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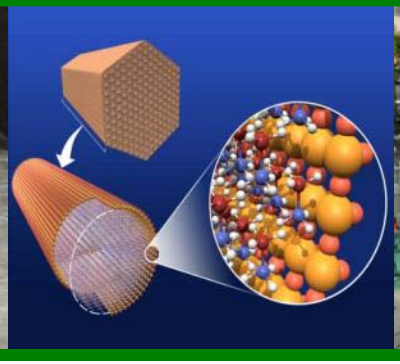

DOE's Hydrogen and Fuel Cells Technologies Manufacturing Sub-program

Nancy L. Garland, Ph.D.

U.S Department of Energy

NREL H_2/FC Manufacturing R&D Workshop

Washington, D.C.

August 11-12, 2011

Goal of Manufacturing sub-program

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- Goal: Research, develop and demonstrate technologies and processes that reduce the cost of components and systems for fuel cells, and hydrogen production, delivery, and storage; grow the domestic supplier base.
- Challenge: Move hydrogen and fuel cells from laboratory-scale production into high-volume, low-cost manufacturing.

Budget

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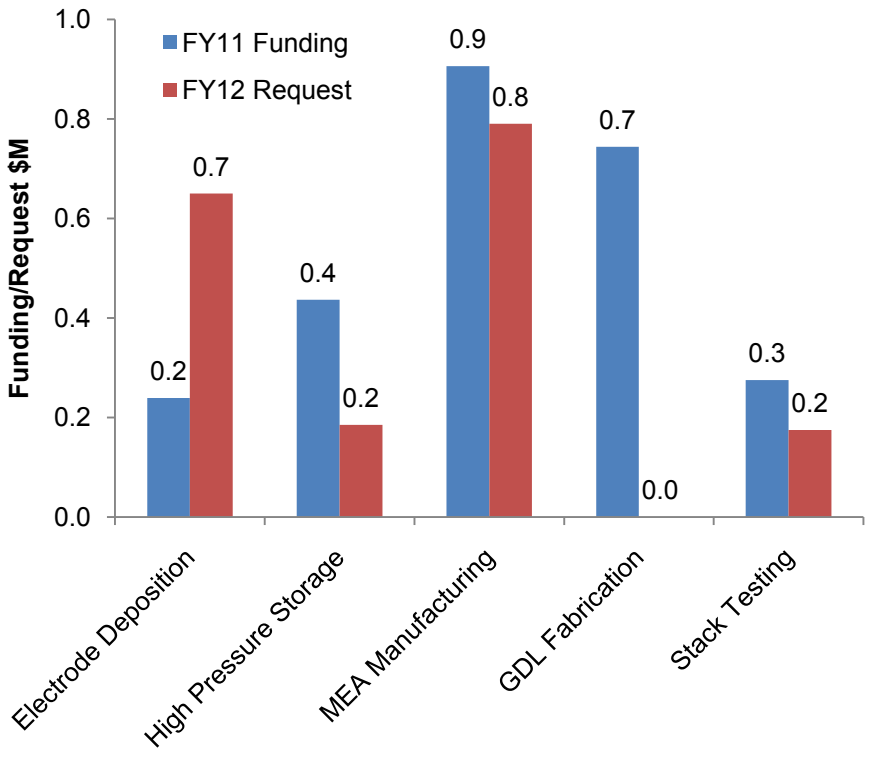
FY 2011 Appropriation = $3 M

FY 2012 Request = $2 M



EMPHASIS

- Develop novel, robust, ultrasonic bonding processes for MEAs to reduce MEA-pressing cycle time
- Develop real-time, online measurement tools to reduce/eliminate ex situ characterization, sampling, and testing
- Develop and demonstrate innovative precision fiber placement and commercial filament winding for high-pressure carbon composite tanks
- Conclude efforts on streamlining GDL fabrication techniques

Progress: GDL Fabrication Cost Reduction

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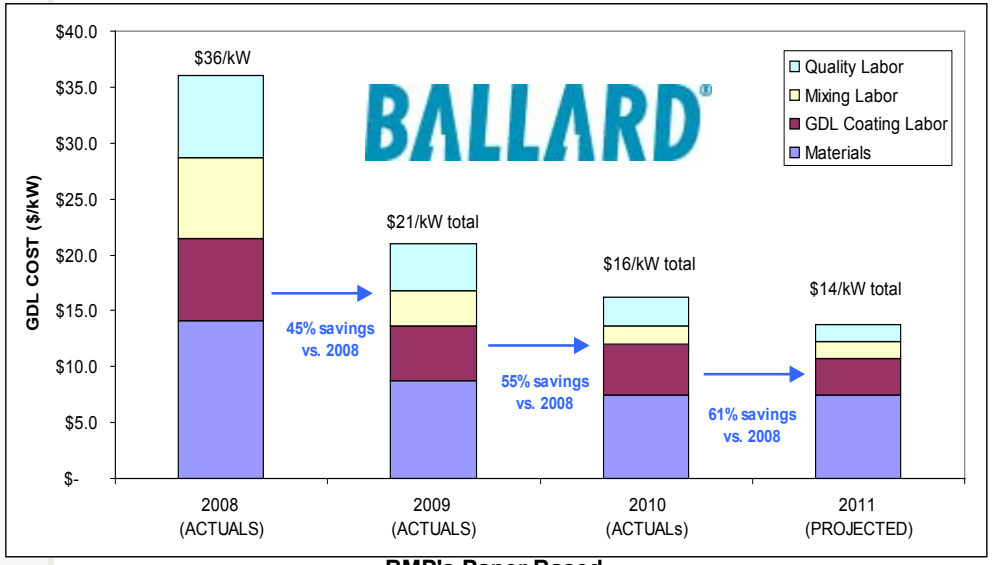
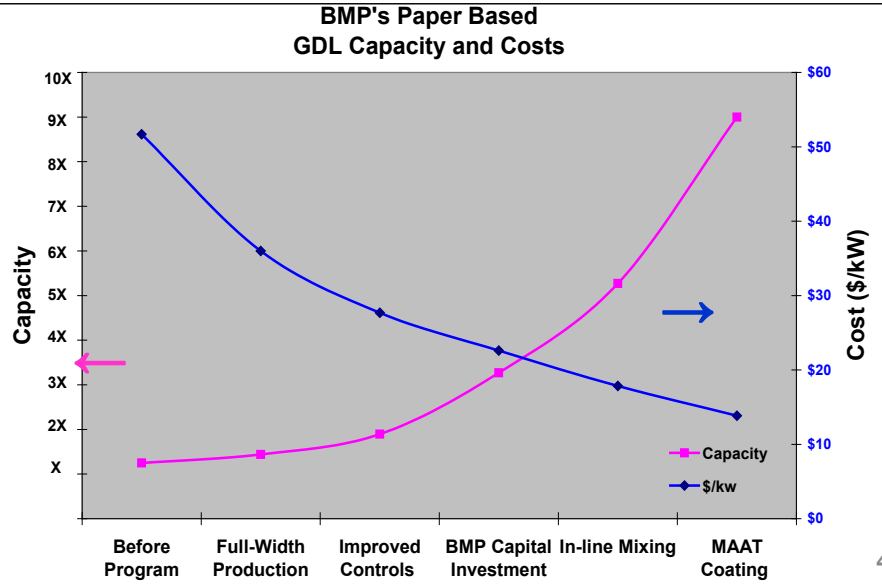
Reduced cost of GDLs by more than 50% and increased manufacturing capacity more than 4x since 2008

- **Ballard has shown GDL production capacity increases of 4x and cost decreases of 50% by:**
  - Eliminating process steps and reducing waste
  - Improving production yields and efficiency
- **Process modifications**
  - Full width production
  - Capital investment
- **Control modifications**
  - New quality control technologies such as mass flow meters to control microporous layer loadings
    - More uniform properties and reduce the amount of ex situ testing required
  - Add an in-line visual inspection station as a final quality tool to improve processing efficiency and accuracy
- **Next Steps**
  - In line mixing and "many at a time coating" (MAAT) are projected to achieve additional improvements





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Progress: Low-cost, durable MEAs

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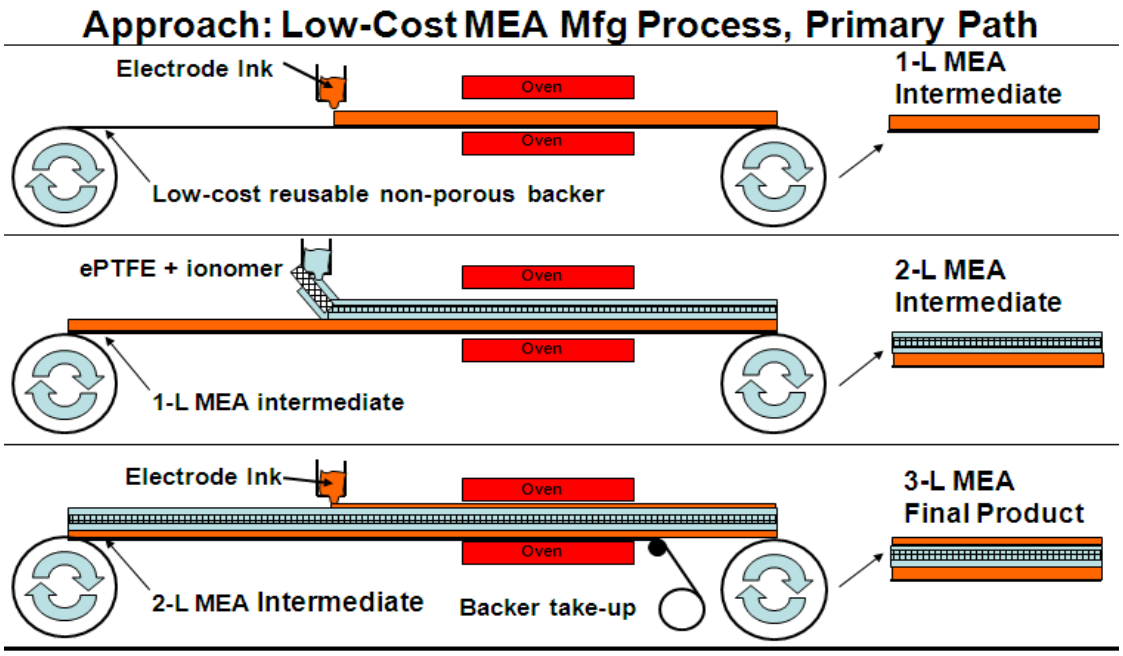
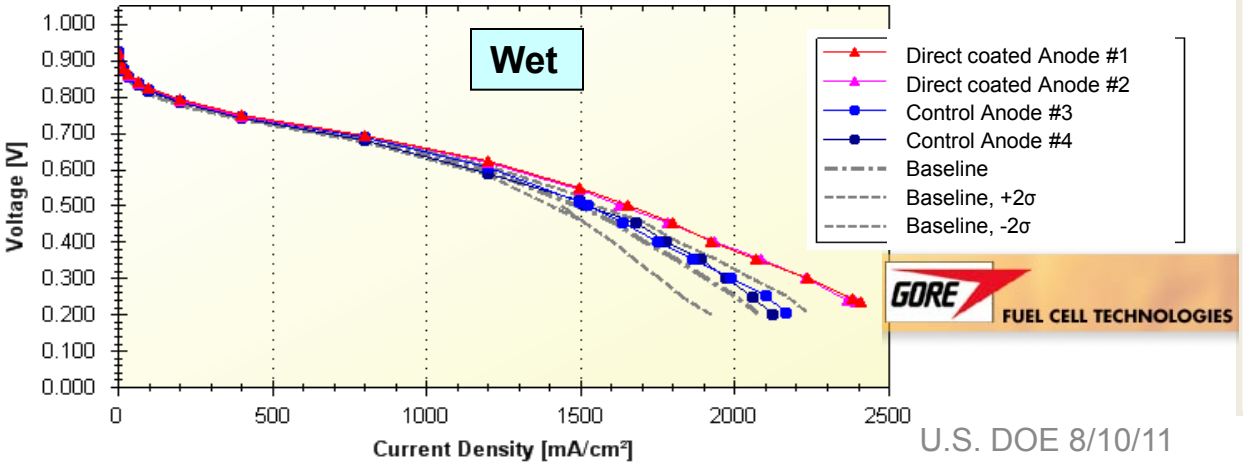
Increased performance by 200 mA/cm² at 0.4 V
by improving the membrane/anode interface through direct coating





GORE FUEL CELL TECHNOLOGIES

W. L. Gore increased performance and reduced MEA and stack cost

- Eliminated intermediate backer materials
- Reduced number of coating passes
- Minimized solvent use
- Reduced conditioning time

Enabling Technologies:

- Direct coating to form membrane-electrode interface
- Gore's ePTFE membrane reinforcement & PFSA ionomers enable durable, high-performance MEAs
- Modeling of mechanical stress and heat / water management
- Advanced fuel cell testing & diagnostics

Progress: Developing diagnostics for MEA manufacture

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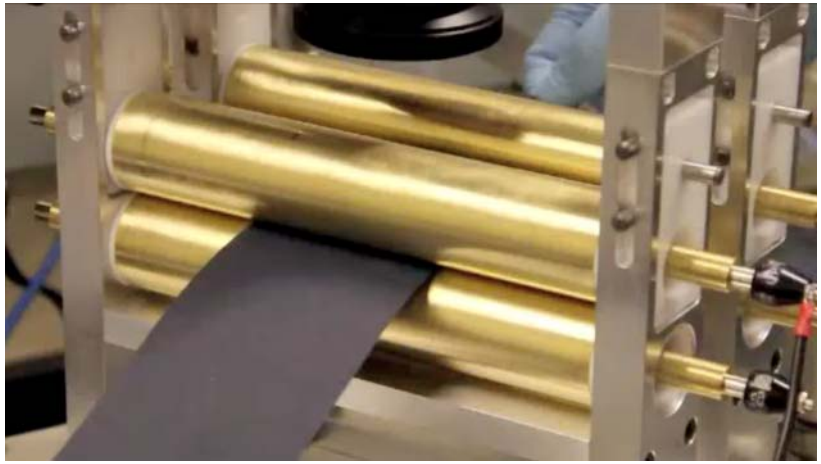
Achieved areal image of catalyst layer uniformity, technique can be scaled up for in-line testing

Project Approach:

Evaluate and develop in-line diagnostics for MEA component quality control, and validate in-line

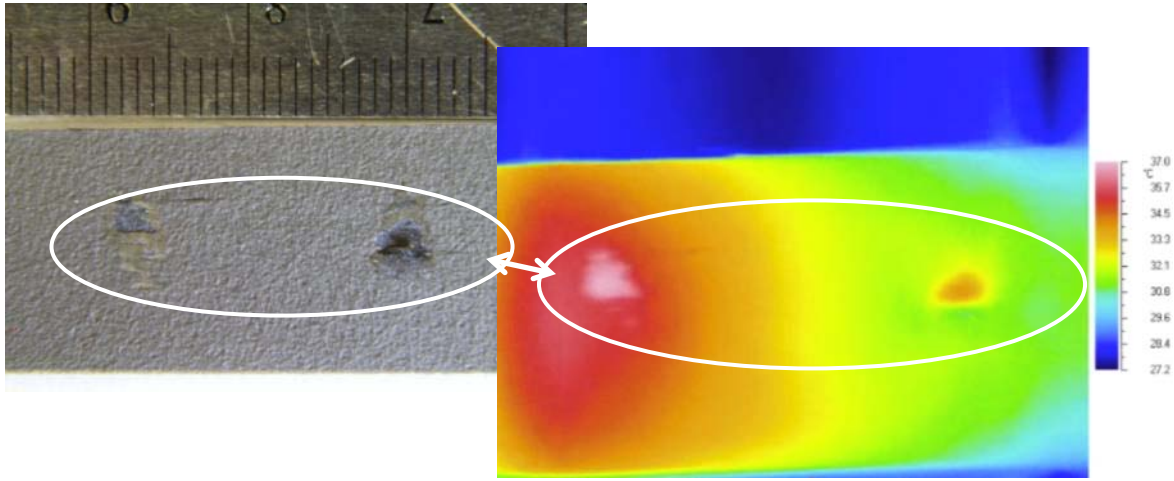
Investigate the effects of manufacturing defects on MEA performance and durability to understand the accuracy requirements for diagnostics

Integrate modeling to support diagnostic development and implementation



Example:

- DC excitation of catalyst-coated membrane causes thermal response
- Defects change catalyst layer resistance, thus altering the thermal response
- IR camera provides rapid, quantifiable 2D data



NREL NATIONAL RENEWABLE ENERGY LABORATORY

BERKELEY LAB

Progress – Lower cost hydrogen tanks

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Objective: To manufacture Type IV H_2 storage pressure vessels, using a new hybrid process with the following features: optimized elements of advanced fiber placement & commercial filament winding, improved understanding of polymer liner H_2 degradation

Improvements made between Baseline and Vessel 7:

- Composite mass reduced from 76 kg to 58.63 kg (22.9% reduction)
- Specific energy increased from 1.5 to 1.78 kWh/kg
- Cost efficiency reduced from $23.45 to $20.80/kWh for $11/lb carbon fiber
- Cost efficiency would reduce from $18.74 to $17.01/kWh for $6/lb carbon fiber

	Baseline 129L	Vessel 1	Vessel 7
Summary Table		FY-2010	FY-2011
	Filament Wound	Hybrid FW + AFP	Hybrid FW + AFP
Total Composite Mass, kg	76	64.9	58.63
Mass Savings, kg		11.1	17.4
Mass Savings, %		14.6	22.9
Specific Energy, kWh/kg	1.50	1.67	1.78
$11/lb Carbon, Cost Effic, $/kWh	$23.45	$21.75	$20.80
$6/lb Carbon, Cost Effic, $/kWh	$18.74	$17.63	$17.01

Workshop Agenda, Thursday August 11

U.S. DEPARTMENT OF ENERGY

Plenary (M. Ulsh, NREL) [Mount Vernon Square]

9:00 **Welcome and Program Overview** (S. Satyapal, DOE)
9:10 **Background/summary of DOE Hydrogen and Fuel Cell Manufacturing R&D activities** (N. Garland, DOE)
9:20 **DOE's Industrial Technologies Program Manufacturing Activities** (L. Christodoulou, DOE)
9:30 **Automation Status** (G. Sperrick, PMD Automation)
9:55 **Summary of DOD Manhattan Project** (J. Christensen, NREL)
10:00 **Low-Temperature** (D. Sousa, Ballard)
10:15 **High-Temperature** (D. Carter, Argonne)

10:30 Morning Break

10:45 **Summary of PEMFC Manufacturing** (E. DeCastro, BASF)
11:15 **Summary of High-Temperature FC Manufacturing** (S. Kanuri, UTC)
11:45 **Summary of High Pressure Tank Manufacturing** (M. Leavitt, Quantum)

12:15 Lunch [Mount Vernon Square]

Technical Session IA: **PEM cells/stack** (N. Garland, DOE) [Mount Vernon Square]
1:15 Invited Talk on industry status – stack manufacturing (D. Sousa, Ballard)
1:40 Breakout session – needs and barriers (M. Ulsh, NREL)
4:45 Session Summary/Wrap-up

Technical Session IIA: **High Temperature cells/stack** (T. Lucas, FCE) [rooms 12-14]
1:15 Invited Talk on industry status – stack manufacturing (M. Richards, Versa)
1:40 Breakout session – needs and barriers (D. Carter, ANL)
4:45 Session Summary/Wrap-up

Technical Session III: **Small Fuel Cell Systems with Hydrogen Storage** (N. Stetson, DOE) [room 16]
1:15 Invited Talk on industry status – (G. Rambach, TruLite)
1:35 Breakout session – needs and barriers (M. Lefenfeld, SiGNa)
4:45 Session Summary/Wrap-up
5:00 Adjourn

Workshop Agenda, Friday August 12

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Technical Session IB: **PEM/Electrolyzer BOP/system** (W. Podolski, ANL) [Mount Vernon Square]

8:30 Invited Talk on industry status – system (J. Torrance, Proton OnSite)
8:55 Invited Talk on industry status – other BOP (D. Frank, Hydrogenics)
9:20 Breakout session – needs and barriers (D. Wheeler, DJW Tech)

Technical Session IIB: **High Temperature BOP/system** (H. Ghezel-Ayagh, FCE) [rooms 12-14]

8:30 Invited Talk on industry status – fuel processing and other BOP (T. Litka, Acumentrics)
9:20 Breakout session – needs and barriers (S. Kanuri, UTC)

Technical Session IV: **Production and Delivery** (E. Miller, DOE) [room 16]

8:30 Invited Talk on industry status – Centralized Production (B. Bonner, Air Products)
8:50 Invited Talk on industry status – Tube trailer design/manufacturing (Norm Newhouse, Lincoln Composites)
9:10 Invited Talk on industry status – Distributed Production (P. Rao, Nuvera)
9:30 Breakout session – needs and barriers (E. Miller, DOE)

Summary (N. Garland, DOE) [Mount Vernon Square]

12:00 Summary Remarks IA
12:10 Summary Remarks IIA
12:20 Summary Remarks III
12:30 Summary Remarks IB
12:40 Summary Remarks IIB
12:50 Summary Remarks IV
1:00 Overall Summary, Next Steps, and Dismissal
1:10 Adjourn

For More Information

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Many thanks to Workshop Organizing Committee!

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Cassidy Houchins, SRA

Nancy Garland, DOE

Michael Ulsh, NREL