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A COMPREHENSIVE REVIEW OF SEMICONDUCTOR-TYPE GAS SENSORS FOR ENVIRONMENTAL MONITORING

Anand Nayyar[1]† --- Vikram Puri[2] --- Dac-Nhuong Le[3]
[1]*Department of Computer Applications & IT, KCL Institute of Management and Technology, Jalandhar*
[2]*G.N.D.U- Regional Campus, Jalandhar*
[3]*Faculty of Information Technology, Haiphong University, Haiphong, Vietnam*

ABSTRACT

In this paper a review of different semiconductor-type gas sensors is presented. The different types of gas sensors from various companies like Hanwei, Libelium, Sandbox Electronics and Sensor Tech SGX are discussed along with their technical specifications. Environment is surrounded by various sorts of gases cum pollutants and it is utmost necessary to keep a efficient check on them as these gases can cause trouble to the health of human beings and pollute environment drastically. The main objective of this research paper is to present all sorts of gas sensors which are based on semiconductors and to generate awareness regarding which sensor is best for which detection. However, for more improved sensitivity and selectivity for these sensors, future trends and outlook for researchers is also suggested. The paper can also act as base for researchers to get hold of these sensors to develop a market ready product like drone or robot for Environmental Gas Detection.

Keywords: Gas sensor, Selectivity, Gas, Hanwei sensor, Libelium, Sandbox electronics, Sensor tech SGX, Sensor.

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1. INTRODUCTION

This paper describes various Gas Sensors [1] which are being manufactured by various organizations that can be used for the purpose of sensing various pollutants in the environment. Environment is surrounded by various pollutants like CO, Propane, NH_3, Ozone, Benzene, Flammable Gases, Alcohol, Smoke along with various Toxic Gases like Sulfureted Hydrogen (H_2S), VOC (Mellow, Aldehyde, Ketone, Ester). Some of the gases or pollutants can cause acid rain and some can even lead to the disaster of Global Warming and produce ozone (O_3) and can cause serious problem to Mankind in coming decades, so these gases and pollutants have to be accurately detected and reduced.

In addition to the pollutants, some other pollutants via construction material and chemicals can also produce dangerous gases which can be fatal to the health of human being and can cause various problems like Migraine, Vertigo, Skin Trouble etc. Considering the issues being caused by various gases which are emitted in the environment and can cause lethal damage to humans and environment, proper sensors are to be deployed for detection. So, gas sensors with excellent efficient sensitivity and stability are required.

21st Century is marked as "Sensor Decade" [2]. Efforts in development of sensor technology especially Research and Development has increased over the last 15 years and now sensors are being used and applied in diverse real world applications for proper monitoring and feedback control.

In the last three decades [1] many solid-state sensor devices to detect various environmental gaseous components are being proposed by organizations and researchers across the nook and corner of the world designed

† Corresponding author

with various principles and ultra-modern material. Various gas sensors developed in recent times are: Semiconductor Gas Sensors using metal oxides detect inflammable gases in air like CH_4, LPG and H_2 are deployed in households worldwide via Gas Leakage alarm systems. Oxygen sensors are deployed for Car Emission control as well as metallurgical process control. Humidity sensors are deployed by various food processing companies for automating processes and also used for Air Conditioning. With examples, it is clear that any automation control system is not complete without integration of Gas Sensors to ensure safety, efficient process control and amenity.

Gas Sensors [3] are used by researchers to monitor various environmental gases and pollutants and gas sensors are available in wide varieties depending on the sensing features. Gas sensors can be classified into various categories like Semiconductor-type, Solid electrolyte-type, electrochemical-type and Catalytic type [4, 5]. The most prominent used sensor by researchers and organizations in the real world are Semiconductor-type gas sensors, being operated by changing its conductivity when exposed to gas. Semiconductor-type gas sensors have high degree of sensitivity, efficiency and detect numerous gases and are fully functional in even sever conditions of high temperature, reactivity, high humidity and even other worsen conditions.

In this research paper, various Semiconductor-type based gas sensors efficient in detecting almost all sorts of Environmental pollutants and gases are explained.

The paper will be organized as: Section II covers regarding Overview of Semiconductor-Type Gas Sensor and its Principle Operation; Section III will cover prominent Gas Sensors- Semiconductor Type for monitoring various Environmental Pollutants and Gases from various Prominent companies, Section IV concludes the paper with future scope.

2. SEMICONDUCTOR-TYPE GAS SENSOR & PRINCIPLE OPERATION

What is Semiconductor-Type Gas Sensor? [6]; [7].

Semiconductor Gas Sensors (also known as Metal Oxide Sensors) are electrical conductivity sensors. Sensors active sensing layer changes coming in contact with gas. The gas actually reacts with the sensor surface in a completely reversible reaction. Because of their chemical composition cum properties, Semiconductor gas sensors are highly recommended for detection of all sorts of reactive gases. Depending on the manufacturing quality of sensor, the operating temperature of sensor ranges between 300^0C to 900^0C.

Fig-1. Semiconductor-Type Gas Sensors
Source: http://m.made-in-china.com/product/Gas-Sensor-Semiconductor-Sensor-689342095.html

Semiconductor Gas Sensors are used in wide range of real world environmental applications like Safety Equipment's (Fire, Explosion, Leakage, Poisoning and Contamination), Air Pollution monitoring for detection of gases like Carbon Monoxide (CO), Nitrogen Oxide (No_2), Ammoniac (NH_3), Sulfurous Gases (H_2S, SO_2), Volatile Organic compounds (VOCs) etc.

2.1. Operating Principle of Semiconductor-Type Gas Sensor

A Gas Sensor consists of: Receptor and Transducer as explained in Figure 2 [5].

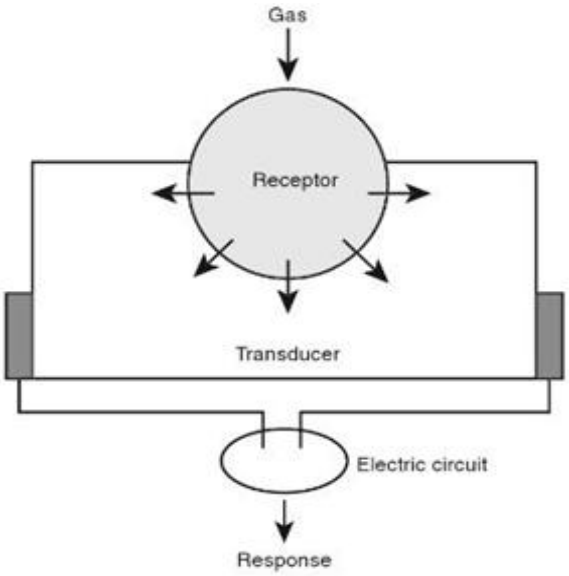

Fig-2. Gas Sensor: Receptor and Transducer

Receptor consists of material which on reacting with gas can either induces a change in its own properties like work function, dielectric constant, electrode potential, mass etc. or emits heat or light.

Transducer on the other hand, is regarded as a device to transform such an effect into an electrical signal. The sensor construction is determined by the transducer used, with the receptor appearing to be implanted within it.

In short, Semiconductor Gas Sensor is regarded as a sensor in which semiconductor material is used either as a receptor or transducer.

3. VARIOUS SEMICONDUCTOR-TYPE GAS SENSORS FOR MONITORING ENVIRONMENTAL POLLUTANTS AND GASES

In this section, various Semiconductor-Type Gas Sensors for monitoring various Environmental Pollutants and Gases are explained.

3.1. Hanwei Sensors

Semiconductor-Type Gas Sensors for monitoring Environmental Pollutants and Gases from Hanwei are explained in this part.

MQ Series- Gas Sensors are composed of micro AL_2O_3 ceramic tube, Tin Dioxide (SnO_2) sensitive layer, measuring electrode and heater are fixed into a crust composed of plastic and stainless steel net.

The types of MQ Series Gas Sensors are shown Figure 3 and the Technical Specifications of MQ Series Specifications are shown in Table 1.

3.2. Libelium

In this section, various Semiconductor-type Gas Sensors from Libelium company is explained.

The Technical Specifications of Libelium Series Gas Sensors Specifications are shown in Figure 4 and Table 2.

3.3. SandBox Electronics

In this section, various Semiconductor-Type Gas Sensors from Sandbox Electronics is explained.

1. MG811: It is developed by solid electrolyte layer, Gold electrodes, Platinum lead, Heater, Porcelain Tube, Steeless net, Nickel and copper plated ring, Bakelite, Nickel and copper plated pin.

Detects: Carbon Monoxide.

Technical Specifications

Voltage	6.0 ± 0.1 v
Heating Resistor	30.0 Ω ± 5 Ω
Heating Current	200 mA
Heating Power	1200 mW
Operating Temperature	-20^{O}C to +50^{o}C
Output	30 – 50 mV
Temperature and Humidity	28^{o}C; 65%

2. MH-Z16: MH-Z16 NDIR infrared gas sensor uses non-dispersive infrared (NIDR) principle to detect Carbon di-oxide in the air. Has in built- temperature sensor. It is developed via light integration of mature infrared absorbing gas detection technology, precision optical circuit design and superior circuit design.

Technical Specifications

Voltage	4.5 ± 5.5 v
Average Current	< 85 mA
Interface Level	3.3 v
Output Signal	PWM UART
Pre Heat Time	3 min
Response Time	< 30 sec
Temperature	0^{O}C to + 50^{o}C
Humidity	0 – 95%
Life Spam	More than 5 Years

3.4. SensorTech SGX

In this section, various Gas Sensors from SensorTech SGX are explained.

1. MiCS-4514: Detects pollution from automobile exhausts like CO, NO_2, H_2, NH_3, CH_4, C_2H_5OH.

2. MiCS-5524: Detects Carbon monoxide, natural gas leakage detection like CO, NO_2, H_2, NH_3, CH_4, C_2H_5OH.

3. MiCS-6814: Detects pollution from automobile exhausts like CO, NO_2, H_2, NH_3, CH_4, C_2H_5OH, C_3H_8, C_4H_{10}.

The Technical Specifications of Gas Sensors from SensorTech SGX is Listed in Table No: 3.

4. CONCLUSION

This review paper presents the comprehensive review of different types of Semiconductor types- Gas sensors for detecting various sorts of Gases and Environmental pollutants and also discusses the technical specifications of various Gas sensors available in the market regarding Gas Sensing from Hanwei, Libelium, Sandbox Electronics and Sensortech SGX. The paper also includes the technical specifications of all gas sensors which highlights various characteristics so that live implementation in the real world becomes much easy depending on the condition of sensitivity.

4.1. Future Scope

In the near future, research would be undertaken to develop full-fledged products integrated with Gas Sensors for detecting environmental gases and other pollutants via Robot or Drone development built on Small and Powerful computers like Raspberry Pi, Chip, Beagle bone and Orange Pi.

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1. **MQ-2:** Detects LPG, Propane, Hydrogen and can also be used to detect Methane and other combustible steam. 	2. **MQ-3:** Detects Alcohol, Gasoline, Smoke and Vapor. 	3. **MQ-4:** Detects CH_3, Natural Gas, LNG. 
4. **MQ-5:** Detects LPG, Natural Gas, Town Gas. 	5. **MQ-6:** Detects LPG, ISO-Butane, propane, LNG. 	6. **MQ-7:** Detects Carbon Monoxide 
7. **MQ-8:** Detects Hydrogen, LPG, Carbon Monoxide. 	8. **MQ-9:** Detects Carbon Monoxide, Methane, Propane and CO. 	9. **MQ-131:** Detects Ozone, CL2, NO2. 
10. **MQ-135:** Detects NH3, NO2, Alcohol, Benzene, Smoke, CO2. 	11. **MQ-216:** Detects LPG, i-butane, propane, methane, alcohol and smoke. 	12. **MQ-309A:** Detects Carbon Monoxide and Methane 

Fig-3. The types of MQ Series Gas Sensors

Source: http://www.hwsensor.com/

Fig-4. Libelium Gas Sensors

Source: http://www.libelium.com/

Table-1. Technical Specification of MQ-Series Gas Sensors from Hanwei

Sensor Name	Operating Voltage	Concentration	Heater Resistance	Heater Consumption	Sensing Resistance	Pre-Heat Time	Temperature and Humidity
MQ-2	5.0 ± 0.2v AC/DC	300-10000 ppm	31 Ω ± 3 Ω	≤900 mW	2K Ω–20K Ω	Over 48 Hours	20°C ± 2°C; 65% ± 5%
MQ-3	5.0 ± 0.2v AC/DC	0.04-4mg/l alcohol	31 Ω ± 3 Ω	≤900 mW	2K Ω–20K Ω	Over 48 Hours	20°C ± 2°C; 65% ± 5%
MQ-4	5.0 ± 0.1v AC/DC	1000-5000 ppm	33 Ω ± 5 Ω	≤750 mW	10KΩ–16KΩ	24 Hours	20°C ± 2°C; 65% ± 5%
MQ-5	5.0 ± 0.1v AC/DC	5000/1000 ppm (CH_4)	31 Ω ± 10 Ω	<800 mW	10KΩ–60KΩ	Over 24 Hours	20°C ± 2°C; 65% ± 5%
MQ-6	5.0 ± 0.1v AC/DC	1000/4000 ppm (LPG)	33 Ω ± 5 Ω	≤750 mW	10KΩ–60KΩ	Over 24 Hours	20°C ± 2°C; 65% ± 5%
MQ-7	5.0 ± 0.1v AC/DC	300/100 ppm	33 Ω ± 5 Ω	About 350 mW	N/A	No less than 48 Hours	20°C ± 2°C; 65% ± 5%
MQ-8	5.0 ± 0.1v AC/DC	1000/5000 ppm (H_2)	31 Ω ± 5 Ω	Less than 800 mW	10KΩ–60KΩ	Over 24 Hours	20°C ± 2°C; 65% ± 5%
MQ-9	5.0 ± 0.2v AC/DC	10-1000 ppm (CO)	31 Ω ± 3 Ω	≤350 mW	2K Ω–20K Ω	Over 48 Hours	20°C ± 2°C; 65% ± 5%
MQ-131	5.0 ± 0.2v AC/DC	10-1000 ppm (ozone)	31 Ω ± 3 Ω	≤900 mW	50KΩ–500KΩ	Over 48 Hours	20°C ± 2°C; 65% ± 5%
MQ-135	5.0 ± 0.1v AC/DC	30-300 ppm (NH_3); 10-1000 ppm (Benzene); 10-300 (Alcohol)	33 Ω ± 5 Ω	<800 mW	30KΩ–200K Ω	Over 24 Hours	20°C ± 2°C; 65% ± 5%
MQ-216	6.0 ± 0.1v AC/DC	500-10000 ppm (LPG); 500-10000 ppm (Butane); 3000-20000 ppm (Methane); 300-3000 ppm (Alcohol)	N/A	<100 mW	30Ω–200Ω	Over 24 Hours	20°C ± 2°C; 65% ± 5%
MQ-309A	09v ± 0.10v AC/DC	200 ppm (CO); 300 ppm (CO); 5000 ppm (CH_4)	4.0 Ω ± 1.0 Ω	=10 mW	20KΩ–200KΩ	More than 48 Hours	20°C ± 2°C; 65% ± 5%

Source: http://www.hwsensor.com

Table-2. Technical Specification of Gas Sensors from Libelium

Sensor Name	Measurement Range	Resistance at 100/5000/1800 ppm	Sensitivity	Supply Voltage	Operating Temperature	Response Time	Min. Load Resistance	Average Consumption
TGS2442	30-1000 ppm	13.3- 133 KΩ	0.13-0.31	5.0v ± 0.2v DC	-10°C to +50°C	1 sec	10 KΩ	3 mA
TGS4161	350-10000 ppm	N/A	44-74 mV	5.0v ± 0.2v DC	-10°C to +50°C	1.5 min	N/A	50 mA
MiCS-2710	0.05- 5 ppm	2.2 KΩ	6-100	1.7v – 2.5v DC	-30°C to +85°C	30 sec	N/A	26 mA
TGS2611	500-10000 ppm	Resistance at 5000 ppm: 0.68-6.8 KΩ	0.6 ± 0.06	5.0v ± 0.2v DC	-10°C to +40°C	30 sec	0.45 KΩ	61 mA
TGS2610	50-10000 ppm	Resistance at 1800 ppm: 0.68-6.8 KΩ	0.56 ± 0.06	5.0v ± 0.2v DC	-10°C to +40°C	30 sec	0.45 KΩ	61 mA
MiCS-2610	10-1000 ppb	Air Resistance: 3-60 KΩ	2 - 4	1.95v - 5v DC	-30°C to +85°C	30 sec	N/A	34 mA
MiCS-5521	30-400 ppm	Air Resistance: 100-1000 KΩ	1.8 - 6	2.1v - 5v DC	30°C to +85°C	30 sec	N/A	32 mA

Source: http://www.libelium.com

Table-3. Technical Specifications of Gas Sensors from SensorTech SGX

Sensor Name	Heating Power	Heating Voltage	Heating Current	Heating Resistance	Max Power Dissipation	Operating Temperature	Humidity
MiCS-4514 (RED Sensor/ OX Sensor)	76/43 mW	2.4/1.7 v	32/26 mA	74/66 Ω	88/50 mW	-30°C to +85°C	5 – 95%
MiCS-5524	76 mW	2.4 v	32 mA	74 Ω	88 mW	-30°C to +85°C	5 – 95%
MiCS-6814 (RED Sensor/OX Sensor/NH_3 Sensor)	76/43/66 mW	2.4/1.7/2.2 v	32/26/30 mA	74/66/72 Ω	88 mW	-30°C to +85°C	5 – 95%

Source: http://www.sgxsensortech.com/