Hydrogen and Electricity Co-Production in a Carbon Fuel Cell: Developing Sulfur Tolerant Anode Materials

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Solid-Oxide Based Carbon Fuel Cell

From Dirty Coal to Clean Hydrogen
Carbon fuel cells (CFCs) utilize solid carbonaceous fuels such as coal to electrochemically produce electrical work and hydrogen.

Advantages of CFCs:
- High efficiency (not Carnot limited)
- Co-production of electricity and carbon-free \( \text{H}_2 \text{(g)} \)
- Concentrated \( \text{CO}_2 \text{(g)} \) product (near-capture ready)
- Fuel flexibility (coals, biomasses, other wastes)
- Solid-state design (no moving parts)

Sulfur Poisoning on Nickel

Current Ni/YSZ-cermet anodes offer high performance for SOFCs at economical cost for hydrogen oxidation and methane-steam-reforming.

Two major disadvantages of nickel-cermet anodes:
- Promotion of hydrocarbon catalytic cracking (leading to coking).
- Susceptible to readily poisoned by even trace amounts of sulfur species.

Studies have shown increasing oxidation resistance as a function of increasing the \( \text{H}_2 \text{S} \) concentration in the fuel—even at sub-ppm levels\textsuperscript{5}.

Beyond Nickel: Alternative Materials

Primary requirements for a sulfur-tolerant anode material:
- High catalytic activity for fuel oxidation
- Small sulfur adsorption energy

Secondary requirements:
- High electronic and ionic conductivity
- Similar thermal expansion to electrolyte at high temperatures (900°C)

The following table compares different classes of materials for their general potential as sulfur tolerant anodes\textsuperscript{4,5}.

Ex-Situ Characterization of Perovskites

X-ray Diffraction (XRD) and x-ray photoelectron spectroscopy (XPS) have been used to characterize phase and elemental compositions.

LST Anode Fuel Cell Performance

The Focus on Perovskites

Perovskites are easily tunable materials depending on dopant element and composition. They form a good platform for creating a sulfur tolerant anode as well as establishing fundamental knowledge of the poisoning process.

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Cited Publications: