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Synthesis And Characterization Of Tin Dioxide Nanoparticles

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Abstract
Metal oxide nanoparticles show distinctive physical and chemical properties due to their narrow size and high surface area. The use of ultrasonic energy has become a growing area of research for the preparation of metal oxide nanoparticles. In the present study, we synthesized Tin dioxide Nanoparticles (SnO_2 NPs) by the Sonochemical method with stannous chloride as the Sn source. The X-Ray diffraction studies confirm the tetragonal crystal structure with a space group of p42/mnm, Morphological analysis was done by using a scanning electron microscope and energy dispersive X-Ray image analysis, and optical properties were studied by using UV absorbance spectrum, UV transmittance spectrum, and Tauc plot analyses.

Key words: *Tin dioxide, Optical properties, scanning electron microscope*

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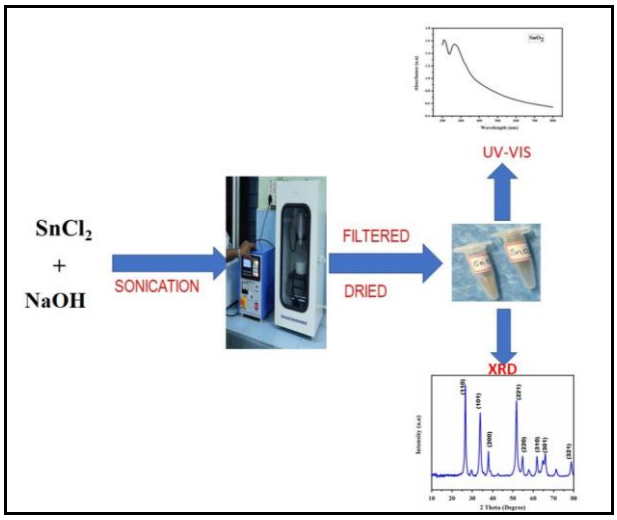
Graphical Abstract



I. Introduction

Nanotechnology has developed at enormous speed in a few decades. Metal oxide nanoparticles play a very important role in diverse areas of science[1]. It exhibits distinctive physical and chemical properties owing to its narrow size, high surface area, etc. The metal elements are able to form a large diversity of oxide compounds[2]. These can adopt a vast number of structural geometries with an electronic structure that can exhibit metallic semiconductor or insulator character.

Tin oxide is a wide band gap n-type semiconducting metal oxide. It has eccentric applications in the field of gas sensing, solar energy conversion, catalysis, transparent conducting electrode preparation, and antistatic coating. These type of multiple applications arises due to their high surface-to-volume ratio, chemical stability, large band gap, high exciton, etc [3]. The optical property of SnO_2 depends on the presence of impurities and its stoichiometry with respect to oxygen. SnO_2 NPs was developed by using different synthesis method such as chemical vapor deposition, sol-gel, sonochemical method, spray pyrolysis, decomposition, etc[4]. In recent years, the use of ultrasonic energy has attained great attention in the NPs synthesis owing to the avoidance of harmful chemicals.

In this aspect, here we synthesized SnO_2 NPs by the sonochemical method with stannous chloride as the Tin source. The synthesized NPs were characterized by various spectroscopic and microscopic analyses.

II. Experimental

Materials used

Stannous chloride ($SnCl_2$ 99%), Silver chloride (AgCl, 99%), Chloroform (95%), 1-Dodecanethiol (DDTh-98%), Sodium hydroxide (NaOH 99%), Ethanol (99%), were purchased from Merck-India.

Synthesis of SnO_2 NPs

SnO_2 NPs was synthesized by sonochemical method using the following synthesis procedures: 0.15 M of $SnCl_2$ was mixed with 50 ml of distilled water followed by stirring for 1 hour. At the same time, 0.3 M of NaOH was added with 100 ml of distilled water and prepared a homogeneous solution of NaOH. Then the prepared NaOH solution was added slowly into the $SnCl_2$ solution to attain a pH value 10. After that, the reaction mixture was sonicated for 6 hrs with 30 mins intervals using ultrasound probe sonication with the frequency of 20 KHz and 230 W. This reactant was kept undisturbed for 2hrs to obtain a white precipitate. This precipitate was filtered and washed with acetone and distilled water and dried in the oven for 90 sec at 80°C. The dried particles were calcined at 550 °C..

Physical characterization

The Structural properties were studied by X-ray diffraction studies (Riganku Ultima XRD spectrometer with a wavelength of 1.5Å (Cu Kα)). Morphology was examined by scanning electron microscope (Zeizz Supra 55VP) image analysis and energy dispersive spectrum analysis. The optical properties were examined by using a UV-Vis-NIR spectrophotometer (Model: L-650 UV, Perkin Elmer).

III. Results and discussion

The X-Ray diffraction spectrum of the synthesized SnO_2 nanoparticles is shown in Fig.1. Sharp and strong peaks are observed in this spectrum. These sharp peaks indicate the crystalline nature of the synthesized NPs. The diffraction peaks at around 2Θ = 26.57º, 33.88º, 37.93º, 51.76º, 55.32º, 61.85º and 65.95º assigned according to the (110), (101), (200), (211), (220), (112) and (301) planes of tetragonal structure of SnO_2 with the space group of p42/mnm (JCPDS file no 41-1445)[5]. The unit crystals dimensions are a= b= 4.73 A^0 and c=3.18 A^0. By using Scherrer equation, the average crystallite size of the prepared SnO_2 is calculated to be 32 nm.

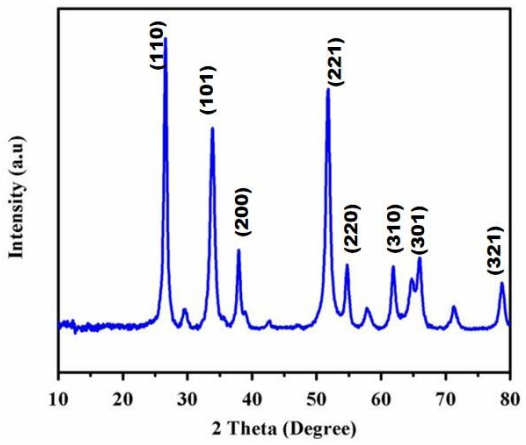


Fig. 1: XRD spectrum of SnO_2 NPs

The morphology of the SnO_2 NPs depicted in Fig2(a). This SEM image confirms the uniform spherical morphology of the synthesized NPs. More agglomerations are also observed in this SEM image. This is due to the narrow size of the particles[6]. From this image, the size of the particle is estimated to be 35 nm. It is almost similar to the size calculated by the Scherrer formula. EDX spectrum (Fig. 2(b)) shows the presence of Sn and O in the 1:2 elemental ratio.

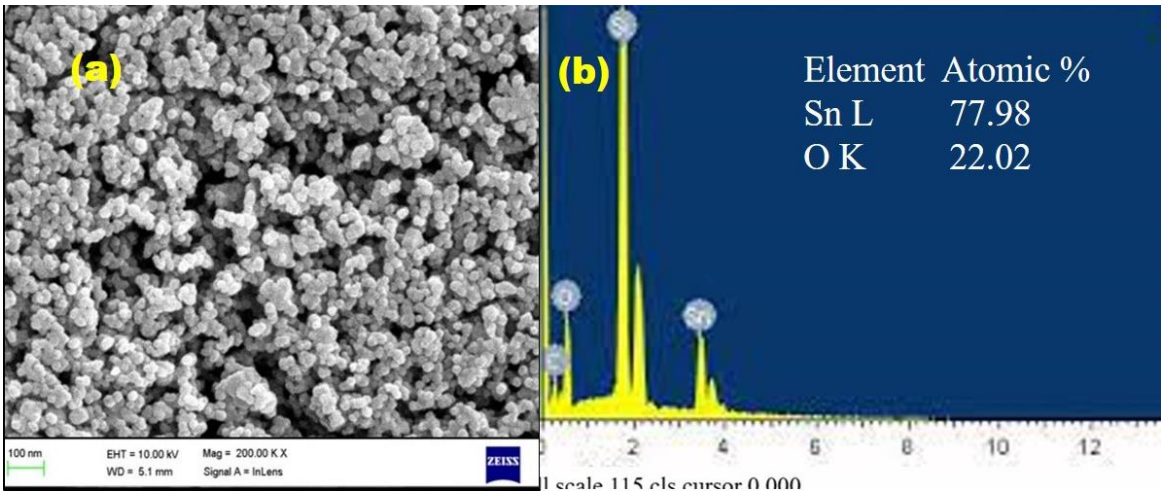


Fig. 2: (a) SEM image (b) EDX spectrum of SnO_2 NPs

The optical property of SnO_2 nanoparticles was studied by using UV – Vis absorbance spectrum recorded between 200 nm to 800 nm and its shown in Fig.3. This shows the wide absorption in the range of 200 to 400 nm and maximum absorbance at 280 nm. The wide absorption range in the visible region represents the light capturing property of SnO_2 nanoparticles from the visible region. Other than this, there is no exciton peaks are present in this spectrum. This clearly explain the high purity of the crystals.

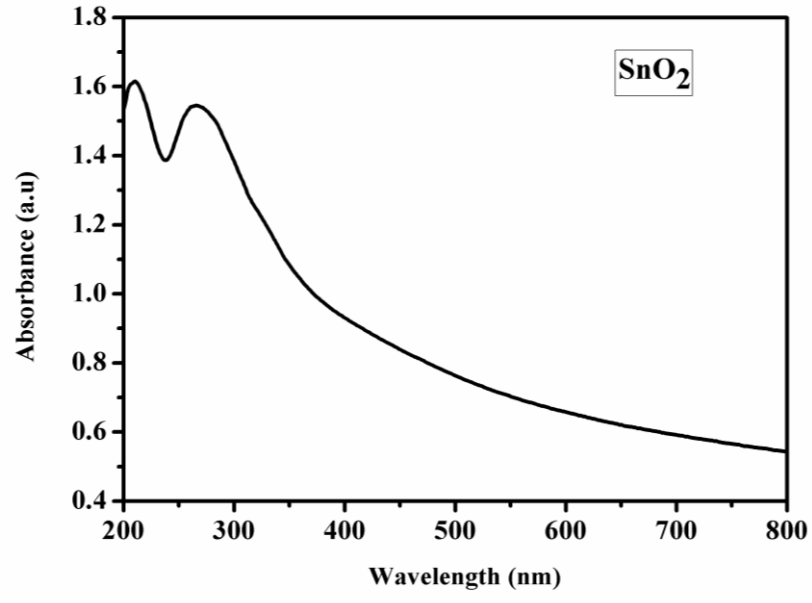


Fig. 3: UV-Vis absorption spectrum of SnO_2 NPs

From the absorption spectrum, the energy value ' hν ' and 'absorbance X hν ' are calculated. Using these values, Tauc plot (plotting $(\alpha h\nu)^2$ versus (hν) graph)[7–10] is drawn and it is shown in Fig.4 and the optical band gap energy value is estimated to be 3.55 eV. The SnO_2 nanoparticles has capturing photon of light greater than or equal to the 3.55 eV energy.

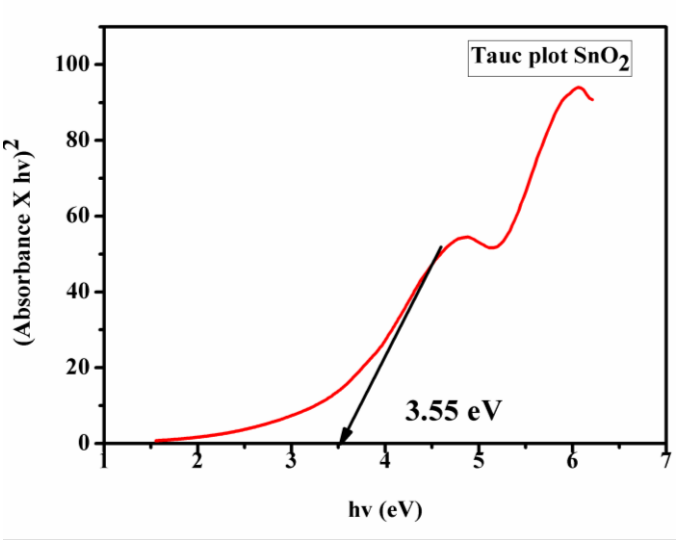


Fig. 4: Tauc plot of SnO_2 NPs

IV. Conclusion

39 nm sized SnO_2 NPs were synthesized through sonochemical method. All diffraction peaks in the XRD diffraction pattern are assigned to the tetragonal crystal phase of tin oxide. UV- VIS absorbance shows that the absorbance takes place from 200 nm to 800 nm. Also, high absorbance peak is observed at around 201nm and 298 nm. From the Tauc Plot, band gap of synthesized tin oxide SnO_2 NP's are determined and found to be at 3.55 eV.

Conflict of Interest

The authors declare no competing financial interest.

Acknowledgment

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