The Effect Of Thickness on The Optical Properties Of ZnS

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Date of acceptance 13/5/2007

Abstract:

Zinc sulfide(ZnS) thin films of different thickness were deposited on corning glass with the substrate kept at room temperature and high vacuum using thermal evaporation technique.the film properties investigated include their absorbance/transmittance/reflectance spectra,band gap,refractive index,extinction coefficient,complex dielectric constant and thickness.The films were found to exhibt high transmittance(59-98%) ,low absorbance and low reflectance in the visible/near infrared region up to 900 nm..However, the absorbance of the films were found to be high in the ultra violet region with peak around 360 nm.The thickness(using optical interference fringes method) of various films thichness(100,200,300,and 400) nm.The band gap measured was found to be in the range (3.52 -3.78)eV.

Introduction:

Zinc sulfide (ZnS) is a wide gap and direct transition semiconductor [1]. Consequently,it is a potentially important material to be used as an antireflection coating for heterojunction solar cells [2] . It is an important device material for the detection,emission and modulation of visible and near ultra violet light [3,4].In particular, ZnS is believed to be one of the most promising materials for blue light emitting laser diodes [5] and thin film electroluminescent displays [6].

Oil and gas,which are at present the main sources of energy,will eventually exhaust after sometime ,necessitating the search for newer energy resources.Nuclear energy is one option,but it induces acute radiative pollution and has some technical problems.Such is a huge source of energy that can converted into electrical energy using the solar cells and this is the best alternative option. In this work ZnS thin films have been studied as an antireflection coating which is an essential part of the heterojunction.Theparameters studied include the bsorbance/ transmittance /reflectance spectra,refractive index,extinction coefficient, complex dielectric constant and thickness.In this work we use the following equations:

$$\alpha = \left(h\upsilon - E_g\right)^{1/2} \quad \text{..................... (1)}$$

Using the fundamental relations of photon transmission and absorbance,

$I = I_0 e^{-\alpha t}$

where t is thickness and

$A = \log I_0 / I$, we have α =2.303A/t

Equation (1) gives the band gap,when the straight portion of α2 versus hν plot is extrapolated to the point α=0.

The reflectance has been found by using the relationship :

$$A + R + T = 1 \quad \text{……………………..(2)}$$

$$R = \frac{(n-1)^2}{(n+1)^2} \quad \text{…………………. (3)}$$

Where R is the normal reflectance;using the above relation the refractive index n was determined.

The extinction coefficient k could be found by using the equation:

$$k = \alpha\lambda / 4\pi \quad \text{………………... .(4)}$$

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where λ is the wavelength.

The real and imaginary parts of the dielectric constant were determined using the equation :

$$\varepsilon_c = \varepsilon_r + \varepsilon_i = (n + ik)^2, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

εr is the real part and is the normal dielectric constant, εi is the imaginary part and represents the absorption associated of radiation by free carrier.

Expermental Work

In this study thermal evaporation technique (Edwards 306) was used to grow the ZnS thin films on cleaned corning glass substrates.Amolbedenuim boat was used as a support to evaporate ZnS.

Optical interference fringes was used for measuring the thickness of the thin films.Polster [7] found that Zns evaporated at o.5 nm/s has negligible absorption.

G. Hass et al [8] have reported that ZnS thin films deposited at high rates and low pressures are found to exhibit bulk values of refractive index 2.4 when evaporated at room temperature.We have therefore,deposited our ZnS thin films with the substrate kept at room temperature.

All the samples were prepared under the conditions which are :

pressure is 2x10-5 (mbar).

Substrate temperature is at room temperature.

Rate of the deposition is 0.6 nm/s.

Other conditions under which the samples were prepared are given in Table 1.

The optical absorption and transmission spectra for a range of samples of ZnS thin films(of different thickness) were obtained in uv/vis/nir region (up to 900 nm) using aphillips uv-880 uv/vis Double Beam spectrophotometer with bare (uncoated) glass slide as the refrence.

Results and Discussion

The absorbance spectra of the thin films of ZnS,having different thicknesses,are shown in Figure 1. These spectra reveal that films,grown under the same parametric conditions have low absorbance in the visible and near infrared regions.However,absorbance in the ultraviolet region is high.The enhanced absorption is observed in the neighbourhood of λ=360 nm.It has been observed that the maximuim absorption peak shifts towards the longer wavelength with increasing film thickness.This suggests the decrease in the bandgap with the increasing thickness.The overall absorbance has been increased with the film thickness.This is because of the reason that in case of thicker films more atoms are present in the film so more states will be available for the photons to be absorbed.

There are small absorption peaks below the fundamental edge.These small absorption peaks are an indication that some states have been created in the region between the conduction and the valance band.

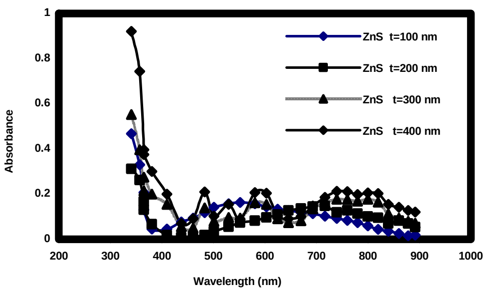

Figure 1. Absorbance versus wavelength of incident radiation

These states may be due to some structural defects in the films.The theory of optical absorption gives the relation ship between the absorption coefficient α and the photon energy hv, for direct allowed transitions.

Figure 2 gives the variation of band gap with the thickness of the films.ZnS thin films grown here have energy band gap in the range 3.53 ev to 3.63 eV . These values are in good agreement with the values 3.33 ev ,3.5 ev,3.6 eV,and 3.7-3.8 eV reported by Seppo Lindroos[9] using successive ionic layer adsorption and reaction (SILAR) technique,Ryoki Nomura [10] using metal organic vapour phase epitaxy (MOVPE),T. Yamaguchi [11], S.Biswas [12] and I.C.Ndukwe [13] using chemical bath deposition (CBD) technique.

Figure 2 also shows that the band gap is decreasing with the increasing thickness of the films.There is the possibility of structural defects in the films due to their preparation at room temperature; this could give-rise to the allowed states near the conduction band in the forbidden region.In case of thick films these allowed states could well merge with the conduction band resulting in the reduction of the band gap.

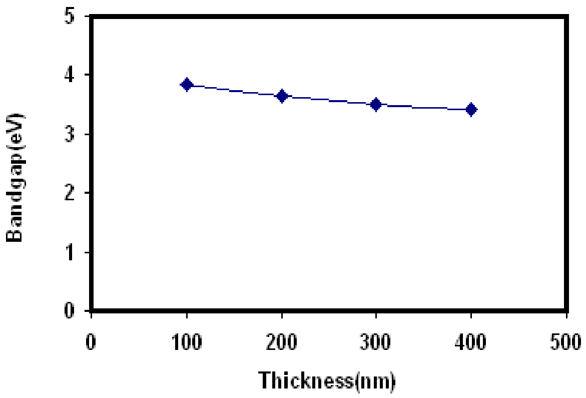

Figure 2. Bandgap versus thickness of the thin films

Figure 3 shows the optical transmittance spectra for the ZnS thin films.All the films demonstrate more than 60% transmittance at wanelength longer than 400 nm,which is comparable with the values for the ZnS thin films deposited by Seppo Lindroos[9] using SILAR method,I.C.Nduckwe[13],T.Yamaguchi[11] using chemical bath deposition method.Below 400 nm there is a sharp fall in the T% of the films,which is due to the strong absorbance of the films in this region.

It has been observed that the over all T% increase with the decrease in the film thickness.This happens due to the over all decrease in the absorbance with the decrease in film thickness.A rise and fall in the transmittance above 400 nm is observed.Asimilar behavior(rise and fall in the transmittance)is reported by S.Y.Kim[14] for TiO2 thin films prepared using electron beam evaporation and is claimed to be due to interference of the light transmitted through the thin film and the substrate.These variation have been observed to increase with film thickness.

Figure 4 shows the optical reflectance spectra for ZnS thin films.The reflectance has been found from equ.(2).

The reflectance of ZnS thin films is small in the near infrared and visible region.The over all reflectance of the film increases with film thickness.

From equ.(3) we determine the refractive index[15].

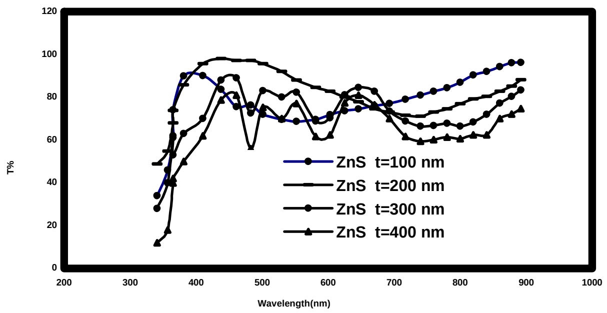

Figure 3.Transmittance versus wavelength of incident radiation

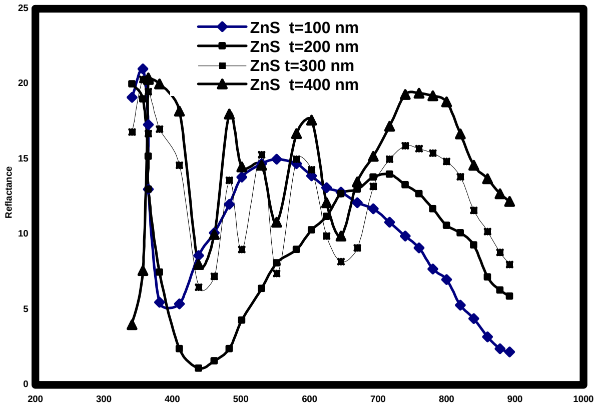

Figure 4. Reflectance versus wavelength of incident radiation

Figure 5 shows the variations in the refractive index with the incident photon energy.The increase in the film thickness results in the over all increase in the refractive index.This increase is due to the over all increase in the reflectance with the film thickness.The peak value of the refractive index for the ZnS films of various thickness vary in the range of 2.58 to 2.64,which is in good agreement with the value 2.62 reported by I.C.Ndukwe[13].

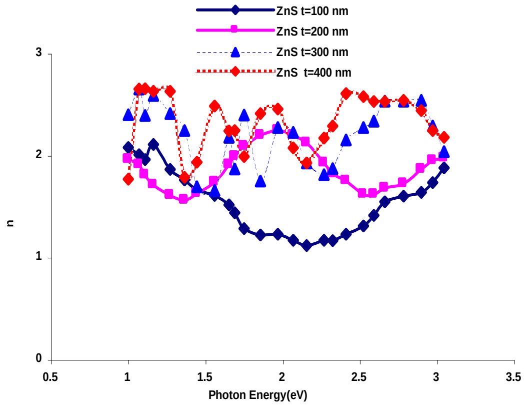

Figure 5. Refractive index versus incident photon energy

The extinction coefficient k could be found from equ.(4)

Figure 6 shows the variations of extinction coefficient with the photon energy.The rise and fall in the extinction coefficient is due to the variation in the absorbance.

The real and imaginary parts of the dielectric constant were determined using equ.(5) [17].

Figure 7 and 8 show the variations in the real and imaginary parts of the dielectric constant with the incident photin energt.

The range of variation of dielectric constant is in agreement with the observations of I.C.Ndukwe [13],M.Y.Nadeem and Waqas Ahmed[18].

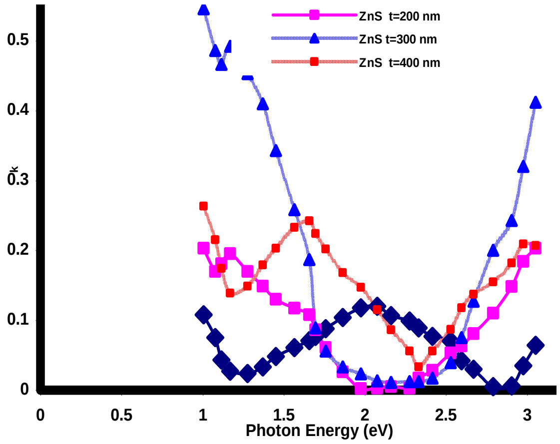

Figure 6. Extinction coefficient versus incident photon energy

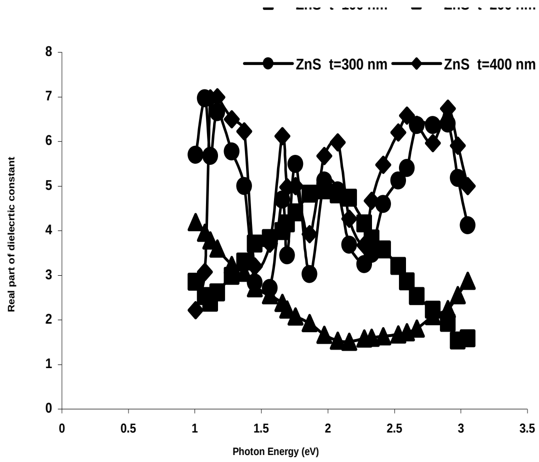

Figure 7. Real part of the dielectric constant versus incident photon energy

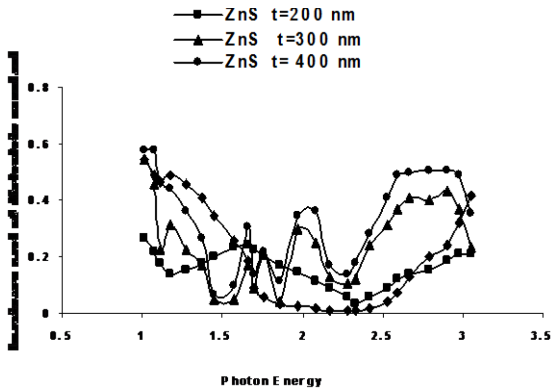

Figure 8. Imaginary part of the dielectric constant versus photon energy

Diffrent shapes of the curves for the real part of the dielectric constant have been observed.This is due to the different effective thickness of the insulator.The imaginary part confirms the free carriers contribution to the absorption.

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تأثير السمك على الخصائص البصرية لمادة ZnS

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الخلاصه

تم ترسيب أغشيه رقيقه من كبريتات الزنك باسماك مختلفه(100و200و300و400 نانومتر)على زجاج نوع كورننك تحت فراغ عالي باستخدام تقنية التبخير الحراري في الفراغ. تم دراسة الخصائص البصريه للغشاء والمتضمنة طيف الامتصاصبه والنفاذيه والانعكاسية وكذلك فجوة الطاقة البصرية ومعامل الانكسارومعامل الخمود وثابت العزل المعقد والسمك.اظهرت الاغشيه نفاذيه عاليه(98-59 %)وامتصاصيه وانعكاسيه واطئه في المنطقه المرئيه وتحت الحمراء القريبه من الطيف ولحد الطول الموجي 900 نانومتر.ان الامتصاصيه وجدت انها عاليه في المنطقه فوق البنفسجيه وحول الطول الموجي 360 نانومتر.تم قياس السمك باستخدام طريقة اهداب التداخل للاسماك (100و200و300و400 نانومتر).تم قياس فجوة الطاقه ووجد انها تتراوح بين 3.52 الى 3.82 الكترون فولت.