FUEL CELL

A fuel cell is energy conversion device. It has no moving parts and thus operates silently. In the fuel cell process enegy is released as heat and electricity. In camparison to battery which also released energy (electricity). The battery is a device that contains chemical energy that when we plug it into a load, it is converted into an electric current. The battery is a sealed device - that is, it contains all its chemicals inside - and can provide a predetermined amount of energy.

Compared to the battery, a fuel cell is an open device, one that continually enters chemicals (this is actually our fuel), and as long as the fuel continues to enter the cell, we will receive energy. Such as a hydrogen-oxygen fuel cell that gets the hydrogen from the tank and oxygen directly from the air.

It is noted that while a battery is an energy storage facility, a fuel cell is an energy conversion facility. Another essential feature is that the efficiency of a fuel cell is higher than the efficiency of the battery. More on that later. There are numerous kinds of fuel cells that differ in all kinds of structures, from the compounds introduced into the cell (the fuel) to the working temperature. While the operation principle of every type of fuel cell is same. Hydrogen fuel cell is commonly used fuel cell in various applications.

Hydrogen

Hydrogen is a chemical element. At room temperature, its aggregate state is gas, colorless, highly metallic, and flammable. It is labeled as H (Hydrogen), and its atomic number is 1 and is the lightest substance. The hydrogen molecule has two hydrogen atoms and is labeled as H_2. Hydrogen is the most common element in nature and the universe (about 90% of the material in it) and is a component of a water molecule and any compound Organic like coal, natural gas, and fossil fuels. He can respond with almost all the basics. Hydrogen is not freely found in nature but is always associated with another substance. The most available source of hydrogen is water. Hydrogen is a highly flammable gas. Hydrogen has a price, almost 100 times higher than the price of an internal combustion engine. The price of hydrogen is also five times higher than the price of gasoline per unit of energy available. the need for pure hydrogen production that can cause environmental pollution. Hydrogen is the lowest-density gas in the universe, so the gas distribution, storage, and safe handling of it pose technological difficulties and infrastructure problems. You can produce hydrogen from a variety of sources. In fact, gas is not fuel in the normal sense of the word. Fuel is something found in nature, like coal, or refined from a natural product, like diesel produced from crude oil, and then burned to do the job. in a natural state, the pure hydrogen does not exist on Earth. Its production is such a complex process that one can actually see it as a means of storing and transporting energy from some other source to the electricity generating plant. Hydrogen can be extracted from methane, the main component of natural gas. Hydrogen and carbon dioxide can be obtained from a chemical reaction between natural gas and steam, but utilizing natural gas to fill hydrogen fuel cells will reduce its best industrial use today: high-combustion combustion turbines for electricity generation.

Redox Reaction

To understand the workings of a fuel cell it is important to have the chemical background for redox reactions. Because of this, we must understand the very basic principles of reduction and oxidation. Reduction and oxidation both refer to changes in the electron configuration of an atom. Reduction is the process of an atom gaining electrons while oxidation refers to the loss of such. Electrons are negatively charged and therefore reduce the atoms oxidation state. From a historical standpoint, reduction described the physical loss of mass when, for example, metal ore was reduced to yield the pure metal. The electron transfer processes were only later understood and the term “reduction” remained. The word oxidation is simply derived from the reaction with oxygen which was the first oxidizing agent to be discovered. The process of oxidation involves an atom losing electrons and therefore resulting in a higher oxidation state due to less negative charges. A so-called redox reaction is the combined process of the two half-reactions reduction and oxidation. This makes sense since for every action there is an opposite reaction and oxidation, as well as reduction, are stoichiometric reactions but with opposite electron processes. This means the electrons one atom loses another one gains. A very easy example is the electrolysis of water to oxygen and hydrogen. A Schematic diagram of a water electrolysis cell is shown in Figure-1.

In this case, water is supplied with electrons by applying a current. At the negative electrode, the cathode (where the reduction happens), the water takes up electrons, is therefore reduced and reacts to hydrogen and negatively charged hydroxyl ions. The ions are able to cross an electrolyte membrane separating the two electrode chambers from each other. At the positive anode (where the oxidation happens) the reaction of the hydroxyl ions results in oxygen, water, and electrons. Since the electrodes are connected via an external circuit, the electrons are able to flow to the cathode. Electrons and ions from both half-reactions are balanced and omitted in the overall reaction:

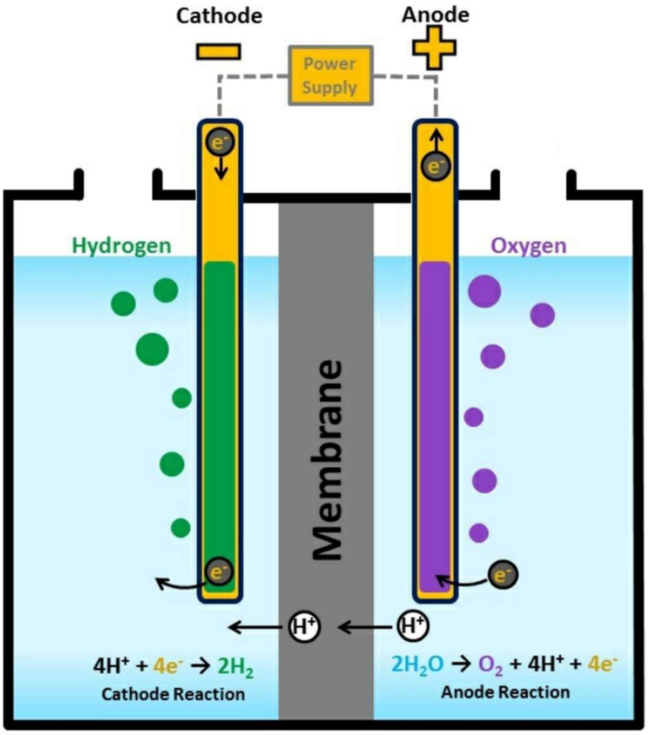

Figure-1 Schematic diagram of a water electrolysis cell.

Anode Reaction: $4 OH^- \rightarrow O_2 + 2 H_2O + 4 e^-$

Cathode Reaction: $4 H_2O + 4 e^- \rightarrow 2 H_2 + 4 OH^-$

Overall: $2 H_2O \rightarrow 2 H_2 + O_2$

The mentioned reaction is a perfect example since a classic hydrogen-oxygen fuel cell uses the exact reverse reaction to generate energy instead of consuming it.

Working Principle and Components

On the basic level, fuel cells convert chemical energy directly into electrical energy very efficiently through an electrochemical reaction. The principle is rather simple but the design can be complicated. A fuel cell is comprised of a cathode, an anode, an electrolyte, a separator between the electrode chambers, the fuel, as well as an oxidant. Cathodes are the positive and anodes the negative terminals of the cell. These two terminals are contacted inside the cell via the electrolyte which allows for ion transfer. The anode is continuously fed with the fuel while the cathode is supplied with the oxidant. The schematic diagram shown in Figure-2 provides an overview of the basic structure of a fuel cell using hydrogen as fuel and oxygen as oxidant. Since different fuel cell types differ internally as well as in fuels and oxidants used, the specific types will have their different workings.

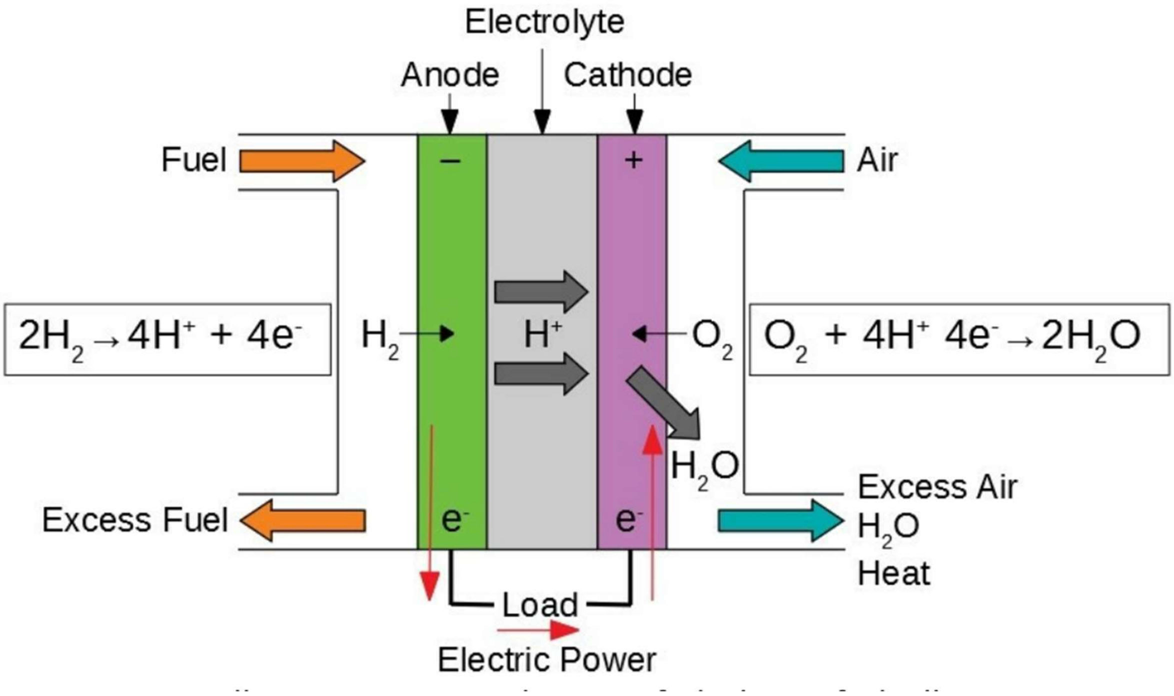

Figure-2 Basic principle diagram of a hydrogen fuel cell.

Chemical reactions at the respective electrodes for classic hydrogen oxidation:

Anode Reaction: $2 H_2 \rightarrow 4 H^+ + 4 e^-$

Cathode Reaction: $O_2 + 4 H^+ + 4 e^- \rightarrow 2 H_2O$

Overall: $2 H_2 + O_2 \rightarrow 2 H_2O$

The anode reaction generates protons (H^+) and electrons (e^-) which move to the cathode via different means. The protons move directly to the cathode via the electrolyte while the electrons move via an external circuit. The movement via the circuit manifests as the electric current which can be measured and used to power electric devices. When the protons and electrons have reached the cathode they combine with the oxygen (O_2) to produce water. This is one of the main advantages of fuel cells since no greenhouse gases are released by this reaction.

Technical Assembly of Fuel Cell

Fuel cells are static devices meaning the actual cells possess no moving parts and therefore do not need extensive maintenance. However, cooling and control systems guaranteeing optimal working conditions might have moving parts like pumps or fans. Unlike in batteries, the components in fuel cells only act as a catalyst and are not consumed during the reaction – at least under optimal conditions. This means the fuel cell operates as long as it is provided with fuel and does not have to be recharged. This is a major advantage in the transport sector where refueling times can be considered critical. Since the power of one fuel cell is usually not enough to power a car, for example, commercial fuel cell implementations involve multiple cells in parallel. This can be achieved through space efficient stacking. The Figure-3 shows the schematic of a setup that would be used in a laboratory, for example, and is intended to convey the basic principle. Fuel cell stacks, on the contrary, employ the same components but they are assembled in a much more different way as displayed in the Figure-3.

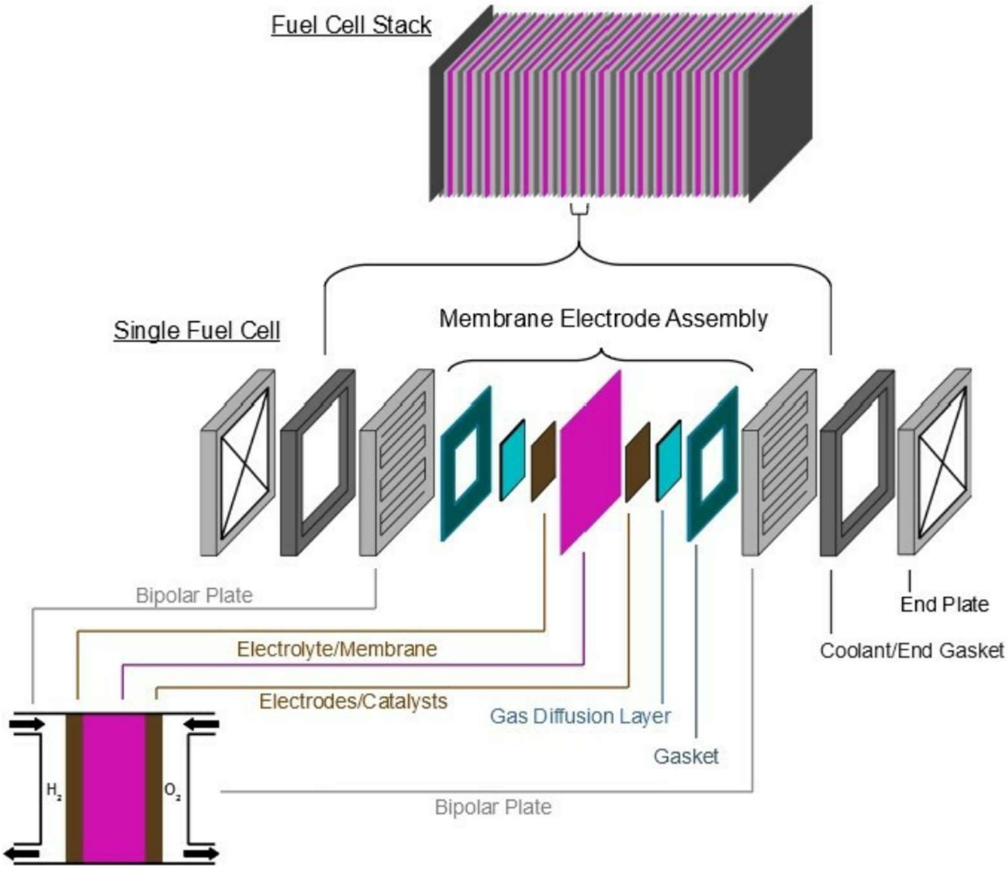

Figure-3 Technical assembly of fuel cell stacks.

The main part of the fuel stack is the membrane electrode assembly (MEA). It is comprised of the cathode and anode electrodes as well as their catalyst layers, the ion conducting electrolyte, and a gas diffusion layer (GDL). The MEA is sandwiched by bipolar plates (BPPs). These plates are often made of graphite composite materials and serve as current collectors as well as reactant flow controllers. The plates are crucial to the fuel cell stack since they have a variety of essential functions. They conduct current away from the cell, help with fuel distribution and water management (if necessary), separate the individual cells, and also facilitate heat regulation. Besides the bipolar plate, the coolant gasket helps with temperature management in the same way but it also serves as a frame and seal. End gaskets and plates seal the whole stack and connect it to the fuel as well as oxidant supply.