Journal of Basrah Researches ((Sciences)) Volume 37. Number 3A/ 15 June ((2011))

The Effect Of Substrate Temperature On The Optical and Structural Properties Of Tin Sulfide Thin Films

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ISSN -1817 -2695

((Received 2/5/2011, Accepted 30/5/2011))

ABSTRACT:

Tin Sulfide thin films were prepared on glass substrate by spray pyrolysis technique .X-ray diffraction confirmed the polycrystalline SnS phase with preferential orientation along (111) plane .The effect of substrate temperature on structural and optical properties was studied. The optical direct allowed band gap was varied in the range (1.6- 1.54)eV as substrate temperature increases which may be attributed to the increase in the grain size and then decrease in the strain .

Keywords: Tin Sulfide, Substrate Temperature ,Optical Properties ,Structural Properties , Spray pyrolysis

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INTRODUCTION:

SnS is one of the Tin chalcogenide layered semiconductors in group IV-VI [1]. It is a potentially important photovoltaic and solar conversion material because of its direct optical band gap of ~1.3 eV[2] .This band gap in the optimum range for solar photoconversion [3].The optical properties of tin sulfide thin films vary depending on the synthesizing or fabrication method, these properties enable SnS thin films to be used as an absorption layer in the fabrication of heterojunction solar cell [4,5].

SnS thin films can be prepared by many methods such as thermal evaporation [6],pulse electrodeposition [7],spray pyrolysis [8],SILAR[9],electron beam evaporation [10],chemical bath deposition(CBD) [11,12] and also deposited by atomic layer deposition [13] each method has its own characteristics merits and demerits in producing homogeneous and defect free thin film nanomaterials. The quality and properties of the films depend largely on the substrate temperature and precursor solution concentration[8] . In the present work the effect of substrate temperature towards the x-ray diffraction and optical properties of SnS thin films has been studied.

EXPERIMNTAL PROCESES:

a-sample preparation.

Specimen of SnS thin films prepared by spraying solution containing of SnCl2 and $(NH_2)_2SC$ on glass substrate heated in the range (200-350)^oC, solution used with molar concentration (0.05)M usually 10mL of solution were sprayed for <30 min, the films extremely adhered to the substrate , free from pinhole . The thickness of the films was estimated by weighing method and they were about 1500 A$^{o.}$

b-structural and optical measurements

The structural analysis of SnS thin films were analyzed by **X Pert Pro MPD by**

PANalytical company with **Cu** target. A filtered **Cuk**$_\alpha$ radiation

(**λ=1.548 A^o**) was used .

An estimation of the grain size of the polycrystalline SnS films was obtained from the broadening of the XRD peaks according to the Scherr's formula [14] . **($D=0.9 \lambda/\beta \cos\Theta$)**

Where **D** is the grain size , **β** experimentally observed diffraction peak width at Full wave half maximum intensity (FWHM) ,and **Θ** is Bragg angle.

The strain ξ of as deposited films has been obtained from the following relation [15]: **$\beta\cos\Theta/\lambda = 1/D + \xi \sin\Theta/\lambda$** .

The measurement of Transmittance T(λ) , Absorbance A(λ) and Reflectance R(λ) was carried out using **UV-VIS** spectrophotometer type (**Thermospectronic)** in the range (300-1000)nm, all measurements were carried out at room temperature (R.T).

Optical parameters namely refractive index (**n**), extinction coefficient (**k**) and dielectric constant (**$\varepsilon_1,\varepsilon_2$**) have been determined from absorbance and reflectance measurements using following relation [16,17]:

$n=1+R/1-R+[(R+1/R-1)^2-(1+k^2)]^{1/2}$ where **$k=\alpha\lambda/4\pi$, α** is the absorption coefficient **.**

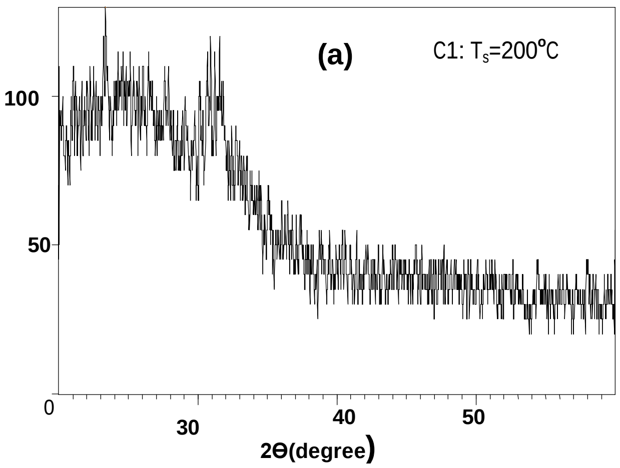
The dielectric constant **$\varepsilon_1,\varepsilon_2$** estimated from the relation[18]:

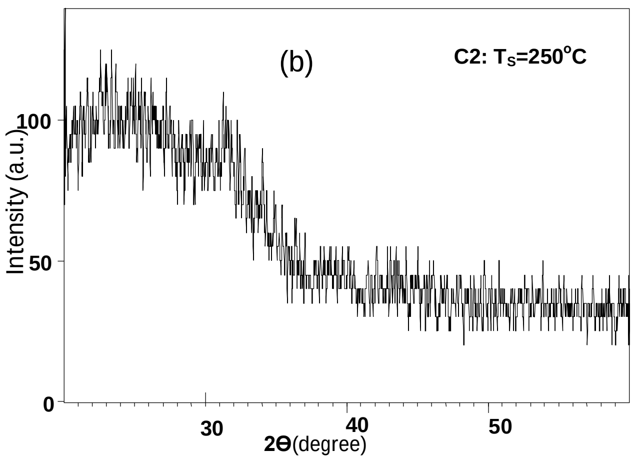
$$\varepsilon_1 = n^2-k^2 \quad , \quad \varepsilon_2 = 2nk$$

RESULT AND DISCUSSION :

a-structural properties

The x-ray diffraction pattern of SnS thin films deposited at different substrate temperature is shown in fig.(1),three peaks corresponding to peaks (111),(120),(101) for the diffraction of orthorhombic SnS phase was observed in figs.(1a,1b and 1c) these result were in good agreement with that reported elsewhere [11] ,the less intense reflection of the peaks could be due to the presence of other phases in the film while the peak intensity is found to be increased in sample (c4) fig.(1d) prepared at 350 ^{o}C indicating to the better crystalinty so it is the optimum temperature to obtain uniform well adherent SnS film is at 350 ^{o}C above this temperature lesser deposition occurs to substrate, specimen broadening intensity arises due to small crystalline (grain) size and strain (lattice distortion).Both grain size and strain effect are plotted as function of substrate temperature as shown in fig.(2), it is clear that the grain size increases as temperature increase with decreasing in strain, this was in good agreement with that reported elsewhere [8] which is correlated with the decrease in band gap with increasing substrate temperature.





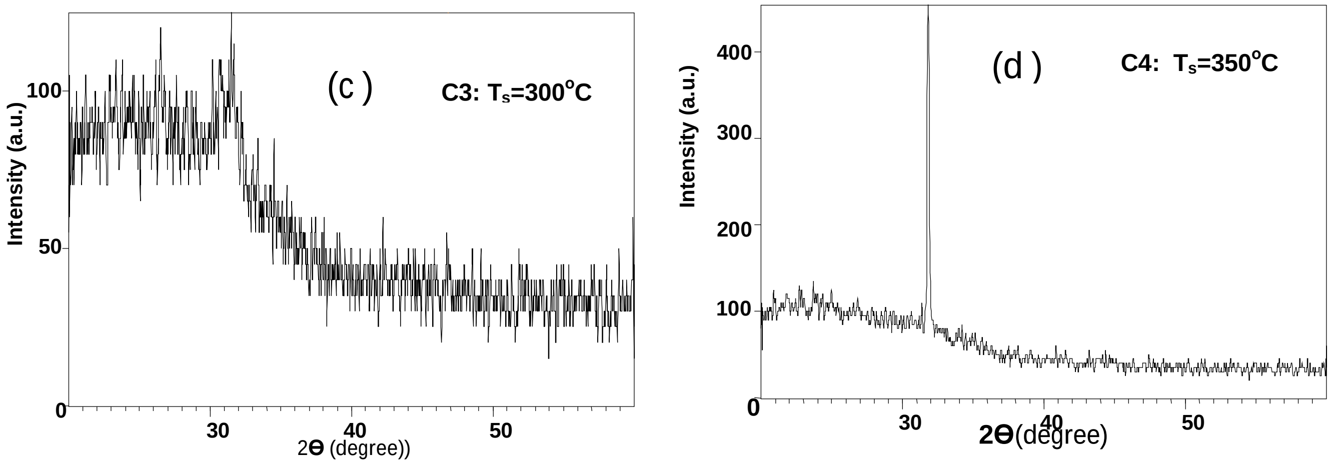


Fig.(1):XRD pattern of SnS thin films prepared at different Sub. Temp .

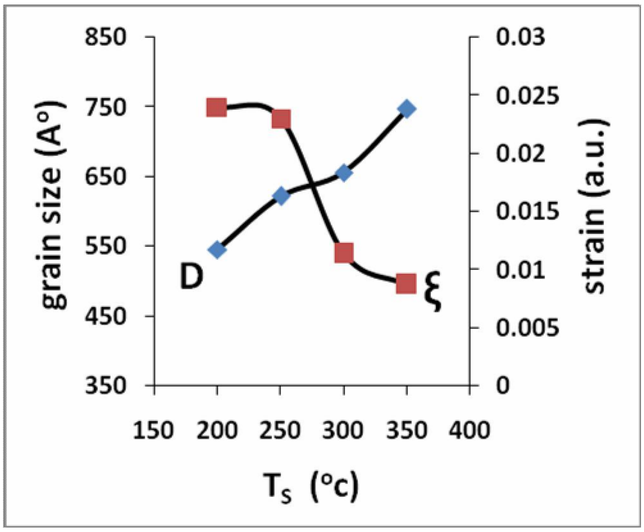
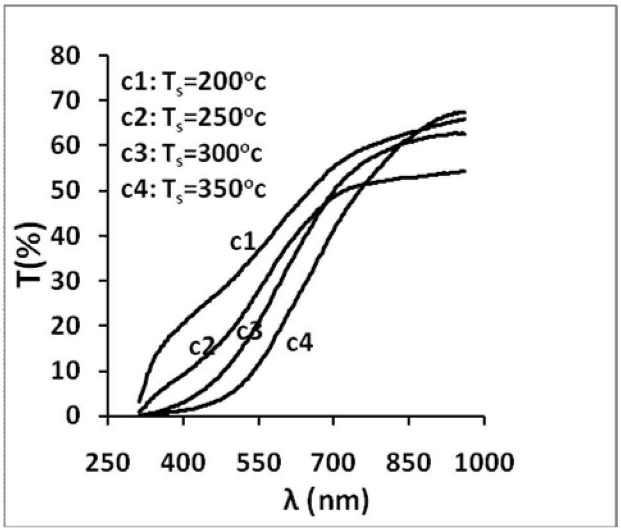


Fig.(2):Grain size and Strain of SnS thin films as function of Sub. Temp.

b-optical properties

The spectral behavior of transmittance T(λ) for SnS films prepared at different substrate temperature was shown in fig.(3),it is clear that the transmittance for all samples under investigation increases with increasing wavelength (λ) however with increasing substrate temperature the transmittance decreases for fixed wavelength ,while fig.(4) shows the absorption spectrum ,it was determined that the absorption began at wavelength 950 nm and reached amaximum value at 300 nm , the spectral dependence of reflectance for SnS thin films is shown in fig.(5) it can be notice the increment of reflectance with wavelength for all specimen to a maximum value 65% then began to decrease as wavelength increases this caused by high transmittance of the films .



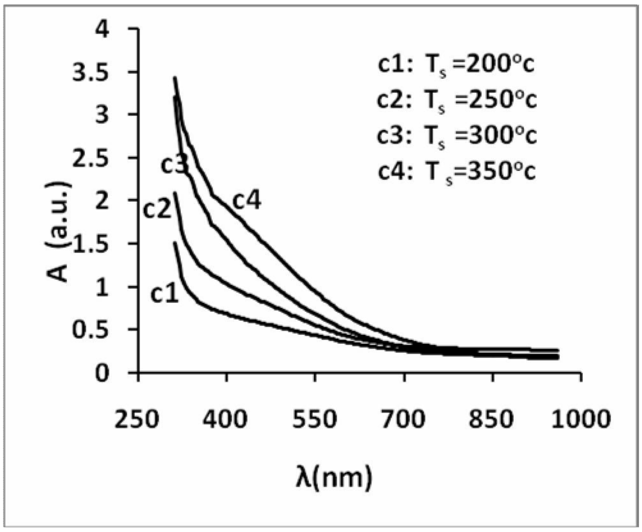


Fig.(3): Optical Transmittance spectrum for SnS thin films prepared at different Sub. Temp.

Fig.(4):Spectral behavior of Absorbance for SnS thin films prepared at different Sub. Temp.

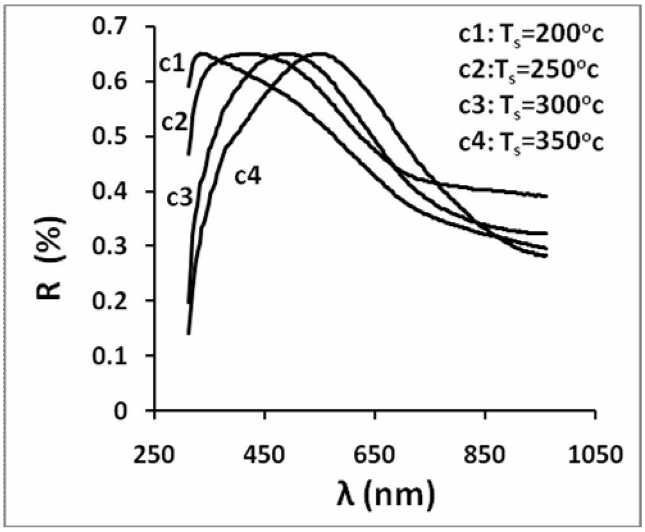


Fig.(5):Spectral behavior of Reflectance for SnS thin films prepared at different Sub. Temp.

The variation of coefficient of absorption (α) with photon energy (hν) for SnS thin films was shown in fig.(6)it is obvious that specimen (c4) prepared at 350 ^{o}C has the highest absorption coefficient . In order to estimate the optical band gap, the following equation connecting the photon energy (hν) and absorption coefficient (α) is used:

$$(\alpha h\nu)^{1/p}=A\,(h\nu-Eg) \qquad [12]$$

where **A** is constant ,exponent (**p**) is the probability for **p=1/2** the transition is direct and allowed , to determine the direct allowed band gap a graph between $(\alpha\ h\nu)^2$ and (hν) was plotted and shown in fig.(7) the straight portion of the graph is extrapolated to energy axis to give Eg value it is found to be in the range (1.6- 1.54) eV as substrate temperature increase within range (200- 350) ^{o}C , also it is seen from table (1) that the energy gaps decreases as substrate temperature increases this behavior correlated with that reported in ref. [8]this change in band gap is attributed to the presence of other phases of SnS such SnO_2 or to the change of orientation of the grain size associated with the orthorhombic structure [19].As the film C4 with band gap 1.54eV, i.e. near the optimum needs for photovoltaic solar energy conversion (1.5 eV) has the best crystalline structure as it clear from behaviors analysis for XRD pattern .

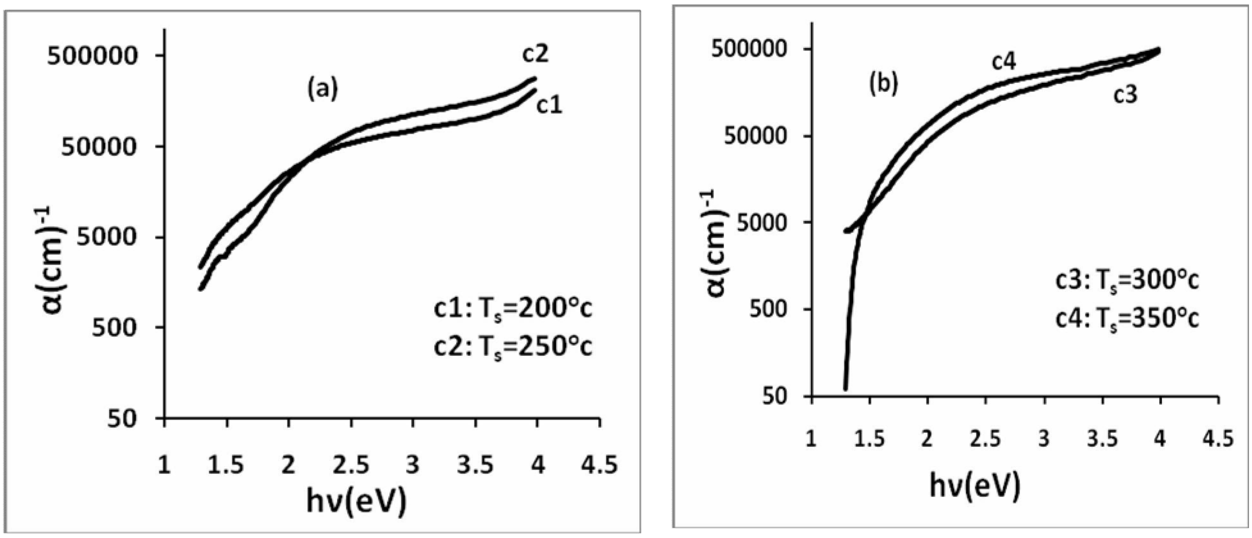


Fig.(6):Absorption Coefficient (α) for SnS thin films prepared at different Sub. Temp.

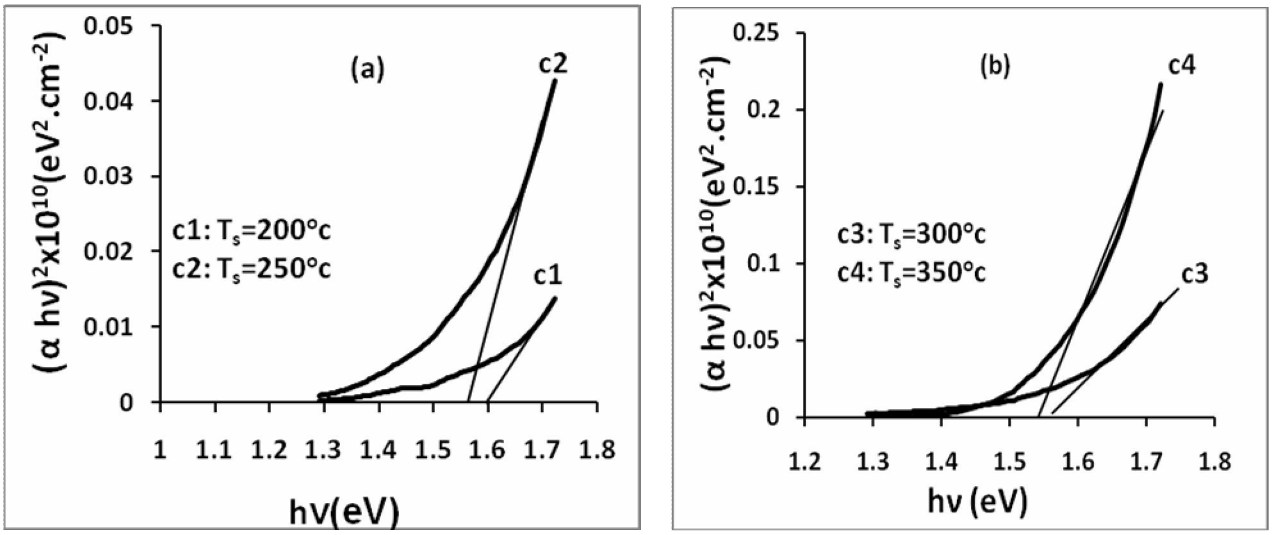


Fig.(7): Plot of $(\alpha h\nu)^2$ as a function of photon energy (hν) for SnS thin films .

fig.(8)(a,b) shows the refractive index(n) , extinction coefficient (k) and dielectric constant (ε_1,ε_2) for sample C4 while fig.(9)(a,b) shows the optical parameters n, k, ε_1 and ε_2, as function of substrate temperature , the extinction coefficient (k) increases from 0.42 to 1.15 with increasing substrate temperature (200- 350) ^{o}C , inversely behavior for refractive index was seen moreover dielectric constant ε1, ε2 has similar behavior.

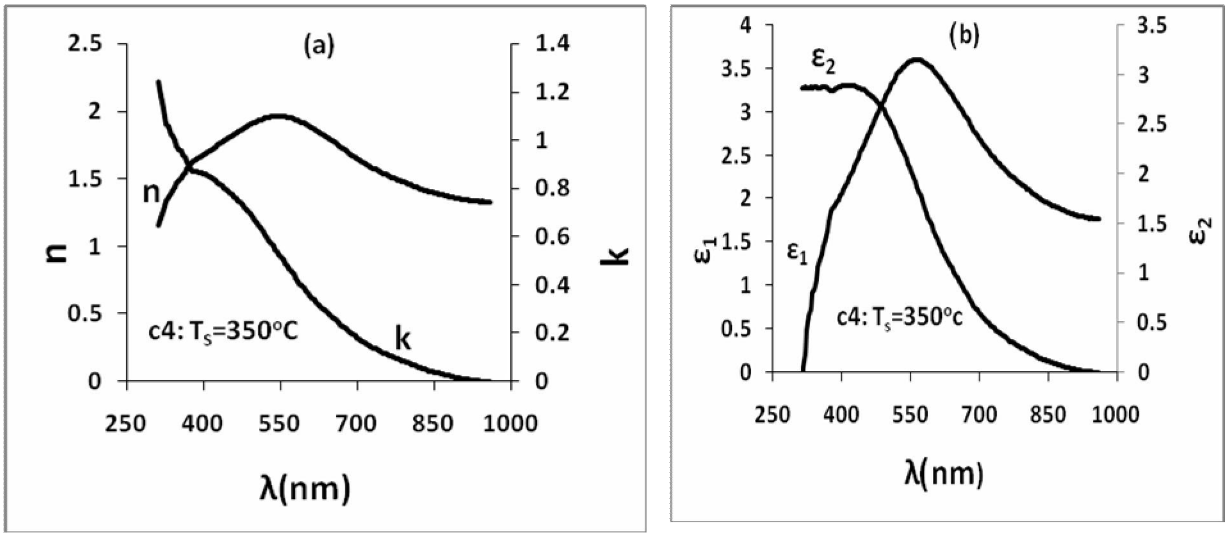


Fig.(8): Spectral behavior of (a): Refractive Index (n)and Extinction Coefficient (k).

(b): Dielectric Constant (ε_1,ε_2) for SnS thin films prepared at 350 °C .

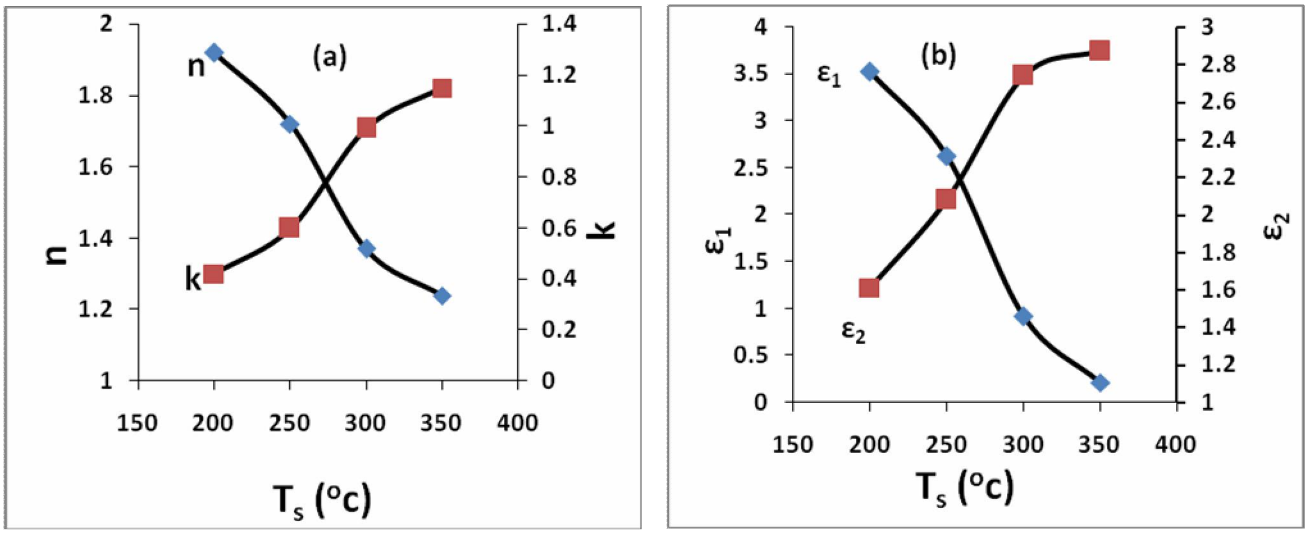


Fig.(9): Optical parameter(a): n, k (b): ,ε_1,ε_2 as a function of Sub. Temp .

Table(1):structural and optical properties of SnS thin films.

no. of samples	Temp. T_s(°c)	Grain size D(A°)	Strain ξ	Band gaps Eg (eV)	n	k	ε_1	ε_2
C1	200	546	0.024	1.6	1.92	0.42	3. 52	1.61
C2	250	622	0.o23	1.57	1.72	0.6	2.62	2.08
C3	300	656	0.0114	1.55	1.37	0.99	0.91	2.74
C4	350	747	0.0087	1.54	1.24	1.15	0.21	2.84

CONCLUTION :

SnS thin films were successfully deposited onto glass substrate by spray pyrolysis method .X-ray diffraction spectrum shows that SnS films were polycrystalline with an orthorhombic structure and prefered orientation (111) plane .It is concluded that to obtain uniform and better crystatallinity SnS film the substrate temperature shoud be at 350 ^oC .The influence of substrate temperature on optical properties were investigated it was revealed that the increase in grain size and decrease in strain led to decrease in(1.6- 1.54) eV band gap as substrate temperature increases in the range (200- 350) ^oC .Due to suitable direct band gap value for absorber layer for efficient light absorption, SnS thin film can be used as absorber layer in solar cells.

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الخلاصة

حضرت أغشية كبريتيد القصدير على قواعد زجاجية بتقنية الترسيب الكيميائي الحراري .أكد حيود الأشعة السينية التبلور المتعدد لأغشية SnS مع الاتجاه المفضل حول المستوى (111) . درس تأثير درجة حرارة القاعدة على الخواص التركيبية والضوئية فقد وجد إن فجوة الطاقة المسموحة المباشرة تتغير ضمن المدى eV (1.6-1.54) بزيادة درجة حرارة القاعدة وقد عزي السبب إلى زيادة حجم الحبيبات البلورية ونقص في الاجهاد.