Cross Sectional-Area Effect on The Optical Properties of The CdS Nanoparticles Prepared by The Exploding Wire Technique

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Abstract. The characteristics of the cadmium sulfide films prepared with the explosive wire were studied and the effect of changing the cross-sectional area of the wire on these properties was found. It was found that the energy gap is inversely proportional to the area where the greater the area, the lower the energy gap values (from 1.65 to 1.12) eV. Also, the absorption and its modulus were increased by increasing the cross-sectional area of the wire. The refractive index and extinction factor showed a clear response, as the value of both decreased due to the effect of this increase in the wire area.

1. Introduction
One of the most advantageous materials for thin film solar cells is CdS thin film. Cadmium sulfide (eg = 2.4 eV) has been commonly used as a semiconductor [1, 3]. The study of atmospheric interactions has been linked to thinning. The resultant covalent bond is formed by the sharing of two electrons between the sulfur atom and the cadmium ions [4, 5]. CdS is a polycrystalline compound with a crystal structure that is either hexagonal (Wurtzite) which is the most stable at room temperature or a cube of the buckle form Zinc [6, 7] which is close to diamond in composition or mixed where it can be obtained by heat treatment [8, 9] and these are regulated by the preparation conditions [8, 9]. Cadmium sulfide has a cubic energy gap of 2.4 eV and a hexagonal energy gap of 2.5 eV. PLD, chemical evaporation, and DC magnetic sputtering are only a few of the methods used to create cadmium sulfide films [10, 11]. The optical properties were used in this study to measure the optical properties of the prepared distillation cadmium sulfide films using the exploding wire method, which is dependent on the wire's cross-sectional area.

2. Experimental Part
Thin films of cadmium sulfide were dried in a liquid containing 75 ml of water and 1 gram of sodium sulfide dissolved in it using an exploding wire technique with a wire and cadmium base with a cross-sectional area (0.3, 0.6, 0.9) mm². Then the wire with a current was blown into the liquid (100 A). The resultant cadmium sulfide was coated in fine films and rinsed on a glass surface size of 76 x 26 x 1 mm for 1 hour at 200 °C. The substrates are pre-washed, rinsed with distilled water and with air dried with alcohol. The thickness of the film measured with the rings of Michelson was approximately (105.5) nm. The natural incidence of light was used to test the absorption spectra of the prepared samples using a double-beam spectrophotometer in the wavelength range (190-1100) nm, with a blank glass as a reference.
The thickness and absorption for each cross-sectional region is used to measure the absorption coefficient [12]:

\[ \alpha = \frac{2.303 \Lambda}{t} \quad (1) \]

where \( t \) denotes the thickness of the film (it is 105.5 nm, which is very similar to the thickness of all the films prepared) and \( \Lambda \) denotes the optical absorption. The refractive index is made up of two actual components, the refractive index and the extinction factor. The following equations were used to quantify these two variables. The absorption coefficient and reflection (R) spectra can be used to calculate the values of (n) and (k). The refractive index (n) is written in terms of surface reflectance as [13]:

\[ n = \left[ 1 + \frac{R}{1 - R} \right] + \frac{4R}{(1 - R)^2} \left( \frac{1}{2} \right) \quad - k^2 \quad (2) \]

If \( k \) is associated with the absorption coefficient \( \alpha \) by:

\[ k = \frac{\alpha \lambda}{4\pi} \quad (3) \]

By using the Taucs Relationship to direct transition[13], the energy gap was calculated.

\[ (\alpha h\nu)^{1/n} = A (h\nu - E_g) \quad (4) \]

Where \( A \) is the constant, \( h \) is the constant of plank, and \( n \) is a constant.

3. Results and discussions

The absorbance variance as a function of wavelength is shown in Figure 2. CdS nanoparticles deposited on glass have a size range of (100-900) nm. The substrates are made with different cross-sectional areas of strip using drip coating, and the current applied is 100A. It can be shown that all films have high absorption at short wavelengths, then absorption decreases as wavelength increases (it has low values in the visible and near infrared regions), and finally absorption decreases at long wavelengths. The incident photons have no impact. The photon can travel because it has enough energy to interact with atoms. As the wavelength of the incident photon is reduced, an interaction between the incident photon and matter occurs. The absorbance would then increase.
Figure 2. Absorption spectra versus wavelength at 100A for various cross-section areas

Figure 3. shows the absorption coefficient of CdS nanoparticles deposited on glass substrates as a function of wavelength. Different nanowire cross-section areas and currents of 100 A were used to obtain the absorption coefficient. Equation1. was used to calculate the absorption coefficient (α). In conclusion, the films clearly have a high absorption coefficient. Both films' wavelength (> 104cm⁻¹) denotes the possibility of a direct electronic transition.

The estimated value of the wavelength of the refractive index VS is shown in Fig. 4. When the current is constant, the refractive index decreases, starting to rise slightly and then holding steady at the visible wavelengths as the cross-section values increase. Since the refractive index is proportional to the particle density, the number of particles generated increases as the cross-sectional area grows.
Figure 4. Refractive index VS wavelength

Figure 5 depicts the extinction coefficient, which has been found to decrease as the cross-section region is increased.

![Graph showing refractive index vs wavelength](image)

The energy gap is a measurement of a material's conductivity. We discovered through research that the energy gap of plasticized cadmium sulfide decreases as the cross-sectional area increases, since the more surface area exposed to the current, the more nanoparticles are formed, and thus the amount of electrons that can be transferred to higher levels increases. As can be observed, the film's band gap energy decreases. With rising current, the voltage drops from 1.65 to 1.61 eV. As the current increases, the energy difference was 1.65 eV at 75 A, 1.63 eV at 100 A, and 1.61 eV at 125 A for 0.6 mm2 and 0.9 mm2 (75A,1.25eV), (100A,1.25eV), and (125A,1.12eV). This is a good result compared to other techniques.

Values of optical power gaps (e.g. A) The CdS nanoparticles generated with this method were chosen. The region of the wire cross-section and the movement of thin films deposited on the glass differ. Tauc's equation was used to calculate the substrate. This formula is applied to select the best line drawing for Relationships (h) 1/2, (h) 1/3, (h) 2/3, and (h) 2 Photon energy (h) to determine the form of optical transfer. He discovered that for r = 1/2, the relationship creates a linear dependency, which corresponds to CdS Nanoparticle films with allowable direct transmission. The asymmetry of optical energy as shown in Fig. 6, it is calculated by extrapolating the fraction at (αhν)^1/2 = 0. The energy gap of a thin film of air-heated cadmium sulfide decreases from 2.4 eV to 2.34 eV, according to Machic et al. [14]. They also reported a decrease in the energy gap value from 2.33 eV to 2.30 electron volts after heating the cadmium sulfide films in H2 medium at 400 °C for 60 minutes [14]. For both inlaid and heated cadmium films, optical bandgap values of 2.15 V and 2.25 V were calculated, ranging from = 1.70 V to 2.72 eV [15], as previously stated.

![Graphs showing Tauc's equation and energy gap](image)

**Figure 6.** (αhν)^1/2 in opposition to energy of photon for CdS in different value of current and a)
0.6mm$^2$ and b)0.9mm$^2$

| Table 1. Energy gap for CdS with different current and different cross section area |
|----------------------------------|-------------------|
| Eg (eV)                          | Current(A) and cross section area mm$^2$ |
| 1.65                             | 75A-0.6mm$^2$     |
| 1.63                             | 100A-0.6mm$^2$    |
| 1.61                             | 125A-0.6mm$^2$    |
| 1.25                             | 75A-0.9mm$^2$     |
| 1.25                             | 100A-0.9mm$^2$    |
| 1.12                             | 125A-0.9mm$^2$    |

4. Conclusion
An exploding wire technique was used to precipitate cadmium sulfide nano films on to the glass slide. To enhance crystallization since when not heated they are amorphous, films are heated in an oven. The energy gap in the cadmium sulfide thin films decreased as the cross-sectional area increased with the current, so the area effect was significant. Increasing the cross-section of the strip made the material better absorbed with high efficiency more than if the cross-sectional area was fixed. The exploding wire method is an inexpensive and safe method that does not affect the environment and can be used in the preparation of semiconducting materials to take advantage of them.

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