Effectof annealing temperature on opticaland electrical propertiesof SnS thin films

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Abstract

SnS thin films have been depositedat R.T. with thickness (300 nm ± 0.01) by using a thermal evaporation technique and annealed at 200°C for 2hour.The optical band gap of the SnS film determined from optical transmittancespectrum, in the range (400-1100 nm)and the data was used to calculate absorption coefficient and optical band gap. The film as grownand annealed has shown a direct band gap ~ 2.24 eV and 2.17eV respectively.The optical constant such as extinction coefficient (k), absorption coefficient (α) and refractive index (n) have been evaluated.

At the annealing temperature the SnS film had the best electrical properties the mobility was up to 52.35 $cm^2.V^{-1}.s^{-1}$, and the resistivity was about 0.14×10^6(Ω.cm).

Keywords: Tinsulfied, thinfilms, Thermal evaporation, Optical & electrical properties.

1. Introduction

In recent years, thin films of SnS have attracted much for photovoltaic applications due to the high absorption ($>10^4 cm^{-1}$)[1,2] and high conductivity .SnS belongs to groups IV-VI compounds formed with Sn as the action and Sas the anion .The constituent elements are inexpensive, nontoxic and abundant in nature leading to the development of devices that are environmentally safe and have public acceptability.SnS is animportant optoelectronic material that is found in zinc blend with lattice constant (a=0.5845 nm) [3], orthorhombic with lattice constants (a=0.385 nm, b= 1.142 nm c= 0.438 nm) [4,6] crystal structures.The optical properties of SnS vary depending on synthesizing or fabrication method, but most work agrees with direct (1.2-1.5 eV) and indirect (1.0-1.2eV) band gap values. These properties enable SnS thin films to be used as an absorption layer in the fabrication of hetrojunction solar cell [7].

SnS thin films can be fabricated by many methods such as thermal evaporation ,pulse electro depositions , ,SILR ,electron beam evaporation, chemical bath deposition [8,9,10]. The film in this study is grown by thermal evaporation, this method has many advantages, it is widely used because it is a simple, economic and viable technique, which produces films of good quality for device applications. In this work, an attempt has been made to prepare SnS films by thermal evaporation in order to investigate their optical and electrical properties.

2.Experimental

Tin sulphide thin films of thickness (300nm± 0.01) were deposited with rate deposition 48 nm/s at R.Tand they were annealed at 200°C on chemically and ultrasonically cleaned glass substrates with the high Vacuum Coating unit at a vacuum about10^{-5}torr. The distance between sourceand substrate was maintained at 6.5 cm for the cases. The prepared films were annealed in vacuum at elevated temperature for 2 hour.Optical transmittance measurements for the film were carried out using UV/VIS double beam spectrophotometer (Schimadzu 160Å Japan Company) in the wavelength range (400-1100nm).Based on Van der Pauwmethod, the electrical properties were determined by a HMS 3000 Hall measurement system.

3. Results and discussion

3.1. Optical Properties

The optical transmission (T) spectrum deposited films at R.Tand annealed at 200°C was taken by using spectrophotometer in the wavelength range of (400- 1100 nm) in order to determine the optical characterization of SnS thin films .This spectra is shown in Fig . (1) it is obviously seen that the SnSthin film as preapared has transmission about 90%, while this value increase with annealing temperature,the transmission curve indicates a nearly saturated at 1100 nm , this may be due to high crystalline nature of the prepared films [11,12].

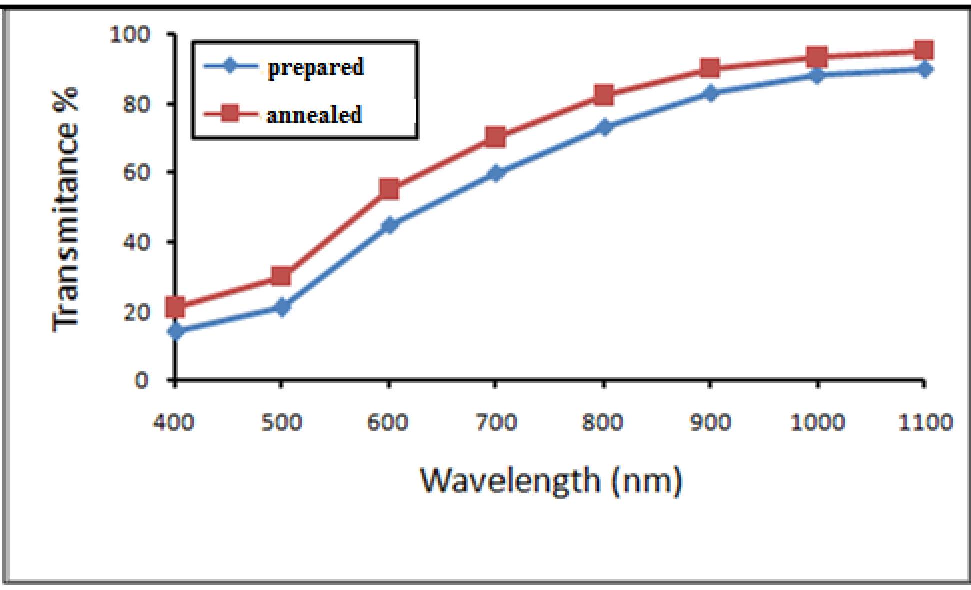


Fig. (1) Transmittance versus wavelength for the as deposited filmsand annealed.

The absorption coefficent (α) can be calculated according to formula (1) [13]:

$\alpha = 2.303\ A/d$ (1)

where A is theAbsorptance, and d is thickness of the films .

Fig.(2) shows the curves of absorption coefficient α vs hν of the two samples.It can be seen that both gradient of curves and the magnitude of α increase with annealing.

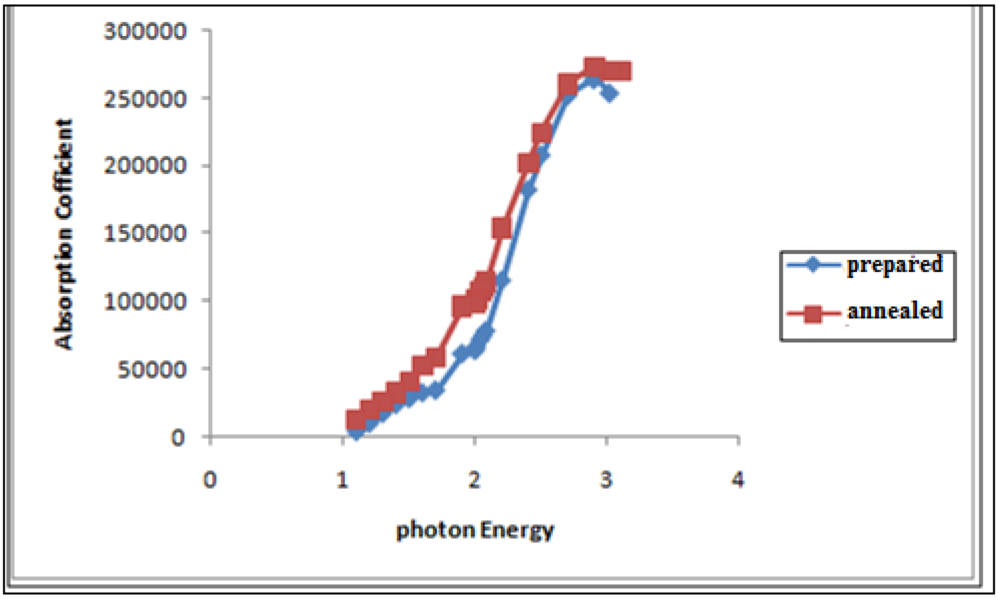
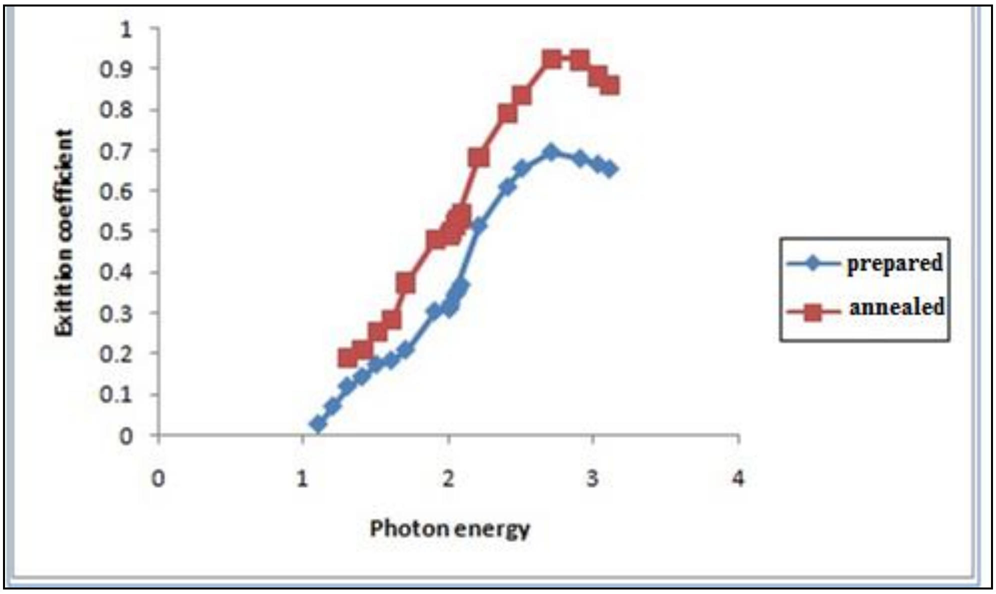


Fig .(2) Absorption coefficient curveof the SnS films deposited at R.T.and annealed

The extinction coefficient (k) was calculated using the relation [14]:

$$k = \frac{\alpha\ \lambda}{4\ \pi} \qquad (2)$$

Where α is the absorption coefficient and λ is the wavelength of the incident photon.Fig. (3) shows that the extinction coefficient as a function of photon energy as seen in the figure , this fig. show that (k) increases for annealing film that due to the band –to band transition and increases in absorption coefficient in this film.



Fig(3). Exitnction coefficient Vs. photon energy for deposited and annealed film

For the allowed direct transition, the variation of α with photon energy (hν) obeys Tauc □ s plot expressed as [14] :

$(\alpha h\nu)^2 = A(h\nu - E_g)$ (3)

Where A is a constant, E_g the optical band gap , h the plank constant and α the absorption coefficient . In Eq. (4) ,E_g denoted the energy gap between the valence band and conduction band. According to Tauc □s plot shown in Fig.(4) ,the optical band gap were determined by extrapolating the linear region of the resulting curve. They were varied from 2.24eV to 2.17eV for as deposited film and for annealed film respectively.It is mainly attributed to the room temperature deposited .

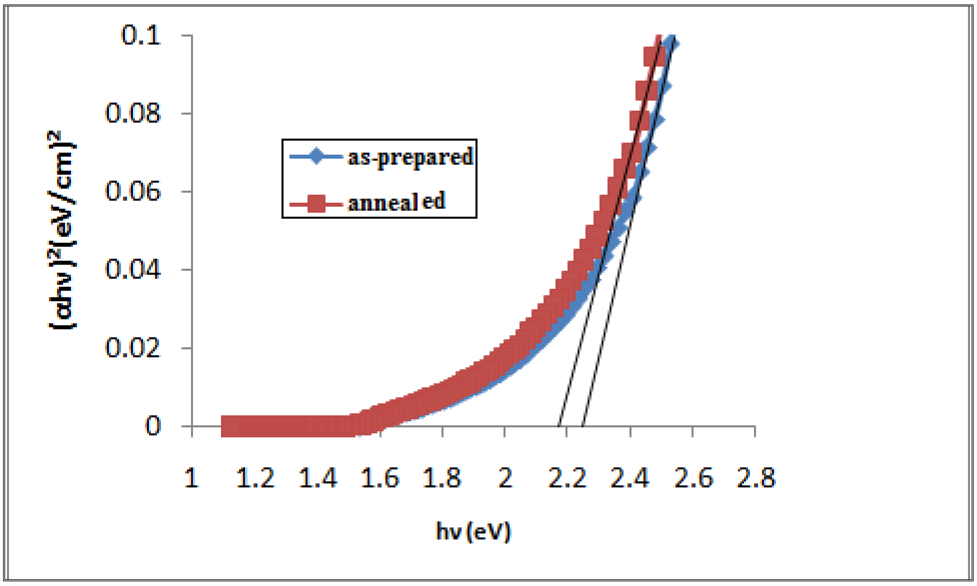


Fig.(4) . (αhv)² Vs hv curve of the SnS film deposited at R.Tand annealed

Fig . (5) shows the refractive index of the SnS films for prepared and annealed as a function of photon energy ,the refractive index increases for the annealing sample from(1.1- 2.5) and it varies with photon energy and seems to have its maximum value at to the peak maxima which was nearly constant for two samples.

The refractive index (n) of the films was calculated using the relation [15] :

$$n=[\left(\frac{1+R}{1-R}\right)^2 - (k^2+1)]^{1/2} + \frac{1+R}{1-R} \qquad (4)$$

Where (R) is the reflectance and (k) is the extinction coefficient

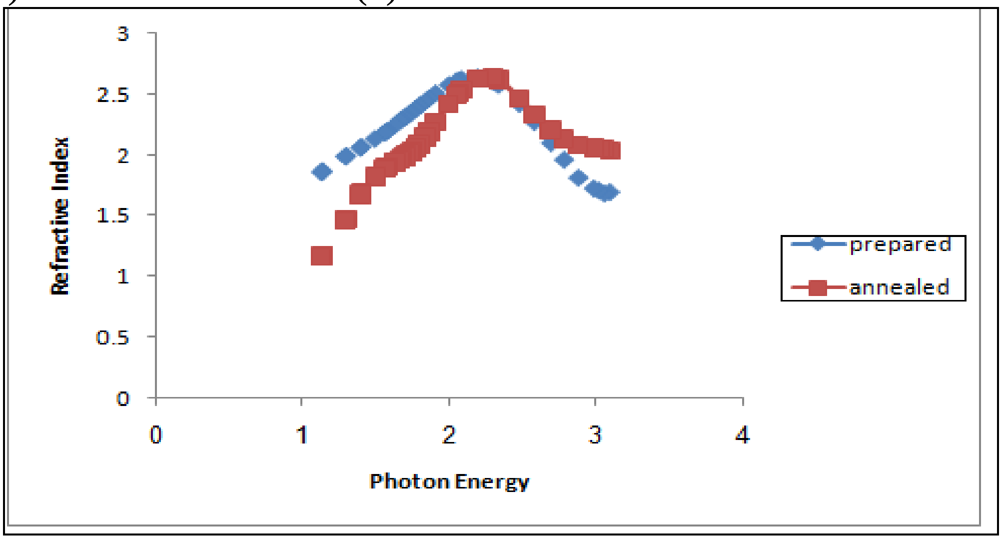


Fig.(5) Refractive index versus photon energy for the as deposited and annealed films

2. Electrical Properties

At roomtempreature, semiconducting properties of the films were measured by a HMS-3000 Hall measurement system .The results are listed in Table 1. Compared with the unannealed sample, the semiconducting properties of the annealed sample has been improved.

The carrier concentration (n_H) of the films was calculated using the relation[16]:

$$n_H = 1/R_H .e \qquad (4)$$

where (R_H) Hall Coefficient and (e) is the charge of electron.

The mobility (μ_H) of the films was calculated using the relation [17]:

$$\mu_H = R_H .\sigma \qquad (5)$$

where (σ) is the conductivity.

It can be seen from Table 1 the carrier concentration of the films decreases from $15.37\times10^{11}cm^{-3}$ (un annealing) to 8.02×10^{11} cm^{-3} with annealing temperature ,and their resistivity decreases from $1.239\times10^{6}\Omega.cm$(un annealing) to $0.147\times10^{6}\Omega.cm$ with annealing temperature .In addition , the carrier concentration for two samples is positive, which indicates that the SnS films are of p- type conduction.Therefore,the annealing can decreases the carrier concentration, reduce the resistivity,the phenomenon can be explained by the fact that at the annealing temperature ,better crystallization and greater grain size in the films lead to decrease defects density and crystal-boundary, therefore the resistivity decreases.These results are similar to result of Hong-Jie Jia et al. [18].

Table 1. Hall measurement results for SnS thin filmsat R.T.and annealed

Sample	(n_H) carrier concentration (cm^{-3}) x10^{11}	(μ_H) Mobility ($cm^2.V^{-1}.s^{-1}$)	Resistivity (Ω.cm) x10^6
As deposited	15.37	3.278	1.239
Annealing at 200°C	8.02	52.35	0.147

4- Conclusion

The SnS thin films were deposited on glass substrate using thermal evaporation technique and the effect of annealing on optical & electrical properties were investigated it was revealed that the effect of annealing lead to decreased the band gap from (2.24-2.217) eV and decreased in absorption, extinction coefficient .In addition to ,the carrier concentration for two samples is positive , which indicate that the SnS films are of p- type conduction .

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تأثير درجة حرارة التلدين على الخواص البصرية والكهربائية لاغشية SnSالرقيقة

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الخلاصة

حضرت اغشية كبريتيد القصدير بطريقة التبخير الحراري بدرجة حرارة الغرفة بسمك (300 nm ± 0.001) ثم لدنت بدرجة حرارة (200ºC) لمدة ساعتين. حسبت فجوة الطاقة البصرية لاغشية SnS من طيف النفاذية ضمن المدى (400-1100 nm) واستخدمت هذه البيانات لحساب معامل الامتصاص وفجوة الطاقة البصرية ، اظهر الغشاء الغشاء الرقيق والملدن فجوة طاقة مباشرة (2.17 eV- 2.24eV على التوالي) حسبت الثوابت البصرية مثل معامل الخمود(k) ومعامل الامتصاص (α) و معامل الانكسار(n) . عند درجة حرارة التلدين, اظهرت اغشية SnSافضل نتائج كهربائية وكانت التحركية $52.35 cm^2.V^{-1}.s^{-1}$, والمقاومية بلغت $0.14X10^6$ Ω.cm .

الكلمات المفتاحية: كبريتيد القصدير, الاغشية الرقيقة, التبخير الحراري, الخواص البصرية والكهربائية.