This lab is required of all graduate students, working in groups of two. Each group will perform 3 experiments during the course of the semester, with minimal overlap. At the end of the semester, the groups will work together and pool in their collective experimental knowledge to generate a single experimental manual suitable for chemical engineering undergraduate students with no electrochemical or fuel cell background.

Objectives

- To obtain an understanding of the various components in a H₂/Air proton exchange membrane fuel cell (single cell only, stacks excluded) and their construction and assembly
- To obtain an understanding of a typical fuel cell test station and the electronic equipment typically used with it. Use the single cell, test stand, potentiostat and load box.
- To use linear sweep voltammetry (LSV) and cyclic voltammetry (CV) techniques to determine fuel crossover through the membrane and electrochemical surface area (ECA) of the catalysts used in the membrane electrode assembly (MEA).

Materials and instrumentation

1. Single cell hardware with a 5 cm² active area MEA in it.
2. Gas tanks with appropriate regulators for N₂, H₂, and air.
3. Hydrogen fuel cell test station with load box, humidifier, pipes, leads, etc.
4. Potentiostat with leads.
5. Deionized water, wrenches and other accessories.

Experiments

1. Setting up the single cell hardware into the fuel cell test system; performing leak tests and humidifying the cell.
2. Hydrogen crossover using LSV
3. Measuring the hydrogen adsorption curves on the cathode catalyst using CV

Results and discussion

1. Plot the Current Density (mA/cm²) vs Voltage (V) obtained during the LSV experiment. Determine the crossover current density of the cell. Develop a procedure to identify short circuit.
2. Plot the Current Density (mA/cm²) vs Voltage (V) obtained during the CV experiment. Calculate the Electrochemical Surface Area (ECA) of the cathode catalyst.

Notes:

1. Figure 1 shows a typical plot of Current Density (mA/cm²) vs Voltage (V) during LSV. This plot (while not properly labeled) shows hydrogen crossover without an electronic short-circuit. The value at which the curve levels off is the limiting current density associated with hydrogen
crossover. In this case, the hydrogen crossover current density is 2.5 mA/cm². Hydrogen crossover with an electronic short-circuit is also indicated in Fig. 1, with a distinct slope being seen in the current voltage curve.

Figure 2 is a typical curve for cyclic voltammetry (CV). Platinum surface area in the electrode can be estimated from this curve. Proton reduction and deposition on the surface of platinum catalyst is shown in Equation 1. The hydrogen adsorption charge due to this reaction can be measured. Using the well-established quantity of 210 µC/cm² Pt (1) for the reduction of a monolayer of protons, as well as known platinum content in the electrode, electrochemical area (ECA) of the Pt catalyst is calculated by Equation (2).

\[
\text{Pt} + \text{H}^+ + \text{e}^- \leftrightarrow \text{Pt} - \text{H} \quad (1)
\]

\[
\text{ECA (cm}^2\text{Pt/g Pt)} = \frac{\text{charge (µC/cm}^2\text{)}}{210 \times \text{electrode loading (g Pt/cm}^2\text{)}} \quad (2)
\]

The CV of JM 40 % Pt/C is shown in Figure 3. The data is plotted as “Specific Current (mA/mg)” vs. “Potential (V)”. The scanning rate for this experiment is 30 mV/sec (0.03 V/s). The reduction potential is within 0.06 V to 0.39 V, which is corresponding to the time of 11 sec \((0.39 \text{ V/s} - 0.06 \text{ V/s})/0.03 \text{ V} = 11 \text{ sec}\). Integrating the area shown in Figure 2, the total hydrogen adsorption charges are 99 mC/mg=99000µC/mg=99000000µC/g. Using the above quantity of 210 µC/cm², the electrochemical area of Pt is about 470000 cm²/g = 47 m²/g \([(99000000µC/g)/(210 \text{ µC/cm}^2)]\). Pt surface area claimed by the manufacture is about 50 m²/g, indicating that most of the Pt is electrochemically active in this MEA.
Figure 1 Hydrogen Crossover

Crossover Current Density of NTPA MEAs (4 mv/s)

\[ \frac{1}{R} = \frac{1}{R_m} + \frac{1}{R_s} \]

Potential (V)

Current Density (mA/cm²)

normal

short
Figure 2. Cyclic Voltammogram.
Figure 3. Calculation of Electrochemical Surface Area

References:
