Fuel Cell Manufacturing R&D

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The Team

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The Opportunity

- One simple example of the potential-
- Laptop Computers
  - 4Q2006 sales of >20M units, exceeding sales of desktop computers for first time
  - 2007 sales projected at 91.7M units, and 137M units in 2010
  - Assume a modest market penetration, say 20%, that's still 27.4M stacks per year- from just one application, 548 Million MEAs
  - That's 52 stacks per minute on a 24/7/365 basis, and 17 MEAs per second 24/7/365

Another Example

- DOE target of 500,000 cars/year
- That requires that one stack be assembled every minute on a 24/7/365 basis, 7 MEAs per second
- That requires that 250,000 m^2 of electrode be produced each day
- We simply cannot take a day or more to assemble an automotive fuel cell stack

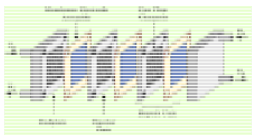
Stack assembly unit process cycle times must be measured in seconds! MEA unit processes in ms.

The Challenge

- 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
  - Design tolerances
  - Application
  - Fuel cell size

The CATS Focus

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



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

Plug Power Prototype HT PEMFC 5KW system on display at 2006 Hanover Fair in Germany

Example Fuel Cell Manufacturing Projects

- Development of a HT (i.e. PBI Based) PEM MEA pilot manufacturing line
- Energy efficient processes for the manufacture of PEM fuel cell MEAs
- Modeling, design and development of membrane forming techniques for Polybenzimidizole (PBI) based sol-gel membranes.
- Machine vision based inspection of HT PEM MEAs.
- Adaptive process controls for MEA pressing.
- Automated assembly of fuel cell stacks

Development of a HT PEM MEA Pilot Manufacturing Line

PBI Based MEA

Pilot line concept design

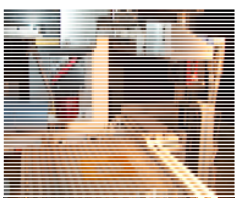
From Concept to Production

Pilot production line

POPM

Energy Efficient Manufacturing Processes for HT MEAs

- Partners: Progressive Machine and Design (Victor, NY) and BASF Fuel Cell
- 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

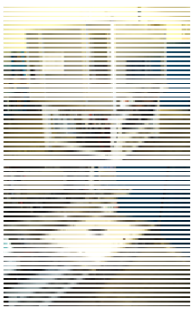


CATS laser processing testbed
- 60 W, CO_2, 9.3 mm laser
- 5W, DPSS UV, 355nm laser
- Precision linear stages
- Flying optics
- Servo positioned tooling

PMD PROGRESSIVE MACHINE & DESIGN

Energy Efficient Manufacturing Processes for HT MEAs

- Resulting commercial laser cell
  - UV or CO_2 lasers
  - High precision, high speed
  - Assist gas
  - Built in exhaust system
  - Certified class 1 laser system



Adaptive Process Controls for MEA Pressing

- 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
- An experimental press being built by CATS researchers will provide the tools necessary to investigate these relationships.
- Results obtained from the experimental press will then be applied to a custom commercial press.
- Similar techniques will be attempted with Ultrasonic sealing of MEAs.
- We anticipate that the knowledge gained from these investigations will lead to more effective process controls and improved fuel cell performance.
- We have just received a $2.5M grant from DOE to pursue this research.

Experimental Press

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

Commercial Press:
- 40 T capacity
- State of art controls
- Custom tooling
- Consigned to CATS by BASF Fuel Cell

Conclusions

- We cannot wait until we know all the answers to address key fuel cell manufacturing issues.
- There will be a "technology tipping point" that will result in an exponential growth of demand.
- To minimize risks employ modular, flexible manufacturing processes and systems.
- Major advances are required to make fuel cells viable on a wide-spread basis.

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