BASF Fuel Cell, Inc.
Manufacturing Barriers to high temperature PEM commercialization

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Background on BASF Fuel Cell

- BASF Fuel Cell was established in 2007, formerly PEMEAS Fuel Cells (including E-TEK)
- Product line is high temperature MEAs (Celtec® P made from PBI-phosphoric acid)

Ribbon-cutting hosted by Dr. Kreimeyer (BASF BoD, right) and attended by various US public officials including former NJ Governor Jon Corzine (left)
Multi-layer product of membrane (polybenzimidazole and phosphoric acid), gas diffusion material and catalysts

Unique characteristics:

- High operating temperature (120 to 180 °C)
- A hybrid of proven phosphoric acid technology with the simplicity of a polymer membrane electrode assembly
- No humidification necessary
- Tolerance to impurities in hydrogen gas
- Far simpler system due to elimination of water and a less complex reformer technology
Celtec® MEA derived from two innovations

1. Formation of PBI Membrane in polyphosphoric acid
   - >90% phosphoric acid by wt

2. Gas Diffusion Electrode
   - Specially designed multi-layer structure for phosphoric acid membrane
   - Fabricated on a roll coater
Performance and Durability
Celtec® P 1000 MEA

Celtec P 1000:
- High performance under reformate with 1% CO
- 20,000 hr. life time verified in steady state operation, voltage drop < 6µV/hr

Test conditions:
- Single cell 45 cm²
- Temperature: 160 C
- No humidification
- Ambient pressure
- Anode: H₂, lambda 1.2
- Cathode: Air, lambda 2.0
- Reformate:
  - 70% H₂, 29% CO₂, 1% CO
Celtec®-P MEA: CO Tolerance

- High level of CO is tolerated due to the high operating temperature
- Preferred range is 160 to 180 C and ~ 1% CO
- Immediate recovery from anode poisoning in the case of CO-peaks
Celtec®-P MEA: Influence of Humidification

- Celtec-P MEA can be operated independently of humidification
- Robust against deviations in temperature
Benefits of HT PEM Technology: Reduction of System Complexity

High temperature PEM technology allows one to simplify the fuel cell system, especially in the case of reformate feed.
Fuel cells in the μCHP market
Energy cost and CO₂-calculation for single family house

5 kW HT-PEM Fuel Cell

- Reduciton of yearly energy costs by 20 %
- Reduction of CO₂-emissions by 2,500 kg/a (17 %)

Efficiency = Improve cost
Manufacturing Barriers

BASF is interested in mass markets for fuel cells

Market forces appear to favor distributed generation

μ - combined heat and power fuel cells offer value in this market

High volume manufacturing technologies are key
Celtec® MEA Manufacturing Cycle
All occur on site

Electro-catalyst → Pt salt reduction

Catalyst ink → Formulation

Carbon ink → Gas diffusion layer (GDL)

Gas diffusion electrode (GDE) → Coating

Sintering → Sintering

Celtec® MEA → Assembly

PBI solution → Polymerization

PBI Membrane → Casting
Membrane Electrode Assembly (MEA)
5 Layer Assembly

GDEs and membranes are pre-cut and assembled on robotic lamination line.
Manufacturing Barriers

What if MEA subcomponents were designed for manufacturing?

- High throughput GDE production
- Sub gasket eliminated
- High speed lamination for large format MEAs

Foresee innovation in materials and process technologies
Manufacturing Barriers
Ultrasonic welding / RPI

• Typical 5 and/or 7 layer MEA has multiple components
  Goal is to make ready for assembly
  Need to laminate numerous components

• Traditional Thermal methods ("hot press"), while low cost, suffer from low throughput and low energy effectiveness

Ultrasonic welding unproven at the large MEA size needed for μCHP
Manufacturing Barriers
Defect detection / scrap minimization

- On-line defect detection
  “black on black” defects a challenge
  Lifetime impact of defects

- Scrap minimization due to platinum content
  Optimized cutting programs
  Maximize yield from point defect sections

High Pt value and substrate in GDEs forces utmost in yield optimization
Manufacturing Barriers

Need standardized MEA platforms

The industrial revolution was built on standardization
Manufacturing Barriers
Need standardized MEA platforms

Aligns supply chain
Aggregate demand lowers cost earlier
Critical to widespread adoption

Standardization allows build up of critical mass for manufacturing efficiencies
### BASF FC Standards

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<th>Active Area</th>
<th>Small APU</th>
<th>Mobility APU</th>
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Only a few standards needed to cover wide range of power needs