Optical Characteristics of Chemical Bath Deposited CdS Thin Film Characteristics within UV, Visible, and NIR Radiation

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ABSTRACT

The effect of the solid-state properties of CdS thin films developed by the solution growth technique was investigated in this paper. These properties were obtained using a PYEUNICAM® SP 8-100 spectrophotometer in the range of UV-VIS-NIR while the optical conductance was computed. The band-gap was also calculated from the equation relating absorption co-efficient with the wavelength. The plotted graphs show the optical characteristics of the film which varied with the wavelength and the photon energy. The optical conductance and band-gap indicated that the film is transmitting within the visible range.

(Keywords: solution growth, transmittance, dielectric constant, adsorption co-efficient, reflectance, band-gap, refractive index, cadmium sulphide)

INTRODUCTION

Chemical bath deposited films are now being developed to be utilized in converting solar radiation into electricity. The effectiveness of a thin film surface in narrowing the photon energy distribution has been extensively established in the literature.

The material properties that are of interest for these films are the optical properties within the range of UV, visible, and near infrared (NIR) which strongly depend on the dielectric constants, refractive index, and the band-gap of the thin film and depends very much on the nature of the film material properties [Ugwu, 2006].

Other applications of this type of film relate to their use in decorative and protective coatings [Ibanga *et al.,* 2003]. These properties determine the absorbance, transmittance, reflectance, and optical conductance characteristics of the film. Thus, the study of the solid-state properties of the film would give one an idea of these characteristics which arise as a result of the interaction between photon energies and the structure of the thin film or between the energy configuration and other optical constants (n and k) of the material [Cox, 1978]. For example, if the band-gap of the thin film were narrow, then most of the incoming radiation would be absorbed by the electrons and be excited from the valence band into conduction band. Such a material is very effective in narrowing the photon distribution. But if the band-gap is wide or indirect, the energy of the photons will be too weak to cause any absorption in such a material film and hence would be ineffective in converting the photon distribution to a narrow distribution. It is clear that only photon energy greater than the band-gap of the film material will be absorbed [5]. Photons of longer wavelength will just pass through (i.e. be transmitted) having only sufficient energy to excite elections [Seiver, 1979].

The narrowing of the broad spectral band of the solar radiation striking the film surface to a sharp photon distribution can be realized by using selective surfaces of thin films. The effectiveness of a surface in narrowing the photon distribution depends very much on the nature of the film material properties [Cody et al., 1992 and Blatt, 1968]. On the other hand, light can be transmitted in the wavelength region confined by the band-gap wavelength λ_g and λ_t (wavelength maximum transmission) [Haitjama et al., 1987 and Simons et al., 1978]. The works already published by some authors in this area show that materials with suitable optical properties, appropriate band gap, and suitable dielectric constants can be used effectively to transmit solar radiation within crucial wavelength regions for various applications.

In this work, the authors undertook the study of the optical properties and other material properties of CdS thin films grown by the chemical bath deposition technique.

EXPERIMENTAL AND THEORETICAL PROCEDURES

The technique outlined here was adopted in this work due to its simplicity, production of fairly good quality films, cost effectiveness, convenience, and high reproducibility.

The deposition reaction was slowed down, thereby preventing spontaneous precipitation by the use of suitable complexing ions, which then release the ions slowly under a suitable medium.

Before the deposition of cadmium sulphide on glass slides, the slides (substrate) were degreased in hydrochloric acid (HCl) for 24 hours, cleaned in detergent/cold water, and then rinsed with distilled water and allowed to drip dry in air.

The chemicals that are involved in the growth of the cadmium sulphide thin film are:

a. Cadmium chloride (CdCl).

b. Ammonia (NH_3) as a complexing agent.

c. Thiourea ($CsNH_2$) as a means of obtaining sulphide ion in the reaction.

d. Distilled water to make up the bath.

All the reagents used were analytical reagent (AR) grade [Ugwu et al 2001].

In the reaction bath, 5ml of a prepared NH_3 solution was added into a 50ml beaker, the reaction bath, that already contained 2ml of CdCl.

This mixture was stirred, after which 5ml of $Cs(NH_2)$ solution was measured and added into the beaker. The mixture was stirred again and the slide was clamped vertically into the solution inside the beaker with synthetic foam in order to prevent dust or unwanted particles from entering into the solution. The mixture of the entire solution was 40ml as 28ml of distilled water was added.

The solution was prepared into 4 separate beakers and left for the required 12 hour, 18 hour, and 24 hour dip times.

After the formation of the film, the optical and solid-state properties of were investigated using a PYEUNICAM® SPD8-100 spectrophotometer in the UV-VIS-NIR regions. These measurements included absorbance, transmittance, reflectance, and refractive index. The dielectric constant and absorption co-efficient are related and can be obtained theoretically with the relation given by the following: [Ugwu, 2006; Okujagu, 1992; Parachiniet et al.,1980; Chalkwski, 1980; Born et al., 1970; and Jenkins et al., 1976].

$$\varepsilon_r = n^2 - k^2 \quad \text{(1)}$$

$$\varepsilon_i = 2nk \quad \text{(2)}$$

where (E_r) is the real part of the dielectric constant and (E_i) is the imaginary part of the dielectric constant, (n) is the refractive index of the material and (k) is the extinction co-efficient given by:

$$K = \alpha\lambda/4\pi \quad \text{(3)}$$

where (α) is the absorption co-efficient and (λ) is the wavelength of the radiation. The optical conductance is obtained using the relation [15],

$$\sigma_o = \alpha n c \varepsilon_o \quad \text{(4)}$$

Where (σ_o) is the optical conductance and (c) is the velocity of the radiation in the space.

The energy gap of the thin film was obtained by plotting α^2 vs. wavelength [Ugwu 2006]. The straight–line part of the graph was extrapolated to meet the wavelength axis at λ_p at the point where $\alpha^2=0$. The wavelength obtained at this point depicts the wavelength of the radiation film. The band-gap was then obtained from the relation:

$$\alpha^2 = \text{photon energy} - \text{band gap.}$$
$$\alpha^2 = h\nu - E_g$$
$$\alpha^2 = hc/\lambda_p - E_g$$
$$0 = hc/\lambda_p - E_g$$
$$E_g = hc/\lambda_p \quad \text{(5)}$$

RESULTS AND DISCUSSION

Figures 1 – 11 show the graphs of some solid state properties of CdS thin films deposited as a function of wavelength or photon energy.

Figures 1 – 4 show the graphs of absorbance, as a function of wavelength, for 6 hours, 12 hours, 18 hours, and 24 hours deposition time. In Figures 1 and 3, it was observed that there was negative absorption within 200nm. In Figure 2, absorbance is negative at 430nm and zero at 390nm as in Figure 4.

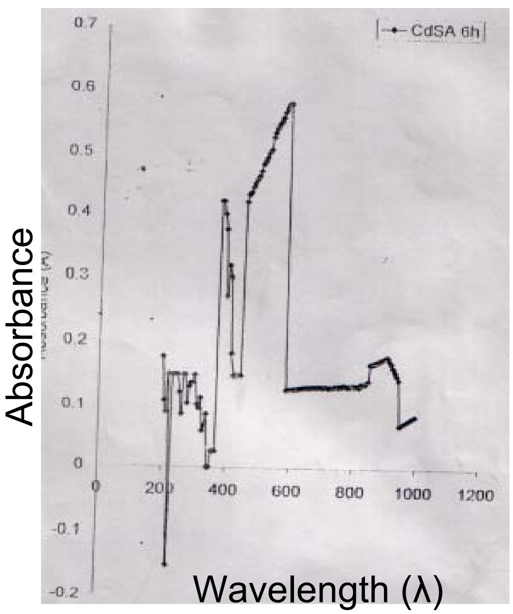

Figure 1: Absorbance (A) as a Function of Wavelength (λ) for CdS Thin Film.

Figure 5 is the variation of $(\alpha hv)^2$ with photon – energy which is extrapolated to show where the energy band-gap is located. The graph of the absorption co-efficient is shown in Figure 6.

The percentage transmittance and percentage reflectance were presented in Figures 7 and 11, respectively. It is observed that the percentage transmittance at near infrared is about 70% and percentage reflectance within the same region is 14%.

Figure 9 indicates the graph of photon energy as a function of wavelength.

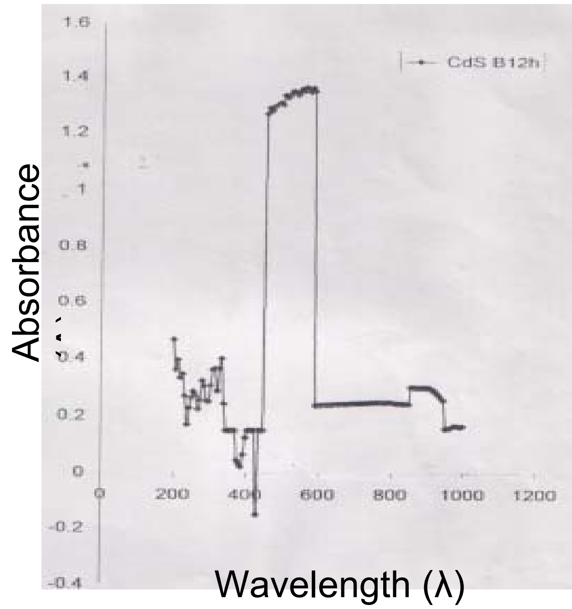

Figure 2: Absorbance (A) as a Function of Wavelength (λ).

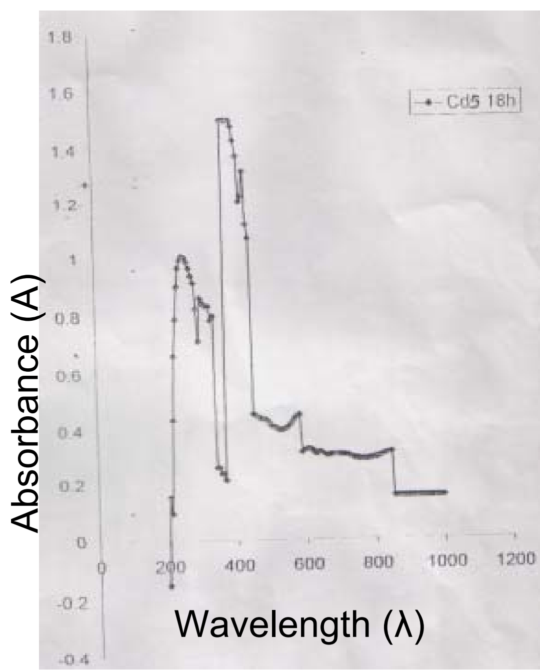

Figure 3: Absorbance (A) as a Function of Wavelength (λ) for CdS Thin Film.

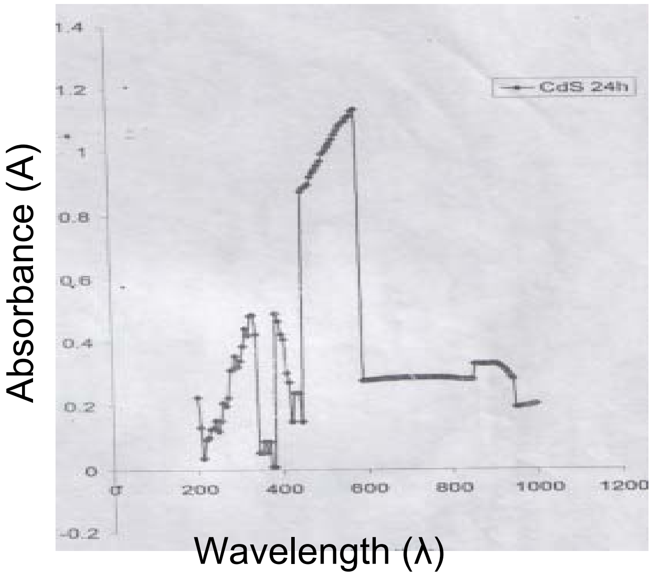

Figure 4: Absorbance (A) as a Function of Wavelength (λ) for CdS Thin Film.

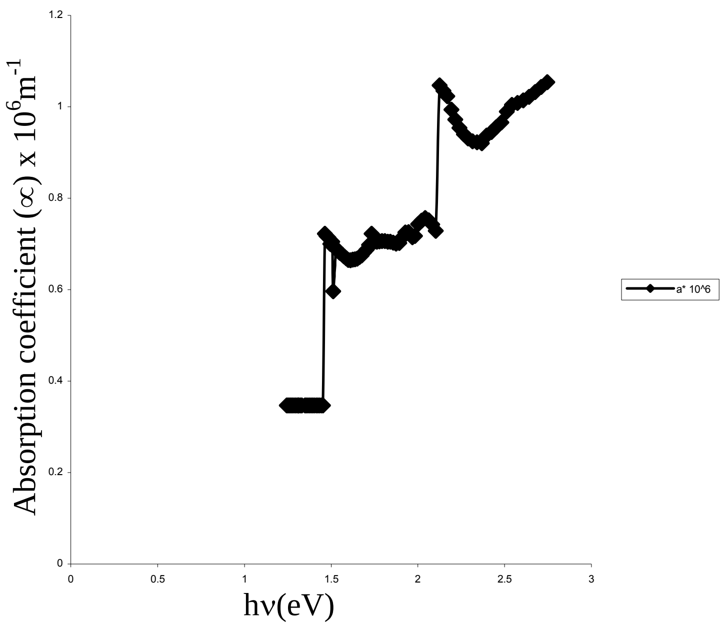

Figure 6: A Plot Absorption Coefficient (∝) as a Function of Photon Energy (hv) for CdS Thin Films.

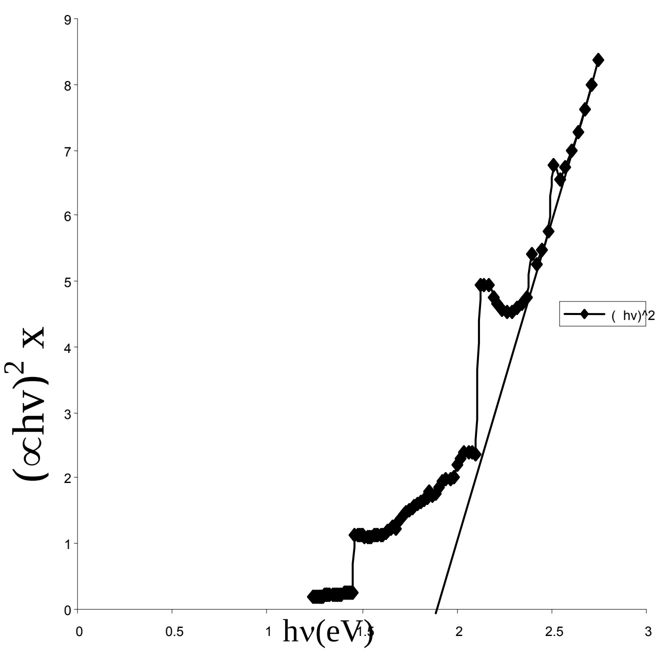

Figure 5: A Plot $(\propto hv)^2$ as a Function of Photon Energy (hv) for CdS Thin Film.

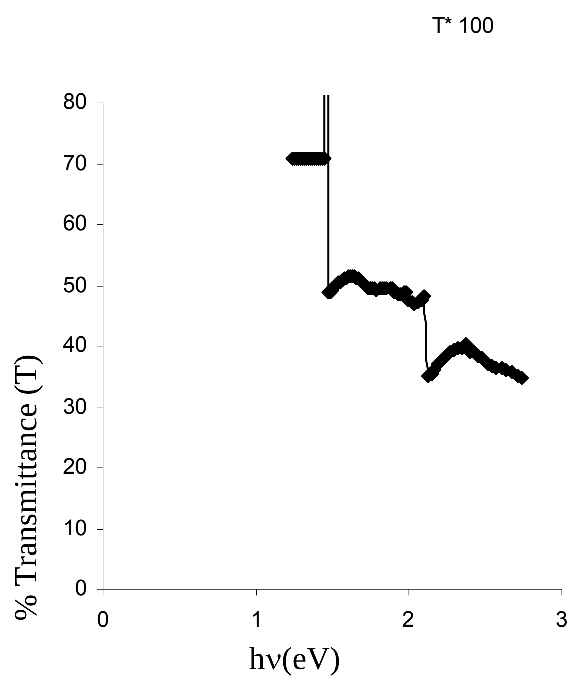

Figure 7: Transmittance (T) as Function of Photon Energy (hv) for CdS Thin Film.

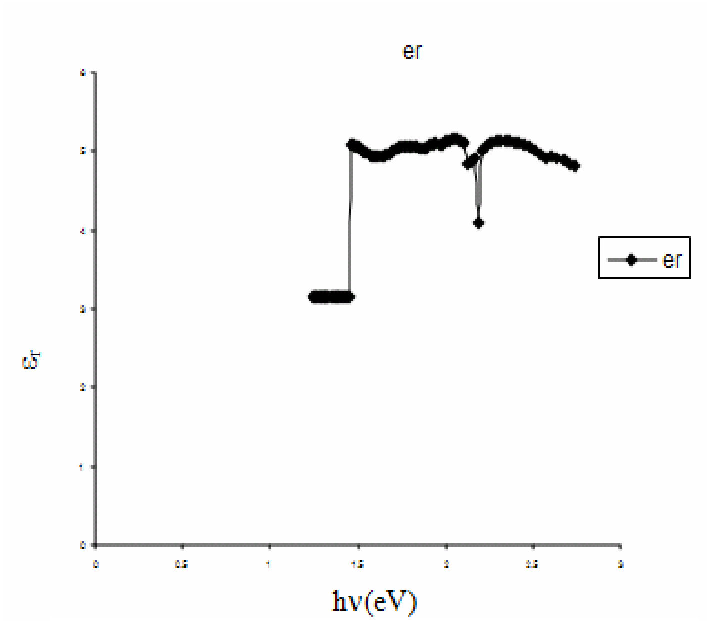

Figure 8: Real Dielectric Constant (ε_r) a Function of Photon Energy (hν) for CdS Thin Film.

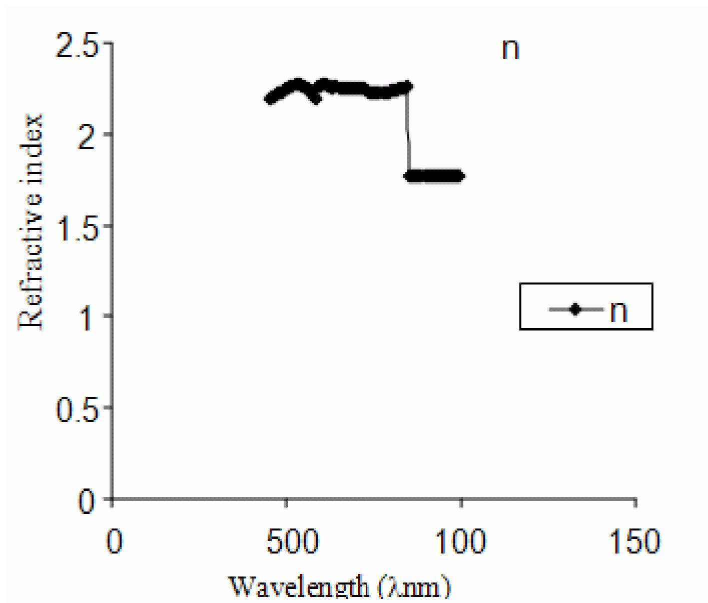

Figure 10: Refractive Index as a Function of Wavelength.

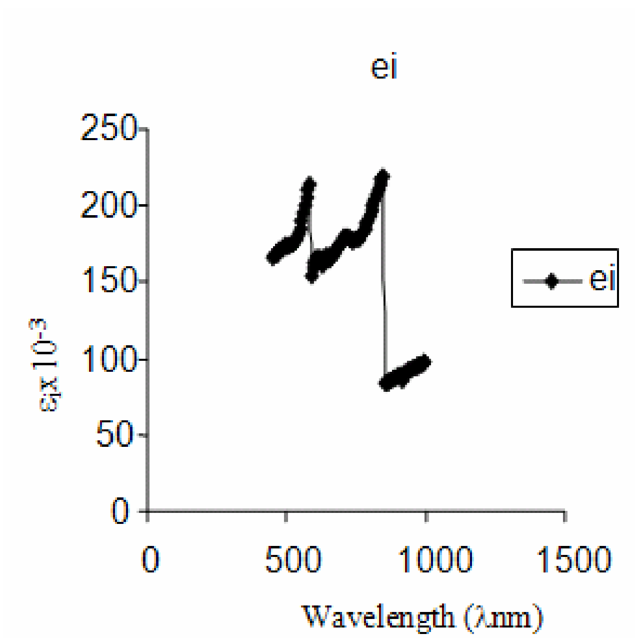

Figure 8: Imaginary Dielectric (ε_i) as Function of Wavelength.

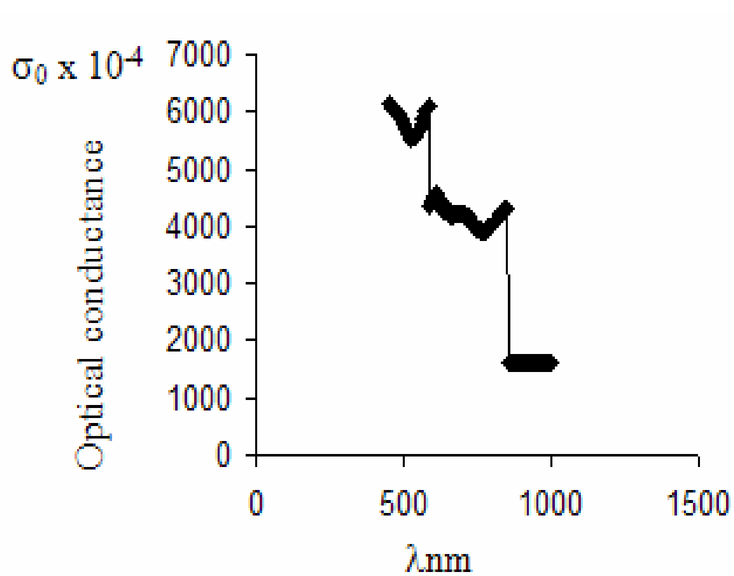

Figure 11: Optical Conductance as a Function of Wavelength.

The graph of refractive index and optical conductance shown in Figure 11 explains the relationship between optical conductance and refractive index.

Figure 8 and Figure 9 present the graphs of both real and imaginary dielectric constants.

Figure 7 indicates clearly that CdS has an average transmittance of 50% within the optical region and as high as 70% in the near infrared region.

The energy band-gap of the film was estimated from Figure 5 which also agreed with value computed using Equation 5. The film has an indirect band–gap and ranges from 1.80eV and 2.0eV, from the band-gap obtained coupled with the nature of Figure 7.

CdS thin film can be considered good for use as a visible transmitting thin film since the range of band gap for visible transmitting film is 1.5eV to 3.0eV [Okujagu *et al.,* 1997 and Cody *et al.,* 1982].

CONCLUSION

This work has clearly presented how CdS thin film was grown using solution growth techniques and how the effect of the solid state properties on spectral absorbance, transmission, and reflectance were obtained. The behavior of the film as illustrated in the graphs shows that the film is a visible transmitting thin film. The absorbance at the near infrared domain is low with high transmittance at the same region. The data explain the relationship between the refractive index, real dielectric constant and optical conductance.

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