Spotlight on Photovoltaics & Fuel Cells: A Web-based Study & Comparison (Teacher Notes)

General Lesson Notes

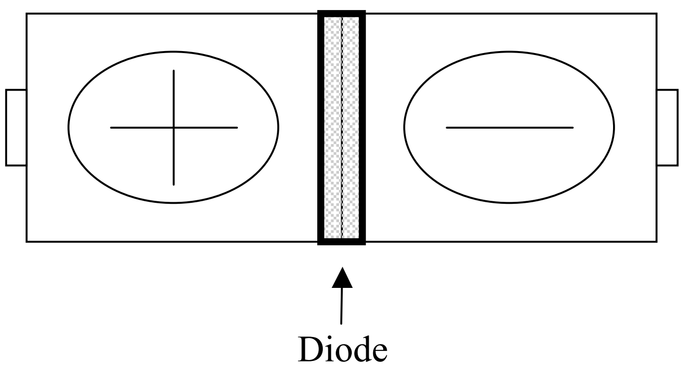
Electrochemistry is defined as the branch of chemistry that deals with oxidation-reduction reactions that transfer electrons to form electrical energy rather than heat energy. An **electrode** is a conductor used to establish electrical contact with a nonmetallic part of a circuit such as an electrolyte. There are two types of **electrodes**, a **cathode** is an electrode where reduction takes place and an **anode** is an electrode where oxidation takes place. Both the cathode and anode together make up an electrochemical cell. There are two types of electrochemical cells: voltaic (galvanic) cells and electrolytic cells.

An electrolytic cell can be seen as an electron pump which simultaneously supplies electrons to the cathode and recovers electrons from the anode. The anode and cathode of an electrolytic cell are connected directly to a power source; this causes *nonspontaneous* redox reactions which produce electricity**. Electrolytic cells** convert electrical energy into chemical energy as is seen in a **fuel cell**. Hydrogen enters the **fuel cell** at the **anode** has a positive (+) polarity; this separates electrons from the hydrogen molecules. A **catalyst** assists in the separation of the hydrogen's electrons from its protons. The Polymer **Electrolyte** Barrier (semi-permeable barrier) allows protons to pass through the **electrolyte** but not electrons. The electrons flow past the **electrolyte** causing a current (electricity). The **cathode** has negative (-) polarity in electrolytic systems because electrons are continuously being pumped into the system; here the protons combine with Oxygen from the air and electrons. A second **catalyst** platinum speeds up the reaction of hydrogen, oxygen and the electrons which produces the by products out of the exhaust in the form of heat and water vapor (H_20). See overhead 2 below.

Voltaic cells (i.e., batteries) serve as a source of electrical power which is produced by *spontaneous* redox reactions. Voltaic cells convert chemical energy into electrical energy. Photovoltaics, as the word implies (photo = light, voltaic = electricity), convert sunlight directly into electricity. However, this is not a chemical reaction like that of a voltaic cell. Sunlight hits the PV cell which is made of both a **p-layer** and **n-layer** both of which are semiconductors. The **n-layer** contains silicon which contains an impurity that allows it to contain an excess amount of electrons. This layer is considered the **anode (**negative (-) polarity) because electrons are continuously being generated there. The **p-layer** also referred to as the **cathode** has a positive (+) polarity which absorbs photons and contains excess holes. Between the two layers lies a **p/n junction** which allows the two layers to act as a battery, thus creating an electric field where they meet. The junction forces the electrons to move out towards the ends of the PV cell towards the back cover and the glass cover thus creating the electric current. A photovoltaic only creates energy during the daylight hours due to sunlight, at night due to lack of sunlight it needs a secondary source of energy. Also the amount of energy produced depends on the orientation of the PV cell in relation to the sunlight.

How a fuel cell differs from a battery. Fuel cells and voltaic batteries (AA, for example) operate on the same principles. Also sometimes referred to as a "flow battery," a fuel cell differs from a regular voltaic battery because a continuous flow of reactants must be supplied to the fuel cell in order for it to generate electrical current. Voltaic batteries have the reactants stored within the system. A fuel cell can therefore theoretically operate indefinitely as long as fuel is supplied; whereas a battery eventually goes dead.[1] (Reference: GREATT Project)

Photovoltaic as a Semiconductor: A PV cell **semiconductor** typically is made of silicon. Silicon is a common element in the periodic table. When it binds to itself it creates a crystal lattice network without any free electrons, thus this silicon crystal is nearly an **insulator**, and little electricity will flow through it. In order for silicon to have **semiconductor** properties which will create electricity it must be able to have free electrons available to produce a current. This is done by doping the silicon with an impurity so that the lattice structure will allow free electrons to be readily available, thus producing a current. This creates a **diode,** defined as a device that blocks current in one direction while letting current flow in another direction. An example of a **diode** is a battery. One end of the battery has a positive (+) end and the other a negative (-) end. There is a zone in the middle that doesn't allow the positive and negative charges to meet, this zone is a **diode**.



[1] The Penn State GREATT Project. "Fuel Cells." http://csats.psu.edu/files/GREATT/FuelCells/FuelCells.doc.

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The following charts compare differences and similarities between these two technologies.

Chart 1- Differences:

Photovoltaic	*Fuel Cell*
Energy created by the PV cell can be stored in a battery.	Fuel cells were invented to replace batteries and engines.
Main parts are Photovoltaic cell: N-Layer, Junction and P-layer	Four main parts of a fuel cell: Anode, Catalyst ,Cathode, and Electrolyte
Voltaic cell	Electrolytic cell

Chart 2- Similarities:

Photovoltaic	*Fuel Cell*
Clean Energy" Pollution reduction No by products.	Clean Energy" Pollution reduction Release of water vapor and heat which are non pollutants.
Produce Electricity in the form of direct current (DC) voltage	
Renewable Technology but high initial cost	
Challenges: 1. Only produce electricity during the daylight hours. 2. Producing and installing solar cell is expensive for their current energy payback.	Challenges: 1. There is a lot of energy required to make and distribute hydrogen. 2. Hydrogen's elemental nature makes it a difficult fuel to transport and store.

Additional Resources:

Visit the following websites for more information:

- http://www.rps.psu.edu/hydrogen/microbial.html
- http://www.eere.energy.gov/hydrogenandfuelcells/
- http://science.howstuffworks.com/fuel-cell1.htm
- http://science.howstuffworks.com/solar-cell.htm

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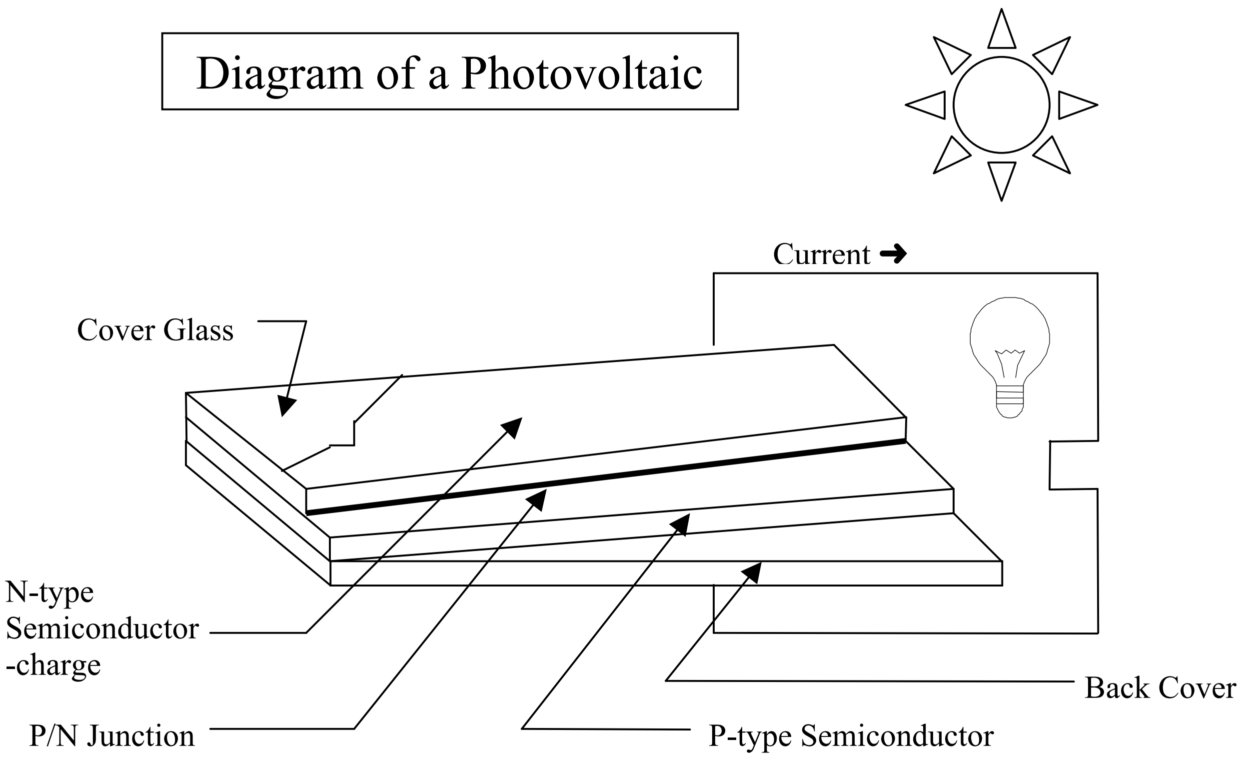

[Spotlight on Photovoltaics & Fuel Cells: A Web-based Study & Comparison](http://)
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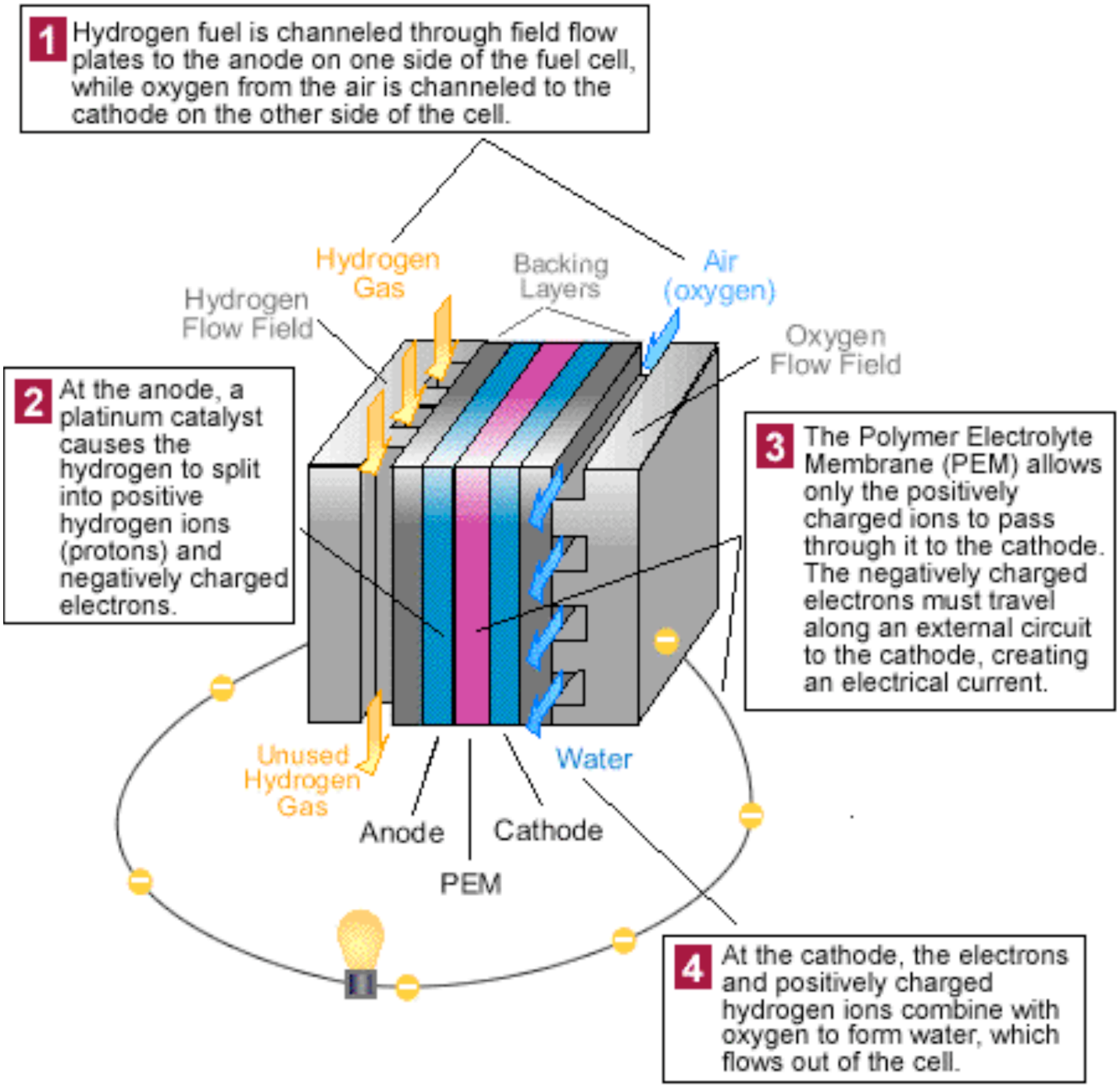

Source: http://www.fueleconomy.gov/feg/fc_pics/fuel_cell_still.gif