Fuel Cell Manufacturing R&D

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Motivation for Our Research

IF we are ever going to realize the significant potential benefits of the switch to a hydrogen economy-

•"The most necessary breakthrough [in order for the hydrogen economy to develop] will have to be cost reductions of fuel cells through the development of large-scale manufacturing capabilities for stationary and mobile units" (DOE 2002).

•"Research and development are needed to enhance the manufacturing capabilities and lower the cost of fuel cells..." (Davis 2002).

•"With fuel cell technology now moving out of the laboratory, the emphasis has shifted to reducing costs in preparation for mass production" (AMI 2002).

•"Manufacturability is the main reason we are not seriously exploring them [fuel cells] for application to increment 1 in future combat systems" (Kotchman 2003).

•"Core Technology Development should focus more attention on advanced materials, manufacturing techniques, and other advancements to lower cost, increase durability, and improve reliability of fuel cell systems."
(DOE, *Fuel cell Report to Congress,* February 28, 2003)

1

The Challenge and Risk

The Fuel Cell Manufacturing Challenge-

Any time you change one or more of the following you may have a profound impact on the viability of certain manufacturing processes and systems
- •Fuel cell type
- •Fuel cell or component architectures
- •Materials
- •Application
- •Fuel cell size

The Risk-

If we do not aggressively pursue Research and Development of fuel cell manufacturing methods and systems we may well find ourselves in the position of leaders in the design and development of fuel cells, only to have the value added manufacturing performed off-shore.

What if fuel cells don't succeed? Will all of our investments be wasted?

BUT,

What if fuel cells do succeed? Will we be prepared for a potentially explosive growth in demand?

2

The Opportunity

One simple example of the potential-

Laptop Computers

- •2002 sales of approximately 30M units
- •Sales could reach 100M/year
- •If each computer uses 20 MEAs…
- •That's an annual demand potential of 2 Billion MEAs and bi-polar plates per year, plus end plates, cell gaskets, balance of plant, etc.
- •Assume a market penetration, say 20%, that's still 400Million MEAs per year- from just one application.

…and What About?

- •Cell phones
- •PDAs
- •Hand held data acquisition devices
- •Stationary power supplies
- •Automotive
- •Marine
- •Military (radios, portable power, APUs, etc)

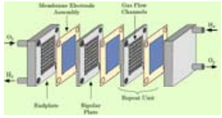
Who will be prepared?

3

Our Strategic Focus

The focus of our fuel cell manufacturing research is on fuel cell stacks, their materials and components, and the production and assembly thereof.

Ballard Fuel Cell Stack. Photo courtesy of USDOE



Schematic of typical PEM fuel cell stack and components (Woodman, 1999)

Example Projects (below):
- •Automated assembly of high temperature PEM MEAs
- •Slot die design for membrane casting
- •Stack assembly consortium
- •Experimental press design
- •Energy efficient manufacturing processes for MEAs

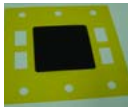
4

Automated Assembly of High Temperature PEM MEAs

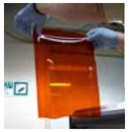
•Partner: PEMEAS Fuel Cell Technologies (Frankfurt, Germany)

•Objectives: Develop manufacturing processes and pilot manufacturing line for assembly of high temperature MEAs

•Approach:
- •Phase I- Analysis, concept development, determine best technical approach
- •Phase II- Proof of principle models, experimentation, system specifications
- •Phase III- Select automation company, detailed design and build oversight
- •Phase IV- Ongoing manufacturing R&D



Typical Membrane Electrode Assembly



High Temperature PBI Membrane

PEMEAS Fuel Cell Technologies

5

Automated Assembly of High Temperature PEM MEAs

Membrane handling POPM in lab

Concept design for pilot line

•Fully automated MEA assembly line

•Modular hardware and controls architecture

•Flexible processes and systems

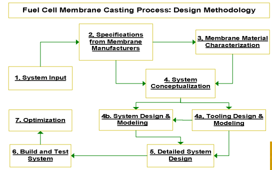
•Capability to grow capacity

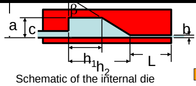
MEA pilot line and membrane process module, Frankfurt, DE. Dedicated September, 2002.

PEMEAS Fuel Cell Technologies

6

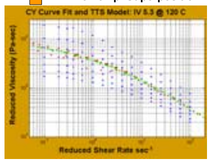
Membrane Casting – Slot Die Design





Schematic of the internal die geometry

Empirical Viscosity (η) Model: Carreau Yasuda & Time Temp. Superposition



- Dynamic Viscosity
- Reduced Viscosity
- Empirical Viscosity Curve

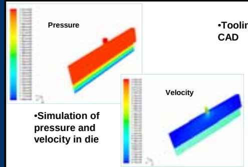
$\eta = f(T_r, \dot{\gamma})$

where T_r = 1000/T K^{-1}

$$\eta = 1200 * (6\times10^{-6} e^{4.929T_r}) * \left[1 + (0.3076 \cdot (6\times10^{-6} e^{4.929T_r})\dot{\gamma})^{0.3505}\right]^{\frac{0.1714-1}{0.3505}}$$

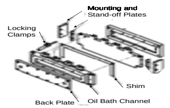
7

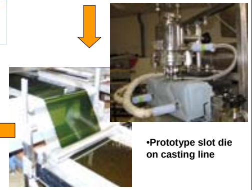
Membrane Casting – Slot Die Design



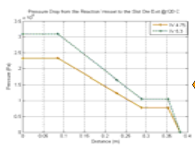
•Simulation of pressure and velocity in die

•Tooling design in CAD





•Prototype slot die on casting line



•Model Validation

8

Fuel Cell Stack Assembly Research Consortium

•While many fuel cell system components have similarities to other manufactured components, the stack is fairly unique.
•A fuel cell stack can consist of several hundred layers of thin fragile materials, each with its own dimensional tolerances.
•Assembly and material tolerances can result in poor sealing and stack failures.

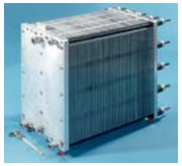


Photo courtesy of DOE/NREL

•Planning workshop to be held in 3Q06, with the consortium membership starting in 4Q06

•CATS researchers have secured the first ever research equipment grant from the Robotics Industries Association (RIA) to support this research.

•For more information, see http://www.CATS.RPI.EDU

9

Experimental Press for MEA Assembly Processes

•There is a need to better understand the relationships among:
- •MEA component material properties
- •Manufacturing process parameters
- •Resulting MEA material attributes, and
- •Performance of the MEA in a stack

•The experimental press being built by CATS researchers will provide the tools necessary to investigate these relationships.

•We anticipate that the knowledge gained from these investigations will lead to more effective process controls and improved fuel cell performance.

Press features:
- •Position/velocity control
- •Force control
- •Temperature control
- •Displacement sensors
- •In-situ electrical measurements

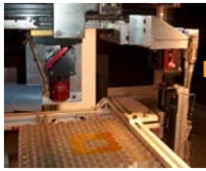
10

Energy Efficient Manufacturing Processes for HT MEAs

•Partner: Progressive Machine and Design (Victor, NY)

•Sponsor: New York State Energy Research and Development Authority (NYSERDA)

•Objectives: To investigate alternative manufacturing processes and systems that will save energy, reduce costs, and improve product quality



•CATS laser processing testbed
- •60 W, CO_2, 9.3 μm laser
- •5W, DPSS UV, 355nm laser
- •Precision linear stages
- •Flying optics
- •Servo positioned tooling

PMD NYSERDA

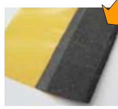
11

Energy Efficient Manufacturing Processes for HT MEAs

•UV laser photo-ablation of high temperature PEM membrane

•Goals for laser process: Reduce process tooling cost by an order of magnitude, and reduce tooling lead time by 80%

•Goals for ultrasonic welding: Reduce weld cycle time by 90%, increase weld strength by a factor of 2, compatible with a broad range of MEA materials.



•Faster, stronger welds with ultrasonics

12