AppliedSensor FE Hydrogen Sensor

M. Kosovic, N. Edvardsson

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AppliedSensor FE Hydrogen Sensor

Miodrag Kosovic, Niclas Edvardsson, AppliedSensor Sweden AB, Sweden

1 Introduction

In the past 5 years AppliedSensor has been appointed by various automotive OEMs and joint ventures to develop selective hydrogen safety and control sensors for their fuel cells and related FC vehicles [1]. Key requirements were plain selectivity to H_2, speed of response < 1s and no need for recalibration throughout the entire lifetime. All this at automotive standards. During a 3-year development AppliedSensor has achieved all above and is now supplying said customer's fleets.

2 AppliedSensor FE Hydrogen Sensor

The AppliedSensor hydrogen sensor uses a sensor component (SC) based on a field-effect (FE) transistor with a catalytic metal stack as the gas-sensing layer [2]. This semiconductor technology approach offers a low cost sensor component based on a well established and reliable high volume technology with excellent sensor properties including high-speed response and outstanding selectivity.

3 The Hydrogen Sensor Component

AppliedSensor offers hydrogen sensor components for different applications using different types of sensitive layers, where one is specially optimized for detection of hydrogen concentrations in the 0-10% range, which can be achieved by using two different response mechanisms [3]. The combination of response mechanisms enables hydrogen predictions with good selectivity over a large hydrogen concentration range.

A calibration curve for the 1-5 % H_2 concentration range is shown below.

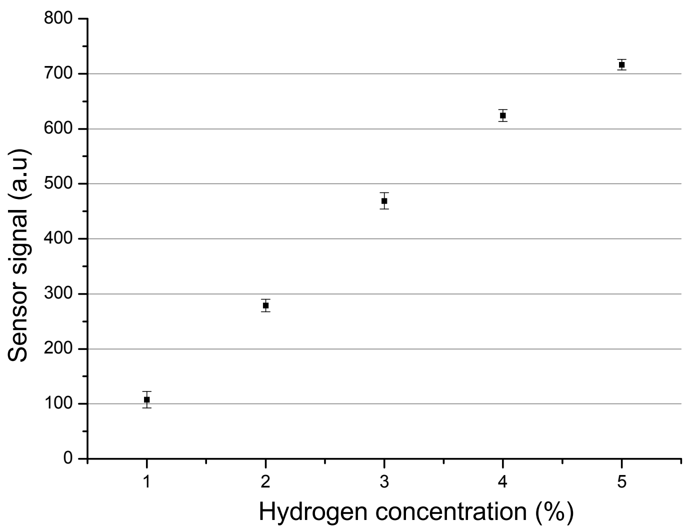
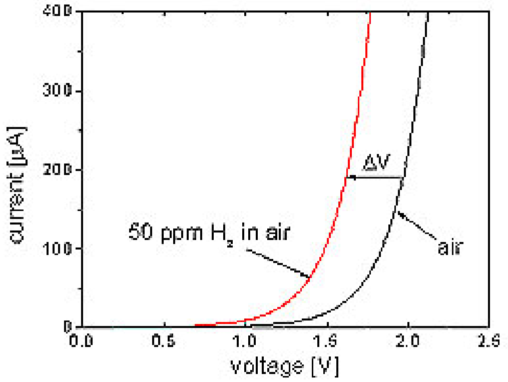


Figure 1: Calibration curve for the 1-5 % H_2 concentration range.

4 Operating Principles

4.1 The transducer

The basis for the sensor is the Field Effect transistor operating in diode-coupled mode. The gas sensitive properties are achieved by depositing a catalytic metal stack as the gate of the device. Through the chemical reactions during hydrogen exposure, the I-V characteristics of the device will shift as shown in the figure below. Operating at a constant current, the response is recorded as a change of the voltage (ΔV) over the device.



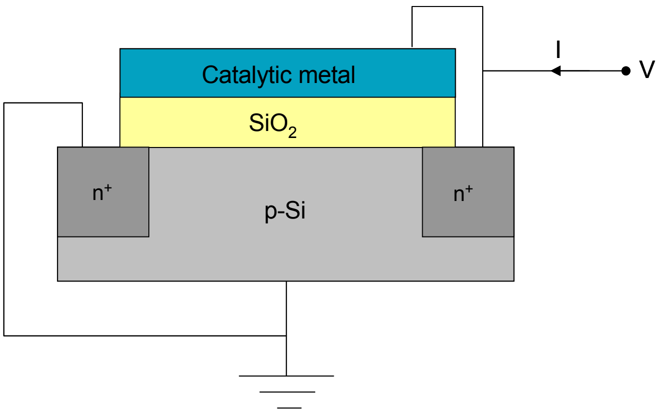


Figure 2a: The effect on the I-V characteristics of the Field Effect transistor due to hydrogen exposure.

Figure 2b: Operation of Field Effect transistor in diode-coupled mode.

4.2 The field effect (FE) response mechanism

The dominating chemical reactions that give rise to the sensing properties are as follows: Hydrogen gas (H_2) will adsorb and dissociate into hydrogen atoms on the surface of the catalytic metal stack. The hydrogen atoms will be transported through the metal down to the metal-insulator interface resulting in an effective dipole layer at the interface. The effective dipole layer will in turn give rise to a potential drop over the interface, affecting the transistor in the same way as if the gate bias had been changed, i.e. shifting the I-V curve. Hence, the actual sensing part of the device is the metal-insulator interface, which is accessible only to hydrogen atoms and thereby gives excellent selectivity and robustness. The back-reactions include transportation of hydrogen from the interface to the surface and water formation ($2H + O \rightarrow H_2O$). The steady-state point between all the reactions is dependent on the actual hydrogen gas concentration in the ambient.

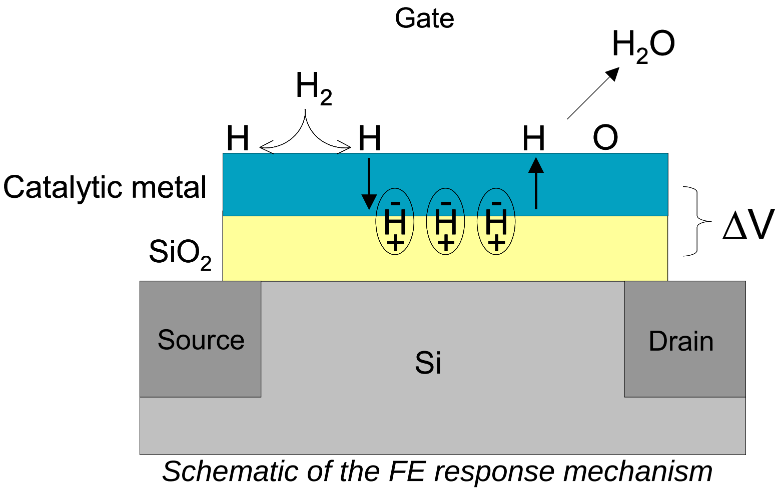


Figure 3: Schematic of the FE response mechanism.

4.3 The thermal conductivity (TC) response mechanism

H_2 is the gas with the highest cooling efficiency, i.e., it has the highest thermal conductivity. The high thermal conductivity as well as a large difference to most other gases is used for measurement purposes. The fact that the thermal conductivity for H_2 is almost 7 times larger than for air allows fairly small amounts of H_2 in air to be detected and quantified. The sensor component is operated at elevated temperature, which permits that the heat exchange between the sensor component and the colder ambient to be monitored. Hence, also the thermal conductivity of the test gas (ambient) can be measured. The H_2 concentration can be determined if a calibration at known conditions has been performed.

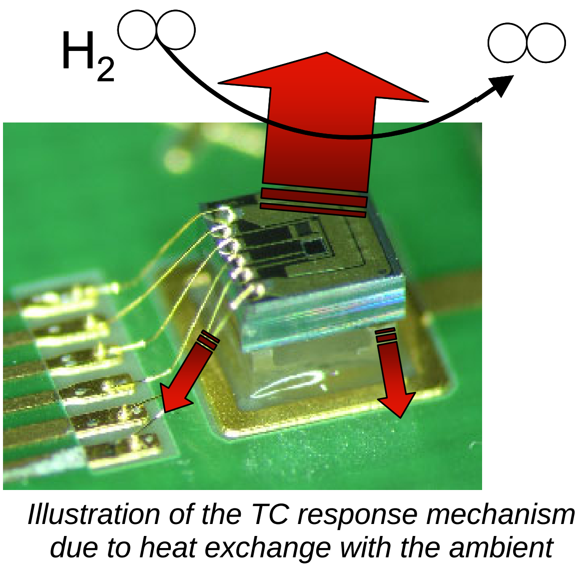


Figure 4: TC response mechanism.

5 Signal Processing and Data Analysis

The signal processing (algorithms) is an essential part of the AppliedSensor hydrogen sensor. The main purpose of the signal processing is to convert the available sensor signals into an output signal indicating the current H_2 concentration. Also, the sensor components suffer from some imperfections, which must be compensated for in order to fulfil the high accuracy demands for the sensor. The two main signals entering the algorithm for further processing are the TC signal and the FE signal. The TC signal is related to the heat conductance of surrounding ambient, whereas a high H_2 concentration will result in a larger signal than the signal of a hydrogen-free environment. The TC signal has best signal to noise properties for higher H_2 concentrations. The FE signal indicates H_2 variations accurately at lower concentrations, and becomes saturated for higher concentrations. The information from the sensor signals is thus partly overlapping and partly complementary. To utilize the available information from the two sensor signals maximally, the sensor signals are weighted in different concentration intervals according to their relative importance. The weighted signals are then converted into a H_2 concentration via a transformation. To compensate the sensor-to-sensor variation, each sensor is individually calibrated, where the FE-TC weighting and the H_2 prediction model are optimized.

6 Features and Benefits

Among many others the key advantages of the AppliedSensor hydrogen sensor product line lies in the following benefits:

6.1 Competitive price using standard silicon process and COB packaging

The component can be easily mass-produced in a standard silicon process foundry. The small chip size yields a very high number of sensors per wafer, leading to low production costs per unit. Another cost advantage of using a standard silicon process is that existing tools for Wafer Level Testing (WLT) can be used to achieve quality management on a component level early in production. Furthermore, AppliedSensor was first to introduce chip-on-board (COB) packaging for gas sensors – a major cost-reducing factor at component level.

6.2 Excellent selectivity to hydrogen

Using a high level of control in metal deposition, the AppliedSensor FE sensor can achieve near perfect selectivity to hydrogen without cross interference from gases such as CO, CO_2, NOx, hydrocarbons or ammonia, as shown in the chart below. Importantly, our sensors show no response to humidity.

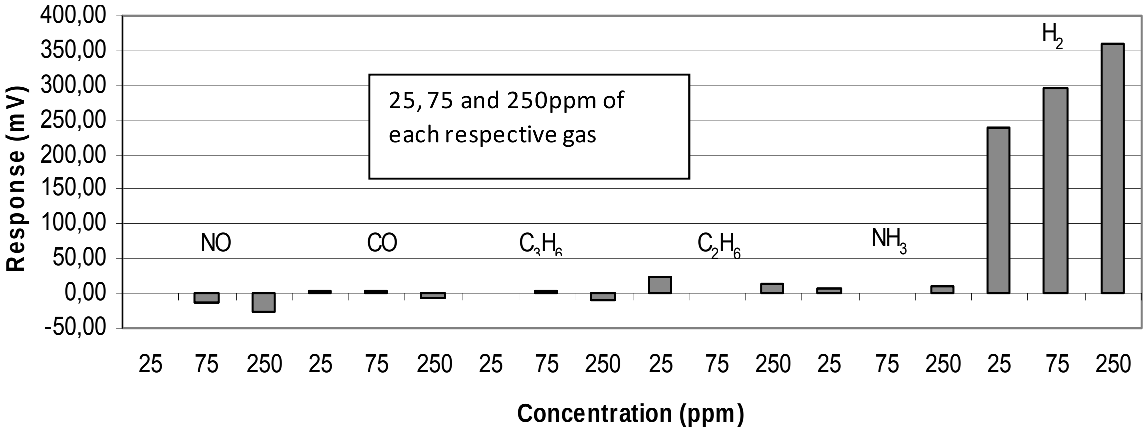


Figure 4: Response=f (concentration).

The AppliedSensor FE sensor shows excellent selectivity

6.3 Speed of response

At elevated operating temperature, the speed of response is in the order of a few seconds. Using data evaluation algorithms the speed of response can be further lowered to less than 3 seconds.

7 Available Products

AppliedSensor are offering following products with various configurations to different market segments.

7.1 Fast and highly selective

The AppliedSensor HLS-440A10 Hydrogen Leak Sensor is an accurate, fast-responding sensor designed for installation in vehicles and hydrogen fuelling stations [4]. Unlike sensors that can be extremely cross sensitive to a variety of combustible gases, AppliedSensor's HLS-440A10 sensor was developed using advancements in Field Effect (FE) technology. This enables it to be highly selective to hydrogen gas without interference from background gases or water vapour.

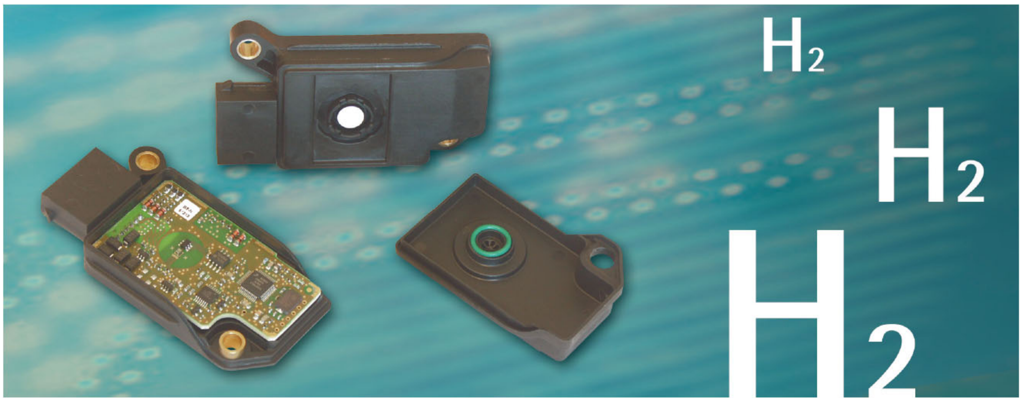


Figure 5: HLS-440 - Hydrogen Leak Sensor.

7.2 Fast and highly selective

The AppliedSensor HSS-440P Hydrogen Process Sensor is an accurate, fast-responding sensor designed for installation in harsh environments such as for example fuel cell exhausts [5]. The sensor will measure hydrogen in the range of 0-10% in air or nitrogen.

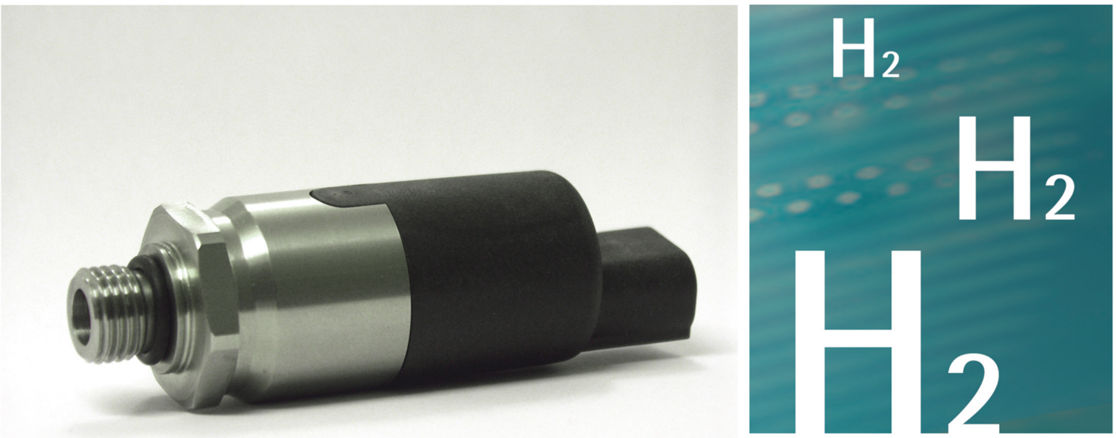


Figure 6: HSS-440P - Hydrogen Process Sensor.

7.3 Tough and resistant

The HSS-440P Hydrogen Process Sensor will provide hydrogen detection and measurement for applications where conditions are harsh. With an IP6K9 rating and designed towards Atex Zone 2 it can be installed almost anywhere.

7.4 Fast and highly selective

The AppliedSensor HPS-100 Hydrogen Process Sensor is an accurate, fast-responding sensor designed for installation in harsh environments such as for example fuel cells [6]. The sensor will measure hydrogen in the range of 0-100% and will function up to 3 bar(a)

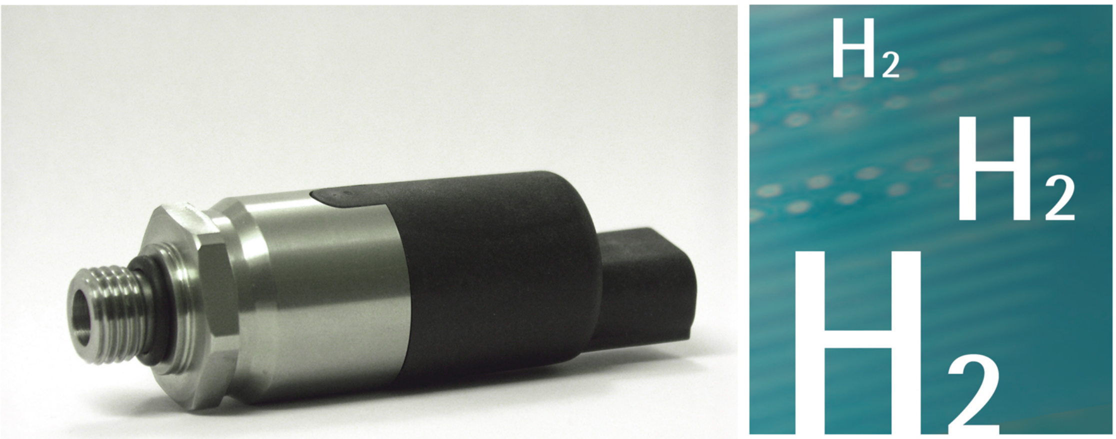


Figure 7: HPS-100 - Hydrogen Process Sensor.

7.5 Tough and resistant

The HPS-100 Hydrogen Process Sensor will provide hydrogen detection and measurement for applications where conditions are harsh. With an IP6K9 rating and designed towards Atex Zone 2 it can be installed almost anywhere.

References

[1] Wasserstoffsensor zur Leckagedetektion im Automobil by Michael Hackenberg, Jürgen Kappler, Miodrag Kosovic, Niclas Edvardsson, Tomas Eklov, Pär Back in Sensoren im Automobil II (expert-Verlag, ISBN: 3816927505), 49 –63 (2007).

[2] I. Lundström, M. S. Shivaraman, and C. M. Svensson, Journal of Applied Fhysics 46, 3876 (1975).

[3] FE Sensor Technology presentation: http://appliedsensor.com/pdfs/APS_FE%20Sensor_1109.pdf

[4] HLS-440 Data sheet: http://appliedsensor.com/pdfs/HLS-440_1009.pdf

[5] HLS-440P Data sheet: http://appliedsensor.com/pdfs/HLS-440P_0410.pdf

[6] HPS-100 Data sheet: http://appliedsensor.com/pdfs/HPS-100_0410.pdf