Design of Diaphragm Based Sensor for detection of Arsorane

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Abstract

In this paper the Diaphragm based sensor design is proposed for the detection of Toxic gas in the environment and proposed system is used to detect the Arsorane which is grouped under Category 3 of toxicity. The design system proposed here uses the Diaphragm suspended from arms attached with the substrate and also contain capacitance circuits to measure the variations in diaphragm. The system here uses single diaphragm instead of using array of beams, so the observation over single system is quiet enough and it enables the generation of accurate result for the optimum temperature of Arsorane.

Index Terms: Intellisuite, Arsorane, Toxicity, Diaphragm.

Introduction:

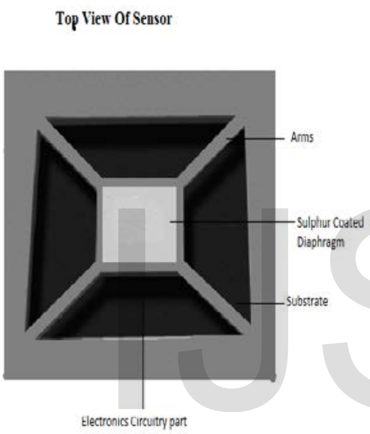
The gas sensors plays an important role in monitoring the various mixture of gases and its amount in the air. The Conventional gas sensors which uses the cantilever beams in arrays which results in generation of varying results due to Varying resonant frequencies. In This sensor system presented here consist of a typical Pressure sensor Diaphragm coated with chemical to sense the target gas. In this sensor the target toxic gas is arsorane which can be detected by oxides of arsorane and Sulphur Fluorides of any combinations. The arsorane gas which is categorized under Class 3 of Toxicity produces acute toxicity when inhaled and it has the capability to infect the Liver cells. And this gas also has Acute inflammable impact when the preserved container is exposed to damages or Heat , water as this gas is highly instable towards water.

1.Gas Sensor

The gas sensors system which is used to sense the various gases in the environment. The gas sensors are usually classified into Semiconductors, Oxidation, Catalytic and Infrared but majorly into Portable and Fixed. The gas sensors are used in various situations where the need of toxicity measure in mandatory and its core application areas are Environmental Pollution control\Monitoring , Industrial Zone, Domestic application, Chemical, Bio-Chemical Laboratories. The Gas sensor system which is used to detect the gas leak and the integrated system with Control system will help to automatic shut down of system. The gas sensors can be used to Detect the inflammable, combustible, Toxic gases and Oxygen Depletion (or) Oxygen Extrusion from Cylinders. The gas sensors are usually Stationary or portable depending upon the application.

2.Experimental Setup

The Sensor system uses silicon as substrate and the diaphragm is coated with sulphur TetraFlouride chemical. The sulphur TetraFlouride chemical coated has the ability to alter the mass of the diaphragm and the diaphragm and arms are fabricated with silicon with proper etching. The system also comprises of Capacitor circuits to observe the change in distance with capacitor attached to Diaphragm. The Sulphur Tetra Flouride is coated over the Diaphragm which has the ability to produce complex reaction when exposed with the Arsorane in the air.



Figure(I):Top View Of Sensor

The Gap between the diaphragm and base substrate is designed to handle the displacement behaviour of the Sensor and an gap of about 10µm gap is allowed so that the stress can be analysed independently. The system Presented here has certain device parameters and is as follows:

Table(I)

S.No	Parameters	Value
1	Substrate	5µm
2	Wall	20µm
3	Arms	2µm
4	Sulphur Diaphragm	(2+2)µm
5	Max.Displacement	12.634µm
6	Pressure on Diaphragm	0.0105 Mpa

Table(I):Device Parameters.

3. Arsorane Gas

The arsorane where also called as Arsenic Pentaflouride and its molecular formula is AsF5 and has the Molar mass of 169.9136g mol^{-1} .The arsorane proposed here is categorised under Category 3 of toxicity as it has an lethal concentration of more than 2000 ppm and less than 2500ppm. It has the ability to infect the Liver cells when inhaled. The Arsorane gas is usually in its gaseous state above the temperature of -56˚C.

Table(II)

S.No	Property	Range
1	Molecular Formula	AsF5
2	Molecular Weight	169.913g/ Mol
3	Toxicity	Class 3
4	Density	7.71g/ L
5	Melting Point	-80˚C
6	Target Organ	Liver Cells

Table(II):Property Tabulation.

4.Operation

The system proposed here consist of an diaphragm coated with Sulphur Tetra Flouride suspended with arms attached with the walls of substrate and a capacitor also attached with the bottom of Diaphragm. And another Capacitor coil is attached with the Substrate of the Sensor. When ever the Arsorane gas is in contact with the sensor, complex chemical reaction takes place in the Diaphragm which results in the Variation of distance Between the two capacitor plates. Thus with the variation in the capacitance measured the Intrusion of gas is measured. The complex Chemical reactivity is as follows

4.a.Reaction with SF4:

Arsenic pent fluoride forms halide complexes and is a powerful acceptor as shown by the reaction with sulphur tetra fluoride forming an ionic complex.

$$AsF_5 + SF_4 \rightarrow SF_3^+ + AsF_6^-.$$

The system coated with Sulphur tetraflouride is having an molecular weight of about 108.07g and its equivalent Pressure scale is 0.01059Mpa. When the Arsorane gas is in contact with the Diaphragm the complex reaction takes place results in the formation of Sulphur tri fluoride and Arsenic Hexa fluoride. This complex reaction over the Diaphragm results in the Increased molecular weight of 89.661g and 188.91g and its equivalent pressure scale is about 0.105Mpa. The Molecular weight involved in reactions as follows:

Table(III)

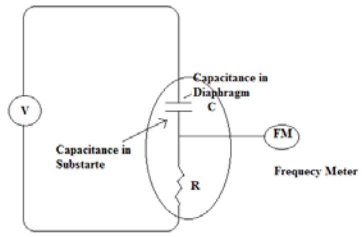
S.No	Mol.Formula	Mol.Weight	Pressure Scaling
1	SF4	108.07g	0.0105 (Mpa)
2	SF3+	89.661g	0.087 (Mpa)
3	AsF6-	188.91g	188.91 (Mpa)

Table(III):Molecular Mass Tabulation with Pressure Scalling.

4.b.Capacitance Calculation

Initially the distance between the Diaphragm and the substrate is about 18.25µm and the same is maintained between the two capacitance. The sensor alarm system is maintained mute till the distance between two capacitance is reduced below 9µm.The capacitance plate in the substrate is provided with Resistor circuit having an fixed resistance and the same in series is connected with Frequency meter. Whenever the capacitance of coil increases, correspondingly frequency increases and with measured frequency and Known resistance the value of Capacitance can be calculated. The capacitance circuit is as follows

Figure(II)



Figure(II):RC circuit

Let the frequency of an RC network is given by

$$F=1/RC.$$

With measured Frequency(F) and Known Resistance(R) the value of capacitance is as follows;

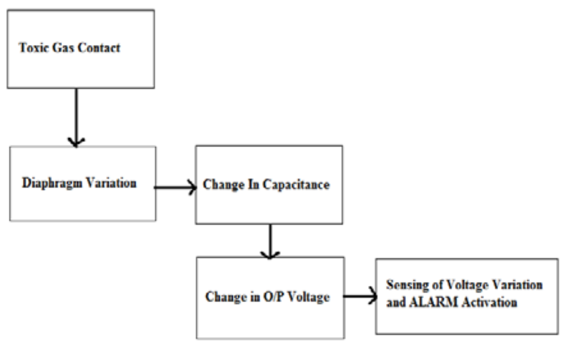
$$C=1/RF.$$

To measure the capacitance the circuit is powered with an voltage rate of about 2 to 5V.

4.C.Sensor System

The block presentation of the sensor system is shown, where the process block starts from Detection of Gas to alarm activation.The Block diagram of the sensor is as follows.

Block Diagram Of Sensor



Figure(III): Sensor Block

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5. Technical Nomenclatures

The tabulation plotted here describes the technical terms and its property.

Table(V)

S.NO	Molecular Formula	Nomenclature
1	AsF_5	Arsenic Pent Fluoride
2	SF_4	Sulphur Tetra Fluoride
3	SF_3	Sulphur tri Fluoride

Table(V):Molecule and Nomenclature.

6.Process Flow

The proposed system has a specific process flow, where the system flow starts from the Design of geometrical layout for the system and the system is processed with Finite element modelling analysis with Intellisuite CAD tool as Simulation platform. The table drawn here describes the Process flow of system.

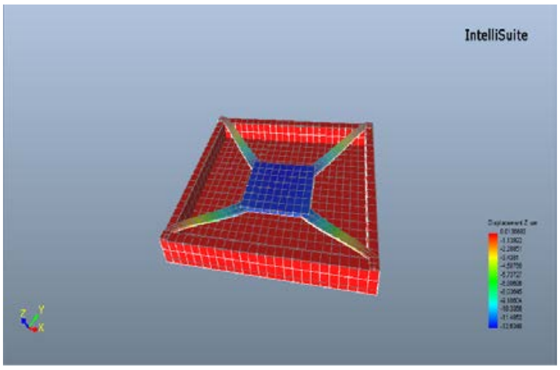
Table(IV)

Design Of Sketch in CAD tool(3D Builder)
Specification of Boundary conditions
Applying Load over Faces
FEM analyses of Model
Simulation and Plot Analyses

Table(IV):Process Flow Model.

7.Simulation and Results

The system is analysed precisely to observe the simulation of Diaphragm and in this paper the analyses is done with Intellisuite CAD tool. The Intellisuite CAD tool which uses 20 Point Nodal analyses technique to generate the 3D Simulation. The Diaphragm is analysed with its arms fixed over the wall as Boundary conditions and the diaphragm is suspended where Pressure is applied over the Diaphragm of the Sensor. When ever the gas is in contact with Diaphragm, the molecular weight of diaphragm exceeds more than 0.105Mpa the displacement of about 12.6348µm is obtained. When ever the resonant frequency of system exceeds certain value the capacitance varies proportionally. Initially when the system is coated with Sulphur before complex reaction the Molecular weight of the system be 108.07g and its displacement is about 1.2654µm

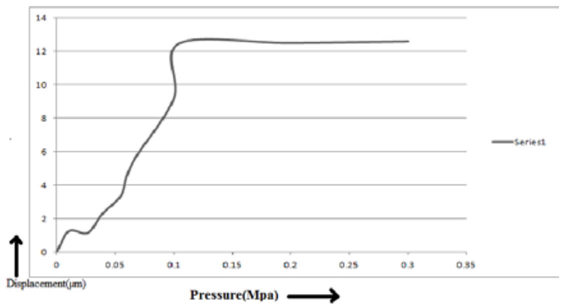


Figure(I):Diaphragm Simulation Of System.

8.Graphical Plot

The plot for sensor system is presented where the initial plot is in Ground state and as the reactivity of Gas increases the molecular weight increases results linear increase of plot. The Graphical plot is as shown.

Plot(I)



Plot(I):Pressure Vs Displacement Graph.

9. Cross correlation Avoidance

The system when tested under proper laboratory condition it produces exact result when exposed with the Arsorane. And same will not be the result in Environment and this

Misinterpretation between pressure exerted and Toxic gas can be avoided by using Proper sealing over the Diaphragm. So the pressure exertion will be crucially controlled and the displacement is also limited within 7 to 8µm in Air filled cavity.

Conclusion

Thus the sensor model for the detection of Arsorane of Class 3 toxic gas was designed. The response of the sensor also analysed under two extremities one with initial state of sulphur coat and another after the complex reaction in the Diaphragm. And in this model the maximum simulation extent of Diaphragm also described and this sensor is efficient for detection of arsorane under Normal temperature.

Future Outcome

The sensor is designed in the Experimental point of view and its commercialized version can be Fabricated by proper Hermetical sealing over the Diaphragm to protect it from shearing stress and disturbances. And this system can also be updated to detect Toxic gases from Vehicles and Domestic House holds.

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