

# Carbon Composite Bipolar Plate for PEM Fuel Cells

T. M. Besmann, J. W. Klett, and J. J. Henry  
Metals and Ceramics Division  
Oak Ridge National Laboratory

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# Objective

To develop a slurry-molded, carbon fiber material with a carbon chemical vapor infiltrated (CVI) sealed surface as a bipolar plate that would meet cost and property goals.

<u><i>Property</i></u>	<u><i>Specification</i></u>
Bulk Conductivity	> 100 S/cm
H <sub>2</sub> permeability	<2 x 10 <sup>-6</sup> cm <sup>3</sup> /cm <sup>2</sup> -sec
Corrosion rate	<16 μA/cm <sup>2</sup>
Cost	<\$10/kW

# Approach

- Bipolar plate will utilize carbon/carbon concept
- Preform is slurry-molded carbon fibers
  - similar to paper or felt production
  - fibers  $\sim 400 \mu\text{m}$
  - features stamped/embossed into preform
- C VI with carbon
  - seals and makes hermetic high-density surfaces
  - provides continuous, high-conductivity material

# Advantages of Approach

- Preforms prepared from slurry-molded carbon fibers
  - net shape process/press-in features
  - process can be continuous (i.e., papermaking)
  - low-cost materials
- Appropriate surfaces sealed via deposition of carbon
  - high-conductivity (graphitic) carbon coating all surfaces
  - infiltration makes component fully integral
  - potential for continuous or semi-batch processing
- Negligible impurities/poisons with no corrosion
- Strength and toughness of carbon/carbon
- Very light weight (less than about half that of other approaches)
- Potential for integral diffuser/catalyst support, therefore, lower ohmic losses

# Timeline of Project Accomplishments

March 1998

Project Initiated

July 1998

3-cm disks with machined flowfield

- High conductivity meas.
- Promising cell perf.

June 1999

100-cm<sup>2</sup> plates with machined flowfield

- Good cell performance
- High conductivity meas.
- Light weight demonstrated
- High strength/toughness
- Initial samples to industry

June 2000

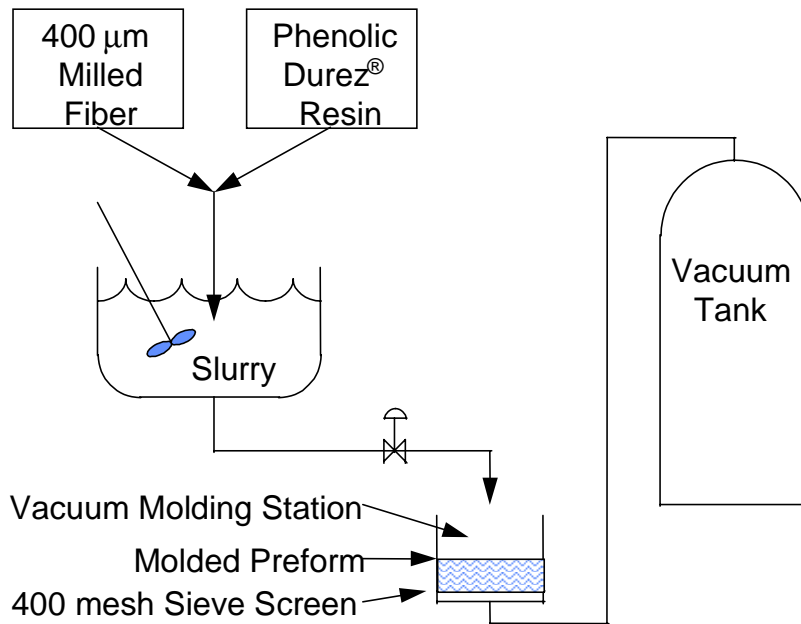
100-cm<sup>2</sup> plates with pressed flowfield prepared and tested

- Pressed preforms
- Freeze/thaw testing
- Low corrosion meas.
- Multiple samples to industry

# Current Accomplishments

- Fabrication of prototypical 100-cm<sup>2</sup> active area plate with pressed-in features
- Corrosion testing indicates as good or better than graphite
- Electrical properties near those of graphite
- Freeze/thaw testing revealed no damage to plates
- Seven 100-cm<sup>2</sup> active area plate provided to PlugPower for testing
- Two sub-scale plates provided to Honeywell for testing

# Slurry Molding of Preforms

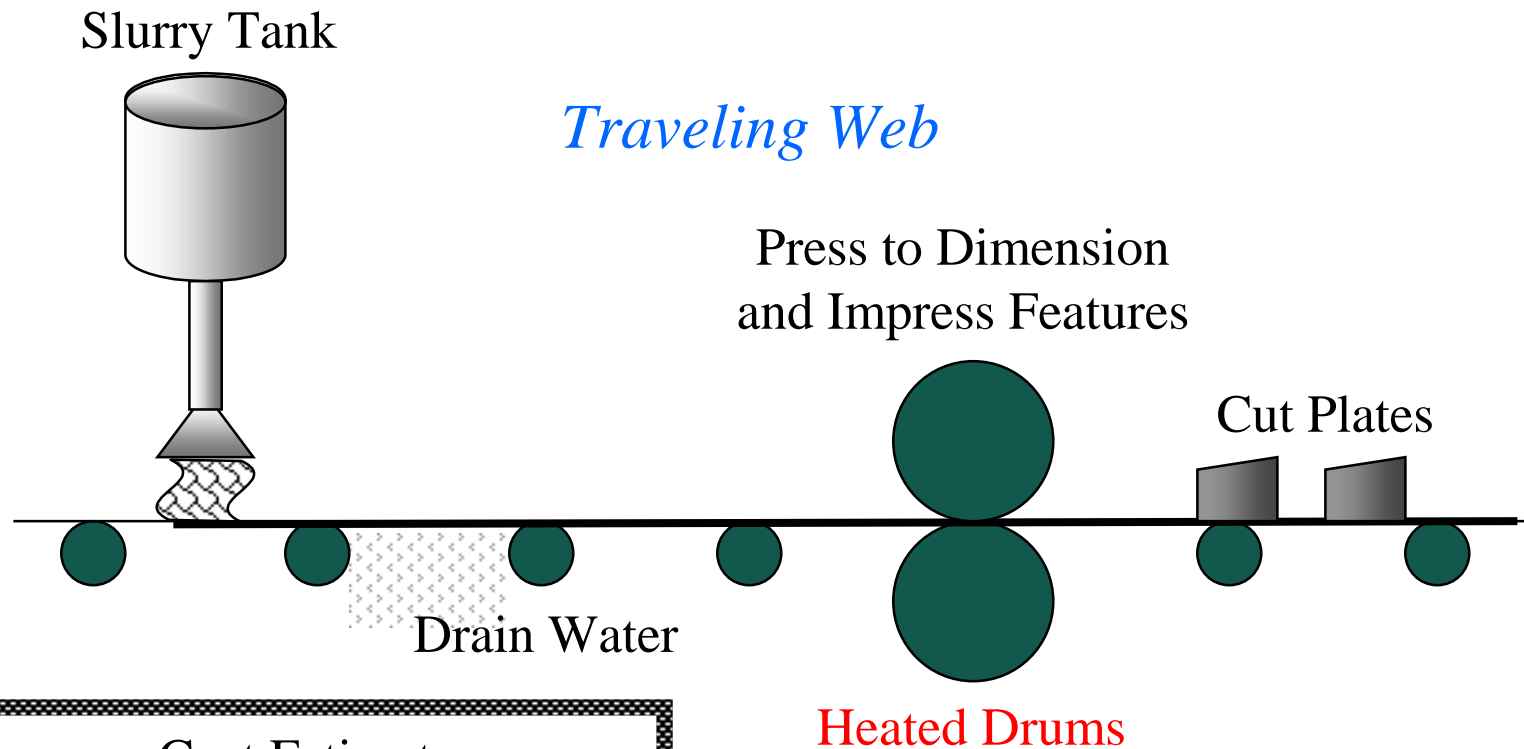


## Water-Based Processing:

- 400-μm pitch-based carbon fiber and phenolic resin slurry
- Slurry applied to vacuum mold
- Application of surface phenolic to decrease pore size

## *Lab-Scale Slurry Molding*

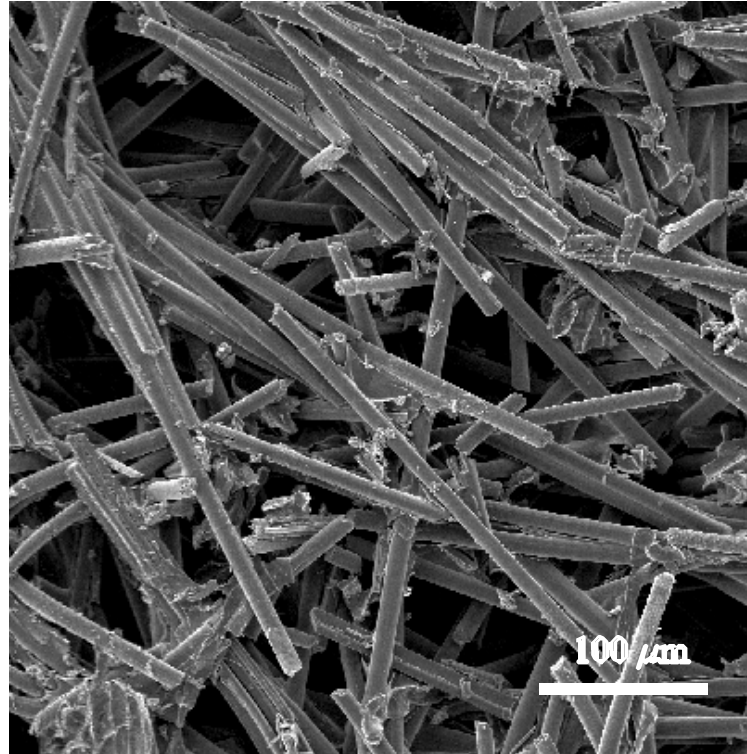
# Preform Preparation Can Be Analogous to Continuous Papermaking



Cost Estimate  
Materials \$0.12/plate  
Processing: \$0.26/plate (batch)

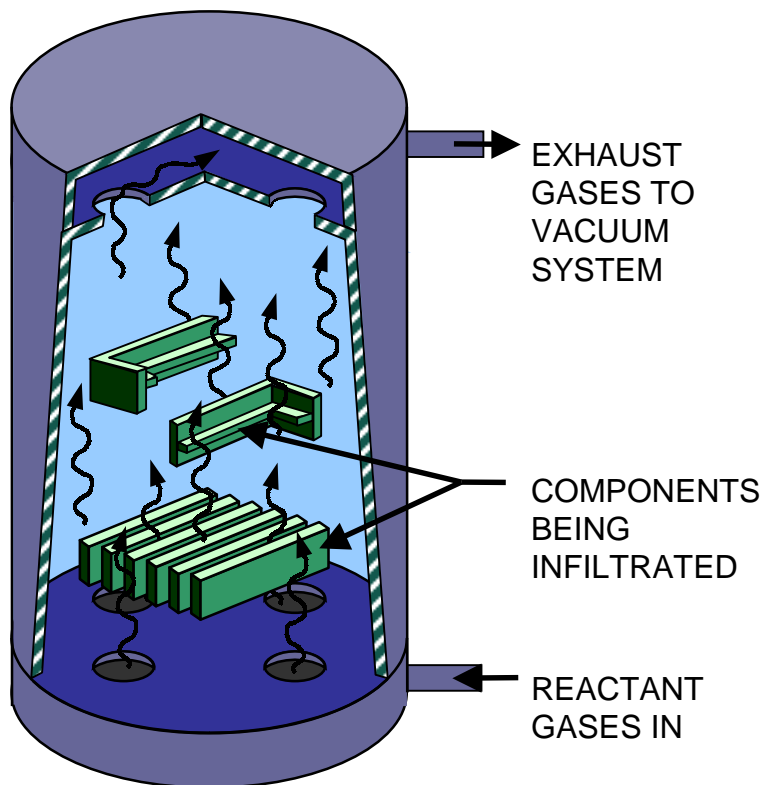


# Carbon Fiber Preform After Slurry Molding



*Amoco DKD-x mesophase pitch carbon fibers*

# CVI Is Rapid and Relatively Low Cost



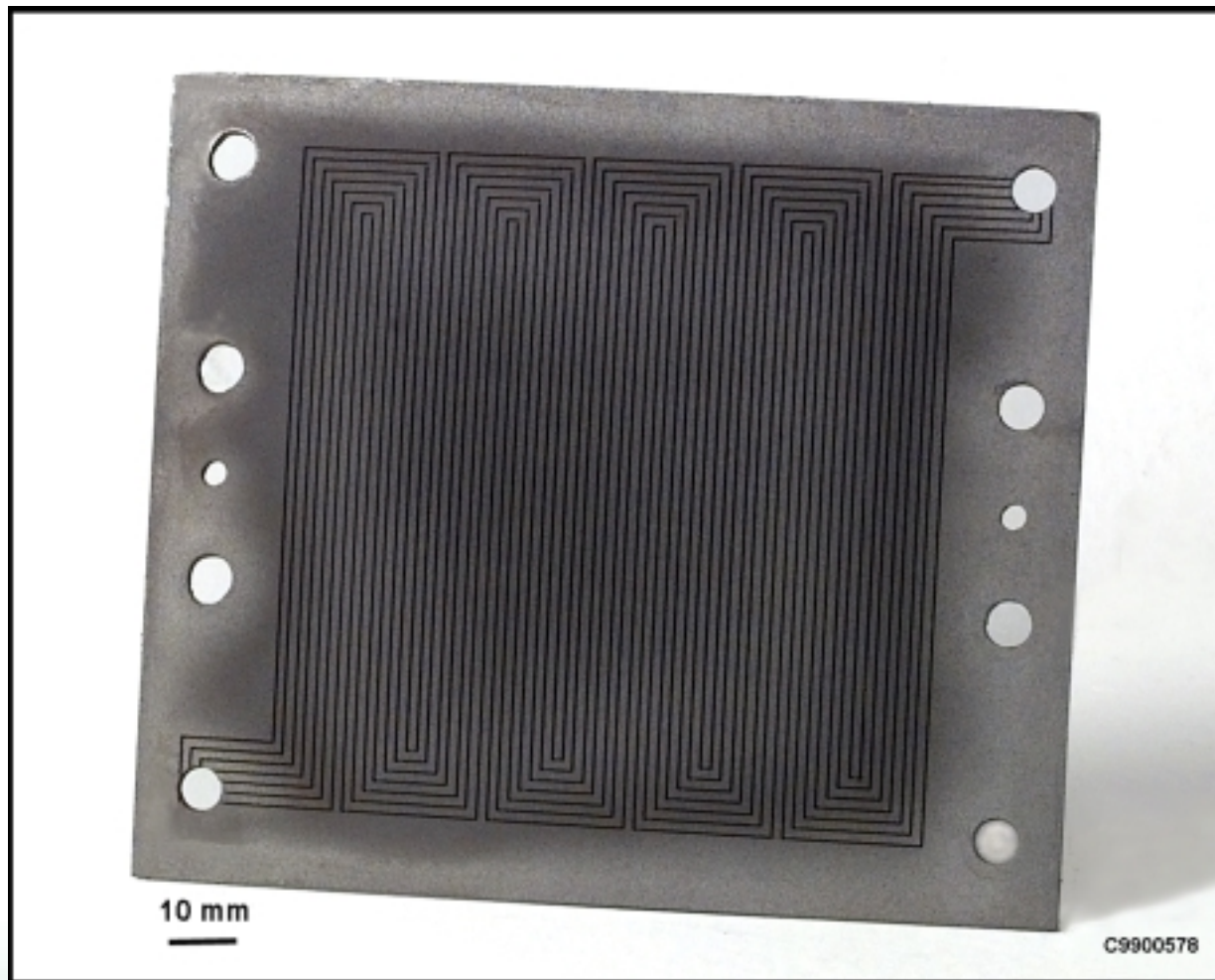
*CVI Reactor*

## Infiltration of Carbon

- Short processing time
- Methane reactant
- 1400°C
- 5 kPa pressure
- Large reactor
- 30,000 parts/run
- \$1/part

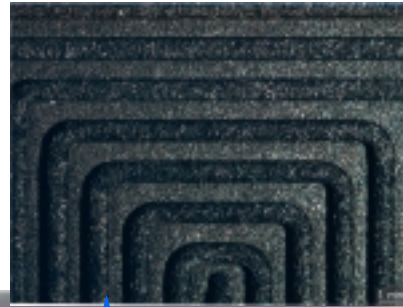
Cost Estimate  
Processing \$1/plate  
(*B.F. Goodrich*)

# 100-cm<sup>2</sup> Active Area Carbon Composite Bipolar Plate



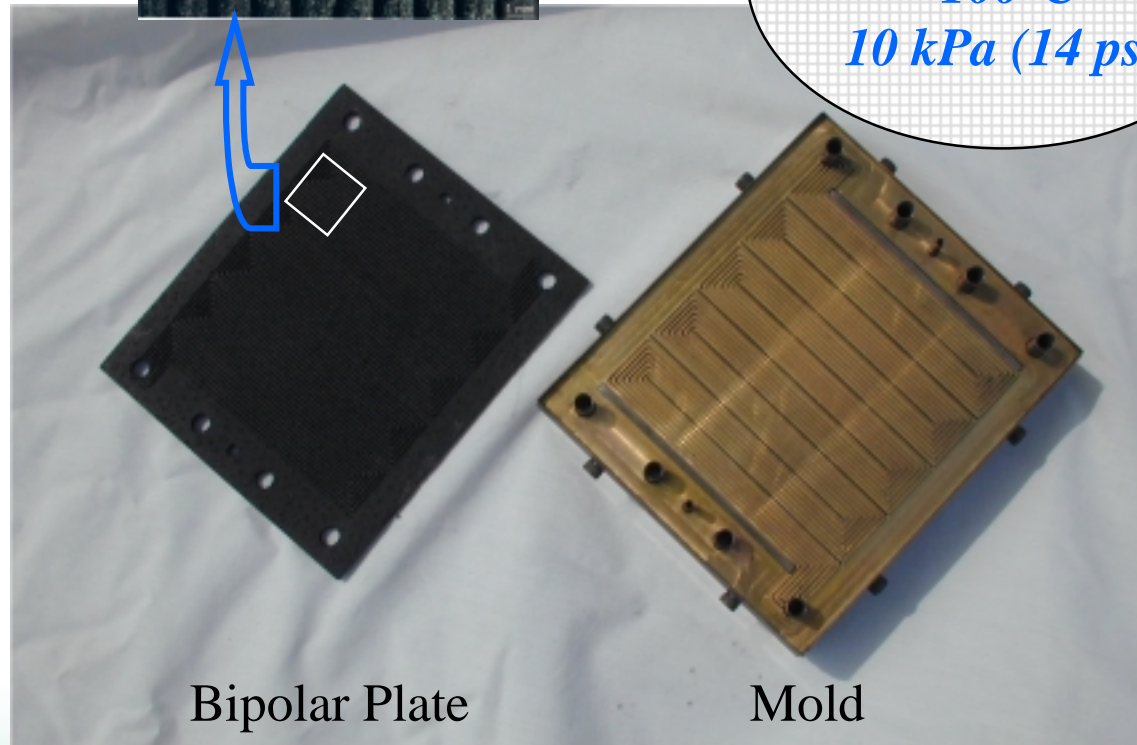
# Plate Mold and Pressed Bipolar Plate Preform

*Channels 0.8 mm  
deep and wide*



*Pressing Conditions*  
*100 °C*  
*10 kPa (14 psi)*

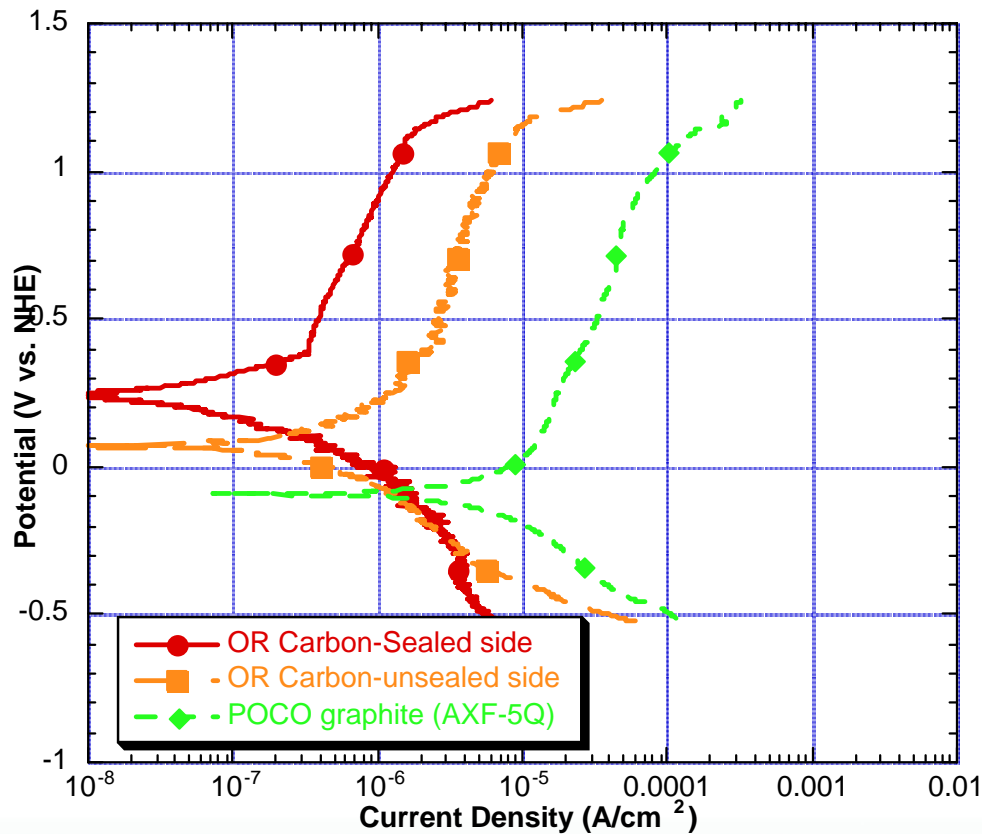
*Successful pressing of  
features into the  
bipolar plate preform  
was necessary for  
demonstrating low-  
cost manufacturing*



Bipolar Plate

Mold

# Polarization Tests Indicate Corrosion of Carbon Composite Less Than POCO Graphite



Conditions  
0.001 N H<sub>2</sub>SO<sub>4</sub>  
2 ppm F<sup>-</sup>  
Temperature 80 °C  
Nitrogen purge

(K. Weisbrod, LANL)



# Corrosion Rates and Electrical Properties of Carbon Composite are Near or Better Than POCO Graphite

	<u>Poco</u> Graphite	<u>Carbon</u> Composite
Corrosion Rate* (A/cm <sup>2</sup> @ 1 V)	8x10 <sup>-5</sup>	6x10 <sup>-6</sup>
Bulk Conductivity** (S/cm)		200-300
Surface Resistivity (Ω/cm)	8	12

\*K. Weisbrod, LANL

\*\*M. Wilson, LANL

# Industrial Interactions

- Plug Power is evaluating ORNL plates
  - testing 100-cm<sup>2</sup> active area plates
- Honeywell is developing fixtures to test plates
- BF Goodrich has interest as materials supplier
  - cost analysis
  - participation in early production

# Continuing Development and Technology Transfer of Carbon-Composite Bipolar Plates

- Supply 100-cm<sup>2</sup> for evaluation by industry
- Scale-up of plate size
  - Need design that industrial partner would like to have fabricated
- Partner with fuel cell component manufacturer to manufacture carbon composite bipolar plates
- Milestone: Transfer technology to a fuel-cell component producing company for their scale-up and work with them to demonstrate production (6/00)



# Some Advisory Panel Comments From Last Year and Responses

- "Work closely with industry/get plates into stacks asap"
  - Providing plates to Plug Power and Honeywell as quickly as they request them
- "Refocus molding on high production rate"
  - Demonstrated molding of full plates
- "Perform corrosion testing"
  - Testing completed, with material behaving better than POCO
- "Address bipolar plate rather than single-sided plate"
  - Currently producing bipolar plates for evaluation
- "Address water freeze"
  - Wetted samples were repeatedly frozen and thawed with no evident damage

# Summary

- Successful fabrication of pressed preform 100-cm<sup>2</sup> bipolar plates
- Plates determined to have:
  - very good conductivity surface and bulk conductivity
  - low corrosion rate
  - tolerance of freeze/thaw
- Costs estimates appear to meet goals
- Testing continuing at Honeywell and Plug Power