

ChE-4550/555: Analysis of Electrochemical Systems

Experiment 3: Fuel Cell Experiment

1. Introduction

The use of solar energy for our everyday electricity needs has distinct advantages: we avoid degrading the environment through polluting emissions, oil spills, and toxic byproducts. Renewable energy frees people from finite, unstable energy resources. There is, however, one disadvantage to solar energy: the sun does not always shine. Therefore, we need a way to store solar energy for times when the sun is not shining. Hydrogen provides a safe, efficient clean way to do this, by using fuel cells.

The solar hydrogen cycle works as follows: electricity from photovoltaic panels and wind turbines may be used to run an electrolyzer, a device which splits water (H_2O) into its elemental parts, hydrogen (H_2) and oxygen (O_2). The oxygen is released into the air and the hydrogen is pumped into storage tanks, where it can be kept on site or transported to sun-poor regions. At night, when solar energy is not available, the hydrogen is recombined with oxygen from the air in a fuel cell to produce electricity.

A fuel cell is an electrochemical energy conversion device. It is two to three times more efficient at converting fuel to power than conventional combustion technologies (e.g., internal combustion engine) of the same size.

Fuel cells are usually classified by the electrolyte employed in the cell. There are low-temperature and high temperature fuel cells. Low-temperature fuel cells are the Alkaline Fuel Cell (AFC), the Proton Exchange Membrane (PEM) fuel cells, the Direct Methanol Fuel Cell (DMFC) and the Phosphoric Acid Fuel Cell (PAFC). PEM fuel cell, also called SPEFC (Solid Polymer Electrolyte Fuel Cells) uses a proton exchange membrane as an electrolyte. They generally operate between 85~105 °C.

Water is the only emission when hydrogen is the fuel. As hydrogen flows into the fuel cell on the anode side, a platinum catalyst facilitates the separation of the hydrogen gas into electrons and protons (hydrogen ions). The hydrogen ions pass through the membrane (the center part of the PME fuel cell) and, again with the help of a platinum catalyst, combine with oxygen and electrons on the cathode side producing water. The electrons, which cannot pass through the membrane, flow from the anode to the cathode through an external circuit containing an electric load, which consumes the power generated by the cell.

2. Objective

The purpose of this experiment is to demonstrate the use of fuel cell – electrolyzer system for the production of electricity. The specific objectives of this experiment are:

1. Determine the charge curves (current and voltage as a function of time) for an electrolyzer (reverse fuel cell).
2. Determine the discharge curves (current and voltage as a function of time) for a fuel cell.
3. Plot characteristic V-I curve for the fuel cell.
4. Calculate the overall efficiency of the system (fuel cell – electrolyzer).

3. Materials

Fuel Cell (one cell, 0.3 W, 350 mA)

Gas collecting columns

Potentiostat / Galvanostat (Arbin Instrument)

4. Procedure

A 350 mW Proton Exchange Membrane (PEM) fuel cell/electrolyzer will be used for the experiment. The testing system also include gas collection columns to store oxygen and hydrogen

produce during the electrolysis of water. These gases would then be used in the fuel cell to generate power.

1. Take the fuel cell and fill the hydrogen inlet with distilled water (almost 1 mL) using a syringe.
2. Similarly the oxygen side has to be filled with distilled water (almost 1 mL) using a syringe.
3. Place the gas collecting columns in a circular holder behind the fuel cell. Normally the hydrogen gas collecting column is placed next to the oxygen side of the fuel cell.
4. Fill the gas collecting columns with distilled water until zero mark.
5. Place the small cap sized tube inside the gas collecting columns. Connect the tube from the inside tube to the top corner of the corresponding gas side on the fuel cell.
6. Connect the red and white cables from Arbin potentiostat to the red terminal in the fuel cell. Similarly connect the black and green cable from potentiostat to the black terminal of the fuel cell.
7. Apply a constant voltage of 1.75 V to the electrolyzer for 2 minutes to generate sufficient amount of hydrogen and oxygen gases. The constant voltage supplied to electrolyzer for producing gases is known as charging.
8. Now to perform the discharging of the fuel cell there will be no changes to the electrical connections to the fuel cell. Red and white cables will remain connected to red terminal and black and green cables will as well be connected to the black terminal.
9. A galvanostatic experiment will be performed, where the program schedule will start with 1 minute 'Rest' followed by applying load in terms of negative current such as -25 mA for 5 minutes. After this 5 minutes step, the current will be decreased to -50 mA for another 5 minutes. This staircase will range from 25 mA to 250 mA with a step height of 25 mA and step time of 5 minutes. The program will also have limit to stop the discharging process if the cell voltage reaches zero volts during any step.
10. Note down the value of the cell voltage after it has stabilized. Using the current and cell voltage data plot the V-I curve for your fuel cell.

5. Discussion

1. Briefly explain how PEM fuel cell works and specify their advantages and disadvantages.
2. Write the charge-discharge reactions of your experiment. Calculate the minimum voltage required for the reactions to take place.
3. Plot the charge and discharge curves for your system.
4. Plot the characteristic V-I curve for your fuel cell. Using the literature, describe the different regions in the V-I curve.
5. Calculate the electric energy efficiency of the system (η , electric energy out/electric energy in). When calculating the efficiency include the total electric energy used to produce hydrogen and the total electric energy provided by the hydrogen.
6. Investigate the cost of different sources of electric energy: Grid, photovoltaic, solar-thermal energy. What is the total energy cost required to produce hydrogen in the electrolyzer using these different sources? Propose alternative solutions to bring down the costs of hydrogen production in the electrolyzer. Would it be appropriate to use grid energy? Why?

NOTE: Make sure to report uncertainties in your data and calculations.