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Investigation of Structural and Optical Properties of SnO_2 Nano-rod by Sol-gel technique

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ABSTRACT

In this paper, SnO_2 nano-rod synthesized by a simple Sol-gel technique. 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 structure. The Transmission Electron Microscopy (TEM) shows the average particle size is of ~ 7.9 nm. The obtained materials are promissing to be useful in various photocatalytic and opto-electronics applications.

Keywords: Sol-gel, SnO_2, Nano-rod, Optical

I. INTRODUCTION

The development electronic devices with nanometer scale is a great challenge for scientific and technological applications. The knowledge of structural and optical properties of nanostructured metal oxides has a fundamental role in the understanding and development of new electronic devices [1].

Tin oxides as a sort of n-type semiconductor, high transparency, high surface-to-volume ratio, enhanced surface modes in their Raman spectra material have potential applications in gas sensing, catalysis, optoelectronics and solar cells [2] etc.
Several phenomena in Material Science are related to grain size growth. It is desirable to produce materials with nanometer scale to obtain and improve some specific properties [1].

The applied synthesis procedures have seen to affect substantially the crystallinity, microstructure and defect structure of the nano-rods. Several methods including Sol-gel [3-4], Hydrothermal [5], Electrospinning [6] have been utilized to synthesize SnO_2. 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. The properties of SnO_2 were found to be dependent on the processing conditions and nature of precursors used. The precursors play an important role in growth, the structure and the morphology as well as optical and electrical characteristics of the material. For optical devices like Solar cells, panel displays applications mainly affected by signal loss and delay, we have to improve the conductivity without affecting the transmission.

Due to the limitation of solubility, these ions acts as grain growth inhibitors and remain aggregates at the grain boundaries.

In the present work, Sol-gel synthesized SnO_2 nano-rods at 400^0C is obtained. The properties of Tin oxide on crystallographic, Morphological, compositional and Optical properties were studied.

II. MATERIALS AND METHODS

2.1 Synthesis

Tin oxide nano-rods were prepared by a Sol-gel technique. In a typical synthesis process of SnO_2,

dissolve 6g of $SnCl_4$. $2H_2O$ from Merck, India in 100 ml water and Stir about 20 min until a transparent sol is produced. Add aqueous Ammonia solution (25% merck, India) drop wise to the solution under constant stirring and pH of solution was adjusted to a value up to 8. After 24 Hr of aging in the air resulting opal gel were centrifuged and washed at least 5 times to remove impurity. The collected gel was dried in furnace over 80^0C/4h in the air. Then after crush the sample and sintered at 400^0C/4 Hr. Finally ashed coloured nano-rods were formed [3, 7-8].

2.2 Characterization techniques

The structure of synthesized nano-rods were characterized by X-ray diffractometer (Bruker D8 Advance). The surface morphology 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.

III. RESULT AND DISCUSSION

3.1 Structural Study

To study the grain size, crystal structure and lattice parameters of SnO_2, XRD data were used. The X-ray diffraction patterns of SnO_2 nano-rod at 400^0C shown in fig.1. The peaks were indexed using Powder X software and they are matched with the (JCPDS 77-0452) with a maximum intensity corresponding to (110) plane [9]. Further it has been observed that lattice parameters a and c are calculated using unit cell software program and cell volume as shown in Table-1.

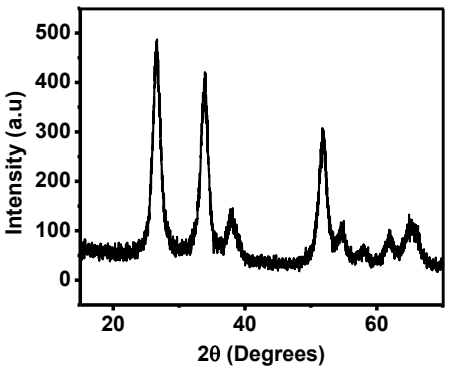


Figure 1. XRD of SnO_2 nanoparticles at 400^0C

The tetragonal rutile structure of SnO_2, which are consistent with the values in the standard card.

The estimated sizes at the most intense crystallographic plane (110) are given in Table 1. The grain size, lattice parameters a and c has been calculated from XRD data (Table 1). The particle size calculated by Scherrer formula for SnO_2 have been further validated by Transmission Electron Microscopy (TEM) observations.

On the other hand, geometric mismatch between crystalline lattices can cause microstrains ( ).

Dislocation is also one of the important factor to investigate growth mechanism. Dislocation density ( ) gives information on length of dislocation lines per unit volume (lines/m^2)[10-11]. The calculated values of and are given in table-1.

Table 1. The calculated values of the Grain size, Lattice parameter, Microstrain ( ) and Dislocations ( ).

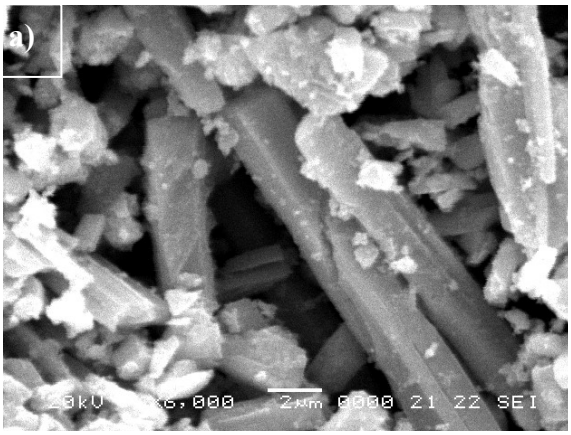
	D_{XRD} (nm)	a (Å)	c (Å)	a^2c ($Å^3$)	strain ξ ($X10^{-4}$)	($x10^{14}$ line/m^2)
SnO_2	8	4.728	3.175	70.97	42.9	156.25

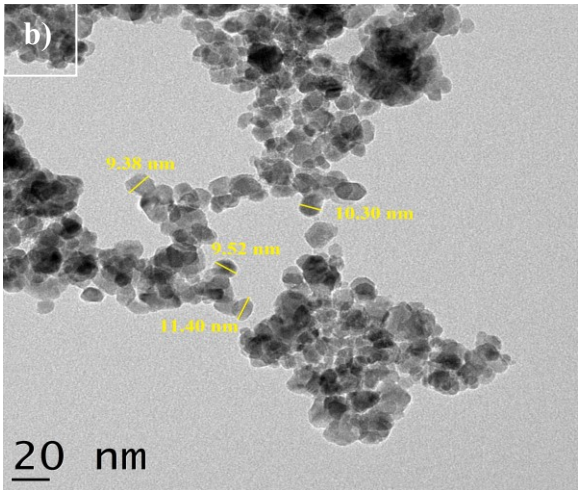
3.2 Morphological and Compositional Study

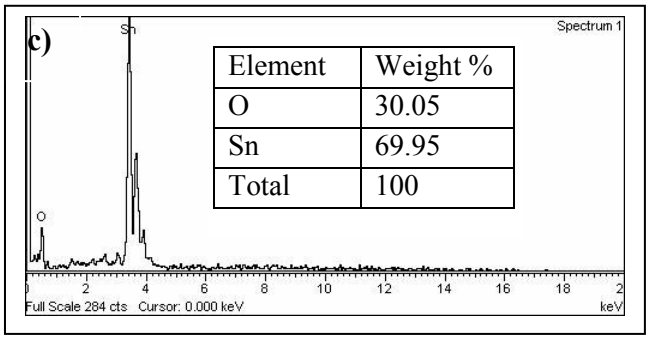
Figure 2 a) shows, the typical morphology of SnO_2 nano-rods. It is seen that SEM image of SnO_2

microstructure of these powder samples shows the size.

Figure 2 b) shows, TEM image of prepared SnO_2 nano-rod showing an average diameter of about 7.9 nm as well. The particle size obtained from TEM is closely match with the grain size calculated from XRD result.







Element	Weight %
O	30.05
Sn	69.95
Total	100

Figure 2. a) SEM and b) TEM image c) EDAX graph of SnO_2 at 400^0C

3.4 Optical Study

Figure 3 a) shows the absorption coefficient □(□) and transmittance of SnO_2 nano-rods from 200 to 1000 nm range. Samples showing low absorption at higher wavelength and strongest absorption at lower wavelength. The absorption spectra between 200 to 450 nm, shows a maximum, which indicates the photo-excitation of electrons from the valence band to the conduction band. It is well established that the absorption depends on several factors such as grain size, defect density and surface roughness etc.[10-11].

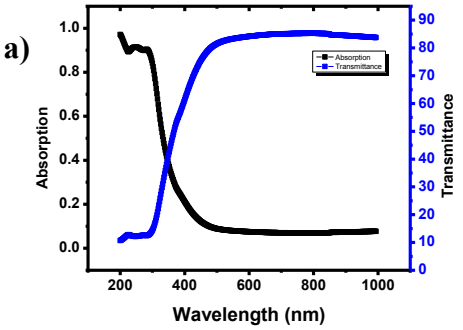
The optical transmittance spectra of SnO_2 nono-rods spectra shows that a transparency coefficient lying between 65 to 95 % in the visible range [10-11].

In order to calculate the optical band gap (Eg) we used the Tauc's relation [10-11],

$$h = A'(h□□ - Eg)^n$$

Where, is the absorption coefficient, A is a constant while the exponent n depends on the type of transition. Therefore, the optical band gap is obtained by the linear region of a tauc's plot by plotting h□ vs (□h□)²[2].

The Tauc's plot of SnO_2 samples are shown in Figure 4 b). The measured band gap Eg was found to be 3.5 eV, which is slightly less to the reported values of bulk SnO_2 i.e 3.6 eV. The Urbach E_U or band tail energy which characterizes the width of the located state and is associated with microstructural lattice disorder [2]. The Urbach E_U values were obtained from the inverse of the slop of Ln(□) vs (h□) Figure 3 c) of SnO_2 nano-rods and calculated value is found to be 0.31 eV.



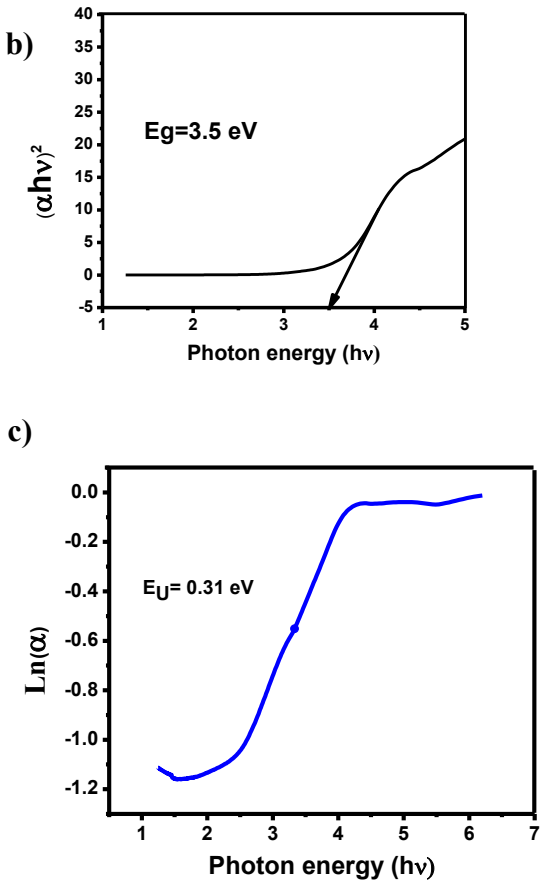


Figure 3. a) Absorption and Transmittance b) Tauch Plot c) Urbach Energy pattern of SnO_2 nano-rods.

IV. CONCLUSION

This paper deals with structural and optical properties of obtained tin oxide nano-rod by Sol-gel method at 400^0C. The XRD study shows that the obtained powder have tetragonal rutil structure. SEM images clearly shows the presence of nano-rods. TEM image confirms that its size closely matches with XRD value. Band gap and band tail is also studied.

V. ACKNOWLEDGEMENT

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