

# Annealing Effect on the Optical Properties of Sb<sub>2</sub>S<sub>3</sub> Thin Films

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## ABSTRACT

Sb<sub>2</sub>S<sub>3</sub> thin films have been prepared using chemical bath deposition .these films were annealed for different temperatures 373, 473 k. Absorbance and transmittance spectra were recorded in the wavelength range (300-900) nm. the nature of electronic transitions was determined, it was found that these films have direct allowed transition with an optical energy gap of 1.72, 1.76, 1.82 eV before and after annealing respectively. the extinction coefficient, refractive index, real and imaginary part of dielectric constant were also measured before and after annealing.

## Introduction

Chalcogenide semiconductor glasses especially antimony trisulphide have received considerable attention due to its properties such as high absorption coefficients ( $\square >10^3 \text{ cm}^{-1}$ ) high refractive index, photo sensitive, thermoelectric properties, well defined quantum size effects, optimum band gap ( $E_g = 1.8 \text{ eV}$ ), exhibit structural modifications when irradiated by light and by an electron beam [1-7].

It has been used in solar energy conversion [8], photoelectrochemical cells [9], as a target material to television camera [10], microsphere of Sb<sub>2</sub>S<sub>3</sub> have also been used as substrates for radiolabeling in routine clinical applications [11], microwave devices [12].

Many techniques have been adopted to prepare thin films of Sb<sub>2</sub>S<sub>3</sub> like, electrode position [13], spray pyrolysis [14], electron beam irradiation [15], hydrothermal method [16], and chemical bath deposition [17].

The aim of this work concentrates on the effect of annealing temperature on the optical properties of Sb<sub>2</sub>S<sub>3</sub>

## Experimental details

Antimony trisulphide (stibnite) were grown on a glass substrate utilizing chemical bath deposition technique.

The choice of this method arises from its low cost, ease of handling and possibility of application on large surface SbCl<sub>3</sub> were used as a source of Sb a 11.5 g of SbCl<sub>3</sub> was dissolved in 50 ml acetone and placed in 50 ml beaker to which 12 ml of 1M Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub> and 33 ml of deionised water. The resulting solution was stirred for 5 minutes, the PH of the bath was kept at 3.5. The glass substrates were cleaned well with detergent and distilled water, and were kept in H<sub>2</sub>SO<sub>4</sub> for a bout one hour.

The substrates were then washed first under running tap water (to clean the acid off), then cleaned with acetone, washed with running water a gain and finally cleaned with distilled water dried in air.

Two substrates were attached to each other and placed vertically in the beaker, after deposition the glass slides were taken out from the bath, washed with distilled water, dried in blowing air. The thickness of the films for an hour were about (0.25 – 0.3)  $\square \square \text{ m}$ .

The samples were heat treated by annealing in air at a rate of 10 k/min from room temperature up to 373 k and 473 k, then sample were cooled down at the same rate.

Absorbance and transmittance were recorded before and after annealing in the wavelength range (400-900) nm using UV/VIS double beam schimadzu 160 Å spectrophotometer (Japan).

## Results and discussions

The optical transmittance of Sb<sub>2</sub>S<sub>3</sub> thin films before and after annealing were determined by the spectrophotometer with the wavelength range (400-

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900) nm as shown in Fig. (1). As can be seen from Fig. (1) the transmittance decrease as the annealing temperature increase. The lower transmittance of the heat treatment films is due primarily to the precipitation of the Sb excess and the high absorption coefficient of Sb in this spectral region [18].

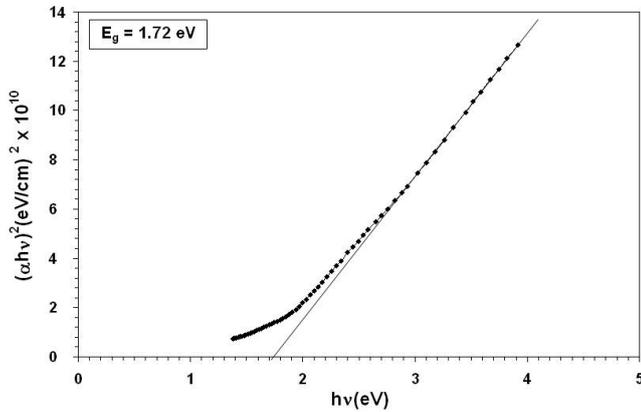


Fig. (1) Transmittance versus wavelength of Sb<sub>2</sub>S<sub>3</sub> thin films before and after annealing.

Taucs has proposed as mathematical equation to present the relationship between optical energy gap and the energy of the incident photon [19]:

$$(\alpha h\nu) = A(h\nu - E_g)^n \dots (1)$$

Where  $\alpha$  is the optical absorption coefficient, A is a constant,  $h\nu$  is the energy of the incident photon,  $E_g$  is the optical band gap and n is an index which could take different values according to the electronic transition. After we try all the possible value of n we conclude that kind of transition is direct which is in good agreement with Ubale et al. [20], the characteristics of  $(\alpha h\nu)^2$  vs.  $h\nu$  (photon energy) were plotted for evaluating the band gap ( $E_g$ ) of the Sb<sub>2</sub>S<sub>3</sub> thin films, and extrapolating the linear portion near the onset of absorption edge to the energy axis as shown in figures (2), (3), (4) shows the value of  $E_g$  before and after annealing, it can be noticed that the value of the optical energy gap decrease as the annealing temperature increase, this could be attributed to the fact that an increase in annealing temperature leads to minimizing structural imperfections in the as deposited thin films. this behaviour was in good agreement with Versavel and Haber [12].

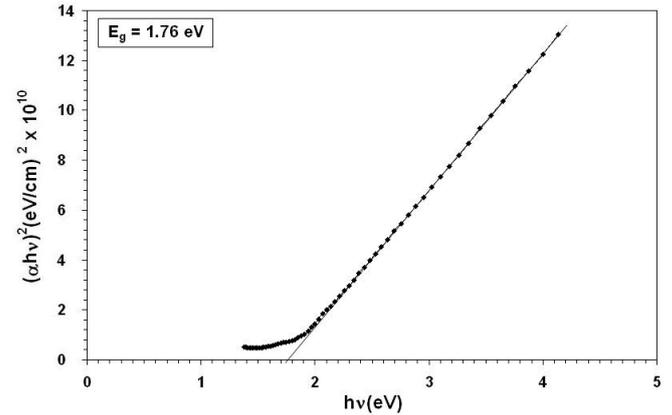


Fig. (2)  $(\alpha h\nu)^2$  versus photon energy for Sb<sub>2</sub>S<sub>3</sub> thin films before annealing.

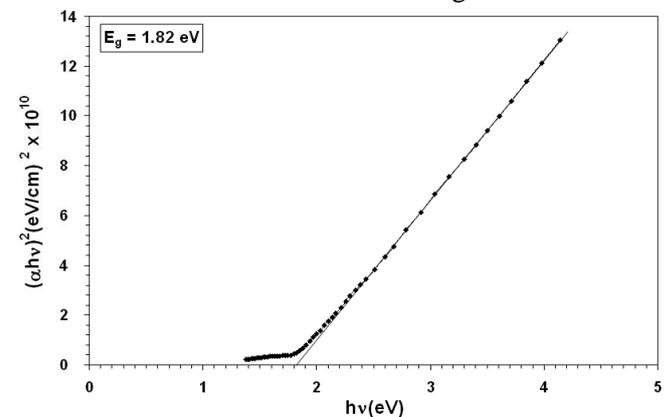


Fig. (3)  $(\alpha h\nu)^2$  versus photon energy for Sb<sub>2</sub>S<sub>3</sub> thin films after annealing at 373 K.

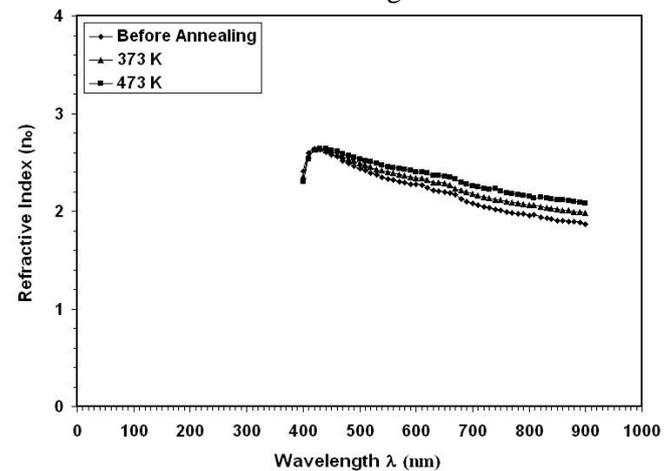


Fig. (4)  $(\alpha h\nu)^2$  versus photon energy for Sb<sub>2</sub>S<sub>3</sub> thin films after annealing at 473 K.

The effect of annealing on the refractive index which could be determined from the relation below [21]:

$$n_o = \left[ \left( \frac{4R}{(R-1)^2} \right) - K^2 \right]^{1/2} - \frac{R+1}{R-1} \dots (2)$$

Where  $(n_o)$  is the refractive index, K is the extinction coefficient.

dedicated in Fig. (5) indicated a slight change in the variation of refractive index up to 500 nm wavelength. The refractive index increases with annealing temperature this due to increase the crystal quality and grain size [22].

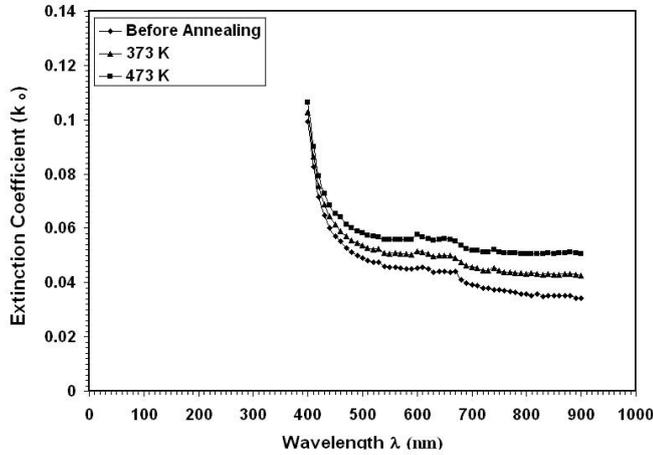


Fig. (5) refractive index versus wavelength of Sb2S3 thin films before and after annealing.

The spectral dependence of the extinction coefficient  $K_o$  which was obtained by the relation [23] :

$$K_o = \frac{\alpha \lambda}{4\pi} \dots\dots(3)$$

Where  $\alpha$  is the absorption coefficient and  $\lambda$  is the incident wavelength. for the as prepared films with different annealing temperature is shown in Fig. (6). It is clear that the extinction coefficient decrease rapidly as the wavelength increase up to 400 nm and behaves as slightly decrease with wavelength, all the curves have the some behavior but the extinction coefficient increase as the annealing temperature increased. This might be due to the change in surface morphology during annealing.

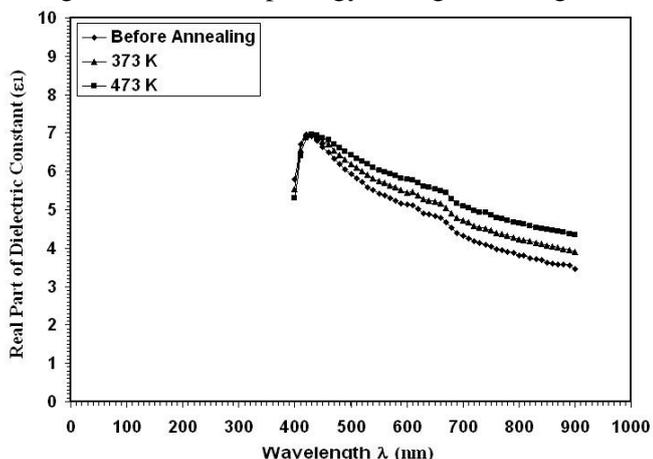


Fig. (6) extinction coefficient versus wavelength of Sb2S3 thin films before and after annealing.

Fig. (7) and Fig. (8) indicate the plot of real ( $\epsilon_1$ ) and imaginary parts ( $\epsilon_2$ ) of dielectric constant versus wavelength. Calculating from the following relations [24]:

$$\epsilon_1 = n_o^2 - K_o^2 \dots\dots (4)$$

$$\epsilon_2 = 2 n_o K_o \dots\dots (5)$$

the real and imaginary parts of dielectric constant follow the same pattern as the refractive index and extinction coefficient respectively, and that is because the dependence of ( $\epsilon_1$ ) on refractive index and ( $\epsilon_2$ ) on the value of extinction coefficient and the value of real part are higher than the imaginary parts.

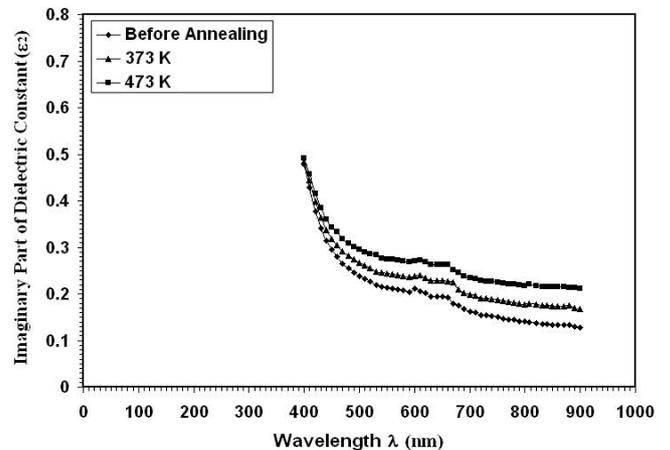


Fig. (7) Real parts of dielectric constant versus wavelength of Sb2S3 thin films before and after annealing.

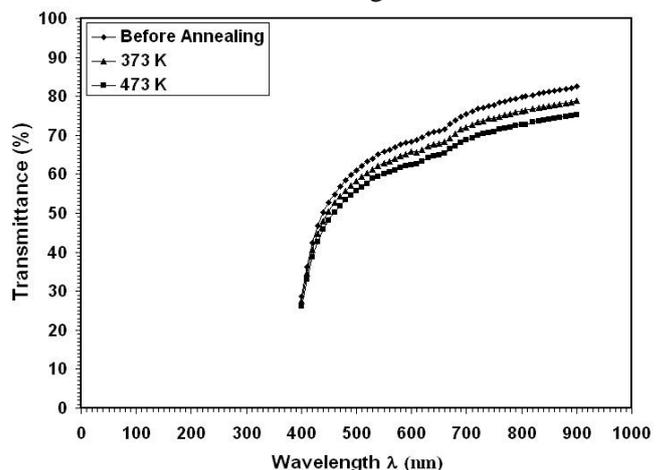


Fig. (8) Imaginary parts of dielectric constant versus Wavelength of Sb2S3 thin films before and after annealing.

### Conclusions

Thin films of Sb2S3 have been prepared successfully using chemical bath deposition. The value

of the optical energy gap was affected by annealing which was decreased as the annealing temperature increase the film deposited in this work shows narrow band gap, as such it could serve as good absorber layers for photocells.

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## تأثير التلدين على الخصائص البصرية لأغشية كبريتيد الانتمون الرقيقة

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### الخلاصة

حضرت أغشية كبريتيد الانتمون بطريقة الترسيب بالحمام الكيميائي. لدنت هذه الأغشية بدرجات حرارة مختلفة 473k, 373k. سجل طيفي النفاذية والامتصاصية قبل وبعد التلدين لمدى الأطوال الموجية 300-900 nm. حددت طبيعة الانتقال الالكتروني والتي وجد بانها ذات انتقال مباشر مسموح وبفجوة طاقة بصري مقدارها 1.72, 1.76, 1.82 eV قبل وبعد التلدين على التعاقب. تم كذلك حساب قيم معامل الخمود، معامل الانكسار، ثابت العزل الحقيقي والخيالي قبل وبعد التلدين.