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# Effect of Substrate Temperature on Electrical and Gas Sensing Properties of Al and PEG Co-Doped $SnO_2$ Thin Films

**S.N.Bajantri[1] and R.D. Mathad[2]**

*[1]Departmentof Physics Govt. First grade College, Navabhaga, Khaza Colony Vijayapur- 586101, Karnataka, India*

*[2]Departments of Physics, Gulbarga University, Kalaburagi -585101 Karnataka, India.*

**Abstract**

This paper reports the effect of deposition temperature of $SnO_2$-Al:PEG thin films on electrical, optical and gas sensing properties. $SnO_2$-Al:PEG thin films were synthesized by varying substrate temperature using chemical spray pyrolysis technique. The films were deposited at four different temperatures ranging $300^0$ C to $425^0$C. The precursor solution was prepared by dissolving $AlCl_3.6H_2O$, PEG (1:1) and $SnCl_4.5H_2O$ in Ethanol. The deposited films were characterized by using XRD, SEM and current-voltage measurement. $H_2S$ gas was used to study the gas sensing behavior.

**Keywords:** - Spray pyrolysis, thin film, XRD, $H_2S$, PEG, and Gas Sensor.

## I. INTRODUCTION

Stannic chloride is a semiconductor which has been used in making heterojunction thin solar cells. It is preferred because it is a wide band gap semiconductor having good thermal stability & can be used as light dependent resistors sensitive to visible & near infrared light. It is found that substrate temperature influences the structural, electrical properties of thin film [1-4]. Sensitivity has been attracting more attention and many efforts have been made to enhance the sensitivity and selectivity of gas sensors.

We prepared thin films by Chemical spray pyrolysis technique (CSP), because of its simplicity and inexpensiveness has found to be better chemical method for the preparation of thin films with larger area. In the chemical spray pyrolysis technique; various parameters like air pressure, rate of deposition, substrate temperature, distance between nozzle to substrate, cooling rate after deposition affect the physical, electrical and optical properties of the thin films [5-7].

In this paper tin oxide material is fabricated by Spray pyrolysis method, the purpose of this work was to investigate the effect on structural, electrical and sensing properties of $SnO_2$-Al:PEG thin film for various Substrate temperatures from 300-425$^0$C.

## II. MATERIALS AND METHODS

### *2.1. Fabrication of $SnO_2$-Al:PEG Thin Film:*

The first precursor solution was prepared by the dissolving 4%of $AlCl_3.6H_2O$, PEG(1:1) and 0.15M of $SnCl_4.5H_2O$ in 25ml of ethanol. The nozzle was kept at a distance of 35cm from the substrate during deposition and the solution flow rate was held constant at 5ml/min. When aerosol droplets came close to the substrates, a pyrolysis process occurred and highly adherent $SnO_2$-Al:PEG films were produced for different substrate temperatures ranges 300$^0$C to 425$^0$C. Once the spray is completed the heater was turned off and the films were allowed to attain the room temperature [8-9].

### *2.2. Characterization of $SnO_2$-Al:PEG Thin Films:*

The prepared $SnO_2$-Al:PEG films were used for further characterization. X-ray diffractometer (Ultima IV Japan) with CuKα radiation (λ=1.5405 Å) at 40 mA and 40 kV at a scanning rate of 0.02˚ per second was used to study the crystalline state of these films. Morphogical properties of the films were studied using SEM. The current-voltage (I-V) characteristics of the films were studied using programmable Keithley source meter (Keithley 2636A).

### *2.3. Gas Sensing Measurements:*

Gas Sensing measurements were carried out using a Gas sensor unit [10-11]. In which a digital multimeter is used to measure resistance and the temperature of the micro heater by digital thermometer using alumel- chromel thermocouple. $H_2S$ is used as probing gas. In our measurements, first the temperature of the oven is set to a particular value by applying 12.5 V to the heater to produce stable temperature of 150˚C and the resistance of the sensor in air is recorded. A known amount of $H_2S$ gas is injected into the chamber, the fall in resistance of the sensor with respect to time is recorded. Once the minimum constant resistance value is reached the bottle is opened and the sensor is exposed to open air. Now the increase in the resistance with respect to time is recorded. Similar procedure was repeated for several times for all samples (films) under the identical condition.

## III. RESULTS AND DISCUSSION

$SnO_2$-Al:PEG thin films were deposited by the CSP technique. Deposited films were transparent and electrically conducting.

### *3.1 Structure Analysis:*

From the XRD pattern shown in Figure (1), the average crystallite size is estimated using Debye Scherer formula. In the present study the XRD peak is broad which indicate the small size of the particles. It is found that at higher temperature the peaks become narrow which indicative of increase particle size and improved crystallanity of the films. The practical size for $SnO_2$-Al:PEG thin film with different temperature is estimated and is given in the following table -1.

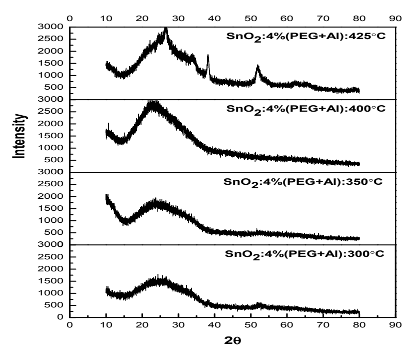


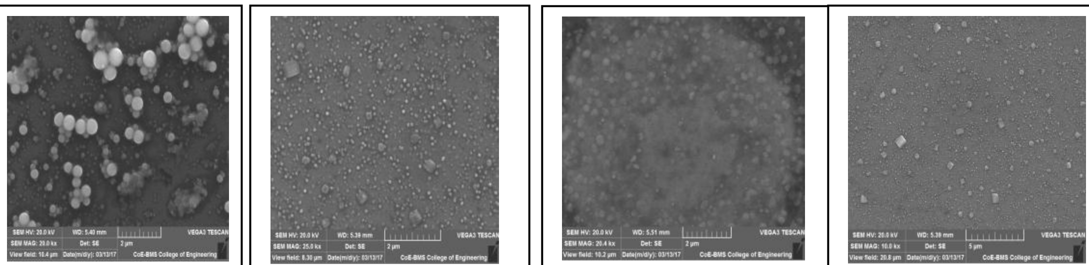

**Figure 1:**X-ray diffraction pattern of spray deposited $SnO_2$-Al:PEG thin film with variation of substrate temperature.

| Sl.NO | Sample | Particle size(nm) |
|---|---|---|
| 01 | $SnO_2$:4%(PEG+Al) with 300°C | 5.85 |
| 02 | $SnO_2$:4%(PEG+Al) with 350°C | 6.11 |
| 03 | $SnO_2$:4%(PEG+Al) with 400°C | 6.50 |
| 04 | SnO :4%(PEG+Al) with 425°C | 7.04 |

***Table 1*:** Particle size estimated for $SnO_2$-Al:PEG film with different Substrate temperature using X-ray diffraction patterns.

### *3.2 Morphological Analysis:*

It is found that from SEM analysis of $SnO_2$-Al:PEG film with different Substrate temperature showed in Figure (2), as the substrate temperature increases decrease in the particle size and agglomeration of particles.



**(a)$SnO_2$:4%(PEG+Al):30** **(b)$SnO_2$:4%(PEG+Al):350°C** **(c)$SnO_2$:4%(PEG+Al):400°C** **(d)$SnO_2$:4%(PEG+Al):425°C**

***Figure2*: SEM image of $SnO_2$-Al:PEG with different substrate temperature.**

### *3.3 Electrical properties:*

The electrical conductivity is measured by measuring current voltage (I-V) curve of these films in two probe configuration. The I-V characteristics curve of the $SnO_2$-Al:PEG thin films with different substrate temperature Show in Figure (3). The curve shows the pseudo ohmic behavior, from the slope of the curves the electrical resistance of these films estimated to be in the range of 6-48 **KΩ**. It is observed that the resistance of the film decreases with increasing substrate temperature of $SnO_2$-Al:PEG thin film.

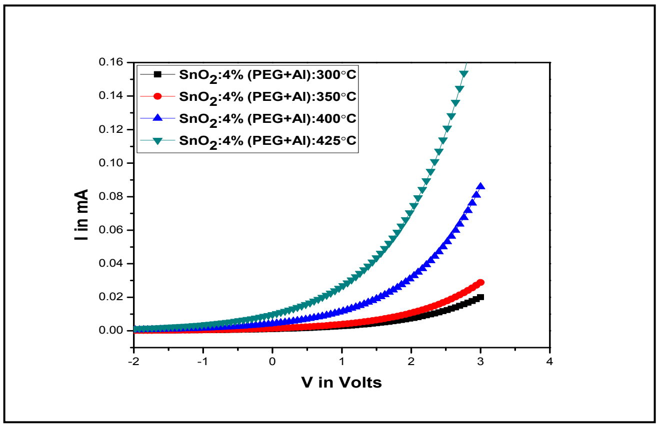



**Figure 3: Current-Voltage (I-V) Characteristic Curves of $SnO_2$-Al:PEG thin film with different substrate**

### *3.4 Gas Sensing Characteristics:*

In present study we have recorded the gas sensor response using Laboratory gas sensor setup to sense $H_2S$ gas at 150˚C.as the substrate temperature increases sensitivity thin film decreases. The gas response characteristics are shown in Figure(4).

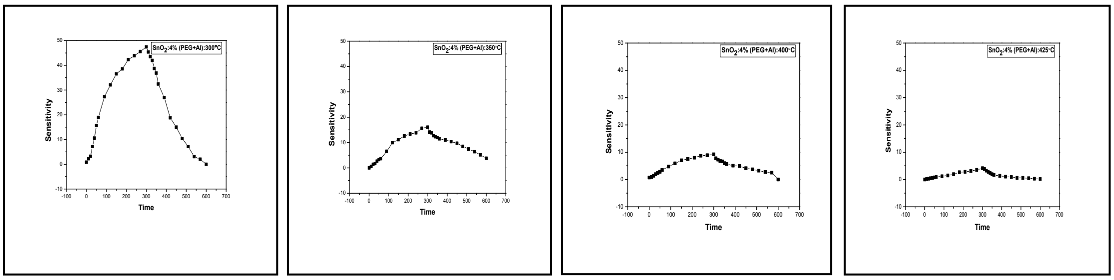


***Figure 4***: Gas response of $SnO_2$-Al:PEG film for $H_2S$ (a) $SnO_2$-Al:PEG with300°C (b) $SnO_2$-Al:PEG

## IV. CONCLUSION

In the Paper as substrate temperature while deposition of $SnO_2$-Al:PEG thin film the XRD peaks become sharper indicating the increases in particles size and improved crystalline. In morphological analysis the particle size increases. From I-V characteristics it is found that resistance decreases with substrate temperature and the gas sensitivity decreases with temperature.

## V. ACKNOWLEDGEMENT

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