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Underground Power Vault Inspection Robot

Sensors Used for Detecting Explosive and Harmful Gasses

Introduction

Explosive gas sensors are widely used in fields such as medical, environmental, industrial and many others. This document examines three types of commercial gas sensors from Figaro Engineering Inc., the technology involved with gas sensing and how these sensors are implemented. Currently on the market there are many types of gas sensors ranging from electrochemical to semiconductor and infrared. The three types of gas sensors that will be examined in this document are MOS-type, electrochemical and catalytic.

In Market Commercial Gas Sensors

There are multiple manufacturers that are currently making and selling gas sensors. Figaro is currently a world leader in gas sensing innovation. One of the sensors that Figaro currently has on the market is the TGS816: Combustable Air Sensor. This sensor has the unit retail price of \$41.00 [1]. The sensing principle that the TGS816 uses is MOS-type. Applications for this sensor include domestic gas leak detectors and alarms as well as industrial safety. The ceramic base makes this sensor resilient to harsh environments. The TGS816 has high sensitivity to methane, propane and butane, all of which are flammable [2]. Another sensor that is sold by Figaro is the TGS5042-A00 Electrochemical sensor. The TGS5042-A00 is highly sensitive to Carbon Monoxide. This sensor can be used for residential CO detector, industrial safety and fire detection. This average cost for the TGS5042-A00 is around \$25.00. Figaro's TGS5042-A00 has many advantages over traditional electrochemical sensors. The electrolyte is environmentally friendly, it poses no risk of electrolyte leakage. The TGS5042-A00 has a long life and Meets UL2034, EN50291, and RoHS requirements[3]. This sensor can also detect concentrations as low as 1% CO. The third sensor that will be examined in this document is the Figaro TGS6812-d00 Catalytic sensor. The current retail price for this sensor is around \$35.00 [4]. The TGS6812 targets Hydrogen, Methane, Butane, Propane and is sensitive to hydrogen, methane and LP gas with a small sensitivity to organic gases [5]. Applications for TGS6812-d00 is hydrogen detection and fuel cell power safety. Some features that the TGS6812-d00 has is a long life and a linear output. This sensor operates at a voltage of +/- 0.1 V and has a detection range of 0 - 100% of each gas.

Technology Behind Gas Sensors

A Mos-type gas sensor is made up of a heater, layered with an alumina substrate and a metal oxide on top. A popular method for making the porous metal oxide and silicon is electrochemical anodization or etching. This method makes the grain and pore size easily controllable. Metals that are typically used are aluminum, tantalum, titanium, and zinc [6]. In clean and safe air donor electrons going through the tin oxide are attracted to the oxygen in the air and are absorbed on the sensing material which prevents current from flowing. In contaminated air, the combustible gas particles absorb the oxygen particles which allows the electron to move through the tin oxide and turn on a notification light or speaker [7]. Electrochemical-type gas sensors are made of an Ion conductor where H^+ can move and two electrodes, one working electrode and one counter electrode connected by a short circuit through a gas meter. When the working electrode comes in contact with a toxic gas such as carbon monoxide, oxidation of the gas will occur with the equation $CO + H_2O \rightarrow CO_2 + 2H^+ + 2e^-$. The short circuit will allow the H^+ protons to move to the counter electrode through the gas meter. The chemical reaction: $CO + (\frac{1}{2}) O_2 \rightarrow CO_2$ causes the sensor to act as a battery with gas being the active material. In order to measure the sensor output current the equation: $I = F \times (A/\sigma) \times D \times C \times n$ where F is the Faraday constant, A is the surface area, σ is the diffusion film thickness, D is the gas diffusion coefficient, C is the gas concentration and n is the number of reaction electrons [8]. The Catalyst-type gas sensor is made up of a compensator element without a catalyst and a detector element with a catalyst. In an environment with combustible gas, the gas will burn on the detector element which causes the a rise in temperature and a raise in the resistance of the catalyst element. In order to measure the concentration of combustible gas, the sensor is connected in a Wheatstone bridge circuit where a variable resistor is used on the output to maintain a state of balance of the bridge circuit. If there is combustible gas is present the increase in resistance will cause an imbalance in the circuit [9].

Implementation of Gas Sensors

In researching Mos-type, Electrochemical-type, and Catalyst-type sensors they all involve hardware aspects over software. Mos-type gas sensors do well integrated in mobile sensing devices like smartphone or other small portable devices. Unfortunately, Mos-type sensors have power consumption limitations which make them harder to use in longer term battery-operated applications [10]. The market for gas sensors is growing. In 2017, the gas sensor market was \$1,936.5 million, the end-use outlook revenue is projected to grow to \$3,436.2 million by 2025 [11].

References

- [1] F. TGS816, "FIGARO TGS 816 Gas Sensor for the detection of Combustible Gases TGS816-in Sensors from Electronic Components & Supplies on Aliexpress.com | Alibaba Group", *aliexpress.com*, 2018. [Online]. Available: <https://www.aliexpress.com/item/FIGARO-TGS-816-Gas-Sensor-for-the-detection-of-Combustible-Gases-TGS816/32342439716.html>. [Accessed: 20- Oct- 2018].
- [2] Figaro, "For the detection of Combustible Gases," TGS 816 datasheet, Oct. 2018.
- [3] Figaro, "For the detection of Carbon Monoxide," TGS 5042 datasheet, Oct. 2018.
- [4] "TGS6812 Industrial Gas Leak Detector Pricing", *SOS Electronic*, 2018. [Online]. Available: <https://www.soselectronic.com/products/figaro/tgs-6812-76571>. [Accessed: 20- Oct- 2018].
- [5] Figaro, "For the detection of Hydrogen, Methane, and LP Gas," TGS 6812-D00 datasheet, Oct. 2018.
- [6] X. Qiu, *Gas Sensors: Developments, Efficacy and Safety*, New York: Nova Science Publishers, Inc., 2012. [E-book] Available: <http://prx.library.gatech.edu/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=nlebk&AN=540284&site=eds-live&scope=site>
- [7] "Operating principle -MOS-type gas sensor", *Figarosensor.com*, 2018. [Online]. Available: <http://www.figarosensor.com/technicalinfo/principle/mos-type.html>. [Accessed: 20- Oct- 2018].
- [8] "Operating principle -electrochemical-type gas sensor", *Figarosensor.com*, 2018. [Online]. Available: <http://www.figarosensor.com/technicalinfo/principle/mos-type.html>. [Accessed: 20- Oct- 2018].
- [9] "Operating principle -catalytic-type gas sensor", *Figarosensor.com*, 2018. [Online]. Available: <http://www.figarosensor.com/technicalinfo/principle/mos-type.html>. [Accessed: 20- Oct- 2018].
- [10] J. Burgues, M. Santiago, "Low Power Operation of Temperature-Modulated Metal Oxide Semiconductor Gas Sensors," *Sensors* (14248220), Vol. 18 Issue 2, p1-N.PAG. 15p. 1 Diagram, 7 Graphs, Feb. 2018
- [11] "Gas Sensor Market Size & Share | Industry Analysis Report, 2018-2025", *Grandviewresearch.com*, 2018. [Online]. Available: <https://www.grandviewresearch.com/industry-analysis/gas-sensors-market>. [Accessed: 20- Oct- 2018].