Hydrogen Sensor Success Story: Solid-State Sensors for Monitoring Hydrogen

Innovation in Hydrogen Monitoring and Control Systems

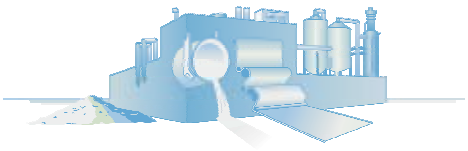
Molecular hydrogen, H_2, is a combustible gas that is produced in large quantities by many industries and that has a broad range of applications. In cases where H_2 is an undesirable contaminant, a monitor must be able to detect concentrations on the order of parts per million; in other cases, a monitor 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. Companies have searched for a way to detect hydrogen reliability, or monitor hydrogen concentrations for industrial applications effectively.

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 Laboratories (SNL) discovered that palladium-nickel (Pd/Ni) 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.

In order to detect H_2 successfully in complex gas mixtures, ITP funded a project to improve the performance of the SNL H_2 sensor to make it practical for industrial use. The project evaluated earlier generation SNL sensors and improved upon them, resulting in the design, fabrication, and testing of a new family of solid-state sensors tailored to key industrial applications.

The sensors, now produced and marketed by H2scan Corporation, measure hydrogen in a range of concentrations from a few parts per million to 100% hydrogen. The technology operates on hydrogen partial pressure and does not require oxygen. The technology has no cross sensitivity to other combustible gases, and is insensitive to species that traditionally interfere with H_2 measurement.

The solid state H2scan Robust Hydrogen Sensor™ is sensitive from 10 parts per million to 100% hydrogen in air, with or without oxygen present.



Benefits for Our Industries and Our Nation:

- Sensors provide real-time, point-of-use, hydrogen-specific monitoring and control systems that target process control applications and leak detection
- Insensitive to other combustible gases
- Stable, repeatable operation over a wide range of H_2 concentrations
- Does not need oxygen to detect or monitor hydrogen
- Small, compact, low power
- Ability to operate in the presence of CO and sulfur; not affected by moisture

Applications in Our Nation's Industries:

H2scan sensors are suitable for applications in petroleum-refining and chemical industries, hydrogen, and chlorine production; nuclear waste monitoring; fuel cells; and monitoring of hydrogen levels in transformer oil. They are also suitable for all safety-related applications where speed of response and the elimination of false alarms are crucial to providing safety and controlling costs. Over 1,000 H2scan sensors have been sold to date.

Project Partners:

Pennsylvania State University
University Park, PA

Air Products and Chemicals, Inc.
Allentown, PA

Sandia National Laboratories
Livermore, CA

Project Summary

Objective:

The goal of this project was to produce improved solid-state hydrogen sensors that can be used over a wide range of hydrogen concentrations with minimal interferences from other gases.

Technology:

- H2scan's sensors sense hydrogen in a range of concentrations from a few parts per million to 100% hydrogen.
- The technology operates on hydrogen partial pressure and does not require oxygen.
- No cross sensitivity to other combustible gases including natural gas, methane, propane, and butane.

How Hydrogen Sensors Work

- Sensors utilize Pd/Ni thin films to measure hydrogen in low and high ranges.

- High level sensor is a palladium-nickel thin film resistor:
    - Resistance of the H-resistor changes as a function of the H_2 concentrations and operates up to one atmosphere (atm) of H and down to 0.005 atm of H_2 (0.5% H_2 in air or nitrogen). Operation demonstrated at H_2 partial pressures up to 35 atm.
    - Pd catalyzes the dissociation of hydrogen molecules and the atoms attach to sites on the surface of the film.
    - H_2 atoms diffuse into the bulk of the thin film and reside in interstitial sites in the metallic surface.
    - Interstitial H_2 atoms increase electron scattering and increase the electrical resistance of the thin film; H2scan electronics measure change.
    - Resistivity of metals increases with increasing temperature. H2Scan manages temperature sensitivity by controlling the temperature of the H-resistor.
    - A resistive thin film heater and temperature sensing resistor are manufactured on the silicon chip.
    - H2scan electronics measure the resistance of the temperatures sensing resistor and control the temperature to a fraction of 1˚C through the heater resistor. The operating temperature is chosen to be higher than ambient to provide control and prevent condensation of water in high humidity operation.

- Low-level hydrogen sensor is a metal-oxide-semiconductor (MOS) capacitator with a Pd/Ni plate for one side of the capacitor:
    - System is configured to measure from 10 ppm to 1% H_2 at 1 atm of pressure.
    - The Pd/Ni thin film is used to form the MOS capacitator; it is deposited on an insulating thin film that forms the dielectric between the Pd/Ni metal plate and the n-silicon opposite plate.
    - Some of the absorbed H_2 atoms in the Pd/Ni reside at the metal/dielectric interface and the presence of this atom changes the electric field of the capacitor, changing the capacitance.
    - The change is proportional to the hydrogen concentration in the sampled gas and is sensed with electronic systems developed at H2scan.

- The sensing ranges of these two implementations overlap, yielding a wide range hydrogen-specific sensor results. The sensors can also be implemented stand-alone.

Commercialization:

H2scan offers premier H_2 concentration sensors in three retail product lines:

- a portable handheld device with lower sensitivity level detection from 10 ppm to an upper level detection of 99.9%;
- hydrogen-specific area monitors with virtually no cross sensitivities; and
- in-line process monitors operating in temperatures up to 300˚F (150˚C) while providing high accuracy and speed of response.

For More Information:

Please visit the website at www.h2scan.com. For sales, contact H2scan sales at sales@h2scan for technical and marketing information on the hydrogen sensor.

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

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The CPS number for this project is 14229.

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