Fuel Cell Characterization: Nature of the Solid Oxide Fuel Cell

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CHALLENGES FACING FUEL CELL DEVELOPMENT

The current dynamic interest in fuel cell (FC) technology reflects strong technological and economical implications. This technology offers more advanced, environmentally friendly ways of generat-ing electricity compared to that based on traditional combustion. Practical applications of FC become more feasible in light of recent advances in modern technology of new materials and processes.

But, despite that several successful FC applications have been built and are currently working, this technology is really in the early stages of development. Significant research is still needed in developing, understanding and optimizing materials for SOFC components.

Solid Oxide Fuel Cell, single cell plate*

SOLID OXIDE FUEL CELLS (SOFCs)

The SOFC is a layered ceramic consisting of at least three discrete materials and functionalities. Like all other fuel cell designs the three essential components are the cathode, the anode and an electrolyte membrane between the two electrodes. Unlike other fuel cell designs, the operating temperature is extremely high, - 800°C, so all the materials of construction, including the interconnects (which "wire" together individual cells into a stack) must be dimensionally stable and resistant to sintering.

THE ELECTROLYTE

This component is not a electron conductor but an ion conductor and passes O^{2-} ions, created at its interface with the cathode, to its interface with the fuel rich anode. The materials most commonly employed is fully dense (i.e. non-porous) yttria-stablized zirconia (YSZ). The lack of porosity is essential in preventing the reactive gases passing directly through from electrode to electrode, in other words a short circuit.

THE CATHODE

Lanthanum mixed-metal oxides with a perovskite structure are the materials of choice for the cathode where oxygen molecules are reduced to anions by electrons from the external circuit. In stark contrast to the electrolyte, therefore, the cathode must be both electrically conductive and highly permeable to gases (air). The porosity ideally should be high, interconnected yet non-tortuous in nature, and must extend all the way to the interface with the electrolyte.

THE ANODE

Conductive material stable under reducing conditions and able to adsorb hydrogen, or to reform methane into hydrogen, are required for the anode which would tend to indicate that porous metals should be suitable. However, the significant differences in thermal expansion between metals and ceramic components, plus the high operating temperature which leads to rapid sintering and loss of porosity make them unsuitable. Modified electroylte materials in the form of metal-doped (typically with nickel), YSZ is popular. In contrast to the electrolyle however, it must have significant porosity to admit fuel gas (e.g biogas). During synthesis therefore, organic or carbon pore-formers are added which are then burned out.

SOFC

- **Cathode Reaction**: $O_2 + 4e^- \rightarrow 2O^{2-}$
- **Anode Reaction:** $H_2 + O^{2-} \rightarrow H_2O + 2e^-$
- **Cell Reaction:** $O_2 + 2H_2 \rightarrow 2H_2O$

FUEL CELL REACTIONS

MATERIALS CHARACTERIZATION IN FUEL CELL TECHNOLOGY

Most commonly used characterization and testing procedures are related to the electrical and energy performance of FC assemblies. However, in developing and characterizing the materials and components there are three main areas that are especially important:

Porosity Characterization

It should be clear that electrode material must allow for transport of gaseous species. In this role, the critical factors that affect diffusion and flow of fluids are overall porosity and pore size distribution. These essential characteristics are readily obtained using mercury intrusion porosimetry and gas sorption. Analyzers like the PoreMaster and NOVA respectively (both Quantachrome ®) can be used effectively both in R&D and QC/QA.

Reactive Anode Characterization

In many respects the SOFC anode is no different than most reducing catalysts. It must be capable of adsorbing hydrogen (or hydrocarbon fuel) and promoting its reaction with a reducible species...in this case the oxygen anion. The gas-accessible active area can be determined quite easily by gas chemisorption in fully automated instruments like Quantachrome's Autosorb-iQ-C. The effective (metal) nanoparticle size is also revealed.

A Highly Porous Electrode

LOOKING FORWARD

Fuel cell development is no different than other applied technologies based on surface phenomena. Industries such as petrochemical, ceramics and pharmaceuticals have long recognized the impact that pore structure has on materials performance, and routinely use the analysis techniques outlined above. Those in the fuel cell arena are adopting similar capabilities to quickly advance the understanding of material properties in order to meet the commercial need for rapid development into the marketplace. ■

For more Information about relevant measurement instruments, contact Quantachrome Instruments by phone: 561.731.4999 or email: qc.sales@quantachrome.com or visit www.quantachrome.com.

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