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Effect of Preparation Method on the Physical Properties of SnO_2 Thin Films

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Abstract

Thin films of tin oxide SnO_2 were prepared using chemical bath deposition CBD and spray pyrolysis method, the films have been examined using different techniques to investigate the optical, structural and electrical properties of them. The scanning electron microscope and x ray spectroscopy Show that the both films are amorphous and grain size within the nanoscale, where the grain size for the films prepared by CBD method was about 70nm while it was about 58nm for the films prepared by spray pyrolysis method. The energy gap also affected by the deposition method, where it was about 2.1eV and 2.3 eV for the films prepared by CBD and spray pyrolysis methods respectively.

Keywords: Tin Oxide, Optical Properties of SnO_2, x- Ray of Tin Oxide and I-V Characteristics of the Thin Films.

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Introduction

Tine Oxide (SnO_2) has a distinctive physical and chemical properties Table 1, it is an n-type semiconductor characterized by a set of properties including , tetragonal crystal structure Fig. 1, wide band gap 3.6-3.8eV (Mendes et al., 2012; Naje et al., 2013), high photosensitivity (Brambilla et al., 2001; Huang et al., 2015), high thermal stability (Cusick et al., 2017; Fujihara et al., 2004; Hwang et al., 2020), high degree of transparency in visible region of spectrum (Sharma, 2020; Karthick et al., 2020) and has large exciton binding energy (130 meV) (Sheng et al., 2013; Tagliente et al., 2010), Due to these unique properties, it has been used in many applications including gas sensors (Ayeshamariam et al., 2013), rechargeable Li batteries (Patil et al., 2012), solar cell (Teimouri et al., 2023) and liquid crystal displays (Kolentsov et al., 2004) and heat reflecting mirrors (Kojima et al., 2001), several techniques have been used to prepare tin oxide nanoparticles and thin films including Sol-gel (Bhagwat et al., 2015), chemical bath deposition (Tay et al., 2023), spray pyrolysis (Gordillo et al., 1994), thermal oxidation (Abdullah et al., 2018) and Room-temperature sputtered (Kam et al., 2019).

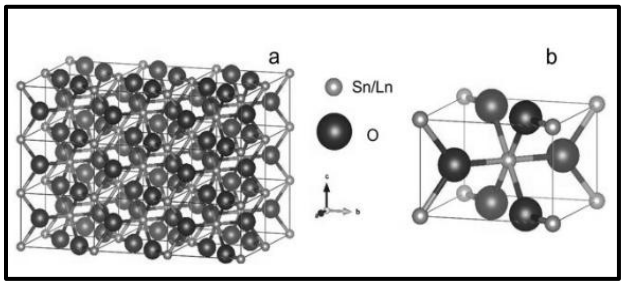

Fig. 1: Crystal Structure of SnO_2 in the Rutile Phase (Cojocaru et al., 2017)

Material and Methods

Tin chloride SnC_{l2} and potassium hydroxide KOH have been used as a precursor to deposit tin oxide SnO_2 on glass slides by chemical bath deposition and spray pyrolysis methods, where 0.6g and 0.3g of SnC_{l2} and KOH were dissolved separately in 50 ml of distilled water respectively. Both solutions then mixed and stirred for 1hr by magnetic stirrer (Younus et al., 2020; Saeeda & Uonisb, 2022). We divide the later solution into two equal halves. The first half was used to deposit tin oxide films using the chemical bath deposition method at 90°C and 20 minutes deposition time, while the second half of the solution was used to deposit thin films of tin oxide using the spray pyrolysis method, with 5 sprays, 3 ml spray quantity, 90°C deposition temperature and 20cm distance between nozzle and substrates (Al-Saqa et al., 2023). The current-voltage characteristics of the films was also measured.

Results and Discussion

The optical properties of the tin oxide thin films prepared using both methods have been measured using single beam spectrophotometer. The Transmittance of the films prepared by the both methods increased with the wavelength of the incident light, but the Transmittance of the films prepared by the spray pyrolysis method was higher than that of the films prepared by the chemical bath deposition method. The absorbance also decreases with wavelength for both films.

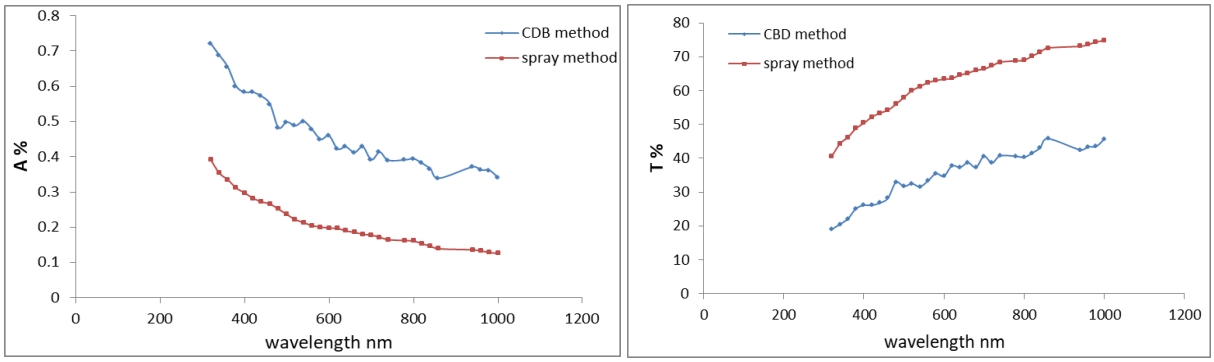

Fig. 2: Transmittance and Absorbance of SnO_2 Films Prepared by Chemical Bath Deposition and Spray Pyrolysis Methods

Transmittance and Absorbance of SnO_2 Films Prepared by Chemical Bath Deposition and Spray Pyrolysis Methods shown in Fig. 2.

The energy gap was calculated for the both films, where it was about 2.1eV for the films prepared by chemical bath deposition and 2.3eV for the films prepared by spray pyrolysis method Fig. 3.

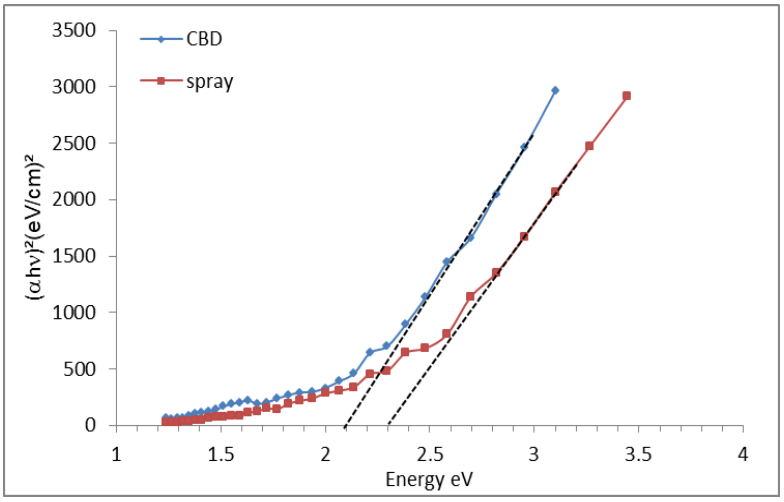

Fig. 3: Energy Gap of SnO_2 Films Prepared by Chemical bath Deposition and spray pyrolysis Methods

Scanning electron microscope images of SnO_2 films are shown in Fig. 4, the images show that the both films are amorphous. The average grain size of the films prepared by CBD method was about 70nm while it was about 58nm for the films deposited by spray pyrolysis method.

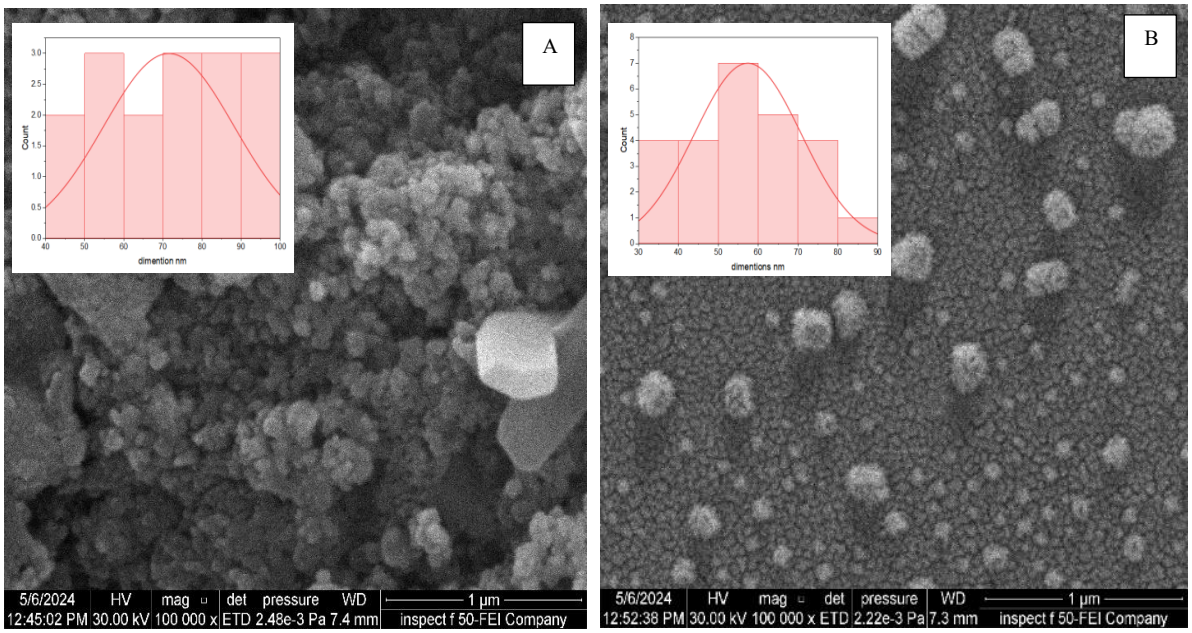

Fig. 4: Scanning Electron Microscope Images of SnO_2 Films Prepared by (A) CBD Method and (B) Spray Pyrolysis Method

The x-ray spectrums of both films are shown in Fig. 5, both spectrums show that the films are amorphous. The average grain size that calculated using Scherer equation was about 80.98 nm for the films prepared using CBD method and about 54.66 nm for the films prepared using spray pyrolysis method and these results are agree with SEM images Table 1.

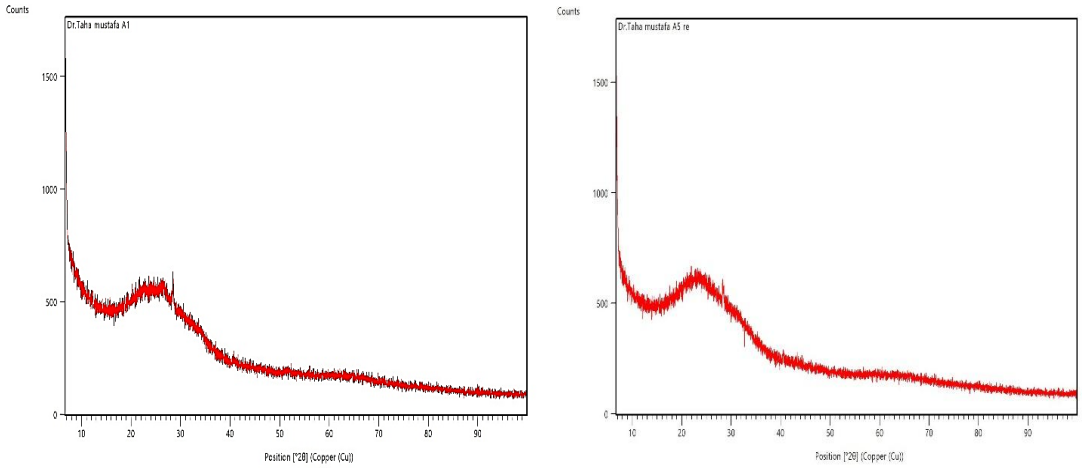

Fig. 5: X-Ray Spectrums of SnO_2 Films Prepared by (A) CBD Method and (B) Spray Pyrolysis Method

Table 1: The Average Grain Size of SnO_2 Films Prepared by CBD Method and Spray Pyrolysis Method

2-Theta (θ)	FWHM [°2Th.]	D nm	Average grain size nm
8.3234	0.15765	50.53096639	80.98988723
28.4644	0.08217	99.75104027	
33.5684	0.05839	142.1199741	
37.0334	0.2655	31.55756814	
27.9584	0.16409	49.89616943	54.66789508
32.6554	0.20188	41.00839088	
32.7104	0.11327	73.09912493	

The current-voltage characteristics of the SnO_2 thin films are shown in the Fig. 6. The thin films showed sensitivity deposition method, we find that at any applied voltage, the current values were higher for the films prepared by the spraying pyrolysis method compared to the current values for the films prepared by the chemical bath method.

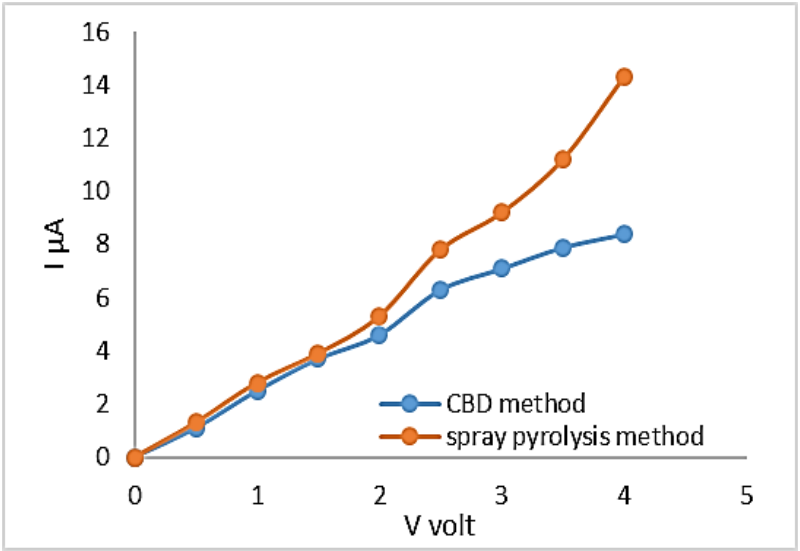

Fig. 6: Current-Voltage Characteristics of SnO_2 Films Prepared by CBD Method and Spray Pyrolysis Method

Conclusions

The optical, structural and electrical properties of the SnO_2 thin films prepared by different methods (CBD and spray pyrolysis methods) were compared and we found the following:

- SEM images and X- ray spectrums of the Both films show that the films are amorphous.
- The grain size for the films prepared by CBD method was about 70nm while it was about 58nm for the films prepared by spray pyrolysis method.
- The energy gap was about 2.1eV and 2.3 eV for the films prepared by CBD and spray pyrolysis methods respectively.

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