SENSORS & CONTROLS

Project Fact Sheet

Real-Time Gas Composition Analyzers for On-Line Process Control

Benefits

- Development of real-time combustion control systems that lead to reduced cost and fuel use per unit product, high productivity, and longer equipment life.
- Superior sensor response time.
- Improved sensor robustness and sensitivity.
- Sensor operation in adverse temperature regimes or hazardous environments.
- Pollution prevention by enabling more optimal operation of furnaces.
- Ability to perform area and volume monitoring of combustion with anticipated manufacturing costs targeted at less than $1 per sensing element.
- Excellent reproducibility in manufacturing.

Applications

The proposed sensor is particularly applicable to harsh environments where real-time profiling measurements of combustion efficiency are not currently possible or are very expensive. These sensors can prevent pollution by enabling more optimal operation of furnaces used in steel, aluminum, metalcasting, glass, forest products, ceramic, and chemical industries. A significant commercial spin-off potential also exists for the automotive industry. The small size and potential low cost of the sensor may allow dynamic A/F ratios for each cylinder in an engine. This would lead to better fuel efficiencies, reduced pollution, and enhanced engine performance.

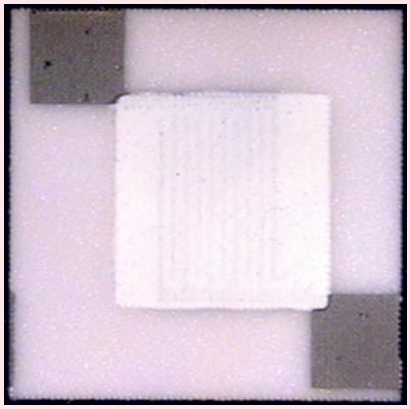
Gas composition analyzers will allow real-time monitoring of air-to-fuel ratios and improve combustion efficiency

Research in this project will focus on multilayered sensors made of nanostructured gallium oxide (Ga_2O_3) powders, which will enable fast response times as well as almost 10 times cheaper bulk manufacturing costs per sensing element than that of conventional sensors. In combustion systems, the air-to-fuel (A/F) ratio required for maximum efficiency and minimum emissions is very specific. The developed Lambda gas composition analyzers, with high surface area allowing rapid detection and response, will monitor the combustion A/F ratio. The result will be faster dynamic optimization of combustion systems and better fuel efficiencies, minimum emission of pollutants, and enhanced performance.

The ability to sense deviations in process operating conditions could provide substantial economic benefits. Reliable, real-time gas composition analyzers can potentially save more than $250 million per year in energy costs for steel, aluminum, metalcasting, glass, and chemical industries. It is estimated that the U.S. glass industry alone can increase its product yield by more than $100 million per year with real-time analysis. Real-time gas composition analysis, in combination with conventional sensors (e.g., temperature, pressure, and flow), can improve raw material use and reduce energy use per unit produced.

Gas Composition Analyzers

0.105" x 0.025"



0.25" x 0.25"

Innovative Lambda sensors (multilayered, left; planar, right) will enable greater sensitivity and cheaper manufacturing costs than conventional sensors.

Project Description

Goal: Develop and profitably commercialize high-performance combustion efficiency sensors for Industries of the Future.

The key innovation for the proposed research is the systematic development of miniature, selective, sensitive, stable, and fast Lambda sensors by controlling the grain size of the sensor material to nanoscale. The sensor envisioned is a resistance-modulating type of semiconductor gas sensor. The nanoscale powders have a high interface area per unit volume that leads to more effective use of materials for sensing applications. The high surface area also yields rapid equilibration and chemical diffusion essential for rapid response.

Nanocrystalline Ga_2O_3 powder will be synthesized using two methods. This ceramic powder offers the most desirable properties at high temperature. Powders produced will be characterized to correlate the relationship between nanostructure and sensor performance. These powders will be used to produce flat plate sensors and multilayered sensors. Automated sensor-testing equipment that features computer automated control of A/F ratios, temperature, pressure, and flow in a test chamber will be used to determine sensor performance. Sensors will be characterized for sensitivity, selectivity, thermal stability, and mechanical robustness. For objective comparison, the developer will also prepare sensors from commercially available, coarser-grained precursors, and their performance will be evaluated.

Some targeted specifications for the sensors include: suitability for high-temperature oxidizing and corrosive environments, temperature operating range of -40 to 900°C with spikes to 1,200°C possible, lifetime of 10 years, response time of 1 second or less, and compatibility with 12 V DC power supplies.

Progress and Milestones

- This project was selected through the Sensors and Controls Program, FY99 Small Business Innovation Research (SBIR) Phase I solicitation, in July 1999. Phase I project tasks will be completed in six months.
- The developer has patented and commercialized a process for economical production of nanopowders in bulk quantities and has produced more than 200 different compositions.
- The developer plans to seek commercial partners early on in Phase I, building on industrial combustion applications, as well as the catalytic converter application in the automotive industry.
- Phase I will establish the proof-of-concept for the combustion efficiency sensor. A performance evaluation will provide goals on optimizing sensor performance to meet or exceed application requirements and customer expectations.
- Phase II and Phase III will focus on optimization, scale up, and production of sensor prototypes for qualification. Collaborators will be identified to assist in overall product development and commercialization.

Project Partners

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