Better Solid Oxide Fuel Cell with thin film technology

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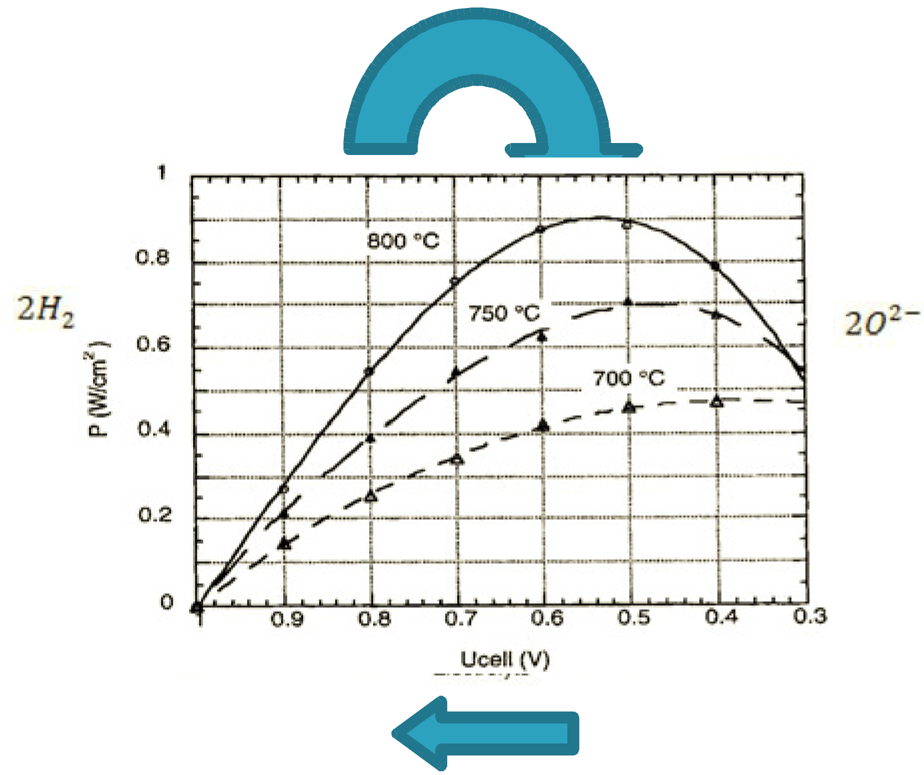
Sold Oxide Fuel Cell

- Advantages:
  - No liquid electrolyte problems
  - High temperature operation requires less sophisticated catalyst
  - Hot exhaust fume can be used to turn another turbine to improve efficiency
- Disadvantages:
  - Creep resistance and



Optimal temperature: 1000C

A very big challenge on material selection

Thin Film Processing

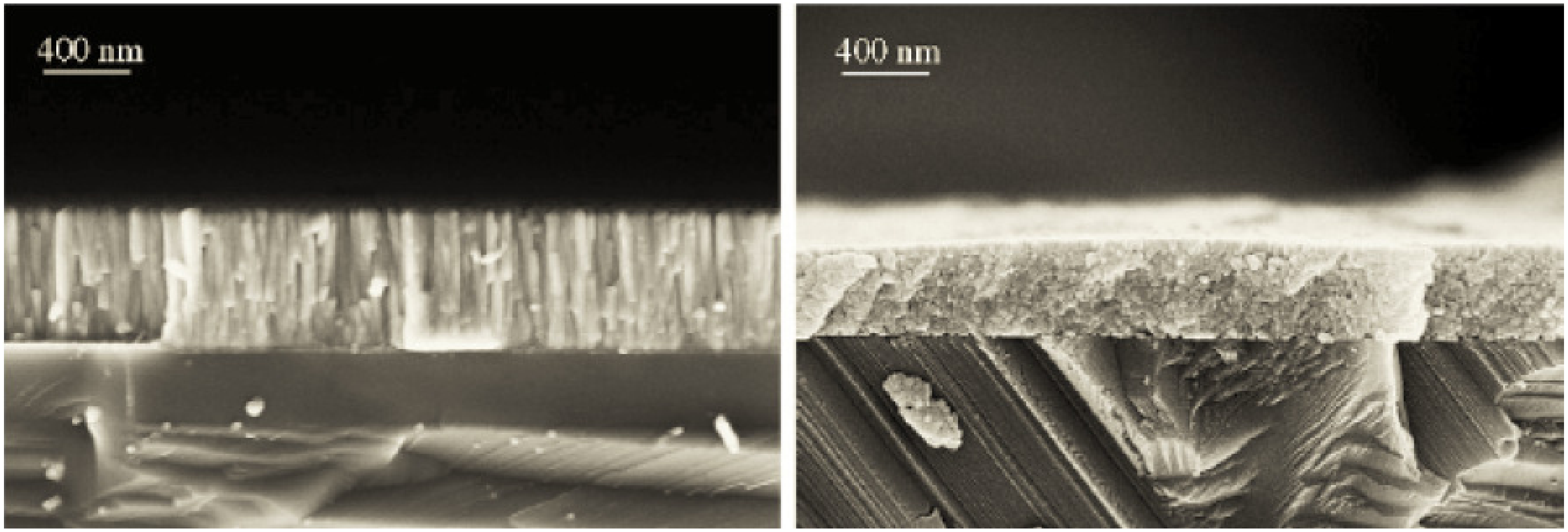
- Why is thinner film better in SOFC and how it is made?

1. Reduced Diffusion Distance

- To reduce resistance, the length of electrolyte (L) should be reduced.
- A 15nm electrolyte should be 1000 times more conductive than one of 15um.
- However, σ in thin

$$R = \frac{1}{\sigma}\frac{L}{A}$$

2. Choice of Processing



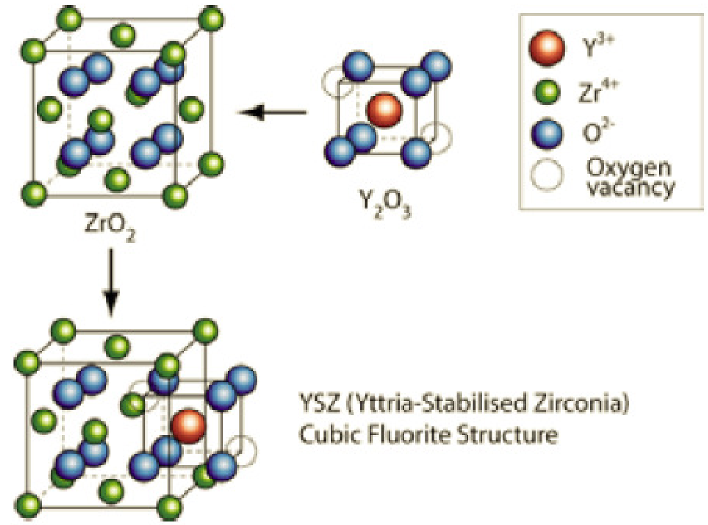
- Pulsed Laser Deposition
  - Gadolinia-doped Ceria
  - Vacuum Deposition
  - Columnar grains
  - Grain boundaries aligned along conduction path
  - Similar microstructure shows

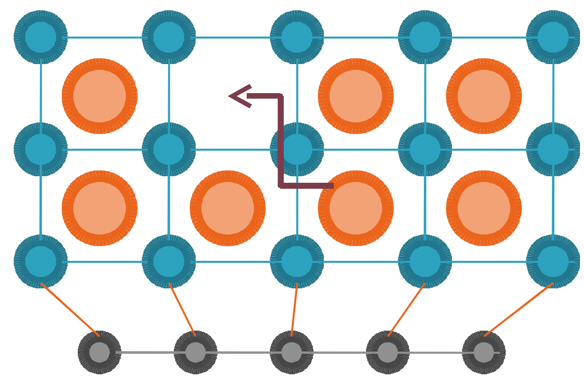
- PSD Deposition
  - Gadolinia-doped Ceria
  - Deposition from a wet solution
  - Isotropic grain distribution
  - Grain boundaries crossing or blocking conduction

Beckel, D., et al., 2007.

3. Film Stress Control

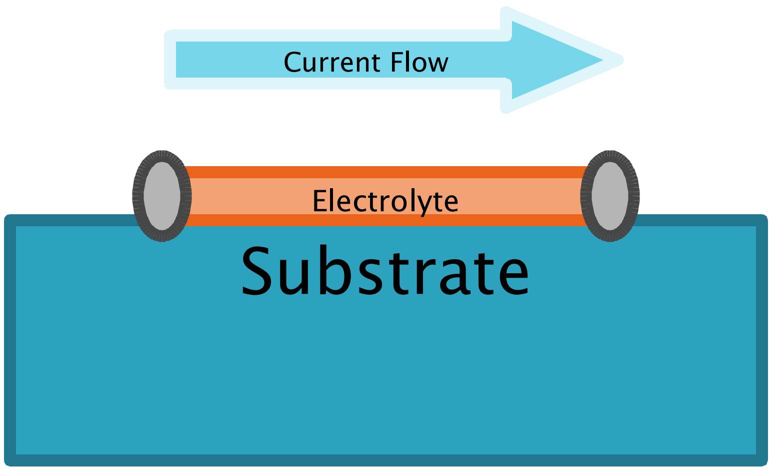
- Oxygen vacancy in YSZ causes lattice stress.
- To release this stress oxygen atom has to moves in and there is an energy cost
- Due to lattice misfit, compressive stress





4. Nano-scale thickness

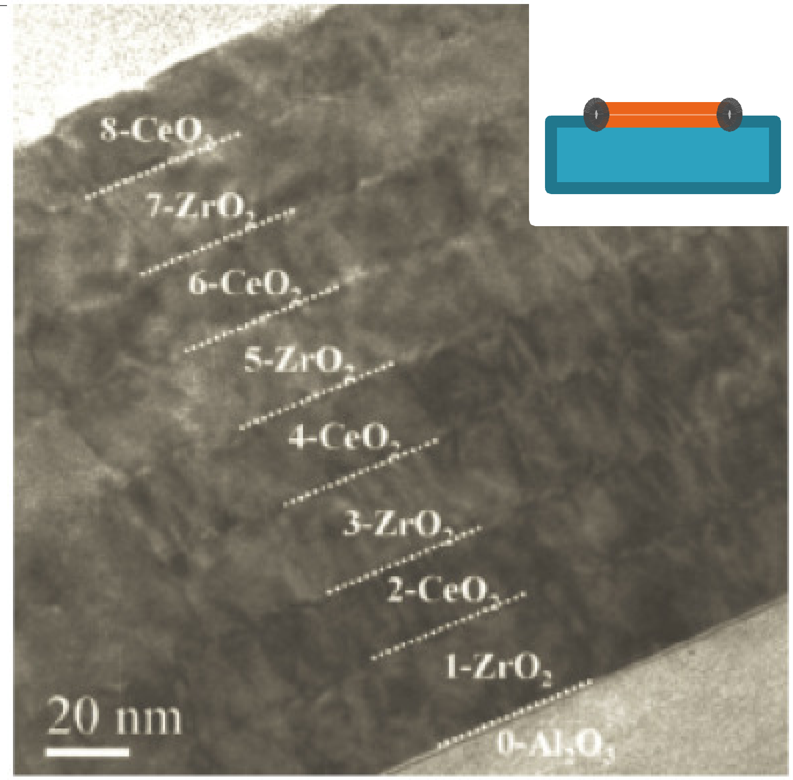
- Maximum conductivity of 60 S/m with 15nm YSZ film
- Compared with 3.16S/m for bulk YSZ
- Mechanism change from bulk diffusion to interface diffusion



Kosacki, I., et al, 2000.

5. Composites

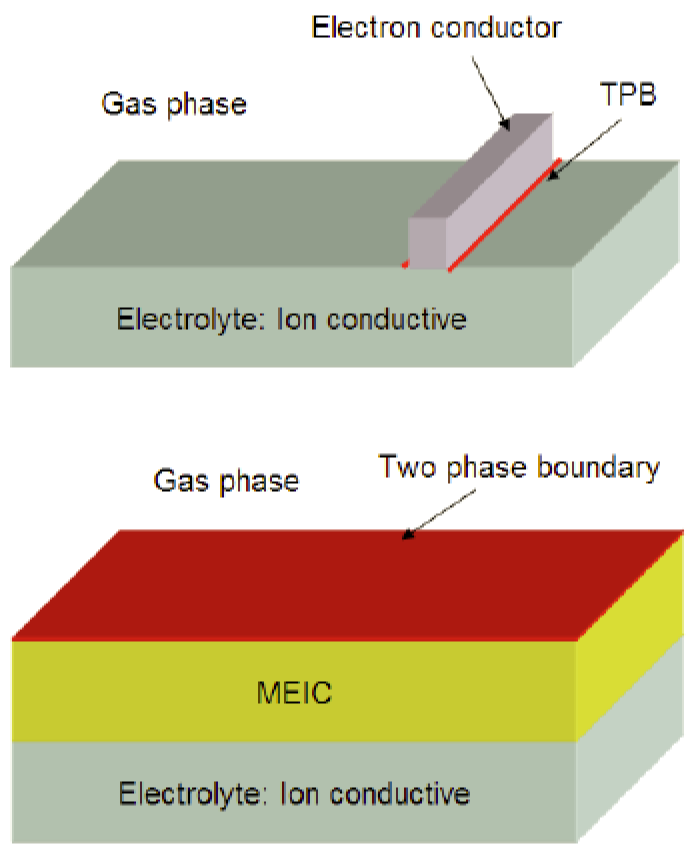
- Ceria is a better ion conductor at low temperature than YSZ but it is chemically unstable
- Composite with zirconia to stabilize ceria
- A 150nm thick electrolyte with 16



Azad, S., et al., 2005

Cathodes and Anodes

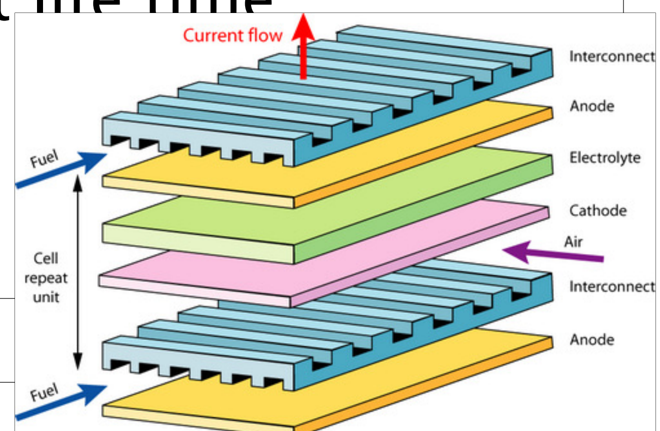
- Generally a lot thicker to increase surface area
- Formed into nano-porous films to facilitate material exchange
- Mixing of electrolyte material with electrode to increase triple phase



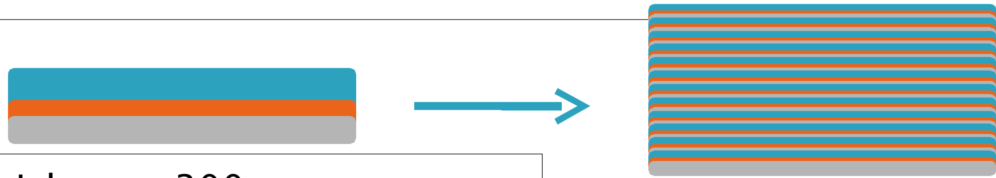
Triple Phase Boundary, RPL Standford, Viewed: 26 May 2009,<http://www-rpl.stanford.edu/research/energy/micro-fuel-cell/sofc/electrode/tpb/>

Problems with thin films

- Thinner films needs better mechanical supports
  - Solution: SOFC supported by anodes or cathodes
- Interconnect materials
  - Solution: No perfect solution
  - Potential candidates such as lanthanum-strontium manganite or lanthanum chromite have problems with low conductivity and short life time



Technological implications



Thickness: 300um
Power density: 800nW/cm2

Volume: 10x10x5cm
Power output: 1300W

SOFC modules at each household

Energy self-sufficiency
- Exhaust heat for heating purpose
- Exhaust fume to generate power to make hydrogen

Efficient consumption
- Obsolesce of existing power grid
- Sharing of energy with the community

Conclusion

- Thin film technology has the potential to solve existing problems in SOFC with advancement in material research through:
  - Reduction in diffusion distance
  - Choice of processing technique
  - Film stress control
  - Nano-scale thickness
  - Composite
- Thin film processing in electrodes and interconnects can be further pursued
- Low-temperature SOFC has the potential to

References

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- 3. E. Garrison, Solid Oxide Fuel Cells, last updated:August 16, 2006, Viewed: May 26 2009, < http://www.iit.edu/~smart/garrear/fuelcells.h