COLLEGE OF ENGINEERING | Chemical, Biological, and Environmental Engineering | CHE6-4

Bipolar Plates for PEM Fuel Cells

Alfie Davis, Sophia Kea, Eric Kwon, Nhu Nguyen

WHAT ARE PEM FUEL CELLS?

Proton Exchange Membrane (PEM) fuel cells react hydrogen fuel with oxygen to produce electrical energy through a polymer membrane. The membrane serves as a reactant barrier and electrical insulator.[1] Advantages of using fuel cells as a clean energy alternative:

- Operate at higher efficiencies and lower emissions than combustion engines
- Products are electricity, heat, and water; no pollutants associated with fossil fuels

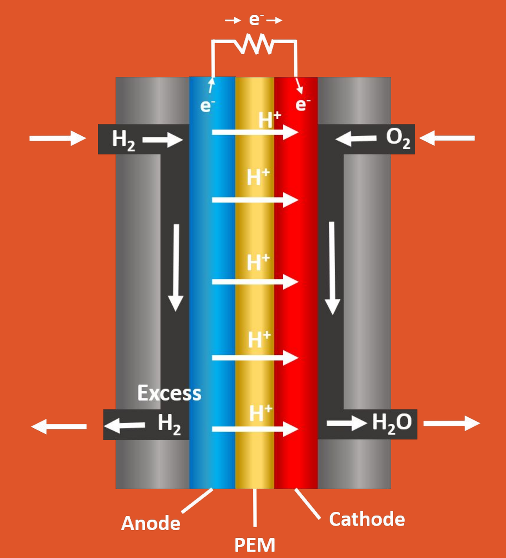

Figure 1. PEM fuel cell configuration showing H_2 on the anode side and protanating through the PEM to the cathode side.

BIPOLAR PLATES

Bipolar plates connect individual PEM fuel cells to conduct current through fuel cell stacks. They separate hydrogen and air supply, water vapor, heat, electrical energy.[2]

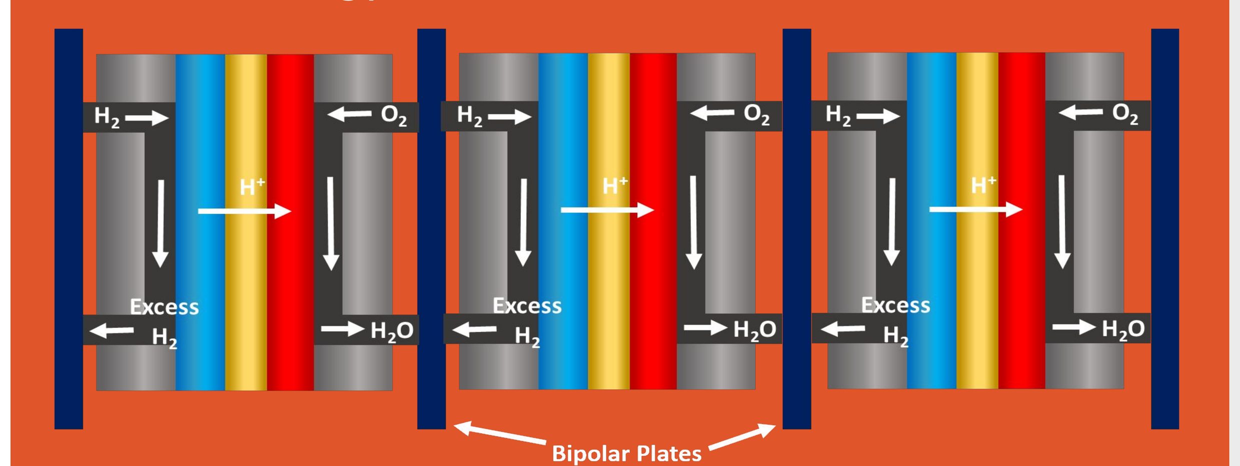

Figure 2. Bipolar plates connecting PEM fuel cells to form a fuel cell stack

OBJECTIVES

This project focuses on producing graphite bipolar plates for **eChemion**, an energy storage and power generation company located in Corvallis, OR, at **low cost** and **rapid processing time** with efficient performances to be marketable

- Determine optimal nickel electroplating amperage and plating time
- Assess the effects of low to mid-level nickel solution pH ranges on plating quality.

Oregon State University

METHODOLOGY

Bipolar Plate Technical Targets:[3]

Characteristic	Units	2020 Targets
Cost	$\$/kW_{net}$	3
Plate Weight	kg/kW_{net}	0.4
Plate H_2 Permeation Coefficient	$\mu A/cm^2/(s\text{-}cm^2\text{-}Pa)$ @80 °C, 3 atm, 100% RH	$<1.3\times10^{-14}$
Corrosion, anode	$\mu A/cm^2$	<1 and no active peak
Corrosion, cathode	$\mu A/cm^2$	<1
Electrical Conductivity	S/cm	>100
Areal Specific Resistance	$\Omega\text{-}cm^2$	<0.01
Flexural Strength	MPa	>25
Forming Elongation	%	40

Electroplating to deposit nickel onto one side of a graphite bipolar plate

- Plating solution: contains metal ions

  Potentiostat: reduces metal ions
- Experimented with current density and deposition time to develop a proprietary plating recipe

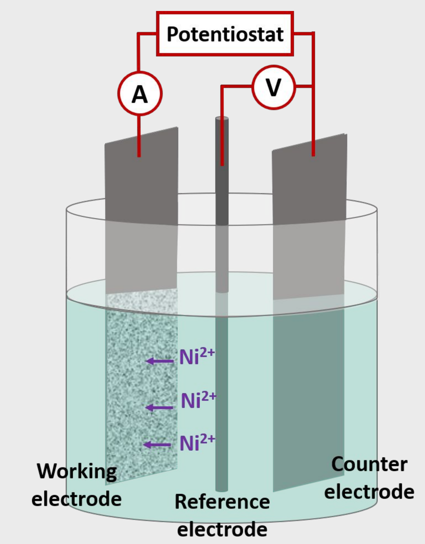

Figure 3. Nickel deposited on one side of bipolar plate via electroplating.

Nickel Deposition Side Reaction Troubleshooting

(a) (b)

Figure 5. Examples of nickel plating with and without the elimination of side reactions. The silver is the nickel and the gray is the graphite.
(a) Sample with deposited nickel where side reactions are also occurring,
(b) Sample with deposited nickel where the side reactions have been eliminated

Medium Chain Alkene Deposition

- Bath used to deposit polymer
- Constant temperature >100°C
- Varied deposition time >1 hour

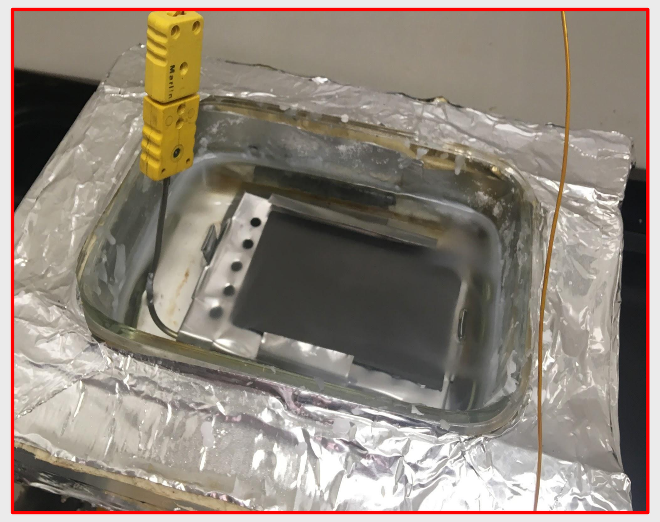

Figure 4. Medium chain alkene impregnation apparatus - composed of bipolar plate bed, thermocouple, stir bar and insulated glass container on a hot plate.

RESULTS

Mass Flux of Alkene Deposition

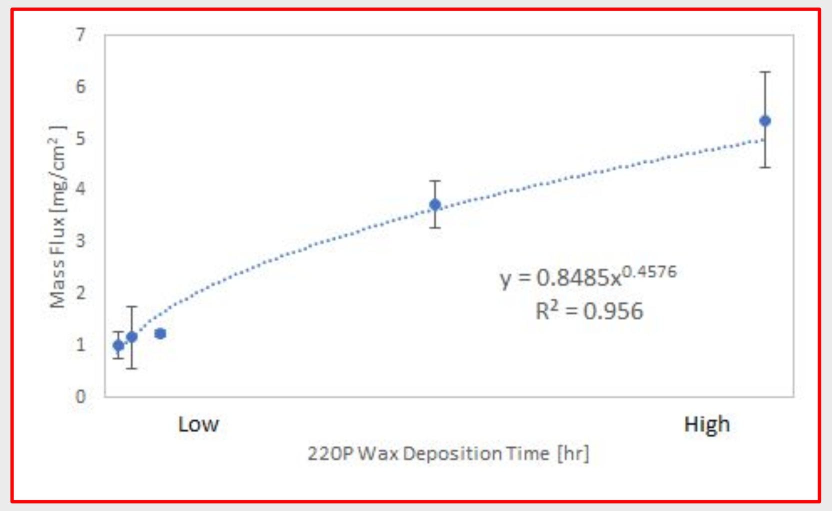

Figure 7. The figure to the left depicts the relation of mass flux through the bipole plate in response to varying durations of wax deposition. The trend displayed suggest a logarithmic relation, although significant error bars at lower durations may suggesting a possible linear trend.

Hydrogen Permeability

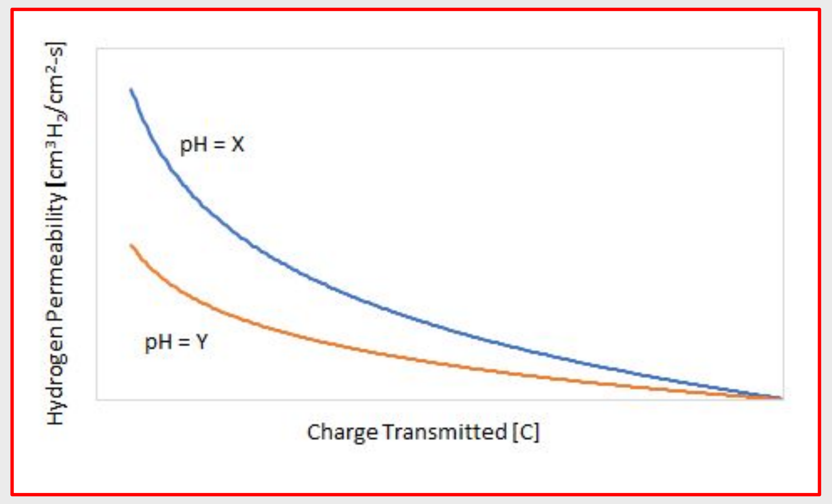

Figure 8. Theoretical model of what the team expects to see when analyzing all of the data. Increases in charge transmitted increase the plating of nickel, resulting in lower hydrogen permeability. We suspect that pH will result in differing permeability levels as the nickel plating occurs more readily at certain pHs.

Tensile Strength

Figure 9. The figure above depicts the tensile strength measurements of alkene-impregnated bipolar plates in relation to the deposition time of the medium chain alkene. Error bars represent standard deviation and experimental data is compared to the tensile strength benchmark of a standard industry bipolar plate. Samples tested were cut into dog-bone geometry and measured with Instron 5969.

CONCLUSIONS

- **Competing side reactions** occur during nickel plating that affect the consistency of nickel deposition.
- Neither nickel plating or wax deposition have a statistically significant effect on **tensile strength**.
- Alkene-coated bipolar plates exhibit **minimal increases in tensile strength**.
- Medium plating solution pH correlates to greater nickel

FUTURE WORK

- Conduct in-plane and through-plane resistivity measurements of alkene coated bipolar plates to assess coating's influence on conductance
- Send alkene-coated bipolar plate samples to external vendor for hydrogen gas permeability testing.
- Analyze effects of the medium chain alkene coating orientation to compare with manufacture-scale production orientation at eChemoin.
- Develop a viscosity curve of the medium chain alkene with respect to temperature

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Dr. Philip Harding, senior project advisor

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[2] Odetola, P., Popoola, P., Delport, D. *Electrodeposition of Functional Coatings on Bipolar Plates for Fuel Cell Applications*.

[3] Richie, N. (2011). *Development of hybrid composite bipolar plates for proton exchange membrane fuel cells.*