DETECTION AND MONITORING OF CARBON DIOXIDE USING CONDUCTING POLYMER POLYPYRROLE

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Abstract

The conducting polymers are playing vital role in the diversified applications because of their flexibility in composition hence properties, ease of preparation, stability over wide range, selectivity and response time. Polyaniline and polypyrrole and their derivatives are the most useful especially the polypyrrole is very important when it is exploited for gas sensing. The polypyrrole and doped polypyrrole are prepared by conventional method in the laboratory. The thick film gas sensors are fabricated on glass plate by screen printing technique. The samples are characterized by SEM. The prepared samples when exposed to CO_2 gas, the sensitivity of the samples increases with the gas concentration. The other properties such as stability, static and dynamic response of the samples are studied.

Keywords: Metal oxides; screen-printing technique; CO_2 gas sensor, sensitivity, selectivity.

1.INTRODUCTION

A Conducting polymer polypyrrole (PPy) has been a subject of many studies because it exhibits relatively high electrical conductivity, good environmental stability and versatility of synthesis. Adhikari *et al* [1] reported that the majority of sensor devices utilize many polymers with definite roles, either in the sensing mechanism or through immobilizing the species responsible for sensing of the analyte component. While some polymers are intrinsically responsible for a sensor function, other polymers are made to augment the sensing operation through modification of the polymer by functionalization. Polymeric thin film deposition technology and the design of more active sensor, specific polymers will lead to successful miniature, multiple sensor arrays. Bhadra *et al* [2] reviewed that the synthesis, processing and applications of polyaniline (PANI).The advantages of the intrinsically conducting polymers (ICPs) over the other conducting polymers and the superiority of PANI among other ICPs are reported by them. A detailed discussion on the mechanism of electrical conduction in PANI and the factors those influence the conductivity of PANI is also included.

2. Experimental:

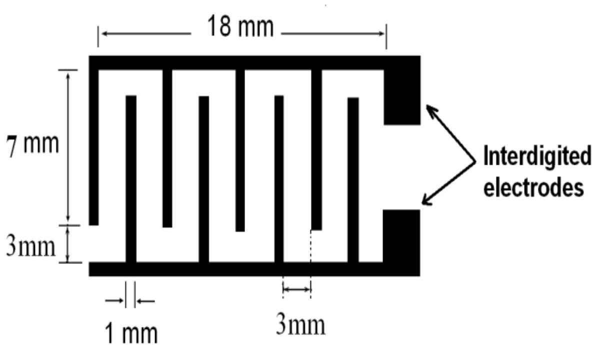
2.1 Preparation of Polypyrrole:

The preparation of polypyrrole is chemical polymerization. Powder polypyrrole was prepared with 4.290 (high) weight ratio of pyrrole (Py) monomer and oxidant ($FeCl_3$). During the synthesis, concentration of $FeCl_3$ was kept constant and methanol was used as a solvent. The Py monomer, anhydrous iron (III) chloride ($FeCl_3$) and methanol were used for synthesis of PPy. The solution of 7 ml methanol and 1.892 g $FeCl_3$ was first prepared in round bottom flask and 8.4 ml Py-monomer was added to ($FeCl_3$ + methanol) solution with constant stirring in absence of light. The amount of Py-monomer was added to the solution in such a way to get maximum yield. The polymerization of Py, which was suppressed in a solution, progressed rapidly due to an increase of oxidation potential caused by evaporation of solvent. In the polymerization reaction of Py, it was observed that as soon as the Py-monomer was added to the solution, the colour changed to dark green/black. There was an increase in temperature of the solution during the start of reaction, which showed that it is an exothermic reaction and it was carried out at room temperature for 4 hr. The final precipitated polymer was filtered by a conventional method. The polymer was washed with distilled water several times till the filtrate obtained was colourless. To remove last traces of un-reacted pyrrole and remaining ferric and ferrous chloride formed due to polymerization, it was then washed with methanol. The polymer, obtained in powder form was dried first at room temperature for a few hours and then finally dried in an oven kept at 80^0C for 5-6 hrs[6-9]. This polypyrrole is then used for active layers of Semiconductor Gas Sensors.

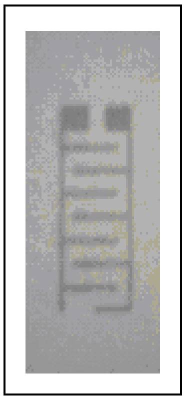
2.2 Sensor preparation:

The ink or paste of the sample was prepared by using screen-printing (thick film technique) technique. The binder for screen-printing was prepared by thoroughly mixing 8 wt% butyl carbitol with 92 wt% ethyl cellulose. On chemically cleaned glass plate, paste of Al_2O_3 was screen printed and it was kept for 24 hr to dry it at room temperature and then heated at 140^0C for 2.5 h to remove the binder. The Al_2O_3 layer provides mechanical support as well as high thermal conductivity. Paste of PPy in proper stiochometry was then screen printed on Al_2O_3 layer. Again plate was dried at room temperature for 24 h and binder was removed by heating it at 150^0C for 2.5 h. Finally PPy and PANi thick film design for detection and monitoring of carbon dioxide gas sensor using conducting polymer polypyrrole and polyaniline.

Finally on the top surface of the sensor, interdigited electrodes [6,7] were fabricated using conducting silver paste as shown in the Fig.1 (b)To measure the sensitivity, electrical resistance was measured with the help of voltage drop method, best one.



(a)



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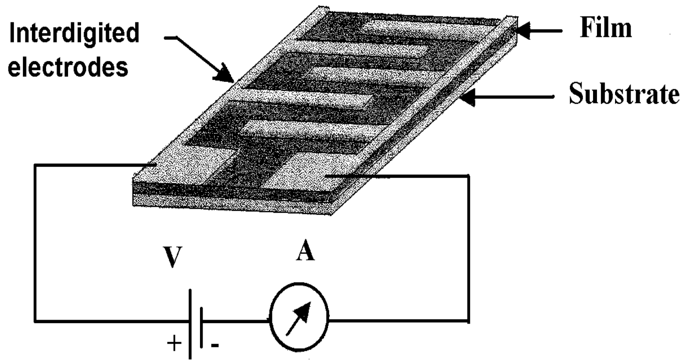

(c)

Fig. 2 (a) Fabrication of interdigited Electrodes (b) Actual photograph of interdigited electrodes (c) Circuit of resistance measurement using interdigited electrodes.

3. Results and Discussion:

3.1:SEM Analysis:

Fig.3(a) SEM of Polypyrrole

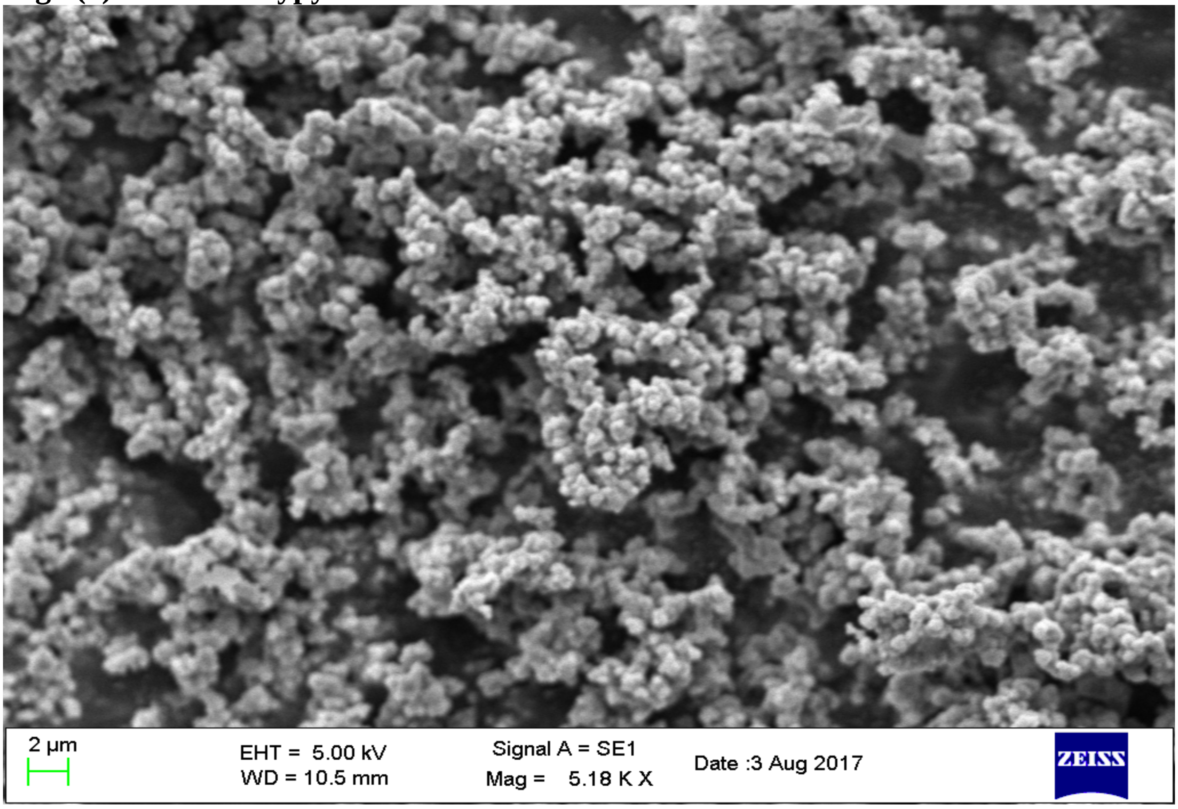

Fig.3(b) SEM of Polyaniline

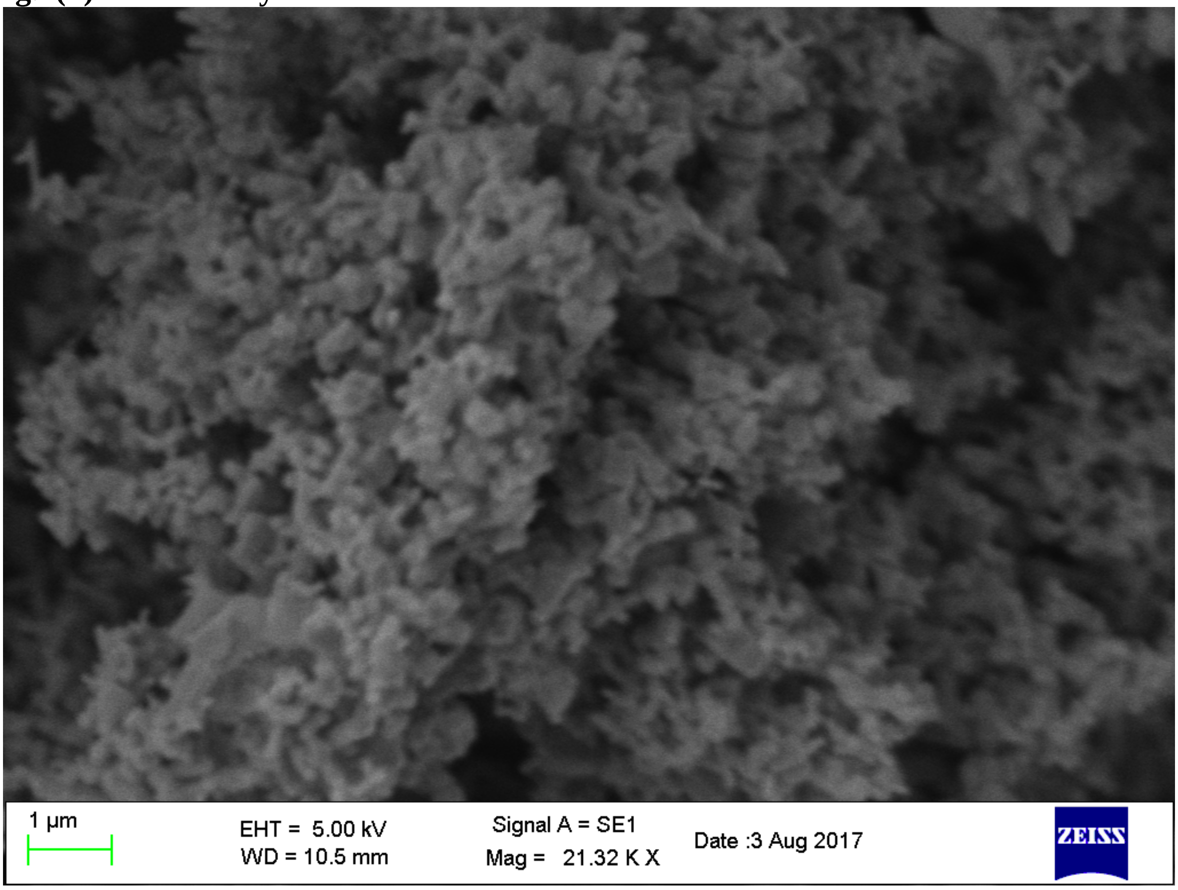

Table 3.1 Average diameter of pore and number of pores per inch of pure samples and their compositions

Sr. No.	Pure sample and their compositions (mole %)	Average diameter of pore (nm)	Number of pores per inch (in x 2000 magnification)
1.	PPy	275	118
2.	PANi	230	70

From the SEM pictures, it is observed that PPy have maximum pores per inch (calculated for x 2,000 magnification for each composition) than PANi. Thus PPy have more surface area and exhibit more sensing nature.

3.2 Sensitivity of sensor:

The sensitivity of the sensor is given by equation (2)

$$S = \left(\frac{R_{air} - R_{gas}}{R_{air}} \right) = \left(\frac{\Delta R}{R_{air}} \right) \qquad (2)$$

Where, R_{air} and R_{gas} are the resistances of sensors in air and gas respectively.

Maximum sensitivity was recorded for Polypyrrole gas sensor.

The sensitivity shown in the following table :2

Sr. No.	Name of Material	Sensitivity (s) at 80 ppm at 300K
1	PPY	0.43
2	PANi	0.32

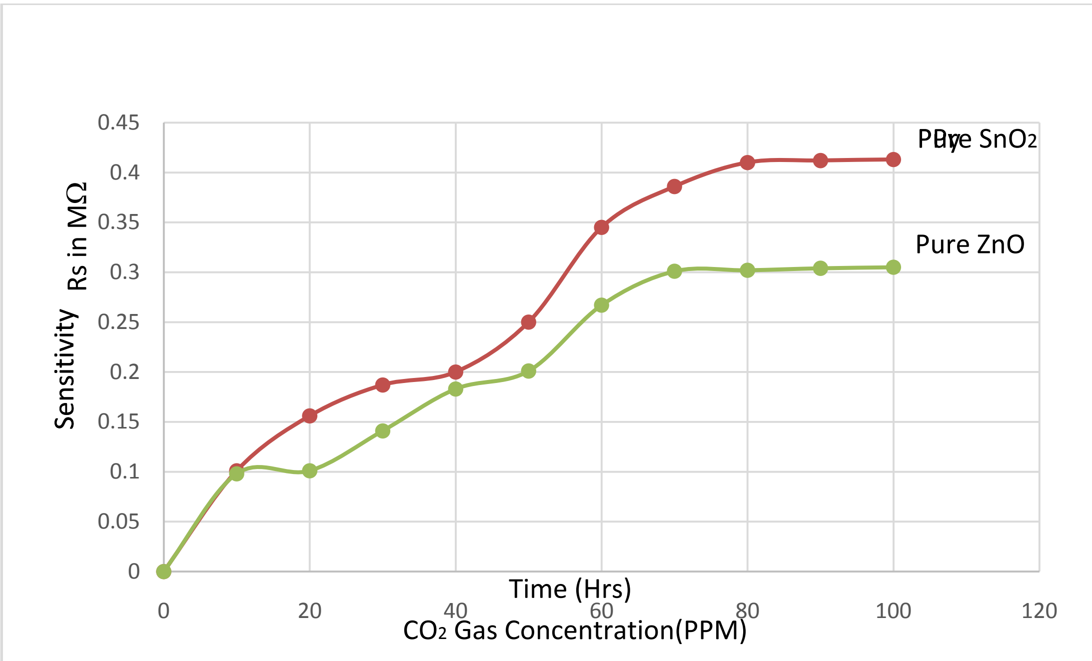

Fig.(3) Variation of sensitivity with of CO_2 gas concentration at room temperature.

3.3 Stability of sensor:

Rate of change of resistance of the sensor with respect to time defines the stability of the sensor. A sensor should be more stable for its better response.

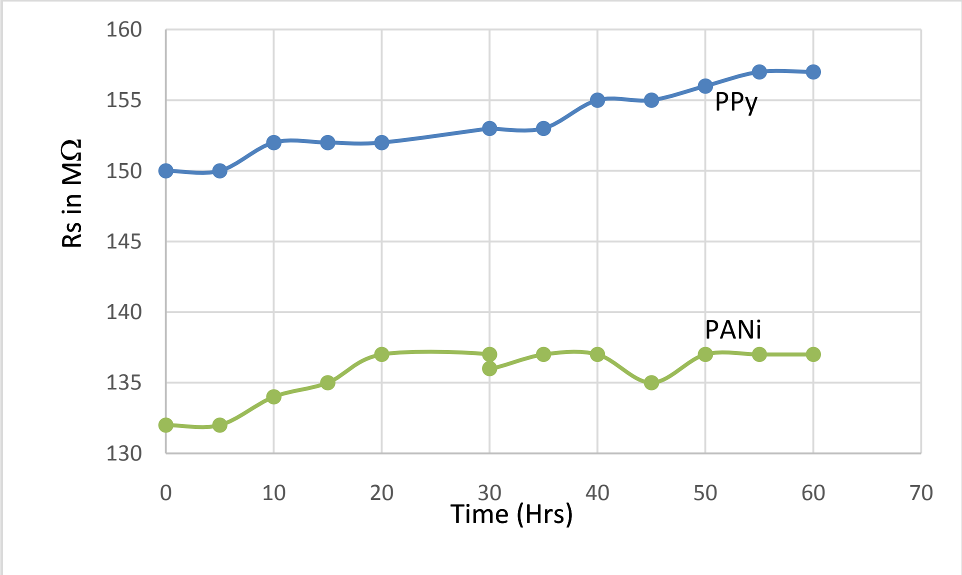

Fig. (4) Stability of the sensor.

From fig. (4), it is observed that resistance of sensor does not change drastically in case of PPy,where as in PANi its shows variations

4. Conclusions:

From SEM characterization it is concluded that the crystallite size of PPy is smaller and it is more porus.It has greater surface area and therefore shows greater response to CO_2 gas as compare to PANi. Screen printing technique is the easiest for the preparation thick film of gas sensor,PPy gas sensor shows good stability and sensitivity as compare with other PANi

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