The Effect of $\alpha$-Particles on Structural, optical and Morphological Properties for Cadmium Selenide Thin Film

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Abstract: In this paper, the effect of alpha particles on cadmium selenide thin film properties was invistigated. (CdSe) thin films prepared on glass bases at 50°C and 70°C tempartures, and pH=9 using the chemical bath deposition method. The irradiation was performed on (CdSe) films use the alpha particles source Americium (Am-241) with activity of 50$\mu$Ci and energy 5.3MeV for a period irradiation of 5 hours. The samples were characterized by using the XRD, FESEM and EDX techniques. The optical measurements have been obtained by using the UV-V spectrophotometer. The results showed that there are effects of alpha particles on the optical and structural properties of the films. It was found that the energy gap increases slightly after the CdSe thin film irradiated, the absorption coefficient ($\alpha$) is increases with irradiation due to the increase in the energy gap. The structure of the CdSe films has been transformed slightly from the cube structure to the hexagonal structure. The grain size increases with irradiation where the relative density increases clearly. The shape of the CdSe thin film at 70°C is affected by irradiation more over than at 50°C.

Key words: CdSe thin film, CBD method, alpha particles.

1. Introduction

Cadmium selenide (CdSe) is one of the semiconductor compounds belong to the (II-VI) group in the periodic table. CdSe was very popular in optoelectronics field because it has a direct energy gap about 1.74ev [1], allowing it to be used in optoelectronic devices, LED diodes, field effect transistors, biosensors, and solar cells applications [2] [3]. The CdSe films were prepared by different deposition techniques such as thermal evaporation, sputtering, chemical deposition [4]. It was found that the chemical bath deposition technique is simple, inexpensive, and convenient technique to deposit a large area of nanocrystals at low temperatures [5]. These films are mainly dependent on deposition time, temperature, pH, and the concentration of materials [6], the following properties improve the size, shape, and homogeneity of crystals [7]. A different types of crystal structures are found either single crystalline or polycrystalline, which is in the hexagonal phase [8], cubic phase [9], or a mixture of the cubic and hexagon [10]. Several studies have been investigated on the effect...
of radiation on the properties of (CdSe) films such as Gamma and $^{60}$Co. However, this study will address for the effect of irradiation with alpha particles on CdSe properties. When charged alpha particles pass through matter, an interaction due to Coulomb force created between the alpha particle and the electrons of substance of matter, \([11]\) \([12]\). As well the substance absorb alpha particle easily and when this particle loses its energy through the ionization or excitation processes of the atoms \([13]\), this leads to the breaking of the bonds of the molecules. The kinetic energy is gradually depleted until it loses all its energy during the film continuously and not in batches\([14]\). Thus charged particles have a specific range in films and the products of this reaction are either an excited atom or an ionic pair \([15]\), and that the radiation affects the cadmium films with the linear energy transfer rate \([13]\) is directly proportional to the square of the charge and inversely proportional to the square of the velocity \([16]\). The distance that the alpha particle travels in the medium depends on the nature of the object being intercepted and on its kinetic energy, which is completely depleted when it reaches the end of the range. This study is aimed to investigate the effect of alpha particles irradiation on CdSe thin films on, structural, optical properties, and the morphology surface of the film.

2. Experimental Details

2.1. CdSe Thin Film Preparation

A glass slides of dimensions \((7.5 \times 1.3 \times 0.1)\) cm were used as a substrate, washed with running water and one of the cleaning powders, the clean slide placed in a solution of hydrochloric acid for 15min, then put it in deionized water, immerse it in a hot alcohol solution, then in acetone, and then it is kept in a vacuum place to keep it from the air and the factors affecting it. The cadmium selenide films were prepared by chemical bath deposition method (CBD) using, \(\text{Na}_2\text{SeSO}_3\) as a source of Se ions and \(\text{CdCl}_2\) as a source of Cd ions. The selenium was mixed with Sodium Sulfite in 10ml of deionized water in the reflux system and heated in a magnetic stirrer for two hours, the \(\text{CdCl}_2\) was dissolved in 10ml of deionized water with the addition of ammonia \(\text{NH}_3\), a white turbidity appears which was dissolved more than ammonia solution and then a few drops added from Triethanolamine TEA. The slides were placed inside the solution vertically at 50°C for 3 hours to complete the deposition. This process was also repeated but at 70°C temperature.

2.2. The Mechanism of Chemical Reaction

CdSe films were prepared by CBD technique, which is based on the slow release of \(\text{Se}^2\) and \(\text{Cd}^{2+}\) ions in solution, and then condensed to deposition on a glass base placed inside the solution. The following equations represent the reaction mechanism to obtain CdSe films, \([17]\).

\[
\begin{align*}
\text{Se} + \text{Na}_2\text{SO}_3 & \rightarrow \text{Na}_2\text{SeSO}_3 \\
\text{Na}_2\text{SeSO}_3 + 2\text{OH}^- & \rightarrow \text{Na}_2\text{SO}_4 + \text{H}_2\text{O} + \text{Se}^2^- \\
2\text{CdCl}_2 + 4\text{NH}_3 & \rightarrow (\text{Cd}^{2+}(\text{NH}_3)_{4})^{2+} + \text{CdCl}_4^{2-} \\
(\text{Cd}^{2+}(\text{NH}_3)_{4})^{2+} & \rightarrow \text{Cd}^{2+} + 4\text{NH}_3 \\
\text{Cd}^{2+} + \text{Se}^2^- & \rightarrow \text{CdSe}^{\text{\downarrow}}
\end{align*}
\]

2.3. Experimental Techniques

The samples were irradiated use alpha rays for 5hours. The (UV-VIS-NIR) spectrophotometer was used to measure the optical properties of CdSe films. The transmittance and absorption were measured as a function of the wavelength of the range from \((340-1000)\)nm and the optical absorption coefficient was calculated from the relationship: \(\alpha = 2.303 \times \frac{A}{t}\), where, \(A\) is the absorption coefficient, and \(t\) is the thickness of the film. The relationship between the square of the absorption coefficient and the energy of the incident photon was plotted to calculate the energy gap \((E_g)\) of the film. The extinction coefficient represents the amount of energy absorbed by the thin film or the inertia that occurs.
in the electromagnetic wave inside the film and can be found from the following relationship [18]:

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

The Urbach energy which represents the number of levels within the optical energy gap, which is indicative of the existence of different types of random levels and defects that arise according to the method used in preparing the film. The relationship between the photon energy and the absorption coefficient is given according to the following equation, [19]:

\[ \alpha = \alpha_0 \exp\left( \frac{h\nu}{E_g} \right) \]

An XRD device was also used to identify the crystal structure of pure and irradiated films by comparing it with the standard card for X-ray diffraction, (JCPDS).

3. Results and discussion

3.1. Optical measurements

The optical energy gap can be determined by specifying the values of the absorption coefficient as a function of the photon energy subject to the Tauc relationship in this region; 

\[ \alpha h\nu = A(h\nu - E_g)^n \]

where \( h\nu \) is the energy of the photon, where \( E_g \) is the energy gap and \( A \) is a constant. The values of \( n \) is taken as 1/2 for direct transition of this film. [20]. From the optical absorption regions at the exponential region, the energy gap \( E_g \) represents the extension points of the tangent to the curve with the photon energy. [21]. The exposure of thin films to radiation doses may lead to an improvement in their behavior, as it was found that the values of optical properties increase with increasing radiation dose, and the energy gap value increases as a result of additional generation energy levels within the defined region between the equivalence and conduction band [22]. Figure 1, shows the set energy gap for pure CdSe films and irradiated Alpha radiation.
Figure 1. Energy gap of CdSe thin films, (a) pure at 50°C (b) radiating at 50°C (c) pure at 70°C (d) radiating at 70°C

It is found that the $E_g$ values before irradiation (1.74)eV and upon irradiation the energy gap increased, it is believed that the increase in the gap is due to the increase in the size of the grains. As shown in FESEM images Figure 7, it also increased the regularity of the internal arrangement of the atoms of the film, which agree with [23] and [24].

Figure 2, shows that CdSe films have low permeability in the ultraviolet region (340-400)nm and increase with increasing wavelength in the visible spectrum region (390 – 770)nm and the near-infrared (700 – 990)nm and this is consistent with what was stated by him and [25], and this indicates that CdSe films have a large energy gap that allows a part of the visible light to penetrate and upon irradiation, the permeability decreases and the absorbance increases due to an increase in the crystal size as well as an increase in the absorbance and optical absorption coefficient.
Figure 2. Transmittance (T) and absorbance (A) as a function of wavelength (λ) for pure and irradiated CdSe films at at 50°C and at 70°C

The Urbach energy is assumed as the width of the tail of localized defect states in the band gap. When the samples are irradiated by a particular wavelength, these defect states are trap the excited electrons, which preventing their direct transition to the conduction band. These defect states are responsible for the absorption tail in the absorption spectra, which extends into the forbidden gap. This absorption tail is called the Urbach tail, which is associated with Urbach energy [26]. The Urbach energy can calculated by plotting ln(α) against photon energy hv. The reciprocal of the slope of the linear fit below the optical energy gap region, gives the value of the Urbach energy [27] and [28]:

\[ E_U = \frac{\alpha(\text{opt})}{\alpha(hv)} \]  

Figure 3. Urbach energy for pure and radiating CdSe films at 50°C and 70°C

Figure 3, shows that E_U increases as the CdSe film irradiation. The increase of E_U indicates the presence of a high density of levels concentrated inside the energy gap resulting from the emergence of a crystalline defect inside the film [29].

Alpha particles do not deviate much from their path inside the films, resulting in a linear path and because they have an equal charge (2e) that forms a dense path of ionization and lose its energy at a short distance inside the film [14].

The interaction of an alpha particle with ions is greater than its interaction with the nuclei of atoms, this is due to the occupancy of the nuclei of the medium as (10^{-15}) of the size of the
atoms. The total radiation dose absorbed by the thin films represents the dose rate multiplied by the time of exposure [22].

**Figure 4.** The extinction coefficient(K) of CdSe films as a function of the photon energy before and after irradiation and at 50 and 70 ºC.

Figure 4, shows that the irradiation has affected on the surface of the thin film, and this lead that the total dose absorbed by the film increases, and thus the defects left by the radiation on the film increase, which may lead to a defect in the crystalline structure of the film and which agree with [30].

Table 1, shows the $E_g$ and $E_U$ values for CdSe thin film at different temperatures before and after exposed with alpha-ray.

| Temperature | T (µm) | Before irradiation $E_U$ (eV) | After irradiation $E_U$ (eV) | Before irradiation $E_U$ (eV) | After irradiation $E_U$ (eV) |
|-------------|--------|--------------------------------|-------------------------------|-------------------------------|-------------------------------|
| 50          | 0.3    | 1.74                           | 1.9                           | 571                           | 800                           |
| 70          | 0.4    | 1.74                           | 1.9                           | 555                           | 769                           |

3.2 X-ray diffraction measurements (XRD)

Figure 5, shows the x-ray diffraction pattern of pure and irradiated CdSe. Here three the characteristic peaks were identified (111) at 25.59, (220) at 42.5 and (311) at 50.14, respectively, when compared with standard data card of (JCPDS no. 19-0191). Also it was found that the pure and irradiated CdSe films were polycrystalline with cubic structure having (111) plane as a preferred orientation. The effect of irradiation on films is observed through the relative intensity value of each peak, where the intensity increases with irradiation and the films have a multi-crystalline, results showed. The increase in the grain size of the CdSe films may be attributed to the appearance of different crystalline forms, and the structure of the films has been slightly transformed from the cube structure to the hexagonal structure. Such a phase transition may occur due to the change in the atomic configuration.
The grain size (D) of the CdSe film was calculated from the Debye-Scherrer equation and it was found that the irradiation led to a narrowing of the peak width and thus a decrease in FWHM and thus the size increased. D = \frac{0.9 \lambda}{\beta \cos \theta}, where k is a constant dependent on crystal type (0.9), \lambda is the wavelength of CuKα=1.54°Å radiation, \beta is the width of the line is at the middle of the highest peak value, \theta is the angle between the incident and scattered X-ray. Table 2, shows the values of some factors obtained from XRD at different temperatures for pure CdSe thin films and exposed with alpha-ray.

**Figure 5.** XRD schemes of pure and irradiated CdSe films

**Table 2:** Summary of some factors obtained from XRD for pure CdSe thin films and irradiated with alpha particles.

| Temp | Model type | 2θ | Peaks no. | Rel. Intensity | Hight | df-spacing | Crystallite Size |
|------|------------|----|-----------|----------------|-------|-------------|------------------|
| 50°C | Pure       | 25.59 | (111)C   | 100            | 885   | 3.47797     | 2.10             | 4.09 CdSe       |
|      |            | 42.50 | (220)C   | 35.04          | 310   | 2.12528     | 2.5              | 4.03 CdSe       |
|      |            | 50.14 | (311)C   | 19.24          | 170   | 1.81805     | 2.7              | 4.16 CdSe       |
|      |            | 23.9  | (100)H   | 31.92          | 240   | 3.71869     | 1.1              | 7.84 CdSe       |
|      | Irradiated | 25.6  | (111)C   | 100            | 750   | 3.47078     | 2               | 4.31 CdSe       |
|      |            | 32.3  | (002)    | 12.93          | 97    | 2.77185     | 0.2              | 45.39 Cd        |
|      |            | 34.08 | (100)    | 24.56          | 184   | 2.62863     | 0.2              | 46 Cd           |
|      |            | 37.94 | (101)    | 14.71          | 111   | 2.36956     | 0.2              | 49.28 Cd        |
|      |            | 42.53 | (220)C   | 40.87          | 307   | 2.12375     | 2.6              | 3.87 CdSe       |
|      |            | 50.14 | (311)C   | 12.51          | 162   | 1.82381     | 2.5              | 4.48 CdSe       |
|      |            | 67.4  | (331)C   | 3.44           | 26    | 1.38920     | 2               | 8.11 CdSe       |
|      |            | 25.69 | (111)C   | 100            | 779   | 3.46438     | 2.41             | 3.57 CdSe       |
|      |            | 42.45 | (220)C   | 44.57          | 347   | 2.12777     | 1.6              | 6.30 CdSe       |
3.3 Compositional Analysis

Initial analysis of the CdSe thin films deposited on glass substrate was performed using EDX analysis as in Figure 6.

It is noted, there are some of oxygen, carbon, and others, which can be attributed to the contamination of the film surface. These materials may be due to the remnants of the primaterials for preparing the CdSe film as well from the experimental kits it might be from the experiment kit. [31].

3.4 Morphological Surface

This technique is useful to determine the morphology of the surface. The results show that CdSe films consist of uniform and homogeneous spherical grain without merging, there is no cracks. After the irradiation, a deformation occurred in surface of the film at 70°C. A part of the film disappears and the grains were clump and become polygon and the grains size was increased.
Figure 7. FESEM image of as-synthesized CdSe nanoparticles by CBD

4. Conclusion
The CdSe thin films were synthesized successfully onto glass substrate using chemical bath deposition technique at (50 and 70)°C. The optical and structural properties were studied before and after exposure to alpha particles, with energy of 5.3MeV for a period irradiation of 5 hours. One can conclude:

- The absorbance spectrum of thin films is affected by irradiation within the wavelength range of (340-1000) nm, the absorbance increases and the transmittance decreases by irradiation. The absorption coefficient increases also with irradiation as well the energy gap increase.
- The extinction coefficient increases with irradiation, this proves that the exposure of the film for a long period to radiation may cause a change in the nature of the surface of the film, which leads to damage the crystal lattice.
- Urbach energy increases by irradiation.
The film’s structure has been transformed from the cube structure to the hexagonal structure. Where the grain size of the crystal increases with irradiation and the relative density increases clearly.

The shape of the film is affected by irradiation at 70°C more over 50°C.

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