A Novel Composite Plate for PEM Fuel Cells

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Introduction

- PEM fuel cells produce electricity out of two electrochemical reactions
  - Hydrogen oxidation: $H_2 \rightarrow 2H^+ + 2e^-$ (1)
  - Oxygen reduction: $1/2O_2 + 2H^+ + 2e^- \rightarrow H_2O$ (2)

  - The overall cell reaction is the production of water:

$$H_2 + 1/2O_2 \rightarrow H_2O \quad (3)$$

- The end product is water and hence has no impact on the environment

What is inside a PEM Fuel Cell?

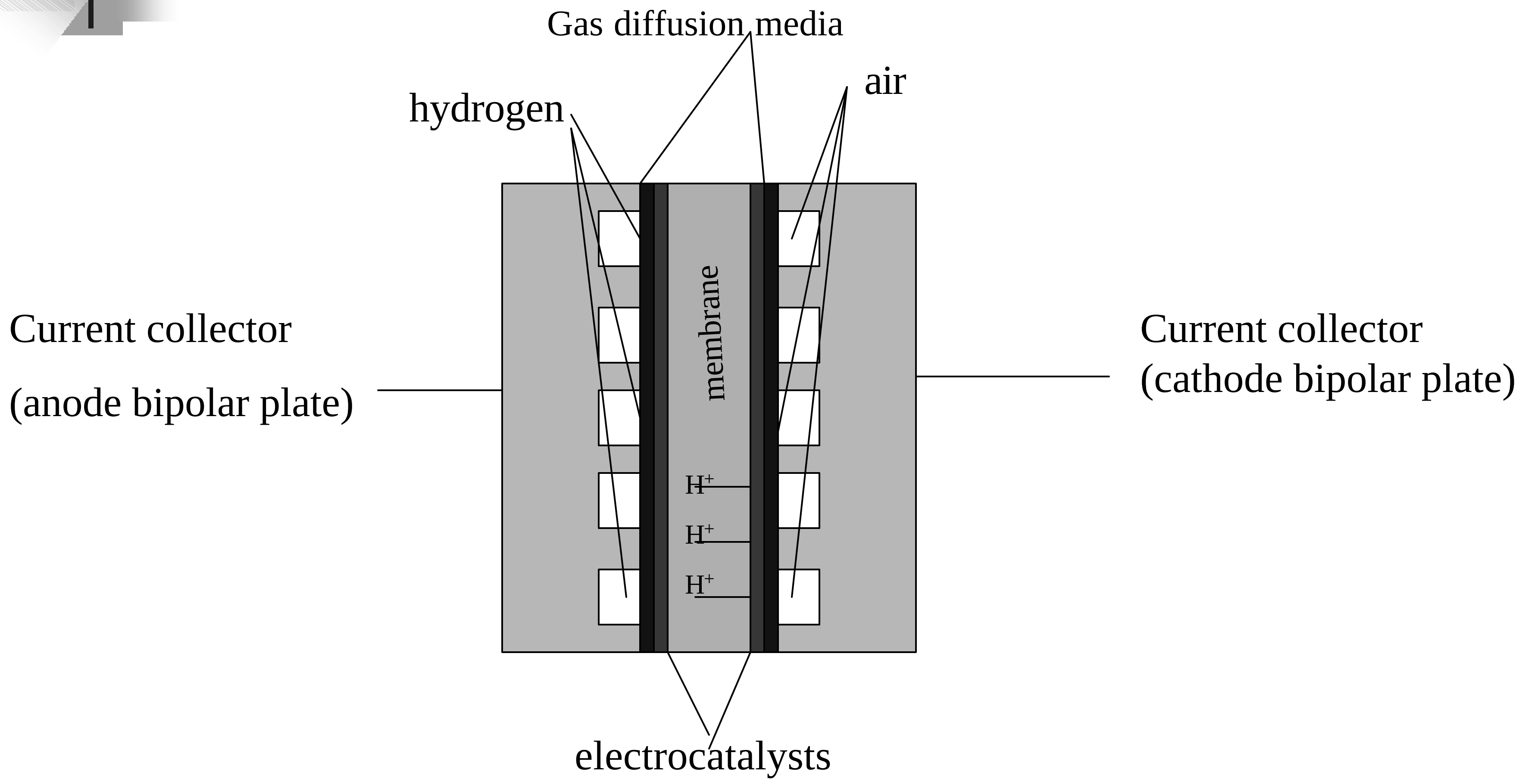

Fig.1 A schematic of the inside of a PEM fuel cell

Current collectors (bipolar plates)

- The main function of the bipolar plate is to collect the current from the catalyst layers and also works as a backbone for the stack.
- Properties
  - Electrochemically stable in the fuel cell environment.
  - High electrical conductivity
  - Inexpensive
  - Available
  - Machinable into plates that have complex geometries ,i.e., with gas and coolant flow field channels
  - Light weight
  - Not permeable to gases (oxygen and hydrogen)

Materials

- **Materials**
  - Graphite and carbon composites
    - Stable, light, available but sometimes poor mechanical properties and high gas permeability.
    - Major drawback: thick compared to metals
      - lower kW/liter (problem for automotive)

  - Metals
    - Light, good mechanical properties, zero gas permeability
      - Noble metals : expensive, not available, electrochemical stable (Pt, Au,..etc)
      - Non-nobel metals:
        - Unstable: corrode in the fuel cell environment (aluminum)
        - Stable: build up oxides and have low corrosion rates (stainless steel, titanium)

Purpose

- Is to investigate the use of stainless steel reinforced graph-foils as alternative bipolar plate materials
  - Graph foils are conductive but permeable to gases and liquids.
  - Break easily
  - Stainless steel has good mechanical properties at very small thicknesses and can be used to reinforce graph foils, thereby, stiffens the graph foil while eliminating the hydrogen gas permeability.

Experimental

- Plate preparation
  - Stainless steel foil (0.1mm) was cleaned Cathodically to remove the oxide film and to minimize the contact resistance on its surface.
  - The the stainless steel foil was then coated with a conductive and protective polymeric material.
  - Two graph foils (2mm thick) were then applied upon the two faces of the stainless steel foil.
  - The assembly was then put under a hot press and the polymeric coating was allowed to cure to bond the graph foils to the stainless steel thin foil.
- Contact resistance measurements, see Fig.1
  - Values for the contact resistance were measured at 200 psi compression pressure and were compared to the values obtained on the graph foil under, otherwise, the same experimental conditions
- Hydrogen gas permeability was measured using a hydrogen permeation setup hocked to a gas chromatograph..
- Electrochemical measurements were done on the graph foil as well as the new sandwich structure under simulated fuel fuel cells conditions..

Contact Resistance Measurements

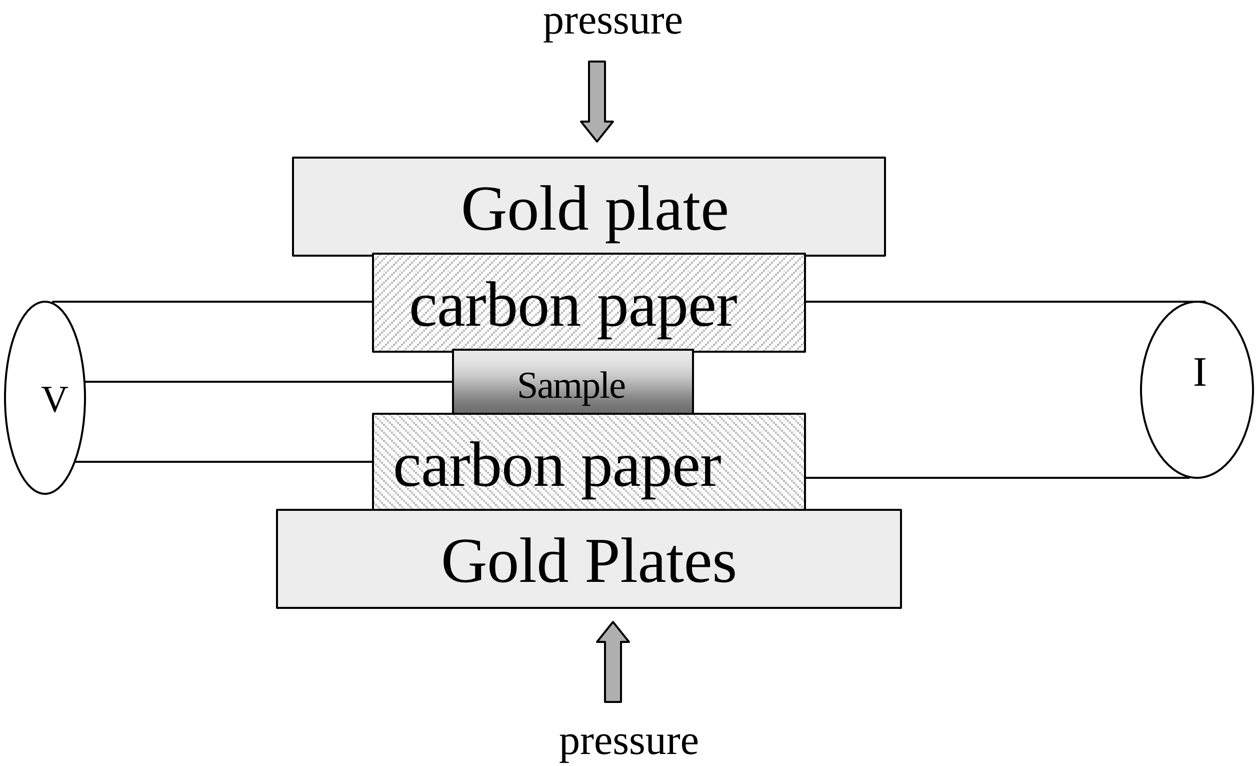

Fig. 2 Resistance measurements assembly

Results (Plate Resistance)

- **Table 1 Values of the contact resistance obtained on the bare stainless steel foil, the conductive polymer coated stainless, and the new sandwich structure (composite material), before and after the corrosion experiments.**

Material	Contact resistance, mohm cm^2 @ 200 psi, measured paper - paper	
	before corrosion	after corrosion
Uncoated clean 316L ss	**16.5-18**	300
Graph foil	**11**	no change
316Lss coated with the conductive polymeric coating	**19-20**	no change
Sandwich structure	**23.5**	no change

Results (Hydrogen Gas Permeation)

- **Table 2 Values for the hydrogen permeation rates measured on the stainless steel foil, graph foil and the sandwich structure under simulated fuel cell conditions (25psig, 50 cm^2 active area, 80^{o}C)**

material	Hydrogen permeation rate, cc/min*
Uncoated 316L ss	0
Impregnated ** graph foil	0.24
Sandwich structure	0

*Target <0.01 cc/min

** non impregnated graph foil gives a value of 2.4 cc/min

Results (Electrochemical Stability)

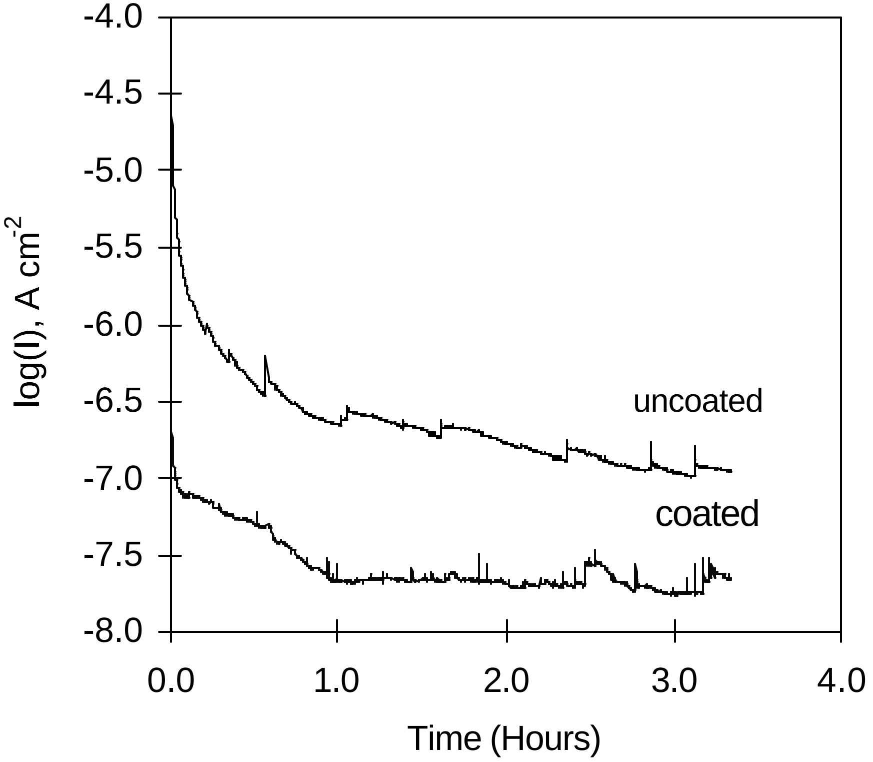

Fig.3 Potentiostatic current transients obtained at +0.6V* (Ag/AgCl) on coated and uncoated 316Lss samples in an aerated solution of pH=3 (10 ppm HF and 0.5 M Na_2SO_4) and at 80°C.

*** +0.6V(Ag/AgCl) =+1.0V NHE**

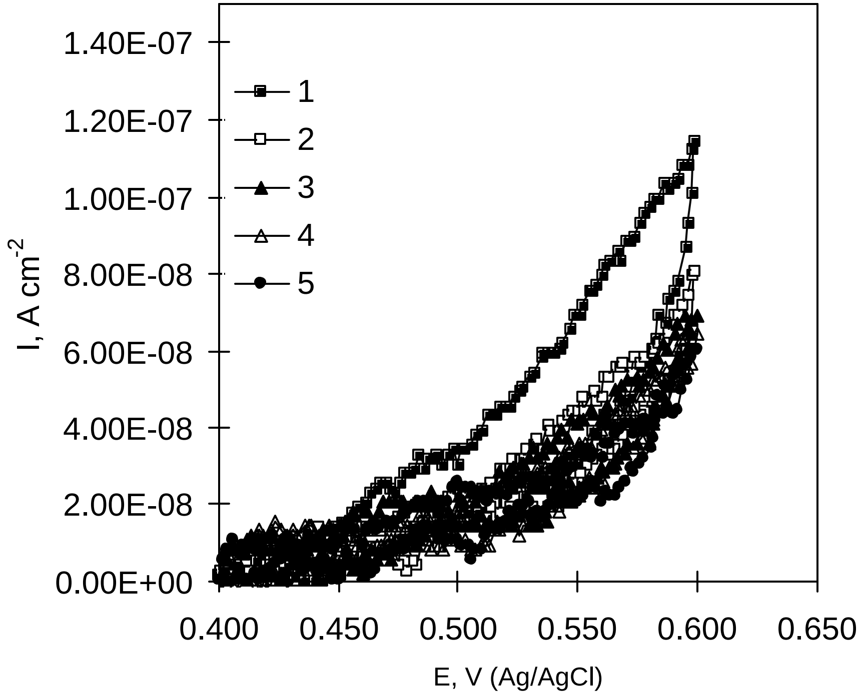

Fig.4 A cyclic voltamogram obtained on the sandwich structure in an aerated solution of pH =3 (10 ppm HF and +0.5 M Na_2SO_4) at a scan rate of 1mV/s and at a 80°C.

Summary and Conclusions

- The new sandwich structure offers the following:
  - Zero gas (hydrogen) permeability
  - Low contact resistance under simulated fuel cell conditions
  - Presumably, good mechanical properties because of the stiffness of the thin stainless steel foil.
  - Good electrochemical stability under simulated fuel cell conditions.