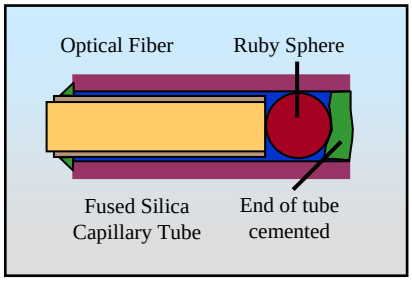
Hydrogen, Fuel Cells & Infrastructure

Miniature Sensors Used to Develop Improved PEM Fuel Cell Systems

Temperature, Humidity and Species Mapping Now Possible

Background

Accurate, reliable and fast-responding sensors have been identified as a critical need for advanced fuel cell designs. Thermal, moisture and reactant concentration gradients play a key role in determining the durability of a fuel cell, and its ability to respond to instantaneous power demands. Furthermore, real-time diagnostic sensors will allow designers to increase stack power density by reducing operating margins and to quickly identify the development of thermo-chemical upsets that limit performance or reduce operating lifetime.



Ruby sphere temperature sensor used in operating fuel cell

The ORNL miniature sensor suite provides intra-fuel cell diagnostics within operating fuel cells. A multi-channel measurement platform, developed to enable mapping conditions within the gas diffusion layer (GDL) of a membrane electrode assembly, provides the capability to measure temperature and moisture distributions as well as species concentrations during operation.

Technology

Luminescence-based thermometry has been an established high-precision, wide dynamic range technique for temperature measurement for over twenty years. Recent developments with fiber optic sensors, combined with luminescence technology, provide the potential for minimally invasive (<100 micron) temperature distribution measurement and thermal mapping. By combining a direct measurement of water concentration (via a micro-capillary coupled mass spectrometer) within the GDL region with temperature, humidity can be determined. Temperature and humidity measurements can provide a means to validate theoretical design models of stack performance. Mass spectrometer measurements also provide a diagnostic for reactants and potential fouling species and can be a valuable tool for monitoring stack dynamics during freeze/thaw and drive cycle excursions.

Fuel Cell with sample probes

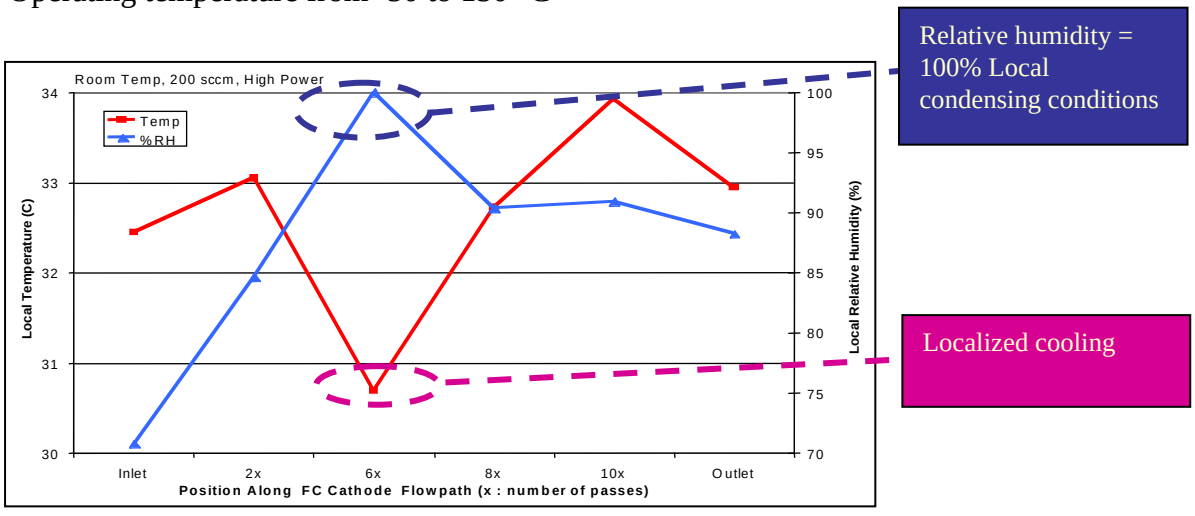
Accomplishments

ORNL has demonstrated the ability to characterize fuel cell thermal profile, reactant concentrations, and water distribution during operation. ORNL continues to develop new miniature measurement tools in concert with fuel cell OEMs to further characterize fuel dynamics including detection of localized temperature events and distributions and local concentrations of reactants as well as water production.

Benefits

The ability to measure temperature and moisture profiles within an operating fuel cell greatly enhances knowledge of how PEM fuel cell systems perform. Fuel cell developers can use this knowledge to verify computer models of emerging systems with increased performance. In situ temperature and humidity sensing can also play a valuable role as safety systems in operating fuel cell based power systems. These sensors are capable of providing:

- Temperature accuracy to ±0.5°C
- Temperature response time of 0.1 second
- Durable performance at <250 microns
- Humidity accuracy within 1.0%
- Humidity response time of 1-2 minutes
- Operating temperature from -50 to 150° C



Temperature and humidity profiles across a fuel cell show that locally condensing conditions create localized cooling

Future Work

A number of additional diagnostic measurements for continued work have emerged including: water and species distributions during freeze/thaw cycles, corrosion onset under various operational conditions (e.g. flooding events, reactant depletions, etc.). measurement of pH (or ionic strength), distribution across the flow field for metallic bipolar plate applications, fluoride ion leaching as an indicator of membrane breakdown

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