Hydrogen Specific Sensor Technology for Wide Range of Applications

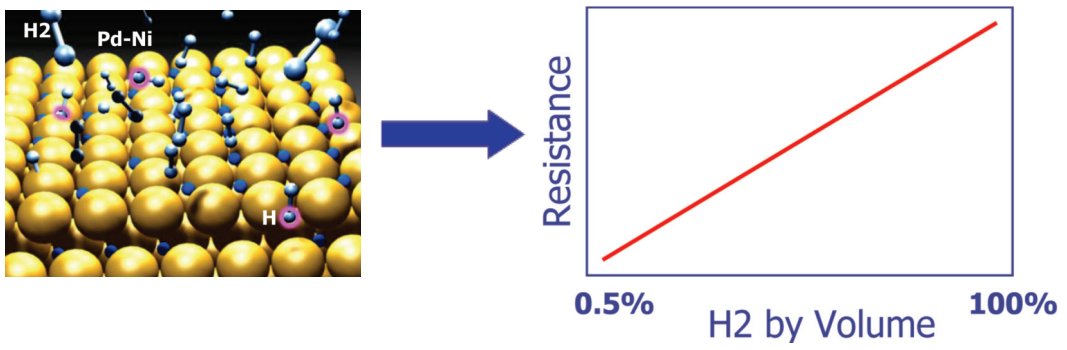
H2scan has commercialized a novel hydrogen specific sensing technology for hydrogen safety and process monitoring applications. The patented technology continuously monitors hydrogen levels from 15ppm to 100% by volume in the presence or absence of oxygen. The technology is based on a palladium-nickel alloy resistor and capacitor on a chip. The hydrogen specific palladium-nickel alloy was first developed at Sandia National Laboratories in the `United States during the early 1990's and has unparalleled hydrogen specificity. H2scan, formed in 2002, made critical improvements in the sensor design and manufacturing processes. The sensor fabrication process was changed from complex CMOS processing to a much simpler semiconductor metal evaporation for higher throughput. Three (3) product series were developed for leak, area and process monitoring applications. This article presents an overview of the technology and the H2scan products, and summarizes the applications in the marketplace.

Technology Overview:

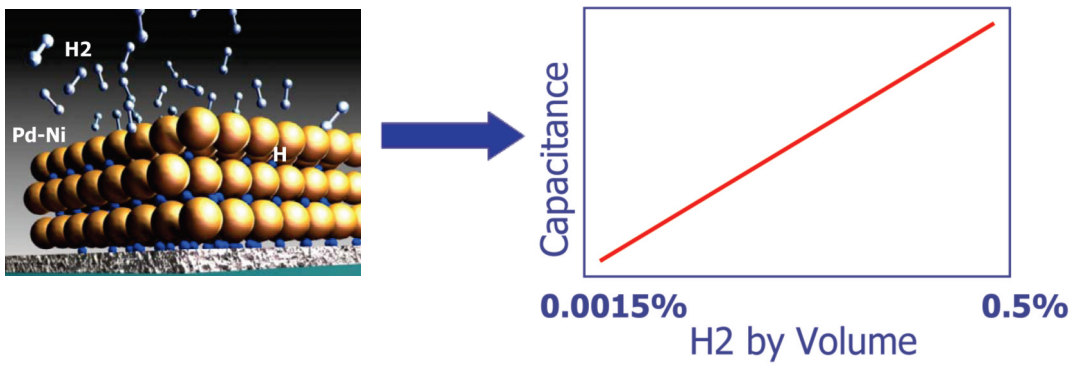
Traditional palladium thin film sensors have limited operational stability in high hydrogen concentrations, suffer from a narrow temperature range of operation, and undergo a phase transition (α, a conducting state to β less conducting state) with hydrogen that causes film delamination. These conditions limit their application for continuous industrial use. The addition of specific quantities of nickel to palladium in H2scan's hydrogen specific sensing material prevents the formation of the palladium hydride and enables the long term operation of the sensor. The hydrogen sensing process on the palladium-nickel alloy is a two step process. In the first rate determining step, the hydrogen molecule (H_2) dissociates into hydrogen atoms (H-H) on the surface of the palladium nickel alloy. In the second step, the hydrogen atom (H) diffuses into the palladium nickel alloy surface and changes the bulk resistivity of the sensor. H2scan's technology has a broad detection range from 15ppm to 100% H_2 by volume that is far superior to any other available solid state sensor technology in the marketplace. This broad detection range is attained by a combination of a hydrogen sensitive resistor *(Figure 1a)* and a capacitor circuit *(Figure 1b)* coupled with an on-chip temperature control loop. The capacitor circuit is used to detect low hydrogen concentrations (15ppm to 1% H_2 by volume) and a resistor to detect high levels of hydrogen (0.5% to 100% H_2 by volume).

H2 sensing process:

- ***Step 1: Pd catalyzes H_2 (molecular) into H_2 (atomic)***
- ***Step 2: Atomic hydrogen (H) absorbed into the Pd/Ni alloy lattice***



Atomic hydrogen absorbed into the resistive sensor element is measured by a change in bulk resistivity.



Atomic hydrogen absorbed into the capacitive sensor element is measured by a change in charge density.

Figure 1: Schematic of the operation of H2Scan's hydrogen specific (a) Resistor and (b) Capacitor.

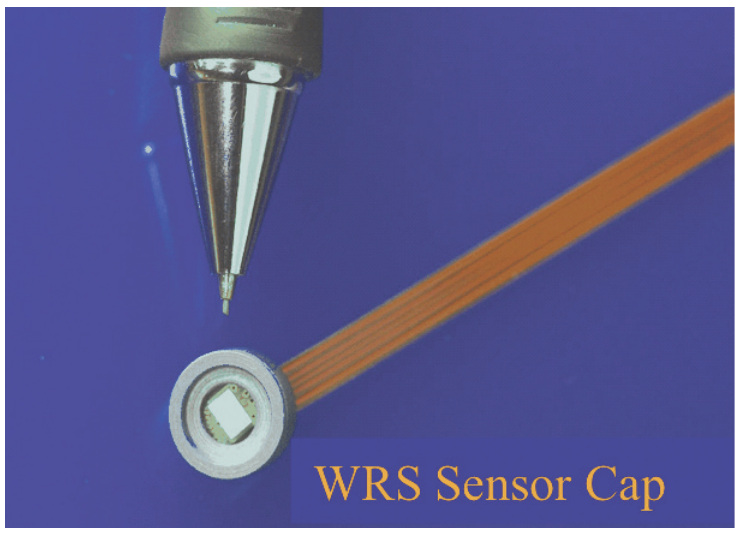


Figure 2: Picture of H2scan's sensor in the patented "chip on a flex" platform. The sensor chip (3mm x 4 mm) shown in the picture has the hydrogen sensitive resistor, capacitor, on-chip temperature sensor and a heater.

The sensor has a broad operating temperature range from -20 to 100°C.

H2scan developed a wide range sensor (WRS) based on a novel "chip on a flex" technology (*Figure 2*); in which the sensor is mounted on a flexible substrate. The sensor is fabricated using semiconductor processing technologies capable of a high throughput (~1500 sensors / 6 "silicon wafer) to reduce production costs. The sensor's electronic circuit has a sophisticated temperature control loop, including a heater that maintains the die temperature above 100°C and a thermistor that controls the die temperature to 0.1°C. The palladium-nickel sensor response to hydrogen is corrected for temperature variations by the temperature control loop. The sensor is protected from liquid splash by a hydrophobic Gore-tex membrane and from particles by a stainless steel metal mesh that also acts as a flame arrestor.

H2scan has developed a proprietary inorganic coating that inhibits penetration of most of the contaminant gas species from poisoning the sensor surface. The proprietary coating preferentially allows hydrogen to pass through and blocks larger molecules such as water (H_2O), hydrogen sulfide (H_2S), carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4), ammonia (NH_3), halogens like chlorine (Cl_2), and nitrous oxides (NO, NO_2). The sensor has a fast response time (t90 <30sec) across 0-100% H_2 concentration range, accuracy of >97% and repeatability of >98%. The sensor has protection from water splashing (IP64 ingress), and a qualified epoxy seal to manage high pressure process applications (up to 100 psig).

Product:

H2scan offers three major product series designed for a variety of area monitoring and process industries namely,

- HY-OPTIMA™ 700 In Line Process Hydrogen Monitor (H2 PROCESS)
- HY-ALERTA™ 600 Hydrogen Specific Area Monitor (H2 SAFETY)
- HY-ALERTA™ 500 Handheld Portable Leak Detector (H2 SAFETY)

The **HY-OPTIMA™** In Line Process Hydrogen Monitors offer the ability to handle harsh process gas (100ppm CO, 1000ppm H_2S) and corrosive environments. Intrinsically safe (IS) versions of the 700 and 600 are available with ATEX certification. H2scan's sensor probe is fully zone 0 certified and the electronic components are zone 1 certified for use in classified hazardous areas. The **HY-ALERTA™** Hydrogen Specific Area Monitor is also offered in an explosion proof housing for safety applications.

HY-OPTIMA™ 700 In Line Process Hydrogen Monitor - Cost-effective solution for process industries:

In a typical process monitoring application it is critical to maintain a uniform concentration of hydrogen in the feed mixture. In most petrochemical applications, hydrogen needs to be accurately detected in a mix of nitrogen (N_2), hydrogen sulfide (H_2S), carbon monoxide (CO) etc. Current technologies used in process monitoring are complex and expensive, such as gas chromatography (>$25,000 /

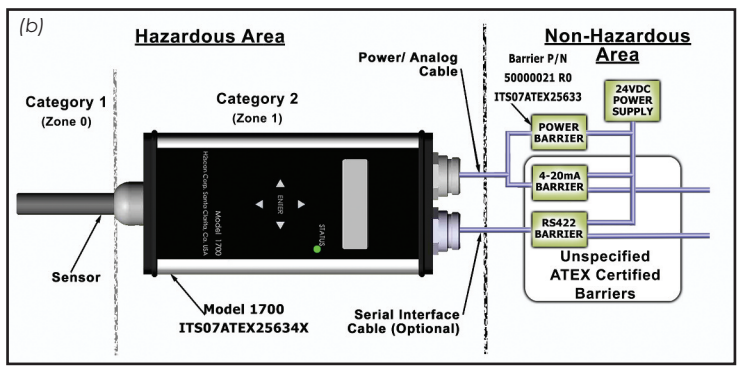


Figure 3: (a) HY-OPTIMATM 700 In Line Process Hydrogen Monitor (b) ATEX certified HYOPTIMA™ 1700 In Line Process Hydrogen Monitor

process point), or mass spectrometry (>$100,000). These technologies, when used, require experienced handling of high pressure sampling containers; allow only limited installation points in process facilities; and, take excessive time to provide a process control point concentration to the data control system (DCS) in a process plant. Furthermore, there is no available solid state technology today that can detect high H_2 concentrations continuously in the absence of oxygen. H2scan's hydrogen specific sensor has a broad range of detection, provides continuous monitoring capability, and is contaminant free. As such, it is the only viable technology for direct hydrogen detection in process monitoring applications. The **HY-OPTIMA™** in-line process monitor has been tested in gas streams of 1000ppm H_2S, 100ppm CO for refinery applications and in 35% Cl_2, 95% relative humidity for corrosive applications. The ruggedness of the coating extends the sensor's operational life in most process streams, including complex hydrocarbons. The sensor has a robust mechanical design with a 3" x 0.5" corrosion resistant sensor probe for installation directly into a gas stream operating at high temperature (>100°C) and pressure

Figure 4: (a) HY-ALERTA™ 600 Fixed Area Hydrogen Monitor (b) ATEX certified HY-ALERTA™ 1600 Fixed Area Hydrogen Monitor (c) Ex-proof HY-ALERTA™ 2600 Fixed Area Hydrogen Sensor and Display unit.

Figure 5: HY-ALERTA™ 500 Handheld Hydrogen Leak Detector

(up to 100 psig) conditions using VCR or compression fittings that make it transferable to the NESSI platform. The sensor is ATEX zone 0 certified for operation in Class I/Div II Gp B hazardous locations.

The **ATEX certified HY-OPTIMA™ 1700** in-line process monitor should be considered for hydrogen production and petrochemical refinery applications where real time hydrogen measurement can enhance plant efficiency and cost savings. The output (4-20mA or 0-5Volts) from the sensor is readily integrated into existing data control systems (DCS) in process plants. An optional RS232 or RS422 serial bus is also available.

The product has a life expectancy of 10 years and the recommended calibration frequency is 3 months. The **HY-OPTIMA™** in-line process monitor is under evaluation in major refineries, hydrogen production, chlor-alkali process plants.

HY-ALERTA™ 600 Hydrogen Specific Area Monitor

H2scan offers a state-of-the art hydrogen specific area monitor. The **HY-ALERTA™ 600** *(Figure 4(a))* is optimized for operation in air backgrounds for safety applications where hydrogen is stored and used. The sensor has broad application because it can be easily mounted on any surface to detect a hydrogen leak in a room or placed in the outlet of a fuel cell. The sensor can operate from -20 to 80°C, has a detection range of 10% to 125% LEL H_2 and a fast response time. Due to the inherent hydrogen specificity of the palladium-nickel alloy, the sensor can be reliably used to monitor hydrogen leaks in an area. Currently, many facilities including nuclear power plants, lead acid battery rooms, fuel cells, hydrogen refueling stations, semi-conductor gas cabinets etc. are using the **HY-ALERTA™** unit. The proprietary coating on the sensors helps to eliminate false alarms from dust, hydrocarbons, contaminants etc. An ATEX certified version, **HY-ALERTA™ 1600** *(Figure 4(b))* is available from H2scan for operation in classified environments. H2scan also offers the **HY-ALERTA™ 2600** explosion proof model *(Figure 4(c))*.

Series 500 Handheld Portable Leak Detector

HY-ALERTA™ 500 Handheld Hydrogen Leak Detector (*Figure 5*) has a detection range from 15ppm to 100% H_2 by volume. The lower detection (15ppm to 1% H_2 by volume) limits are attained by a MOS capacitor with a Pd/Ni plate for one side of the capacitor.

The presence of Hydrogen changes the electric field of this capacitor, causing a proportional change in capacitance. The high concentration part of the sensor is a Pd/Ni thin film resistor. The leak detector has visual indication for different hydrogen levels and a user friendly probe to detect small leaks. The detector can be used for leak detection in gas process, chemical process, hydrogen production facilities, and transformer headspace monitoring applications.

The **ATEX certified** version, **HY-ALERTA™ 1500** will be available soon from H2scan for operation in classified environments.

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New Software for UV-A, UV-B and UV-E Measurements

To improve the accuracy of your UV-A, UV-B and UV-E measurement results, **Kipp & Zonen** (The Netherlands) have developed the unique UVIATOR software package.

Each Kipp & Zonen UVS radiometer is already supplied with extensive factory calibration data. This allows manual correction of the data to minimize errors. UVIATOR takes this a step further by carrying out the process automatically and providing graphical visualization of the results.

Combining UVIATOR software with the spectral characteristics of the radiometer, corrects the mismatch between the actual sensor response and the ideal sensor response. This first step enables further corrections to be made to compensate for changing conditions of the UV spectrum.

The correction methodology is based on an atmosphere transmission model and the use of the Ozone Monitoring Instrument (OMI) satellite data that can be retrieved from the internet. This satellite gives the total Ozone column density based on position (longitude and latitude) and time (GMT). The improved Kipp & Zonen UVS radiometers are now delivered with the UVIATOR software included as standard.