The Development of a Novel Photosynthetic Fuel Cell

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Introduction

______Fossil fuels are hydrocarbons formed from the remains of dead plants and animals. In developing countries, fossil fuels serve as the commonplace source of energy. Their usage has enabled large-scale industrial development. The burning of fossil fuels, is the largest emissions source of carbon dioxide. The transportation of fossil fuels, has led to multiple oil spills, the effects of which are still seen today. Coal, petroleum, and natural gas are the three forms of fossil fuels. The burning of coal for electricity causes mercury to leach into the air and waterways. Overall, the burning of fossil fuels results to an exorbitant amount of carbon dioxide to be released into the atmosphere. By developing a fuel cell that harnesses the photosynthetic and metabolic energy produced by algae, the device can reduce the cost of production and manufacturing, and lessen, but not replace, the reliance on fossil fuels.

Photosynthesis is a plant process of converting light energy into plant energy. It comprises of both light reactions and dark reactions. During dark reactions, ribulose and bisphosphate is bound to carbon dioxide by the enzyme ribulose bisphosphate carboxylase.This is the initial step to the formation of sugars. During light reactions, light energy is converted into the chemical energy necessary for dark reactions.

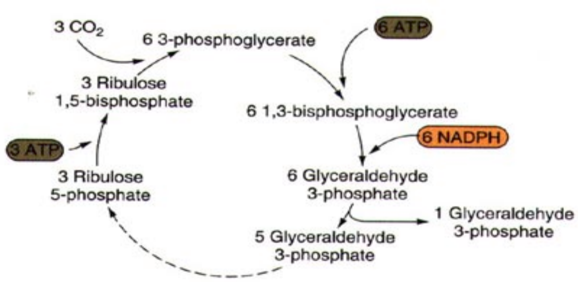


Figure 1. The above image illustrates the Calvin Cycle, the process by which

A fuel cell is a cell producing an electric current directly from a chemical reaction. A Proton Exchange Membrane is a semi-permeable membrane impervious to gases, while a conductor of protons.

The current, voltage, and differential voltage of the fuel cell will be measured. Current is the rate at which electric charge flows past a point in a circuit, and voltage, is the potential difference in charge between two points in an electrical field. Differential voltage is the relative voltage between two signals- the difference. The Vernier and Labquest 3 Software will be used to measure energy yield. To measure voltage, differential voltage, and current with Vernier software, the Vernier Voltmeter, the Vernier Differential Probe, and the Vernier Current Probe, will be used, respectively. To measure voltage, differential voltage, and current with the LabQuest 2 software, the voltmeter, differential voltmeter, and the current meter will be used, respectively.

The purpose of this experiment is to develop a novel fuel cell in which the Proton Exchange Membrane is on the bottom of the cell, and to develop a device capable of harnessing and yielding energy produced by algae.

Purpose

- To develop a novel fuel cell in which the Proton Exchange Membrane is on the bottom of the cell, allowing it to become a dual-purpose cell.
- To develop a device capable of harnessing and yielding energy produced by algae.

Materials

- Unflavored gelatine
- Sodium Chloride
- Distilled H_20
- 1000 milliliter beaker
- Marine grade wire
- Vernier voltmeter
- Vernier Current Probe
- Vernier Differential Voltmeter
- LabQuest 2 Voltmeter
- LabQuest 2 Current Meter
- LabQuest 2 Differential Voltmeter
- Logger Pro 3
- Hot plate

Procedure

Developing a Proton Exchange Membrane

(*Formula adapted from a procedure given by Instructables)*

1. Using a hot plate, bring 72 milliliters of distilled water to a boil.
2. Once at a boil, add 8.5 grams of sodium chloride and 18.3 grams of unflavored gelatin.
3. Once solution has fully dissolved, pour contents into a 1000 milliliter beaker, over the anode wire.
4. Put the beaker into the refrigerator to cool overnight.

Determining cell density using the FlowCam Flow Cytometer

1. Attach a 50 micron capillary tube to the instrument.
2. Pipette distilled water into the cuvette and purge the system.
3. Once the distilled water has fully exited the tubing, pipette algae into the cuvette and set the switch to ‘Forward’.
4. Once the algae has fully exited the tubing, record and export data.

Constructing the Fuel Cell

1. Once the PEM has been set on the bottom of the cell, add the algae.
2. Insert the cathode wire into the algae and connect the Vernier system to the wire.

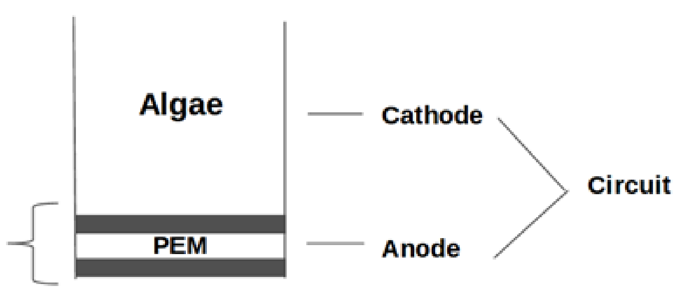


Figure 2.The above image illustrates the design of the fuel cell. The Proton Exchange Membrane is on the bottom of the cell with the anode wire embedded within it. The algae is free-floating above the PEM with the cathode wire fixed within it.

Proposed Budget:

- Unflavored gelatin: (2 boxes/ $1.09 each): $2.18
- Morton Iodized Salt: $1.48
- Vernier Current Probe: $39
- Vernier Voltmeter: $39
- Grow Lamp: $52
- Sigma-Aldrich Hexane Chromasolv: (100 mL): $53.70

Total Budget: $105.70

Actual Budget:

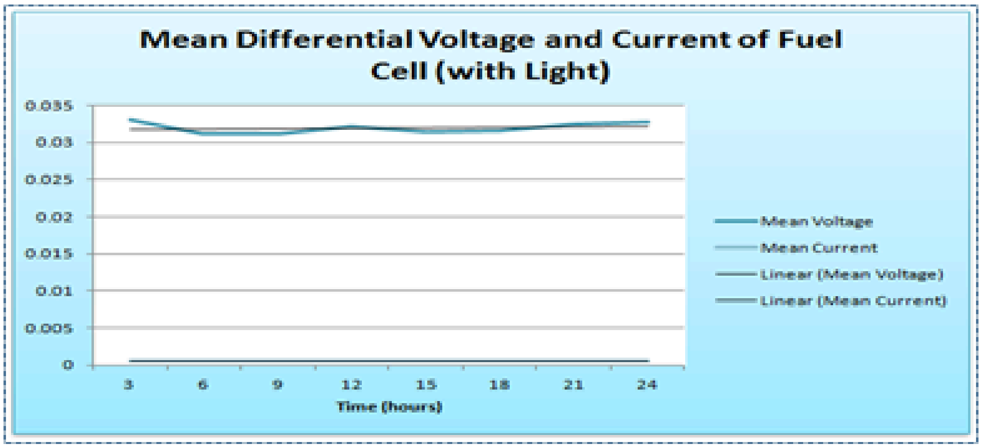
- Unflavored gelatin: (12 boxes at $1.99): $23.88
- Vernier Current Probe: $39
- Vernier Voltmeter: $39
- Morton Iodized Salt: $1.48
- FlowCam Operation (12 days at $75): $900

Total Budget: $1003.36

Observations and Data

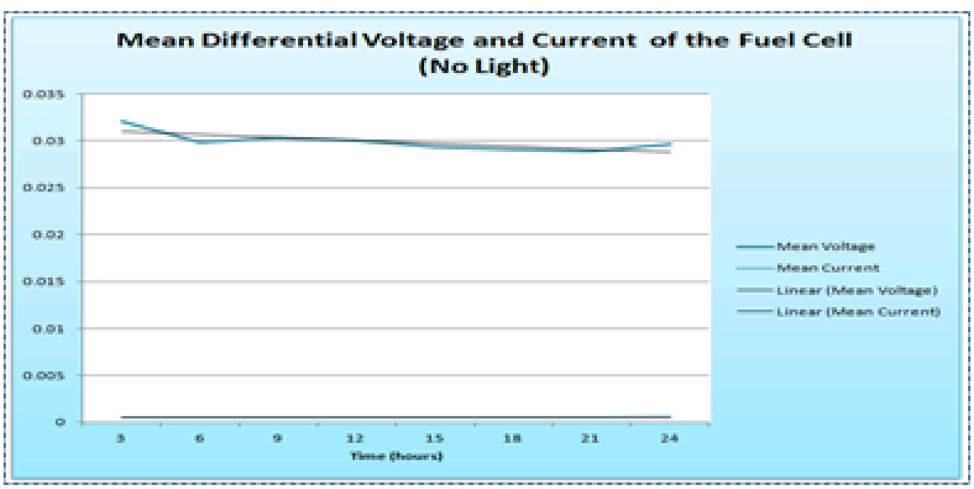
*Each trial ran for 24 hours. The data was divided into three hour blocks. The mean differential voltage and the mean current were found for each three hour block.

Cell Density: 18191 particles/mL



Graph 1. This graph shows the differential voltage and current yield of a fuel cell which was exposed to light.

Cell Density: 265256 particles/mL



Graph 2.This graph shows the differential voltage and current yield of a fuel cell which was exposed to no light.

Results and Discussion

Based on the energy yield of the fuel cell under light, and the fuel cell without light, it can be determined that the fuel cell is effective and the energy of algae can be harnessed. The data shows that the fuel cell under light has a energy yield lower than the cell under light. The average energy yield of the cell under light was higher than the one under no light. For the first three hour block of the cell under light, the average was 0.0331, while the cell under light was 0.031994 volts. This trend continued and all energy readings for the cell under light had a higher differential voltage yield than the cell with no light. The current however did not follow the same trend and the current for the cell under no light, was always higher than the current yield for the cell with light.

The higher current yield for the cell under no light could be due to the metabolic activity of algae within the cell. In theory, the energy of the cell, if strictly photosynthetic, should reduce or even be obsolete without light. However, the cell could also be harnessing the metabolic activity of algae, which would explain the slight increase in energy yield seen at the end of both graphs.

Time (h)	Mean V	Mean C
3	0.031994	0.000596
6	0.029869	0.000587
9	0.030331	0.000556
12	0.030003	0.00055
15	0.029378	0.000566
18	0.029031	0.000563
21	0.028908	0.000599
24	0.029667	0.000609

Table 1. The table above shows the mean voltage and current per three hour time blocks. This is the data from the device exposed to no light.

Time (h)	Mean V	Mean C
3	0.033111	0.000512
6	0.03112	0.000535
9	0.03111	0.00054
12	0.032096	0.000553
15	0.03148	0.00056
18	0.03161	0.000558
21	0.032424	0.000551
24	0.03281	0.00053

Table 2. The table above shows the mean voltage and current per three hour time blocks. This is the data from the device exposed to light.

Conclusion

When conducting trials, the device yielded a steady voltage and current proving the device is capable of harnessing the energy produced by the algae. On a trial with one cell exposed to light and the other in total darkness, the device under light yielded an average differential voltage of 0.03197 and an average current of 0.00054. In total darkness, it yielded an average differential voltage of 0.02990 and an average current of 0.00058. (Differential Voltage is the difference between voltages at two different points). The positive differential voltage yield of the cell in no light indicates metabolic activity also had an effect on the energy yield of the device. The larger current and differential voltage, is due to a redox reaction occurring where algae is using glucose produced during photosynthesis.

Future Research

Future Research will be conducted on the effect the metabolic activity of the algae has on the energy output.The following variables will be tested as well:

Cell Concentration: Currently, algae is being filtered using a 100 micron sheet. Further methods of concentrating algae will be explored in order to find optimal algae concentration.

Identifying algae type: Currently, algae the algae being used is from a supply provided by the school. The smaller sized algae has a higher lipid concentration, and if identified, algae can be appropriately filtered to increase energy yield.

The effect of time: Two devices will be tested, one that has the same batch of algae for the duration of the trial, and the other, gets new algae every x amount of time. This will determine the amount of time the device can utilize the same algae, and also help in determining the effect the metabolic activity has on the cell.

Developing an optimal cell: Different variations of the fuel cell will be developed to make it more conductive. Currently, the cells are being tested with a thin strip of carbon tape on the bottom of the cell, above the anode wire. Future variations include testing the effect that adding biochar below the PEM has on the energy yield.

Acknowledgments

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