Solid oxide fuel cells (SOFCs) are the most efficient devices known to convert chemical energy stored in a fuel to electrical energy:

- Efficiencies as high as 75% are projected, far in excess of what is possible with combustion systems.
- Substantial reductions in global CO₂ emissions
- A wide range of fuels can be utilized: hydrogen, methanol, methane, propane, coal-derived syngas, and diesel reformate.

However...

- Cost per kW of current-generation SOFCs is an order of magnitude higher than DOE target of $400/kW.

New nanofabrication methods have the potential to completely change how SOFCs are made, resulting potentially in much higher performance, and substantially lowering the cost per kW.

High Performance SOFCs: What is possible?

We have developed a detailed physical model of SOFC performance that is well-validated with experiment.

Overpotentials – voltage drops that subtract from the ideal cell output voltage, and determine the maximum power output from the cell.

- finite-rate kinetics at the electrodes (activation overpotentials),
- finite electrical conductivity of the electrolyte (ohmic overpotential),
- finite mass transfer rates through the porous electrodes (concentration overpotentials).

The key to achieving a high-performance, high-power SOFC is to significantly reduce all of these overpotentials.


Conceptual design of an engineered, high-performance membrane electrode assembly (MEA).

Lowering concentration overpotential: Optimizing gas transport

- The structural backbone of the MEA is the oxide skeleton or framework.
- Micron-sized porous framework “carpeted” with nanowire arrays.

Nanoparticles and nanowires infiltrated into the oxide framework, left. Nanowires grown from catalyst particles.

Lowering the activation overpotentials

- Nanostructured catalysts to substantially increase the surface area available for electrochemistry.
- Catalyst particles on nanowire supports to allow gaseous species access to the surface reaction sites.

Materials

- Electrolyte: Samaria doped ceria (SDC)- high ion conductivity at intermediate temperatures. Novel, low-temperature deposition to achieve enhanced conductivity.
- Cathode: BSCF (Ba₂Sr₃Co₂Fe₄/3O₇−δ) - the highest known activity for oxygen electroreduction of any SOFC cathode.
- Anode: SDC + Ni cermet- SDC can be a highly effective electroreduction catalyst under anodic conditions.

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