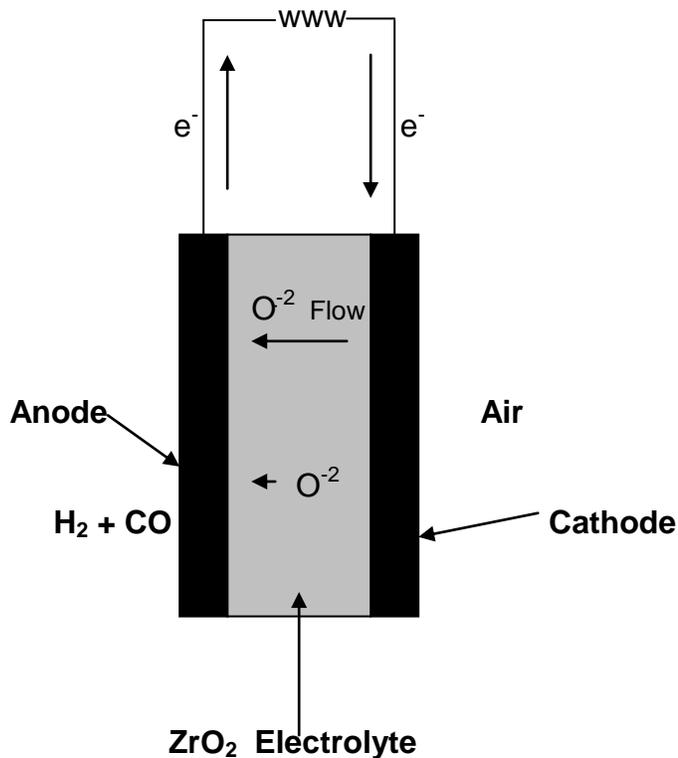


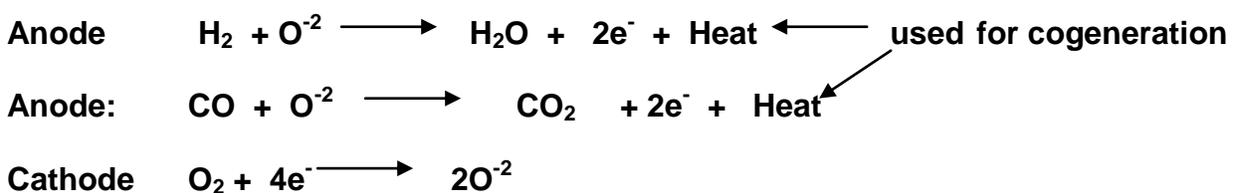
Solid Oxide Fuel Cells

BASICS

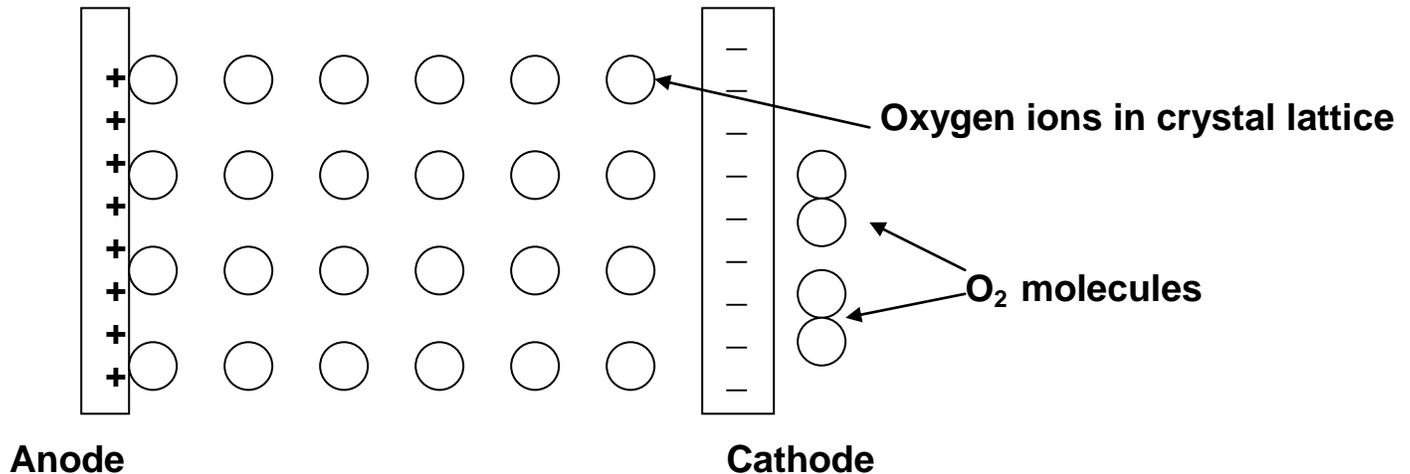
1. Solid oxide fuel cells use a ceramic oxide as the electrolyte
2. The fuel at the anode is a **mixture of reformed H₂**, which also contains **CO**
3. The electrolyte is a **zirconia ceramic ZrO₂** which is doped with Y₂O₃ or CaO.
4. The fuel cell operates at high temperatures of typically 1000°C.
5. The ion used is different from other fuel cells because **oxygen ions** travel through the electrolyte.
 - a. Direction of O⁻² ion flow is **from the cathode to the anode**. See below:
6. SOHC fuel to electric efficiencies are in the range of 45%



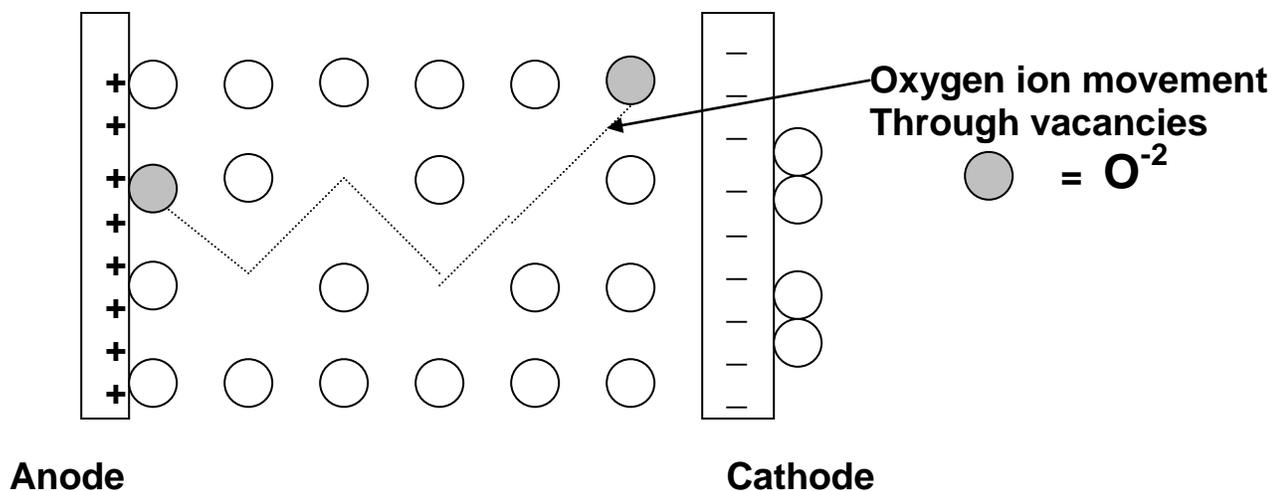
Chemical Reactions



ZrO₂ Not doped with Y₂O₃ or CaO



ZrO₂ doped with Y₂O₃ or CaO producing oxygen vacancies



Crystal Considerations Structure of ZrO₂

1. Zr as a metal combines with O and forms the ceramic compound of ZrO₂
 - a. This is a solid oxide with low ionic conductivity at 1000⁰C.
2. However, ionic conductivity can be improved by doping ZrO₂ with Y₂O₃ or CaO.
 - a. 8% Y₂O₃ and 92% ZrO₂ (mole %) is a common composition for the electrolyte.
 - b. The result is a significant increase in ionic conductivity at 1000⁰C
 - i. The reason is "**Oxygen vacancy sites**" in the crystal lattice are produced, allowing O ions to travel to the anode and become electrically neutral.

Other Factors

The **anode** consists of metallic Ni and Y_2O_3 -stabilized ZrO_2 skeleton, which serves to inhibit sintering of the metal particles and to provide a thermal expansion coefficient comparable to those of the other cell materials. **The anode structure is fabricated with a porosity of 20 to 40% to facilitate mass transport of reactant and product gases.** The Sr-doped lanthanum manganite ($La_{1-x}Sr_xMnO_3$, $x = 0.10-0.15$) that is most commonly used for the cathode material is a p-type conductor. Similar to the anode, the **cathode** is a porous structure that must permit rapid mass transport of reactant and product gases.

The 1830°F (1000°C) operating temperature of the SOFC requires a significant start-up time. The cell performance is very sensitive to operating temperature. A 10% drop in temperature results in ~12% drop in cell performance due to the increase in internal resistance to the flow of oxygen ions. The high temperature also demands that the system include significant thermal shielding to protect personnel and to retain heat. While such requirements are acceptable in a utility application, they are not consistent with the demands of most transportation applications nor do they lend themselves to small, portable or transportable applications.

The high operating temperature of the SOFC offers the **possibility of internal reforming**. As in the MCFC, CO does not act as a poison and can be used directly as a fuel. The SOFC is also the most tolerant of any fuel cell type to sulfur. It can tolerate several orders of magnitude more sulfur than other fuel cells.

The excess heat produced from the anode reactions also permits the use of **cogeneration**. Cogeneration is the simultaneous production of heat and power in a single thermodynamic process. The common feature in all cogeneration systems is the prime mover, which will either convert waste heat into power or generate heat and power from a single energy input. Prime movers can either be reciprocating engines (such as an automobile engine, which produces both power and heat) or a turbine. Turbines can be powered by steam, hot air, and occasionally other media. Combustion turbines have a compressor, combustor, and hot air turbine in a single unit. Prime movers can be combined in a variety of ways to increase energy utilization. One common method is to use the waste heat from an engine or combustion turbine to generate steam, which is then used to power a steam turbine. Almost all cogeneration utilizes hot air and steam for the process fluid, although certain types of fuel cells also cogenerate.