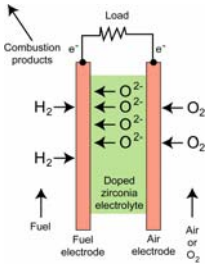
Class 1: Introduction to Solid Oxide Fuel Cells

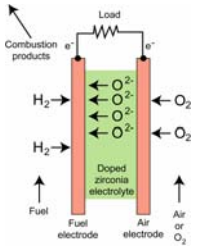


PRIME Modules
Project-based Resources for Introduction to Materials Engineering

A fuel cell consists of an anode, cathode, and electroltye

A FUEL CELL is consists of two electrodes (an anode and a cathode) that sandwich an electrolyte (a specialized material that allows ions to pass but blocks electrons).

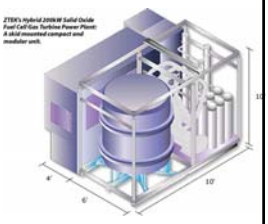
Fuel cells could power cleaner buses and cars and could provide electricity, heat and hot water to a home, but key engineering and economic obstacles remain which delay widespread adoption of the technology.



Scientific American, July 1999, pp. 72-93.

Several advantages make SOFC more attractive than H fuel cells for some applications

- **SOFCs are over 60% efficient (conversion of fuel to electricity) making them the most efficient fuel cell currently being developed.**
- **The efficiency makes them a good candidate for a distributed power source (generator or power plant).**
- **Because they are solid, SOFCs are quieter than other types, making them good for indoor applications.**
- **The reactions in SOFC require a high temperature. The advantage is that this creates a by-product of heat.**
- **There are no liquids that cause safety and environmental problems.**



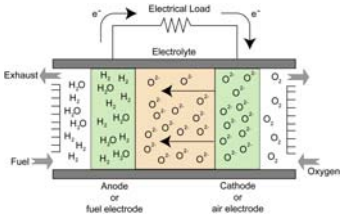
http://www.ztekcorporation.com/sofc_200kw.htm

In a Solid Oxide Fuel Cells (SOFCs) air is supplied to the cathode

A solid oxide fuel cell (SOFC) is a device that converts gaseous fuels (hydrogen, natural gas, gasified coal) via an electrochemical process directly into electricity.

Air is supplied to the cathode (air electrode)

At the cathode, the O2 molecules are ionized

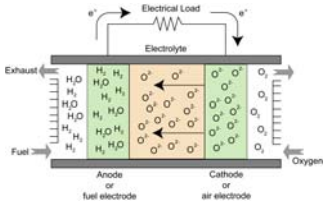


In SOFCs oxygen ions react with H_2 from the fuel

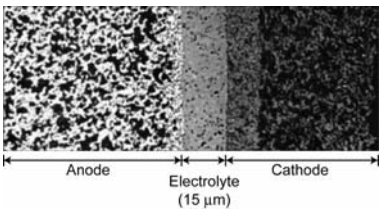
The ionized oxygen diffuses across the electrolyte

At the anode, the O^{2-} ions react with H (in the fuel).
$H_2 + O^{2-} \rightarrow H_2O + 2e^-$

The reaction produces electrons to do work and water.



The anode and cathode are porous while the electrode is dense



The anode and cathode must be porous to allow the air and fuel in

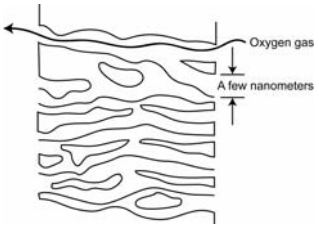
The electrolyte must be dense to prevent the air and fuel from mixing.

F. Tietz, H.-P. Buchkremer, and D. Stöver, "Components manufacturing for solid oxide fuel cells," *Solid State Ionics*, **152-153** (2002) 373-381.

Nanomaterials play a key role in the SOFCs

Large surface areas (nanopores) are needed for oxygen transport within the air electrode, as well as hydrogen and water transport within the fuel electrode.

Nanoporosity (i.e. pores less than 100 nm in size) can be attained by careful processing of nanosized ceramic particles.



Desired Cathode Structure

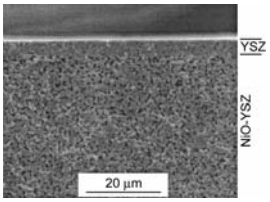
The anode would have the same structure, but the gas that would flow through is hydrogen.

Ceramics are needed to allow for the ionic conduction

The most common electrolyte material is ZrO_2 (zirconia), which is doped with small amounts of Y_2O_3 (yttria). This material is known as yttria-stabilized zirconia (YSZ). This is a ceramic material - a compound of a metal with a non-metal.

Ni/YSZ cermet (ceramic-metal composite) is used as the anode material because of its low cost. It is also chemically stable at high temperatures and its thermal expansion coefficient is close to that of the YSZ electrolyte.

The cathode is based on a $(La_{1-y}Sr_y)MnO_{3-\delta}$ (LSM) perovskite material.



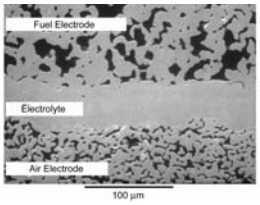
J. Will, A. Mitterdorfer, C. Kleinlogel, D. Perednis, and L.J. Gauckler, "Fabrication of thin electrolytes for second-generation solid oxide fuel cells," *Solid State Ionics*, **131** (2000) 79-96.

There are a number of materials related research items to improve SOFCs

Thinner layers are being designed to minimize ohmic resistance.

Manufacturing processes are being optimized for lower temperatures to avoid undesirable mixing.

New materials of higher performance are being investigated



S.C. Singhal, "Advances in solid oxide fuel cell technology," *Solid State Ionics*, **135** (2000) 305-313.

A.J. McEvoy, "Thin SOFC electrolytes and their interfaces - a near-term research strategy," *Solid State Ionics*, **132** (2000) 159-165.

In summary, SOFC operate by passing oxygen ions across a solid electrolyte.

SOFC has a ceramic cathode that ionizes oxygen. The cathode needs to be porous to allow air in.

The oxygen ions diffuse across a solid, dense, ceramic electrolyte.

At the anode, the oxygen ions react with hydrogen to form water and electrons.

The electrons can not flow through the electrolyte so they leave through the load.

SOFC are being investigated for power plants and generators. They have high efficiency, are quiet, and have no liquids that can be unsafe or dangerous to the environment.