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Sno_2-Wo_3 Mixed Oxide as A Semiconductor Gas Sensor for Co_2

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Abstract: ***SnO_2 and WO_3 oxide powders is mixed different composition thoroughly in an acetone medium by using a mortar and pestle and then heated at 900^0C in a muffle furnace. The above mixed oxide powder is used to form a thick film by screen printing method. The sensors based on the mixed oxide were used to detect the CO_2 gas at room temperature (303K).The experimental results show that the 45 mol.% SnO_2-55 mol% WO_3 mixed oxide based sensor exhibits the highest response(sensitivity = 12.45) on 802ppm CO_2 gas at room temperature. The response and recovery time for all the sensors was studied. The average crystalline size was calculated from XRD spectra is ranging from 21.22mm to 23.10mm for mixed oxide powder whereas pure WO_3 is 28.23mm.***

***Keywords*—Mixed oxide; screen-printing technique; CO_2 gas; sensitivity; response time; recovery time.**

I. INTRODUCTION

Gas sensors are used for many applications such as process controls in chemical industries, detection of toxic environmental pollutants, and for the prevention of hazardous gas leaks. Different oxide semiconductors such as SnO_2, WO_3, ZnO, MoO_3, TiO_2, In_2O_3 and mixed oxides have been studied and showed promising applications for detecting target gases such as NOx, O_3, NH_3, CO, H_2S and Sox [1–3] The working principle of these sensors is based on the detection of a change in resistance on exposure to a gas. Due to the constraints of gas permeation only the surface layers are affected by such reactions. Among various oxide sensors, WO_3 is responsive to NO_x, H_2S, and NH_3 [4–6].

In this study, WO_3 as a main gas-sensing element with a metal oxide of SnO_2 was added in order to stabilize the electrical characteristics. To enhance the sensitivity of the gas sensor to detect gases different mol% of SnO_2 and WO_3 were added .The WO_3 thick film was manufactured based on the screen printing process, which is not only economical but also enables mass production. We studied the optimal conditions of the gas sensor to detect CO_2 through the analysis of the characteristics of gas detection based on the experimental parameters.

II. EXPERIMENTAL PROCEDURE

A. Construction of sensor

SnO_2 and WO_3 is mixed (Sample code SA_1: 20:80, SA_2 :30:70, SA_3:45:55) thoroughly in an acetone medium by using a mortar and pestle and then heated at 900^0C in a furnace. The paste used in Screen-printing was prepared by maintaining inorganic to organic material ratio at 70:30. The inorganic part consisted of a mixture of SnO_2:WO_3. The organic part consisted of 8% Ethyl cellulose (EC) and 92% butyl carbitol acetate (BCA). A solution of EC+BCA (in ratio 8:92) was made and added drop wise to the above resultant mixture until proper thixotropic properties of the paste were achieved. The substrate used for the screen printing was cleaned by using distilled water and then acetone .The paste was screen printed on an glass substrate [7], of size was 75mm X 25 mm .The films were dried at 150 ^{0}C for about 20 min to remove the organic material. The film was aged for 4 weeks in open air [8] for drying. For the electrical characterization purpose form the electrode on two side of thick film by using silver paste. Thickness of the SA_1, SA_2 and SA_3 films was measured by digital micrometer having resolution ± 1μm and is found to be 12, 13.5 and 15.3μm respectively.

B. Measurement of gas sensing characteristics

The gas sensing properties of these samples (thick film) were studied in a home –built static gas characterization system. The system consist of a base plate with gas inlet, insulator base, glass plate, Aplap make DC power supply, resistor (Rs), DC Millivoltmeter (Scientific make type ±1μV), and chamber(Volume :12 lit). The base plate, insulator plate and glass plate are placed one above the other. This whole assembly is kept inside the chamber. Using silver paste between two sides of thick films forms the electrodes. The DC power supply (V) in series with resister (Rs=1MΩ) is connected to sensor. The voltage drop (V_s) across the R_s is measured by the microvoltmeter. The required gas concentration inside the system is achieved by passing gas through flow meter with flow rate

200 ml/min in the airtight chamber at ambient condition. The samples were tested for a wide range of concentration of CO_2. The sensitivity is calculated by using the formula

$$S = \frac{R_g - R_a}{R_a}$$

Where R_a&R_g are the electrical resistance of the sensor in presence air and gas+air respectively.

The structure was of sensor material was examined by X-ray diffractometer (PANalytical PW: 3040/60 made in Netherland) using CuKα radiation (1.5418 Å) in the 2θ range of 5 -100º. The 2θ step and step acquisition time were 0.0170º and 7.7523 s respectively.

III.RESULTS

The thrust for the present work was to study the gas sensing characteristics of SnO_2: WO_3 thick films. The results obtained are analysed, discussed and presented in the following part of this section.

A. Characterization of film by XRD

X-ray diffraction patterns for $20SnO_2$-$80WO_3$, $30SnO2$-$70WO_3$, $45SnO2$-$55WO_3$, Pure SnO_2 and pure WO_3 sensors are shown in Fig. 1. The XRD is obtained in terms of 2θ and intensity in the range $5\text{-}100^0$. The XRD spectra shows number of peaks suggests the total crystalline behavior of the films. It was investigated that W-O system is rather complex with a large number of phases. From Fig.1, it is observed that XRD–pattern contain nearly 15-18 peaks, out of these, nearly 14-15 peaks are prominent peaks of WO_3. The tungsten oxide exhibits a cubic perovskite like structure which based on the corners sharing of WO_6 regular octahedral with the W atoms at the centre of each octahedral.

The peaks obtained about 30^0 is observed in all samples corresponds to WO_3. In WO_3 five distinct crystallographic modifications takes place between absolute zero and its melting point (1700 K).When temperature is decreased from the melting point, the crystallographic modifications: tetragonal-orthorhombic- monoclinic-triclinic-monoclinic having phases αWO_3, βWO_3, γWO_3, δWO_3 and sWO_3 respectively forms [9-14]. The observed peaks of SnO_2 having (h,k,l) values (101), (301) and (321) are reflected in all samples and related to the stable state of cassiterite or rutile phase. The lattice parameter values obtained for SnO_2 are a=b= 4.7382 A˚ and c=3.1771A˚ with c/a ratio of 0.6725.

These values are in the range 21-23◦ corresponds to (002), (200) and (106) phases related to WO_3. Similarly a prominent phase (202) at close agreement with the values reported by Diegnez [15] and Robertson [16,17]. It has been reported that thin films of SnO_2 -WO_3 mixed oxides crystallize in the tetragonal, cassiterite SnO_2 structure with the lattice parameters slightly larger than those for undoped SnO_2.

This is in agreement with the ionic radii of W6+ (0.074 nm) and Sn4+ (0.071 nm). This suggests the substitutional mechanism of W incorporation.

The average grain size can be determined from XRD pat- tern using Debye-Schrrer formula [18]

$$D = K\lambda / \cos\theta. \qquad (1)$$

Where D is the crystallite size, K is the shape factor, which can be assigned a value of 0.89 if shape is unknown, θ is the diffraction angle at maximum peak intensity, λ is the wave- length of radiation and ß is the full width at half maximum of diffraction angle in radians. The average crystallite size for these samples is found to be in the range of 21.22mm to 23.10mm. It is observed that the average crystallite size is found to be nearly same for all samples except pure WO_3 sample for which it is 28.23mm. This indicates that the crystallite size of SnO_2 -WO_3 composite decreases.

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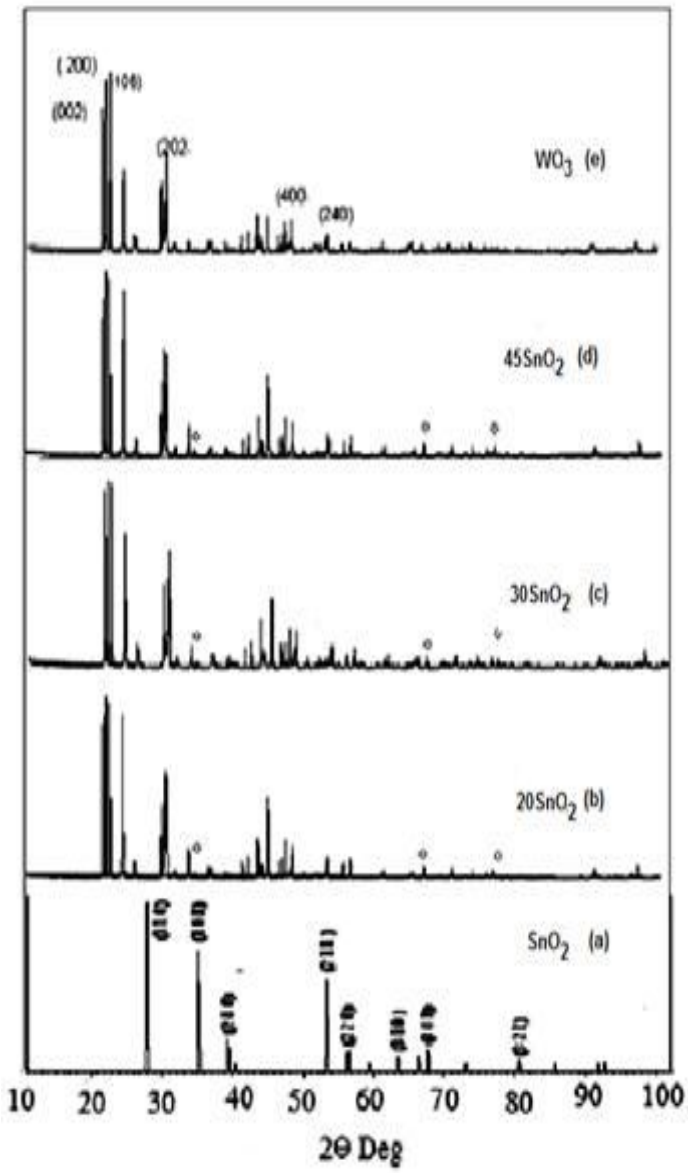

Fig.1. XRD pattern of (a) SnO_2 (b) $20SnO_2$-$80WO_3$ (c)$30SnO_2$ -$70WO_3$ (d) $45SnO_2$ -$55\ WO_3$ (e) WO_3 .

B. Sensitivity of Sensor

The resistance of the prepared sensors is found to increase with increasing the CO_2 as concentration. The sensitivity of the sensor is calculated by the following formula

$S = (Rg - Ra)/Ra = \Delta R/Ra$. (2)

Where *Ra* is the resistance of the sensor in air and *Rg* is the resistance of the sensor in CO_2 gas. The sensitivity of these sensors increases linearly with the CO_2 gas concentration at room temperature (303 K). The variation of sensitivity with CO_2 gas concentration at room temperature for various concentration of SnO_2 is shown in Fig.2. It is observed that the sensor $45SnO_2$ - $55WO_3$ shows highest sensitivity 12.45, while sensor of pure SnO_2 ,pure WO_3 and other composition i.e $20SnO_2$- $80WO_3$,$30SnO_2$- $70WO_3$ shows least sensitivity to CO_2 gas. In case of $45SnO_2$ -$55WO_3$ sensor the active surface area will be more than the other samples causing more adsorption of gas therefore the sensitivity will be more. As far as the gas sensing is concerned the structural properties are utmost important. In the mixed oxide SnO_2 -WO_3 the porosity of the surface and the active surface area enhance the sensitivity.

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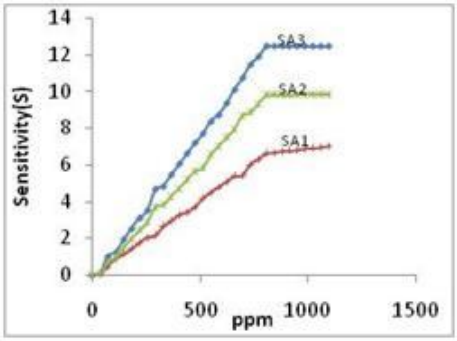


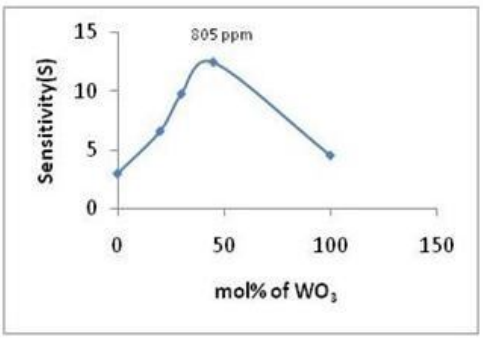


Fig.2.Variation of sensitivity with concentration of CO2 (ppm) gas at room temperature (303K

Fig.3.Variation of sensitivity with WO3 composition at room temperature for 805ppm of CO_2 gas

TABLE I

RESPONSE TIME AND RECOVERY TIME OF SENSORS

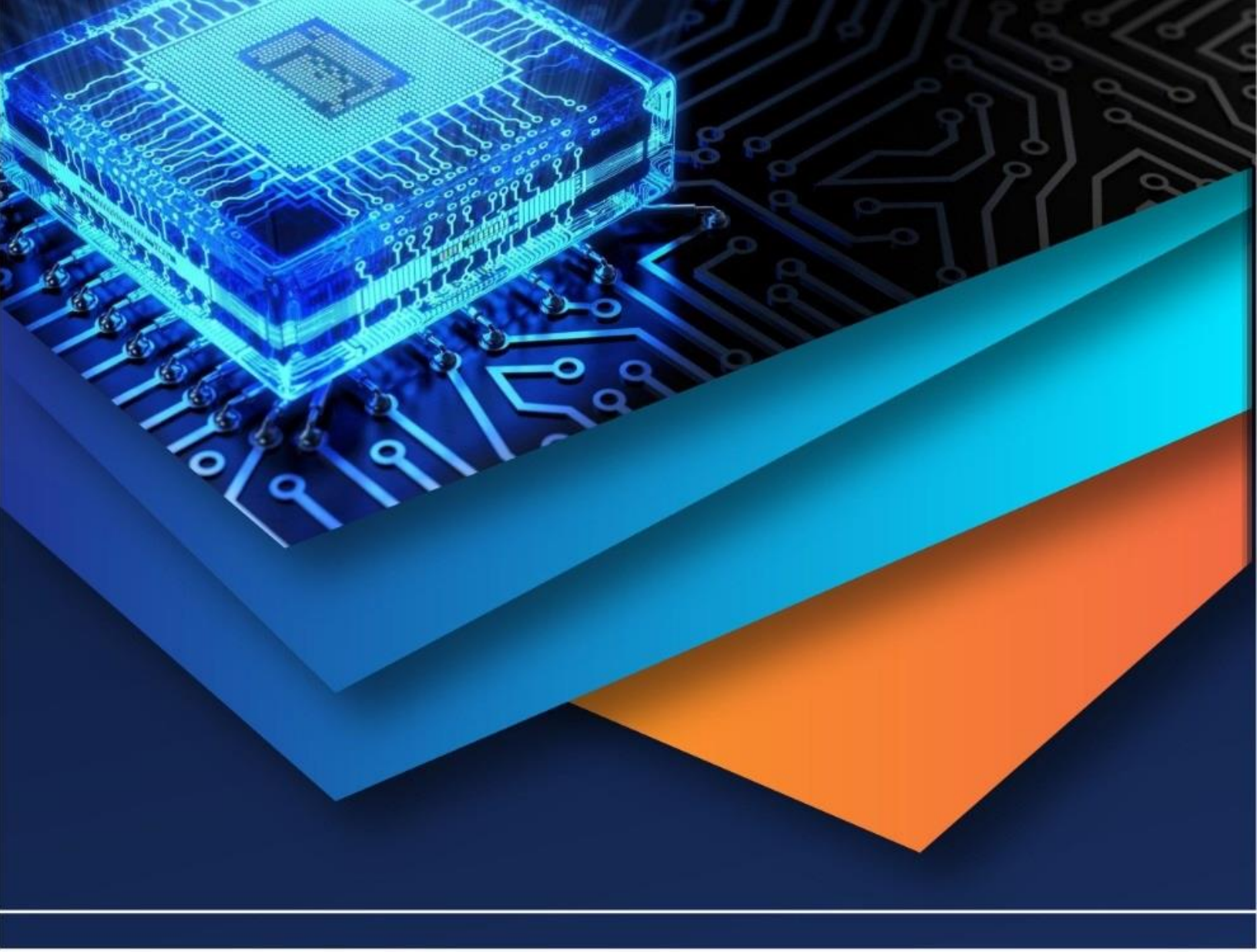
Sr. No	Composition (mol %) SnO_2-WO_3	Response time (s)	Recovery time (s)
1	100-00	137	72
2	80-20	121	413
3	70-30	124	37
4	40-60	109	22
5	00-100	134	86

IV. CONCLUSION

The sensing properties of thick film pure SnO_2,20SnO_2-80WO_3,30SnO_2-70WO_3, 45SnO_2-55WO_3 ,Pure WO_3 gas sensors were investigated. The highest sensitivity of about 12.45 was achieved by the SA_3(45SnO_2-55WO_3) sample. From the XRD pattern average crystalline size was found , it shows that crystalline size is less for mixed oxide than the pure oxide. Among all the sample fast response and recovery time was found for SA_3 sample is 109 S and 2 S.

REFERENCES

[1] W.Gopel, “Ultimate limits in the miniaturization of chemical sensors”, Sensors and Actuators A: Physical,Vol.56, pp.83–102,1996.
[2] K.Dieter, “Function and applications of gas sensors”, Journal of Physics D: Applied Physics, pp.125,2001.
[3] G.Korotcenkov, “Metal oxides for solid-state gas sensors: what determines our choice?”, Materials Science and Engineering,Vol.139, pp.1–23,2007.
[4] W.Yu-De, C.Zhan-Xian, L.Yan-Feng, Z.Zhen-Lai, W.Xing-Hui, “Electrical and gas-sensing properties of WO3 semiconductor material”, Solid-State Electronics, Vol.45,pp. 639–644,2001.
[5] Marquis B.T., Vetelino J.F., “A semiconducting metal oxide sensor array for the detection of NO_x and NH_3”, Sensors and Actuators B: Chemical, Vol. 77 ,pp.100–110,(2001).
[6] Srivastava V., Jain K., “Highly sensitive NH_3 sensor using Pt catalyzed silica coating over WO_3 thick films”, Sensors and Actuators B: Chemical, Vol.133,pp.46–52,2008.
[7] C.A.Harper, “Handbook of Thick Film Hybrid Microelectronics”, McGraw-Hill, New York,1974.
[8] S.K.Joshi, C.N. Rao ,S.Nagakura (Eds), “New Materials”, Narosa Publishing House, New Delhi,1992.
[9] W.Kehl, R.Hay, D.Wahl, “The Structure of Tetragonal Tungsten Trioxide” J.Appl. PhysVol.23,pp.212-215,1952.
[10] E.Saljie, Acta Crystallography. B Vol.33 pp.547-577,1977.
[11] S.Tanisaki, J. Phys. Soc. Jpn Vol.15 pp.573-581,1960.
[12] B.U.Loopstra, J.L. Rietveld, Acta Crystallogr. B Vol.25 pp.1420-1421,1969.
[13] R.Diehl, G.Brandt, E.Saljie; “The crystal structure of triclinic WO_3”, Acta Crystallogr.pp.1105-1111,1978.
[14] E.Saljie, “Ferroelectrics”Vol.12 pp.215-217,1976.
[15] Dieguez A., “Structural analysis for the improvement of SnO_2 based gas sensor, Ph.D. Thesis, Universitat de Barcelona, Barcelona, 1999.
[16] Robertson J., Phys.Rev.B Vol .30 pp.3520-3522,1984.
[17] JCPDS data file no.41-1445,1997.
[18] Cullity B.D., “Elements of X-ray diffraction” Addison–Wesley Pub. Co. Inc., London, 1978.



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