Effect of Thickness and Thermal Annealing on Optical Properties of Sb Thin films

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Abstract
Antimony (Sb) films are fabricated by depositing (Sb) on glass substrates at room temperature by the method of vacuum evaporation with thickness (0.25 and 0.5µm), with rate of deposition equal to (2.77Å/sec), the two samples are annealed in a vacuum for one hour at 473K. The optical constants which are represented by the refractive index (n), extinction coefficient (k) were determined from transmittance spectram in the near Infrared(2500-3500)nm regions. The tests have been shown that the optical energy gap increases with increasing of annealing temperature for the two samples.

Keywords: optical properties of Sb films, effect of thickness on optical properties of Sb films, effect of annealing on optical properties of Sb films.

تاثير السمك وحرارة التلدين على الخواص البصرية لأغشية الانتيمون

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الخلاصة
تم تحضير أغشية الأنتيمون بترسيب الانتيمون على قواعد زجاجية بدرجة حرارة الغرفة بطريقة الترسيب بالفراغ بسمك(0.25,0.5)µm وبمعدل ترسيب 2.77 Å/sec, ثم لدنت العينات بالفراغ بدرجة حراره 473 K لمدة ساعه واحده.الثوابت البصريه المتمثله (بمعامل الانكسار وعامل التوهين) حددت من خلال طيف النفاذية بالمنطقة تحت الحمراء .أظهرت الفحوصات ان قيم فجوة الطاقة لجميع اغشية الانتيمون تزداد بزيادة حرارة التلدين وتقل مع السمك.

المفتاح: الخواص البصرية لأغشية الأنتيمون، تأثير التلدين على الخواص البصرية للأنتيمون،تأثير السمك على الخواص البصرية للأنتيمون.

Introduction

Antimony (Sb) is a semimetal. It is found of use in semiconductor technology for making infrared detectors, diodes and Hall effect devices. Antimony has been known since ancient times. It is usually obtained from the ores stibnite (Sb2S3)andvalen-tinite(Sb2O3)[1].

Thermal evaporation is used for preparation Sb films in this research. Deposition by thermal evaporation method is simple, very convenient and most widely used for producing thin films. Thin films preparation in thermal evaporation depends on substrate temperature, substrate-source separation and orientation, base gas pressure in the chamber and boat or filament temperature[2 and 3]. The aim of this paper is study the effect of thickness and annealing temperature on optical properties of Sb films.

Experimental part

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Sb films were deposited on the glass substrates by the method of vacuum evaporation with pressur 10^{-5} mbar. The thickness of each deposited thin films is (0.25, 0.5) μm, in general the thickness was measured by weight method.

$t=m/2\rho\pi h^2$ ………………………..(1)

Where t=is the film thickness in cm,
m =is the mass of the materials to be evaporated in gm, h = is the source (boat) to substrate distance and ρ = is the density of materials to be evaporated.

The films are annealed in a vacuum at a temperature of 437K for one hour.

The optical absorbance spectra of the Sb films are measured using FTIR Shimadzu spectrophotometer model 8300, Japan, with range of wave length (2500-3300) nm. The optical constants including, the refractive index and extinction coefficient were calculated from transmittance and absorptance spectrum.

When the light of intensity (Io) incident on the film of thickness (t) the transmitted intensity (I) can be given as [4].

$I=I_o \exp(-\alpha t)$…………………...(2)

I/Io represents the transmittance (T), since the absorbance (A) :

$A=\log(1/T)$ …………………… (3)

Then α (absorption coefficient) is given by[4]:

$\alpha = 2.303\ A/t$………………….. (4)

The Optical Energy Gap is given by equation [5 and 6] :

$\alpha h\nu = B(h\nu - E_{opt})^r$…………….(5)

Where B is the constant involving the properties of the bands.

The optical energy gap was calculated by plotting $(\alpha h\nu)^{1/r}$ versus the photon energy (hν) and taking the extrapolation of the linear portion of $(\alpha h\nu)^{1/r}$ at $(\alpha h\nu)^{1/r}=0$ and the value gives the optical energy gap (E_{opt}). The index (r) takes the value between $0< r < 3$.

The optical constants which are represented by the refractive index (n) and extinction coefficient (k). The refractive index was calculated from the equation [7]:

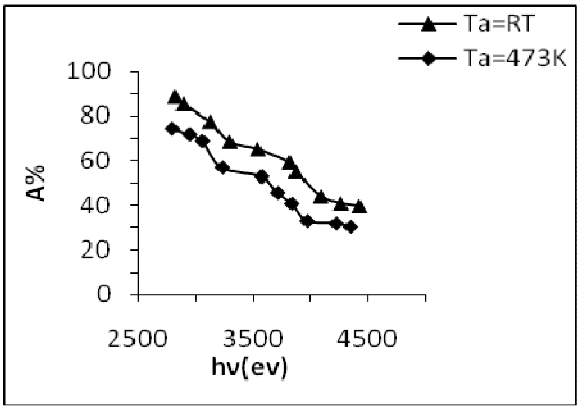
$$n=\left[\frac{4R}{(R-1)^2}-k^2\right]^{1/2}-\frac{(R+1)}{(R-1)} \quad \text{.........}(6)$$

Where R is the reflectance, extinction coefficient (k) can be determined by using equation[8] :

$$k=\frac{\alpha\lambda}{4\pi} \quad \text{.......... ....}(7)$$

Results and Discussion

The absorbance spectrum for Sb films with different thicknesses and annealing temperatures are shown in figure 1. The absorbance decreases with increasing of annealing temperature and this may be due to decrease the crystallization and increase the transmittance. The absorbance increases with the increasing of film thickness because in the case of thicker film, more atoms are present in the film so more states will be available for the photons to be absorbed [8].



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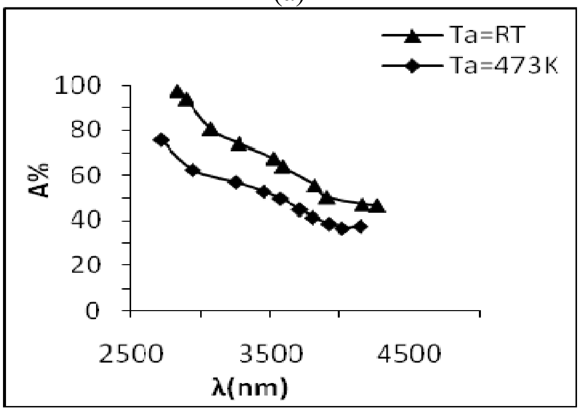
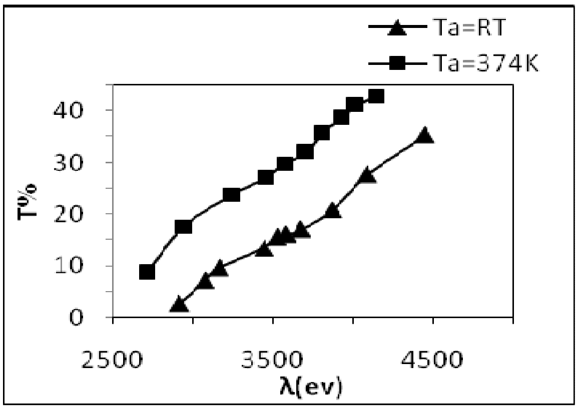


(b)

Figure 1- Absorbance spectrum as a function of wavelength for Sb films at different thicknesses and annealing temperatures (a): 0.25μm, (b): 0.5 μm



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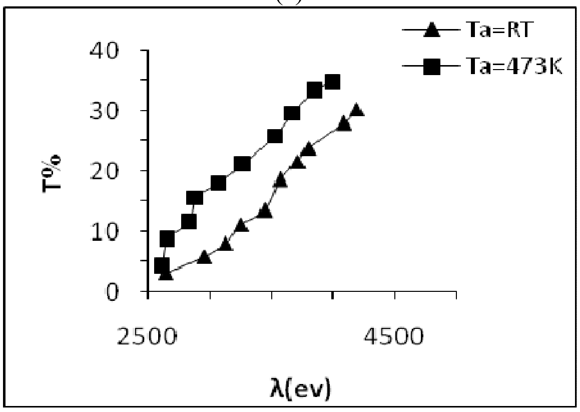


(b)

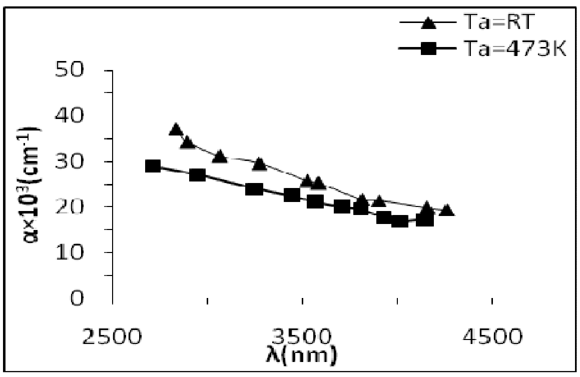
Figure 2 - Transmittance spectrum as a function of wavelength for Sb films at different thicknesses and annealing temperatures (a): 0.25μm (b): 0.5 μm

The transmittance increases with increasing of annealing temperature for all thicknesses as shown in figure 2.

We notice also that the transmittance decreases with increasing of thickness and shifted to shorter wavelengths. This may be attributed to the creation levels at the energy band by increasing thickness [4].

The Absorption Coefficient

We can notice that α (absorption coefficient) in general decreases with increasing of T_a for all thicknesses. In general α has increased with the increase of film thickness as shown in figure 3. α has the same behavior of the absorbance.



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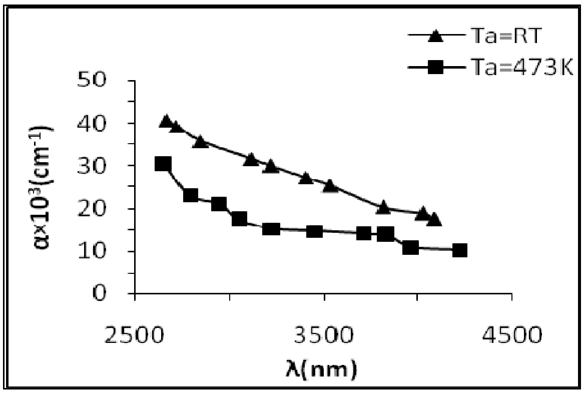


(b)

Figure 3 - absorption coefficient as a function of wavelength for Sb films at different thicknesses and annealing temperatures (a): 0.25μm (b): 0.5 μm

The Optical Energy Gap

The optical energy gap values (E_g) for Sb films have been determined. A plot of $(\alpha h\nu)^{1/2}$ versus hν for Sb films with different annealing temperatures and thicknesses is shown in figure 4. The plot is linear indicating the indirect band gap nature of the films. The value of the optical energy gap increases with increasing of T_a for all samples due to the annealing temperatures remove some defect states in the gap [9]. The optical energy gap decreases with increasing thickness as shown in figure 5.This is due to the increase of the density of localized states in the E_g [10] .

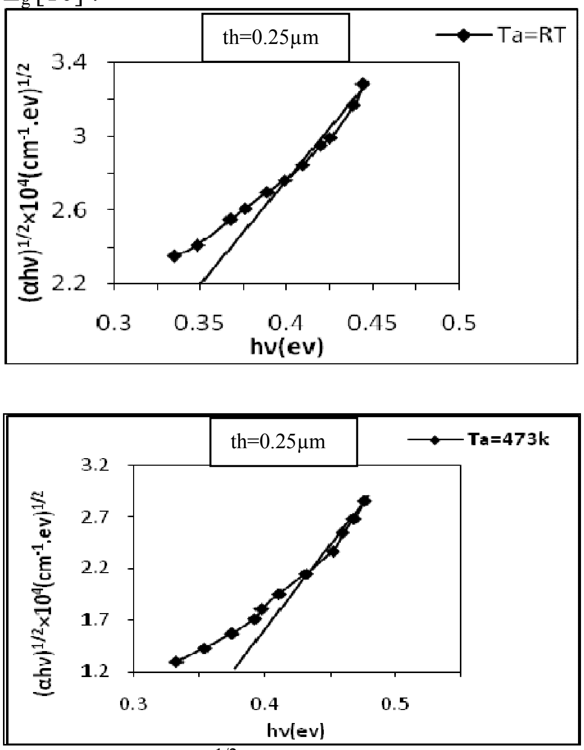


Figure 4 - $(\alpha h\nu)^{1/2}$ as a function of hν for Sb films at thickness (0.25μm) and different annealing temperatures

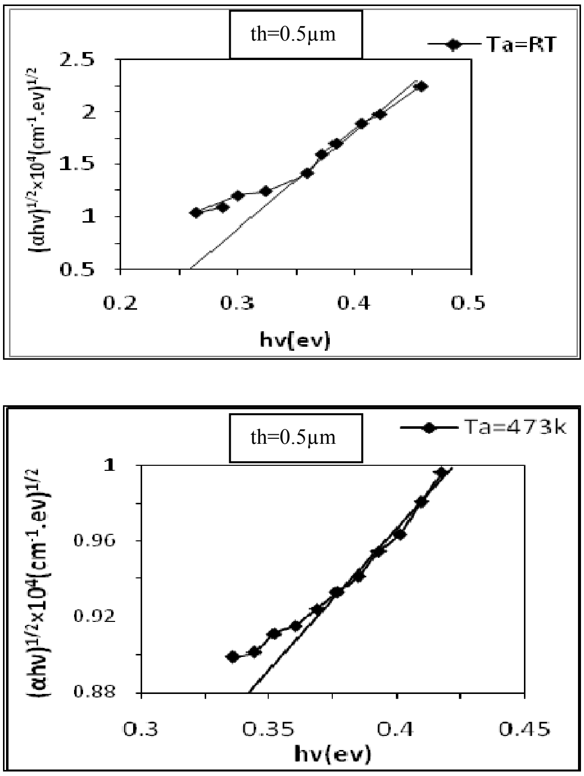
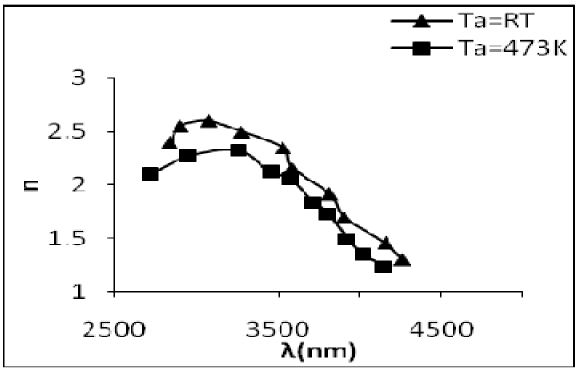


Figure 5- $(\alpha h\nu)^{1/2}$ as a function of hν for Sb films at thickness (0.5µm) and different annealing temperatures

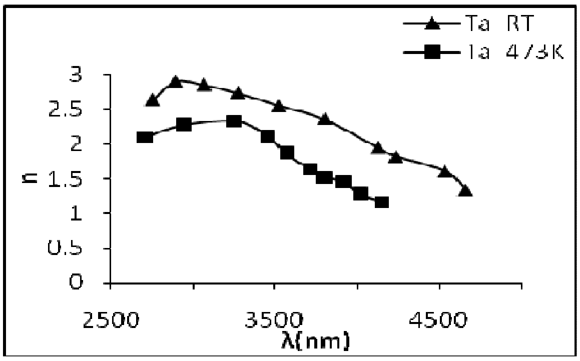
Refractive Index

The refractive index decreases with the increasing of T_a due to the decrease of the compactness of the films after the heat treatment simultaneously with the decrease of the crystallite size as shown in figure 6.

The refractive index increases with the increasing of thickness as shown in figure 6. This is due to the variation in crystal structure of the films.



(a)

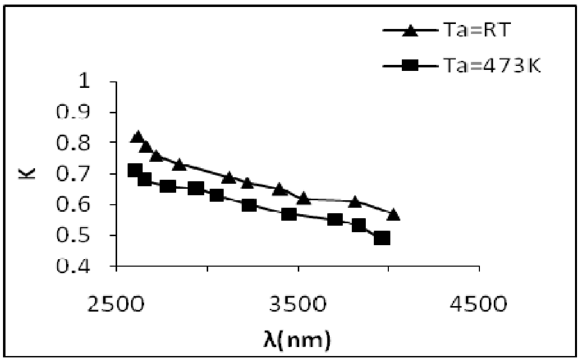


(b)

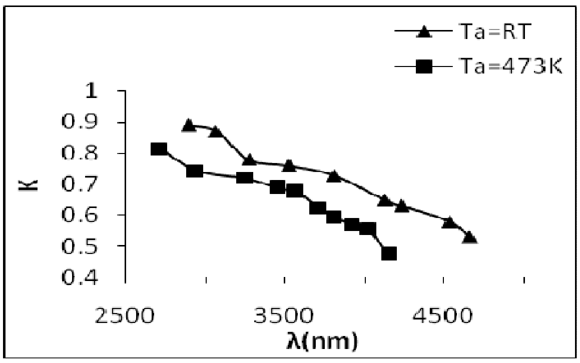
Figure 6- Refractive index as a function of wavelength for Sb films at different thicknesses and annealing temperatures (a):0.25µm(b): 0.5 µm

Extinction Coefficient

The extinction coefficient (k) decr-eases with increasing of annealing temperatures for all films, and increases by increasing of thickness in the range as shown in figure 7. This is attributed to the same reason mentioned previously in the absorption coefficient because the behavior of k is similar to α.



(a)



(b)

Figure 7- Extinction coefficient as a function of wavelength for Sb films at different thickness and annealing temper-atures (a): 0.25µm(b): 0.5 µm

Conclusions

From transmittance spectram in the near Infrared, the transmittance increases with increasing of annealing temperature, but it decreases with increasing of thickness. Absorption coefficient (α) decreases with increasing of T_a for all thicknesses, but α has increased with the increase of film thickness, absorbance spectra it was observed that the optical transition in the Sb thin films is an allowed direct transition and the value of the optical energy gap increases with increasing of T_a for all samples, but optical energy gap decreases with increasing the thickness.

Table 1- Parameter of optical properties of Sb films at two thickness and annealing temperature 473K.

Thickness (μm)	T_a K	$\alpha\times10^3(cm)^{-1}$ λ(2850nm)	Eg (eV)	n λ (2900 nm)	k λ(2850nm)
0.25	RT	33	0.35	2.72	0.75
	473	28	0.377	2.31	0.67
0.5	RT	37	0.26	2.95	0.86
	473	22	0.34	2.42	0.75

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