

Preparation and studying optical properties of sprayed nanostructure SnO₂ thin films

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ABSTRACT

Tin oxide (SnO₂) thin films were prepared by spray paralysis on glass substrates at temperature 400C⁰ with thickness (80,90,100) nm. Structural properties was studied using X-Ray diffract grams and the optical properties was measured at wavelength rang (300-900)nm. Also the optical constant was calculated. Direct and indirect optical band gap energy were estimated and found to be decreasing with increasing film thickness.

Keyword:- SnO₂ thin films ,Spray paralysis ,Optical properties ,Structural properties .

1.INTRODUCTION

Transparent conducting oxides (TCOs) are electrical conductive materials with a comparably low absorption of electromagnetic waves within the visible region of the spectrum. TCOs have been known and employed technologically for more than(50 years) [1]. They are usually prepared with thin film technologies and used in optoelectrical devices such as solar cells, displays, optoelectrical interfaces and circuitries [2]. The transparency of a TCO is due to the wide band gap of the material, which is at least (3.1 eV) [3,4], corresponding to the highest energy of visible light, their conductivity can be tuned from insulating via semiconducting to conducting as well as their transparency adjusted. As they can be produced as n-type and p-type conductives, they open a wide range of power saving optoelectrical circuitries and technological applications. As transparent conducting oxides are usually compound semiconductors where the nonmetal part is oxygen they are discussed along their metal elements. Metals were used as compound materials or dopants. Semiconducting metal-oxides such ZnO, SnO₂, TiO₂, In₂O₃, WO₃ are promising candidates for gas sensing applications because of their high sensitivity towards many target gases in conjunction with easy fabrication methods, low cost and high compatibility with other parts and processes. It was found that both the surface state and morphology of the metal-oxides play important roles in gas sensing performance [4].

Theory

The reflectance of the films can be determined from measurements of both T and A [5].

$$T+A+R=1 \quad (1)$$

Where A is the absorbance ,R is the reflectance of the films.

Where R is the

The absorption coefficient(α)of the films was determined from transmittance measurements [6]

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

where T is the normalized transmittance, (t) is the film thickness. These absorption coefficients values were used to determine optical energy gap. The energy gap (E_g) was estimated by assuming a direct transition between valence and conduction bands from the expression [7]:

$$\alpha h\nu = B(h\nu - E_g)^n \quad (3)$$

where (h ν) is the incident photon energy, (B) is constant and n is a constant which takes the values (1/2, 3/2, 2, and 3) depending on the material and the type of the optical transition (whether it is direct or indirect)[8]. The grain size (D) of the crystalline material; which plays an important role in the material properties, can be estimated easily from the X-ray spectrum by means of full width at half maximum (FWHM) method that is often calculated by Scherrer's relation [9] .

$$D = 0.94 \lambda / B \cos\theta \quad (4)$$

where (D) is the mean grain size and B is the full width at half maximum (FWHM) of the diffraction line in radius, θ is the diffraction angle and λ is the wave length of X-ray (1.542Å). System of Chemical Spray paralysis The system consists of many simple instruments sorted to be used it in the preparation of thin films . Figure (1) illustrates the Setting of the spray paralysis used in the present work, it contains the parts as showing in Fig.(1).

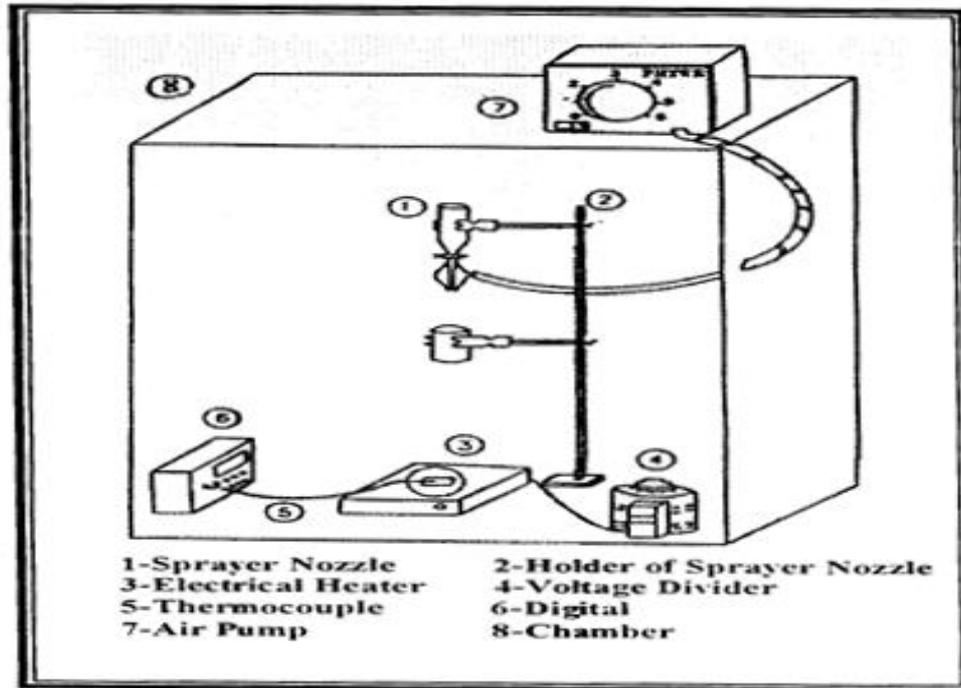


Fig. (1) Setting of spray parolysis equipments

Results and Discussion

The transmittance , absorbance and reflectance of the SnO₂ thin films prepared with thickness approximately (80,90 and 100)nm, at substrate temperature (T_s=400) C⁰ have been determined by using spectrophotometer in the wavelength range (300-900) nm . The films has high transparency in the visible and near IR region of the electromagnetic spectrum with transmittance value of about (90%) recorded at (λ>800 nm).This indicates that SnO₂ films are convenient as a window for solar cell application , therefore more attention has been paid to study this type of films for using in solar cells.

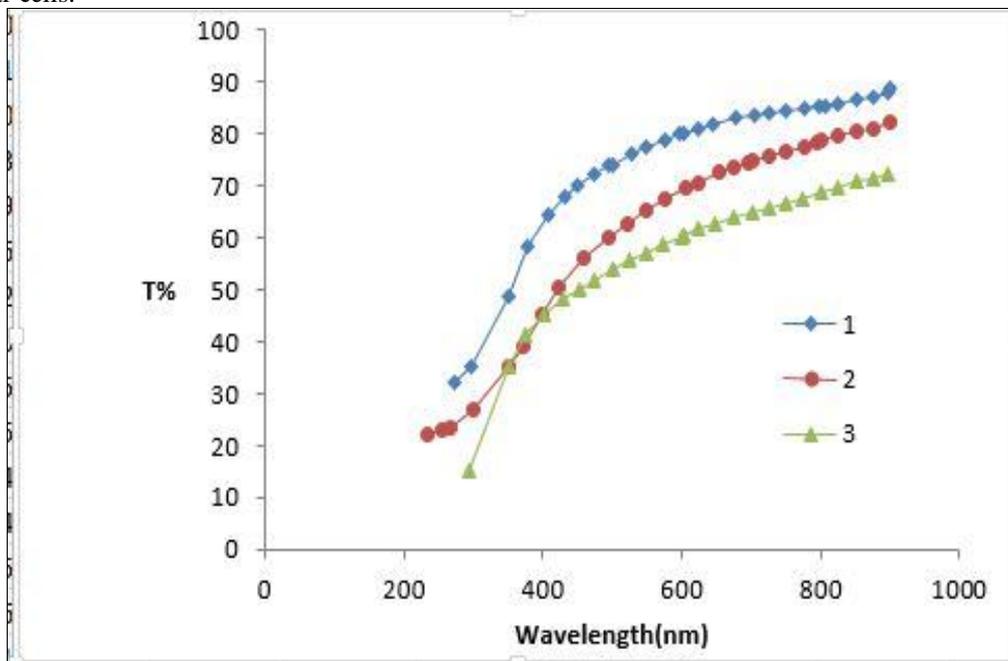
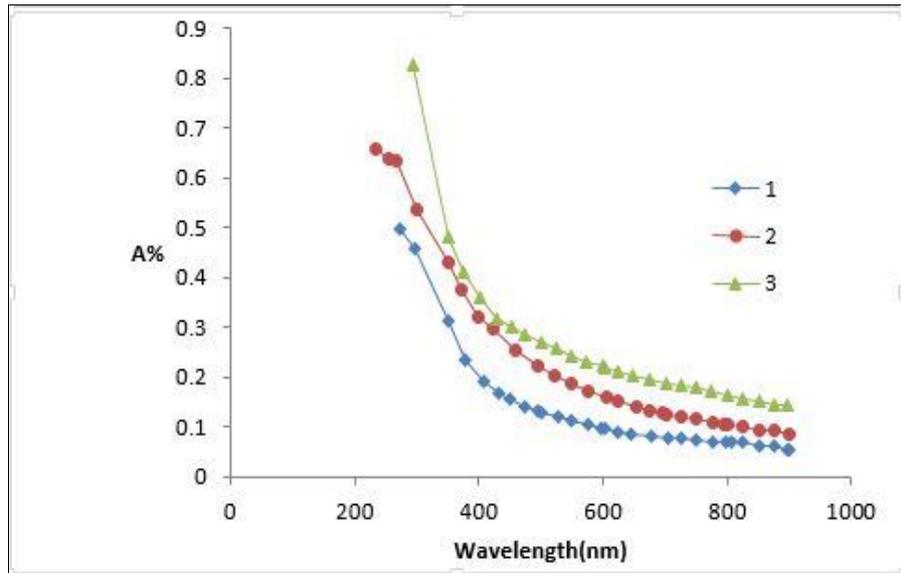


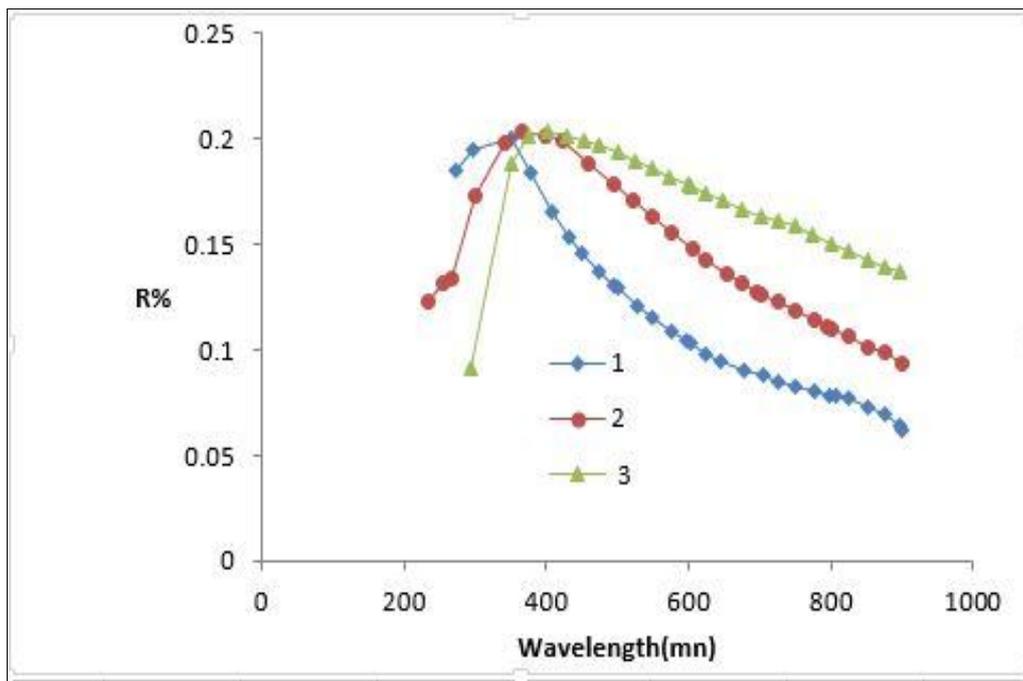
Fig (2)shows the transmittance spectra of nanostructure SnO₂ thin films as a function of wavelength at substrate temperature (400C⁰)

Figure (3) shows that the absorbance of the film decreases gradually at low energies within a range of (λ=600-900 nm) this change is due to the low absorbance of the photons which has lower energies than that of the film . The absorbance increases rapidly at high energies (short wave lengths) corresponding to the energy gap of the film, (when the incident photon has an energy equaling or bigger than the energy gap value).



Fig(3) : Shows the absorbance spectra of SnO₂ thin films as a function of wavelength at substrate temperature (400C⁰)

Figure (4) shows that the reflectance of the thin films decreases with the increases the wave length , and it behavior inverse of the transmittance .



Fig(4) shows the reflectance spectra of SnO₂ thin films as a function of wavelength at substrate temperature (400C⁰)

When we compare the value of refractive index which is practically calculated to the SnO₂ thin films in the best condition as in fig (6) from calculating the energy for the rate of the unilateral wavelength (589.3nm) from relationship ($E=1240/ \lambda(\text{nm})$) and from point of intersection of energy value with the curve which shown in fig (6) we fall columns from the sodium light energy value on the value of refractive index so we get the refractive index value of the SnO₂ thin films which equal to 2.6 which is close to theoretical value ($n=2$) [] at the same wavelength ,which is qualifies thin films to be antireflective coating for solar cell because it is material with refractive index medium between silicon refractive index ($n=3.44$) and refractive index of air

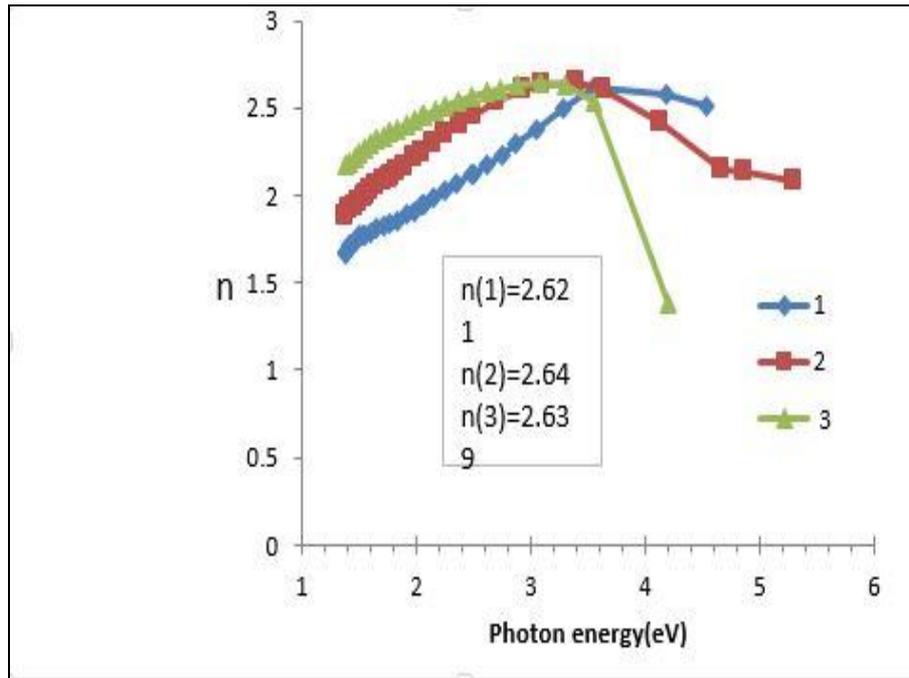


Fig (6) shows the refractive index as a function of wavelength for nanostructure SnO₂ thin films at substrate temperature (400°C)

The optical energy gap was calculated for (SnO₂) thin films with substrate temperatures (400) °C for all samples by using the absorption coefficient values, Figure (7) shows the plot of $(\alpha h\nu)^2$ vs. $h\nu$. The energy gap (E_g) was

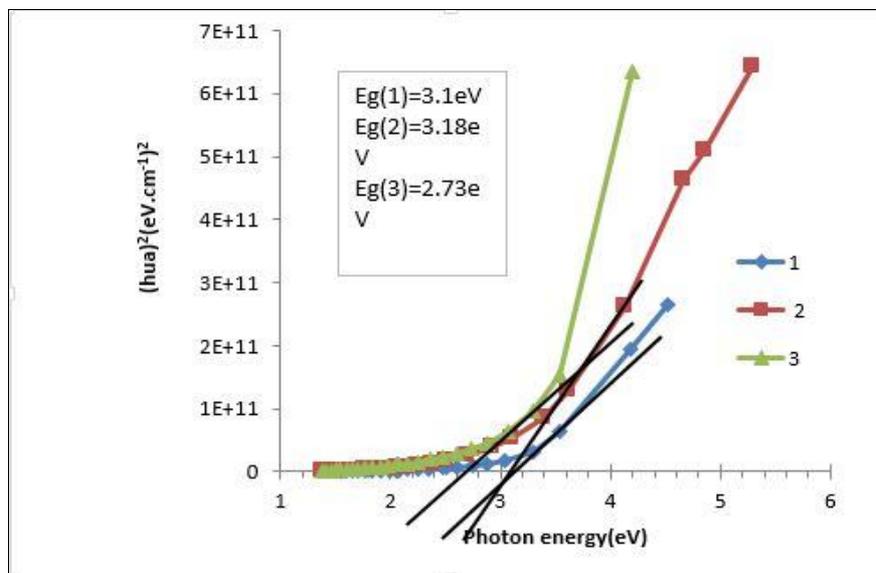


Fig (7) shows the direct electronic transition for nanostructure SnO₂ thin films

In the same way we can plot the relation between $(\alpha h\nu)^{2/3}$ and $h\nu$ for (SnO₂) thin films with substrate temperatures (400, °C) to find the forbidden direct electronic transition as is shown in figure (8).

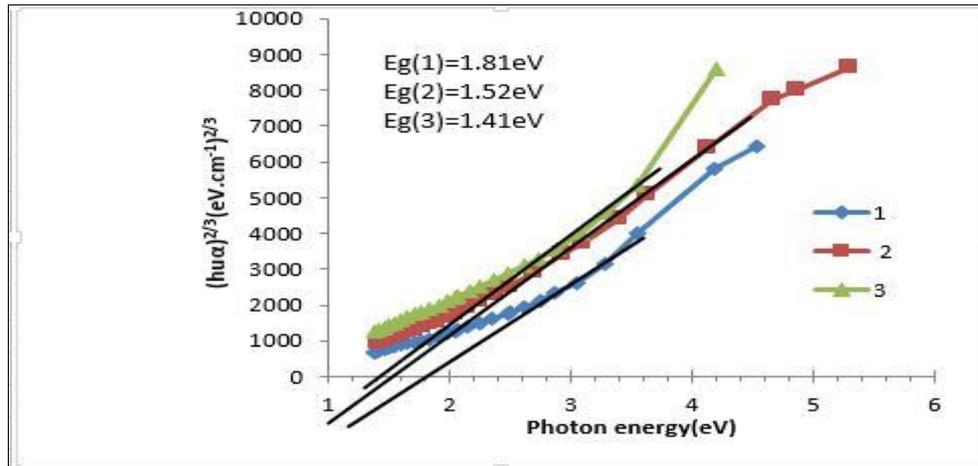
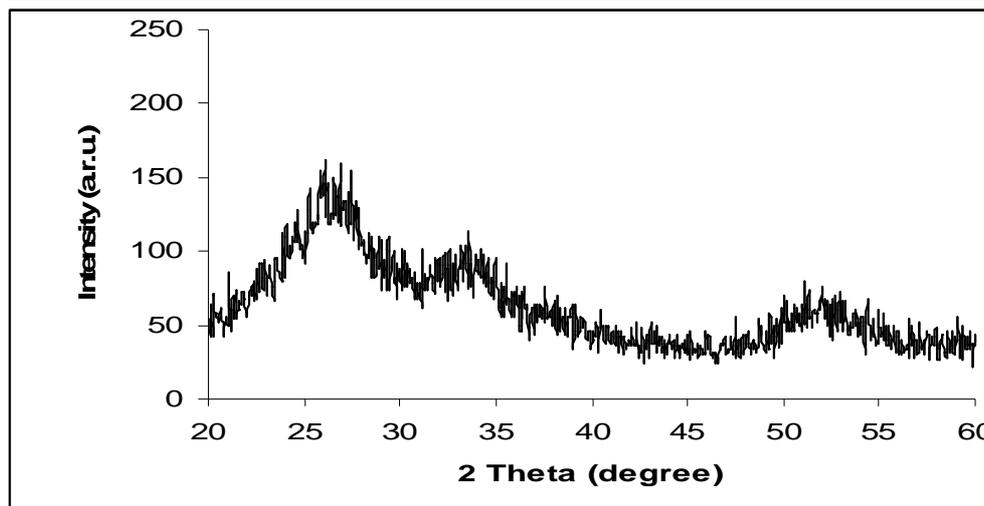


Fig (8) shows the indirect electronic transition for nanostructure SnO2 thin films

Table (1): The results from UV measurements of SnO2 thin film for different thickness .

Sample	Thickness(nm)	Refractive index(n)	Direct Energy gap(Eg)	Indirect Energy gap(Eg)
1	80	2.62	3.1	1.81
2	90	2.64	2.18	1.52
3	100	2.63	2.63	1.41

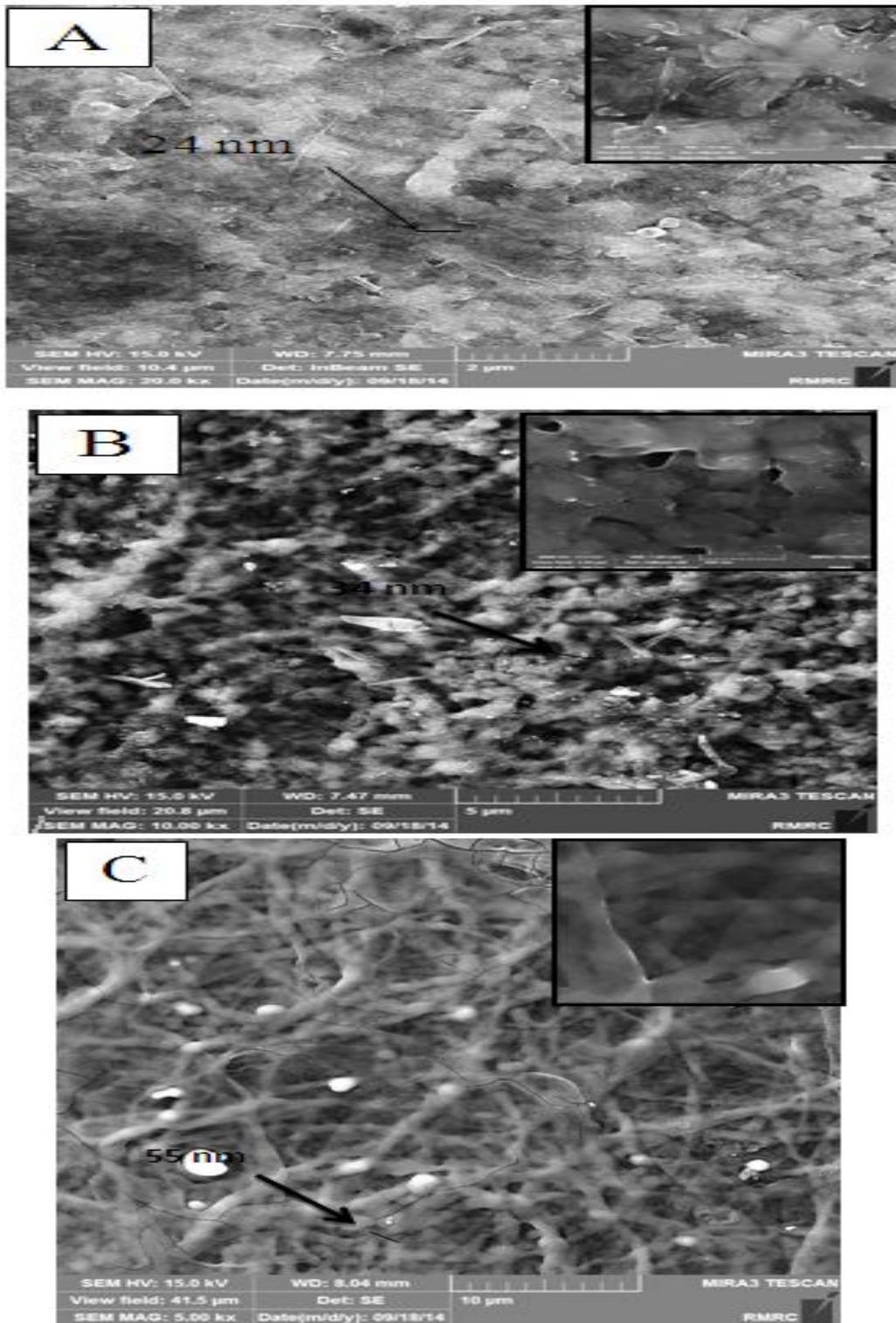


Fig(9) shows the observed X-ray diffract gram of nanocrystalline SnO2 thin films

Scanning Electron Microscope (SEM)

The surface morphology of the pure SnO2 thin films deposited on a glass substrate at a substrate temperature by chemical spray pyrolysis (CSP) technique at different Spray time (25, 35 and 50 min) was examined by Scanning Electron Microscope (SEM) study carried out by (Hitachi FE-SEM model S-4160, Japan) in the DayPetronic Company. A flat surface morphology of the SnO2 were clearly observed from the micrography that smooth and continuous networks nanofiber are extra-fine, with an average diameter found to be (25 nm) were analysis using particle size analysis software Imagej, and randomly distributed of a rods-like or fiber-like that result because a break networks

nanofiber during formation states as shown in Figure (9A). At increasing spray time (35 and 50 min) the nanofiber length and diameter will increase in the range of (34-45) nm and (55-90) nm respectively as shown in Figure(9B,C)

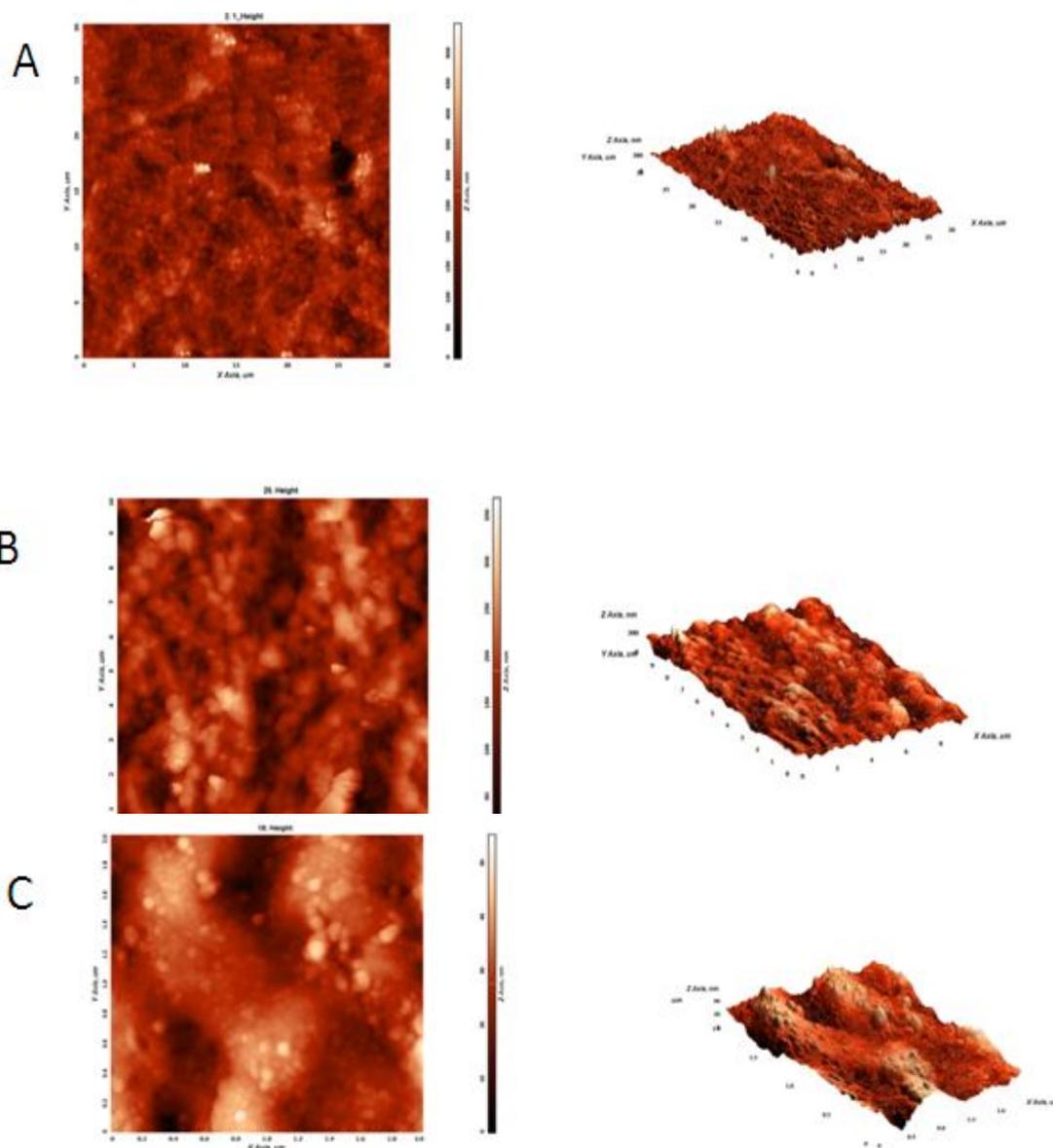


Figure(9). The SEM images of thin film SnO₂ for different spray time a(25 min), b(35 min),c (50 min)

Atomic Force Microscope (AFM)

The surface morphology of SnO₂ thin films were prepared at different Spray time (25, 35 and 50 min) deposited on glass substrate at substrate temperature (400°C) has been examined by atomic force microscopy (AFM, scanning probe microscope). The three-dimensional (3D) topographic views of AFM images for films are shown in figure (10). The AFM images reveal that the solution spray rate has a strong effect on the surface morphology. The films reveal homogenous surface and consists of well-shaped pyramidal grains with sharp edges and tip. The grain size of thin films were evaluated at (50.9, 64.5 and 75.5) nm respectively it can see at the surface of the film are clusters of crystallites.

Grain size was less than (100 nm) which confirms the presence of nanostructures. Figure (10B) showed that the grain size increases with Spray time. It is generally recognized that large grains are formed due to the recrystallisation of smaller grains. The AFM study showed that the RMS roughness of the films reduced considerably from (37.5to 34.7nm) at increasing spray time which makes a suitable reason to use it in solar cell applications as shown in Table (2) .These result is good agreement with [MerikeKriisa]



Figure(10). The AFM images of thin film SnO₂ for different spray time a(25 min), b(35 min),c (50 min)

Table (2): The results from AFM measurements of thin film SnO₂ for different spray time.

<i>sample</i>	<i>Roughness average</i>	<i>Rough mean square</i>	<i>Grain size(nm)</i>	<i>Thickness (nm)</i>
1	36.1	37.5	50.9	80
2	34.8	36.4	64.5	90
3	32.3	34.7	75.5	100

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