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## Characterization of tin-doped titanium dioxide thin films prepared by SILAR method

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### ABSTRACT

*The Titanium dioxide and Tin-doped Titanium dioxide thin films were being deposited by Successive Ionic Layer Adsorption and Reaction (SILAR) technique. The prepared samples were characterized using X-ray diffraction, Ultraviolet-visible spectroscopy; photoluminescence and Fourier transform infrared spectroscopy. The XRD pattern of the films confirmed tetragonal structure with the polycrystalline nature. The optical transmittance was increased with the decrease in the optical energy band gap. The optical constants such as extinction coefficient and refractive index were determined. The intensity of the photoluminescence emission was observed at 700 nm for doped films. The Fourier Transform Infrared Spectroscopy confirms that a TiO<sub>2</sub> phase has been formed. The field dependent conductivity showed an insignificant rise in photocurrent for TiO<sub>2</sub> which was in conformity with its wide band gap nature.*

**Keyword:** Thin films, Silar coating method, XRD, UV, PL.

### 1. INTRODUCTION

Transparent conducting oxide (TCO) materials are of great interest due to their distinctive physical, chemical, optical and optoelectronic properties. Among these materials, TiO<sub>2</sub> plays a most promising role in several areas of research because of its high efficient photocatalytic activity, high refractive index, resistance to photo-corrosion, chemical stability, low cost and non-toxicity. In order to obtain the thin film of high quality and good responsibility the deposition parameters have to be maintained constant. The thin film can be prepared by many methods and methods has its own characteristics, merits, and defects in production homogeneous and defects free thin film. Among many methods available, silar coating technique is chosen for this study due to inexpensive and reproducible quality.

### 2. EXPERIMENTAL PROCEDURE

In this work, the glasses are used as the substrate. The procedures employed in cleaning this substrate are pointed below; the hands must be washed in pure water. Take the glass plate and it is immersed in the solution of H<sub>2</sub>SO<sub>4</sub> for few minutes. After the glass substrate is dried, rinse it in pure water. Clean the same with the de-ionized water (or) distilled water. Clean the substrates with pure cotton soaked in acetone. Allow drying on the clean atmosphere. After drying the substrate it is used for the film deposition. Tin-doped TiO<sub>2</sub> films were prepared using 0.5 M and dissolved in methanol.

The doping was achieved by the addition of Tin chloride (SnCl<sub>4</sub>·5H<sub>2</sub>O) in at. % (1,2,3,4 and 5 at.%) to the spraying solution and the whole mixture was sprayed on the glass substrate. The grown films. The structural characterization of the deposited films was carried out by X-ray diffraction technique on Shimadzu XRD-6000 X-Ray Diffraction Unit.

### 3. RESULT AND DISCUSSION

#### X-Ray Diffraction

X-ray diffraction patterns of tin-doped titanium dioxide thin films are shown in Fig. 1. The films are polycrystalline and fit well with the tetragonal crystal structure. The thin films have anatase phase. At 1 at.% of Sn, the intensity of (101) plane decreases which may be due to the decrease in the mobility of titanium and oxygen atoms which lead to the reduction in the nucleation of crystallization phase of anatase TiO<sub>2</sub>. Whereas Sn % concentration increasing, the intensity of (101) plane is again increased which

may be due to the presence of Sn into TiO<sub>2</sub> lattice structure, leading to the stabilization effect on the crystalline structure of anatase TiO<sub>2</sub>.

### Ultraviolet-Visible Spectroscopy

UV-vis absorption spectra of a methanol solution mixed with hollow-structured Sn-doped TiO<sub>2</sub> with different Sn doping levels. The UV-vis spectrum of pure TiO<sub>2</sub> displays a strong peak at 300 nm, which is attributed to an electronic transition from the valence band (VB) to the conduction band (CB) of TiO<sub>2</sub>. When dopant and defects are introduced, additional extrinsic electronic levels can be located in the energy band gap of the TiO<sub>2</sub>. It can be seen that both pure TiO<sub>2</sub> and Sn-doped TiO<sub>2</sub> exhibit obvious UV light absorption. As compared to the UV-vis spectrum of pure TiO<sub>2</sub>, the absorption edges for TiO<sub>2</sub> with different Sn doping contents exhibit a gradual red shift. In particular, it is worthwhile to note that the UV-vis spectrum of Sn-doped TiO<sub>2</sub> extends into the visible-light region, due to the incorporation of Sn dopant into the lattice of TiO<sub>2</sub>.

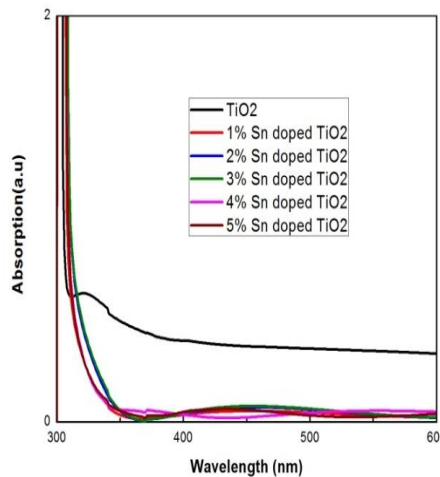


Fig.2 Absorption spectra of TiO<sub>2</sub> and Sn-doped TiO<sub>2</sub> films

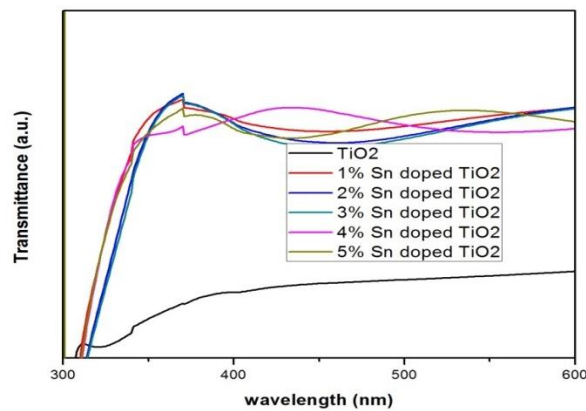


Fig.3 Transmission spectra of TiO<sub>2</sub> and Sn-doped TiO<sub>2</sub> films

The absorption spectra of TiO<sub>2</sub> films with different doping percentage of Sn. There is a strong absorption in the UV-Visible region for pure TiO<sub>2</sub> films. The absorption edge for pure TiO<sub>2</sub> and different Sn doped films is having almost the same wavelength around. Initially, the red shift was observed due to low doping of Sn (1-3%). After that, the blue shift was observed for high doping content due to grain growth induced shift.

The transmission spectra of TiO<sub>2</sub> films with different doping percentage of Sn. Strong absorption is observed in UV –visible region. The higher transmittance was observed for Sn doped films. It can be attributed to improvement in the crystallinity and grain growth.

### Photoluminescence

With the increasing Sn<sup>4+</sup> concentration, the photoluminescence intensity decreases. A decrease in the photoluminescence intensity indicates a lower recombination rate of electron-hole pairs and hence higher separation efficiency.

Fig.4 .shows the PL spectra of TiO<sub>2</sub> films with different doping percentage of Sn. All the films excited at 660 nm wavelength. Only one emission peaks were observed for all the samples. The emission peaks were centered 660 nm for all samples. The changes in intensity are due to improvement in crystallinity. The emission and bandgap values are interesting to develop next-generation solar cells.

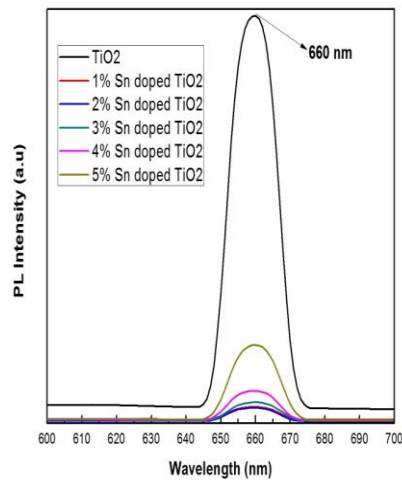


Fig: 4 Photoluminescence emission spectra for Sn-TiO<sub>2</sub> films

Fourier Transform Infrared Spectroscopy Analysis

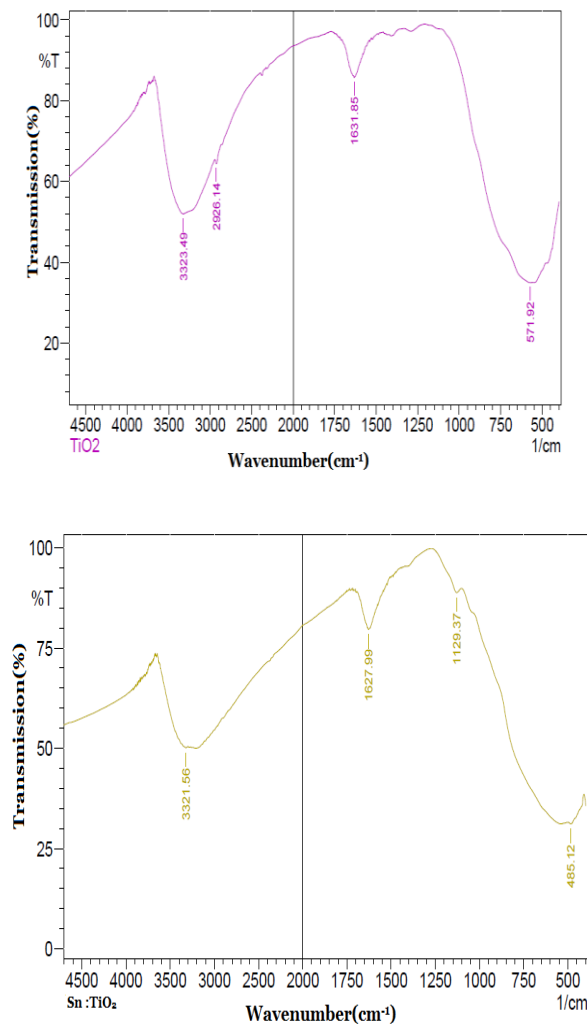


Fig.5 FTIR spectrum of Sn- TiO<sub>2</sub> Thin film

Figure 5. The graph shows the FTIR spectrum of the Sn doped TiO<sub>2</sub> synthesized by silar method, which was acquired in the range of 4500-500 cm<sup>-1</sup>. The band between the 450-500 cm<sup>-1</sup> correlated to metal oxide bond (sn:TiO<sub>2</sub>).From this FTIR we can also observe that increasing the annealing temperature sharpens of the characteristic peaks for metal oxide, suggesting that the crystalline nature of TiO<sub>2</sub> increases on increasing the calcination temperature. The peaks in the range of 4000 - 3500cm<sup>-1</sup> correspond to the C=O bonds. The adsorbed band at 337.70. Cm<sup>-1</sup> is assigned O-H stretching. The peak at 3018.71 cm<sup>-1</sup> and 637.50 cm<sup>-1</sup> corresponds to C=O andTiO<sub>2</sub> stretching vibrations.

#### 4. CONCLUSION

The pure Titanium Dioxide and Tin doped Titanium Dioxide thin films were prepared using Silar method. The prepared samples were characterized using XRD, VU, PL and FT-IR results reveal that the crystal structure and optical studies. XRD pattern of the deposited films ( $\text{TiO}_2$  and Sn-doped  $\text{TiO}_2$ ) revealed the tetragonal structure with preferential orientation along (101) plane. The absorption and transmittance spectra of the Sn-doped  $\text{TiO}_2$  films were measured and the higher transmittance was observed for the Tin doped Titanium Dioxide sample. The PL intensity was decreased with increase in dopant and it was attributed to the retardation of recombination process. The results obtained show that Sn-doped  $\text{TiO}_2$  thin films can be successfully prepared by Silar pyrolysis and observed good optical properties, high transmittance, and infrared reflectance allows Sn doped  $\text{TiO}_2$  thin films very attractive for usage in solar cells, many optoelectronic device applications and IR coating windows.

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