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U.S. Department of Energy
Office of Fossil Energy
National Energy Technology Laboratory

Novel sensors for high temperature in-situ monitoring of fossil fuel gases

Description

Novel types of sensors are needed to withstand the harsh environments characteristic of advanced power generation systems, particularly gasification-based systems. These types of sensors are essential to the development of high-efficiency, clean energy technologies such as low-emission power systems that use coal or other fossil fuels.

In a project sponsored by the University Coal Research Program for the U.S. Department of Energy, electrochemical engineering researchers at the University of Missouri-Rolla, the University of Cincinnati, and Arizona State University have teamed to develop a new type of sensor that is suitable for in-situ and fast gas monitoring in advanced fossil-energy systems. This sensor is to be formed by coating silica-based optical fibers with nanocrystalline doped ceramic materials. The nanocrystalline structures not only allow formation of functional dense films under temperatures (<750 ^{o}C) tolerable to the fiber but also make the films more chemically sensitive than traditional materials in bulk form.

Objectives and Scope

The specific technical objectives of this research include:

(1) Identifying single-phase or heterophase doped ceramic sensor materials with the chemical, structural, and optical properties needed to detect coal-derived synthesis gases (syngas);

(2) Synthesizing nanocrystalline ceramic films and protective silicalite layers on structured optical fibers;

(3) Designing and fabricating structured fiber devices for enhanced sensor performance; and

(4) Testing the developed sensors in simulated high-temperature and high-pressure syngas environments.

The scope of work encompasses research for the selection of coating materials, fabrication processes, and sensor design that will lead to the development of silica fiber-based gas sensors that will detect coal-derived syngas of varying compositions. Design of special optical fiber structures, performance testing of sensor devices in simulated application environments, and improvement of the selectivity, sensitivity, reversibility, and stability of the sensor devices will allow for a thorough understanding of this new type of gas sensing technology. The work will be accomplished in two phases.

- **Phase 1:** The primary focus of this phase is to identify highly selective doped ceramic materials and optimize the thickness and microstructure of the nanocrystalline ceramic films. The films are needed to detect hydrogen (H_2), carbon monoxide (CO), carbon dioxide (CO_2), and/or hydrogen sulfide (H_2S) in the concentrations and conditions found in the production and treatment of syngas. Qualification of materials and sensor designs will target those that

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PERIOD OF PERFORMANCE

06/21/05 to 06/30/08

COST

Total Project Costs
$703,922

DOE/Non-DOE Share
$527,942 / $175,980

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can sense at least two gases. The project will leverage interdependent research efforts in the areas of material, chemical, and electrical/optical engineering to arrive at a novel multiplexed fiber optic-based gas sensor that can be used in high-temperature and high-pressure environments.

- **Phase 2:** Work will concentrate on integrating the components of the sensor, followed by extensive testing to characterize and optimize overall performance. Sensor integration will include the development and use of a suitable data acquisition system and sensor packaging, both of which are needed to conduct laboratory performance testing. The prototype sensors will be tested under a variety of conditions including temperatures up to 500 ºC and pressures up to 200 pounds per square inch (psi), and multi-component gas mixtures. Phase 2 is expected to result in at least one sensor with acceptable selectivity, sensitivity, and overall ability to accurately detect the target samples as well as reasonable long-term survivability/stability of the assembled prototype.

The primary technological product expected from this work is an operational prototype (see Figure 1) that demonstrates the commercial viability of multiplexed fiber optic-based micro-sensors for distributed gas detection.

Benefits

This device is expected to fill a need for a low-cost, reliable, miniaturized gas sensor that will be capable of fast, accurate, in-situ monitoring of gas composition in flue or hot gas streams in harsh environments, which are characteristic of advanced power generation systems. These new types of sensors are expected to have uses in many critical areas, including emission control, environmental pollutant monitoring, food and water quality assurance, biological and medical analysis, and even in homeland security, to detect explosives.

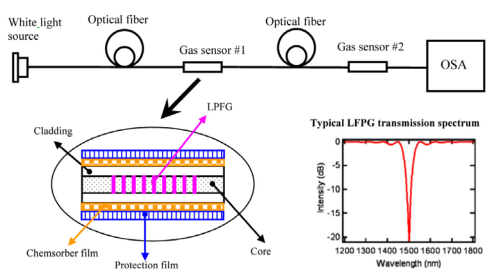

Figure 1. Schematic illustration of nanomaterial-coated thermal long-period fiber grating (TLPFG)-based high-temperature gas sensors

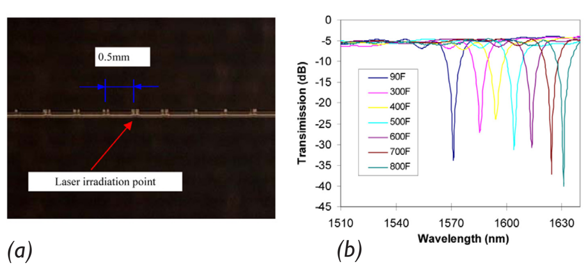

Figure 2. Thermal long-period fiber grating (TLPFG) fabricated by CO_2 laser irradiations:
(a) microimage of a TLPFG,
(b) TLPFG transmission spectrum at various temperatures

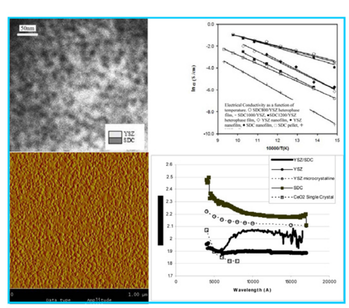

Figure 3. Microstructure of YSZ/SDC heterophase nanocrystalline thin films and their electrical and optical properties suitable for the proposed optical gas sensors