تأثير زاوية الترسيب على الخواص البصرية لأغشية (SnTe) المرسبة بشكل مائل والمحضرة بطريقة التبخير الحراري

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الخلاصة:

تم في هذا البحث دراسة الخصائص البصرية لأغشية (SnTe) المحضرة بطريقة الترسيب الحراري الفراغي تحت ضغط (10^{-6} Torr) على قواعد زجاجية عند درجة حرارة الغرفة وبزوايا ترسيب مختلفة (θ=(0°,40°,70° وبسمك (50nm± 10 nm). وقد تم تحديد فجوة الطاقة المسموحة من أطياف الامتصاصية و النفاذية وان زيادة زاوية الترسيب له تأثير واضح في تقليل النفاذية وزيادة الامتصاصية مع إزاحة نحو الأطوال الموجية الطويلة. أما بالنسبة لفجوة الطاقة المباشرة المسموحة فتقل بين eV (١,٨) و eV (١,٤٧) على التوالي عند زيادة زاوية الترسيب بين (70°,0°).

Deposition Angle Effect on the Optical Properties of Obliquely Deposited (SnTe) Thin Films Prepared by Thermal Evaporation

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ABSTRACT

The Tin Telluride thin films of obliquely and normal deposited were prepared using thermal evaporation method at pressure of 10^{-6} torr on glass substrates at room temperature. The optical band gap of films has been determined from the transmission and absorption spectra. The optical band gap of as-grown films has been found to have direct band gap of ~(1.8, 1.62, 1.47) eV for deposition angle θ = (0˚, 40°, 70˚) respectively. The optical band gap of SnTe thin films decreases with angle of deposition increases.

Keywords: Thin films, SnTe, Obliquely Deposited, Optical band gap, transmission analysis.

1. Introduction:-

Tin Telluride (SnTe) semiconductor undergoes a ferroelectric phase transformation with the displacement type from a cubic to rhombohedral structure at about 100 K [1]. Several methods for deposition of SnTe based alloy thin films have been developed, such as thermal evaporation [2]. The obliquely deposited thin films are interest for the application like angular selective coating, where angular selective coating involves transmittance for the same angle of incidence [3].

The growth process and structure of obliquely deposited films are different of those of normally deposited films; the islands in the former have a shape that elongated in the direction of the incident vapor beam and their mutual coalescence proceeds perpendicularly to the vapor beam by self-shadowing effect [4].

The morphologies resulting from this method of vapor deposition affected the optical and structural properties.

The selective absorber employing surface morphologies allowing for high absorption of solar spectra of incident light, the absorptivity obtained by these surfaces were over 95% in some instance [5].

The purpose of the search study the effect of deposition angle (θ) on structural and optical properties of (SnTe) thin films.

2. The experimental work:-

The SnTe compound was synthesized as an alloy by using Tin , and Tellurium produced by (May and Baker LTD, Dagenham England), their purity is (99.99%) and then weighting each element according to the atomic weight (Sn=118.710 g. mol^{-1}) , (Te=127.60 g. mol^{-1}) and using sensitive electrical balance type (AE 166 Metter), then mixing these elements.

Quartz tube is carefully cleaned in order to remove dust, grease and other possible contaminants, then putting this combination in it (the tube is 10 cm length and 1.5 cm diameter) which is evacuated by using rotary pump has been designed for this purpose. When the pressure reached ≈ (10^{-2} Torr), the tube is sealed and put in electric furnace of type SRJX-5-13 Model Box-Resistance Furnace by (Tianjin Taisite instrument co. LTD), the ampoules containing material were heated to 200 °C for 3 h under a vacuum. The temperature of the furnace was raised slowly at a rate of 3°C/min, then the temperature raised to 450°C and heating until the temperature for 830˚C stay for 15 min [5].

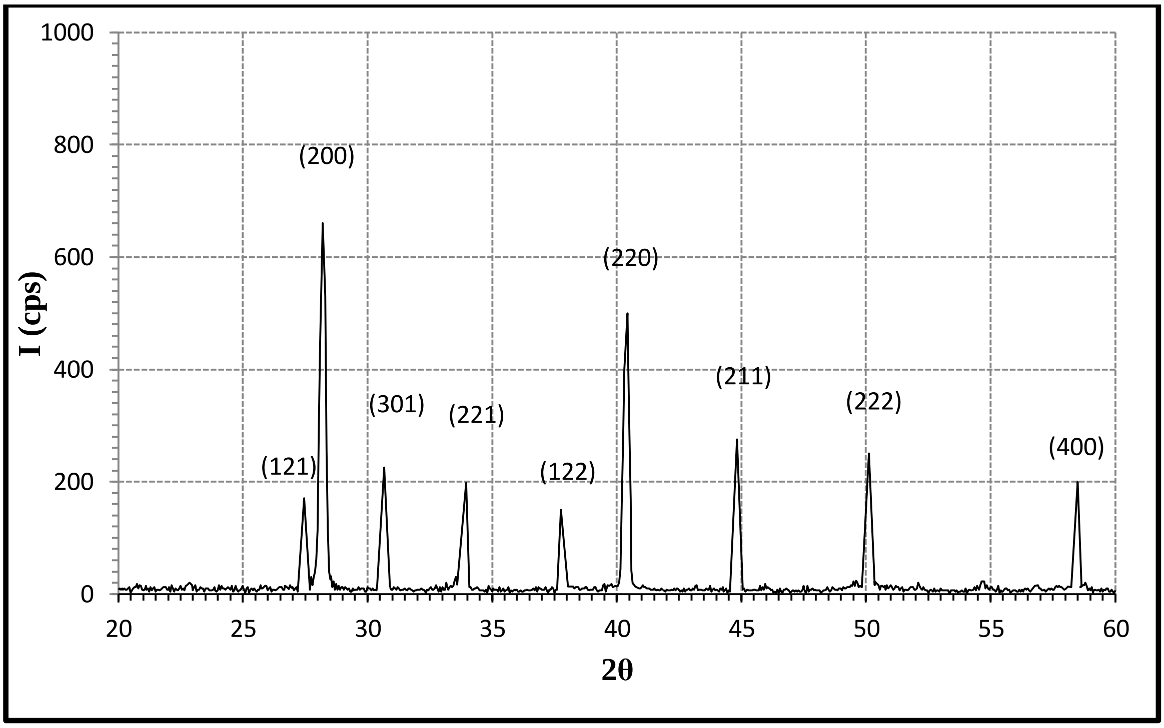
The quartz ampoules were constantly rocked .This was done to obtain homogeneous glassy alloys, after that the ampoule was taken out, and cooled rapidly in cold water to reduce segregation and to obtain more homogenous alloy. The quenched samples were then taken out by breaking the quartz ampoules. Thin films were grown by vacuum evaporation of SnTe using molybdenum boat in a high vacuum of 10^{-6} torr on glass substrate kept at room temperature. Prior to deposition, the glass substrates were cleaned with alcohol (C_2H_2OH) with purity (99.9%) and deionised water and dried. The optical properties measurements for SnTe thin films obtained by using the UV-Visible recording Spectrometer (UV-1650PC Shimadzu), made by Phillips, (Japanese company). The Absorptivity and Transmittance for SnTe thin films with deposition angles θ = (0^o, 4٠^o,70^o) and films thickness t =(50) nm measured by using (Minitest 3000 by Erichsen Germany company) which measured for spectrum range of (300-900) nm.

3-Results and discussion:-

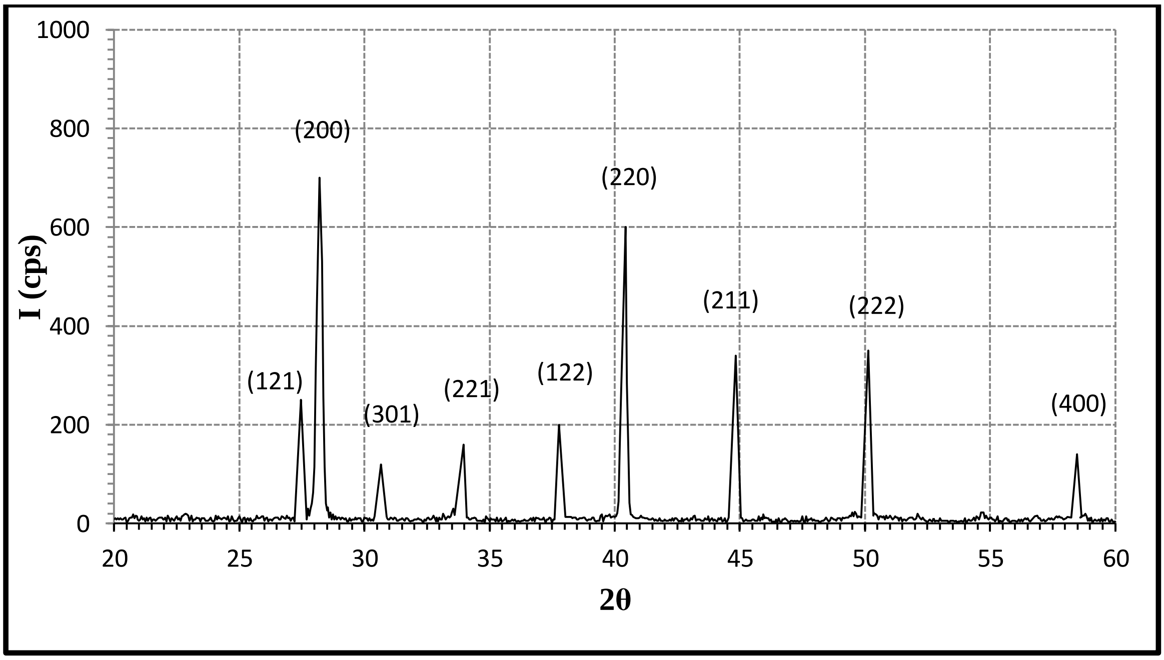
1-Structural properties:

Throughout studying the X-ray diffraction spectrum, we can understand the crystalline growth nature of (SnTe) thin films at different deposition angles on glass substrates at room temperature.

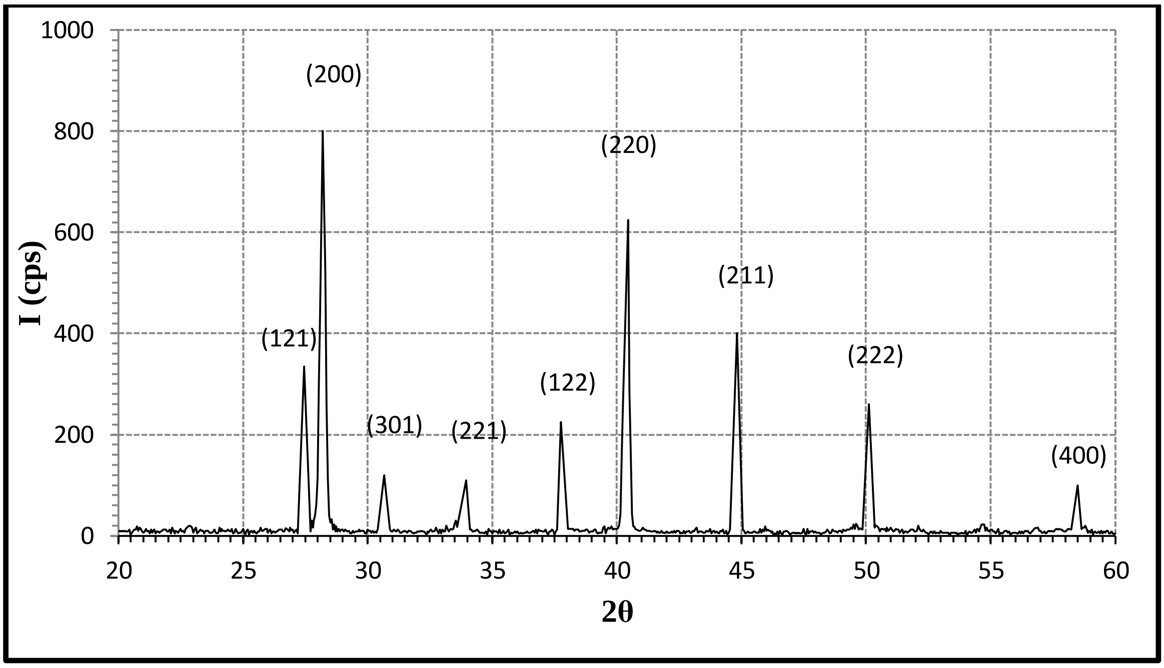
Figures (1) , (2) and (3) shows X-ray diffraction patterns for (SnTe) films with deposition angles ϴ= (0^o, 4٠^o,70^o) respectively with thickness (t=100±10) nm. The films exhibit a polycrystalline nature having (١٢١) , (٢٠٠) , (301) , (221) , (122) , (220) , (211) , (222) and (400) planes. The peak intensities of (301) , (221) , (220) and (400) decreases with the increasing deposition angles, while planes (121) , (200) , (122) , (211) and (222) are increase with increasing deposition angles. The diffraction peaks existed at 2Φ=(27.4649°, 28.2207, 30.6628°, 33.955°,37.767°, 40.4443°, 44.8265°, 50.128°, 58.4885) corresponding to (١٢١) , (٢٠٠) , (301) , (221) , (122) , (220) , (211) , (222) and (400) planes, this agree with (ASTM). the deposition angles have great influence on the crystal structure and the columnar growth . When the angle increases the columnar growth and the voids between columns increase [6].



Figure(1): XRD of SnTe thin films for deposition angle θ = 0°



Figure(2): XRD of SnTe thin films for deposition angle θ = 40°



Figure(3): XRD of SnTe thin films for deposition angle θ = 70°

Table (1) shows the X-ray diffraction results for deposited (SnTe) films at different angles on glass substrates at room temperature in which the values of Bragg angles ($2\Phi^o$) and spaces (d) between planes (h k l) are fixed and there is a comparison between the ratio of ($I/I_\circ$) of the results that we found in this research with (ASTM) tables.

(I) represents the reflection intensity in diffraction patterns.

($I_\circ$) represents the highest intensity in (XRD) patterns of (SnTe) films deposited at different angles.

There is an obvious difference between the results that we found in this research and the values fixed in (ASTM) because of the intensity change in main peak of the reflection as a result of the deposition angle change. It is clear that the deposition method and preparation conditions had a great effect on films structure prepared in this research. It is obvious that the varying of the deposition angle has a great effect on the structural properties of these films which means that it has a great effect on the optical and electrical properties.

***Table (1):- Shows (h k l) planes and comparison between ($I/I_{\circ}$) of (XRD) in this research with (ASTM) of* the *(SnTe) films deposited at different angles*.**

θ°	2Φ°	d (Å)	(hkl)	$I/I_{\circ}$ (XRD)	$I/I_{\circ}$ (ASTM)
0	٢٧.55	3.23426	121	٤١٥	٥٠٠
	28.3	3.15019	200	٤٤٠	١٠٠٠
	30.66	2.91343	301	٨٢	١٠٠
	33.95	2.63804	221	١٤٨	٦٠٠
	38.27	2.34975	122	١٦٤	٨٠٠
	40.44	2.22848	220	٢٦٥	٩٠٠
	44.82	2.02027	211	٨٠	٢٠٠
	50.12	1.81833	222	٦٦	١٤٠
	56.78	1.62005	421	٩٠	١٠٠
	58.48	1.57675	400	٤٥	١٠٠
٤٠	٢٧.55	3.23426	121	٤٤٢	٥٠٠
	28.3	3.15019	200	٤٧٦	١٠٠٠
	30.66	2.91343	301	٩٨	١٠٠
	33.95	2.63804	221	١٣٠	٦٠٠
	38.27	2.34975	122	١٨٢	٨٠٠
	40.44	2.22848	220	٢٢٢	٩٠٠
	44.82	2.02027	211	١٢٠	٢٠٠
	50.12	1.81833	222	١١٠	١٤٠
	56.78	1.62005	421	٦٨	١٠٠
	58.48	1.57675	400	٨٠	١٠٠
70	٢٧.55	3.23426	121	٥١٠	٥٠٠
	28.3	3.15019	200	٥٤٥	١٠٠٠
	30.66	2.91343	301	١١٤	١٠٠
	33.95	2.63804	221	١١٧	٦٠٠
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	58.48	1.57675	400	٨٨	١٠٠

2-Optical properties:-

(2-1) Transmittance properties

Figures (4), show the relation between transmittance and wavelength of (SnTe) thin films deposited at angles Θ=(0^o,٤٠^o,70^o) respectively and thicknesses t =(٥٠) nm. It has been observed that the transmittance of (SnTe) thin films decreased with increase deposition angles, this agree with reference [٧], on the other hand, the nature of the material has a high transmittance at wavelength λ=325 nm and it decreases rapidly between (λ= 325-390) nm, then it increases slowly till the end of the studied range (λ= 900) nm.

It is clearly, that the increasing of the deposition angle has an obvious effect on the transmittance decreasing, and this is resulted from roughness increasing for film surface obtained by increasing the columnar growth with needles and rods like shape. This structure increases the film trapping efficiency when rays falling on it, and this reduces the transmittance [٨].

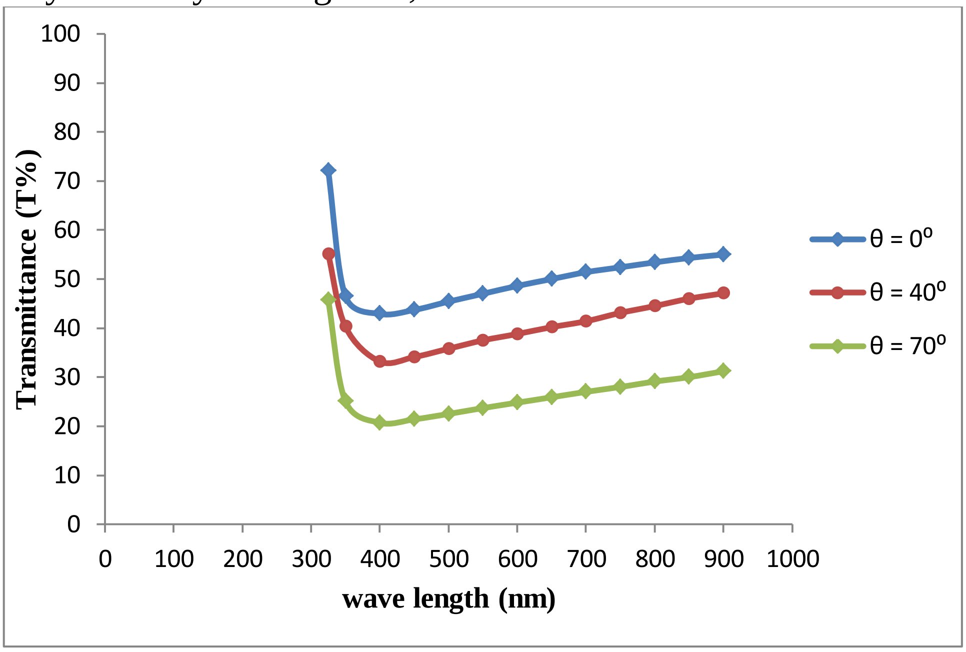

Figure (4): The transmittance variation with wavelength for SnTe thin films for different deposition angle

(2-2) Absorptivity properties:

Figure (5), shows the material nature and its rays absorbing ability variation with the wavelength for (SnTe) thin films deposited at deposition angles Θ=(0^o,40^o,70^o).

One of the material nature has a low absorptivity for λ=325 nm and it increases rapidly for spectral range between (325-390) nm then decreases slowly till the end of the studied range λ=900 nm.It is noticed the increasing of the deposition angle has an obvious effect on the absorptivity increasing, and this is resulted for the same reasons in the transmittance properties [٧], there is a shift in absorptivity towards long wavelengths with the increases of deposition angles and this happened because that the ability of the thin films to absorbe the low photons the energy when the angle of deposition increased of thin film trapping efficiency when rays falling on it.

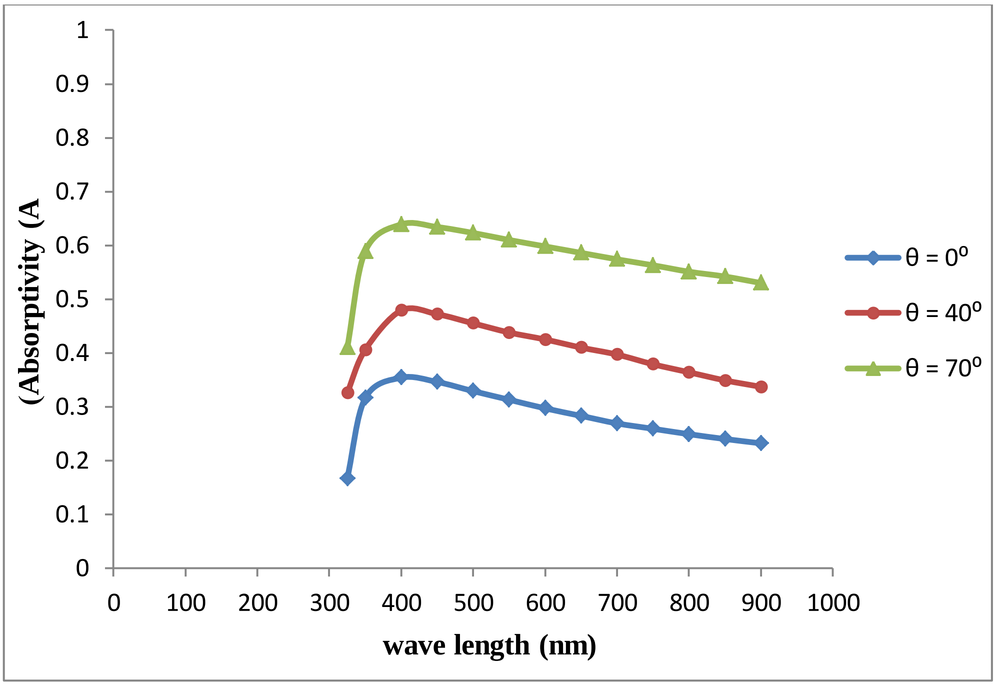

Figure (5): The absorptivity variation with wavelength for SnTe thin films for different deposition angles

(2-3) Energy gap properties:

The optical energy gap value depends on film evaporation conditions and its preparation method which influences in the crystalline structure [٨]. The variation in the structural properties and other variations is a reason for making variation in optical energy gap. The structural properties influences by deposition angle variation and this affect the absorptivity properties. Figure (6) show the relation between $(\alpha h\upsilon)^2$ and photon energy $(h\upsilon)$ for (SnTe) films at deposited angles θ=(0°,40°,70°) respectively.
Extrapolation of linear portion of the graph to the optical energy axis at (α=0) gives the band gap energy ($E_g^{opt.}$). It noticed that when the deposition angle increases the energy gap decreases.

The decrease in optical band gap can be due to the influence of various factors such as grain size, structural parameters, carrier concentration, presence of impurities, deviation from stoichiometry of the film and decrease in lattice strain [8]. Also the lower value of ($E_g^{opt.}$) is attributed to the creation of allowed energy states in the band gap at the time of film preparation while the higher value of ($E_g^{opt.}$) is accounted to the very small grain size of the film [١٠]. The columns and voids that formed in obliquely deposited films increase the absorption for all wavelengths because of the ability of trapping rays due to the increasing in the surface area of the films and multiple reflections that happened because of film roughness and this process increase with increasing deposition angle and all this increases the ability of absorbing low photon energies so we can get less optical energy gap.

The energy band gap of thin films was calculated with the help of transmission spectra using the following equation [11]:

$$\alpha h\upsilon = A\ (h\upsilon - E_g^{opt.})^n \qquad \text{------------------(1)}$$

Where ($h\nu$) is the photon energy, (α) the absorption coefficient, (Eg) the band gap, (A) is the constant, (n) =1/2 for the allowed direct transition

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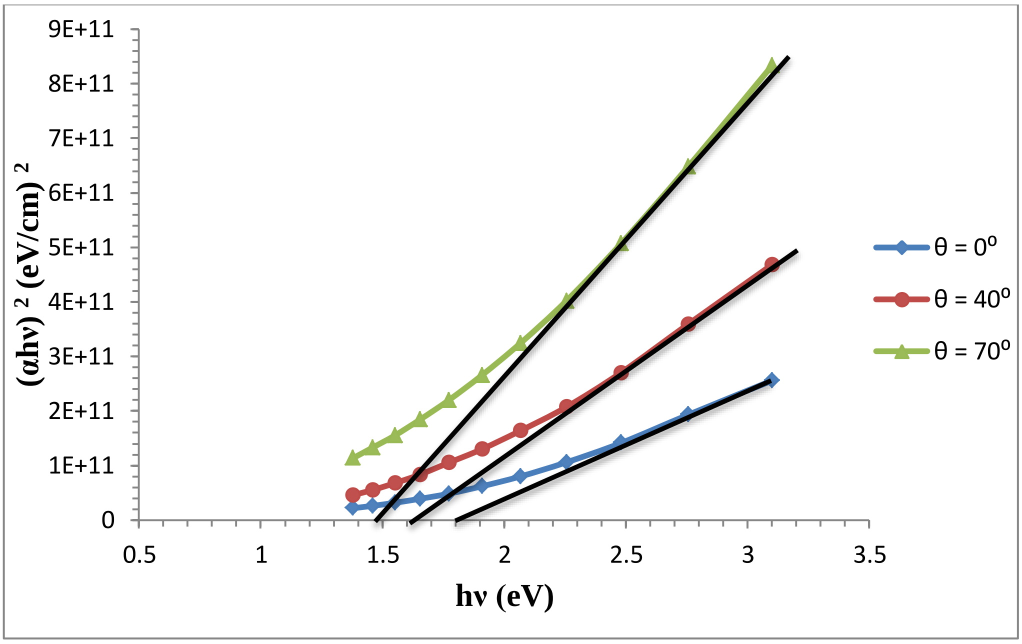

Figure (6): The variation of allowed direct transition with photon energy for SnTe films.

The allowed direct transition decreases from (1.8-1.47) eV, when deposition angle increases from (θ=0°-70°) as table (2) and this agree with the reference [6].

The possibility of having films of different absorptivity is greatly influenced by deposition angle variation. These variations are important in manufacturing the detectors as well as the increasing of deposition angle has an effect in increasing the absorptivity as it is mentioned previously. So, It can make high efficiency detectors and for wide spectral ranges.

Table (2):- Shows the energy gap for the direct allowed transition with deposition angle for (SnTe) films

Deposition angle (θ°)	*Allowed direct band gap(eV)*
0°	1.8
40°	1.62
70°	1.47

٣-Conclousions:-

Tin Telluride thin films were prepared by thermal evaporation method. The increasing of deposition angle has a great effect of increasing the absorptivity and decreases the transmittance and the allowed direct energy gap. The optical band gap of as-grown films has been found to have direct band gap of ~1.8, 1.62, 1.47 eV for deposition angle θ= (0° , 40°, 70°) respectively.

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