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SHORT COMMUNICATION

Urbach energy and dispersion parameters of CdS chemically deposited thin films on the effect of thickness

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ABSTRACT

Optical transmittance spectra of CdS thin films were recorded from UV-Visible spectrophotometer in the range 380-900 nm. The films were prepared by chemical spray pyrolysis by spraying an aqueous solution of cadmium chloride ($CdCl_2$) and thiourea [$(NH_2)_2CS$] with de-ionized water. UV-Visible spectrophotometer used to recording the transmittance spectra in the range of 380-900 nm. The transmittance decreased with the increasing of CdS film thickness, while the reflectance increases. The energy gap decreased with the increasing of film thickness, while Urbach energy increased. Dispersion parameters such as; E_d, E_o, ε_∞, n(0), S_o, λ_o, M_{-1}, and M_{-3} are studied.

***Keywords*:** CdS thin film, Urbach energy, Dispersion parameters, chemical spray pyrolysis

1. INTRODUCTION

Cadmium sulphide (CdS) is one of the most investigated thin films for photovoltaic application in the last five decades. Literature gives that CdS exist in two crystalline forms namely hexagonal phase and cubic phase [1]. CdS thin film is a direct band gap (2.42 eV)

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metal chalcogenide II-VI semiconductor with high refractive index (2.5) and n-type conductivity [2]. CdS has been used as a window material in high efficiency thin film solar cells based on CdTe and $Cu(In,Ga)Se_2$(CIGS) [3,4]. It has also been used in other applications including electronic and optoelectronic devices [5]. CdS thin film can be deposited using several techniques such as RF sputtering [6], chemical bath deposition (CBD) [7], thermal evaporation [8], chemical vapor deposition (CVD) [9], close space sublimation (CSS) [10], molecular beam epitaxy (MBE) [11], spray pyrolysis [12] and hot wall epitaxy [13]. Among all the processes, CBD is the very common process to make very thin CdS thin film for solar cells. The chemically deposited CdS film was found to consist of a continuous film relating to the ion-by-ion deposition of CdS [14, 15].

In this work, the Urbach energy and dispersion psrameters are studied for CdS thin films prepared by chemical spray pyrolysis.

2. EXPERIMENTAL DETAILS

The CdS thin films were prepared by spraying an aqueous solution of cadmium chloride ($CdCl_2$) and thiourea [$(NH_2)_2CS$] with de-ionized water to form the final spray solution, a few drops of HCl were added to make the solution clear. A total volume of 100 ml was used in each deposition.

The spray pyrolysis was done by using a glass atomizer, which has an output nozzle of 1 mm. The glass substrates at a temperature of 350 °C with the optimized conditions that concern the following parameters: spray time was 10 sec, the stopping period 3 minutes to avoid excessive cooling of glass substrate. The carrier gas (filtered compressed air) was maintained at a pressure of 10^5 Pascal, distance between nozzle and substrate was about 30 cm, solution flow rate 8 ml/min. Thickness of the sample was measured using the gravimetric method and was found to be 300 ±20 nm. The optical properties are calculated from recording the transmittance spectra via UV-Visible spectrophotometer in the wavelength range (380-900) nm.

3. RESULTS AND DISCUSSION

From UV-Visible spectrophotometer, we recording the transmittance spectra in the range of 380-900 nm and then calculating the Urbach energy and dispersion parameters of CdS thin films. The transmittance spectra relationships with the wavelength are presented in Fig. 1. From this figure, it can notice that the transmittance increase with the increasing of wavelength of CdS thin films, and decrease with increasing of thickness. This behavior can be attributed to the increasing of atoms with increasing thickness, lead to increasing the number of collisions for incident photons on CdS thin film.

Fig. 2 represent the relationship between the reflectance and the wavelength of the CdS thin films. From the figure, it can notice the increases of reflectance with the increasing of the prepared thin films. This attributed to the increasing of free electrons with thickness.

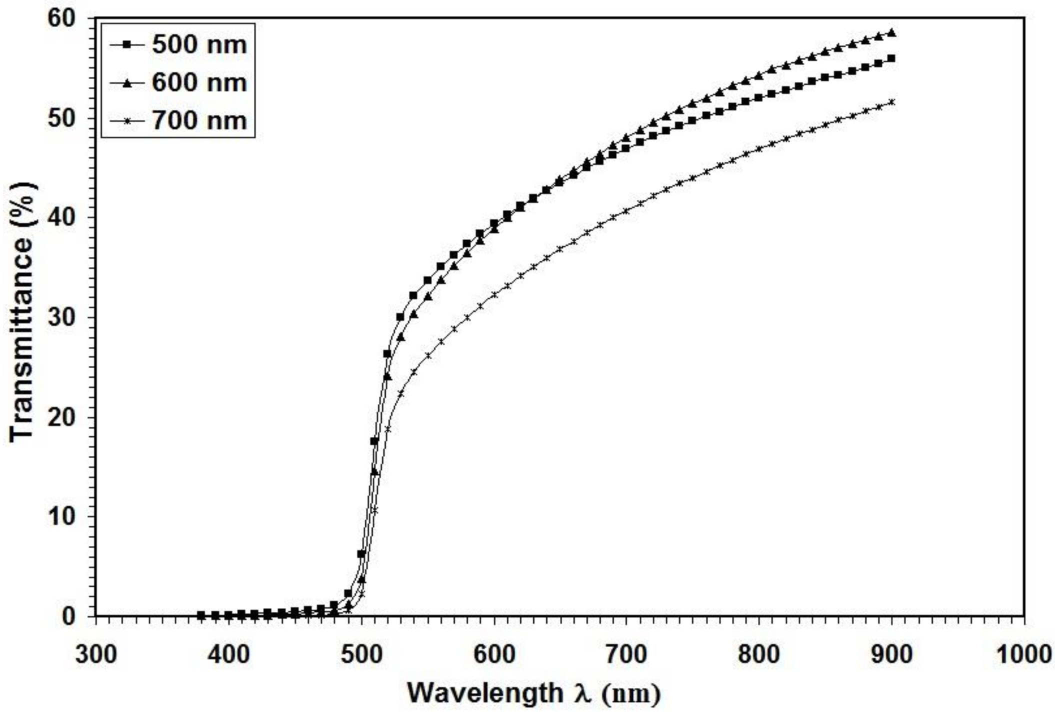

Fig. 1. Transmittance of CdS thin films obtained with different thicknesses.

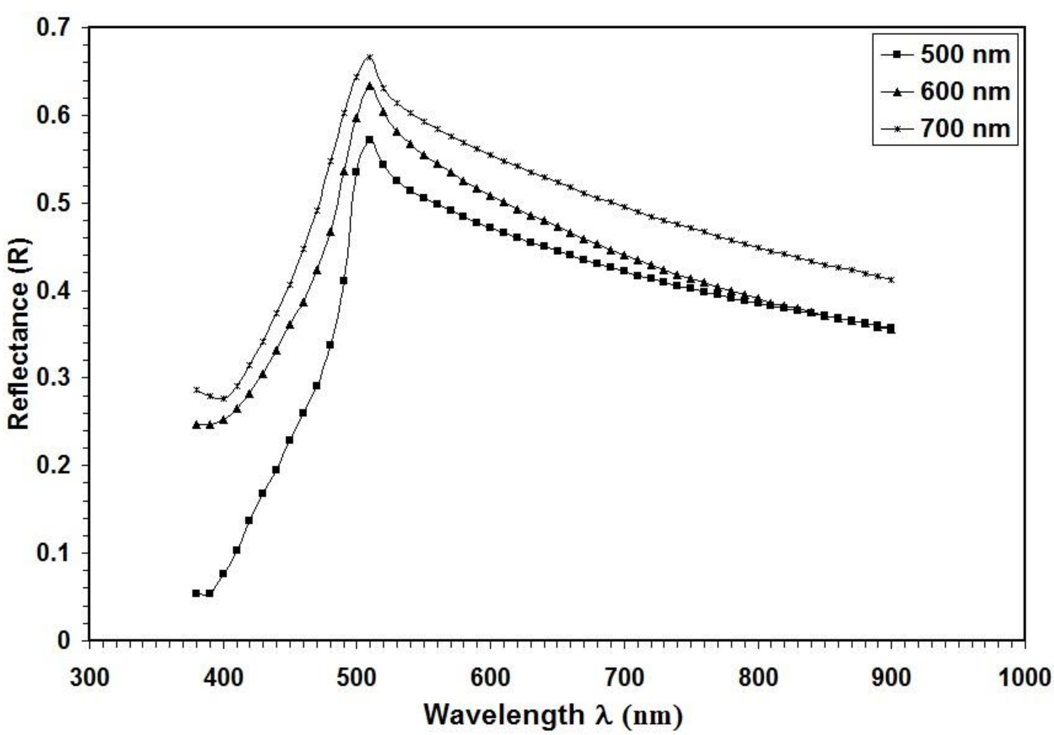

Fig. 2. Reflectance of CdS thin films obtained with different thicknesses.

The relationship between real (ε_r) and imaginary (ε_i) dielectric constants with wavelength for CdS thin film for various thicknesses that calculated from the following formulas [16]:

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

$$\varepsilon_i = 2nk \quad (2)$$

where: n is the refractive index and k is the extinction coefficient. Real and imaginary dielectric constants are represented in Figs. 3-4. From these figures, it can be notice the increases of real and imaginary dielectric constants with the increasing of film thickness.

The absorption coefficient in the exponential edge region α(hυ) known as Urbach law (E_u) is well described by the exponential law [17]:

$$\alpha = \alpha_o \exp\left(\frac{h\upsilon}{E_U}\right) \quad (3)$$

where: α_o is a constant, hυ is the incident photon energy, and E_{at} is called Urbach energy, which characterizes the slope of the exponential edge region and is width of the band tails of the localized states. The Urbach tail of the absorption edge is usually ascribed to the optical electronic transitions between the excited sates and the near edge localized states. Fig. 5 represent the plot of lnα versus hυ that represent the variation of Urbach energy of CdS thin film for various thickness. The Urbach energy increased with the increasing of film thickness. An increase in Urbach energy refer that more disorder has taken place. These values are shown in Table 1.

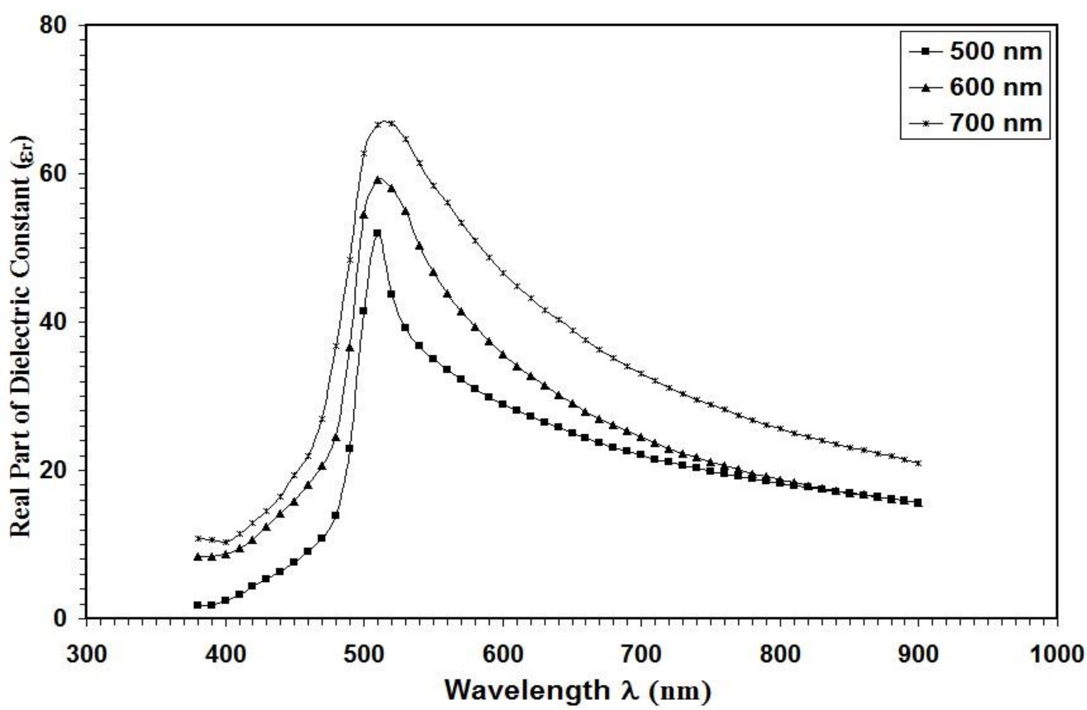

Fig. 3. Real part of dielectric constant of CdS thin films obtained with different thicknesses.

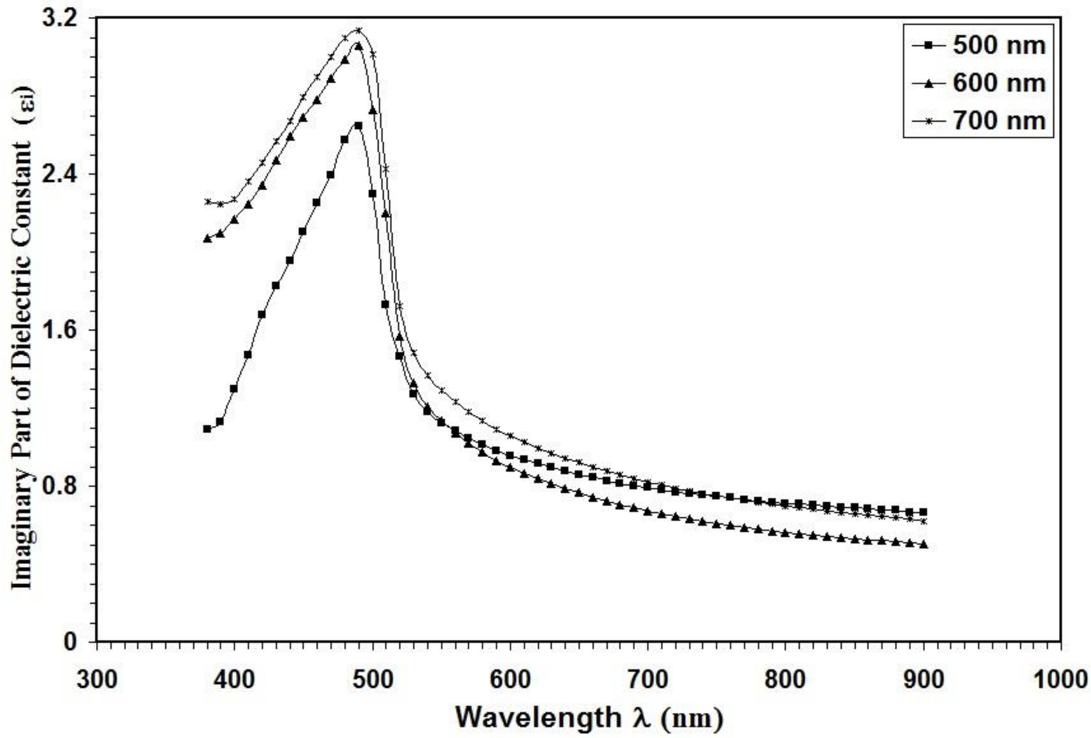

Fig. 4. Imaginary part of dielectric constant of CdS thin films obtained with different thicknesses.

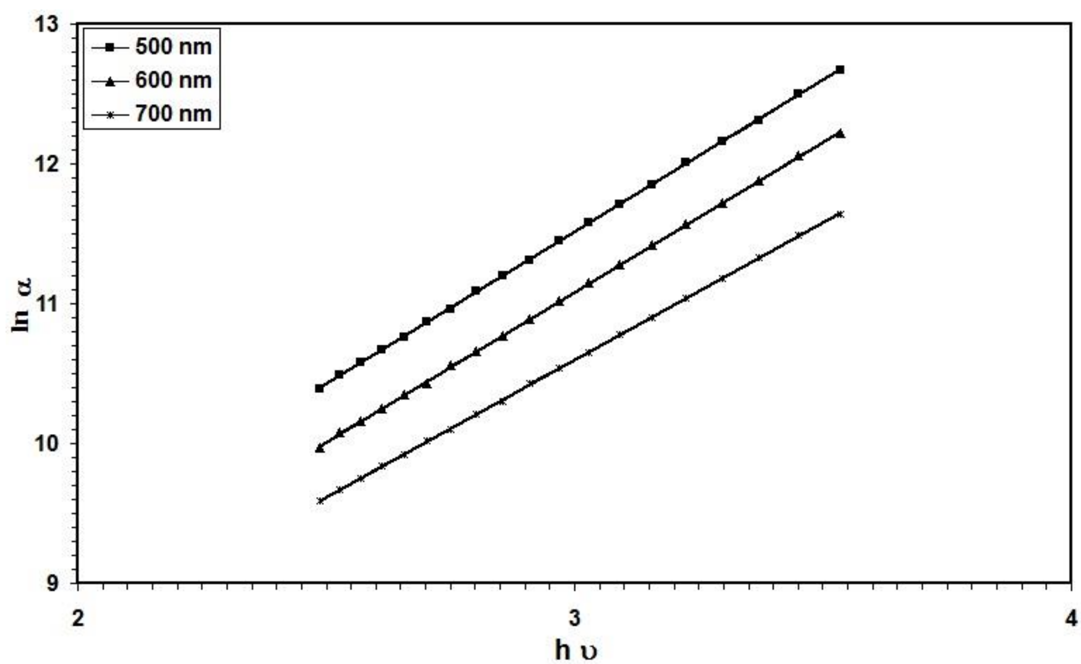

Fig. 5. Variation of lnα versus photon energy of CdS thin films obtained with different thicknesses.

The dispersion energy E_d and the single oscillator energy E_o are obtained in terms of the single oscillator model and these values are related to the refractive index as [18]:

$$n^2 - 1 = \frac{E_o E_d}{E_o^2 - (h\upsilon)^2} \tag{4}$$

The values of E_o and E_d for interband optical transitions are calculated and shown in Fig. 6, plotted as $(n^2-1)^{-1}$ with $(h\upsilon)^2$. From these values, the long wavelength limit of refractive index (n_∞) can be determined using the expression:

$$n_\infty = \sqrt{1 + E_d / E_o} \tag{5}$$

The values of E_o, E_d and n_∞ are decreased with the increasing of CdS thin film thickness as shown in Table 1.

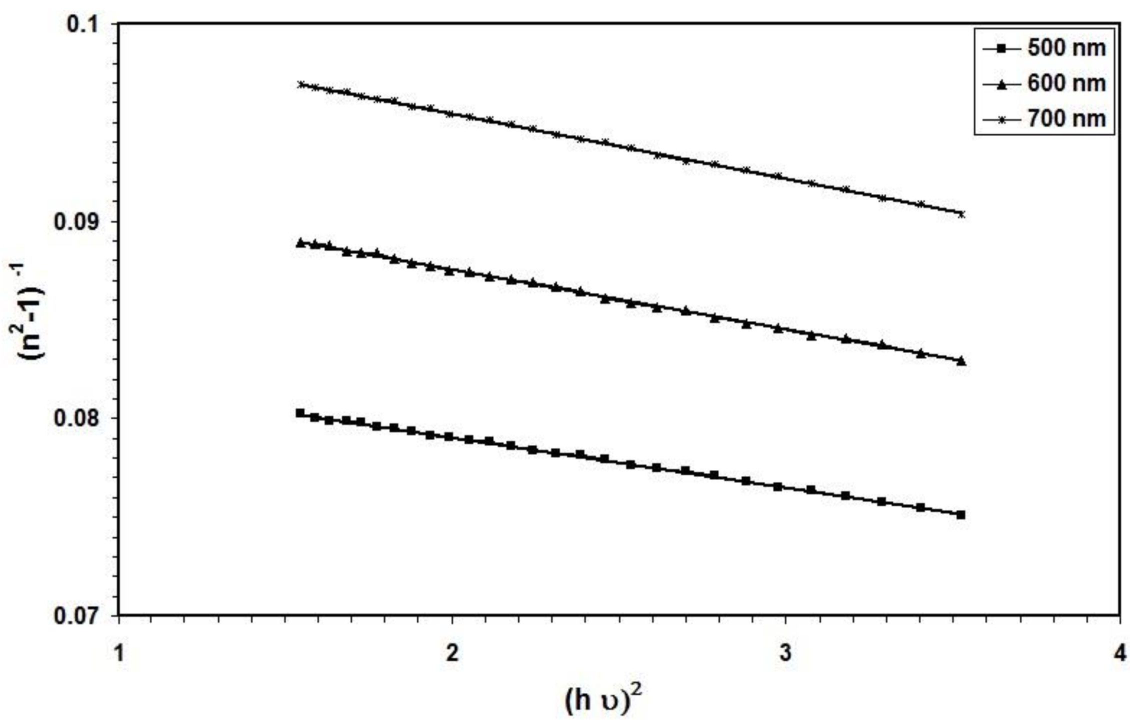

Fig. 6. Variation of $(n^2-1)^{-1}$ versus $(h\upsilon)^2$ of CdS thin films obtained with different thicknesses.

From plotting $(n^2-1)^{-1}$ versus $1/\lambda^2$ it can experimentally find the values of S_o and λ_o, the slope of the resulting straight line gives $1/S_o$, and the infinite-wavelength intercept gives $1/S_o \lambda_o^2$ [19]. These parameters are listed in Table 1, which decreased with increasing of CdS film thickness.

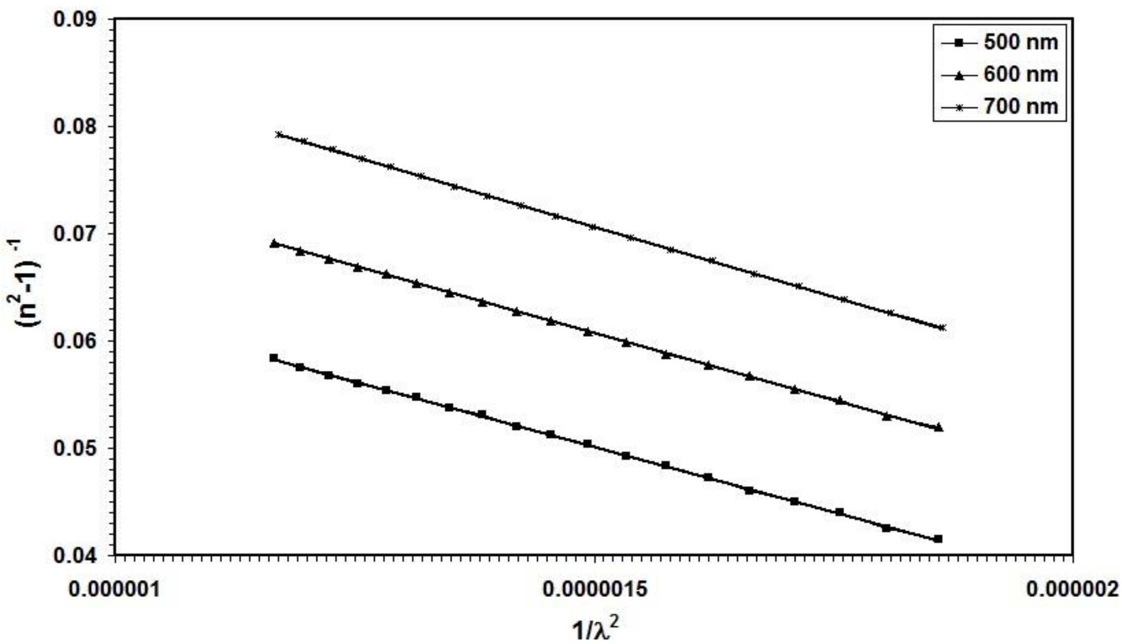

Fig. 7. Variation of $(n^2-1)^{-1}$ versus $1/\lambda^2$ of CdS thin films obtained with different thicknesses.

The M_{-1} and M_{-3} moments of the optical spectra can be obtained from the following relations [20]:

$$E_o^2 = \frac{M_{-1}}{M_{-3}} \quad (6)$$

$$E_d^2 = \frac{M_{-1}^3}{M_{-3}} \quad (7)$$

The values of M_{-1} and M_{-3} moments of CdS thin films are decreased with the increasing of film thickness as in Table 1.

Table 1. Optical parameters of CdS thin films obtained with different thicknesses.

Thickness	E_d (eV)	E_o (eV)	E_g (eV)	ε_∞	n(o)	M_{-1}	M_{-3} eV^{-2}	$S_o \times 10^{13}$ m^{-2}	λ_o nm	E_U meV
500 nm	59.39	4.81	2.405	13.34	3.65	12.34	0.533	4.16	693	455
600 nm	52.41	4.76	2.380	11.90	3.46	10.98	0.483	4.00	597	476
700 nm	47.91	4.74	2.370	11.10	3.33	10.10	0.448	3.86	568	513

4. CONCLUSION

Spray pyrolysis method were used to prepare CdS thin films with various thicknesses at substrate temperature 350 °C. The optical properties such as transmission, reflectance, optical band gap, and real and imaginary dielectric constant were affected by film thickness. Energy gap decreased when the Urbach energy increased for all deposited CdS thin films. In addition, the dispersion parameters (E_d, E_o, n_∞, S_o, λ_o) and optical moments (M_{-1}, M_{-3}) are affected by film thickness.

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