Hierarchical Nanoceramics for Industrial Process Sensors

Nanoengineered Sensors will Monitor Combustion with Enhanced Sensitivity and Flexibility

Remarkable progress in nanotechnology has led to the development of new classes of materials with unprecedented control of structure, composition, defects, and resulting properties. A range of multifunctional ceramics, potentially applicable to high-temperature sensors, have been produced using templated synthesis and self or directed assembly. This bottom-up approach has also enabled production of hierarchical architectures not possible with traditional ceramic processing methods.

This project is developing a robust, tunable materials platform for high-temperature gas-sensing applications. When applied to sensors design, these nanoengineered materials could achieve improved sensing response due to a vastly increased sensor surface area, enhanced selectivity from control of sensing activity, and superior stability based on a unique multi-scale architecture.

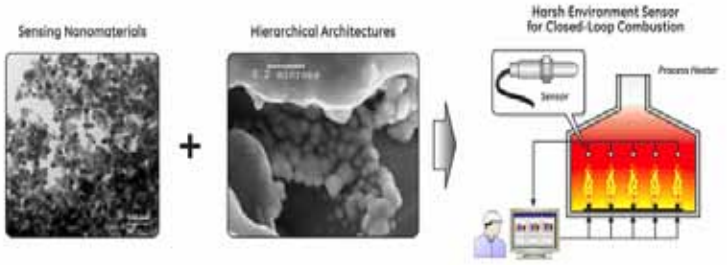
These materials could enable a new generation of sensors for industrial process environments, including furnaces and process heaters. Burners in industrial process heaters typically are controlled by adjusting the air-fuel ratio without real-time, online diagnostics. The new sensors could provide the input needed for real-time tuning and balancing of combustion burners. The performance of these sensor materials will be validated in a simulated service environment typical of industrial process heaters.

Benefits for Our Industry and Our Nation

Process heating is the largest fuel end-use in U.S. industry. Improved efficiency in combustion systems for industrial heat and power will increase economic competitiveness by reducing both national energy consumption and costs for materials widely used in consumer goods. An array of nano-ceramic gas sensors for real-time burner balancing could potentially increase combustion efficiency by 0.5% to 2.0%, which can result in large energy savings if widely implemented across industrial process heating systems.

Applications in Our Nation's Industry

Development of new nanoengineered ceramics for use in industrial process sensors could provide real-time feedback control over air-fuel mixtures in all industrial combustion heating applications.



Application of hierarchical nanoceramics to develop gas sensors for high-temperature industrial processes.

Images and illustration courtesy of GE Global Research.

Project Description

The goal of this project is to develop a robust, tunable, hierarchical nanoceramics materials platform for industrial process sensors in harsh-environments. Control of material structure at multiple length scales from nano to macro is predicted to dramatically increase sensing response of the materials to a wide variety of gases while retaining selectivity. These materials are also expected to be stable at relatively high temperatures, enabling detection close to the source of combustion. It is anticipated that these materials will form the basis for a new class of sensors enabling widespread use of efficient combustion processes with closed loop feedback control in the energy-intensive industries.

Barriers

Major barriers include:

- Lack of reliable gas sensors with the required sensitivity and selectivity for measuring CO, NO_x, and other combustion products in harsh furnace environments
- Insufficient stability of electrode microstructure in other ceramic and metal sensor materials under development

Pathways

The objectives of this project are being achieved by:
(1) synthesizing and optimizing hierarchical nanostructures;
(2) synthesizing and optimizing sensing nanomaterials;
(3) integrating sensing functionality into hierarchical nanostructures; (4) demonstrating material performance in a sensing element; and (5) validating material performance in a simulated service environment.

The first phase of the project focuses on materials selection and process development, leading to hierarchical nanoceramics that can be evaluated for sensing performance. The second phase focuses on optimizing the materials processes and microstructures, followed by validation of performance of a prototype sensor in a combustion environment.

Milestones

- Synthesize hierarchical porous nanostructures (Completed)
- Develop a preliminary process for synthesizing sensing nanomaterials (Completed)
- Synthesize catalytic nanomaterials for harsh environments (Completed)
- Develop a process for functionalizing hierarchical structures (Completed)
- Characterize and validate material and sensing performance in a simulated service environment (Completed)
- Analyze and report on results of validation testing in a simulated service environment

Commercialization

Industry participants in this project are well-placed to leverage the new technology in a variety of markets. GE's sensor businesses already supply advanced sensors to an international market and are prepared to provide an integrated path to servicing many processes in the power industry.

Project Partners

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