الخصائص البصرية والتركيبية لأغشية SnO_2 المحضرة بطريقة الترذيذ

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الخلاصة

حضرت أغشية SnO_2 الرقيقة وبسمكين مختلفين على سطوح زجاجية باستخدام طريقة الترذيذ المغناطيسي درس التركيب البلوري واتجاه الأغشية باستخدام طيف الأشعة السينية. وأظهرت النتائج بان النماذج المحضره ذات تركيب متعددة التبلور . حسب حجم الحبيبة ووجد بأنه يساوي

nm (28.8 ,25.35) درس التركيب السطحي الدقيق للغشاء ومكوناته باستخدام SEM و EDX وكانت الأسطح كلها متجانسة ومرصوصة. حسبت فجوة الطاقة المباشرة وكانت مساوية eV (3.85) وبعض الثوابت البصرية مثل معامل الانكسار، معامل الخمود والمركبة الحقيقية والخيالية لثابت العزل الكهربائي من خلال طيف النفاذية ضمن المدى nm (300-900).

Optical and Structural Properties of SnO_2 Thin Films Prepared by Sputtering Method

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Abstract

SnO_2 thin films of different two thicknesses were prepared an glass substrate by DC magnetron sputtering. The crystal structure and orientation of the films were investigated by XRD patterns. All the deposited films are polycrystalline. The grain size was calculated as 25.35, 28.8 nm. Morphological and compositions of the films were performed by SEM and EDX analyses respectively. The films appeared compact and rougher surface in nature. The allowed direct band gap was evaluated as 3.85 eV, and other optical constants such as refractive index, extinction coefficient, real and imaginary parts of dielectric constants were determined from transmittance spectrum in the wavelength range (300-900) nm and also analyzed.

Introduction

Transparent conducting oxide thin films are of great interest, due to their variety of application. Consequently, thin films with high optical transparency and electrical conductivity have been a subject of investigation since last century [1-3]. Thin oxide is one of the most promising materials for optoelectronic and sensor applications owing to its high transmittance and electrical conductivity. The SnO_2 films are n-type semiconductors with a direct optical band gap of about (3.87-4.3) eV [4-5]. The structure of the material in its bulk form is tetragonal rutile with lattice parameters a=b=4.737 ^{o}A and c= 3.816 ^{o}A [6]. However in thin film form depending on the deposition technique its structure can be polycrystalline or amorphous [7]. The grain size is typically (200-400) ^{o}A, which is highly dependant on deposition technique, temperature, doping level etc. [4-5]. SnO_2 films close to stoichiometric condition have low free carrier concentration and high resistivity, but non-stoichiometric SnO_2 films have high carrier concentration, conductivity and transparency. This comes about from an oxygen vacancy in the structure so that the formula for the thin film material in $SnO_{2-x,}$ where x is the deviation from stoichiometry [4].

There are several deposition techniques to grow SnO_2 thin films including chemical vapor depositions [8], magnetron sputtering [9], spray pyrolysis [10] etc.

In this work, we have investigated the optical properties of SnO_2 thin films prepared by sputtering techniques.

Experimental

The SnO_2 films were prepared by DC magnetron sputtering. Fig.(1) is the schematic diagram of the equipment. The glass substrate is positioned obliquely above the target. The substrate heater is positioned in the anode, and substrate temperature is controlled by a thermocouple, and held constant at 200^{o}C. The substrate makes thermal contact with the anode through the copper substrate holder, and the target anode distance is kept at about 30mm.

Tine oxide SnO_2 was carried out by using magnetron sputter source coupled to 60W dc power supplies. The vacuum was evacuated by an Edwards 306 pumping system , the vacuum chamber was exhausted by an oil-diffusion pump at $2x10^{-6}$ Torr in around 30 minutes, in an atmosphere of argon and oxygen Ar 95% and O_2 5% respectively, and magnetic field 370 gauss. Tin Oxide was sputtered from targets on the glass substrate at temperature 200^oC. The targets material are in the form of plates with 60mm diameter and 2mm thickness and made from SnO_2 powder.

The crystal structure, surface morphology, and thickness of the films were analyzed by using x-ray diffraction (XRD) and scanning electron microscope (SEM). The optical transmittance measurements were performed with UV/VIS/NIR spectrophotometer with a double beam in the wavelength range of (300-900) nm.

Results and Discussion

Fig. (2) Shows the diffraction patterns of SnO_2 thin films. As seen in this figure, the films are polycrystalline, and characterized by the presence of stronger but broader characteristic peaks located at 2θ = 26.6, 33.9, 37.8, 46.4, 51.7, 61.9, 65.4, arising out of reflection from (110), (101), (200), (210), (211), (310), and plan (301) respectively. The average grain size g can be estimated by using Scherreris formula. [11]

$$G = 0.9\ \lambda / \beta \cos\theta \qquad (1)$$

Where β is the full width at half maximum (FWHM) of distinctive peak (read), θ the Braggs angle, and λ = 0.154 nm Cuk_{α}.
The crystallite size is estimated about 25.35, 28.8 nm for 0.802, 0.705 nm thickness respectively. The increase in films thickness enhances the preferred orientation with an increase in grain size and intensities

The EDX spectra of the films are shown in Fig. (3), these spectra show that the expected elements exist in the solid films.

Fig.(4) shows scanning electron microscopy SEM of films at 20000X magnification. The films appeared to be compact and rougher surface in nature, the average grain size was measured between (200-250) nm
To calculate the thickness of the films, we used SEM picture of the cross sections of the films as shown in fig. (5). The films thickness was found to be 0.802 and 0.705 nm approximately.

For most applications, high transmission in the visible range is very important. Fig. (6) Shows transmittance of SnO_2 films. The average transmittance value of the films is >80 in the visible range, and it is evident that the transmittance decreases with the increase of thickness .This is due to a decrease in light scattering losses.
The absorption coefficient α was calculated by using the following expression [12]

$$\alpha = \frac{1}{t} \ln(T) \qquad (2)$$

Where T is transmittance, t is the films thickness. The direct optical band gap E_g was determined by using equation

$$\alpha h\upsilon = \beta \left(h\upsilon - E_g\right)^{\frac{1}{2}} \qquad (3)$$

Where β is a constant, E_g is determined by extrapolating the straight line portion of the spectrum to $(\alpha h\upsilon)^2 = 0$. From this drawing, the optical energy gap, E_g = 3.85 eV is deduced and independent on the film thickness, as shown in Fig. (7). This value is very close to the previously reported data of SnO_2 thin films (3-5).
The complex optical refractive index of the films is described by the following relation [12]

$$n = n(\omega) + ik(\omega) \quad (4)$$

Where n is the real and k is the imaginary part (extinction coefficient) of complex refractive index. The refractive index and extinction coefficient of the films were determined from the following relations [12]

$$n = \frac{1+R}{1-R} + \left[\left\{ \frac{1+R}{1-R} \right\}^{\frac{1}{2}} - (k^2+1) \right]^{\frac{1}{2}} \quad (5)$$

$$K = \frac{\alpha\lambda}{4\pi} \quad (6)$$

Where R is the reflectance. The n and k value decrease up to certain value with the increasing wave length λ as shown in Fig. (8) and Fig. (9). This result is in a good agreement with earlier results [3،10]
The dielectric constant ε is defined as [13]

$$\varepsilon(\omega) = \varepsilon_r(\omega) + i\,\varepsilon_i(\omega) \quad (7)$$

The real ε_r and imaginary parts ε_i of dielectric constant are related to the n and k values, the ε_r and ε_i values were calculated by using the formulas [13]

$$\varepsilon_r(\omega) = n^2(\omega) - k^2(\omega) \quad (8)$$

$$\varepsilon_i = 2n(\omega)\,k(\omega) \quad (9)$$

Both ε_r and ε_i values decrease with the increasing wavelength as shown in Fig.(10) and Fig.(11). It is clear that the optical constant has the same behavior, decreases up to certain value with the increasing wavelength and the effect of thickness is only at log wave length.

Conclusions

The X-ray diffraction analysis showed that the SnO_2 films are polycrystalline in nature, and the increase, in film thickness enhances the preferred orientation with an increase in the grain size and intensities. Optical measurements show that the film possesses high transmittance over 80% in the visible region and sharp absorption edge near 325 nm. The film has a direct band gap of 3.85 eV which is independent on the thickness. Optical constants slitly depend on the film thickness.

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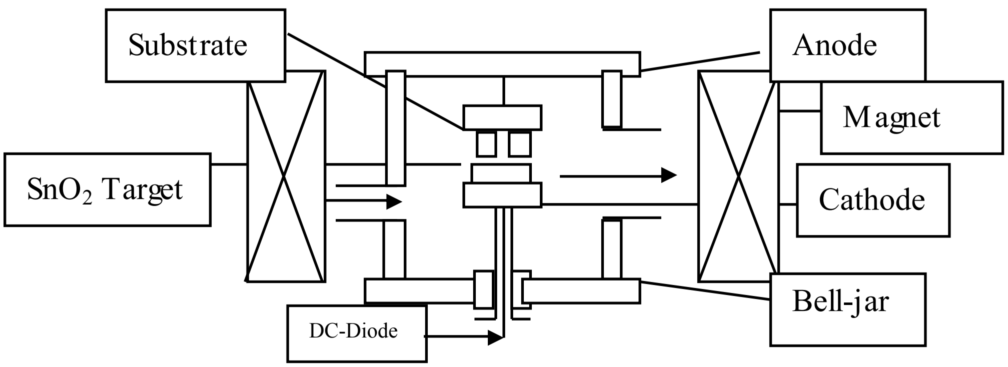

Fig. (1) :Schematic diagram of sputtering equipment

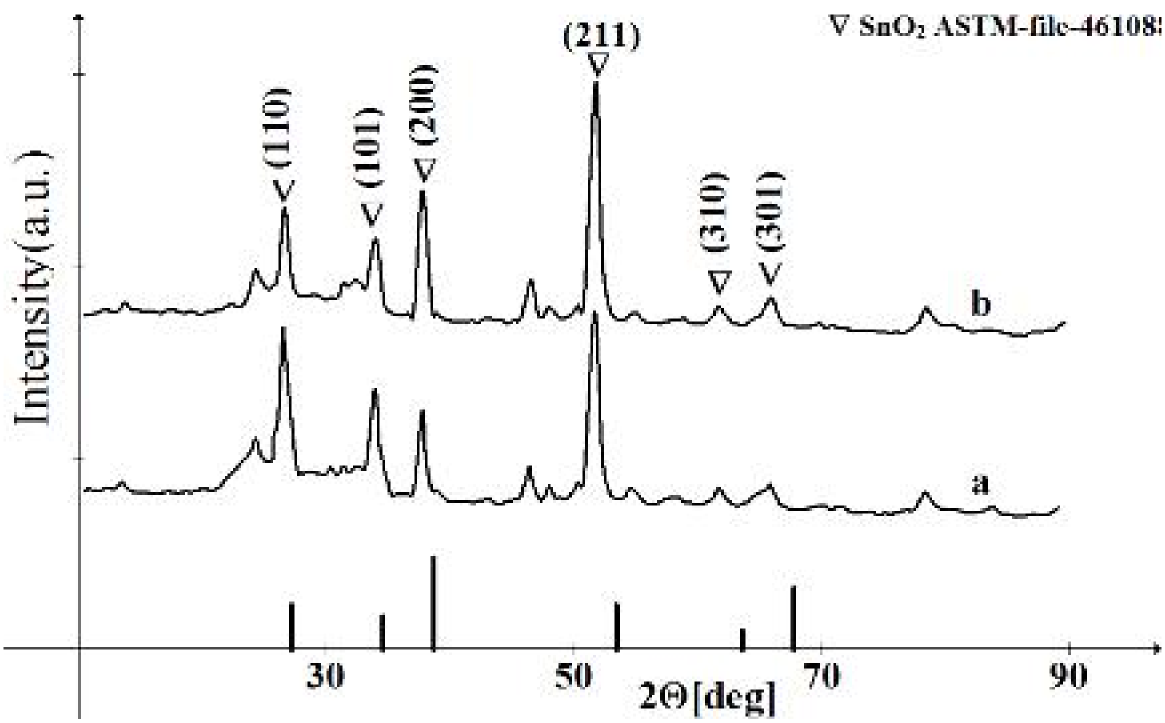

Fig. (2): X-ray spectra of SnO_2: a- 0.702 nm b- 0.805 nm thickness.

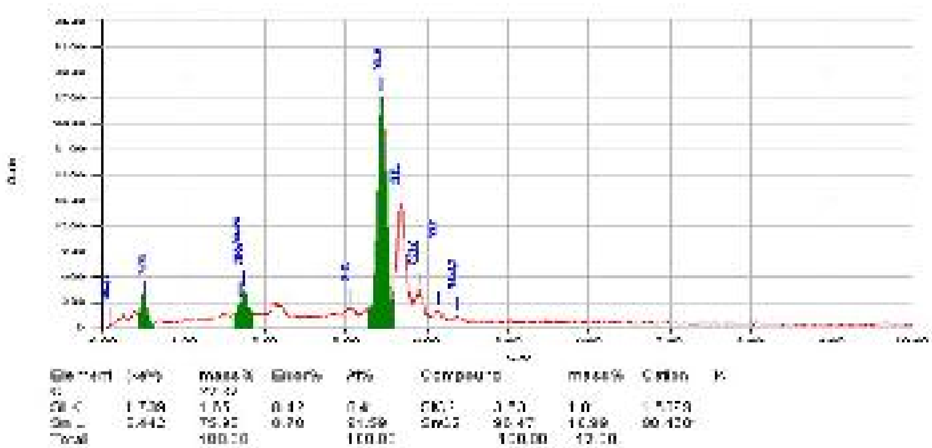

Fig.(3): EDX spectra of SnO_2

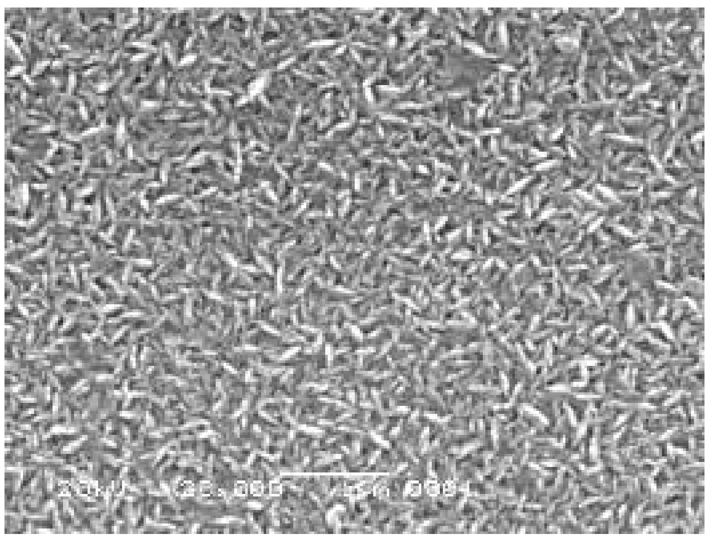

Fig. (4): SEM image of SnO_2

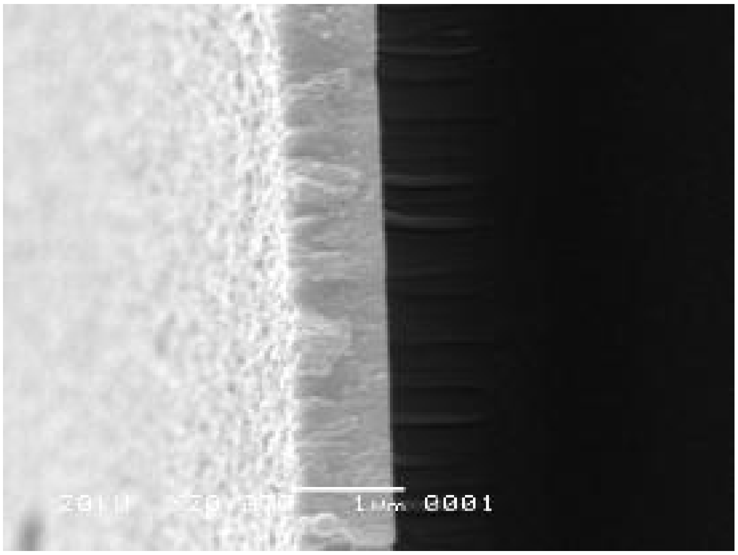

Fig. (5): SEM picture of SnO_2 thickness

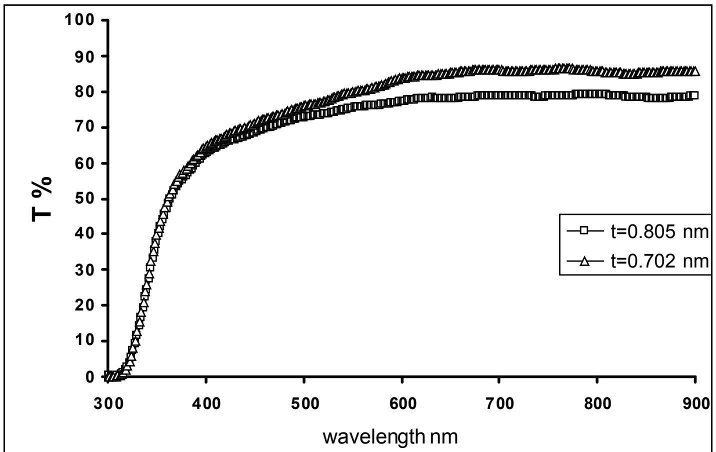

Fig. (6) Optica transmittance of SnO_2 vs. wavelength.

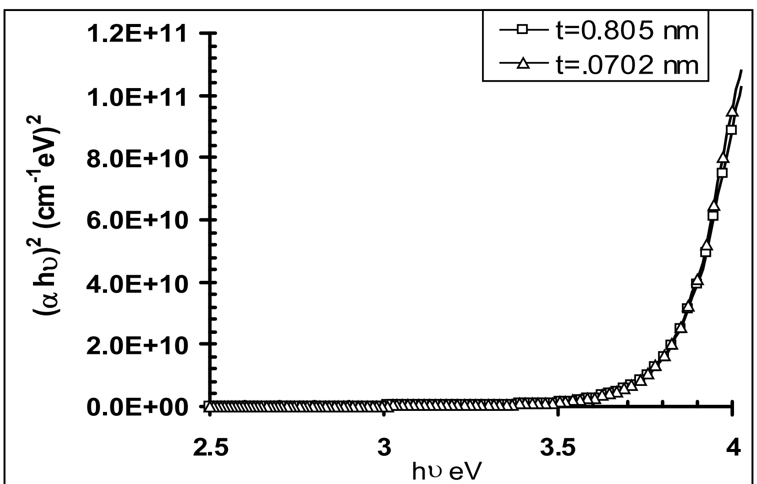

Fig.(7) $(\alpha h\upsilon)^2$vs. photon energy.

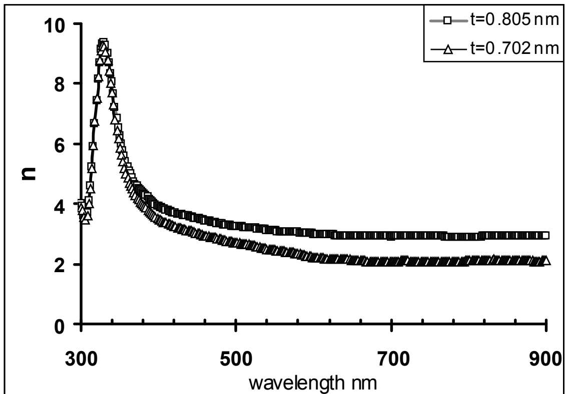

Fig. (8) Refractive index vs.wavelength.

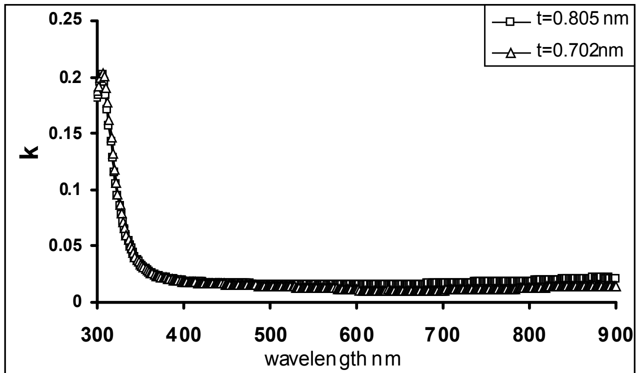

Fig.(9) extinction coefficient vs. wave length.

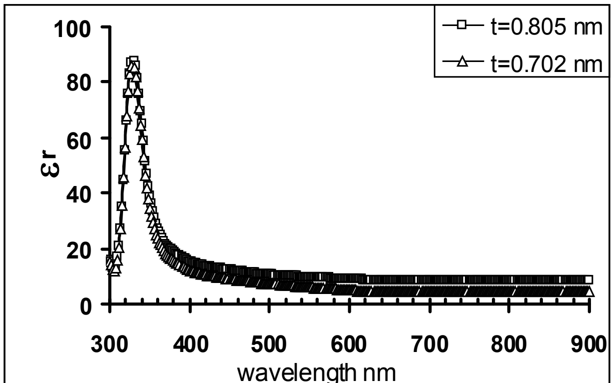

Fig.(10) Real part of dielectric constant vs. wavelength.

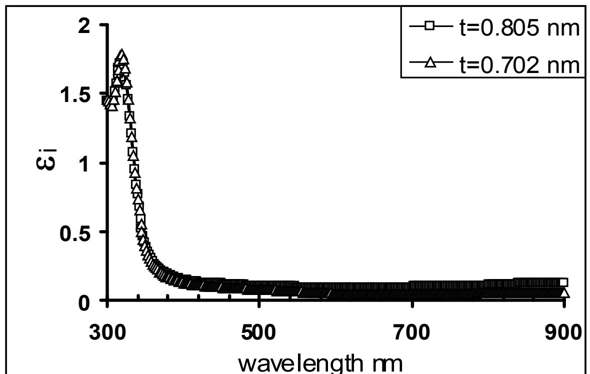

Fig.(11) Imaginary part of dielectric constant vs. wavelength.