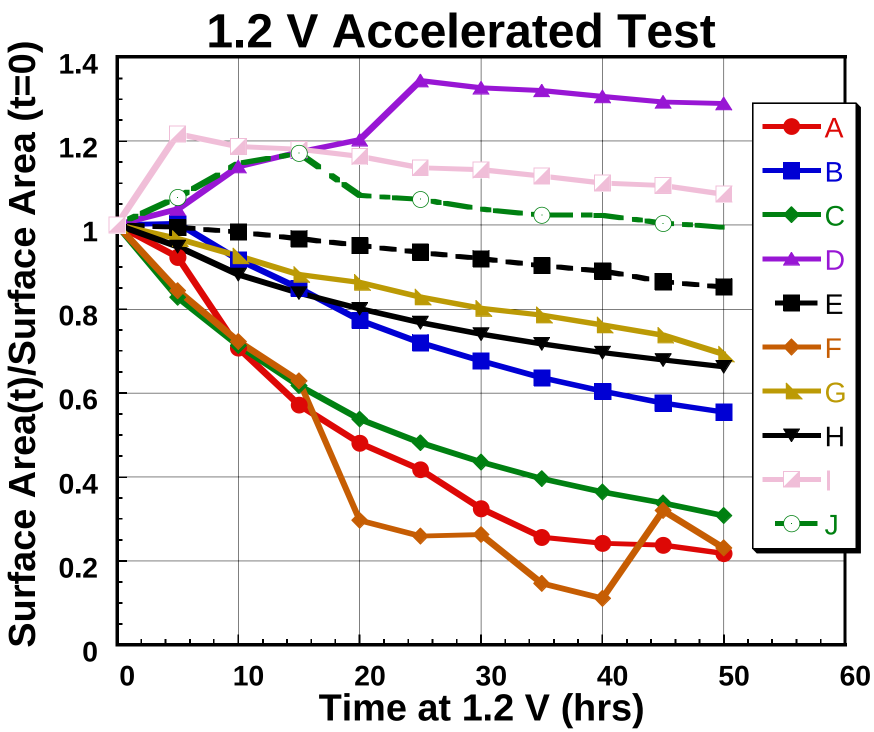


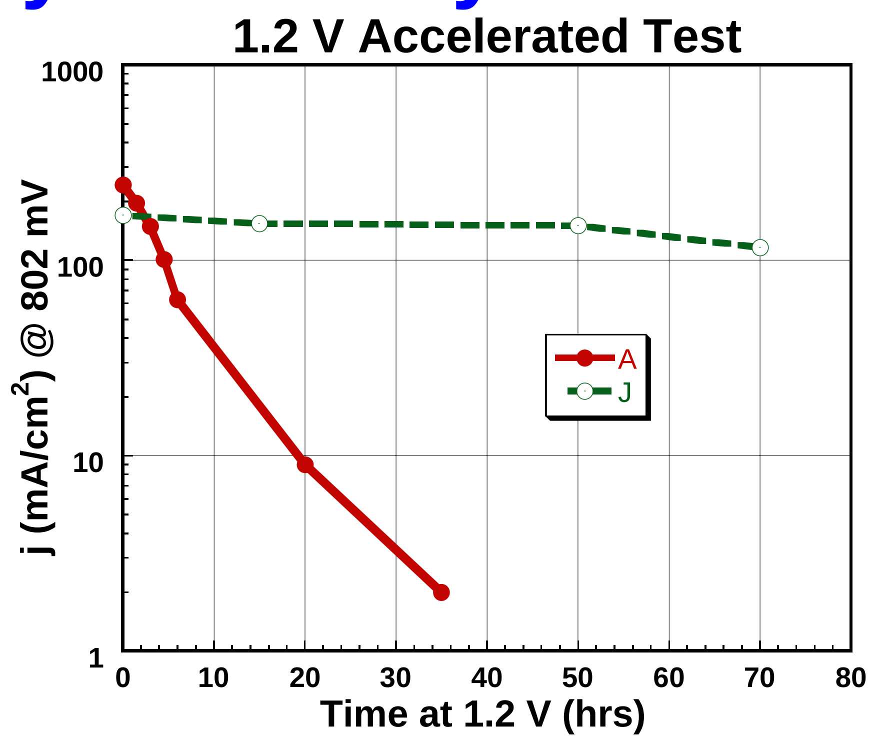
Contact Angle of Aged GDLs



- GDL oxidation affects performance
- Link between contact angle and durability
- GDL 1 shows poor stability
- GDL 4 does not easily oxidize

Cathode Catalyst Stability





Fuel Cell 500 hr Durability Test

Catalyst	ECSA Loss
A	25%
J	5%

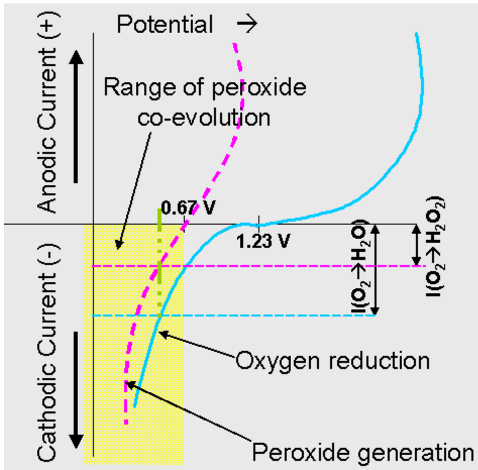
Investigated 10 catalysts labeled A to J
- Variables: support, metal loading and vendor

Surface area loss depends on catalyst type
- Results in loss of performance

1.2 V test results confirmed in fuel cell durability test

Note: Portion of data from DOE Program No. DE-FC36-02AL67621

CASE: Electrochemical H_2O_2 Co-generation Studies



Competing O_2 reactions:

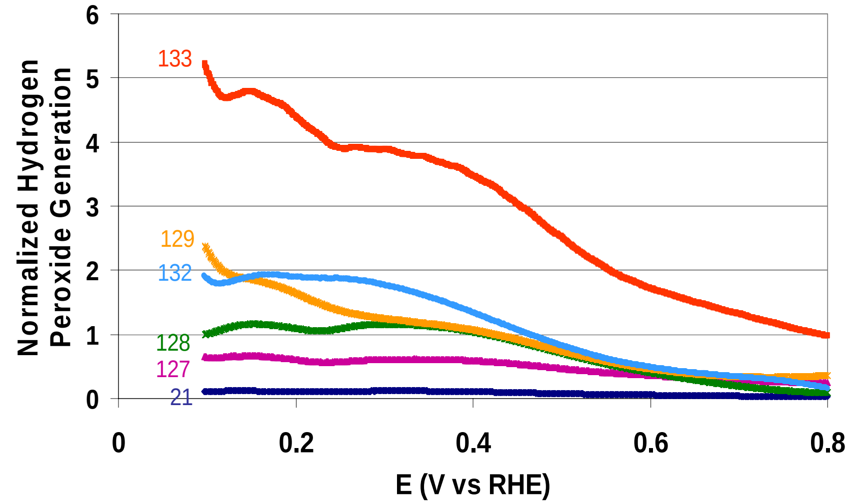
ORR

$$O_2 + 4e^- + 4H^+ \rightarrow 2H_2O$$

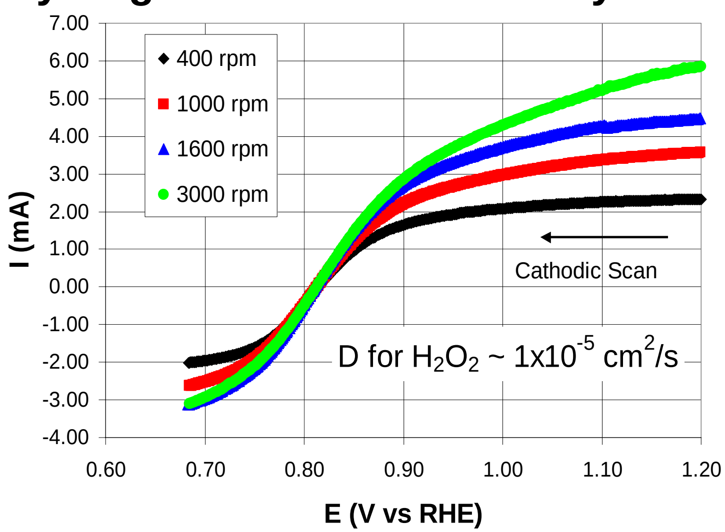
Hydrogen peroxide

$$O_2 + 2e^- + 2H^+ \rightarrow H_2O_2$$

Catalyst Hydrogen Peroxide Generation



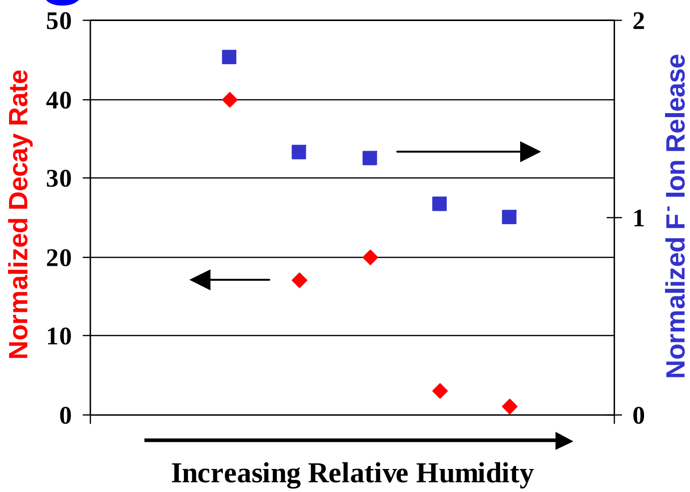
Hydrogen Peroxide Diffusivity in Acid

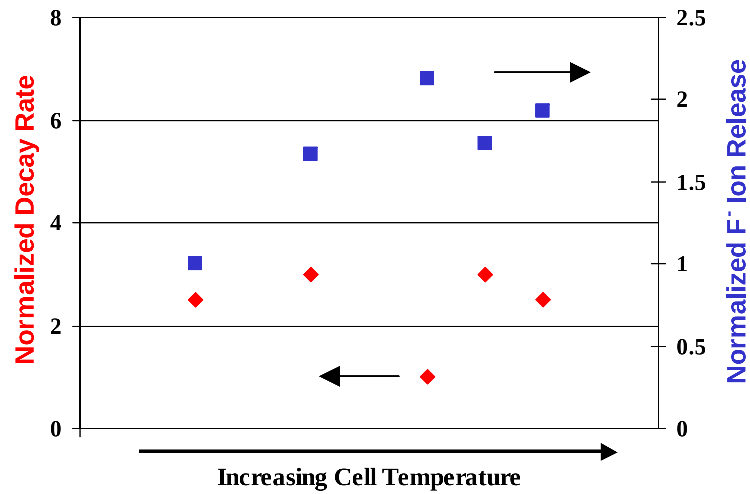


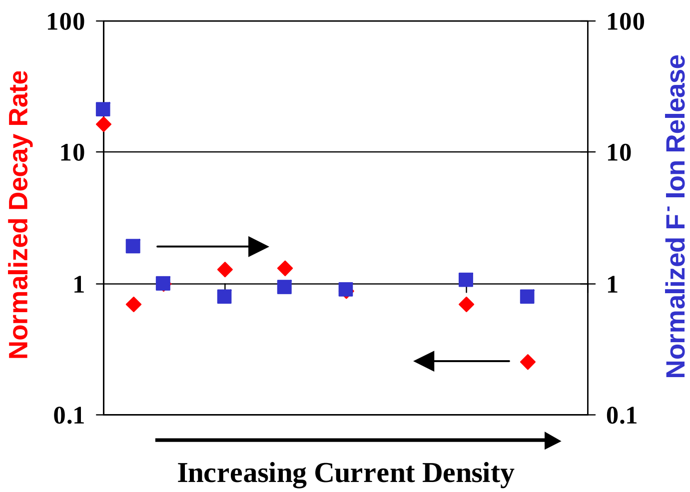
Measured hydrogen peroxide diffusivity via RDE
- Kinetic model on peroxide effects

Investigated 6 catalysts for hydrogen peroxide generation via RRDE
- Variables: support, metal loading and vendor

Plug Power: > 1000 hr MEA Latitude Testing







- Defining operating window
- Fluoride release and decay decrease with increasing relative humidity
- Fluoride release increases with cell temperature
- Decay independent of cell temperature
- Fluoride and decay decrease then level-off as current density increases

Interactions and Collaborations

- Plug Power
  - Performance and durability testing of single cells, modules and stacks
  - System and stack design
- Case Western Reserve University
  - Characterization test method development
  - Ex-situ accelerated test method development
  - Characterization of virgin and aged components and MEAs
- University of Miami (Finalizing subcontract)
  - 3M modeling of cell and MEA

Future Work

- Remainder of 2004
  - Ongoing MEA component development
  - Determine decay mechanisms and kinetic parameters
  - Develop accelerated lifetime predictor tests
  - Complete initial 3D model and segmented cell work
  - Study interactions of system parameters on MEA durability
- 2005-2006
  - Select MEA components
  - Link accelerated test results to lifetime
  - Develop and implement strategies to mitigate decay mechanisms
  - System demonstration