

Preparation and Studying the Optical Properties of (Sb₂O₃) Thin Films

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Abstract

In this paper I present the preparation of (Sb₂O₃) thin films using thermal evaporation in vacuum, procedure with different thickness (100, 150, 200, and 250) nm, by using (hot plate) from Molybdenum matter at temperature in (900°C) and the period of time (15min), the prepared in a manner thermal evaporation in a vacuum and precipitated on glass bases, pure Antimony Trioxide (Sb₂O₃) thin films with various condition have been successfully deposited by (T.E.V) on glass slide substrates. The substrates temperature of about 100°C and the vacuum of about 10⁻⁶ torr, to investigated oxidation of evaporated, measure spectra for prepared films in arrange of wavelength (250 – 1100 nm). The following optical properties have been calculated: the absorption coefficient, the forbidden (E_g) for direct and indirect transitions "absorbance, refractive index, extinction coefficient, real and imaginary parts" of the dielectric constant.

1. Introduction

Pure Antimony is a metal that manifests naturally in the earth's crust, the most important mercantile compound derived from antimony is antimony trioxide ordinarily known as "ATO", chemical formula Sb₂O₃. ATO is utilized in a wide diversity of industrial applications, fundamentally as a "synergist" with flame dilatory chemicals and as a catalyst in the industry of polyester. The total global exhaustion of "ATO" in 2010 was approximately 125,000 tons [1]. Antimony trioxide (Sb₂O₃) is solid and is commercialized as a white, scentless, crystalline powder, founded on "handbook-data", the melting point is (655°C) and effervescence point is (1550°C), and vapor compression at ambient temperature is deemed to be very small [2].

Over the last few contracts, fire integrity in our homes and public places have amended greatly, thanks mainly to international calibration efforts in electrical and electronic tools. Antimony Trioxide (Sb₂O₃) very promote the efficiency of flame retardants, when used as a component in combination with halogenated flame retardants in plastics, dyeing, adhesives, rubber and textile back coatings [3]. Antimony Trioxide (Sb₂O₃) is so used in numerous appliances within our house and offices; TVs, computers, processing electrical assembly, optical cables, mains modifier and portable electronics and to fire safe plastic wraps, resin circuit boards. Antimony Trioxide (Sb₂O₃) is not acutely poisonous, It is not considered toxic via inhalation or oral ingestion [4], [5]. For the evolution of such optical devices, Antimony Trioxide (Sb₂O₃) thin films require thorough optical description. There are a number of physical and chemical routes for preparing (Sb₂O₃) thin films. These include, sol-gel spin coating method, the evaporation method, spray pyrolysis, chemical bath deposition, etc [6].

The research on the optical characteristic of Antimony Trioxide (Sb₂O₃) has attracted much notice in view of their wide application in optical devices and electronic equipment. The optical properties are calculated to check polarization properties, interference and better reflection [7]. In a group of former papers, we include reported the structural and electrical properties of several (V–VI) semiconducting components "Sb₂O₃ and Sb₂S₃" in thin films. This paper concentrates on the test of optical properties of (Sb₂O₃) thin films prepared by (TVET) [8].

2. Experimental Details

High purity (99.99% purity from Merck) antimony trioxide (Sb₂O₃) from J. M. (United Kingdom) was used in the thin films making ready. The antimony trioxide (Sb₂O₃) powder settled in a (vacuum deposition chamber) for the production of thin film. The vaporization was loaded out in a classical vacuum coating unit (inficon V90) beneath a vacuum of a request of (6×10⁻⁶ torr). A molybdenum box was used as the vaporization container and the glass layers were cleaned at (100 °C), where it was placed directly above the source with a displacement of almost (18cm). The glass substrates were cleaned with solution distilled water. Films of various thickness deposition were intended through

different singular evaporations. Film thickness was measured after evaporation by optical interferometer system, using (He-Ne Laser $\lambda=0.632 \mu\text{m}$) and determined the thickness according to:

$$(d = \frac{\lambda}{2} \cdot \frac{\Delta X}{x}) \dots\dots\dots(1)$$

Where : d is the thickness of the sample, (x is fringe width), (ΔX is the distance between two fringes) and λ is the (W.L) of (He-Ne laser L.). The absorbance Spectrum was recorded of the (W.L) range (200 - 1100) nm by using the "double-beam spectrophotometer UV- 1800 shimedza".

3. Results and Discussion

ultra-violet-vis spectroscopy corresponds to electronic excitation between the energy levels linked to the molecular orbital of the system. (U.V-vis) spectra of all thin films are registered at the hall (T) in the framework of (200-1100) nm , and the absorbance spectra of antimony trioxide (sb_2o_3) thin films as shown in figure (3.1), it is clearly seen that growing the absorbance with increased thickness of thin films .

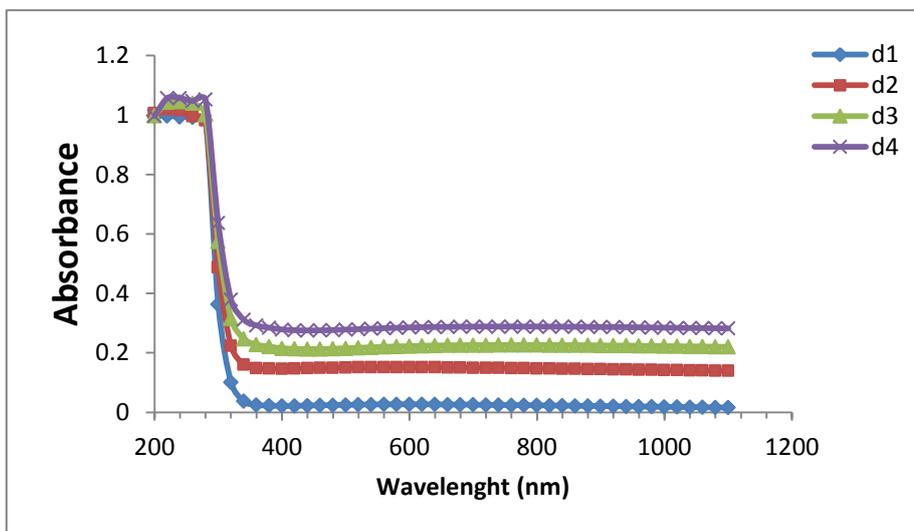


Fig. (3.1): Absorbance versus wavelength for the (sb_2o_3) thin films with different thickness of thin films .

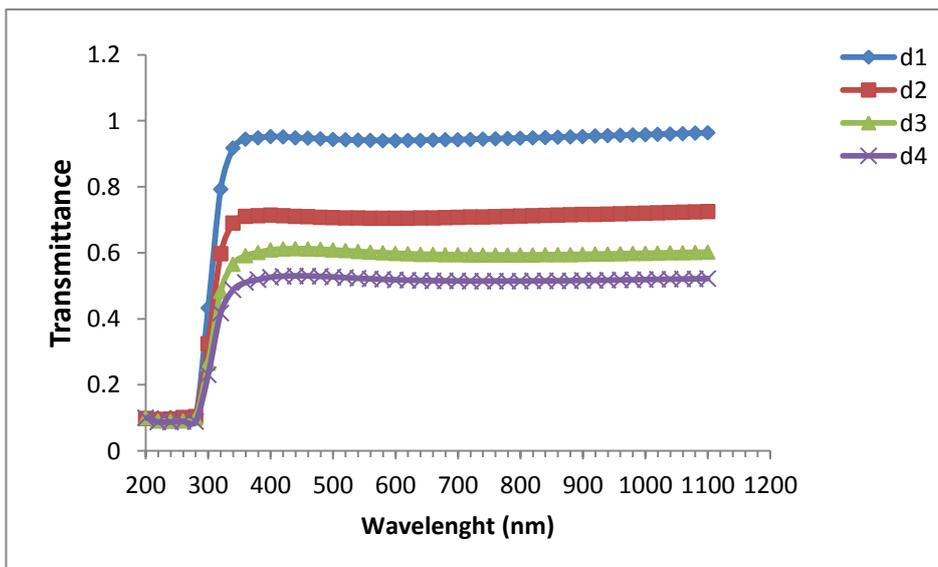


Fig. (3.2): The transmittance as a mark to wavelength for the (sb_2o_3) thin films with different thickness.

Figure (3.2) show the transmittance spectrum in the rang (200-1100)nm, exhibit very small transmittance in the ultra-violet range while in the visible range and the near infrared regions showed very high transmittance to all thin films. Consequently these materials are considered as an optically transparent in the visible region [9]. The transmittance percent decreases with increasing thickness of thin films.

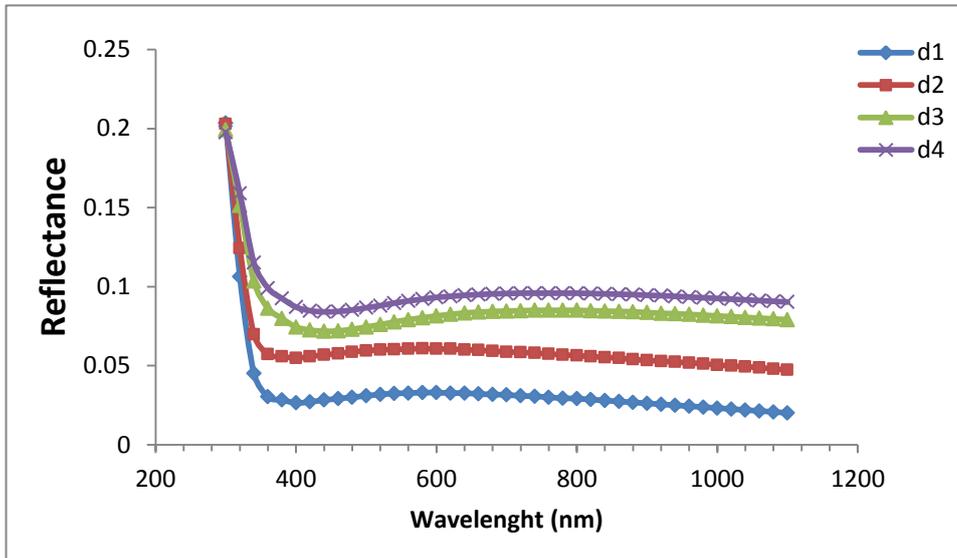


Fig. (3.3): The reflectance as a mark to wavelength for the (sb₂o₃) thin films with different thickness.

Figure (3.3) described the relationship between the reflectance and wavelength, the reflectance has been found by using the relationship[10] .

$$R + T + A = 1 \dots\dots\dots (2)$$

Where: R is the reflectance. The (R) of Sb₂O₃ thin films is low in close to the infrared and visual area , this can be attributed to the low absorbance in the (vis. and infr. region). The overall (R) increases with the film thickness in the "vis. and infrared" region. The (R) spectra of the films are showing the customary interference modality in the R spectra.

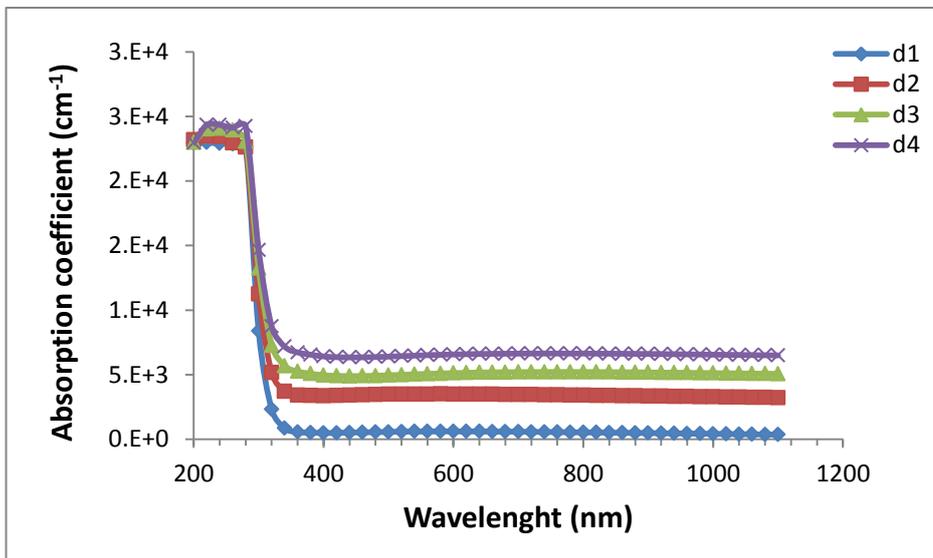


Fig. (3.4): The (α) as a function of wavelength for the (sb₂o₃) thin films with different thickness.

Figure(3.4) shows the optical absorption coefficient (α) as a function of incident wavelength on the (sb₂o₃) thin films with difference thickness onto scoured glass sub strate at 100°C and I got the thickness of the border (100 - 250)nm . We can clearly see that all films have an amount (α <10⁴ cm⁻¹) then indirect transformations occur more frequently . Notes the increase in the (α) with increased thickness of the thin films, the (α) is related to (A) and thickness

of the thin films according to a mathematical relationship [11] [12]. As it is shown in relations specified between incident intensity and piercing light intensity is given by equation 3 [13] :-

$$I = I_0 e^{-\alpha d} \dots\dots\dots(3)$$

Where thin films measure (cm) and (α) is (cm^{-1}),

$$\alpha d = 2.303 \log I/I_0 \dots\dots\dots(4)$$

Where the amount of $\log I/I_0$ represents the absorbance (A). The (α) can be calculated by:

$$\alpha = 2.303 (A/d) \dots\dots\dots(5)$$

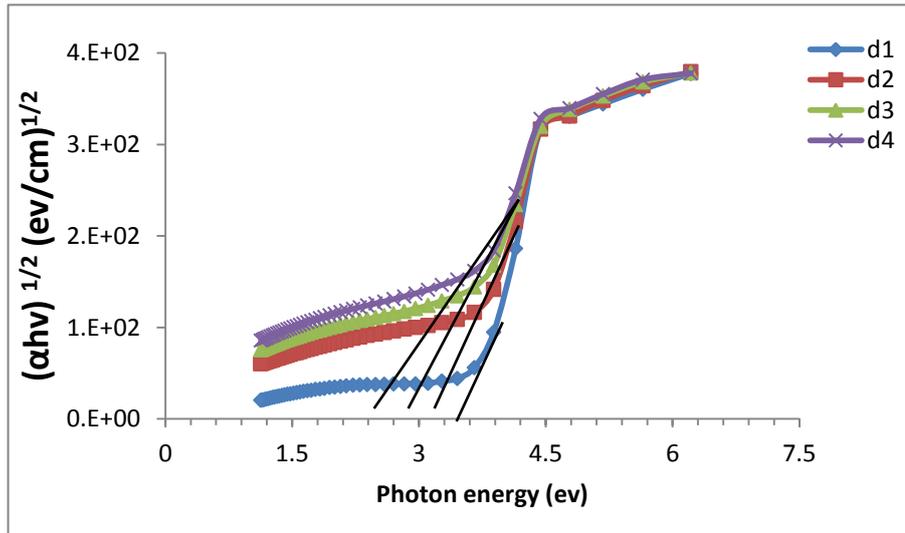
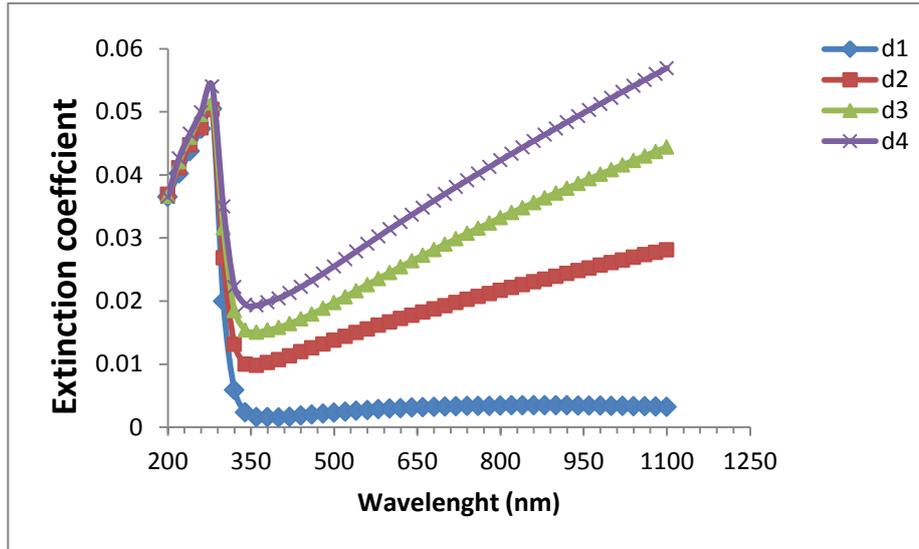


Fig. (3.5): Variation of the allowed indirect transition $(\alpha hv)^{1/2}$ versus (hv) of the (sb_2o_3) (th.f.) with different thickness.

Figure (3.5) show the relationship between $(\alpha hv)^{1/2}$ and photon energy (hv) , well we can see in figure that the value of the energy gap (E_g) decreased as the (sb_2o_3) thin films with different thickness, show an indirect allowed transition, these values were (3.5, 3.2, 2.9 and 2.5) eV respectively. Extrapolating the upright line of the plot $(\alpha hv)^2$ with (hv) for zero value ($(\alpha hv)^{1/2} = 0$) give the energy band gap value. Make sure that the thin films (sb_2o_3) are semiconductors with an indirect band gap, the transmission happens between expanded states of band and Location states of the appendage of the other band and the (α) is given by the Urbach relation [14] [15].

$$\alpha hv = B (h v - E_{gopt.})^r \dots\dots\dots(5)$$

Where: $E_{gopt.}$: optical energy gap, ' B ' constant rely on the nature of the material, ' r ' exponential constant, depends on the transition method, for the allowed direct transition give($r = 1/2$), for the forbidden direct transition give($r = 3/2$) [16].



(3.6):The

(k) as a function of wavelength for the (sb₂o₃) thin films with different thickness.

Fig.

Figure(3.6)show the relationship between extinction coefficient (k) and wavelength for Sb₂O₃ thin films deposited at different thickness. From the figure it showed that the extinction coefficient (k) is clearly affected by the thickness of thin films, but (k) increases with increasing of the thickness of thin films. This is refered to increased (α) with increased thickness of thin films [17] [18] .extinction coefficient (k) is given by the following equation:

$$k = \frac{\alpha\lambda}{4\pi} \dots\dots\dots (6)$$

Where (λ) : is the wavelength of fallen photon rays.

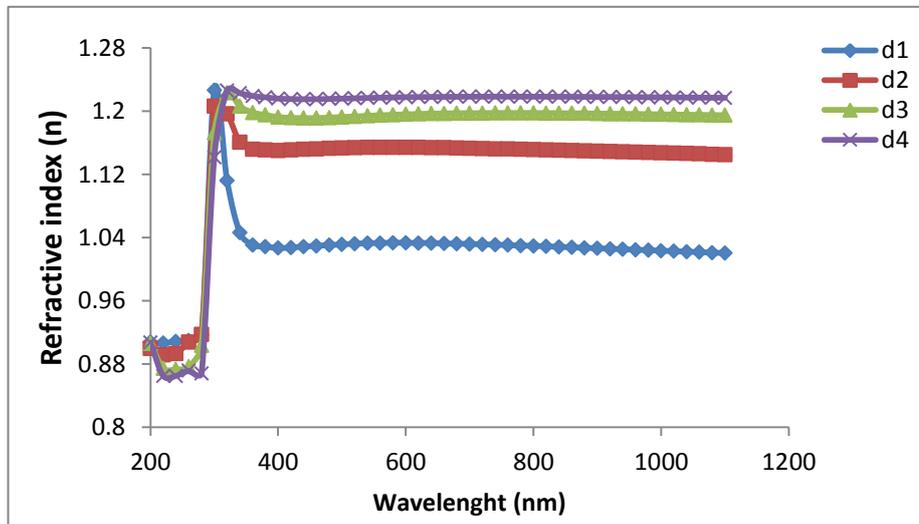


Fig. (3.7):The (n) as a function of (λ) for the (sb₂o₃) thin films with different thickness.

Figure (3.7) show the variations in the(refractive index) with the (λ). The increase in the film thickness results in the total increase in the(n) in the(vis. - infr.) regions. This increase is explained by a general increase in the reflectivity of the thickness of the film in those regions. The refractive index figure (3.7) was found from:

$$1-(R)^{1/2} = 1+(R)^{1/2} / n \dots\dots\dots (7)$$

" Where ' R' : is the reflectance".

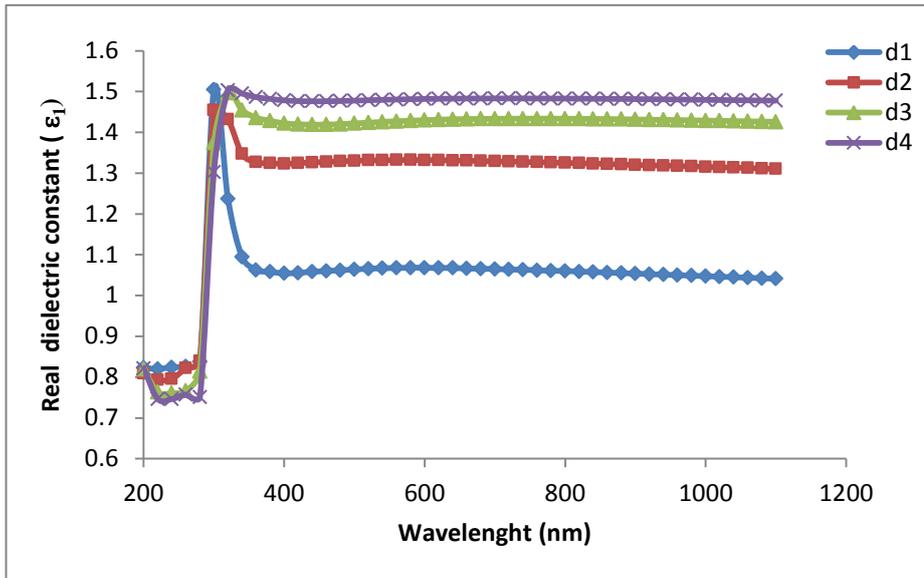


Fig. (3.8): The real dielectric constant as a function of wavelength for the (sb₂o₃) thin films with different thickness.

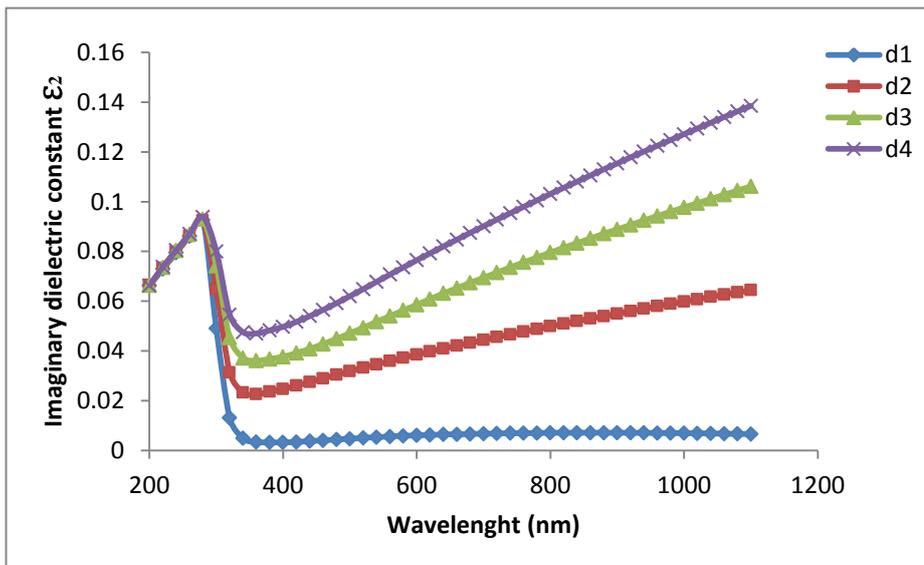


Fig. (3.9): The imaginary dielectric constant as a function of wavelength for the (sb₂o₃) thin films with different thickness.

Figures (3.8) and (3.9) shows the variations in the (ϵ_1 and ϵ_2) parts of the dielectric constant with the wavelength for the (sb₂o₃) thin films with difference thickness. Natural changes were observed depending on the thickness the films, the curves values of (ϵ_1) for the films of different thicknesses in the visible and infrared region. The (ϵ_2) prove the free carrier's contribution to the (A), the ' ϵ_1 ' is increased with the increase of difference thickness.

The (ϵ_1 and ϵ_2) parts of the dielectric constant were specified using the relation :-

$$\epsilon_1 = n^2 - k^2 \dots\dots\dots(8)$$

$$\epsilon_2 = 2nk \dots\dots\dots(9)$$

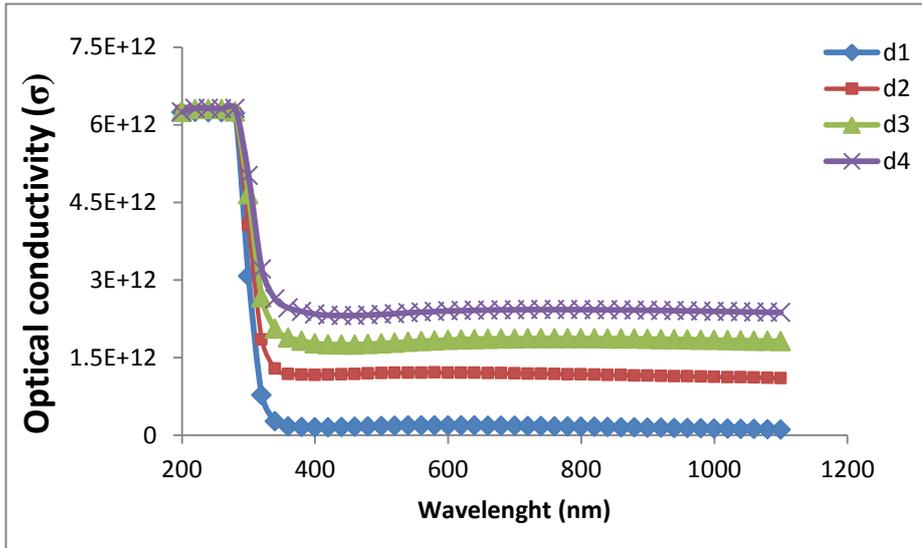


Fig. (3.10): (σ) as a function of wavelength for the (Sb_2O_3) thin films with different thickness.

Figure (3.10) show the variations in the optical conductivity with the wavelength. When the thickness of the film is increased, there is a direct increase in optical conductivity in (vis. and infra.) regions. The "optical conductivity" is determined using the relation :-

$$\sigma = \alpha n c \dots\dots\dots(10)$$

4. Conclusions

Sb_2O_3 thin films with the thickness of (100 ,150, 200 and 250) nm where glass slides were present in the way of thermal evaporation in the vacuum (6×10^{-6} torr), sedimentation conditions have an effect on transmission spectra, such as substrate temperature. We see higher transmittance of films when their thickness decreases. It was found that transmittance, absorbance and $E_{g_{opt}}$, E_g , depend markedly on the thickness of the films.

The absorbance and absorption coefficient for Sb_2O_3 thin films increases with the increasing of the film thickness. The transmittance decreases with increasing film thickness. (n , k and dielectric constant ϵ_1, ϵ_2) are increasing with the increase the film thickness. The (E_g) for indirect transition allowed, forbidden decreases with the increasing of the film thickness . The high transmittance of wavelengths in the (vis. and near infr.) regions and the high absorbance in the (ult-v.) region offered the possibility of using Sb_2O_3 films in various fields including, laser visible diodes and ultraviolet filters , fire safe plastic casings , switches , resin circuit boards and microsensors components.

CONFLICT OF INTERESTS

There are no conflicts of interest.

5. References

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الخلاصة

في هذه الدراسة، انا حضرت اغشية رقيقة من اوكسيد الانتيوم الثلاثي Sb₂O₃ باستخدام طريقة التبخر الحراري في الفراغ مع اختلاف سمك الاغشية (100,150,200,and 250)nm نانو متر، باستخدام البوت الحراري من مادة الموليبيديوم عند درجة حرارة (900^oc) وحضر في زمن (15mint) دقيقة، اعدت بطريقة التبخر الحراري في الفراغ على قواعد من الزجاج، الاغشية الرقيقة لأوكسيد الانتيوم الثلاثي النقي مع اختلاف الظروف نجح الترسيب باستخدام التبخر الحراري في الفراغ على قواعد الزجاج. درجة حرارة القواعد بحدود 100^oC وتحت ضغط فراغي 10⁻⁶ torr، ليتحقق تبخر الاوكسيد وقياس طيف الاغشية المحضرة في مدى طول موجي (250– 1100 nm). وبالتالي حساب الخصائص البصرية: معامل الامتصاصية، فجوة الطاقة المباشرة الممنوعة وغير المباشرة، والانعكاسية، وعامل الخمود ، معامل الانكسار، ثابت العزل الحقيقي والخيالي.

الكلمات الدالة : ثالث أكسيد الأنتيمون (sb₂o₃)، أفلام رقيقة، التبخر الحراري في الفراغ.