

Figure 4:  $(\alpha hv)^{1/2}$  Vs.  $h\nu$  for SnO<sub>2</sub> film

It has been observed the band gap was 3.65eV and 3.52eV in case SnO<sub>2</sub> thin film deposited by Sol-Gel and Thermal Evaporation technique respectively. This band gap value suitably matches the values given by J.E. Dominquez [4]. The less band gap of the film deposited by thermal evaporation technique may be due to improvement of the degree of crystallization and growth of grain.

### 3.2 Structural

XRD measurement was carried out by Siemens Diffractometer Model- D 5000 using CuK $\alpha$  having wavelength  $\lambda = 1.540 \text{ \AA}$  radiation with a diffraction angle  $2\theta^0$  to  $65^0$ . The graphs are shown in fig 5 and 6.

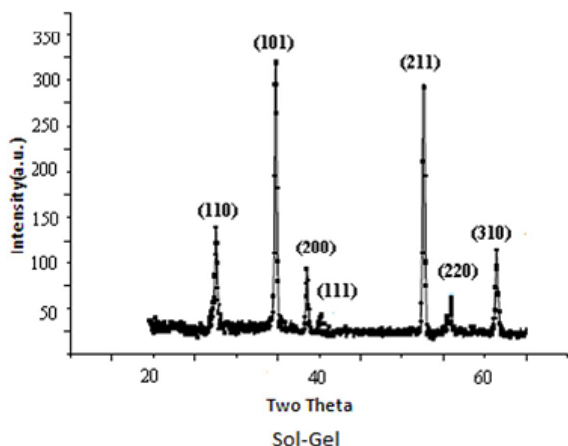


Figure 5: XRD- Sol-Gel

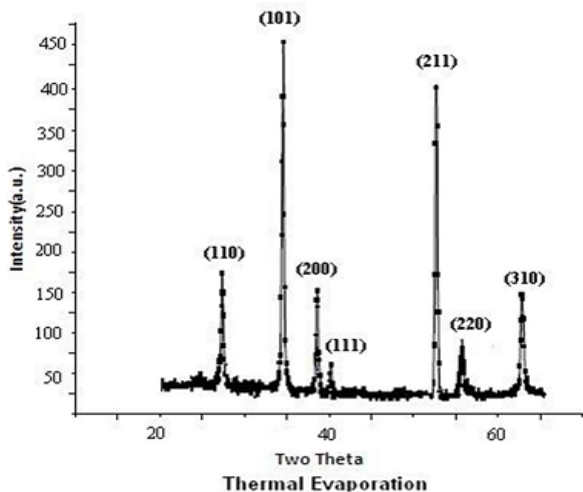


Figure 6: XRD-Thermal Evaporation

From the graph it was clear that in both the cases well defined sharp diffraction peaks were seen nearly at same angle of  $2\theta$  which may be considered to be the crystalline tetragonal rutile structure of SnO<sub>2</sub>(JCPDS Card No. 88-0287). XRD peaks were very narrow and sharp which shows higher crystalline quality of the SnO<sub>2</sub> film. The (101) peak has the largest intensity in both the cases, so it may be believed the preferential growth along direction (101) hence Sn forms an interstitial bond with oxygen and exist as rutile SnO<sub>2</sub>.

The figure depicts a significant increase in the intensity of the X-ray diffraction peaks in case of thermal evaporation this may be due to additional nucleation centers for the SnO<sub>2</sub> growth due to which grain size also increased. Grain size of the particles was determined by using Debye-Scherrer formula  $D = \frac{0.94\lambda}{\beta \cos\theta}$ , the symbols are having their usual

meaning. Using the above formula the average grain size of the deposited film was calculated as 45.24 and 40.18nm for the film grown by thermal evaporation and sol-gel technique respectively. This difference may be probably due to the presence of strains distributed unevenly in the film.

SEM measurement was carried out by Scanning Electron Microscope Model- Philips XL 30. SEM micrograph are shown in the figure 7 and 8 which shows agglomeration of the grain particles in both the cases. The grain size calculated is about 48nm and 44nm for thermal evaporation and Sol-Gel technique. From the SEM images it was clear that microstructural properties as well as grain size changes a little due to method of preparation. SEM micrograph of thin film contains domes like structure and the size of the domes were more or less same size in both the cases. This dome like structures may be believed as the top surfaces of the grains of the film.

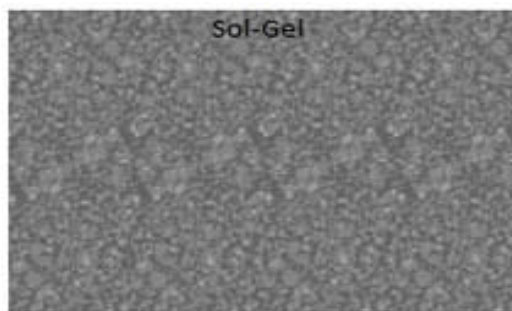


Figure 7: SEM-Sol-Gel

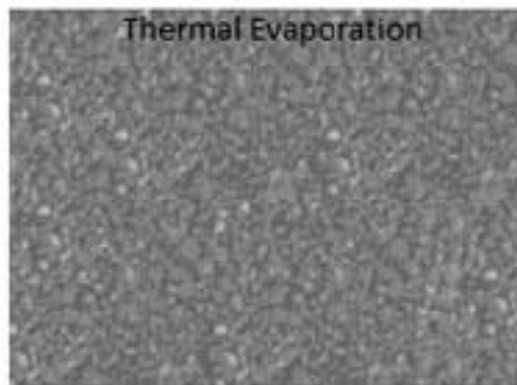


Figure 8: SEM-Sol-Thermal Evaporation

### 3.3 Gas Sensitivity Analysis

According to Stoichiometric, tin oxide is an insulator at room temperature. But when thin film of tin oxide comes in contact with air, the surface of the film absorb oxygen [6] at grain boundaries which ensnare electrons and build a barrier around each grain [7] which behaves like doping, and produces ionization levels close to the bottom of the conduction band and finally exhibits the property of n-type semiconductor with a band gap ( $\approx 3.6$  eV)[9]. When thin film of SnO<sub>2</sub> was exposed to air, oxygen from the air is adsorbed onto the surface of the SnO<sub>2</sub> thin film. Electrons from the surface region of the SnO<sub>2</sub> are transferred to the adsorbed oxygen, leading to the formation of an electron-depleted region near the surface of the SnO<sub>2</sub> film. The electron depleted region, where electron density is less, is an area of high resistance and the core region of the film, where electron densities are high, is an area of relatively low resistance. Now the adsorbed oxygen becomes O<sup>-</sup> and

O<sub>2</sub><sup>-</sup> species. When the thin film of SnO<sub>2</sub> is exposed to a reducing gas like CO, surface reactions such as CO + O<sub>ads</sub><sup>-</sup> → CO<sub>2</sub> + e<sup>-</sup>

and 2CO + O<sub>2,ads</sub><sup>-</sup> → 2CO<sub>2</sub> + 2e<sup>-</sup>

took place. Due to which electrons releases and the electrons released from surface reaction transfer back into the conduction band leading to a decrease in the resistance or increase in conductance of the SnO<sub>2</sub> thin film.

The sensitivity of the SnO<sub>2</sub> thin film for carbon monoxide gas has been studied at concentration 50ppm. The variation of the sensitivity with temperature is shown in the figure 9.

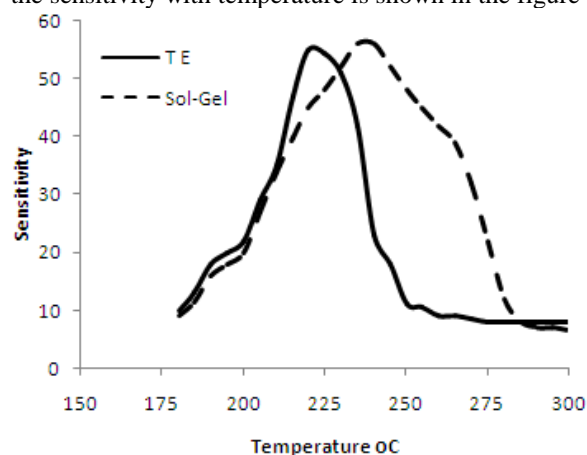


Figure 9: Sensitivity Vs. Temperature in °C.

Figure 9 depicts that maximum sensitivity occur at temperature of 220°C for Thermal Evaporation Technique and 235°C for Sol-Gel technique. At low temperatures there is less oxygen coverage, when the sensor is exposed to air and therefore when the target gases are introduced there is negligible change in sensitivity. As the operating temperature increases, number of adsorbed oxygen species would have reacted more and more number of electrons which are released due to this reaction sent back to conduction band i.e desorption rate of adsorbed gases also increases with increasing temperatures.

### 4. Conclusion

Tin oxide thin films were synthesized by Thermal evaporation and Sol-Gel technique. From optical measurement the band gap was measured as 3.65eV and 3.52eV in case SnO<sub>2</sub> thin film deposited by Sol-Gel and Thermal Evaporation technique respectively. XRD and SEM study revealed the grain size is more incase of the film synthesized by thermal evaporation method. The film was studied for carbon monoxide gas sensing. It was observed that the sensitivity of the film for CO gas at 50 ppm was more at 220°C for thermal evaporation technique and 235°C for sol-gel technique which may conclude that tin oxide film synthesized by thermal evaporation method is better for gas sensing than sol-gel method due to more surface area is available to expose.

### 5. Acknowledgement

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