Effect of diode laser on physical properties of CdS thin films

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Abstract: In this study, Cadmium Sulphide (CdS) thin films are deposited on glass substrates by means of Spray Pyrolysis method to examine the influence of electromagnetic and optical features of these films by diode laser. Accordingly, samples are feasibly irradiated by laser pointer with a power of 500 mw and a wavelength of 532 nm at distance of 10 cm from the source during dissimilar exposure times of 10,20,30,40,50,60,70 and 80 minutes. The absorbance spectrums have been measured by UV-visible spectrophotometer under range of 190-1100 nm. Optical parameters such as transmission, reflection, absorption coefficient (α), extinction coefficient (K), optical band gap (Eg), refractive index (n), and complex dielectric constants were evaluated from absorbance spectra. The results show that the laser pointer irradiation cause decreased in transmittance (T), reflectance (R), absorption coefficient α, the extinction coefficient (K), refractive index (n) and the real and imaginary parts of dielectric constant and decrease in the value of the energy gap (Eg). In study of FTIR-spectrum of CdS films in different ratio of irradiation times, there was no change in the peak positions just bigger or smaller with increase in times of irradiation.

Keywords: Thin Film, Cadmium Sulfide (CdS), Spray Pyrolysis, Laser Irradiation, Electromagnetic and Optical Properties.

1. Introduction
Metal chalcogenides (Sulfides, tellurides and selenides) have received more attention by researchers because of optoelectronic uses as in solar cells, thin film transistors, photodetectors. Cadmium sulfide (CdS) is an important metal chalcogenides. Thin films of CdS stand for highly promising constituents for heterojunction thin film solar cells as a result of CdS has transitional energy band gap, practical conversion efficiency, cost effectiveness and stability as depicted in Figure 1. [1-3]:

CdS represents imperative II –VI group semiconductor with 2.42 eV direct band gap [4, 5], and employed as the window material jointly with numerous semiconductors as in CdTe, Cu2S, InP and CulcnSe2 with efficiency ranged from 14 to 16% [6, 7]. Numerous approaches have testified for depositing CdS thin films. They involve sputtering, evaporation, spray pyrolysis, chemical bath deposition, molecular beam epitaxy (MBE) technique, metal organic chemical vapor deposition
MOCVD), and electrodeposition, photochemical deposition. [8,9]. In this study, spray pyrolysis was selected as simpler technique for depositing CdS thin films than other recent sophisticated techniques reported in the literature. Laser crystallizing of thin films on glass is extensively exploited to enhance an electronic transference. Laser crystallization has increased the carrier mobility in thin film transistors in the flat panel displays production. Appropriate laser intensity profiles combined with numerous scanning sequences were used to lessen the grain boundaries number [10].

Laser crystallization is more promising than thermal crystallization since it doesn't harm the glass substrate and most of the laser energy is straightforwardly absorbed into the CdS film [11]. Using laser pointer stands for greatest practical importance between molecular lasers. The top levelled efficiency of laser that its laser radiation is feasibly generated in continuous wave (CW) and pulse operation is its most interesting feature. Laser radiation is resultant by electron transitions nearly to the limit for solitary or double ionization in the case of atom and ion lasers [12].

The significance of investigating the optical features of a material is to make available information concerning the fundamental gap, electronic transition, trapping levels and localized states [13]. There are many reported studies that investigated the radiation effect on thin films as in [14-17].

In [14], the effect of laser irradiation throughout the deposition process on the features of CdS films 1995 has been conducted. While in [15], chlorine doping effect on the physical, morphological, optical and electrical features of spray deposited CdS thin films has been described in details.

Investigation about the optical features of CdS radiated by (He-Ne)laser has been explained in[16], while in [17], the optical and structural properties of pure and lithium doped CdS thin films as a result of chemical bath deposition method has been reported [17].

In the current work, a comprehensive specific investigation about the effect of diode laser on optical and electromagnetic properties of such CdS thin films has been conducted since optical features of these films are significant in countless scientific and industrial applications in the optoelectronic devices field, chiefly for solar cells. CdS thin films are specifically deposited on glass substrates by means of Spray Pyrolysis method in this study. The objective of this paper is to investigate the consequence of fast neutron radiation on the band edge, localized states, optical constant, and dispersion parameters of CdS thin films.

2. Experimental work

The CdS thin films have been organized by spray pyrolysis of aqueous solution of (CdCl₂·H₂O) cadmium chloride and (NH₂CSNH₂) thiourea . The molar concentration of the solution has been adjusted to be 0.1 mole/liter. Concentrations from this material are weight required from each of them, melted in 50 liter of distilled water, in relation to [18]:

\[ m = \frac{MwVC}{1000} \]  

(1)

Where

- \( m \): the amount of the dissolved material (g)
- \( MW \): Molecular weight of material (g/mole)
- \( V \): solvent volume (ml)
- \( C \): concentration of dye (mole/liter).

This composition has been in the finest manner to provide greater optical transparency. The substrate have been heated under 300°C for 20 minutes before spraying in small quantities to prevent extreme cooling of hot substrate throughout spraying. In the aim to acquire films of standardized thickness, the distance amid sprayer and substrate has been kept as 30±1 cm.

CdS films have prepared on glass substrate. The process of coating has been stable and in remarkable adhesive features. Then, samples are irradiated by diode laser pointer of power (500mwatt) and
wavelength (532nm) at distance of 10 cm from the source for the period of diverse exposure times of 10,20,30,40,50,60,70 and 80 minutes. The absorption and transmission spectrums have been determined by UV-Visible spectrophotometer (T70/T80 Series) in the wavelength range spectrums have been determined by UV-visible spectrophotometer under 190-1100 nm.

FTIR spectra instrument have been employed in the wave number domain of (400-4000) cm⁻¹. The thickness of films has been measured through digital micrometer (Tesha Version) with 0.001 mm measurement exactness under (0 – 150) mm scope of measure.

3. Results and Discussions

The absorption spectrum for CdS film is depicted in Figure 2. The peak of CdS is begun at wavelength of 485 nm with intensity of 0.598. The peak is decreased with increasing the amount of different exposure times of irradiation, and the peak is then disappeared due to embrittlement of the film surface, making it more liable to corrosion and the film surface became uneven. Therefore, the scattering of light is increased on the film surface and the amount of transmitted light through the film increases after irradiation. The irradiation causes some structural defects in the films [19]. This may be attributed to the creation of energy states in the region between the conduction and the valance band that will be available for the incident photon to be absorbed.

![Figure 2. Absorption spectrum of CdS films after and before laser irradiation for dissimilar irradiation periods.](image)

The transmission and reflectance illustrated in Figures 3 and 4, respectively. Reflectance has calculated based on [20]:

\[ R + A + T = 1 \]

![Figure 3. Transmission spectrum of CdS films after and before laser irradiation for dissimilar irradiation periods.](image)
Based on Eq. 3, the absorption coefficient can be calculated and its value gives us information about the nature of electronic transition [21]:

$$\alpha = 2.303 \left( \frac{A}{x} \right)$$  \hspace{1cm} (3)

At what time the high absorption coefficient magnitudes are occurred ($\alpha > 10^4 \text{cm}^{-1}$) at upper energies, direct electronic transitions will be predictable with energy momentum preservation of the electron and photon. On the other hands, if magnitudes of absorption coefficient are low ($\alpha < 104 \text{ cm}^{-1}$) at low energies, it will lead to indirect electronic transitions. From Figure 5, we noted that the value of absorption coefficient is less than $10^4 \text{ cm}^{-1}$ so that indirect electronic transitions have been realized. Figure 5. showed the absorption coefficient for CdS films.

Table 1. Optical energy gap for CdS films before and after laser irradiation for dissimilar periods

| Eg (eV) | Irradiation Times (min) |
|---------|-------------------------|
| CdS     | 0  | 10  | 20  | 30  | 40  | 50  | 60  | 70  | 80  |
| 2.30    | 2.22| 2.21| 2.20| 2.18| 2.17| 2.14| 2.10| 2.08|
The extinction coefficient (K) and refractive index (n) have been determined based on Eqs. 4 and 5, and depicted in Figures 7 and 8. These dual parameters decreases as the effect of laser irradiation time up to certain point is increased. The increasing in refractive index to be big magnitude points to that the compound is absorbing material [22]:

\[ K = \frac{\alpha \lambda}{4\pi} \]  

(4)

The refractive index can be evaluated by using Eq. (5) [23]:

\[ n = 1 + \sqrt{R} \div (1-\sqrt{R}) \]  

(5)

The refractive index is evaluated according to Eq. 5 that depends on reflectance, so that the refractive index for all samples is similar to behavior of reflectance. Figure 8. illustrates the refractive index for CdS films.
Furthermore, the complex dielectric constant $\varepsilon^*$ can describe the optical features of material computed by [24]:

$$\varepsilon^* = \varepsilon_r + i\varepsilon_i$$  \hspace{1cm} (6)

Where $\varepsilon_r$ and $\varepsilon_i$ stand for the real and imaginary parts of dielectric constant, correspondingly, computed by:

$$\varepsilon_r = n^2 - K^2$$  \hspace{1cm} (7)

$$\varepsilon_i = 2nK$$  \hspace{1cm} (8)

These constants have been schemed in Figure 9. It is comprehended that the performance of these constants is identical to refractive index and extinction coefficient. On the other hand, the real dielectric constant is greater as compared with other constants.
Figure 9. Complex dielectric constants spectrum of CdS films after and before laser irradiation for dissimilar irradiation periods.

Figure 10. shows the FTIR spectrum for CdS films in different ratios of irradiation times. The peaks appear between (626-920) cm$^{-1}$ refer to Cd-S stretching bending. The bands at (1000-3550) cm$^{-1}$ have been related to bending vibration of water and band at O-H stretching of adsorbed water on surface of CdS. The medium strong band between 626 and 920 cm$^{-1}$ has been assigned as CdS band. There was no change in the peak positions just bigger or smaller with increase in time of irradiation.
4. Conclusions

The influence of diode laser irradiation on optical features of CdS films in dissimilar irradiation periods were investigated in this paper. The transmittance, absorbance, reflectance and each optical constant of exposed films to diode laser has investigated. Moreover, the optical band gap is reduced as irradiation time increases. In investigation of FTIR-spectrum of CdS films in different ratios of irradiation times, there was no change in the peak positions just bigger or smaller values with increase of times irradiation as follows:

- Decrease in absorption, reflectance R, absorption coefficient $\alpha$, the refractive index n, the extinction coefficient K, the value of the band gap energy $E_g$ as well as the real part and imaginary part of dielectric constant.
- Intensification in the transmittance T.
- Finally, the peaks appear between 626 and 920 cm$^{-1}$ refer to CdS stretching bending. The bands at (1000-3550)cm$^{-1}$ are attributed to bending vibration of water.

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