TGS 6812 and FECS-H20 Catalytic and TGS 2616 MOS Hydrogen sensors and their application from Figaro Engineering Inc.

Introduction

Hydrogen is seen as one of the energy sources of the future, and for good reason. With the pressing challenges of climate change and the need to replace fossil fuels, hydrogen offers a promising solution. Hydrogen can be produced from a variety of sources, including renewables such as solar and wind power, and has the potential to provide a clean, sustainable energy supply. Unlike fossil fuels, the use of hydrogen in energy production produces no harmful emissions, making it a key building block for an environmentally friendly future. Hydrogen can also be stored and transported efficiently, making it ideal for the global energy market.

Why do hydrogen levels need such close monitoring around production, transportation and storage facilities?

Leakage monitoring is crucial when using hydrogen. Pure hydrogen cannot burn. However, if hydrogen mixes with air at atmospheric pressure, it becomes highly flammable within the range of 4-75%.
Another important aspect is that hydrogen molecules are smaller and lighter than many other gases, this means that they will leak faster and with greater agility.

Some application examples for the use of hydrogen:

Fuel cell in the transport sector

A power generating device that continuously produces electricity through the chemical reaction of hydrogen with oxygen.
Goods vehicles such as lorries and vans consume a lot of energy on long journeys. A hydrogen-powered fuel cell with a long range can serve as an alternative to a battery. In addition to transport fleets, hydrogen-powered vehicles are also suitable for urban transport such as buses and and for refuse collection vehicles, both of these cover a calculable distance daily and typically return to the same depot facilitating refuelling with hydrogen at the end of the day. Hydrogen trains are expected to play a growing role in decarbonising rail transport, offering zero emissions, quiet operation, and long-range capability compared to battery-electric alternatives. Germany launched the world’s first commercial hydrogen-powered train, The Alstom Coradia iLint in 2018, and have since built further units to expand the area of operation. Trials are underway in many European countries and the infrastructure is being developed to prepare for operation on a larger scale.

In use in the new TOYOTA MIRAI

The FCS-H20, a sensor manufactuired by New Cosmos and included in the Figaro H2 sensor range is already employed on board TOYOTA's latest hydrogen-powered vehicle, the MIRAI, and fulfils TOYOTA's strict performance and quality standards as well as GTR-13 (Global Technical Regulation No. 13 on Safety of Hydrogen and Fuel Cell Vehicles), the safety standard for FCEV sensors. The FCS-H20 can be purchased by automotive customers under the product designation CSD-02/04.

Hydrogen refuelling stations

This station is used for refuelling vehicles with fuel cell or hydrogen engines. The hydrogen is either generated on-site by electrolysis or transported on site in gaseous or liquid form, and is stored under pressure (typically 350-700 bars). Prior to refuelling the gas is cooled to -40 degrees C, it is then dispensed through a gas-tight nozzle/seal into the vehicle.

Sensors are installed in hydrogen refuelling stations to monitor for leaks as hydrogen has a wide flammability range (4–75% in air) making early detection essential to avoid ignition.The sensor is enclosed in an explosion-proof housing to ensure safe and reliable operation. Since hydrogen has a low atomic weight and diffuses rapidly, the design of the detector unit plays a crucial role in effective leak detection.

(a)Diffusion Type Gas Detector Head (b)Portable Gas Detectors

To optimise performance, **New Cosmos, Japan**, conducted hydrogen diffusion experiments and CFD (Computational Fluid Dynamics) simulations. Based on these findings, they developed the KD-12 diffusion gas detector head with a display, engineered to consistently and accurately detect hydrogen (Figure (a)).
In addition to fixed sensors which continuously monitor hydrogen levels in storage tanks, pipelines, and dispensing areas and can trigger ventilation systems and shut down refueling operations automatically in the event of a leak, portable gas detectors with concentration display are also used on a daily basis to check for hydrogen leaks at various valves and pipe connections (Figure (b)).

Fuel cell systems for private households

Fuel cell systems, known as micro-CHP (Combined heat and power) fuel cells are already in use, generating electricity and heat from hydrogen or natural gas for private homes in countries such as Japan, Italy, Germany, Netherlands and the UK. As hydrogen infrastructure expands and costs decrease, these systems could play a larger role in sustainable home energy solutions.

Climate-friendly industrial production

Large parts of industry continue to use fossil fuels and emit high levels of CO2. For example: Steel, glass and ammonia production use coal or natural gas to power their factories. Hydrogen can replace these traditional fuels vastly reducing greenhouse gas emissions such as CO2.

Hydrogen can also be used in other ways: as an alternative feedstock to natural gas in many chemical processes, as a coolant in power plants due to its high heat capacity and in the production of carbon-neutral synthetic fuels (e-fuels) or useful chemicals such as methanol and synthetic methane, by combining it with captured CO_2

Figaro hydrogen sensor options

Figaro Engineering Inc. develops, manufactures, and distributes gas sensors that are suitable for the safe monitoring of applications involving hydrogen, these sensors use catalytic or metal oxide semi-conductor technology.

The choice between a catalytic hydrogen sensor and a metal oxide sensor for hydrogen leak detection depends on several factors, including sensitivity, response time, environmental conditions, and safety requirements.

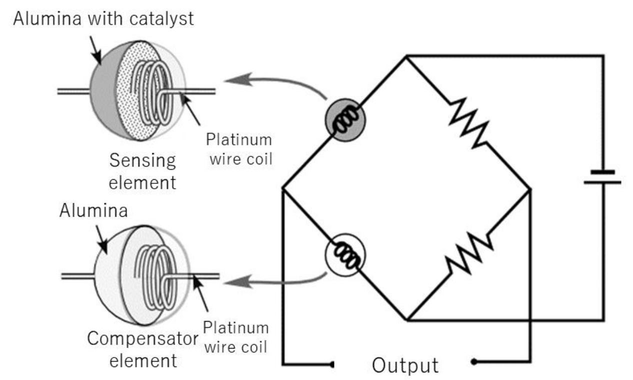
A catalytic sensor is best: for detection of hydrogen above 100% LEL (approximately 4% in air), when fast response times are required for safety shutdowns, where cross-sensitivity to other hydrocarbons such as methane and propane is acceptable and when an accurate measurement of the concentration of H2 is required.

A metal oxide hydrogen sensor is best: for detection of low concentrations of hydrogen, ppm levels up to a few percent, for applications where there are low levels of oxygen precluding the use of catalytic sensors, for continuous monitoring of small leaks and in situations where long-term robustness is required. Note that metal oxide sensors are cross-sensitive to other gases so can provide false readings if the specific metal-oxide sensor selected isn't designed to eliminate the interfering gas/gases.

As a general rule catalytic sensors are preferred for Safety-Critical applications (e.g. fuel cells and hydrogen storage) because they provide a clear signal at flammable levels. For early leak detection and long-term monitoring (e.g hydrogen pipelines or enclosed spaces), metal oxide sensors are the best option due to their sensitivity at low concentrations.

Detection principle of catalytic sensors

Catalytic sensors convert the heat generated by the combustion of combustible gas (catalytic combustion) on a precious metal catalyst into an electrical signal. The sensor consists of a detector element and a temperature compensator. The two elements form a Wheatstone bridge circuit and are operated by applying a defined voltage which heats the Pt wire coil to 300 to 500 °C. The detector element consists of aluminium oxide coated with a precious metal catalyst (Pt or Pd) which is applied to a 20-30 µm spherical Pt wire coil and sintered.

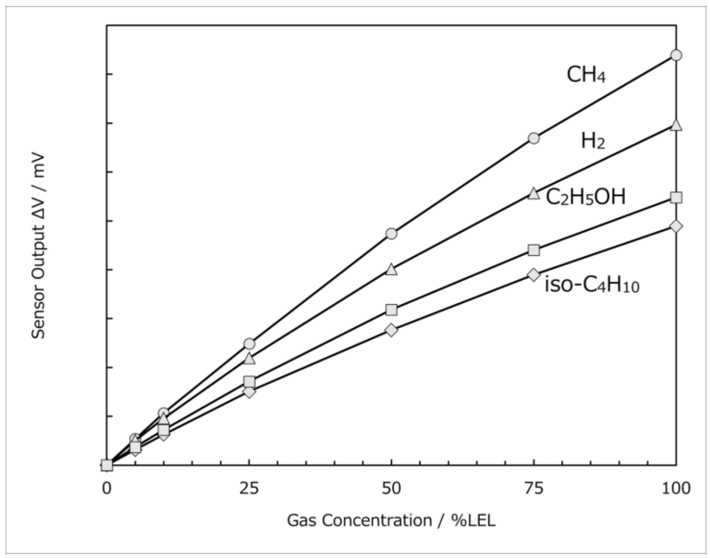


The temperature compensator consists of aluminium oxide without a precious metal catalyst, which is also sintered onto a Pt wire coil in a spherical shape. This structure allows the temperature to rise only in the sensor element (higher resistance) due to gas combustion in the presence of combustible gas, note that the resistance of both elements changes in a similar way to compensate for ambient temperature changes

The temperature change of the element due to gas combustion can be measured with high accuracy even if the temperature changes in a wide range from -40 to 100 °C. The amount of heat ΔH generated by gas combustion at the detector element is proportional to the gas concentration C and the heat of combustion Q, as shown in equation (1), and its value is determined by the combustion efficiency (catalytic capacity) K of the detector element.

(1) $\Delta H \propto K \cdot C \cdot Q$

The figure shows the gas sensitivity characteristics of the sensor for flammable gases.



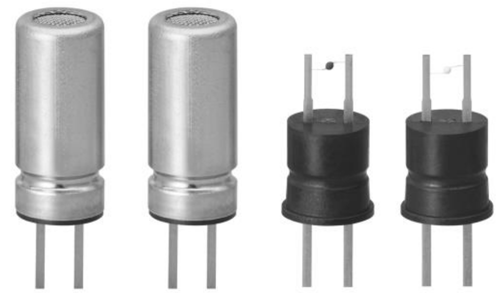
Catalytic hydrogen sensors for industrial applications

The FCS-H20 catalytic hydrogen sensor (H2)

This sensor is 'Fuel Cell Electrical Vehicle' (FCEV) compliant

It offers:

Maximum safety performance
Rapid start-up
A fast response time
Long sensor life
Durability
Resistance to siloxane poisoning



Characterised by its low power consumption, small size, low weight and low cost, the **FCS-H20 maintains its measuring range of 0 to 4 % vol**. maintenance-free for more than 15 years, even under extreme conditions such as those found in the automotive sector.

TGS6812-D00 - for the detection of hydrogen, methane and liquid gas

The TGS6812-D00 catalytic gas sensor can detect hydrogen concentrations up to 100%LEL. This sensor is characterised by high accuracy, good durability and stability, fast response and a linear characteristic curve. The TGS6812-D00 can detect not only hydrogen but also combustible gases such as methane and LP gas, making it an excellent solution for monitoring gas leaks from stationary fuel cell systems that convert combustible gases into hydrogen.
The sensor has a special filter material in the sensor cap, which reduces its cross-sensitivity to organic vapours. In addition, the TGS6812-D00 is also resistant to silicone compounds in harsh environments.

Detection principle of metal oxide semiconductor sensors (MOX)

Tin dioxide (SnO_2), a metal oxide, changes its conductivity under the influence of gas. Naoyoshi Taguchi utilised this property and developed the tin dioxide-based 'Figaro sensor'.

Tin dioxide sensors utilise the effect that oxygen defects in the crystal lattice of the material act like an n-doping. Oxygen molecules from the ambient air are adsorbed on the particle surface and oxygen ions are formed, which can react with flammable gases. When molecules of a reducing gas such as hydrogen (H_2) or carbon monoxide (CO) come into contact with the surface of the sensing element, SnO_2 they react with the adsorbed oxygen and the electrons previously bound by the oxygen become available again as free charge carriers in the material. The electrical conductance of the sensor increases and this can be measured in a change in resistance. A simple electrical circuit can convert the change in conductivity into an electrical output signal proportional to the gas concentration.

Metal oxide semiconductor (MOS) sensors are heated to enhance their sensitivity and selectivity when detecting gases. The heating element inside the sensor maintains an optimal temperature to facilitate the adsorption and reaction of gas molecules on the metal oxide sensor surface. Different gases require different temperatures for optimal detection (e.g., CO at ~250°C, methane at ~500°C). Heating also reduces any interference from humidity and prevents the buildup of non-gaseous contaminants such as oil and dust which can interfere with gas adsorption.

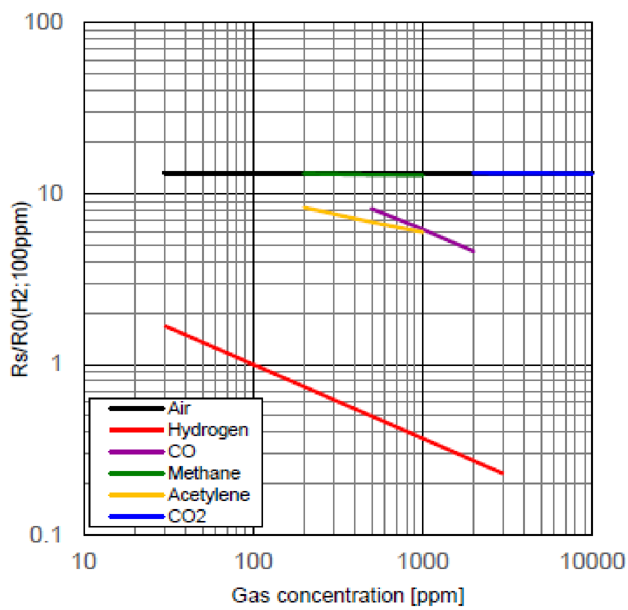
TGS 2616-C00 and TGS 2616-C01 - for the detection of hydrogen

Both of these MOS sensors have high selectivity to hydrogen, but the TGS 2616-C01 is specially configured for applications where acetylene, an interference gas could be present,for example transformer oil maintenance.   The sensing element comprises a metal oxide semiconductor layer formed on an aluminium oxide substrate of a sensor chip, together with an integrated heater. This is housed in a standard TO-5 housing.

Sensitivity characteristics:

The figure on the right shows typical sensitivity characteristics measured under standard test conditions. The Y-axis shows the resistance ratio of the sensor Rs/Ro, where Rs and Ro are defined as follows:

Rs = sensor resistance in different gases and concentrations
Ro = sensor resistance in 100 ppm hydrogen



For further information on the above sensors please click on the links below:

[TGS 6812]
[CGM 6812 Pre-calibrated module]
[TGS 2616-C01]
[TGS 2616-C00]