Investigation of Structural and Optical Properties of Tin Oxide and Zinc Oxide Nanoparticles by Sol-Gel Route

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Abstract: ***In this paper, Tin oxide and Zinc Oxide synthesized by a simple Sol-Gel technique using non-alkoxide Stannous Chloride and Zinc Acetate as a precursors. The structural and optical properties were studied by using XRD, SEM, TEM and UV–vis techniques. The X-ray Diffraction (XRD) shows the samples have a tetragonal rutile and hexagonal wurtzite structure for SnO_2 and ZnO resp. The Transmission Electron Microscopy (TEM) shows the average particle size is of ~11.26 nm and 150 nm for SnO_2 and ZnO resp. Band gap and band tail is also discussed in details.***

Keywords: Sol-gel, SnO_2, ZnO, Nanoparticles, Optical

I. INTRODUCTION

High transparency semiconductor such as SnO_2 and ZnO have potential applications in catalysis, gas sensing, optoelectronics and solar cells [1-4] etc. Several methods such as Sol-gel [5-6], Hydrothermal [7], Electrospinning [8] have been utilized to synthesize SnO_2 and ZnO. Among these techniques, the Sol-Gel method seems suitable due to its simplicity, easy to add doping materials, promising for mass production and low cost [1]. The applied synthesis procedure have seen to affect substantially the crystallinity, microstructure and defect structure of the nanoparticles. Considerable efforts have been put to obtain pure SnO_2 and ZnO nanoparticles. Structural, morphological and optoelectronic properties of the synthesized nanoparticles have been investigated.

In the present work, Sol-Gel synthesis method is employed to obtain pure SnO_2 and ZnO nanoparticles at 500^0C.

II. EXPERIMENTAL PROCEDURE

A. Synthesis

All chemicals used in the experiment were analytic reagent (AR) grade. Stannous Chloride ($SnCl_2.2H_2O$), Zinc Acetate $(CH_3COO)_2$ $Zn.2H_2O$ and Ammonia solution (25%) was purchased from Merck, India. All chemicals were used as received without further purification. Deionized water was used during the reaction.

In preparation of SnO_2, 5g of stannous chloride dihydrate is dissolved in 100 ml water. The mixture was stir for about 20 min. until a transparent sol is produced. After complete dissolution, Ammonia solution is added about pH reach 8 to above aqueous solution with stirring. Stirring is continued for 30 min. White gel precipitate is immediately formed. It is allowed to settle for 12 hrs. Then it is filtered and washed with water 5 times. The obtained sol is dried for 24 hrs at 80 ºC. Dried powder is crushed and heated at 500 ºC for 4 hrs [1, 2, 5, 9-10]. Same procedure repeated for ZnO nanoparticles using Zinc Acetate.

B. Characterization Technique

The structure of synthesized nanoparticles were characterized by X-ray diffractometer (Bruker D8 Advance). The surface morphology & grain size observed by Scanning Electron microscopy (JEOL JSM 5600) and Transmission electron microscopy (JEOL/JEM 2100). UV-Vis measurement was recorded using Jasco Spectrophotometer V-770 in a 200-1000 wavelength domain.

III. RESULT AND DISCUSSION

A. Structural and Morphological Analysis

Table I: Grain Size, Lattice Parameter, Microstructure, Dislocations Density(□) & Intensity

	D (nm)	a (Å)	c (Å)	V ($Å^3$)	strain ξ ($X\ 10^{-4}$)	δ ($x10^{14}$ line/m^2)	Intensity
SnO_2	12	4.740	3.184	71.555	19.45	59.17	717 (110)
ZnO	26	3.24	5.21	47.51	10.97	14.79	4171 (101)

XRD patterns of pure SnO_2 and ZnO nanoparticles sintered at 500^0C shown in Fig. 1. The obtained XRD peaks are matched with the tetragonal rutile structure for SnO_2 and hexagonal wurtzite structure for ZnO. All lattice parameters values a, c and cell volume are in good agreement with (JCPDS 77- 0452) and (JCPDS 05-0664) for SnO_2 and ZnO resp. as shown in Table I.

Average grain size of the sample was calculated using Debye-Scherrer's formula [11]. The estimated grain size, microstrain (□□□and dislocation density (□□□are given in Table I.

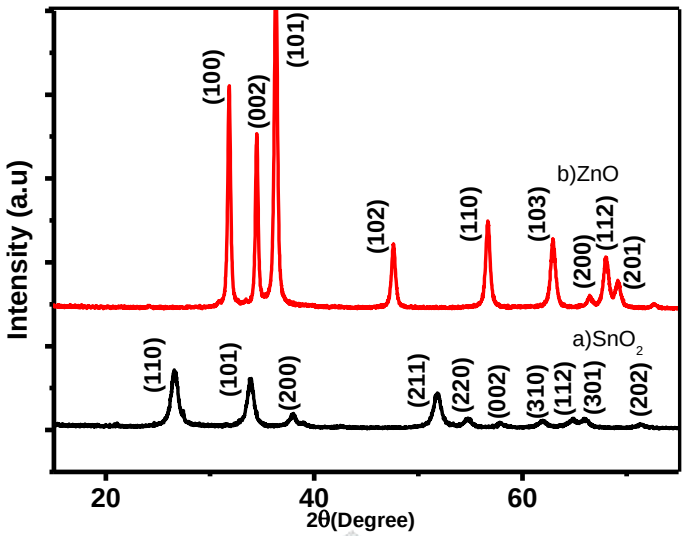

Fig. 1: a) XRD pattern of SnO_2 at 500^0C JCPDS 77-0452
b) XRD of ZnO at 500^0C, JCPDS -05-0664

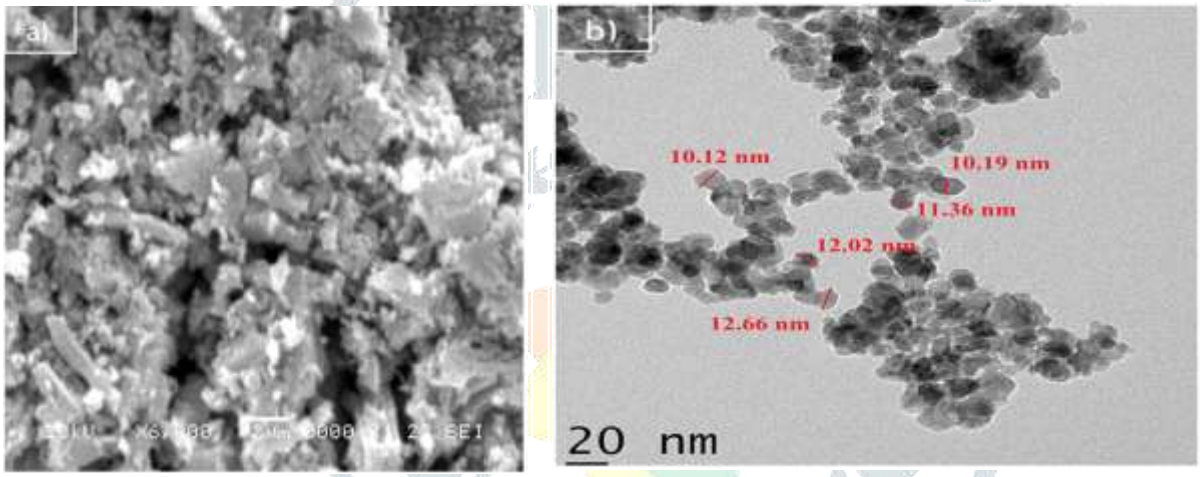

Fig. 2: a) SEM and b) TEM image of SnO_2 nanoparticle at 500^0C

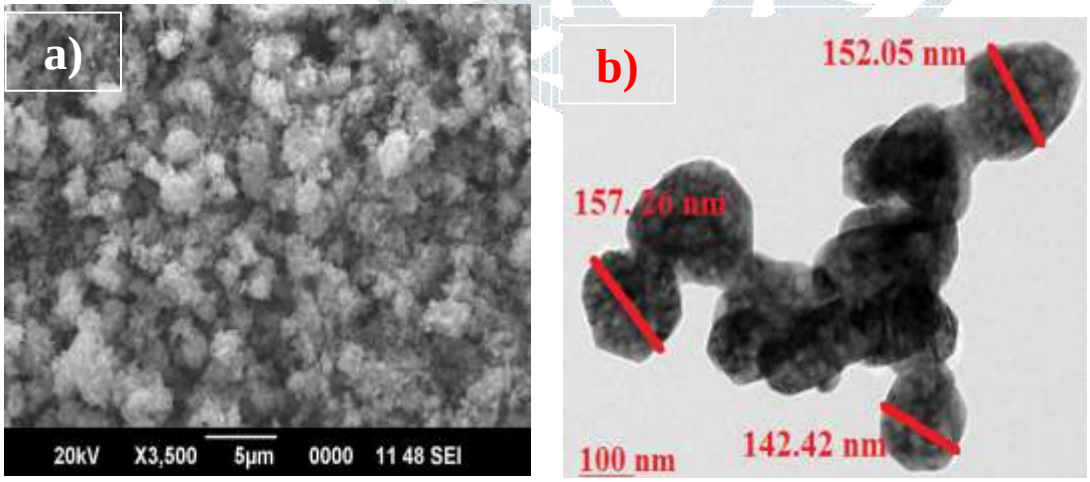

Fig. 3: a) SEM b) TEM image of ZnO nanoparticle at 500^0C

Fig. 2 and 3 shows the typical morphology of SnO_2 and ZnO nanoparticle respectively. It is seen that SEM image microstructure of these samples show the presence of large spherical aggregates of smaller individual nanoparticles. The surface state of such oxide nanoparticles influence the optical and electrical properties.

TEM image of the prepared nanopawder showing an average diameter of about ~11.26 nm and 150 nm for SnO_2 and ZnO respectively. The particle size obtained from TEM analysis is clearly match with the crystalline size calculated from XRD data of SnO_2 and higher for ZnO as shown in Table-1.

The surface state of such oxide nanoparticles influence there optical and electrical properties which are essential to ensure the implementation of the different optoelectronic devices and gas sensors.

B. Optical Study
Uv-vis Analysis

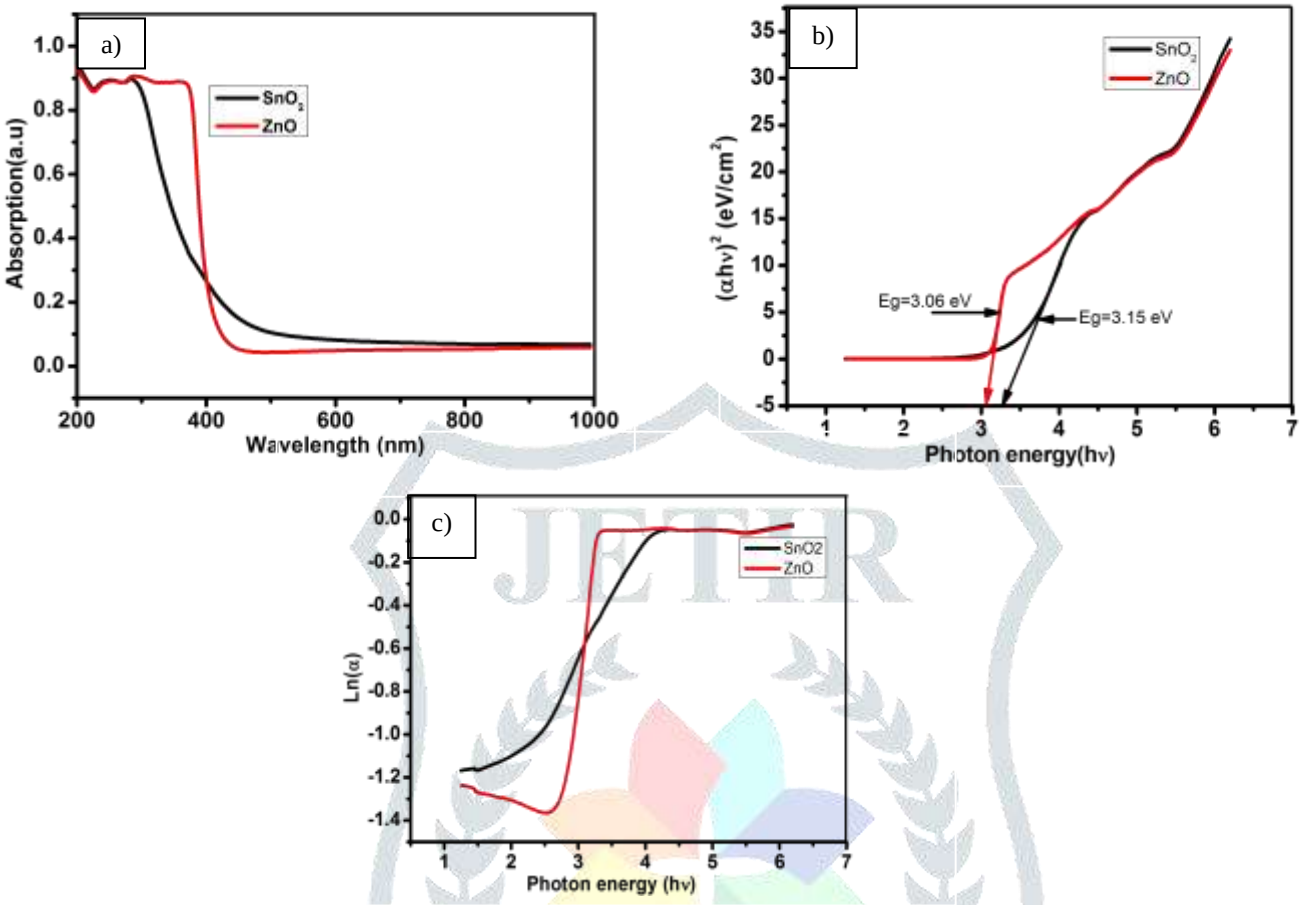

Fig. 4**:** a) Absorption b) Tauch Plot and c) Urbach Energy pattern of SnO_2 and ZnO

Fig. 4 (a), shows the absorption coefficient □(□) of SnO_2 and ZnO nanoparticles, with stronger absorption at lower wavelengths and low absorption at higher wavelengths. At 200 nm and 300 nm absorption spectra shows maximum, which indicates that the photo-excitation of electrons from the valence to the conduction band.

The optical band gap (Eg) is obtained by the linear region of a Tauc's plot by plotting $(\square h\square)^2$ vs h□□as□shown in fig. 4(b). The measured band gap (Eg) is found to be of 3.15 eV for SnO_2 and 3.06 eV for ZnO, which are slightly smaller as compared to the reported values of bulk 3.6 eV and 3.37 eV for SnO_2 and ZnO respectively [1, 5].

The Urbach E_U or band tail energy which characterizes the width of the located state and is associated with microstructural lattice disorder. The Urbach E_U values were obtained from the inverse of the slop of Ln(□) vs (h□) as shown in fig. 4 (c). The calculated value is found to be 0.5 eV and 0.37 eV for SnO_2 and ZnO respectively.

IV. CONCLUSION

This paper deals with structural, morphological and optical characterization of obtained SnO_2 and ZnO by Sol-Gel route at 500^0C. The XRD study shows that the obtained SnO_2 powder have rutile tetragonal structure and hexagonal wurtzite structure for ZnO. SEM images reveal the presence of agglomerates. TEM image confirms that its size closely matches with XRD value of SnO_2 and higher value for ZnO. UV-vis has successfully investigated to obtain band gap and band tail value.

The novel materials based on SnO_2 and ZnO with an interest in Opto-electronics, Photocatalytic, sensing devices and fabrication of smart windows definitely will demonstrate in recent years.

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