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# Development of Computer Controlled Test Measurement System for Gas Sensing Applications

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## Abstract

This paper reviews the description, differentiation and latest developments in the gas sensing technologies. Taxonomy of sensing technology is given with their applications and attributes. Detailed establishment to sensing mechanisms based on electrical variation is canvassed through sensing material used, including metal oxide semiconductors, conducting polymers. The avail of conducting polymer as a favorable sensor material has been widely analyzed, because of its relatively high sensitivity, low cost, low power consumption and good chemical stability. Furthermore, The prime objective of this research is dynamism. However monitoring of the sensor characteristics are accomplished using lab view software and progressed a computer controlled gas system that automated test procedure for the characterization of gas sensors. Also different deposition techniques have been canvassed.

**Keywords: 1)** Gas sensing methods 2) sensing materials 3) sensitivity 4) selectivity

## 1. Introduction

Gas sensor is a device that is used to discover the existence of heterogeneous gases. Gas sensor is significant because there are various gases which can be injurious to organic life. The insistence enlarging day by day because of their constructive exploitation in the ecological monitoring and other solicitations, the complication of emission of noxious gases and air contamination is increasing hastily to our humanity. Hence the gas sensors are essential to frequently supervise and organize the poisonous gases and other gases which are affecting the surroundings. In the medical field gas sensors can be used to discover convenient and hand-held breath testing devices. It can also be used in ventilation technology. The specifications on sensor systems diverge significantly, depending on where and how the ventilation device is used. Apart from ecological and medical solicitation gas sensor also finds application in manufacturing and agricultural field. In industrialized situations, including chemical dispensation, mining, or manufacturing, leakages of flammable or volatile gases such as propane or methane, or the presence of other potentially hazardous gases like carbon monoxide can present a threat to safety and need to be diagnosed instantaneously and in agriculture by providing the precise information about soil, climate, crop, and environmental circumstances the efficiency can be improved.

## 2. Classification of gas sensors

This paper categorizes the gas sensors into various groups basis on their characteristics as shown in the Table 2.1.

Table 2.1: Comparison of various types of gas sensors

| Parameter | Type of gas sensors | | | | |
|---|---|---|---|---|---|
| | Semi-conductor | Catalytic combustion | Electro-chemical | Thermal conductive | Infrared absorption |
| Sensitivity | E | G | G | B | E |
| Accuracy | G | G | G | G | E |
| Selectivity | P | B | G | B | E |
| Response time | E | G | P | G | P |
| Stability | G | G | B | G | G |
| Durability | G | G | P | G | E |
| Maintenance | E | E | G | G | P |
| Cost | E | E | G | G | P |

E: excellent; G: good; P: poor; B: bad.

Table 2.1. Indicating the attributes and applications of semiconductor, Catalytic combustion, Electrochemical, Thermal conductive and Infrared absorption gas sensors.

## 3. Design of Experiment

First part assigns with the electro spinning technique availed for the deposition of conducting polymer thin films on the substrate followed by the structural characterization techniques used to study the nanostructure and morphology of the deposited films, i.e., Scanning Electron Microscopy (SEM) and X-ray Diffraction (XRD). Second part assigns with the electrical characterization carrying experimental set-up and methodology used for the gas sensing and further with the evaluation of diverse sensing properties of gas sensor like sensitivity, selectivity, response time, recovery time, reproducibility and long term stability. Third part deals with the hardware and the software used to interface sensors with Data acquisition (DAQ) system and Mass Flow controller (MFC).

## PREPERATION OF SOLUTION USING SOL-GEL PROCESS

**i.** 0.31 gm of SnCl4.5H2O is added to 3 ml of Iso-propanol under vigorous stirring for three hours with 50 degree Celsius temperature.

ii. Now 0.14gm Polyethylene oxide (PEO) and 2ml of DMF are to be stirred at 50 degree Celsius until it becomes transparent.

**iii.** The obtained solution of 2ml of DMF and PEO is then mixed with 2ml of aforementioned solution. The obtained 4ml solution is stirred for an hour with 50 degree Celsius temperature until it is viscous.

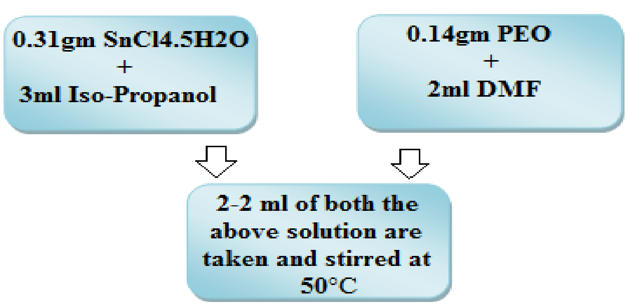


Figure3.1: Sol-gel process for the solution formation

## ELECTROSPINNING DEPOSITION TECHNIQUE

This technique is used for the generation of nanofibers. It consists of a syringe, precursor solution, high voltage power supply, peristaltic pump and a grounded collector.

Electrospinning can be used in various solicitations and because of its large surface to volume ratio of the nanofibers makes this technique suitable for utilization in chemical sensors.

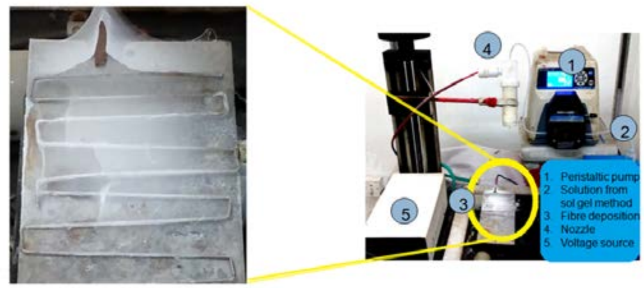


**Fig.3.2**: Electro spinning set up with nano fibers deposited

## POLYMERIZATION

The deposited sample is introduced to the process of polymerization as follows:-

**i.** A solution is made by adding 0.05gm of Docusate Sodium (DS) and 0.27gm of FeCl3.6H2O in 10 ml of water. This solution is stirred until it becomes homogenous. (the DS lump which did not get dissolved is remover later)

**ii.** The samples are then dipped in this solution and kept for half an hour at 60 rpm with no heat provided.

**iii.** Later 0.0346 ml of polypyrrole is added.

**iv.** The samples are then retained at the intervals of 3 minutes, 5 minutes and 10 minutes. Then they are washed and kept for drying in an incubator for some time.

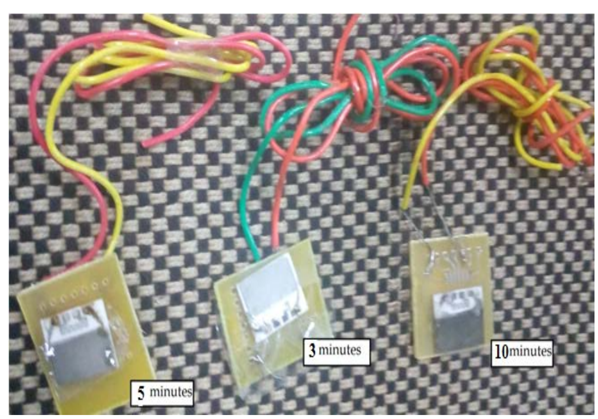


**Fig.3.3**: Samples deposited and polymerized

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## Dynamic measurement method

The block diagram incorporates of two way valve, nitrogen gas supply, mass flow controllers, bubbler system, gas chamber which incorporates of four sensors; humidity sensor is also utilized to assess the humidity of gas chamber, DAQ, USB hardware, and a LabVIEW compatible pc .In this two way valve works as a splitter which splits the drift of nitrogen gas equally, from two way valve nitrogen gas infiltrates into mass flow controllers ,here Aalborg AFC 2600D Thermal analog mass flow controller are utilized to manage the flow rate of carrier gas ,in order to manage the flow of carrier gas and to robotically function the mass flow controller the MFC's are coupled to data acquisition unit i.e. DAQ 6210 hardware. Then proscribed flow of carrier gas is applied to bubbler system ,bubbler system incorporates of analytes, nitrogen gas is bubbled in bubbler system and evaporates the analyte ,from that evaporated analyte enters into gas chamber which consists of four sensors, two commercial Tagauchi sensors and two homemade sensors.

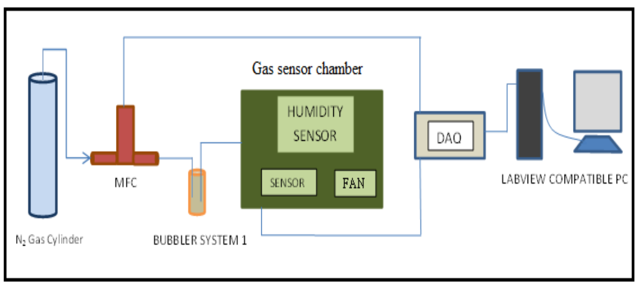


**Fig.3.4** shows the Dynamic measurement system

Four sensors are associated to DAQ hardware, so as the gas enters the gas chamber the response of four sensors are shown on front panel of lab view .we can switch off/on any sensor coupled to the DAQ (data acquisition unit)once we attain the data we can constitute the whole system. The analyte used here is ammonia. The concentration of the gases in the gas chamber can be recognized using vapor pressure, density and molecular mass of these analytes in the chamber. The volume of cylinder should be known to discover the concentration of gases in the gas chamber.

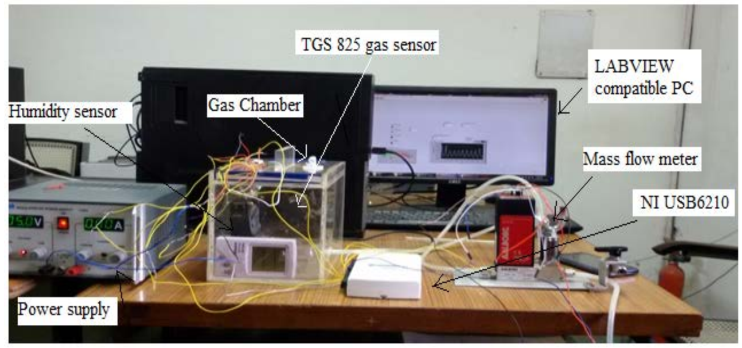


**Fig.3.5**: Shows Experimental setup of dynamic testing of Gas sensors

change in resistance was tested for different materials of sensing layer at different analyte concentrations. On exposure to the reducing gas the resistance of the semiconductor sensor changes and by measuring the change in the electrical resistance, the sensitivity was calculated as

Sensitivity = $(R_{gas} - R_{base}) / R_{base}$

Where, $R_{gas}$ is the resistance of the sensor under gas exposure and $R_{base}$ the resistance of the sensor in air.

Similar practice was repeated for manipulating other parameters like selectivity, response time, reproducibility and recovery time etc. for each analyte at diverse concentrations with sensors having different sensing layers present in the array.

## Response as a function of Concentration

Sensitivity of the sensors is a purpose of concentration. Therefore, the sensors were uncovered to analytes with unstable concentration in the range 1 ppm to 100 ppm and the vary in sensitivity of different analytes as a use of concentration studied.

## Response as a function of Time (Response Time)

For response time measurement the change in resistance was recorded from the point when the analyte was injected into the chamber as a function of time. Time taken by a sensor to attain 90% of maximum resistance value was noted as the response time of the sensor.

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## Response as a function of Time (Recovery Time)

For recovery time measurement the change in resistance was recorded from the point when the analyte was pumped out or removed from the chamber as a function of time. Time taken by the sensor to reach 90% to 10% of maximum resistance was noted as the recovery time of the sensor.

## Reproducibility

Reproducibility of sensor was observed by applying the same analyte at same concentration under similar environmental conditions and regeneration of the same response was taken as the reproducibility of the gas sensor.

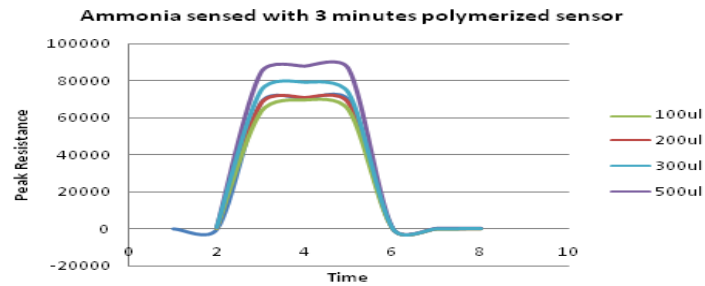
## Selectivity

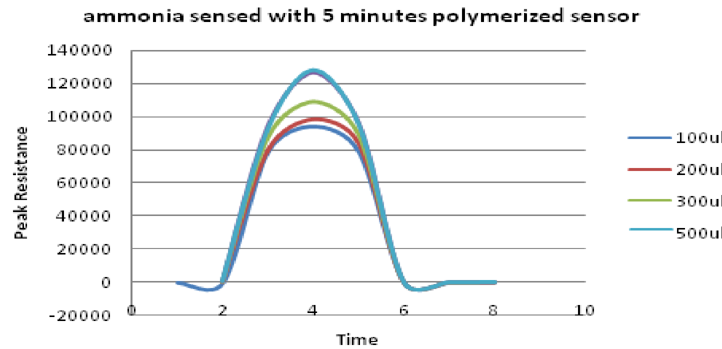
The selectivity of a sensor was measured by exposing the sensor to different analytes and recording the sensor's response (change in resistance) more effectively towards a certain analyte as compare to others.

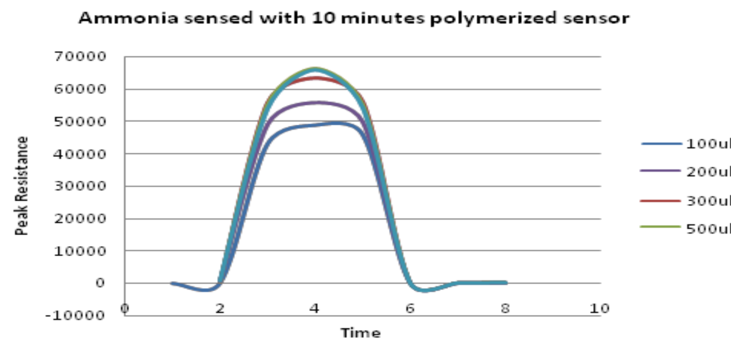
## Results and discussions

## ELECTRICAL CHARACTERISATION

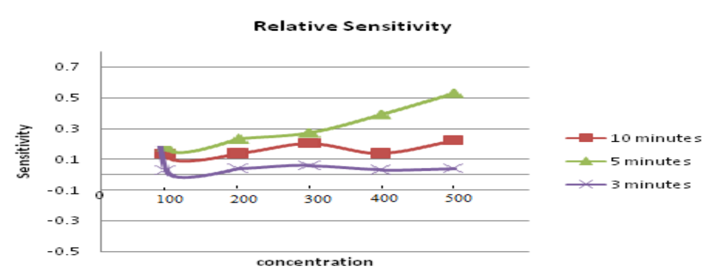
The electrical characterization of each sensor is shown below, in which change in resistance (ΔR) vs. time graphs, sensitivity vs. concentration graphs are shown for each sensor at various concentrations and study of ammonia gas is discussed on the basis of graphical results. The main study here revolved around the three samples of sensor which are made of conductive polymer based metal oxide semiconductor sensor using Pyrrole and Tin Oxide. Polymerization for 3 minutes, 5 minutes and 10 minutes are performed and the graphs are displayed accordingly.



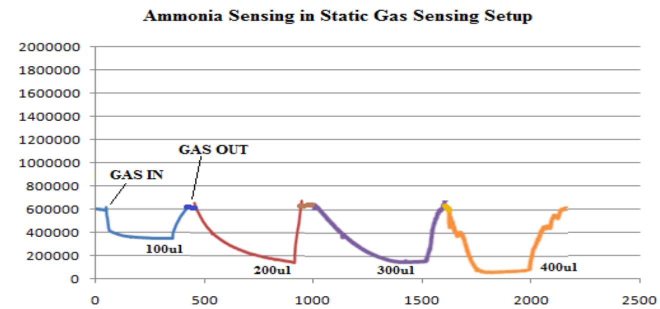



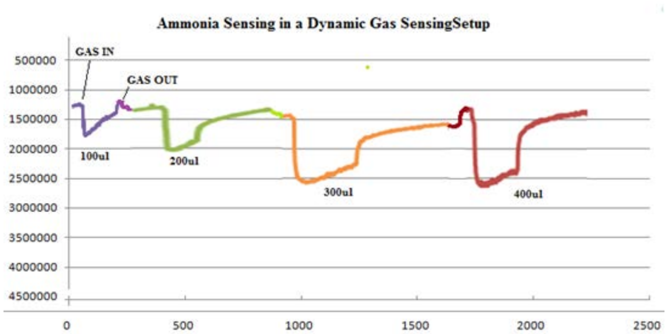

**Sensitivity response of all three sensors**




## COMPARISON BETWEEN THE TESTING RESULTS FROM STATIC AND DYNAMIC SYSTEMS




The static system mainly consisted of a vacuum pump, a gas chamber, a source precision measuring unit, temperature controller and a monitor to display the output. Since ammonia is a volatile inorganic compound, a certain concentration of ammonia is manually merged into the gas chamber and the chamber is closed. Since there is a heater provided in the chamber the heat evaporates the liquid ammonia and allows the fumes to reach the sensor. The sensor then shows considerable change in the conductivity depicting the sensing pattern of the gas. After the sensor is saturated, the gas chamber is vacuumed. The graph here is the outcome of a static system. The response is decreasing downwards here. But the peak resistance of the maximum concentration 400ul is also 600kΩ only. The manual in and out of the gas in the system is inaccurate and vapour formation in the chamber can also not be managed uniformly. Thus the necessity of dynamic system came into picture.




In a dynamic setup we have a vacuum pump, a mass flow controller, a bubbler, a gas chamber, a source precision measuring unit, temperature controller and a monitor to display the output. The mass flow controller controls the pressure of the gas circulating in the system and ammonia is introduced in the bubbler. The dynamic flow of the gas leads to a cyclic detection. As we can see the graph, proper peak and saturation regions are present. Also the resistance varies from a range of 1MΩ to 2.5MΩ. The maximum concentration i.e. 400ul has a wide range of 1MΩ value. The gas is more evenly distributed in the chamber using a dynamic system and the flow can be in a more precise and controlled manner.

Therefore for a better sensing of gases one must go with a dynamic system where manual precision errors can be avoided and the system tends to get smarter and effective for better gas sensing.

## REAL TIME DATA ACQUISITION USING DAQ USB 6210 and LABVIEW

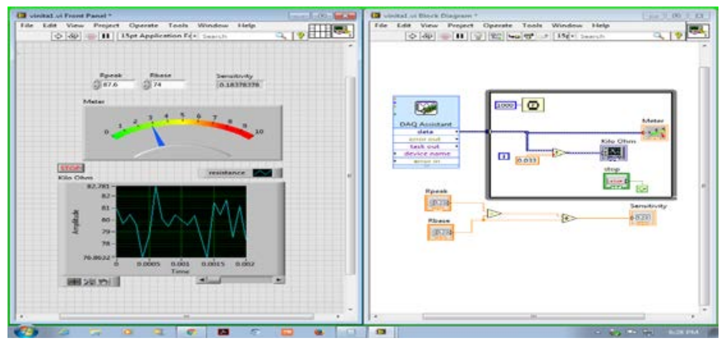


Figure5.10 : ammonia response in a dynamic sensing setup

## CONCLUSION

This research deals with the study of sensing properties of different materials for the detection of ammonia. Different material used includes tin dioxide doped polypyrrole ($SnO_2$+PPy). The sensitivity of the films is calculated by measuring the resistance of film in air and when exposed to target gas vapors. Response and recovery times are calculated by measuring the time the film takes to respond to certain target gas species and time it takes to recover back to its baseline resistance after the gas is flushed out using vacuum pump. The study shows that the dynamic testing setup of gas sensors has many advantages over static testing setup of gas sensors, as in dynamic case modulating working parameters is somewhat advantageous as in this we are modulating flow rate of mass flow controller, for this we are interfacing mass flow controller with USB DAQ 6210. Controlling Mass flow controller through lab view has been done successfully .We have concluded that by using Lab view we can easily acquire data from outside the system such as instruments connected to the USB 6210.

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