Sensors and Controls Research

High-Temperature Gas Sensing

Advancing the Forefront of Combustion Measurement and Control

Purpose: Develop techniques for combustion exhaust measurements and fuel characterization. The emphasis is on techniques suitable for harsh, aggressive environments and high temperatures.

Sponsor: Department of Energy Fossil Energy Program.

Features:

- Fully automated high-temperature test stands for sensing element characterization.
- Mixtures of up to six gases can be used in testing.

Complementary ORNL Facilities:

- National Transportation Research Center.
- High Temperature Materials Laboratory.

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Combustion of fossil fuels currently generates most of the nation's energy, and 2008 forecasts by the Energy Information Agency predict this will continue to be the case for at least the next two decades. In addition to generating the greenhouse gas CO_2, combustion of any carbonaceous fuel can generate pollutants such as oxides of nitrogen (NO_x, NO and NO_2), carbon monoxide (CO), and residual hydrocarbons. Further, combustion of coal and diesel has the prospect of generating sulfur dioxide (SO_2), which will form acid rain when mixed with the water and oxygen naturally found in the Earth's atmosphere.

Environmental stewardship demands remediation of these pollutants, and techniques for this are currently in use. For example, SO_2 is removed from exhaust streams by adsorption on limestone and / or wet scrubbing, while NO_x can be reacted with ammonia (NH_3) to form the harmless species water, nitrogen, and oxygen.

Most of these remediation techniques require accurate and precise sensing capabilities for detecting the pollutants and reagents of interest to ensure correct functioning of remediation equipment in real time. Because of this, Oak Ridge National Laboratory (ORNL) is pursuing high-temperature techniques for the detection of pollutants such as NO_x and SO_2 and reagents such as NH_3. Operation at high temperature enables deployment closer to the combustion source or treatment module and avoids difficulties such as condensation and the time delays inherent in techniques that require extraction and cooling before measurement.

We have demonstrated success in detecting NO_x, SO_2, and NH_3 at high temperature (Figures 1–3) and are currently refining these techniques while simultaneously expanding our suite of technologies to encompass high-temperature CO_2 measurement and feedstock characterization.

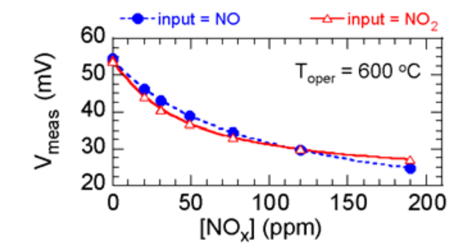

Fig. 1. "Total NO_x" sensing behavior. NO and NO_2 yield nearly identical responses, eliminating the need for conversion to a single species before measurement.

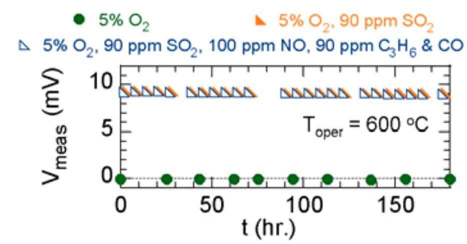

Fig. 2. Selective and stable SO_2 detection. The output if $[SO_2] = 0$ is ~0 mV; the output if $[SO_2] = 90$ ppm is ~10 mV, irrespective of the presence/ absence of the interferents NO, C_3H_6, and CO. Operation without calibration or adjustment over approximately 1 week is shown.

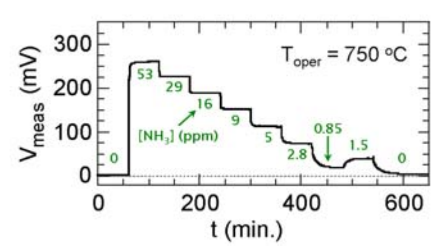

Fig. 3. Detection of single-digit "parts-per-million levels" of NH_3 at high temperature.

Capabilities

Our current capabilities include sensing element fabrication and characterization. Fabrication facilities include ceramics processing equipment for tape casting, lamination, and sintering and equipment for manufacture and screen printing of dispersions (Figure 4). Characterization facilities include fully automated high-temperature test stands and equipment for electrochemical investigations.

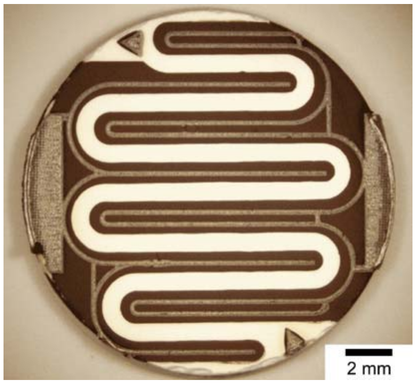

Fig.4. High-temperature sensing element.

Additional Nearby Facilities

- The High Temperature Materials Laboratory (http://www.ms.ornl.gov/htmlhome/) is a DOE User Facility dedicated to solving materials problems that limit the efficiency and reliability of systems for power generation and energy conversion, distribution, and use.
- The National Transportation Research Center (http://www.ntrc.gov/about.html), a collaborative venture of ORNL and the University of Tennessee, addresses issues related to expanding and maintaining transportation systems that move people and goods safely, efficiently, and reliably.

Selected Publications

- D. L. West, F. C. Montgomery, and T. R. Armstrong, "Total NO_x sensing elements with compositionally identical oxide electrodes," *Journal of the Electrochemical Society*, **153**(2), H23–8, 2006.
- D. L. West, F. C. Montgomery, and T. R. Armstrong, "NO-selective NO_x sensing elements for combustion exhausts," *Sensors and Actuators B*, **111–112**, 84–90, 2005.