the ENERGY lab

PROJECT FACTS

Crosscutting Research

Multifunctional Nanowire/Film Composites Based Bi-modular Sensors for In-Situ and Real-Time High Temperature Gas Detection

Background

Real-time monitoring of gas composition is important for improving the efficiency of combustion processes and reducing the emission of pollutants. However, such measurement usually requires that sensors operate at high temperatures and in harsh environments. Commercially available in situ sensor technology capable of withstanding such harsh environments is extremely limited; therefore, there is a need to develop novel high-temperature gas sensors. While sensor development for gasification is the primary focus of this project, the materials and sensors developed could also be used in other areas such as energy harvesting and storage, petroleum refining, and industrial pollution control.

Description

Researchers at the University of Connecticut are developing a unique class of multifunctional metal oxide/perovskite-based composite nanosensors for industrial and combustion gas detection at high temperature (700–1300 degrees Celsius [°C]). A sensing platform will be designed and fabricated with an array of integrated electro-resistive and electrochemical nanosensors to meet the challenge of gas detection in complex, high-temperature gaseous environments under various combustion conditions. The miniaturized platform will be bi-modular, i.e., made up of two forms of new composite nanomaterials: three-dimensional (3-D) nanowire arrays and two-dimensional (2-D) composite nanofibrous thin film. The 3-D and 2-D composite architectures are assembled with single-crystal 3-D nanowire or polycrystalline 2-D nanofibrous films made of multifunctional metal oxides. These nanocomposites will combine the functions of wire arrays and thin film to increase the nanosensors' sensitivity to gases, stability at high temperatures, and ability to detect multiple gases.

Goals and Objectives

The goal of the project is to advance gas measurement capabilities by developing high-temperature, in situ, real-time gas sensors using a unique class of multifunctional metal oxide/perovskite core-shell composite nanostructures for industrial and combustion gas detection to facilitate the production of hydrogen from coal and contribute to U.S. energy security. The specific objectives are to:

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PROJECT DURATION

Start Date	**End Date**
10/01/2009	6/1/2013

COST

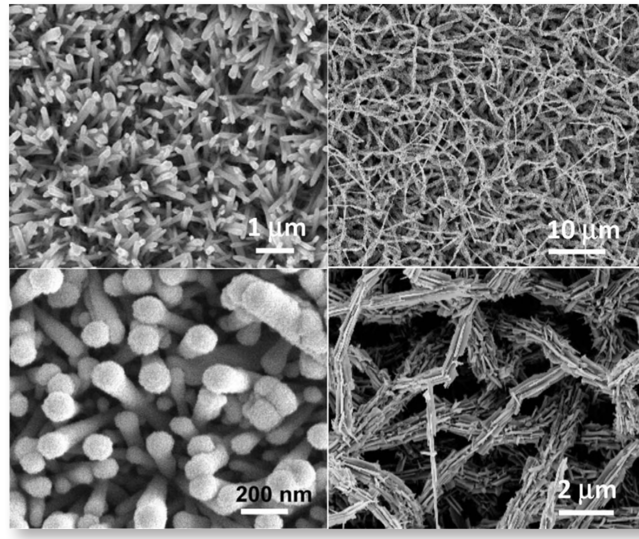
Total Project Value
$1, 010,772

DOE/Non-DOE Share
$795,607 / $215,165

- Synthesize metal oxide-based nanowire/film composites by vapor phase/solution phase deposition or electrospinning.
- Determine and optimize the deposition parameters for growth of nanowire/film composites with specific dimensionality, spacing, thickness, aspect ratios, and uniformity.
- Investigate nanowire/film composites in terms of structure, morphology, electronic structure, chemical properties, and high-temperature stability using a range of microscopy and spectroscopy techniques.
- Design and fabricate bi-modular nanosensors using the nanowire/film composite nanostructures.
- Characterize the resistive detection module of the nanosensors in various high-temperature, gaseous environments and establish corresponding calibration curves.
- Characterize the potentiometric detection module of the nanosensors in different high-temperature gaseous environments and establish corresponding calibration curves.

Accomplishments

Project personnel have successfully designed and developed a new class of high temperature sensing nanomaterials for harsh environment such as high temperature and highly reactive atmospheres. The team has successfully fabricated and demonstrated bi-modular high-temperature gas sensors sensitive to various gas species and gas concentration based on 3-D composite nanowire arrays and 2-D composite nanofibrous films. The bi-modular sensing is of two complementary detection modes: surface nanostructure sensitive electrical resistance (electrochemical impedance), and bulk electrochemical potential response to different gas species with different concentrations. The bi-modular nanowire/nanofilm sensors have demonstrated high sensitivity, stability, and enhanced selectivity at 600 °C, 800 °C and 1000 °C. They have developed viable materials sets for the detection of carbon monoxide (CO), nitrogen dioxide (NO_2), and oxygen (O_2)



Metal Oxide-based Nanowire/Film Assembly

Benefits

The bi-modular gas sensor developed through this project will be more robust and provide more information than sensors currently available because the nanostructure will be more sensitive and more likely to retain its structure when exposed to harsh conditions at high temperature. Good selectivity, fast response, and enhanced sensitivity in high-temperature gas detection can be achieved by these nanosensors due to the diversity of the nanomaterials, inherent large specific surface area of nanostructures, and minimized gas diffusion resistance. Applications for this technology include combustion monitoring in industrial and power plants and high-temperature gas sensing for vehicle and aircraft engines.

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