STUDY OF SENSING PROPERTIES OF MIXED METAL OXIDES FOR CO_2 GAS

B.M. Mude[1*] and K.B. Raulkar[2]
[*1]Department of Physics, Ramnarain Ruia College, Matunga (E), Mumbai, MS, India
[2]Department of Physics,Vidyabharti Mahavidyalaya, Camp,Amravati, MS, India
Corresponding: [1*]mudebm@gmail.com

ABSTRACT

In recent time, carbon dioxide gas sensing properties are very well explained and significant as far as environment safety is concern. While learning this,we decided to improve gas sensing properties by varying weight percent of mixed metal oxide and notice substantial increase in gas sensing properties in this paper. The gas response of SnO_2:TiO_2 composites observed, very good response. The metal oxide used for the designing of gas sensor were first calcinated at 700^0C for 7 hr. Composites of SnO_2:TiO_2 were prepared by screen printing technique with Al_2O_3 as substrate on glass plate. The surface morphologies of composites of SnO_2:TiO_2were analyzed by SEM. Static and dynamic responses also studied, it was found that response of optimized sample $70SnO_2$:$30TiO_2$ shows enhancement in gas sensing properties as compared to pure SnO_2 and TiO_2.

Keywords: *SnO_2:TiO_2; screen-printing technique; CO_2 gas sensor.*

1. Introduction

Currently, electronics is a fast-developing field; gas sensor plays a key role for controlling, monitoring and analyzing each and all era. We have multiple type of sensors, depending upon their working. Among these, the chemical gas sensor is the better and its preferred due to its high sensitivity. The sensor has countless advances and has taken origin in industry and human life as a feature of recent modern technology and also notable progress is expected in the prospect. In the last decade, it had an increasing attention in the electronic industry for those aspects related to semiconducting gas sensor (SGS) materials. Semiconductor gas sensors having good benefits related to other sensor devices, due to its low price, simple implementation, good reliability for real-time control systems and easy make. The gas sensor is a electronic noses, because sensing devices are able to capture and process signals generated by surface interaction processes with gas molecules, in one or multiple built-in sensitive layers. Chemical gas sensors, which prepared from metal oxides have been one of investigated devices of gas sensors. Maximum of the industry use such type of sensors due to their wide applications**.**

We know that that the sensing properties of metal oxide-based material depend upon its chemical and physical characteristics, which are strongly hooked in to the preparation conditions, dopant and grain size. This suggests that the synthesis of the sensing material may be a key step within the preparation of high-performance Metal oxide semiconductor (MOS) gas sensors. SnO_2, TiO_2 powders and films are often prepared by a spread of synthesis methods [1-5]. DC-electrical resistance of the films TiO_2 doped with SnO_2 and SnO_2:TiO_2 sensor was measured in presence of humidity, $70SnO_2$:$30TiO_2$sensors are found to be good sensing materials for humidity. The present investigation mainly deals with the preparation of CO_2 gas sensor in composite pattern with TiO_2 doped with SnO_2. it had been found that $70SnO_2$:$30TiO_2$ system shows more sensitivity for CO_2 gas concentration even at temperature. A gas sensor may be a device, which detects the presence of various gases in an environment, especially those gases which may be harmful to living animals. the planning of gas sensor technology has received considerable attention in recent years for monitoring environmental pollution. Metal oxide based chemiresistors have high gas sensing response as compare to the chemiresistors supported conducting polymers but they're operated at heat (>200 °C).

2. Materials and Methods

2.1. Materials: SnO_2, TiO_2 and Al_2O_3 powders (AR grade).

2.2. Synthesis and Sensor preparation

SnO_2, $TiO_2$and Al_2O_3powders (AR grade) were calcinated at about 800 °C for 4-5 h and were crushed in mortal pestle to urge fine powder of the samples. Optimized sample of SnO_2:TiO_2characterized by SEM analysis. 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 had been kept for twenty-four hr to dry it at temperature then heated at 140^0C for 2 to 3 hour to get rid of the binder. The Al_2O_3 layer provides mechanical support also as high thermal conductivity. Paste of SnO_2 and TiO_2 mixed in proper stoichiometry was then screen printed on Al_2O_3 layer. Again, plate was dried at temperature for twenty-four h and binder was removed by heating it at 150 ^{0} C for two.5 h. Finally, TiO_2 doped with SnO_2 layer by screen printing, whole plate was dried and again binder was removed as above. Fabrication of composite sensor is shown in following figure1. Finally on the highest surface of the sensor, interdigited electrodes [6] were fabricated using conducting silver paste as shown within the Figure 1(b). Thickness of TiO_2 doped with SnO_2 were recorded with the assistance of digital micrometer having resolution of + 0.001 mm and were found to be 10 µm and 7µm respectively. The sensitivity, electric resistance measured with the assistance of drop method, best one.

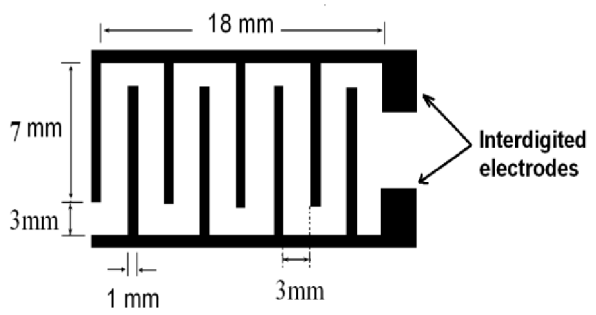

Figure1(a) Fabrication of interdigitate Electrodes.

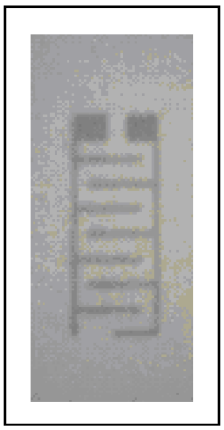

Figure1 (b) Actual photograph

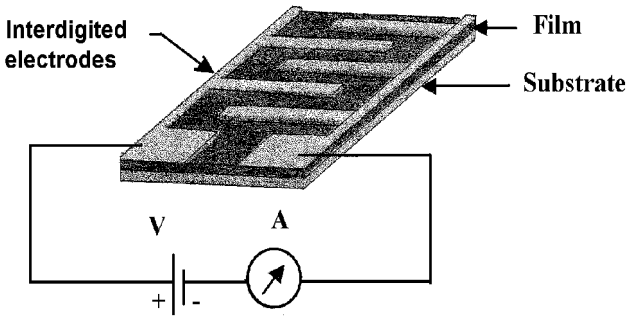

Figure2. Circuit of resistance measurement using interdigitate electrodes.

3. Result and Discussion

3.1. Sensing properties

We noted (table 1) that sensitivity increases linearly up to 700 ppm and beyond that it shows saturation. Sensitivity of $70SnO_2$:$30TiO_2$ composite has found maximum value. It is also observed that with decreasing in doping of TiO_2 in SnO_2:TiO_2 composites, the sensitivity increases and becomes maximum for $70SnO_2$:$30TiO_2$ composite. For pure SnO_2 and TiO_2 sensitivity is less as compare to 70 and 30 compositions.

It is due to the high porosity of $70SnO_2$:$30TiO_2$ composite as compared to other pure of TiO_2 and SnO_2.Thus, active surface area may available due to high porosity [7-9]. Also, the average crystallite size of $70SnO_2$:$30TiO_2$ composite is small and it means large active surface area. That's why sensitivity of $70SnO_2$:$30TiO_2$ composite is large as compared to other compositions and pure samples at different CO_2 gas concentration (ppm) at room temperature (303 K).

Table 1- Composition of metal oxide with varying weight percentage of SnO_2

Sr.No.	Sample composition Wt %	Series	Maximum sensitivity at 900 ppm of CO_2 gas
1	$70SnO_2:30TiO_2$	E	2.28
2	$50SnO_2:50TiO_2$	D	1.51
3	$30SnO_2:70TiO_2$	C	1.22
4	Pure SnO_2	B	1.07
5	Pure TiO_2	A	0,47

Static responses of SnO_2:TiO_2series for 300 ppm, 500 ppm and 700 ppm are studied and the response time and recovery time are calculated and are recorded in the table 2 for 700ppm of CO_2 gas concentration at room temperature (303K). Under static condition, it is observed that response is fast for $70SnO_2:30TiO_2$. It is also observed that recovery time for all sensors is very slow than the response time. The response and recovery time for all sensors for 700 ppm CO_2 gas concentration at room temperature (303 K) are listed in following table 2.

Table 2. Response and Recovery times of pure and composite sensors at 700 ppm of CO_2 gas concentration at room temperature (step response) (303 K).

Sr. No.	Sample Compositions	Response time (s) for 700 ppm	Recovery time (s) for 700 ppm
1	TiO_2	110	180
2	$70SnO_2:30TiO_2$	70	125
3	$50SnO_2:50TiO_2$	130	205
4	$30SnO_2:70TiO_2$	120	175
5	Pure SnO_2	120	135

Dynamic responses of SnO_2:TiO_2 series for 300 ppm, 500 ppm and 700 ppm are studied and the response time and recovery time are calculated and are recorded in the table 3 for 700ppm of CO_2 gas concentration at room temperature (303 K). Under dynamic condition, it is observed that recovery is fast for $70SnO_2:30TiO_2$. The recovery time for all sensors for 700 ppm CO_2 gas concentration at room temperature (303 K) are listed in following tables.

Table 3. Recovery times of pure and composite sensors at 700 ppm of CO_2 gas concentration at room temperature (dynamic response) (303 K).

Sr. No.	Sample Compositions	Recoverytime (s) for 700 ppm
1	TiO_2	115
2	$70SnO_2:30TiO_2$	35
3	$50SnO_2:50TiO_2$	40
4	$30SnO_2:70TiO_2$	45
5	Pure SnO_2	55

From table 3, it is observed that $70SnO_2:30TiO_2$sensor shows fast recovery as compared to other sensors [10-13]. Hence$70SnO_2:30TiO_2$sensor is the best sensor among the sensors.

3.2. SEM Analysis

The surface morphologywas evaluated using Field Emission Scanning Electron Microscopy for optimized sample for two different magnification which is shown in follwing SEM images.

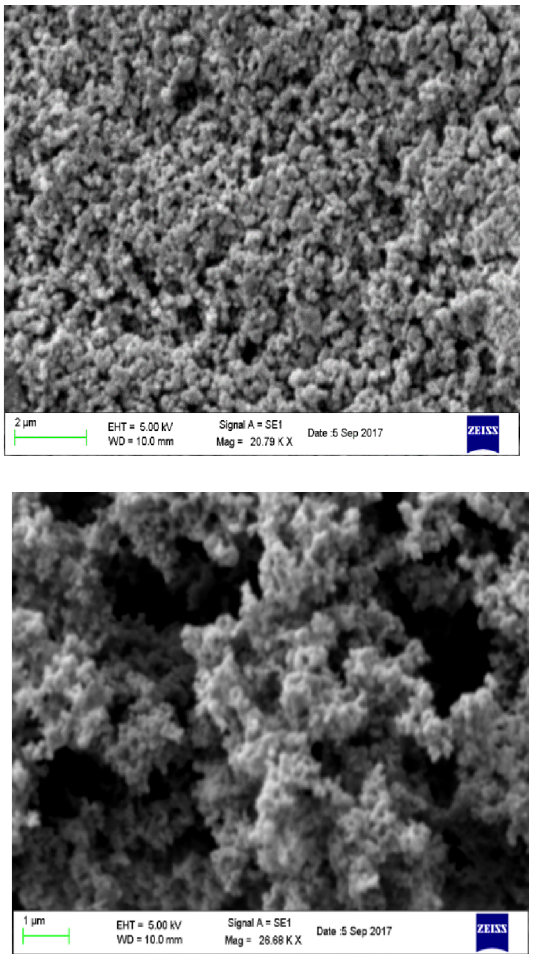

Figure 3. Surface morphology of (a) $70SnO_2:30TiO_2$

From above figure 3 of SEM analysis it has been observed that crystalline size of $70SnO_2$:$30TiO_2$is smaller in comparison with pure SEM of SnO_2 and TiO_2reported in literature by the other researcher. Porosity for optimized sample of composite of metal oxide by doping $30TiO_2$in $70SnO_2$is found more and shows enhancement in CO_2 gas detection.

4. Conclusion

From analysis of SEM, it is concluded that the crystalline size of optimized sample $70SnO_2$:$30TiO_2$ is smaller as compared with pure SnO_2 and TiO_2. Also observed that, optimized sample ismore porous and hence has large surface area. It has been also observed that enhancement ingas (CO_2) response for optimized sample $70SnO_2$:$30TiO_2$as compare to other composition. SEM analysis confirmed the surface morphology. From step response, it has been observed that optimized sample shows good stability.

5. Acknowledgement

Author of this research paper expressed sincere thanks to Professor and Head ,Department of Physics, Govt.Vidarbha Institute of Science and Humanities,Amravati, India,for constant support to carried out this research work and also thanks to Department of Physics,RTM Nagpur University Nagpur for SEM analysis.

References

1. Mude, B.M., Mude, K.M., Raulkar, K.B, Zade, R.N.,Yenorkar, S.M. and Yawale, S.P, (2017). Study of CO_2 gas detection by multilayer SnO_2-ZnO-PPy sensor, Int. Res. J. of Science & Engineering, Special Issue A1 :143-148
2. Waghuley, S.A., Yenorkar, S.M., Yawale, S.S., & Yawale, S.P. (2008). Application of chemically synthesized conducting polymer-polypyrrole as a carbon dioxide gas sensor. Sensors and Actuators B: Chemical, 128(2), 366-373.
3. Moseley, P. T. (1997). Solid state gas sensors. Measurement Science and technology, 8(3), 223.
4. Yawale, S. P., Yawale, S. S., &Lamdhade, G. T. (2007). Tin oxide and zinc oxide based doped humidity sensors. Sensors and Actuators A: Physical, 135(2), 388-393.
5. Pinna, N., &Niederberger, M. (2008). Surfactant-free nonaqueous synthesis of metal oxide nanostructures. AngewandteChemie International Edition, 47(29), 5292-5304.
6. Waghuley, S. A. (2011). Tin dioxide/polypyrrole multilayer chemiresistor as a hydrogen sulfide gas sensor. Journal of Electron Devices, 10, 433-437.
7. Asmus, T., & Wolf, G. K. (2000). Modification and structuring of conducting polymer films on insulating substrates by ion beam treatment. Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms, 166, 732-736.
8. Mastragostino, M., Arbizzani, C., &Soavi, F. (2002). Conducting polymers as electrode materials in supercapacitors. Solid state ionics, 148(3-4), 493-498.
9. Dhawan, S. K., Singh, N., & Rodrigues, D. (2003). Electromagnetic shielding behaviour of conducting polyaniline composites. Science and technology of Advanced Materials, 4(2), 105.
10. Koul, S., Chandra, R., & Dhawan, S. K. (2001). Conducting polyaniline composite: a reusable sensor material for aqueous ammonia. Sensors and Actuators B: Chemical, 75(3), 151-159.
11. Jain, S., Chakane, S., Samui, A. B., Krishnamurthy, V. N., &Bhoraskar, S. V. (2003). Humidity sensing with weak acid-doped polyaniline and its composites. Sensors and Actuators B: Chemical, 96(1-2), 124-129.
12. Rzaij, J. M., & Abass, A. M. (2020). Review on: TiO2 thin film as a metal oxide gas sensor. Journal of Chemical Reviews, 2(2), 114-121.
13. Sarf, F. (2020). Metal oxide gas sensors by nanostructures.Gas Sensors, 1.