Replacing the Anode in a Proton Exchange Membrane Fuel Cell

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**Introduction**

There are several types of hydrogen fuel cells, but the one that shows the greatest promise in practical application is the Proton Exchange Membrane Fuel Cell, henceforth known as PEMFC. The PEMFC is favored due to its relatively low operating temperature of 60-100°C and its low cost in comparison to other fuel cell technologies (Fuel Cell Technologies Program: Glossary, 2011). PEMFCs utilize a special electrolyte polymer, which allows positively charged particles, called protons, to pass through it, but doesn't allow the negatively charged particles, electrons, to pass. These electrons are what give off electricity, effectively converting electrochemical energy into useful mechanical energy (Proton Exchange Membrane, para. 1-3).

PEMFCs have several distinct features in its cell (See Figure 1; Untitled Diagram of a Proton Exchange Membrane Fuel Cell). It includes an anode, a special polymer to pull the protons through the anode, and a cathode. The anode is made of platinum dust. This dust separates the electrons from the hydrogen atoms and pulls them into an electric current. The polymer, called nafion, then pulls the hydrogen ions (H$^+$) into the cathode, thus combining hydrogen and oxygen to form water (H$_2$O) (Products, 2004, para. 1). The cathode is made out of nickel. Once the electrons have been pulled from the hydrogen atoms, they travel through a circuit, creating electric current.

Platinum is usually chosen due to its high electric potential. This high potential of +1.200 makes platinum one of the least reactive metals, so the hydrogen won't bond with it (Galvanic Corrosion Chart, para. 2). Its positive electric potential also allows electrons to flow very easily (Fundamentals of Electrochemistry, 2011, p. 22). Because of these properties, it’s mainly used as a catalyst to separate the electrons from the atom, creating the cation H$^+$.

A recent study by Wang, Yu, and Dai (2011) has shown that carbon nanotubes could reduce the need for large amounts of platinum in fuel cells, which would make PEMFCs significantly cheaper (p. 5182). However, this research has not been physically tested, only mathematically observed. These
nanotubes create a positive charge in the different carbon bonds, which attract the electrons from the hydrogen atom, effectively emulating platinum's role as an anode and catalyst for separating the two oppositely charged particles.

**Research Question**

Current fuel cell technology makes these alternative sources of energy too expensive for mainstream optimization. With the high cost of platinum as a luxury metal and limiting reserves, large-scale production of PEMFCs is nearly impossible. If a catalyst could be found that mimics the electric properties of platinum, it could become a viable alternative to our crippling dependence on fossil fuels. These nanotubes, however, would need to be able to operate under the confined temperatures (60-100°C), and maintain a long durability and service life (Fuel Cell Technologies Program: Glossary, 2011).

This study aims to explore each of these problems and to create a more cost effective PEMFC. A graphenated carbon nanotube (g-CNT) will be used as an alternative to the current platinum anode (Wang, Yu, Dai, 2011, p. 5182). These g-CNTs are a hybrid of current carbon nanotubes and the mineral graphite (Hsu, Wang, Nataraj, Huang, Du, Chang, Chen, & Chen, 2012, p. 176). G-CNTs are also much cheaper than platinum, which, if successful, will make fuel cell technology much cheaper. A gram of g-CNT costs $25 USD, but gets much cheaper in bulk quantities (Graphitized Nanotubes, 2009, para. 4). One gram of platinum, however, runs close to $52 USD, and only lessens by about a dollar in million-dollar quantities (Current Platinum Price, 2012, para. 1). Cutting out even a little bit of platinum will significantly lower the cost of a PEMFC.

**Study Design**

The project will be conducted either by designing and building a new version of a PEMFC, or by buying a current PEMFC and replacing the platinum anode with the proposed g-CNT anode. The PEMFC will follow the current design of a normal PEMFC, with the exception of a modified anode. These PEMFCs or parts will be ordered from an online website called fuelcellstore.com
This modified anode will be based off of a g-CNT buckypaper, which is a thin sheet of carbon nanotubes. G-CNTs will be ordered online or bought with the help of Dr. Woo at the Governor's School for Science and Technology. This buckypaper will be lightly coated with platinum by means of electrical bonding, but has not been fully determined yet. The more surface area the platinum spans, the more catalytic activity that will occur, so the thickness of the platinum coating is not important. In fact, the thinner the coating, the cheaper the anode will be to manufacture. The anode will have multiple sheets of this platinum coated anode for maximum catalytic activity.

This new PEMFC will have several factors monitored, including operating temperature, voltage produced, cost of production, and amount of hydrogen and oxygen used in a normal hour. These factors will be compared with the current PEMFC data, and hopefully mimic the data in temperature, voltage, along with hydrogen and oxygen consumption, but lower the cost of production. It is worth noting that because the study will be buying all materials at consumer price, and not bulk price, the cost difference may not be as significant as in a manufacturing setting.

**Data Processing**

Data will be logged using several different instruments, including a temperature probe, a pressure gauge, and a multimeter. The temperature probe will be used to test the operating temperature of the cell, the pressure gauge will be used to measure the PSI used in the tank of hydrogen and oxygen, and lastly, the multimeter will be used to measure the voltage produced from the PEMFC. This will then be compared with literature from credible sources to see how the new PEMFC stacks up with the current design.

Lastly, costs for each individual piece will be logged and combined to compare with the price of a cell of current technology, which uses platinum as the anode. This cell will be bought at current market value, as each individual piece in the new PEMFC will be bought at a consumer level as well.
Appendix

1. Hydrogen fuel is channeled through field flow plates to the anode on one side of the fuel cell, while oxygen from the air is channeled to the cathode on the other side of the cell.

2. At the anode, a platinum catalyst causes the hydrogen to split into positive hydrogen ions (protons) and negatively charged electrons.

3. The Polymer Electrolyte Membrane (PEM) allows only the positively charged ions to pass through it to the cathode. The negatively charged electrons must travel along an external circuit to the cathode, creating an electrical current.

4. At the cathode, the electrons and positively charged hydrogen ions combine with oxygen to form water, which flows out of the cell.

Figure 1 (The current PEMFC Design) (Untitled Diagram of a Proton Exchange Membrane Fuel Cell)
Works Cited


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