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Yttrium-Stabilized Zirconia

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MSE 395

Materials for Energy Efficient Technology

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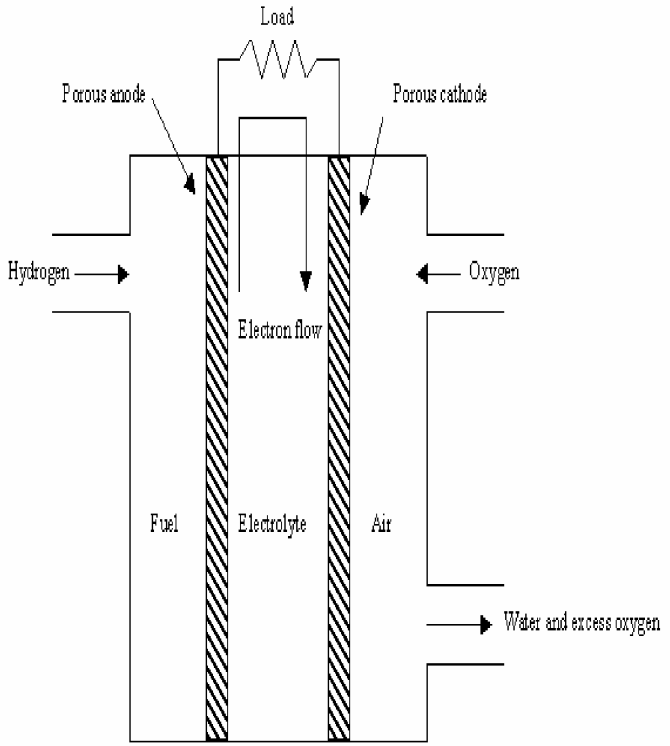
Fuel Cell Basics

- H^+ and O^{2-} ions are formed at the anode and cathode respectively.
- Ion-conducting electrolyte permits flow of one ion from the anode to cathode, or vice versa
- Result: Voltage across the cell as electrons flow across electrical load to balance electrochemical reaction
  - Theoretical V: 0.6-1.2 V.



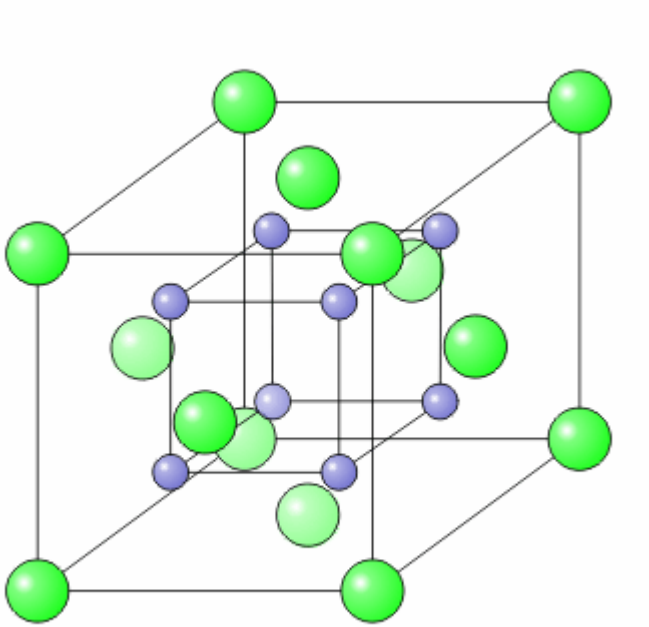
Solid Oxide Fuel Cells

- Conducted Ion: O^{2-}
- Electrochemical Reaction:
  - Anode Reaction:2 H2 + 2 O2- => 2 H2O + 4 e-
  - Cathode Reaction:O2 + 4 e- => 2 O2-
  - Overall Cell Reaction:2 H2 + O2 => 2 H2O
- Recombination of ions occurs at the anode

- Electrolyte Material: Yttrium-Stabilized Zirconia

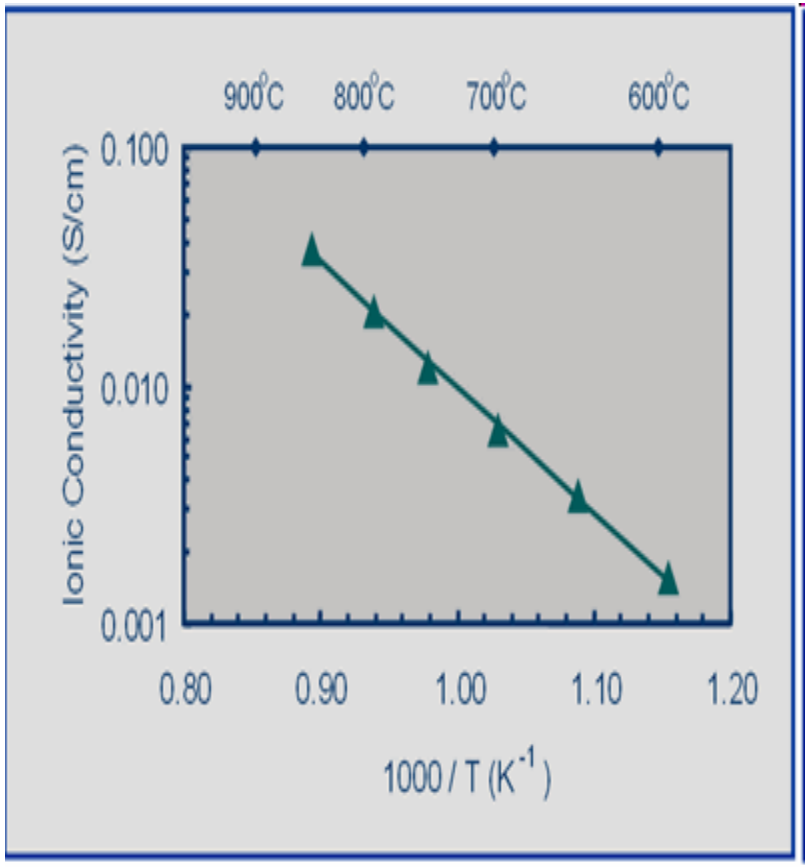
Why YSZ?

- Zirconia (ZrO_2) is a thermal insulator with high thermodynamic and chemical stability
- Doping Zirconia with Yttria (Y_2O_3) replaces Zr^{4+} with Y^{3+}
  - Adds Oxygen Vacancies
  - Ionic Conductivity



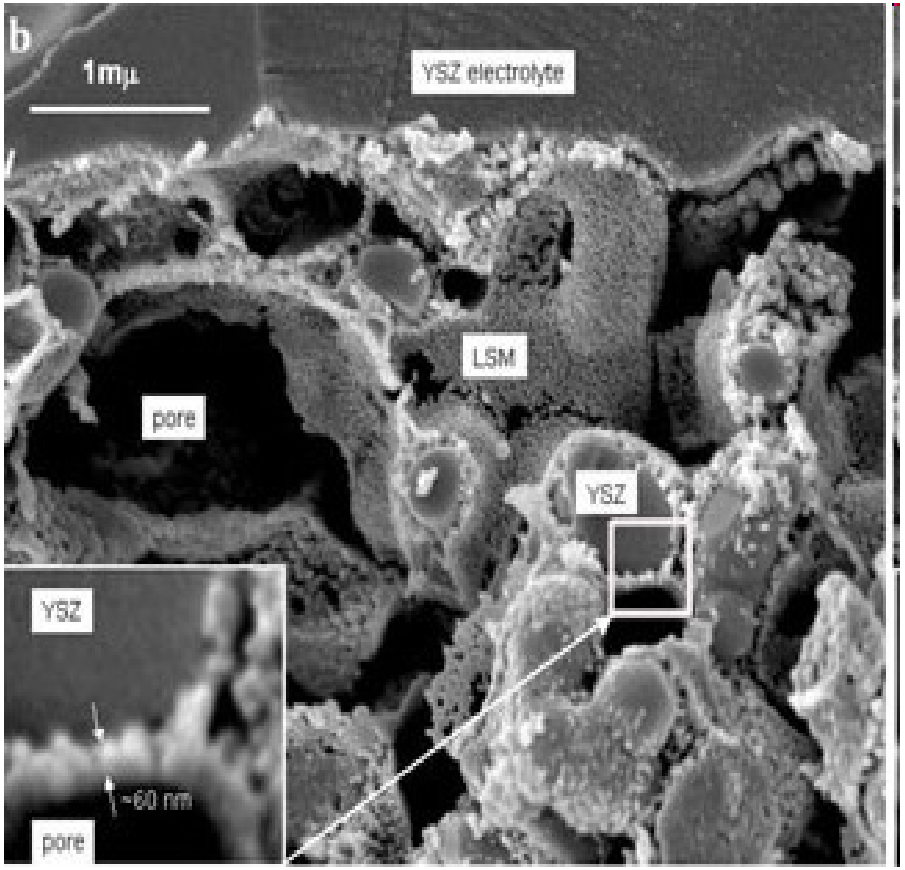
Ionic Conductivity of YSZ

- At low temperatures, low vacancy mobility limits O^{2-} Mobility.
- Above 700-800 C, high ionic conductivity (comparable to liquid electrolyte fuel cells)
- Result: SOFCs used at high-T.



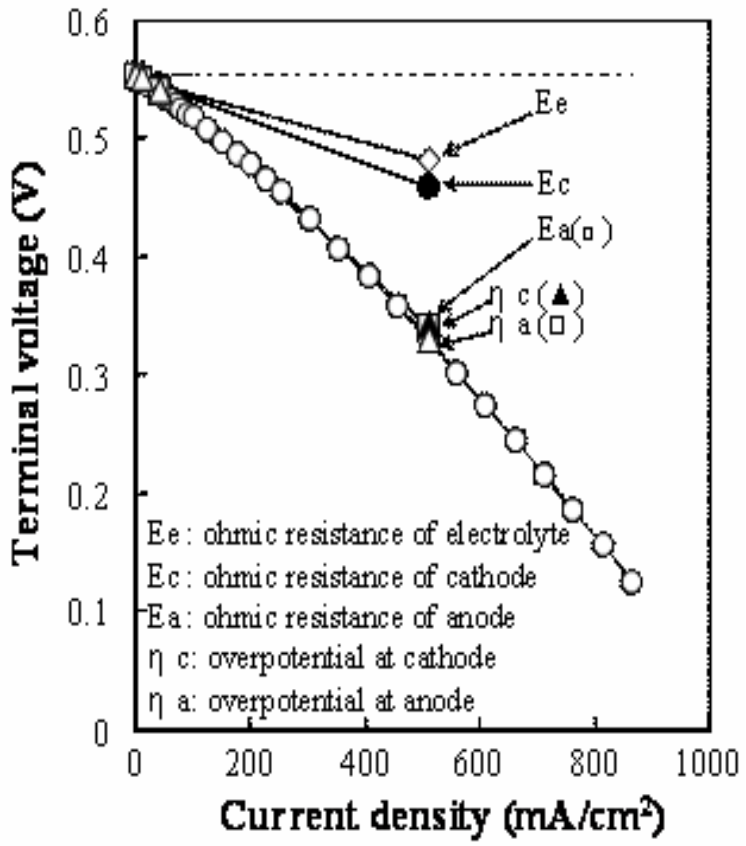
YSZ, Porosity, And Electrochemical Reactions

- Energy stems from recombination of ions:
  - $2H^+ + O^{2-} => H2O$
- For the recombination of ions to occur, a 3-phase boundary between the electrolyte, anode, and air is needed.
- 3-phase boundary maximized by porous electrolyte-anode structure



Advantages of YSZ Use

- High Temperature Reduces Voltage Loss due to ***current***, a problem with fuel cells
- Since YSZ remains solid throughout, electrolyte does not vaporize; minimal corrosion
- Good ionic conductivity removes need for expensive electrocatalysts



Disadvantages of YSZ Use

- Temperature, Temperature, Temperature:
  - High Temperature Operation reduces the reaction energy of forming water from oxygen and hydrogen ions (can be mitigated somewhat with CHP setup).
  - High Temperature can be expensive to maintain
  - High temperature can cause thermal expansion stresses in the material
- Zirconia is brittle
  - Electrode Support is needed to keep oxide electrolyte from fracturing too easily, particularly as it is thin
  - Also makes the cell very sensitive to thermal stresses
- Result: Long Warm-Up Time Needed

Future of YSZ

- Increased ionic conductivity at lower temperature
  - Reduced Operation Costs, Shorter Warm-Up Time
  - Higher No-Loss Voltage
  - Less thermal stress
- Complex Dopants
  - Add Ceria; Higher Ionic Conductivity, Lower Stability
- Alternative Materials
  - LaSrGaMgO; Not as well documented or understood

Questions?