Hydrogen sensing:
Efficiently avoiding signal drift

Hydrogen holds significant future potential as an alternative energy source. However, H_2 poses certain challenges for pressure measurement technology, whether electronic sensors or mechanical pressure gauges. Hydrogen atoms penetrate the metal of the instruments, which has a negative effect on measurement accuracy. To prevent this, manufacturers frequently plate their sensors with gold. A new technology now offers a more efficient alternative for this.

Hydrogen has the ability to penetrate rapidly into many materials. In electronic pressure sensors, for example, H_2 atoms that have been produced from dissociated H_2 molecules diffuse into the metal diaphragm. This so-called permeation can impact on the long-term stability of the measurement signal, especially at high temperatures. To prevent signal drift, a systematic deviation of the output signal, manufacturers frequently plate their sensors with gold. An alternative technology now exists that is not only more cost-efficient but also more robust.

H_2 diffusion can cause signal drift

Thin-film pressure measuring cells are based on the principle of electrical resistors arranged on a diaphragm and connected together to form a Wheatstone bridge. When the diaphragm is deformed under pressure, the resistors are compressed or stretched depending on their position. In other words, the resistance changes proportionally to the pressure. This is detected by the sensor and converted to an electrical signal. Hydrogen as the

Titanium nitride coatings effectively protect pressure sensors from hydrogen-induced signal drift.

Source: ©Evgenii & Karina Gerasimovi, stock.adobe.com medium can result in signal offset. This is because when the H_2 molecules are dissociated into atomic hydrogen, the atoms penetrate through the metal diaphragm. They diffuse into the resistance elements of the Wheatstone bridge on the other side of the diaphragm, causing individual resistance values to change. Since this effect is not evenly distributed across all resistors, the resistance of the Wheatstone bridge changes, leading to a signal drift. This problem is particularly common at high temperatures.

Plating with gold prevents penetration

Gold plating is an effective, and widely used, solution to prevent signal drift due to hydrogen permeation. In flush-mounted measuring systems filled with oil, the wetted structures are plated with this precious metal. Gold has a much lower diffusion coefficient than steel. Although hydrogen can penetrate through any metal eventually, it takes significantly longer to do so with gold than with steel. Signal drift can be reduced to a minimum in this way throughout the product's service life.

Unfortunately, this method also has a number of disadvantages. Gold plating puts up the cost: both the material itself and the process of coating the sensor during production are expensive. Furthermore, special care must be taken when installing the sensor because the ultra-thin gold plating is applied on a front-flush membrane and is very sensitive. Even the smallest scratch will diminish the effect of the gold or eliminate it altogether.

Titanium nitride layer offers an alternative

This is where a new alternative to gold plating comes in: the technology is used in an innovative thin-film pressure sensor and minimises the effect of H_2 just as effectively as gold plating. The body of the new sensor is made from the proven material Elgiloy®, a cobalt-chromium-nickel alloy. The material is ideal for pressure sensors owing to its high elasticity and strength. Moreover, provided certain design specifications are observed, it is not susceptible to hydrogen embrittlement. An additional layer of titanium nitride (TiN) is applied to the sensor manufactured from this material, which minimises the influence of H_2 on the sensitive structures. It is applied between the sensor's insulating layer and the resistance layer and, like them, is no more than a few nanometres thick.

The thin-film sensor measures pressures precisely from 0 to 1,000 bar. Source: WIKA

Cost-efficient and easy to retrofit

The additional layer of titanium nitride offers a range of benefits compared to flush gold plating. There is no longer any risk of scratching during installation, because the TiN layer is inside the instrument and there is no direct contact with the medium. It is also far more cost-effective to coat sensors with an additional layer of titanium nitride. On the one hand, the material is more cost-effective than gold and on the other, the fact that existing plants and processes can continue to be used is an advantage with regard to production costs. Another point in its favour is that users can easily integrate pressure transmitters built with this sensor into applications already in operation. Whereas gold-plated instruments require flush-mounted process connections as well as appropriately dimensioned counterparts, standard pressure connections are perfectly adequate with the new thin-film sensor element.

Using pressure gauges in ventilated environments

Unlike with electronic pressure measuring instruments or diaphragm seals, H_2 diffusion has no impact on the measurement accuracy using mechanical pressure gauges.

Titanium nitride coatings can replace traditional material technologies. Source: WIKA

In future, electrical pressure sensors will ensure safe refuelling at hydrogen refuelling stations. Source: WIKA

Amongst other things, these instruments monitor pressure at measuring locations where an on-site display is a must or act as a back-up for electronic systems. Stainless steel pressure gauges with wetted parts made of austenitic steel are generally preferred for hydrogen applications, especially in the high-pressure range, because certain austenitic types such as 316L are immune to H_2 embrittlement. In spite of this, hydrogen can leak into the case of the pressure gauge via the measuring element over a long period of time. The case design – which includes plastic components – means the H_2 concentration is equalised with the environment. Therefore, it is always recommended to use the pressure gauge in a ventilated environment. In the majority of applications, H_2 occurs in gaseous form and is typically exposed to pressures between 60 bar (initial filling) and 1000 bar (refuelling station). The EN 837-2 user standard on the selection and installation of pressure gauges recommends pressure gauges in a safety version – level S2 or better – for gases and pressures > 25 bar. However, safety levels S1 and S3 are the market standard today when it comes to stainless steel pressure gauges.

Bourdon tube pressure gauges offer maximum safety for high-pressure measurements.

Safety level S3 is a must

Mechanical pressure gauges in hydrogen service should comply with the highest safety level S3 for this reason. These instruments have a non-splintering window, a solid baffle wall between the measuring system and the dial and a blow-out back. The latter ensures that, in the event of a failure, the operating personnel at the front are protected if any components or media are ejected. For measuring locations where there is a risk of explosion due to the high flammability of certain hydrogen mixtures, pressure gauges also require ATEX certification.

Setting the course for hydrogen sensing

The challenges posed by hydrogen as a medium require more than just technical solutions. Rather, they require a new way of thinking in the development and use of pressure measuring instruments. The titanium nitride coating is a prime example of how material technologies can not only complement traditional approaches, but also replace them in the long term – leading to more efficient, robust and cost-effective sensors.

In future, the focus will increasingly be on multi-functional protective coatings and adaptive sensor concepts that not only prevent H_2 permeation but also cushion other environmental influences. At the same time, there is a growing demand for intelligent monitoring systems that detect signal drift and material fatigue in real time, thereby further increasing operational safety. Hydrogen sensing therefore remains a dynamic field with potential for innovations that will contribute to the acceptance and safety of hydrogen technology.

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