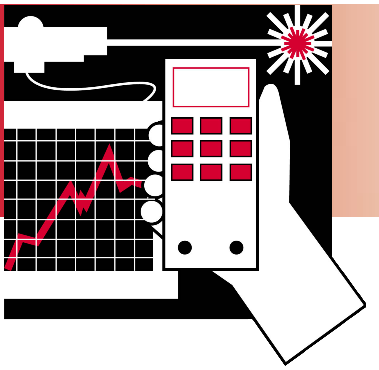
SENSORS & CONTROLS

Project Fact Sheet



Solid-State Sensors for Monitoring Hydrogen

Benefits

- Solid-state sensors can be fabricated by mass-production techniques, making them much less expensive than competing sensors.
- Analysis times with the solid-state devices range from 1 to 10 seconds, which is suitable for interfacing to control systems.
- Application to the feedstock of a refinery feed hydrogen/carbon monoxide facility could affect overall performance by up to $250,000 per year per plant.
- Float-glass manufacturing is an energy-intensive industry that produces 2.6 million tons of glass per year. Hydrogen plays a critical role in this production, and improper monitoring can lead to substantial increases in defects and wasted energy.

Applications

Applications for solid-state sensors include:

- Monitoring trace levels of H_2 in high-purity feed gases for chemical processes.
- Monitoring the production of hydrogen from methane and refinery off gases, where it is often mixed with carbon monoxide.
- Monitoring and control of hydrogen, which is crucial to obtain the correct molecular-weight distributions in the gas-phase polymerization of polyethylene and polypropylene.
- Analysis of fugitive hydrogen emissions in ambient plant environments or in materials subjected to high-energy radiolysis, which is crucial for safety in those environments.

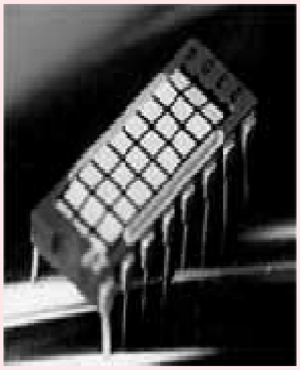
Improved solid-state sensors will provide rapid determinations of hydrogen for improved safety and efficiency in numerous industrial processes

Molecular hydrogen, H_2, is a combustible gas that is produced in large quantities by many industries and that has a broad range of applications. In cases where H_2 is an undesirable contaminant, a monitor must be able to detect concentrations on the order of parts per million; in other cases, a monitor must be usable in nearly pure H_2. Although gas chromatography and mass spectrometry techniques are widely used for H_2 detection, these methods require bulky, expensive equipment.

Based on the knowledge that hydrogen has a high solubility in certain metals, devices for detecting H_2 that use transition-metallized electrodes on metal-insulator-semiconductor structures and thin-film resistors were developed many years ago. These devices were later improved after researchers at Sandia National Laboratory (SNL) discovered that nickel/palladium alloys greatly improve their stability and make them less susceptible to sulfur poisoning and other reactions that made the earlier devices impractical for routine use. Hydrogen sensors based on the SNL technology are currently marketed by DCH Technology.

In response to continuing difficulties with detection of H_2 in complex gas mixtures, this project will evaluate the existing sensor technology in industrial environments. In its second phase, the work will encompass the design, fabrication, and testing of a new family of solid-state sensors tailored to key industrial applications.

Solid-State Hydrogen Sensor



A DCH Technology solid-state hydrogen sensor, left, will be evaluated in an Air Products and Chemicals, Inc., hydrogen production site in California, right, for further development in partnership with Sandia National Laboratory and Pennsylvania State University.

Project Description

Goal: Produce improved solid-state hydrogen sensors that can be used over a wide range of hydrogen concentrations with minimal interferences from other gases.

Metal-insulator-semiconductor (MIS) devices function because H_2 dissociatively adsorbs onto the metallized surface to produce adsorbed hydrogen atoms, which diffuse through the metal to the metal-insulator interface. The presence of H atoms at the interface changes the barrier height and alters the electrical characteristics of a biased junction. These devices saturate at high H_2 concentrations, so they are most suitable for low concentrations. For high concentrations of H_2, the sensors are thin films whose resistance changes in response to the presence of H atoms that have diffused into the bulk material. As with the MIS devices, regeneration is accomplished through thermal annealing at about 200ºC.

Although the previous SNL work resulted in the production of improved sensors, there are still difficulties with detection in complex gas mixtures. The facilities available to this project will enable rapid, flexible, low-cost fabrication of new sensor designs and compositions in order to tailor sensor performance to particular applications. In addition to modified surface compositions, selective surface barriers will also be explored as another method for improved selectivity for hydrogen. Thus, the prototype development and field testing will advance the general field of knowledge on the effects of alloy composition, surface chemistry, and device architecture.

Progress and Milestones

- This project was selected through the Sensors and Controls Program FY00 solicitation and was awarded in January 2000. All tasks are scheduled for completion in 36 months.
- Phase I involves an assessment of existing technology and is to be completed at the end of the first year of the project. Specific tasks include:
  a) fabricate sensors using current SNL technology in Pennsylvania State University (PSU) laboratories,
  b) determine the sensor response to pure hydrogen and gas mixtures appropriate to industrial environments as specified by Air Products and Chemicals, Inc. (APCI) and DCH Technology, Inc. (DCHT), and
  c) conduct preliminary field tests at APCI processing plants to evaluate the sensor operation in actual industrial process environments.
- The go/no-go decision for Phase II will be based on the sensor performance observed in Phase I. The tasks for the second and third years of the project include:
  a) design new sensor structures at SNL using theory, modeling, and experimental results from Phase I,
  b) fabricate new hydrogen sensors with advanced alloy architectures at PSU,
  c) test the new sensors at both high and low hydrogen concentrations at several APCI facilities, and
  d) transfer the newly developed technology to the commercial partner (DCHT) or other appropriate manufacturers.

Project Partners

Pennsylvania State University
University Park, PA

Air Products and Chemicals, Inc.
Allentown, PA

Sandia National Laboratory
Livermore, CA

DCH Technology, Inc.
Valencia, CA

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