# CuO- $SnO_2$ nanocomposites thin films for the fast detection of $H_2S$ gas

Sharad B. Patil[a] and R.H. Bari*[a],

[a] Nanomaterials Research Laboratory, Department of Physics, G. D. M. Arts, K. R. N. Commerce and M.D. Science College, Jamner 424 206, India

**Abstract**

CuO-$SnO_2$ nanocomposites thin films were prepared by spray pyrolysis method onto the heated glass substrate at 250 °C. The films were fired at 500 °C. As prepared thin films were studied using XRD and SEM. The gas sensing performance of different composition of CuO-$SnO_2$ was studied on exposure of different gases for 10 ppm. sensor shows quick response (3 s) and fast recovery (6 s) time. The results are discussed and interpreted.

**Keywords:** Spray Pyrolysis, CuO-$SnO_2$ nanocomposites, $H_2S$ gas sensing, quick response, fast recovery

## 1. Introduction

The semiconductor-based chemical sensors own their popularity to their small size, simple operation, high sensitivity, selectivity, and relatively simple associated electronics. The metal oxide-sensing layer ($SnO_2$ or CuO) has been fabricated in different physical forms such as thin film, thick films, and bulk pellets. However, the thin film form is expected to be most effective, because sensing is basically a surface phenomenon of film [1].

Monitoring of $H_2S$ is crucial in laboratories and industrial areas. Hence a sensor with fast detection and high gas response is desired. It was demonstrated that the cations with a low electro- negativity value are best suited for $SnO_2$ doping with regard to hydrogen sulfide detection. However, it was found by Yamazoe and co-workers, that doping of tin dioxide with copper that is intermediate in electro negativity, gives rise to the outstanding sensitivity [2].

This paper deals with the preparation of composite thin films of $SnO_2$ and CuO. These films were studied using different analytical techniques. These CuO-$SnO_2$ nanocomposites thin films were tested for sensing different gases and was observed to be most sensitive to $H_2S$ at 250 °C.

## 2. Experimental details

### *2.1. Preparation of pure CuO - $SnO_2$ nanocomposites thin films*

The starting material used for the preparation of CuO-$SnO_2$ nanocomposites thin films were copper chloride dehydrate ($CuCl_2.2H_2O$ Purified Loba Chemie) and tin chloride dehydrate ($SnCl_2.2H_2O$ Purified Merk ). Copper chloride dehydrate and tin chloride dehydrate were mixed at various volume ratio such as 30:70, 50:50 and 70:30 as indicated in Table 1. To stabilize the starting solution, a few droplets of hydrochloric acid (HCl) were added. The temperature of the substrate is maintained at a constant value by using a temperature controlled hot plate. The deposition parameters like substrate temperature (250 $^oC$), rate of spraying solution (7 mL/min.), nozzle to substrate distance (30 cm), quantity of the solution sprayed (30 ml), pressure of carrier gas, and to and fro movement of the nozzle were kept constant. The as prepared CuO- $SnO_2$ nanocomposites thin films samples (S1, S2, and S3) were annealed at 500 $^oC$ for 1 h.

**Table 1** Amounts of spraying solutions and reactant

| Sample No. | $CuCl_2.2H_2O$ ($cm^3$) | $SnCl_2.2H_2O$ ($cm^3$) | Reactants |
|---|---|---|---|
| **S1** | 30 | 70 | CuO:$SnO_2$ |
| **S2** | 50 | 50 | CuO:$SnO_2$ |
| **S3** | 70 | 30 | CuO:$SnO_2$ |

## 3. Results and discussion

### *3.1. Structural analysis*

Fig. 1 shows the X-ray diffractogram of CuO-$SnO_2$ nanocomposites thin film. The structural properties of the films were investigated using XRD. The 2θ values were varied from 20 to 80. The calculated average crystallite size was found to be 14 nm respectively.

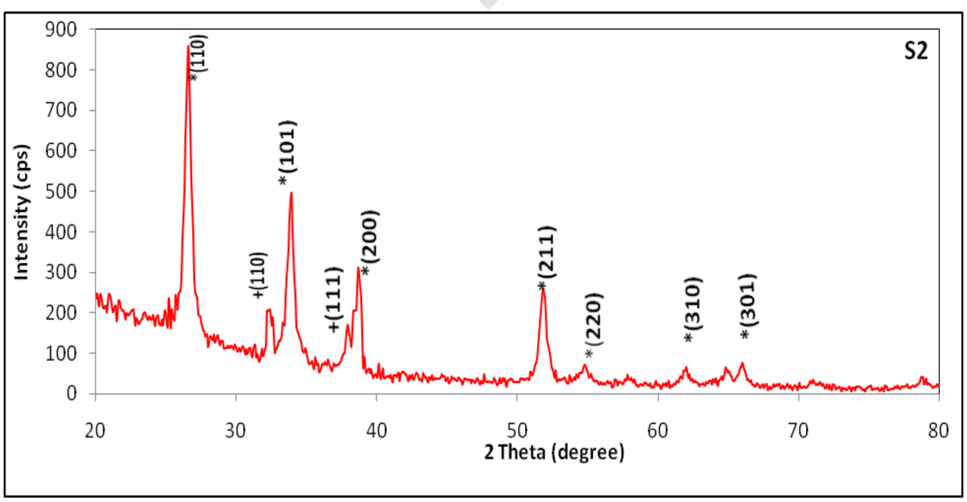


**Fig. 1.** X-ray diffractogram of CuO-$SnO_2$ nanocomposites thin film (most sensitive sample (S2))

### *3.2. Surface Morphology*

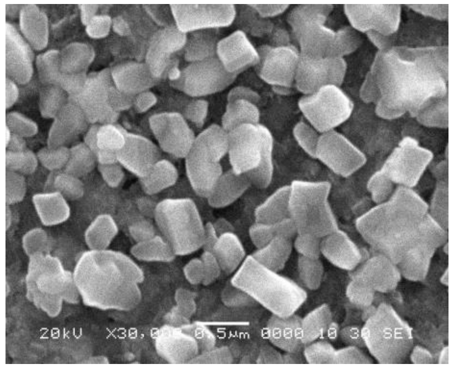


**Fig.2.** SEM image CuO-$SnO_2$ nanocomposites thin film (most sensitive sample (S2))

SEM imaged of CuO-$SnO_2$ nanocomposites was represented in Fig.2. Grain size observed to be in the range of 23 - 33 nm.

### *3.3. Elemental composition using (EDAX)*

Stoichiometrically expected at % of Sn ,Cu and O is : 20, 20 and 60, Observed at % pure CuO - $SnO_2$ nanocomposites thin films were given in Table 2. It is clear from table 2, that as prepared CuO - $SnO_2$ nanocomposites thin films were observed to be nonstoichiometric in nature.

**Table 2** Quantative elemental analysis as prepared CuO-$SnO_2$ nanocomposites thin film

| Element | Observed | | | | | |
|---|---|---|---|---|---|---|
| | S1 | | S2 | | S3 | |
| | mass % | at % | mass % | at % | at % | mass % |
| O | 27.19 | 72.36 | 67.96 | 27.19 | 72.36 | 67.96 |
| Cu | 4.85 | 3.26 | 19.61 | 4.85 | 3.26 | 19.61 |
| Sn | 67.96 | 24.38 | 60.03 | 67.96 | 24.38 | 60.03 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

## 4 Gas sensing performance of the sensors

### *4.1. Gas response:*

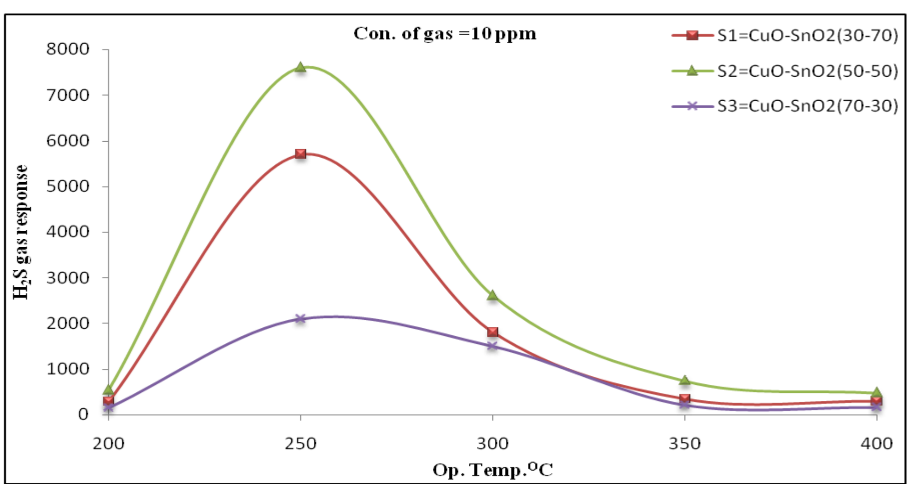

Fig. 3 represents the response characteristics of the $CuO$-$SnO_2$ nanocomposite thin films as a function of operating temperature. Among all the films, the sample (S2) film shows the maximum response (7599) at 250 $^0$C to 10 ppm of $H_2S$.

*4.2. Response and recovery of the sensor*

The response and recovery of the $CuO$-$SnO_2$ nanocomposites thin film (S2) sensor on exposure of 10 ppm of $H_2S$ at 250 $^oC$ are represented in Fig. 4.The response is quick (3 s) and recovery is fast (6 s). The high oxidizing ability of adsorbed oxygen species on the surface nanoparticles and high volatility of desorbed by-products explain the quick response to $H_2S$ and fast recovery.

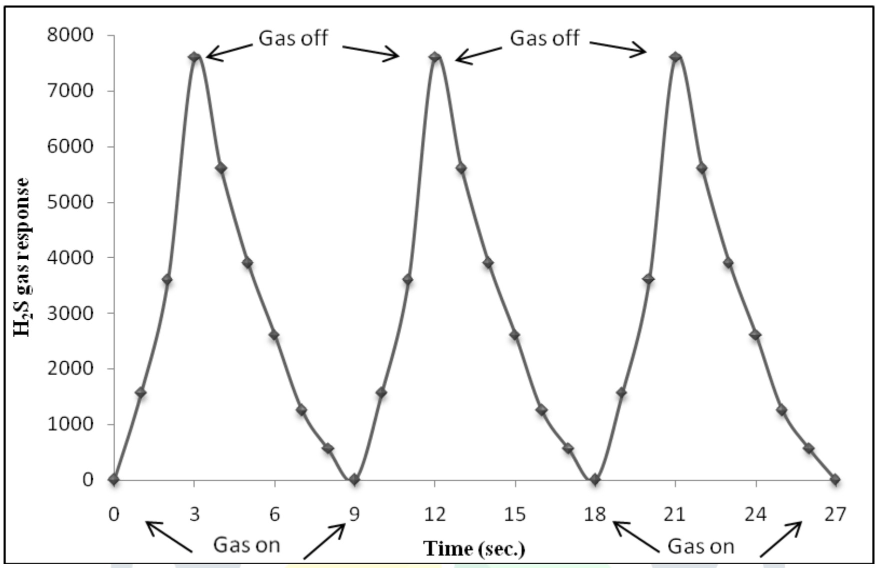


**Fig. 4.** Response and recovery of the sensor for most sensitive sample (S2).

**Conclusion:**

$CuO$-$SnO_2$ nanocomposites thin films were prepared by simple spray pyrolysis technique. The structural and microstructural properties confirm that the as-prepared $CuO$-$SnO_2$ nanocomposites thin films are nanostructured in nature. The $CuO$- $SnO_2$ thin film of (Sample S4) was most sensitive to $H_2S$ gas and exhibit the response of S = 7499 to the gas concentration as 100 ppm at the temperature of 250 $^oC$. The $CuO$-$SnO_2$ nanocomposites thin films exhibit rapid response–recovery which is one of the main features of this sensor.

**Acknowledgements**

The authors are thankful to the University Grants Commission, New Delhi for providing financial support. Thanks to Principal, G. D. M. Arts, K. R. N. Commerce and M.D. Science College, Jamner, for providing laboratory facilities for this work.

**Reference**:

[1] Jinhuai Liu, Xingjiu Huang, GangYe, Wei Liu, Zheng Jiao, Wanglian Chao, Zhongbai Zhou and Zengliang Yu, Sensor, 3 (2003) 110-118.

[2] G. E. Patil, D. D. Kajale, D. N. Chavan, N. K. Pawar, P. T. Ahire, S. D. Shinde, V. B. Gaikwad, G. H. Jain, Bull. Mater. Sci., 34 (2011) 1–9.

[3] L.A. Patil, A.R. Bari, M.D. Shinde, Vinita Deo and M.P. Kaushik, Sensors and Actuators B: Chemical, Available online.