BASF Fuel Cell, Inc.

Manufacturing Barriers to high temperature PEM commercialization

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The Chemical Company

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)
- Dedicated a new advanced pilot manufacturing facility in Somerset NJ May 2009.

Ribbon-cutting hosted by Dr. Kreimeyer (BASF BoD, right) and attended by various US pubic officials including former NJ Governor Jon Corzine (left)

Celtec ® -P MEA for power generation Membrane Electrode Assembly

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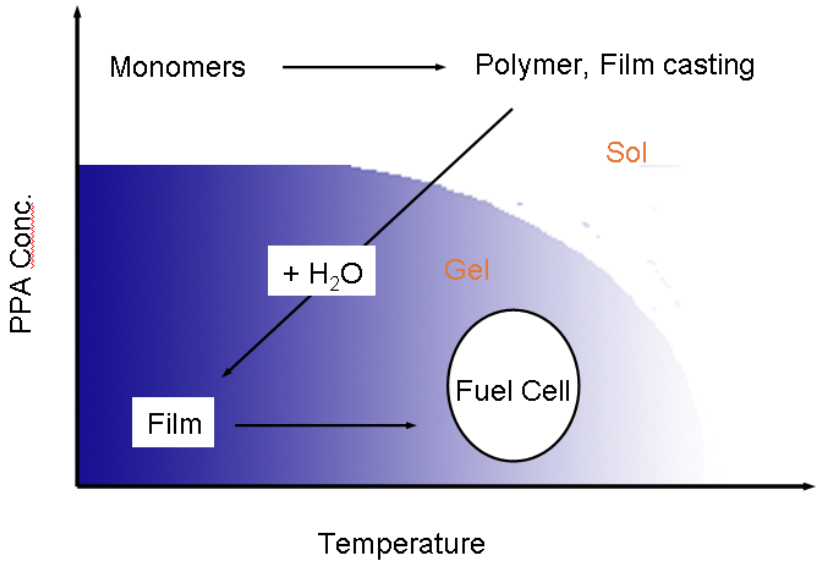
Multi-layer product of membrane (polybenzimidazole and phosphoric acid), gas diffusion material and catalysts

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



PBI membrane

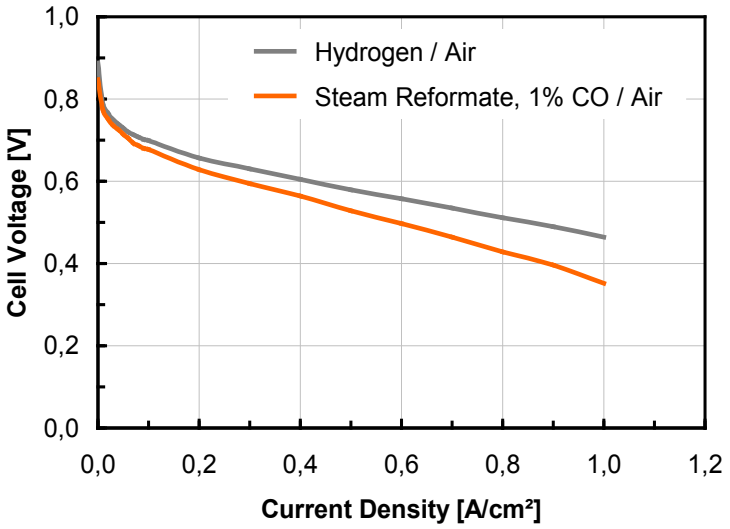
1. Formation of PBI Membrane in polyphosphoric acid

- >90% phosphoric acid by wt

2. Gas Diffusion Electrode

- Specially designed multi-layer structure for phosphoric acid membrane
- Fabricated on a roll coater

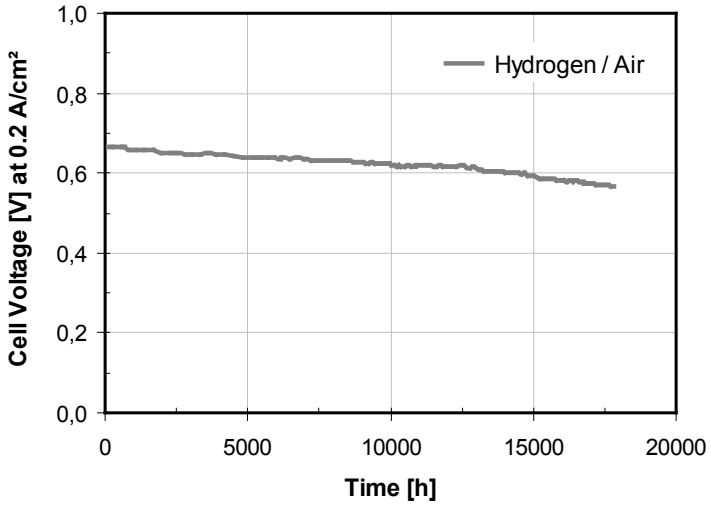
Performance and Durability
Celtec® P 1000 MEA



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

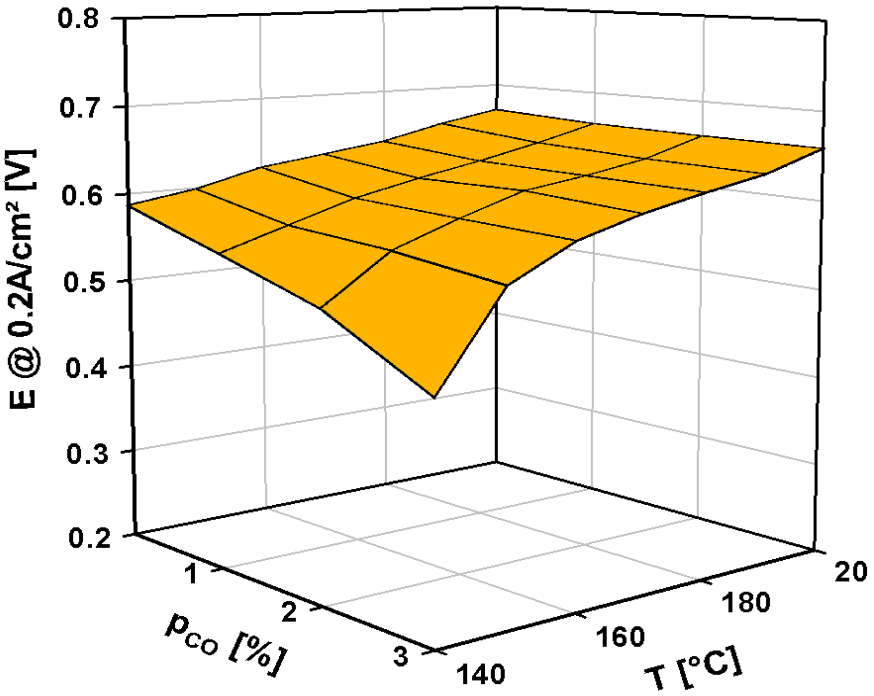
Celtec P 1000:

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



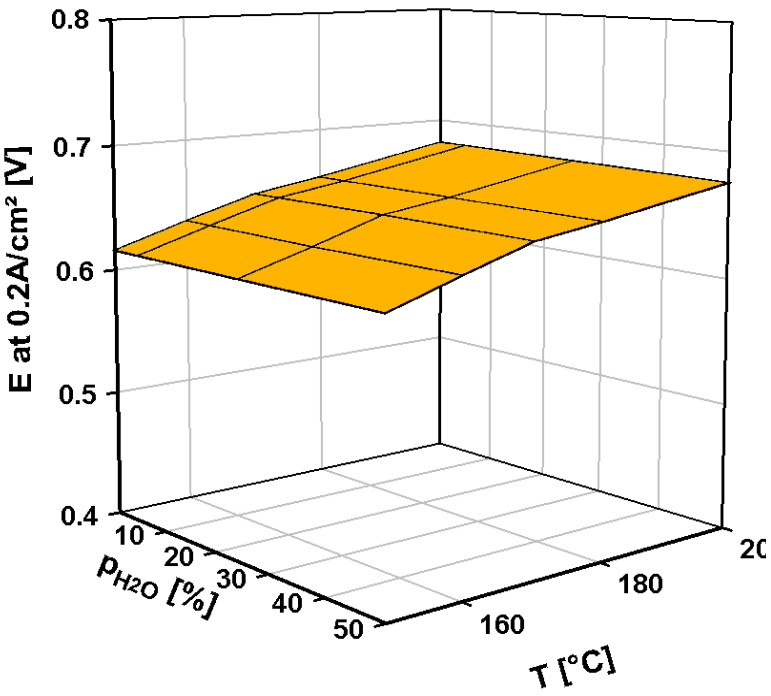
Celtec®-P MEA: CO Tolerance

- 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

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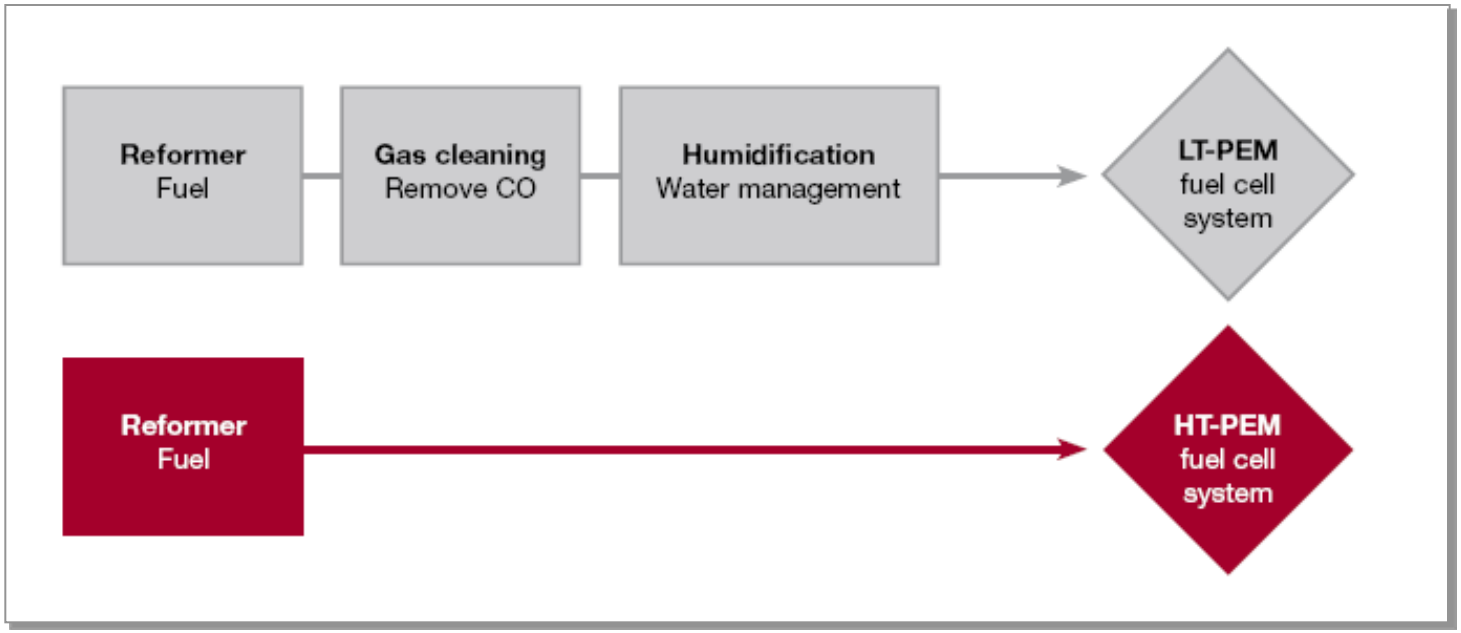
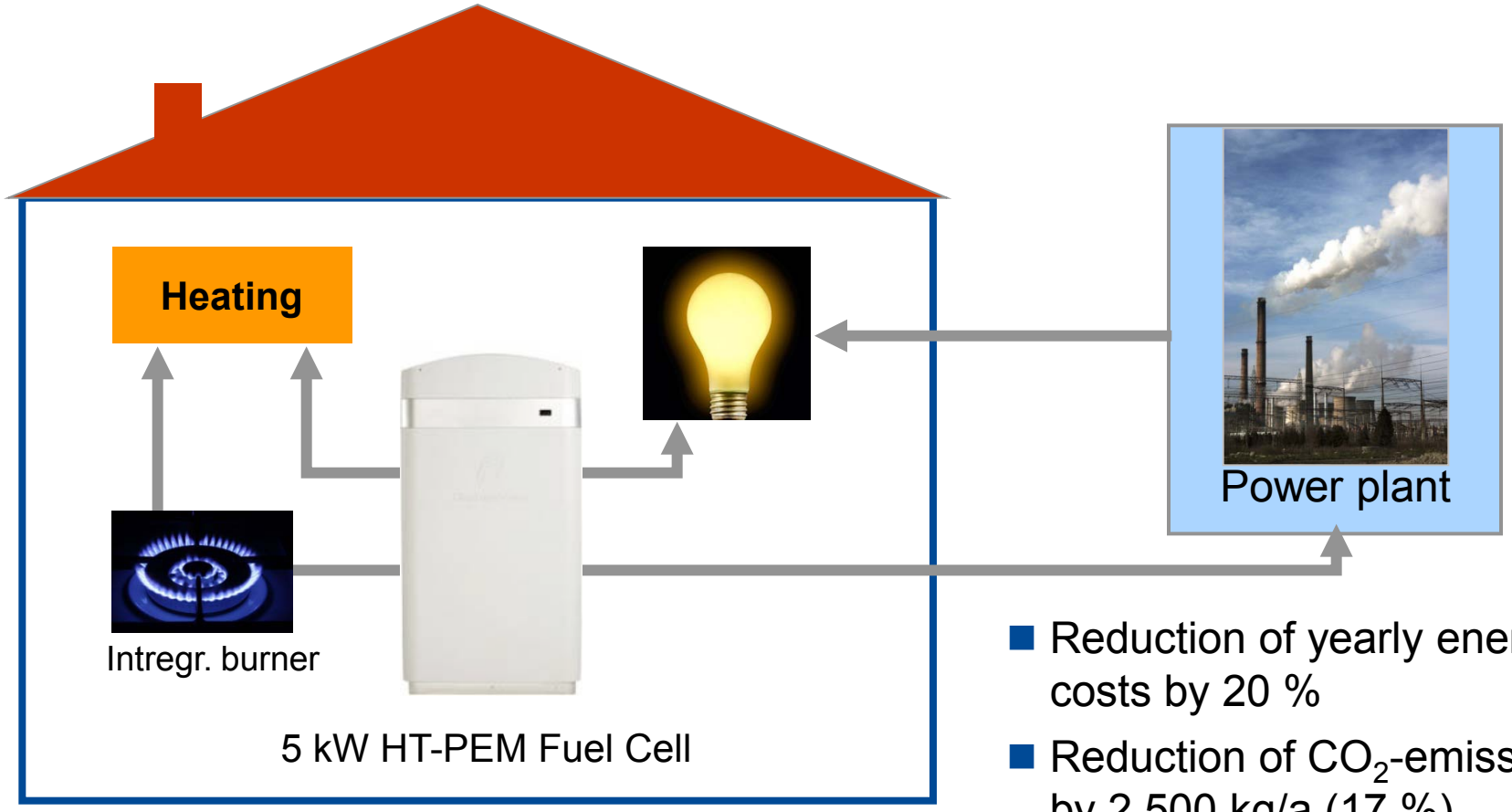


High temperature PEM technology allows one to simplify the fuel cell system, especially in the case of reformate feed.

Fuel cells in the µCHP market

Energy cost and CO_2-calculation for single family house



- Reduction of yearly energy costs by 20 %
- Reduction of CO_2-emissions by 2,500 kg/a (17 %)

Efficiency = Improve cost

Manufacturing Barriers

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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

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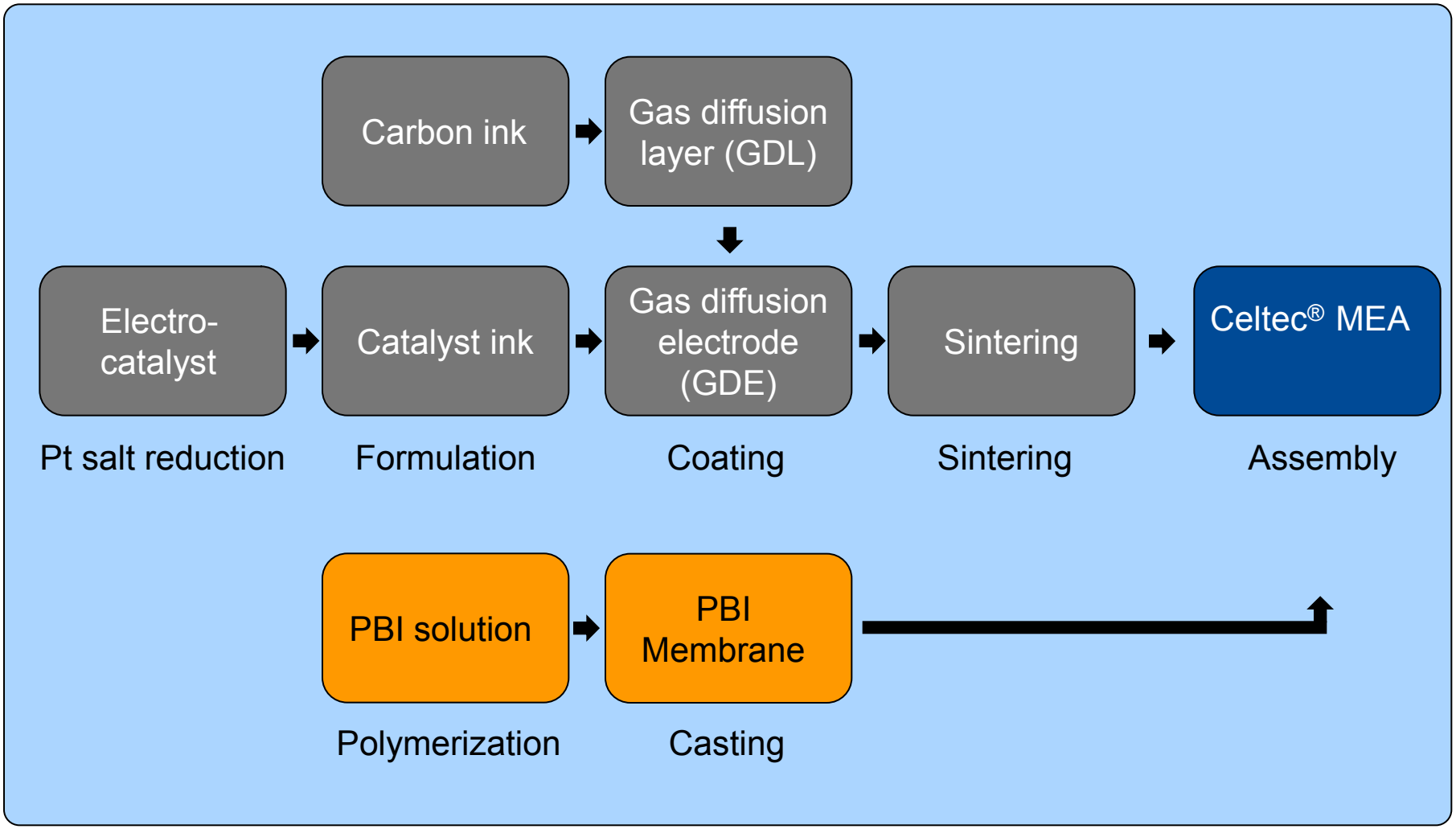

Membrane Electrode Assembly (MEA)
5 Layer Assembly

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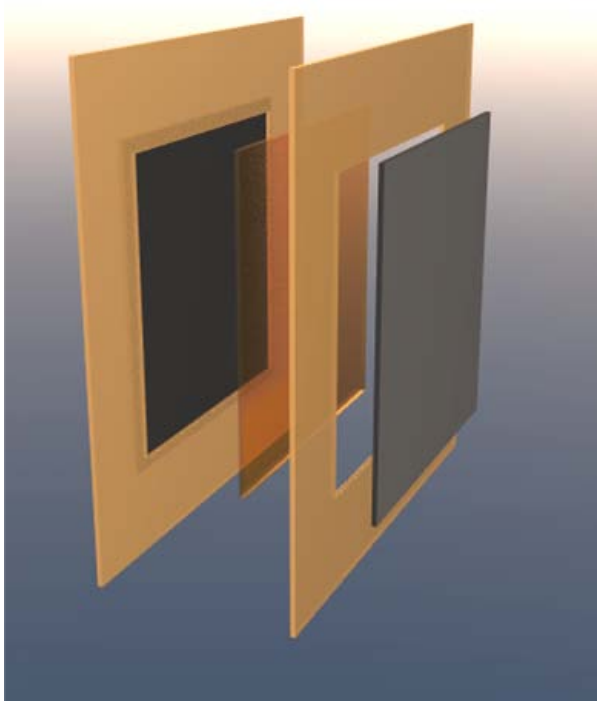

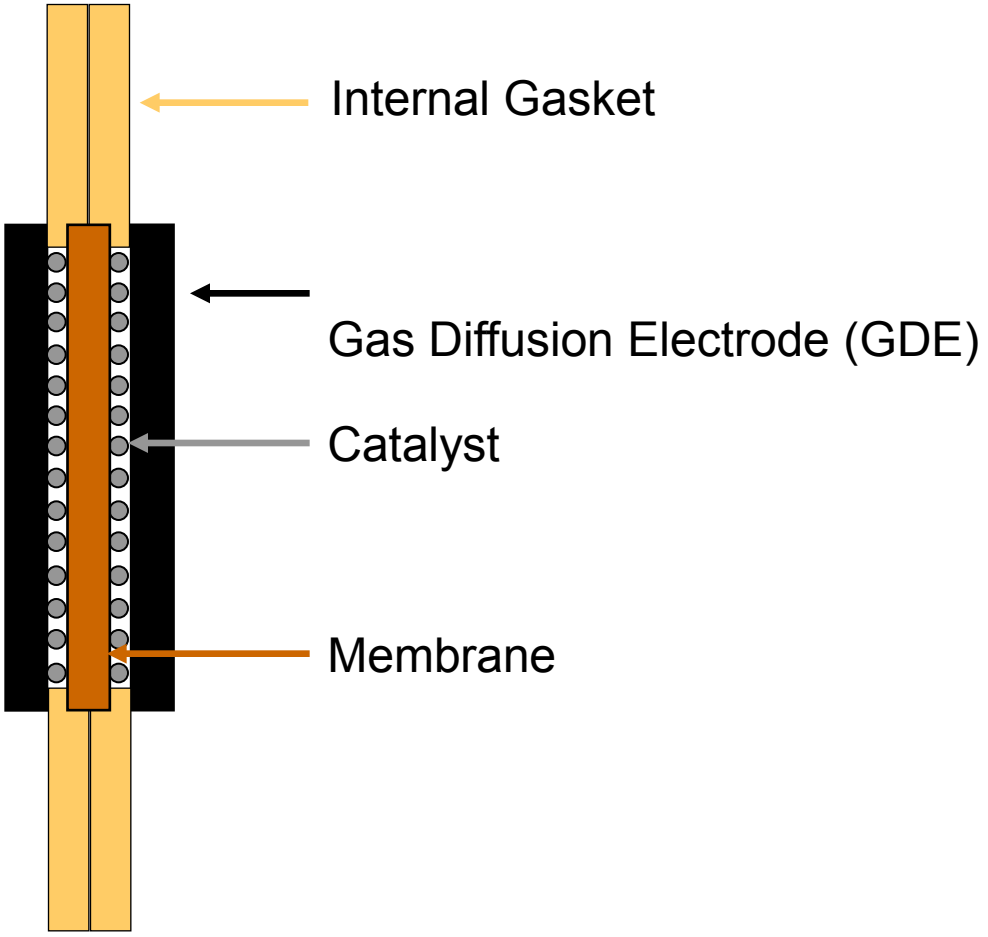

GDEs and membranes are pre-cut and assembled on robotic lamination line

Manufacturing Barriers

What if MEA subcomponents were designed for manufacturing?

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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

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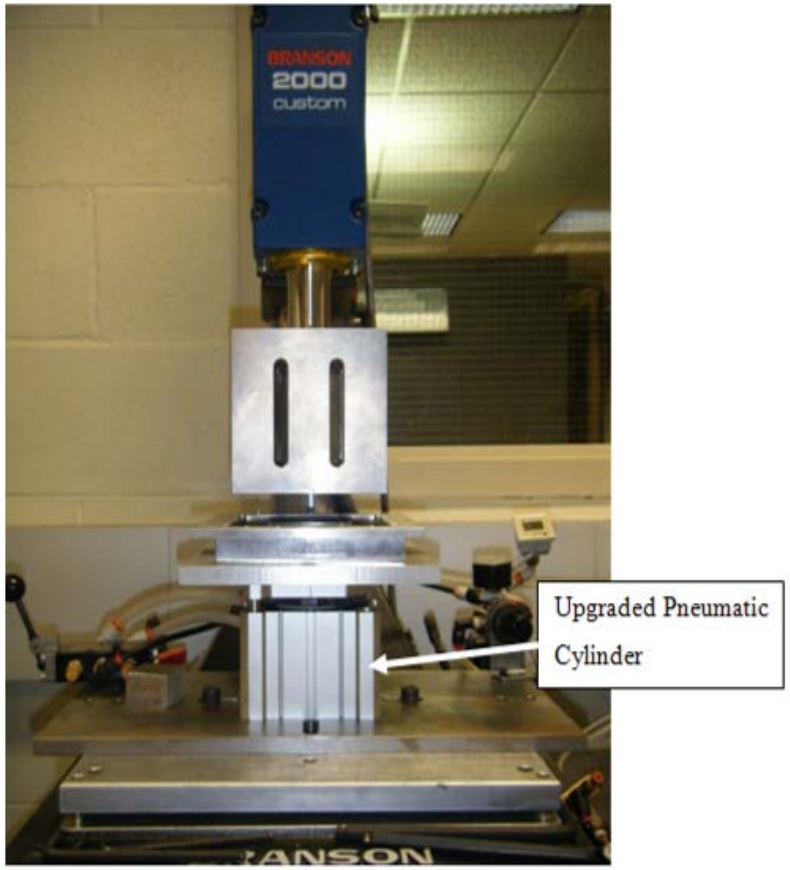
- Typical 5 and/or 7 layer MEA has multiple components
  - Goal is to make ready for assembly
  - Need to laminate numerous components

- 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

Agglomerate

Uncoated sections

On-line XRF for Pt distribution

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

Manufacturing Barriers

Need standardized MEA platforms

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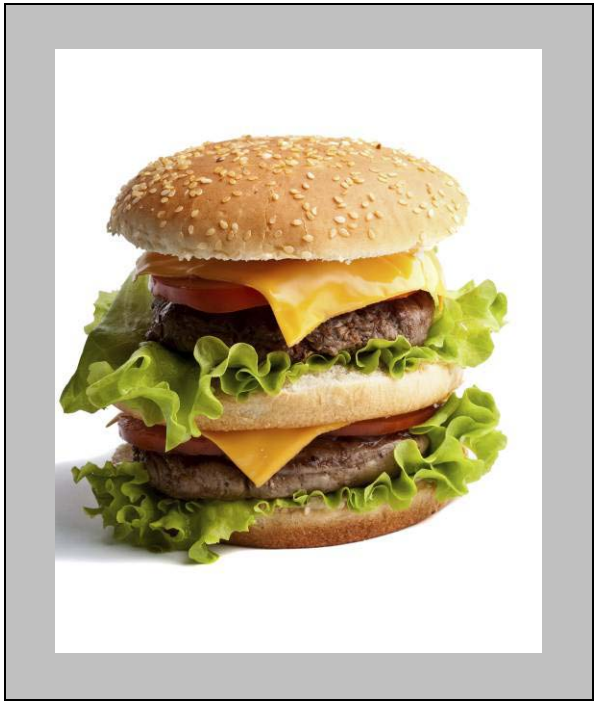

The industrial revolution was built on standardization

Manufacturing Barriers

Need standardized MEA platforms

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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

Active Area	**Small APU**	**Mobility APU**	**µCHP**
cm^2	<1 kW	1-5 kW	1-5 kW
45	✓	✓	
165	✓	✓	✓
605			✓

Only a few standards needed to cover wide range of power needs

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