

WHAT IS A FUEL CELL?

The fuel cell was invented by Sir William Grove in 1839. It was not until the 1950s, however, that the National Aeronautics and Space Administration (NASA) constructed the first practical fuel cells to produce power for space vehicles.

Fuel cells directly convert the energy released in certain chemical reactions, primarily combustion (oxidation) of hydrogen or a carbonaceous fuel, to electrical energy. Typically, combustion reactions are of interest because they release a large amount of energy per unit mass of fuel and because some of these fuels are available at relatively low cost. The reaction of hydrogen (the fuel) with oxygen (the oxidizer) to produce water is such a suitable reaction. Other fuels used in fuel cells include methane, methanol, and even gasoline. More chemically complex fuels, like gasoline, typically require pre-processing into a hydrogen-rich gas stream before introduction to the fuel cell.

The fundamental building block of a fuel cell is an electrochemical cell (see figure) consisting of two electrodes separated by an ionically conducting medium (or membrane). The ionically conducting medium can be an acid, base, or salt (in liquid, they are in polymeric or molten forms) or a solid ceramic that conducts ions; the choice of electrolyte is dependent on the nature of the fuel, the temperature of operation, and the specific application of the technology. Fuel enters the cell on the left side and oxygen enters on the right side. Any reaction products (water and perhaps carbon dioxide [CO₂] — depending on the fuel and type of cell) must also exit the cell. As fuel is oxidized, electrons are released to travel through the external load to the cathode, where oxygen consumes the electrons. The following other essential parts of a real fuel cell are omitted from the diagram: all the container and support materials that keep the fuel and oxygen flowing (but separate) and direct the reaction products out of the cell, the interconnections between a series of cells, etc.

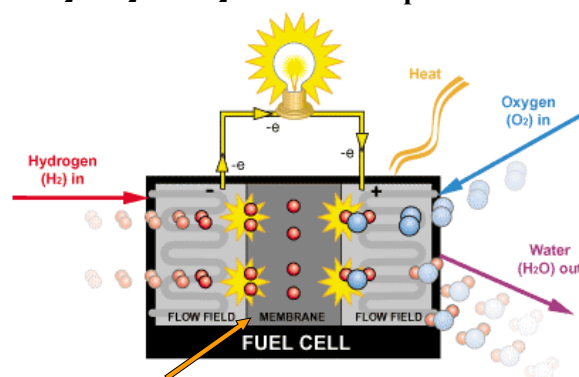
The electrodes serve several functions. First, they must be electronically conducting. Second, they usually contain the electrocatalytic materials that facilitate the reaction of fuel at one electrode (the anode) and of oxygen at the other electrode (the cathode). Some catalytic materials are much better than others at facilitating the reactions and may themselves also be electronic conductors. Grove used solid pieces of platinum metal for both electrodes; platinum was both the conductor and the electrocatalyst. In most contemporary low-temperature fuel cells, platinum electrocatalysts are still used, but in highly dispersed form as nanoparticles.

The electrocatalyst is highly dispersed in order to attain large electrochemical reaction rates that result in high electrical power output. Furthermore, for the fuel cell to function properly, the electrocatalyst particles have to be easily reached by the fuel (or by oxygen on the other side of the cell), and they also must be contacted by the ionically conducting medium and by the electronically conducting medium. Consequently, current low-temperature fuel cell electrodes consist of porous composites of ionic/electronic conductors with embedded nanosize particles of the electrocatalyst in order to obtain as high an electrical power from as small an amount of precious metal as possible. The electrode contains open pores for the fuel (and any waste products) to enter or exit the electrode. Producing electrodes that offer optimal performance is challenging.

More than 150 years after Grove's discovery, fuel cells that operate near room temperature still contain the precious metal platinum. One goal of an ambitious fuel cell R&D program is to replace the expensive platinum with much cheaper materials. No one thinks this objective will be easy to attain — after all, nothing better has been found in 150 years!

Many web sites are dedicated to fuel cells and to Sir William Grove; a few of the many interesting ones are listed below:

<http://fuelcells.si.edu/basics.htm> (at the Smithsonian Institution)
<http://science.howstuffworks.com/fuel-cell.htm>
<http://education.lanl.gov/resources/fuelcells/>



Membrane conducts protons from anode to cathode
proton exchange membrane (PEM)