Thesis Report

"Study on Gas Sensor and Its Application as a IOT Device"

B.Sc. in Electronics and Telecommunications Engineering
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DECLARATION

We hereby declare that we carried out the work reported in this thesis in the Department of Electronics and Communications Engineering, East West University under, the supervision of Dr. Mohammad Arifuzzaman. We solemnly declare that to the best of our knowledge, no part of this report has been submitted elsewhere for award of any degree. All sources of knowledge used in this report have been duly acknowledged.

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CERTIFICATE

This is to certify that the thesis entitled "Study on Gas Sensor and Its Application as a IOT Device", being submitted by Tamanna Akter, Abdul Waaje, J.M Saiful Islam Department of Electronics and Communications Engineering, East West University, Dhaka in partial fulfilment for the award of the degree of Bachelor of Science in Electronics and Telecommunication Engineering, is a record of major thesis carried out by them. They have worked under my supervision and guidance and have fulfilled the requirements which, to my knowledge, have reached the requisite standard for submission of this dissertation.

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APPROVAL

This is to certify that the thesis entitled "Review of Gas Sensors According to Gas Hazard Limits & IOT Base Gas Sensor", submitted to the respected member of the faculty of Engineering for partial fulfilment of requirement for the degree of Bachelor of Electronics and Telecommunications Engineering (ETE) under complete supervision of the undersigned.

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Abstract

This paper reviews the gas sensors according to the hazard limits and introduces a model of IOT based gas sensor. It is also containing a market review based on previous year's gas sensor global market, nevertheless special types of gas sensors also noted in this paper. According to WHO the world is facing a tremendous climate change in recent years, which mainly focused on the increasing number of hazardous gases limit in atmosphere. Moreover, the EU also declares to fulfil worker safety from the hazardous effect from the poisonous gases of production wastes. So it can be said that it is the alarming period of being aware and acquire knowledge about the gases, importantly how to get primary solution of it. Study of hazardous gases, specially their hazardous limits and the detection process of them can be a primary solution of being aware of any miserable explosion occurred by hazardous gases. This paper will help to give a clear overview of this kind of situation. Moreover, this paper can be a study of gas sensors which will be helpful for our upcoming global changes.

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CHAPTER 1

Introduction

Sensor refers to a device that is capable of measuring a signal by acquiring information from the real world. In a scene, it is a device which provides a usable output in response to a specified measured [ANSI]. In this paper we are going to discuses short brief on **Gas Sensor** from a various types of sensor technology.

Gas sensor is able to specify and measure the concentration of gas in its vicinity. It is a sub class of chemical sensor. The transducer which is a part of a gas sensor that works on detecting gas molecules and which produces an electrical signal with a magnitude proportional to the concentration of the gas. To specify the gas the gas sensor measures the breakdown voltage of the gas; which is unique for different gases. Moreover, the concentration of the gas can be determined by measuring the current discharge in the device. Figure-1 provides an overview of common gas sensor elements.

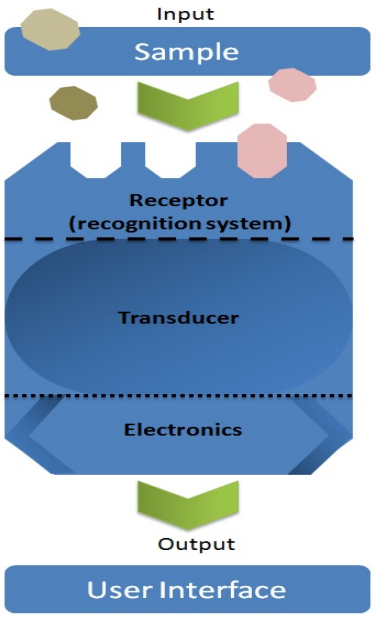


Figure 1.1 – Basic Gas Sensor Module

A real sensor era has started in 1970s during which semiconductor combustible gas sensors, solid electrolyte oxygen sensors and humidity sensors were commercialized for non-professional uses. On the occasion of the first IMCS held at Fukuoka, Japan in 1983, major topics of gas sensors were comprised of gas sensors. In the two decades since, extensive

efforts have been compiled not only for advancing these sensors but also for developing various new gas sensors, which have been in great demand to make sure safety, health, amenity, environmental reservation, energy saving and so on.

In recent years, modern society has brought numerous luxury items but along with them there are certain disadvantages: like air pollution and emission of toxic gasses are introducing to our society. There is an ever-increasing recognition of health and well-being impacts of both indoor and outdoor air quality in cities and industrial installations. The air surrounding us contains different amount of gases which could be hazardous to human health, atmospheric pollutants of significance to an industrial or medical process. Thus, gas sensors are coming forward as a need of our safety.

Nevertheless, the importance of gas sensors for our modern society is never so minor, as easily exemplified by the importance of oxygen sensors for automobiles. Gas sensor technology has already grown to be indispensable for various aspects in our life. Yet further advancements of the technology are strongly needed in order to improve sustainability of our society and quality of life.

CHAPTER 2

Related Works

In [1], authors are trying to review the gas sensor's technologies. The different types of gas sensors technologies including catalytic gas sensor, electrochemical gas sensors, thermal conductivity gas sensor, optical gas sensor and acoustic gas sensor are discussed together with their principle of operation. In this paper, there have a brief detail about the Surface Acoustics Gas Sensor Technology. The main highlighted parts are the advantages and disadvantages of each sensor technology. For several decades, all these technologies have been used for the development of highly sensitive and responsive gas sensors for the detection of flammable hazardous gases. Moreover, improvement of sensitivity and selectivity for those gas sensors will be the future trends and outlook for the researchers, which was suggested at the conclusion of this article.

In [2], there have a meaning full discussion about the gas sensor in the field of various technologies. Mainly a classification of sensing technologies has given, based on the variation of electrical and other properties. It contains detailed introduction of sensing methods based electrical variation, which overviews further classification according to the materials which are sensible. Again, it gave emphasis on sensitivity and selectivity for being performed indicators to compare with various sensing technologies, also analyzes the factors which influence those indicators and listed several corresponding improved approaches. Moreover, it overviews the activities of the German gas sensor research community.

In [3], there have a study whether nano-structured particles of WO_3 could be competitive counterparts of traditional, more bulky materials in resistive gas sensor applications. Pristine and various surface decorated derivatives of three different types of WO_3 nano-particles applied on the surface of lithographically defined Si chips were used in the work to analyse the electrical behaviour of thin films when exposed to different gas atmospheres. Commercially available nanoparticles of WO_3 were also studied.

In [4], authors described about the technologies of fabricate and optimize gas sensor based on epitaxial grapheme. Optimization of grapheme or metal contact configuration manifested a low contact resistance. Complementary tempering of graphene sensor, improvement of sensing performance after each gas exposure led. The available technology with additional

annealing improves the level of performance of the graphene based sensor and which makes it applicable for the environmental nitrogen dioxide gas monitoring.

In [5], authors have discussed about sensors with wireless network within the wider context of IoT. Moreover, they provide a review of WSN sensor applications, while also give emphasise on infrastructure technologies, applications and standards featured in WSN designs.

By reviewing these papers one cannot feel the need of having gas sensors in our daily life also in the industrial uses. They tried to cover some specific area of gas sensors and its technologies along with the fabrication. On the other hand, we tried to provide the massage of hazardous limit of various gases and the detecting technologies of those specific gases. It containing the available gas sensors models for hazardous gases and also has a market studies about the future gas sensors.

CHAPTER 3

Gases and Gas Sensors

Gas Sensor has become a very viral topic to research because of its enormous and useable use at present world. By reviewing a high amount of Journal and Research Paper it can easily said that it's too tough to classify gas sensors. Authors are tried to classify gas sensors by reserving them into various kinds of specific area. Moreover, many of them tried to inform the technologies and the working methodologies of gas sensors

In this paper, we are trying to give the details of gas sensors based on the types of Gases. We have discussed about the gas sensors details individually with the heavy knowledgeable technologies of those gases.

From the definition Gases are the volatile forms of matter present on the earth.

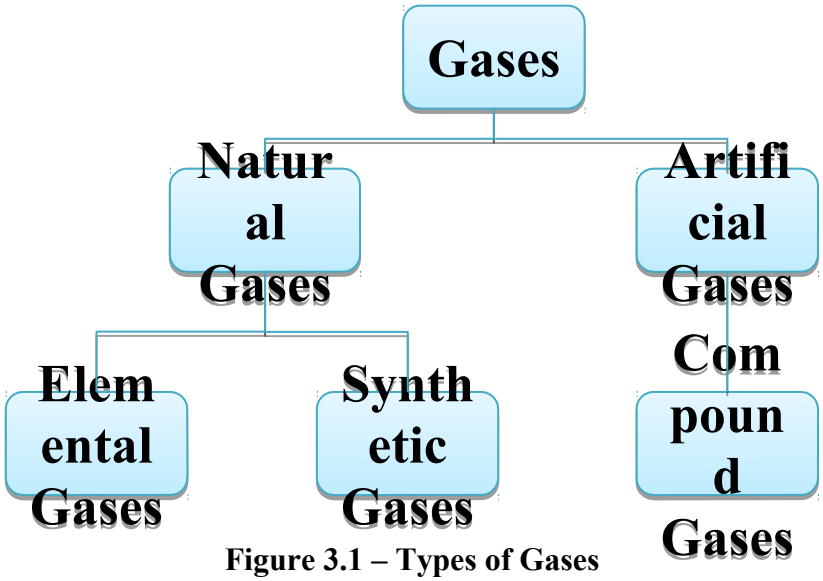


Figure 3.1 – Types of Gases

Basically there are two types of gases; those are natural gases and artificial gases. There have to sub division of Natural gases; those are respectively Elemental Gases and Compound Gases. Artificial Gases also have one sub division which is Compound Gases.

Spontaneously natural gasses are present in nature while the artificial gasses are obtained by some chemical reactions. According to the definition of elemental gases it can be said that these gases are made of single element atoms, such as Hydrogen gas $(\overset{H}{¿¿2})$, Oxygen gas

O
$(¿¿2)$ etc. On the other hand, compound gases are formed in nature out of biological
¿

processes. Chemically, these are combinations of two or more elements, such as Carbon-dioxide (CO_2) , Sulfur-dioxide (SO_2) etc. The artificial gasses are prepared by synthetic means for human use which are included chlorofluorocarbons, anaesthetics, sterilizing agents etc. Because of its preparation of synthetic means artificial gasses are also called synthetic gases.

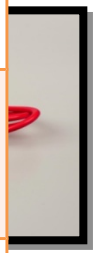
Now, it's time to introduce the gas sensor of specific gases with their hazardous limits and the present technologies of those gas's sensors.

3.1O_2 Gas Sensor:

Oxygen gas is extremely important to sustain life. Man can become passed away by exposure to air inadequate of oxygen. Asphyxiation is the greatest hazard associated with oxygen. Generally health effects begin at oxygen concentration of 19%, which is tough to be, noticed [33]. Workers can become affected badly for asphyxiation.

Table 3.1 - Effects of Oxygen-Inadequate Exposure

Oxygen(% vol)	**Health Effects**
19	Some adverse physiological effects occur (not noticeable).
17	Increased breathing volume; accelerated heartbeat; Night vision.
16	Dizziness reaction time for new tasks in doubled.
15	Poor judgment; Poor coordination; Abnormal fatigue upon exertion; Loss of muscle control.
10-12	Very faulty judgment; Impaired respiration that may cause permanent heart damage; Loss of consciousness.
8-10	Nausea; Vomiting; Coma.
<8	Permanent brain damage.



<6	Spasmodic breathing; Convulsive movements; Death in 5-8 minutes.

Globally three different technologies are using much in making of Oxygen gas sensors; thermo-magnetic, optical and electro-chemical. Thermo-magnetic oxygen sensors are based on the physical properties of oxygen. But the slow response of thermo-magnetic oxygen gas sensor, distinct measurement error, and thermal element corrosion raised the difficulties for sensing the oxygen gas. On the contrary, research on electrochemical sensor development has not received considerable attention. A chemical sensor or biosensor comes forward to solve the problem of sensing oxygen gas and other difficulties. Moreover, with the development of technologies oxygen gas can also be detected by wireless sensor with the platform of surface acoustic wave gas sensor.

BT59i Oxygen Gas Sensor is an available electrochemical gas sensor in global market. The Oxygen Gas sensor BT59i measures the gaseous oxygen concentration in the range of 0 to 100 %. It uses an electrochemical cell. Here, electrochemical reaction generates a current that is proportional to the partial pressure of oxygen in the gas mixture. The current is measured across a resistance to generate a small voltage output. The voltage output is amplified to the 0. 5V output range. The Oxygen Gas sensor has a limited operating lifetime of 5 years in open air.

Figure 3.2 - BT59i Oxygen Gas Sensor

3.2 N_2 Gas Sensor:

Nitrogen gas contains 78.08% of the atmosphere. Usually it is a nontoxic, ordorless, colorless, tasteless non-flammable gas. Many people said that nitrogen is not injurious for health. But there has a condition that nitrogen is safe to breathe only when mixed with the

appropriate amount of oxygen. Asphyxiation hazards of nitrogen had occurred in industry from 1992 to 2002 which resulted in 80 deaths [16]. Here, Nitrogen displaced oxygen and created oxygen deficient (<19.5%) atmospheres without significant physiologic effects. Then many people had died due to insufficient oxygen supply in the air. As a gas, nitrogen is a "silent-killer".

Moreover, nitrogen gas is classified as a "simple asphyxiant". This means Nitrogen will displace oxygen and create oxygen deficient (<19.5%) atmospheres without significant physiologic effects. Exposure limits are not normally given to "simple asphyxiants" because the limiting factor is the available oxygen. Therefore, Nitrogen has no exposure limit.

As it is tough to set the hazed limit of nitrogen gas, so there have a little amount of nitrogen gas sensor in global market. Oxygen gas sensors usually use to overcome the hazed situation for increasing nitrogen in the air as oxygen deficiency decrease then.

3.3 NO_2 Gas Sensor:

Nitrogen dioxide's availability on air is too low. But the highly emission of nitrogen dioxide from various man made source like power plants, industrial emissions and off-road sources such as construction, lawn and gardening equipment are the reason of the hazardous situations.

On January 22, 2010, EPA (Environmental Protection Agency, US) strengthened the health-based National Ambient Air Quality Standard (NAAQS) for nitrogen dioxide (NO_2). EPA set a 1-hour N_2O standard at the level of 100 parts per billion (ppb) [18]. EPA also retained the annual average N_2O standard of 53 ppb. Additionally, EPA established ambient air monitoring and reporting requirements for NO_2 .

On the basis of the monitoring result of MSHA (Mine operators and Mine Safety and Health Administration) the threshold limit value (TLV) time-weighted average (TWA) health limit for NO_2 exposure is 3 ppm for a conventional 8-hr workday and a 40-hr workweek.

Table 3.2 - NO_2 Standard Exposure Limit

Time Period	Concentration (ppm)	Health Effects
8-hr	5	Irritation to the eyes and pulmonary tract.
48-hr	10-20	Coughing and burning in the throat induce slowly evolving pulmonary edema.
Up to 30min	20	Immediately dangerous to life or health.
60min	25	Chest pain
60min	50	Pulmonary edema with possible sub acute or chronic lesions in the lungs
60min	100-200	Serious complications, including death

These hazards can be prevented by using NO_2 gas sensor. Nitrogen Dioxide gas sensor will detect the gas according to the exposure limit then it will warn us. Globally, there have various types of nitrogen dioxide gas sensor available in the market. Electrochemical based gas sensors are using mostly to detect nitrogen dioxide gas. Moreover, researchers are inventing various types of nitrogen dioxide gas sensor according its working principle, sensing property and the material by which the sensor has made. From the review of research papers nitrogen dioxide can be made based on metal-oxide gas sensor, nanostructured $Sr\,Ti_{0.85}Fe_{0.15}O_3$ thin film, optical fibre coated gas sensor etc.

NE4-NO2 is an electrochemical nitrogen dioxide NO_2 gas sensor. The NE4-NO2 Gas Sensor is a 3-Electrode electrochemical gas sensor designed for the detection and measurement of nitrogen dioxide (NO2) in the range 0-30 ppm, in a wide range of industrial and commercial safety applications. By adhering to industry standards for size and connection orientation, the NE4-NO2 can be retrofitted easily to existing product designs.

Figure 3.3 - NE4-NO2 electrochemical NO_2 gas sensor

3.4 H_2 Gas Sensor:

H_2 gas is known as a flammable , colorless ,odorless, high volatile and explosive gas that is undetectable by the human senses and the low concentrations of a leak must be fabricated by those sensors. At room temperature the lower flammable limit of hydrogen gas in air is 4% by volume, which makes hydrogen gas very dangerous for public health and safety of property.

Table 3.3 – H_2 Standard Limits on Various Situations

Situation	Hydrogen Limit
Flammability Limits (in air)	4-74%
Explosion Limits (in air)	18.3-59%
Ignition Energy (mJ)	0.02
Flame Temp in air (℃)	2045
Stoichiometric Mixture (most easily ignited in air)	29%

Based on the technology there have different types of hydrogen sensors such as optical fibre hydrogen sensor, MEMS hydrogen sensor, thin film sensor, thick film sensor, electro

chemical sensor etc. Each sensor not only different by the technology but also different form their sensing characteristics and materials by which it builds.

The MQ-8 a hydrogen gas sensor, it is a semiconductor based gas sensor which is suitable for sensing hydrogen concentrations in the air. The MQ-8 can detect hydrogen gas concentrations anywhere from 100-10000ppm. This sensor has a high sensitivity and fast response time.

Figure 3.4 - Hydrogen Gas Sensor MQ-8

It can be used in gas leakage detecting equipments in family and industry, are suitable for detecting of Hydrogen (H2), avoid the noise of alcohol and cooking fumes, LPG,CO. Moreover, Resistance value of MQ-8 is difference to various kinds and various concentration gases. So, when using this component, sensitivity adjustment is very necessary.

3.5 CO Gas Sensor:

Carbon Monoxide is a poisonous gas and is a common yet preventable cause of death from poisoning worldwide. Approximately half of the deaths from unintentional CO poisonings result from the inhalation of smoke from fires. Other significant causes are vehicle exhausts and deaths in industrial settings. On average between 1 and 2 people die each year in Ireland from unintentional CO poisoning in the home in incidents related to domestic heating or other fossil fuel installations in the home (i.e. excluding the inhalation of smoke from fires).The incomplete combustion of organic fossil fuels such as oil, gas or coal is a common environmental source of CO and is responsible for many cases of non-fatal unintentional CO poisoning. Exposure at 100 ppm or greater can be dangerous to human health.

Table 3.4 – CO Standard Limits of Exposition

CO ppm	Health effect
800	Dizziness, muscle pain and diminished consciousness
1600	Headache, dizziness, death within 2 hours.

For being aware from the exposure of CO we can use various technology based CO gas sensor. Opto-chemical, biomimetic, electrochemical, semiconductor and metal oxide based gas sensors are available in global market. MQ-7 gas sensor is a metal oxide based CO gas sensor. This MQ-7 CO gas sensor is high sensitivity to carbon monoxide. It has excellent long term stability. Its service life can reach 5 years under using condition. Usually it used in gas detecting equipment for carbon monoxide (CO) in family and industry or car.

Figure 3.5 – CO Gas Sensor MQ-7

3.6 CO_2 Gas Sensor:

CO_2 is the primary anthropogenic greenhouse gas, as well as a proxy for assessing ventilation conditions in indoor environments. CO_2 is denser than air and as such can accumulate to dangerous levels. Breathing air with more than 30% CO_2 can quickly induce unconsciousness and cause death.

Table 3.5 – CO_2 Standard Limits of Exposition and Health Effects

CO_2 **Concentration**	Health Effects
350 - 450 ppm	Typical atmosphere
600 - 800 ppm	Acceptable indoor air quality
1000 ppm	Tolerable indoor air quality
5000 ppm	Average exposure limit over 8 hours
6000- 30000 ppm	Concern, short exposure only
3 - 8 %	Increased respiration and headache
10 % +	Nausea, vomiting, unconsciousness
(20 – 30) %	Sudden unconsciousness, death

Based on technology basically there have four types of carbon dioxide sensors respectively mass airflow sensor (thermal conductivity), solid state electrochemical sensor, mixed oxide sensor, ion selective membrane sensor and optical sensor. Among them the electrochemical sensors are inexpensive and have low power requirements, but generally have slower response times, shorter life spans, and are more susceptible to poisoning. To maintain the cost and enhance the power and response of sensor two new technology of carbon dioxide gas also can introduce respectively NDIR-type sensor and Chemical based sensor.

Nowadays, NDIR is the most common type of sensor used to measure CO_2 . It is term for "non-dispersive infrared". BT25i CO_2 Sensors is an available NDIR gas sensor. It is used to monitor gaseous carbon dioxide levels in the range between 0 to 100,000 ppm.

Figure 3.6 – BT25i CO_2 **Sensors**

3.7 SO_2 Gas Sensor:

SO_2 is not combustible but it is considered an extremely toxic gas. When combined with water, sulfur dioxide becomes sulfuric acid which is highly corrosive and cause chemical burns. It is important to monitor sulfur dioxide levels power plants emit large amounts of sulfur dioxide and sulfur dioxide is a highly reactive gas. Sulfur dioxide is heavier than air. OSHA designated the PEL for sulfur dioxide to be only 5 ppm, because being exposed to even small amounts for a short period can be extremely dangerous. Nevertheless, we must have to know about the hazard limits of this. As its alarming for us, so the more we are alert the more we will be safe from the hazardous situation of this gas.

Table 3.6 – SO_2 Standard Limits of Exposition and Health Effects

SO_2 **ppm**	Health effects
1-5	Respiratory response in healthy individuals upon exercise or deep breathing
3-5	Gas noticeable. Fall in lung function and rest. Increased airway resistance
5	Increased airway resistance in healthy individuals
6	Immediate irritation of eyes, nose, and throat
10	Worsening irritation
10-15	Threshold of toxicity for prolonged exposures
20+	Paralysis or death occurs after prolonged exposures
150	Maximum concentration that can be withstood for a few minutes by healthy individuals

Electro-chemical gas sensor is useful to detect SO_2 as it is toxic. SO_2-BE is a sulpur dioxide detector. Highest rang of its 20ppm. This ultra-lower sensor is appropriate for applications in: indoor air monitoring, air purifier controls, early fire detection, HVAC ventilation controls and Smart Homes.

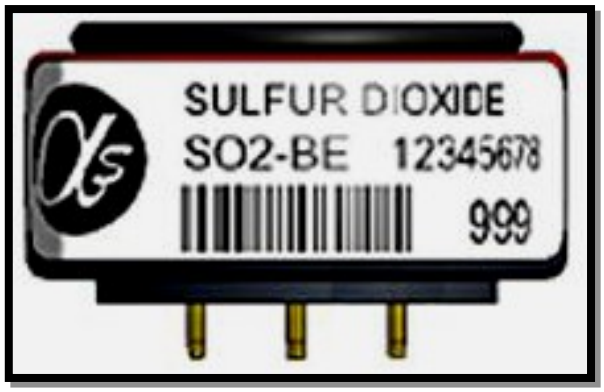


Figure 3.7 – $SO_2 - BE$ **Sensors**

3.8 H_2S Gas Sensor:

H_2S is extremely flammable and highly toxic. Hydrogen sulfide gas causes a wide range of health effects. Workers are primarily exposed to hydrogen sulfide by breathing it. The effects depend on how much hydrogen sulfide you breathe and for how long. Exposure to very high concentrations can quickly lead to death. As its alarming for us, so the more we are alert the more we will be safe from the hazardous situation of this gas**.**

Table –3.7 H_2S Health effects from exposure to hydrogen sulphide

H_2S **(ppm)**	**Health effect**
0.01 - 0.3	Odour threshold
1-20	Offensive odour, possible nausea, tearing of the eyes or headaches with prolonged exposure
20-50	Nose, throat and lung irritation; digestive upset and loss of appetite; sense of smell starts to become fatigued; acute conjunctivitis may occur (pain, tearing and light sensitivity)
100-200	Severe nose, throat and lung irritation; ability to smell odour completely disappears.
250-500	Pulmonary edema (build up of fluid in the lungs)

500	Severe lung irritation, excitement, headache, dizziness, staggering, sudden collapse (knockdown), unconsciousness and death within a few hours, loss of memory for the period of exposure
500-1000	Respiratory paralysis, irregular heartbeat, collapse and death without rescue.
>1000	Rapid collapse and death

Usually there have various types of H_2S gas sensors such as metal oxide base, nano -structured based, thin-film based and electrochemical H_2S gas sensors. Moreover electrochemical sensors, solid state sensors, impregnated paper, and laser based open path detectors are among those methods used to supply early warning and initiate an appropriate automatic protective response.

NTMOS H_2S sensor is a metal oxide semiconductor gas sensor. It contains the latest nanotechnology for the assurance of accuracy, reliability, and repeatability. It provides H_2S in extreme temperature and humidity conditions. It can be installed with a display for local indication. Moreover, it performs reliably in extreme climates with accurate and consistent operation proven through performance testing to the ISA-92.0.01 standard.

Figure 3.8 – NTMOS H_2S sensor

3.9 *Ne* Gas Sensors:

Neon is a colourless, odourless, non-flammable gas or a colourless, odourless, cryogenic liquid. It has a range of uses in industry, including in the popular business signs advertising

stores as open. Neon is on the hazardous substance list because it is cited by ACGIH (American Conference of Governmental Industrial Hygienists) and DOT (Department of Transportation). When it explore then it causes various types of problem.

Since workers cannot see or smell the gas, they need a way to know when they are in danger of asphyxiation. As acute health effects direct skin contact can cause frostbite and high exposure can causes fatigue, vision disturbance, headache, dizziness and suffocation from lack of Oxygen. According to the information presently available to the New Jersey Department of Health and Senior Service, Neon has not been tested for its ability to cause cancer and other long term effects

.

As neon is not too much hazardous as other gases so the researcher are not thinking to build any types of gas sensor to detect it. There have a few gas sensor companies who are investing of making neon gas sensor. Neon® gas sensor is a neon gas sensing sensor which is available in the global market. It is a product by Kuntze Instruments GmbH which offers high quality and long-term reliability, made in Germany.

Figure 3.9 – Physical Structure of Neon® Gas Sensor

3.10 CH_4 Gas Sensor:

Methane is the most abundant reactive trace gas in the atmosphere and arises from both natural and anthropogenic sources. It is a valuable gas and is usable at a wide range of concentrations, down to 5%. Explosion of this gas can be too much hazardous for human being.

Table 3.8 – CH_4 Health effects from short-term exposure.

Hazard Type	Symptoms
Fire	Extremely Flammable
Explosion	Gas/air mixtures are explosive
Inhalation	Suffocation
Skin	On contact with liquid: Frostbite
Eyes	On contact with liquid: Frostbite

To be aware of explosion need to use of this kind situation we methane gas sensor. In this field there have various types of technology of making methane gas sensor. But only semiconductor based gas sensor is only available one in the global market. MQ-4 semiconductor sensor is an available gas sensor for sensing Methane gas. It is highly sensitive to CH_4 with a fast response and the life time is long and stable. Moreover, it is used in gas leakage detecting equipments in family and industry, are suitable for detecting of CH_4 .

Figure 3.10 – MQ-4 CH_4 **Sensor**

CHAPTER 4

Special Types of Sensors

Among all those individual gas sensors which are specified by the definition of gases there have some special sensors those can detect many gases in a sensor. According to the specification there can have various types of special sensors. In this paper, e-nose and e-tongue is going to describe as special types of sensor. Definitions, History, Basic Mechanism and Application areas are going to describe in these of e-nose and e-tongue.

4.1 *E-nose:*

An e-nose (electronic nose) is a device intended to detect orders or flavours. It is based on 'Electronic Sensing' technology. E-nose consists of certain mechanism such as array of electronic sensors for chemical detection and artificial neural network for pattern recognition. 'Electronic Sensing' refers to the capability of reproducing human senses using sensor and pattern recognition systems. It has undergone important from a technical and commercial point of view. Moreover, it consists of arrays of sensors which are able to generate electrical signals in response to either simple or complex volatile compounds present in the gaseous sample. Essentially, e-nose consists of three major parts:

4.1.1 *Sample Delivery System:*

Enables generation of a sample which is to be analyze and then it is injected to detection system.

4.1.2 *Detection System:*

Sensors react to the compound and the response is recorded by an electronic interface. Transforms signal into digital value.

4.1.3 *Computing System:*

It combines the responses of all sensors to produce a result. These results can be easily analyzed with a database of qualified samples. New samples are identified by comparing those with the samples in database,

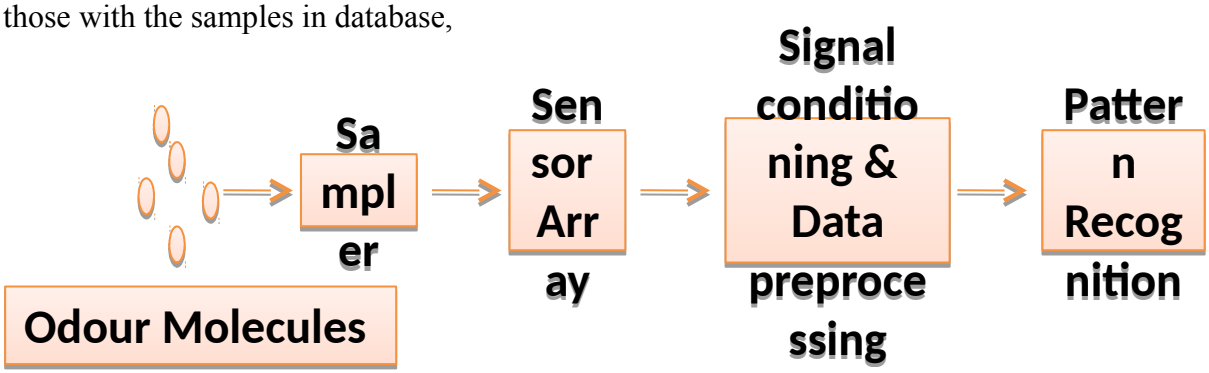


Figure 4.1 – Block Diagram of E-nose System

4.1.4 *Application of Electric Nose:*

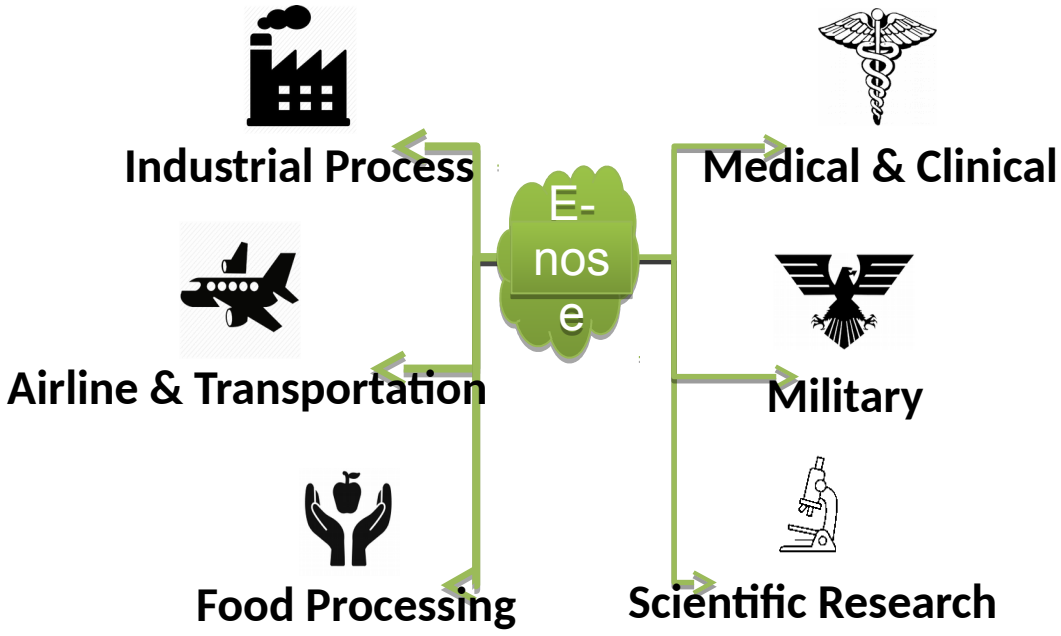


Figure 4.2– Application of E-nose System

4.2 *E-Tongue:*

Electronic nose (e-nose) instrumental systems were designed to crudely mimic human olfactory and taste sensory organs and are composed of an array of sensors. Complex data sets from electronic nose and electronic tongue signals combined with multivariate statistics represent rapid and efficient tools for classification, discrimination, recognition and identification of samples, as well as for the prediction of concentrations of different compounds. A wide variety of sensors can be employed into the design of these instrumental systems, especially that of electronic tongues, offering numerous practical applications. In this study, characteristics of sensors and possibilities of electronic tongue applications in the dairy industry were reviewed.

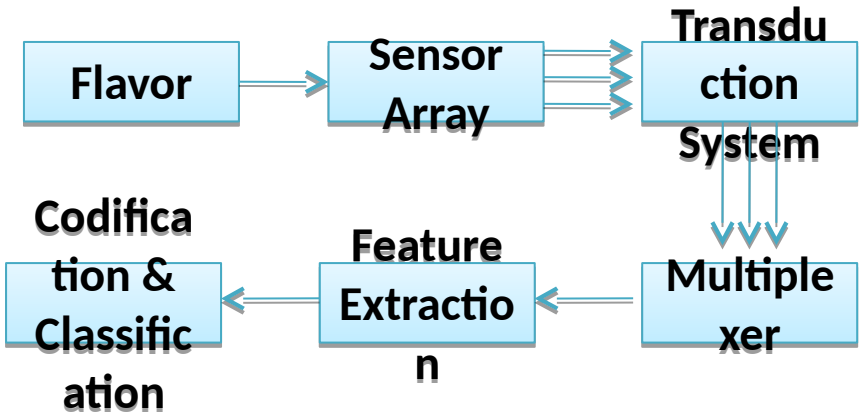


Figure 4.3– Basic Block Diagram *E-Tongue System*

The application area of e-tongue is too big. It usually quantifies taste masking efficiency of formulations and analyzes medicines stability in terms of taste. It's also use for benchmark target products and analyzes flavor ageing in beverages. Moreover, there have also many application area of e-tongue.

CHAPTER 5

Gas Sensors Market

Gas sensor has a huge market in global market. The increasing growth of industries with having hazardous gases as sub product, gas sensors market will pass a booming seasons in next decade. But it is tough to find any gas sensors or gas sensors company in the third world countries. Global leaders of this sector are thinking about to expand the business throughout the world.

A report had published by Fost and Sullivan, there was a predication about European gas sensor market revenue between 1996 to 1999. According to that a projected comound annual growth rate of 6.3 percent and it was continuing almost the same percentage through 2006.

Table 5.1 -European Sensor Market Revenues (in billions)

Year	Revenue (USD Billions)
1996	0.97
1999	1.15
2006	1.76

Now, the Gas Sensors Market size was over USD 2 billion, with more than 900 million units shipped in 2016.

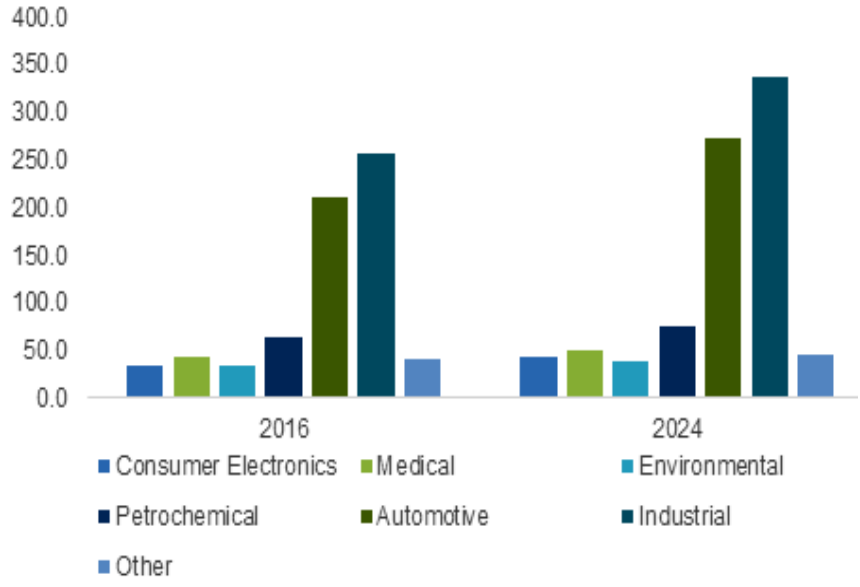


Figure 5.1– U.S. gas sensors market size, by application, 2016 & 2024 (USD Million)

CHAPTER 6

Conclusion

At the end this paper shows the values of gas sensors which are totally individualise. Having the data sheets of the hazardous limit of gases provides an extreme notation of future research. To maintain the world in path of happiness and to achieve the future global goal of being having green global village we need to keep research about our air containing gases. This paper will help any researcher to work with the technologies inside the gas's detection principle and the useful material to build those gas sensors. It will also review the global market structure of gas sensor. Nevertheless, the importance of acquire knowledge about gases and it detection process and its sensing device will be like a gold mine for future upcoming hazardous and poisonous world.

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Appendix

```
*/

const int gasPin = A0; //GAS sensor output pin to Arduino analog A0 pin

void setup() {

  Serial.begin(9600); //Initialize serial port - 9600 bps

}
```

```
void loop() {

  Serial.println(analogRead(gasPin));

  delay(150); // Print value every 1 sec.

}
```

Output