Highly Selective and Stable Multivariable Gas Sensors for Enhanced Robustness and Reliability of SOFC Operation

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GE Global Research, in partnership with SUNY Polytechnic Institute and GE–Fuel Cells LLC, proposed an 18-month program to develop and perform initial field validation tests of highly stable and gas-selective sensors for in situ monitoring of gases produced with on-site steam reforming in solid oxide fuel cell (SOFC) systems. The knowledge from this sensor will allow accurate SOFC control and will deliver a lower operating cost for SOFC customers.

**Abstract**

**Project objective**

The program objective is to achieve the highly desired selectivity and stability of sensing of gases for SOFC application by implementing a new generation of gas sensors, known as multivariable sensors (1–4). This program will culminate with field validation of developed sensors on GE SOFC systems.

In Phase 1, we will develop sensing materials, perform lab tests for sensitivity and selectivity, develop sensor design, and perform field validation of developed sensors on a SOFC system at GE–Fuel Cells. Phase 1 will advance fundamental understanding of multivariable gas sensing at high temperatures and will enable cost-effective and stable sensors for SOFC systems. In situ data generated by the sensors will allow development of recommendations for Phase 2 deliverables.

**The team**

GE Global Research, SUNY Polytechnic Institute, and GE–Fuel Cells. The team is comprised of experts in materials science, physical transduction, sensor science, and SOFC systems. The team will work closely with GE–Fuel Cells to develop and validate sensors for SOFC applications.

**Examples of available offerings and the proposed sensor**

- **SUNY Polytechnic Institute**
  - Fabrication of sensors, lab tests for selectivity with gas mixtures, stability tests, and sensor characterization, field validation

- **GE Global Research**
  - Requirements flow-down from optical system design to multi-gas sensing, fabrication of sensors, lab tests for selectivity with mixtures, stability tests, sensor characterization, field validation

- **GE Fuel-Cells**
  - Field validation assistance, sensor benchmarking, recommendations for Phase 2 plan and deliverables

**Accuracy demands in gas sensors**

- **Sensor example:**
  - Response to specific analyte gas (desired), other interference gases (not desired)

**Selectivity challenges in major types of sensors**

- **Electromechanical:**
  - Metal oxide
  - Mechanical

- **Capacitors:**
  - Breakdown status quo: multivariable gas sensors

**Breakthroughs in sensor technology**

- **Graphene:**
  - Measurement dynamic range for applications. In situ data generated by the sensors will allow development of accurate SOFC control and will deliver a lower operating cost for SOFC customers.

**Bio-inspired gas sensors**

- **Design rules for gas selectivity control:**
  - Electrochemical sensor:
    - Relative gas sensitivity (%) vs. time
  - Selective sensors
    - Origin: conflicting requirements for sensor selectivity vs. reversibility

**Improvement of material and system stability using a four-step Six Sigma process**

- **SUNY Polytechnic Institute**
  - Characterization of materials, development of new materials, and sensor design

- **GE Global Research**
  - Physical transducer + sensing material is the key for meeting requirements of material and system stability using a four-step Six Sigma process

**Example of proposed optical grating-based sensor**

- **Proposed multivariable optical grating-based sensor**
  - Response to analyte gas (desired), other interference gases (not desired)

**Proposed multivariable optical grating sensor**

- **Final results:**
  - Relative gas sensitivity (%) vs. time

**Selectivity optimization of multivariable optical gas sensors**

- **Sensor specifications:**
  - Measurement dynamic range for individual gases in dry conditions
  - Discrimination between different gases in dry conditions
  - Measurement dynamic range for individual gases in humid conditions
  - Discrimination between different gases in humid conditions

**2025 roadmap for gas sensors**

- **Reliability:**
  - Cost (US$)
  - Power (mW)
  - Gas application (e.g., breath, odors)
  - Sensing material
  - Transduction

**Conclusion**

The team will work closely with GE–Fuel Cells to develop and validate sensors for SOFC applications. The knowledge from this sensor will allow accurate SOFC control and will deliver a lower operating cost for SOFC customers.