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REGULAR ARTICLE

Synthesis by Organic Solar Cells SnO_2 Thin Films for Gas Sensing

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In the present work, SnO_2 thin films were successfully elaborated on a glass substrate by spray pneumatic method with 0.1 M using tin chloride dehydrate at 450 °C by organic solar cells. The effect of deposition rate (5, 10 and 15 ml) on structural, optical and electrical characterizations of SnO_2 was investigated. After characterized, we have observed that the elaborated SnO_2 thin films have a polycrystalline structure with maximum crystallite size is 35.3 nm for 10 ml. The transmittance of SnO_2 thin films were decreased and increased with increasing SnO_2 rate in the visible region, it about 60 %, the optical bandgap energy increased with increasing of SnO_2 rate from 3.2 eV for 5 ml to 3.6 eV for 15 ml. The electrical conductivity was increased from 0.01 $(\Omega\cdot cm)^{-1}$ for 05 ml of SnO_2 to 0.06 $(\Omega\cdot cm)$ for 15 ml of SnO_2. The prepared SnO_2 thin film was suitable for gas sensing applications due to the existing phase and higher electrical conductivity.

Keywords: SnO_2, Thin films, Spray pneumatic method, Organic solar cells, Electrical conductivity.

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1. INTRODUCTION

In the latest research, for the important subjects, in the field of materials science, the synthesis of thin films from a metal oxide (semiconductor) that was used as a gas sensor. SnO_2 is one of the most n-type semiconductor materials due to the good electrical conductivity and its good chemical stability, SnO_2 can be deposited onto glass, oxides, ceramics, and substrate materials of other types [1, 2]. Gas sensors based on SnO_2 thin films are used to detect a variety of hazardous gases, combustible gases, industrial emissions, and pollution gases [3, 4]. In addition, SnO_2 thin films are also used for film resistors, electric conversion films, heat reflective mirrors, semiconductor–insulator–semiconductor (SIS) heterojunction structures, and surface protection layers of glass. At present, its most common application is as the anode material of solar cells [1-5].

The aim of this work is to obtain a thin film with good physical properties for gas sensing applications. In the past research, the literature was investigated the SnO_2 thin film as detection in the environment for various gases such as CO, CO_2, SO_2, NO_2, CH_4. However, we have prepared the SnO_2 thin films for furthers application in gas sensing due to the corporation of the Sn and O increasing the electrical conductivity. The spray pneumatic method has been used in this work to fabricate the thin films of SnO_2 by new methods (organic solar heater) for deposition of SnO_2 thin films (see Fig. 1). This method was developed for readers and researchers for the electricity economy and the presence of oxygen in the open has a role in the formation of thin layers of SnO_2 easily.

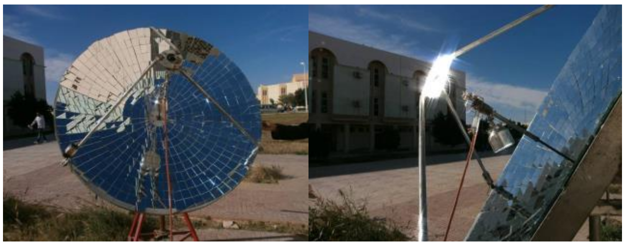

Fig. 1 – A photograph of the experimental setup.

2. EXPERIMENTAL DETAILS

The prepared solutions SnO_2 have been dissolved of 0.1 M of the Tin(II) chloride dihydrate $SnCl_4.2H_2O$ in the absolute H_2O, HCl was used as a stabilization solution of SnO_2. The solution was stirred a heated at 40 °C to have a solution with high transparent. The organic solar cells were fabricated through this process. We fabricated the organic solar cells, which consisted of a mirror layer inside (ITO glass) and a substrate holder. We established the substrate layer to maintain the substrate temperature using the mirror layer (see Fig. 1).

The SnO_2 thin films have been characterized in order to get the physical properties such as the optical, structural and electrical. The crystalline structure of fabricated films was obtained by X-ray diffraction (Bruker-XRD AXS-8D, λCuKα = 0.15406 nm with 2θ varying between 20° and 80°). The optical transmittance of fabricated SnO_2 films was measured by an UV-visible (35-LAMBDA) in the range of 300-900 nm. And the electrical conductivity was measured by injection current-voltage by four-point method into the deposited film surface. All characterizations have been made at stable conditions.

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3. RESULTS AND DISCUSSION

The crystalline structure of SnO_2 thin films is detected in Fig. 2, it is presented the X-ray diffraction variation in the range of $2\theta = 20°$ to $80°$. The XRD of SnO_2 thin film presents same diffraction peaks at different diffraction angle are (110), (101), (200), (211), (310) and (112) crystal peaks of SnO_2 at $2\theta = 26°$, $33°$, $38°$, $54°$, $62°$ and $66°$. After characterized, we have observed that the elaborated SnO_2 thin films have a polycrystalline structure.

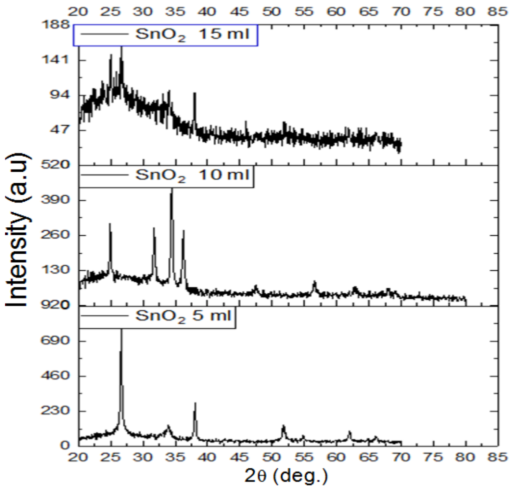

Fig. 2 – X-ray diffraction spectra of SnO_2 thin films at different deposition rates

The crystallite size of all deposited SnO_2 thin films was calculated by the Debye-Scherrer formula [6]:

$$G = \frac{0.9\lambda}{\beta \cos\theta} \qquad (1)$$

where G is the crystallite size, λ is the wavelength of X-ray ($\lambda = 1.5406$ A), β is the FWHM and θ is the half diffraction angle. Reported in the Fig. 3 as a function of deposition rate the variation of the average crystallite size of SnO_2 thin films, as seen, the crystallite size increased and decreased with increasing of SnO_2 rate from 32.5 nm for 5 ml to 35.3 nm for 10 ml and 29.6 nm for 15 ml, the decrease of crystallite size can be explained by the increase of electrical conductivity.

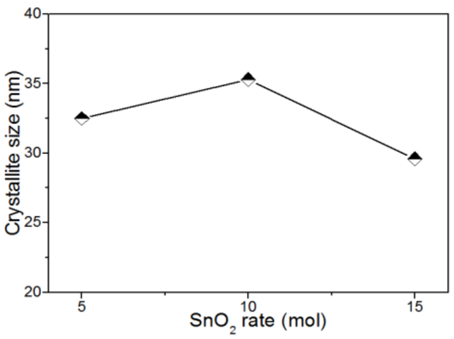

Fig. 3 – The variation of crystallite size as a function of deposition rate in SnO_2 thin films

In Fig. 4, the variation of optical transmittance of elaborated SnO_2 thin films have been presented as a function of the longer of the wavelength in the range of 300-900 nm. As seen from these spectra's the transmittance of SnO_2 thin films were decreased and increased with increasing SnO_2 rate in the visible region, the maximum transmittance of SnO_2 thin film was obtained for 15 ml.

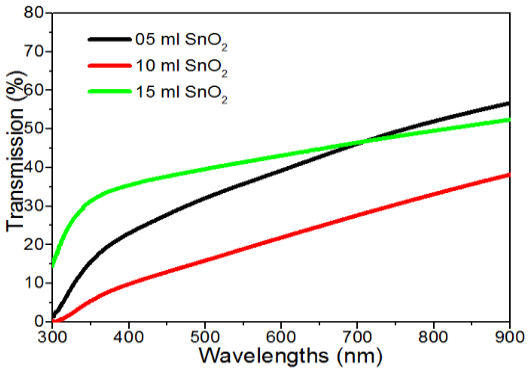

Fig. 4 – Transmission spectra of SnO_2 thin films as a function of deposition rate

The optical bandgap energy of fabricated thin films of SnO_2 have been derived from the direct transitions of interband in the valence band and conduction band, it was determined by following equation [7]:

$$(Ah\upsilon)^2 = B(h\upsilon - E_g) \qquad (2)$$

Where A, $h\upsilon$, B and E_g are the absorbance, the energy of photon, a constant and the bandgap energy of SnO_2 thin films, respectively. Fig. 5 shows the variation of the optical bandgap energy of fabricated SnO_2 thin films at several SnO_2 rates. As seen, the optical bandgap energy increased with increasing of SnO_2 rate from 3.2 eV for 5 ml to 3.6 eV for 15 ml, this increase can be explained by the corporation between Sn and O, which was showed for the oxygen vacancy.

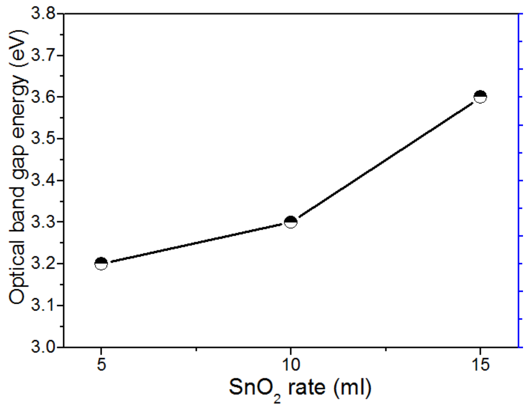

Fig. 5 – The variation of optical band gap E_g of SnO_2 thin films with deposition rate

The electrical characterization as the conductivity of fabricated SnO_2 thin films is placed in Fig. 6, as seen, the electrical conductivity was increased from 0.01 $(\Omega\cdot cm)^{-1}$ for 05 ml of SnO_2 to 0.06 $(\Omega\cdot cm)$ for 15 ml of SnO_2, , it is comparable with the variation of the crystallite size (see Fig. 3) and optical bandgap energy (see Fig. 5). The decrease of electrical conductivity of SnO_2 thin films caused by the oxygen vacancy and the increase can be linked by the oxygen diffusion.

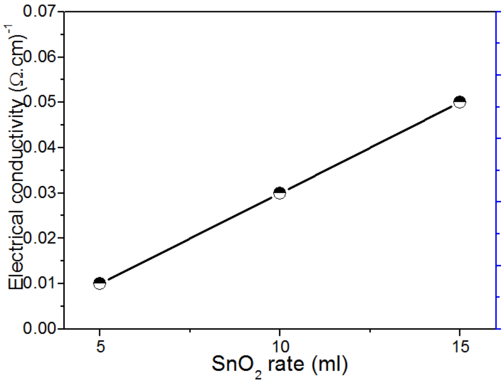

Fig. 6 – Electrical conductivity of SnO_2 thin films at different deposition rate

4. CONCLUSION

In this work, SnO_2 thin films were successfully elaborated on a glass substrate by spray pneumatic method with 0.1 M using tin chloride dehydrate, the organic solar cells were fabricated through this process. The effect of deposition rate on structural, optical and electrical characterizations of SnO_2 was investigated. After characterized, we have observed that the elaborated SnO_2 thin films have a polycrystalline structure with maximum crystallite size is 35.3 nm for 10 ml. The transmittance of SnO_2 thin films were decreased and increased with increasing SnO_2 rate in the visible region, it about 60 %, the optical bandgap energy increased with increasing of SnO_2 rate from 3.2 eV for 5 ml to 3.6 eV for 15 ml. The electrical conductivity was increased from 0.01 $(\Omega\cdot cm)^{-1}$ for 05 ml of SnO_2 to 0.06 (Ω·cm) for 15 ml of SnO_2. The prepared SnO_2 thin film was suitable for gas sensing applications due to the existing phase and higher electrical conductivity.

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Синтез тонких плівок SnO_2 для вимірювання газу органічними сонячними елементами

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У роботі тонкі плівки SnO_2 були синтезовані на скляній підкладці пневматичним методом розпилення з 0,1 М з використанням дегідрату хлориду олова при 450 °C органічними сонячними елементами. Досліджено вплив швидкості осадження (5, 10 і 15 мл) на структурні, оптичні та електричні властивості SnO_2. Було виявлено, що розроблені тонкі плівки SnO_2 мають полікристалічну структуру з максимальним розміром кристалітів 35,3 нм на 10 мл. Коефіцієнт пропускання тонких плівок SnO_2 зменшувався і збільшувався зі збільшенням швидкості SnO_2 у видимій області і становив близько 60%, оптична енергія забороненої зони збільшувалася зі збільшенням швидкості SnO_2 від 3,2 еВ для 5 мл до 3,6 еВ для 15 мл. Електропровідність була збільшена з 0,01 $(\Omega\cdot см)^{-1}$ для 05 мл SnO_2 до 0,06 (Ω·см) для 15 мл SnO_2. Підготовлена тонка плівка SnO_2 може бути використана для датчиків газу.

Ключові слова: SnO_2, Тонкі плівки, Пневматичний метод розпилення, Органічні сонячні елементи, Електропровідність.