the ENERGY lab

PROJECT FACTS

Crosscutting Research

Development of Novel Ceramic Nanofilm Integrated Optical Sensors for Rapid Detection of Coal-derived Synthesis Gas

Background

Novel sensors and advanced process controls are key enabling technologies for future high efficiency, near zero emission power systems. The Crosscutting Research Program within the United States Department of Energy (DOE) National Energy Technology Laboratory (NETL) is leading the effort to develop sensing and control technologies and methods to achieve integrated and intelligent power systems. The performance of advanced power systems is limited by the lack of low-cost sensors capable of withstanding high temperature and pressure conditions and adaptive system controls that can manage inherent complexities of the advanced power systems. Harsh environments are created in new systems to achieve high efficiency with low emissions. As research and development enhances the understanding of these evolving advanced power systems, robust sensing approaches using durable materials and highly automated process controls are needed to optimize their operation and performance. New sensor designs will be subject to requirements of packaging for survivability, accuracy, low power consumption, portability, connectivity, and ease of manufacture, installation, and use.

In alignment with the Crosscutting Sensors and Controls Program goals, NETL partnered with the University of Cincinnati to develop a new fiber optic based gas sensor that can monitor select species present in coal-derived synthesis gas.

Project Description

This project developed new types of high temperature fiber optic chemical sensors for monitoring coal-derived gases (e.g. H_2, CO, H_2S, etc). This was accomplished by physically and functionally integrating advanced nanoceramic materials with fiber optic devices. The first type of device was a Long Period Fiber Grating (LPFG) self-compensating interferometer sensor; the second was an Evanescent Tunneling sensor. Both types of sensors were highly selective and targeted at specific gas molecules through application of nanocrystalline thin film coatings of doped-ceramics.

The project began with a model-based design of the LPFG interferometer and evanescent tunneling fiber sensors as well as the development of the nanocrystalline doped ceramic materials suitable for gas sensing. The project focused on sensor fabrication through improvement of the ceramic nanofilm properties and fiber structure integration for enhancing sensor performance. Finally, the sensor performance in multi-component gas mixtures under high temperature and pressure was evaluated. The three-year project involved interdependent research efforts in the areas of materials, chemical, and electrical/optical engineering.

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PERFORMANCE PERIOD

Start Date	End Date
04/01/2009	09/30/2012

COST

Total Project Value
$326,958

DOE/Non-DOE Share
$299,915 / $27,043

AWARD NUMBER

NT0008062

Goals and Objectives

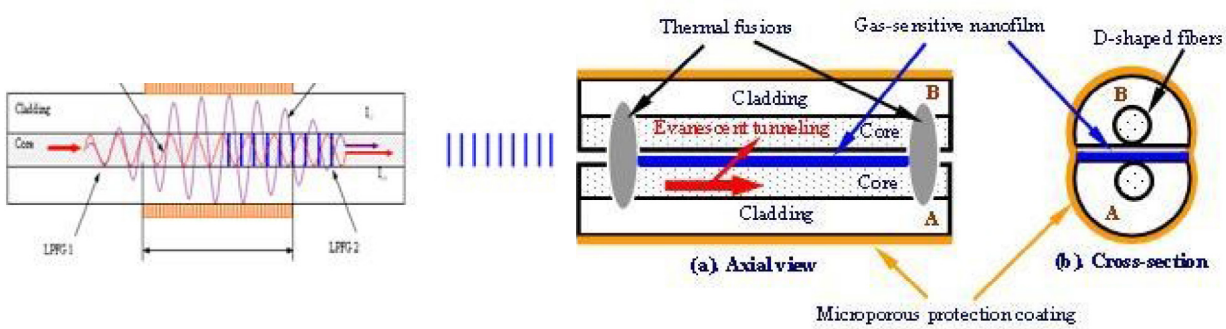
The goal of this project was to design and fabricate fiber optic chemical sensors (FOCS) for monitoring coal-derived gases (syngas) in environments with temperatures greater than 500 degrees Celsius (°C) and pressures up to 250 pounds per square inch (psi). Specific objectives included studying material formulations that would enhance the gas selectivity and sensitivity of coated fiber optic sensors and investigating and demonstrating two new types of nanocrystalline-doped ceramic-coated fiber optic sensors that possess the desired stability, sensitivity, and selectivity for rapid gas detection in syngas streams.

Accomplishments

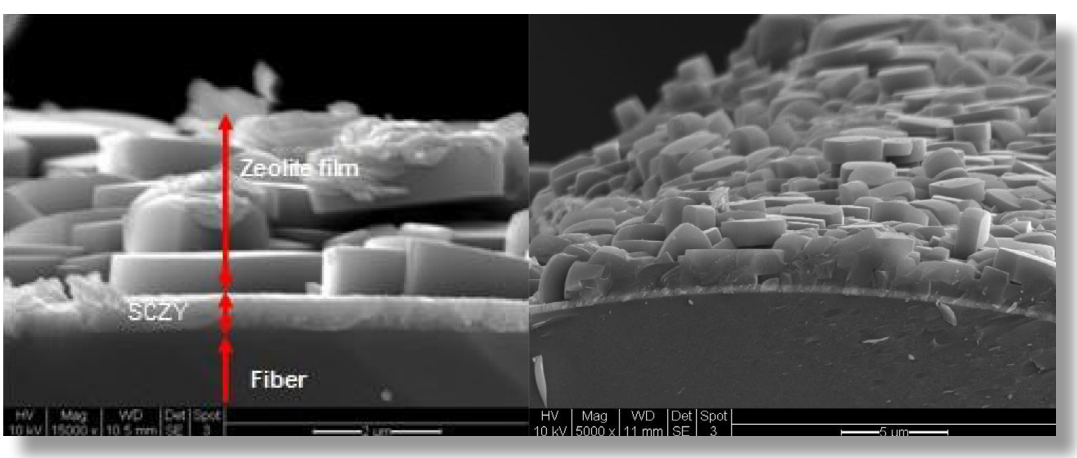
The research team designed LPFG interferometer and evanescent tunneling sensors, obtained geometric and physical parameters necessary for fabrication, and fabricated the nanofilms of sensing materials on the LPFG. Materials suitable for H_2 and H_2S sensors were identified and the chemical, structural, and optical properties of these materials were characterized. The research team identified a process to control the film grown of silicalite protective layers on the optical fiber enabling it to sense gases while protecting it from other impacts on the optical response to the sensor, such as those from other gases and moisture. The silicalite layers were found to have no appreciable effect on the sensors response speed and acceptable H_2 sensing sensitivity. Because of the proven thermal and chemical stabilities, the silicalite thin film can be an effective protection for fiber optic sensors in the harsh conditions in syngas production environments.

Benefits

High temperature gas sensors for coal-derived gases are enabling tools for developing advanced fossil energy systems with enhanced efficiency and reduced pollutant emissions. These sensors will allow real time detection of gases, thus providing valuable information to aid in the control and performance of advanced power generation systems. The completion of this project resulted in new types of fiber optic sensors that meet increased gas detection requirements. The fundamental findings on gas-selective optical nano-materials, material structure performance relationships, and optical properties of the novel fiber devices will have a broad impact on the development of functional nano-materials and optical sensor technologies for other fossil energy processes such as combustion and emission monitoring and control.



Conceptual designs for an LPFG-coupled self-compensating interferometer sensor (left) and a nanocoated evanescent tunneling sensor (right).



Scanning electron microscope images of the silicalite film coated on the five-coating SCZY-LPFG sensors.