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Study the Optical and Structural Properties SnO_2 Films Grown by (APCVD)

Nagham T. Ali * and Talib Zeedan T. Al-Mosawi**

** Center of Laser and Optoelectronic –Directorate of Materials Research, Ministry of Science and Technology-Baghdad-Iraq

*Physics Department, College of Science, AL-Mustansiriyah University, Kut University College

*Nagam2105@gmail.com and **talib.almosawi@alkutcollege.iq

Abstract

In this research thin films of SnO_2 semiconductor have been prepared by using (APCVD) on glass substrates. Our study focusses on prepare SnO_2 films with high optical quality at various temperature. The optical transmittance was measured by UV-VIS spectrophotometer. Structure properties were studied by using X-ray diffraction. (XRD) studies; shows the peaks becomes sharper indication to improve the crystallinity, the (110) peak has strongest intensity in all films with increasing growth temperature from (350-500) ^{0}C and the grain size was (31.5nm) which measured by using Scherer equation. (AFM) where use to analyze the morphology of the tine oxides surface, the roughness and average grain size for different temperature have been investigated. Maximum transmission can be measured is (90%) at 400 ^{0}C.

Keywords : APCVD, SnO2 thin film, Optical and structural properties

دراسة الخصائص البصرية والتركيبية لاغشية اوكسيد الخارصين المرسبة بطريقة التركيب الكيمياوي بالبخار بالضغط الجوي الاعتيادي

نغم ثامر علي* و طالب زيدان تعبان الموسوي**

*مركز الليزر والاليكترونيات البصرية / دائرة بحوث المواد / وزارة العلوم والتكنولوجيا / بغداد / العراق

**قسم الفيزياء / كلية العلوم / الجامعة المستنصرية

*Nagam2105@gmail.com and **talib.almosawi@alkutcollege.iq

الخلاصة

في هذا البحث تم تحضير أغشية شبه الموصل اوكسيد القصدير بطريقة الترسيب الكيماوي بالبخار بالضغط الجوي الاعتيادي على أساس من الزجاج. في بحثنا هذا تم التركيز على تحضير أغشية اوكسيد القصدير ذات نوعية بصرية عالية لمختلف درجات الحرارة.

تم دراسة الخصائص البصرية للغشاء باستخدام جهاز (UV-Vis.) أما الخصائص التركيبية فقد تم دراستها باستخدام حيود الأشعة السينية التي أوضحت ان قمم الحيود أصبحت حادة وهذا مؤشر على دعم التركيب ألبلوري القمة (110) تمتلك أعلى شدة في جميع الأغشية بتغيير حرارة نمو الغشاء لمدى ^{0}C (350-500) أما الحجم الحبيبي فقيمته كانت (31.5 nm) التي تم احتسابها باستخدام معادلة شرر.لقد تم الحصول على أعظم نفاذية والتي كانت (90%) عند درجة (400^{0}C). استخدم مجهر القوى الالكترونية لتحليل طوبوغرافيا سطح أغشية اوكسيد القصدير وحساب معدل الحجم الحبيبي والخشونة لمختلف درجات الحرارة.

الكلمات المفتاحية : الترسيب الكيمياوي بالبخار، اغشية اوكسيد الخارصين، الخصائص التركيبية والبصرية.

Introduction

The tin oxide is a wide band gap semiconductor (energy bandgap 3.6 eV), and it has only the tin atom that occupies the center of a surrounding core composed of six oxygen atoms placed approximately at the corners of a quasiregular octahedron (Figure 1). In the case of oxygen atoms, three tin atoms surround each of them, forming an almost equilateral triangle. The lattice parameters are a = b = 4.737 Å and c = 3.186 Å [1].

SnO_2 is a special oxide material because it has a low electrical resistance with high optical transparency in the visible range. Due to these properties, apart from gas sensors, SnO_2 is being used in many other applications, such as electrode materials in solar cells, light-emitting diodes, flat-panel displays, and other optoelectronic devices where an electric contact needs to be made without obstructing photons from either entering or escaping the optical active area and in transparent electronics, such as transparent field effect transistors [2]. SnO_2 owing to a wide band gap is an insulator in its stoichiometric form. However, due to the high intrinsic defects, that is oxygen deficiencies, tin oxide ($SnO2-X$) possesses a high conductivity. It has been shown that the formation energy of oxygen vacancies and tin interstitials in SnO_2 is very low. Therefore, these defects form readily, which explains the high conductivity of pure, but nonstoichiometric, tin oxide.

SnO_2 thin films have been deposited using different techniques, such as spray pyrolysis [3], sol-gel process [4], chemical vapor deposition [5], sputtering [6], and pulsed laser deposition [7].

Experimental Details

The schematic diagram of the Atmospheric Pressure Chemical Vapor Deposition APCVD system is given in Fig. (2). It contains a tubular furnace which has a diameter of 50 mm. APCVD is basically a chemical process which consists of heating hydrated tin dichloride ($SnCl_2$, $2H_2O$) under a dry oxygen flow. The vapor of the precursor reacts with oxygen then carried on the glass substrate by the O_2 gas.N_2 gas use to prevent the oxidation of substrate during heating. The fundamental chemical reaction SnO_2 thin films is:

$SnCl_2 + O_2 \longrightarrow SnO_2 + Cl_2$

operating parameters shown in table (1)

(1) N_2 gas (2) flow meter (3) furnace (4)spiral hater (5) (13) heater electronic control with thermal sensor (K-type) (6) O_2 gas (7) flow meter (8) circular heater (12) sensor with controller (9) byproduct treatment unit (10) (11) substrate and susceptor.

Table (1) Deposition parameters of tin oxide film

Deposition parameters of tin oxide film	
Thin film	SnO_2
Substrate	Glass
susceptor	Stainless steel
Temperature (^{0}C)	350-500
O_2 gas flow rate	2L/min
N_2 gas flow rate	0.5l/min

Results and Discussion

1-Structural properties by XRD

XRD measurement were made to determine the phase, crystallographic structure and the grain size of crystallites. X-ray diffraction pattern SnO_2 films deposited on glass substrate at various temperature (350-500)^{o}C are shown in Figure (3).The max. peak at 2θ values of 31.85°. A matching of the observed and standard (hkl) planes confirmed that the product is of SnO2 having a tetragonal Structure. The average particle size (D) was estimated using the Scherrer equation:

$$D = 0.9\lambda / \beta \cos(\theta)$$

where D is the crystallite size, λ is the X-ray wavelength, β is the full width at half maximum of the diffraction peak, and θ is the Bragg diffraction angle of the diffraction peaks. The average particle size was found to be (31.5 nm). X-ray diffraction patterns show only five sharp peaks (110), (101), (200), (211), (220), this evidence polycrystalline of SnO_2 in nature.

2-Optical properties

SnO_2 thin film successfully deposited on to glass substrate and thin film were very transparent. The optical transmission of the samples is investigated in the range of 280 to 1100nm using UV-VIS spectrophotometer as shown in Fig. (4). The measurements are taken in the wavelength scanning mode for normal incidence Transmission spectra show 79-90% transmission in visible and near infrared region. maximum transmission can be measured is (90%) at 400 ^{0}C.

3- Surface topography properties

The study of surface morphology of SnO2 thin films deposited by chemical vapor deposition method has been carried out using atomic force microscopy (AFM). We report the AFM images of SnO_2 thin film in three dimensions view 3D. It is clear that the deposited layer is very flat. In order to have quantitative information about the sample topography we analyzed the surface heights histogram. figure (5) show typical roughness and distribution histograms a for(a) 450 ^{0}C(b) 500 ^{0}C. In figure (6) compares typical morphology of the SnO2 sample (450-500)^{0}C in three dimension It can be seen from fig. (5) & (6) that with increasing substrate temperature the degree of surface roughness increases.

Conclusions

Tin oxide thin film has been successfully deposited at glass substrate by using CVD method. Structural investigations using. XRD reveal that the layers are composed of SnO_2, grain size was 31.5 nm measured by Scherrer equation. Max. transmittance was 90% in a visible light spectrum, the average roughness of thin film surface is about (1.82- 2.92 nm).

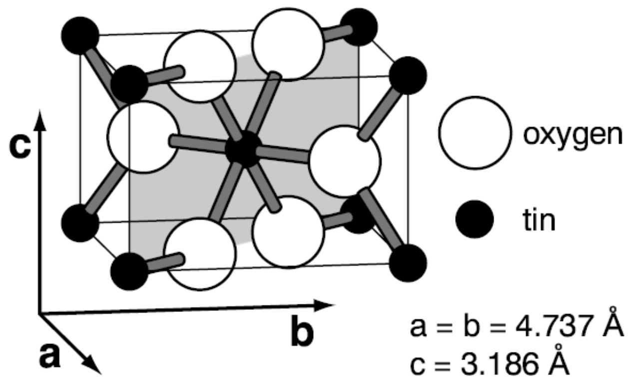


Figure (1) The rutile structure of SnO_2 unit cell

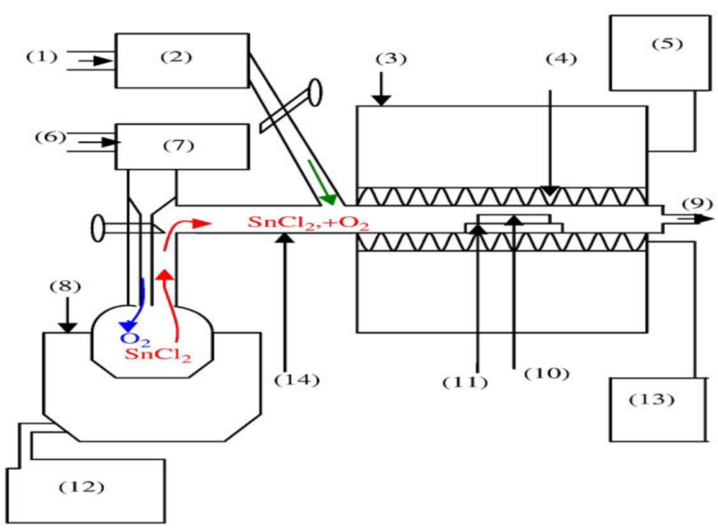


Figure (2) APCVD tube furnace system

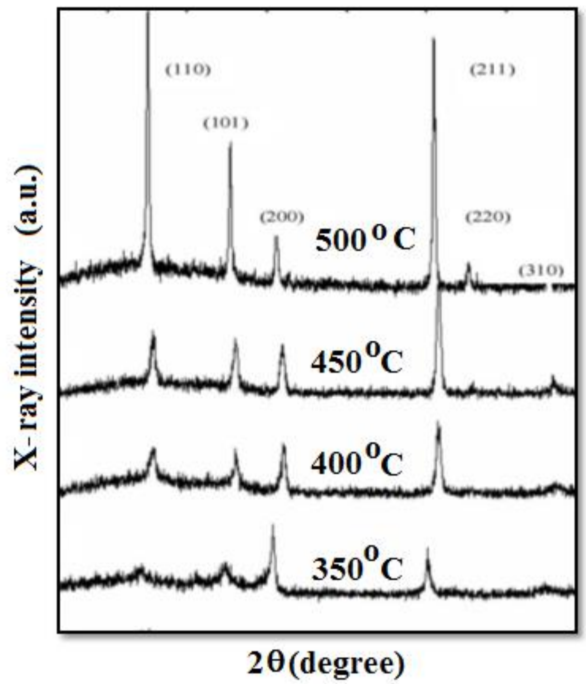


Figure (3) X-ray diffraction pattern for SnO2 film deposited on glass substrate at various temperature (350-500)0C

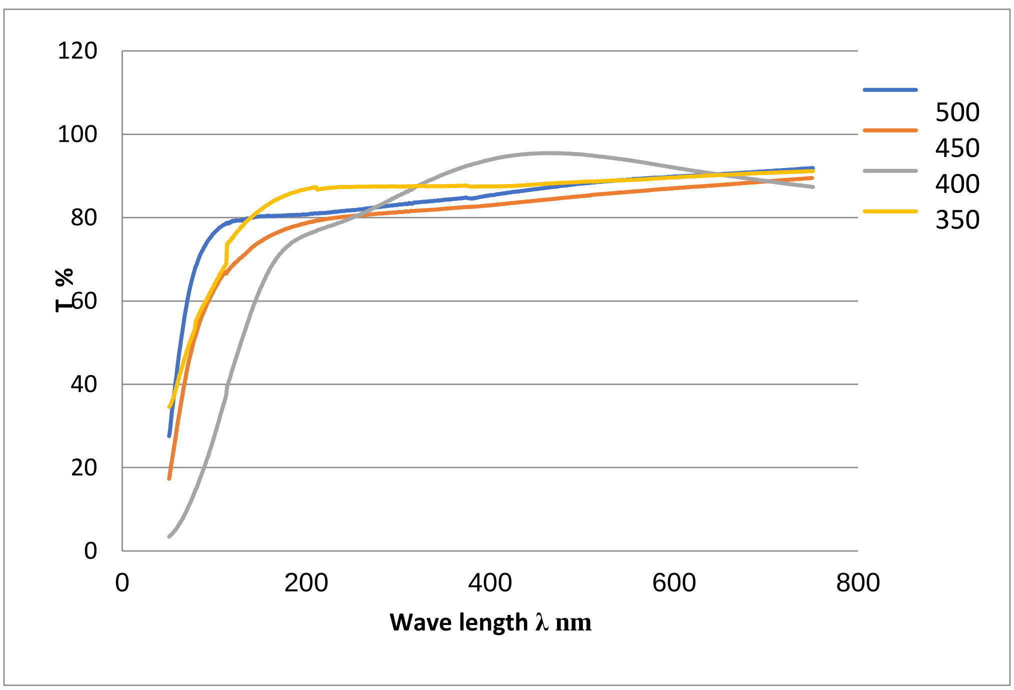


Figure (4) transmittance spectra for SnO_2 films.

Figure (5) : (a) Distribution Report for (450 ^{0}C)

Sample:450 **Code:**Sample Code

Roughness Average: 1.82(nm) **Grain No.:**47

Instrument:CSPM **Date:**2013-03-16

Avg. Diameter:119.74 nm

Diameter (nm)<	Volume (%)	Cumulation (%)	Diameter (nm)<	Volume (%)	Cumulation (%)	Diameter (nm)<	Volume (%)	Cumulation (%)
70.00	2.13	2.13	120.00	10.64	48.94	170.00	4.26	93.62
80.00	2.13	4.26	130.00	21.28	70.21	180.00	4.26	97.87
90.00	8.51	12.77	140.00	10.64	80.85	190.00	2.13	100.00
100.00	12.77	25.53	150.00	2.13	82.98			
110.00	12.77	38.30	160.00	6.38	89.36			

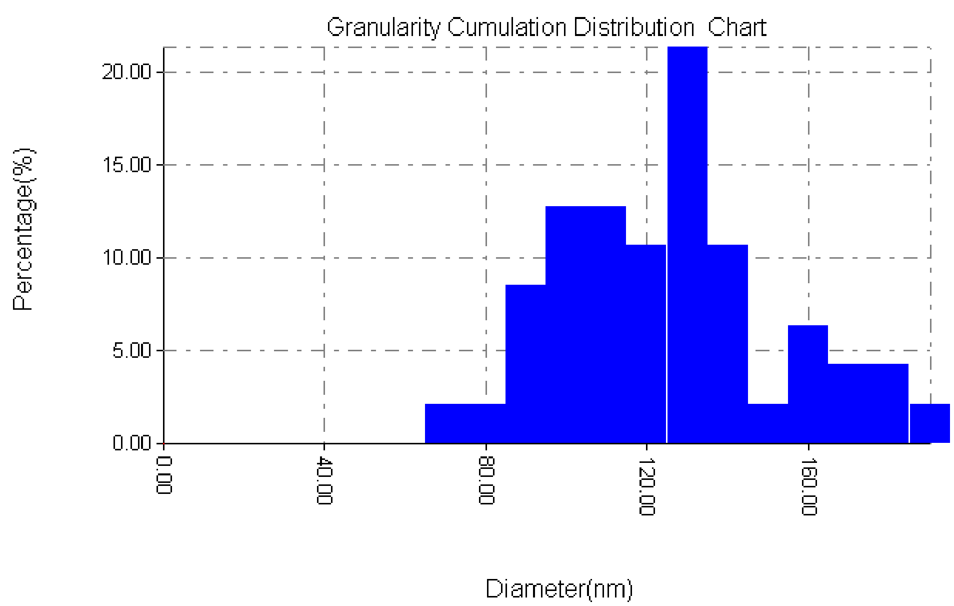
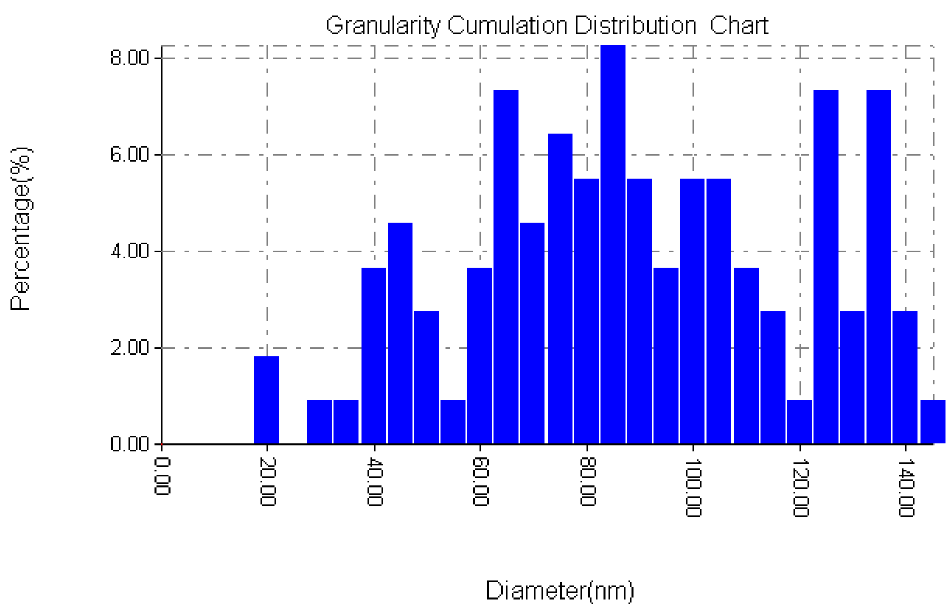


Figure (5) : (b) Distribution Report for (500 ^{0}C)

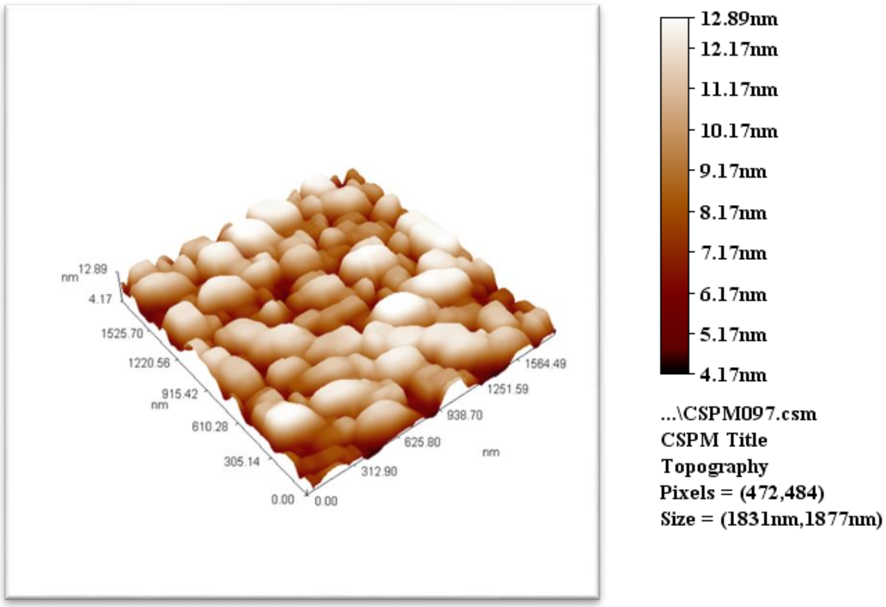
Sample: 500	**Code:** Sample Code
Roughness Average: 2.92(nm)	**Grain No.:** 109
Instrument: CSPM	**Date:** 2013-03-16

Avg. Diameter: 86.31 nm

Diameter (nm)<	Volume (%)	Cumulation (%)	Diameter (nm)<	Volume (%)	Cumulation (%)	Diameter (nm)<	Volume (%)	Cumulation (%)
20.00	1.83	1.83	70.00	4.59	31.19	115.00	2.75	77.98
30.00	0.92	2.75	75.00	6.42	37.61	120.00	0.92	78.90
35.00	0.92	3.67	80.00	5.50	43.12	125.00	7.34	86.24
40.00	3.67	7.34	85.00	8.26	51.38	130.00	2.75	88.99
45.00	4.59	11.93	90.00	5.50	56.88	135.00	7.34	96.33
50.00	2.75	14.68	95.00	3.67	60.55	140.00	2.75	99.08
55.00	0.92	15.60	100.00	5.50	66.06	145.00	0.92	100.00
60.00	3.67	19.27	105.00	5.50	71.56			
65.00	7.34	26.61	110.00	3.67	75.23			



(a) 450 ^{0}C



(B) 500 0C

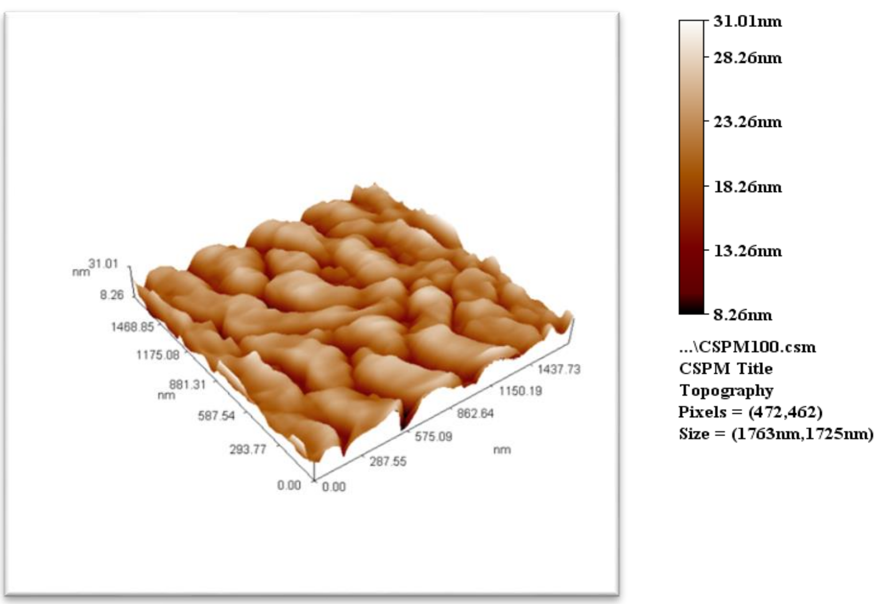


Fig. (6) compares typical morphology of the SnO2 sample (450-500)^{0}C in three dimension.

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