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The Effect of Gamma-ray (Low Energy Cs-0.660 MeV) Irradiation on the Energy Gap of CdSe Thin Films Prepared at Different Temperatures

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Abstract
In this study, CdSe thin films were prepared by the Spray pyrolysis method at different substrate temperatures and then subjected to gamma rays from a (Cs-source) with an energy of about 0.66MeV for two hours. The impact of gamma rays on the energy gap values was examined at the temperatures mentioned above. There was a significant increase in the energy gap value by about (0.1 to 0.15)eV.

Keywords: CdSe, Thin Film, Spray Pyrolysis, γ-irradiation

Introduction

Cadmium Selenide belongs to the wide band gap semiconductor class [1]. CdSe has attracted significant attention recently due to its 1.74 eV band gap and high exciting binding energy of 15 meV [2]. CdSe-based nanostructures find applications in various fields such as solar cells [3], transistors, light-emitting diodes (LED) [4], Ultra-violet (UV) detectors and thin-film transistors [5, 6]. With an optical energy gap of approximately 1.75 eV, the optical absorption properties demonstrate a direct bandgap nature, leading to a high responsively of 4.9 A/W in CdSe film photodetectors. The study suggests that CdSe films can be used for nanoscale photodetectors [7]. CdSe is a promising photovoltaic material because it has a high absorption coefficient and is near the band edge and its direct band gap [8, 9]. Moreover, CdSe electrical conductivity n-type semiconductor [10]. Cadmium selenide can be found in three different crystalline forms that are in rock salt (cubic), sphalerite (cubic, zinc blende), and 3 hexagonal (wurtzite) structure [11]. Nowadays, CdSe thin films have received more attention owing to their physical properties**.** The technique of chemical Spray Pyrolysis involves spraying a precursor solution onto a heated surface to deposit thin films onto a substrate [12]. This method is widely used for producing thin films and coatings in various fields, including electronics, energy applications, and materials science. The thin films prepared using chemical spray pyrolysis find applications in solar energy, the manufacturing of photovoltaic cells, gas sensors, and detectors, as well as in the study of various physical properties. By spraying the precursor solution with powerful air pressure, the solution adheres to the substrates, ensuring that the particles adhere to the surface and form a homogeneous film with small grains tens to hundreds of nanometers in size.

The high energy photon of γ-ray may cause ionization and displacement damage in the semiconductor material [13, 14] which can modify the material parameters [15]. Even a thin film semiconductors exposed to low radiation may be degraded in their properties, some thin films have shown an enhancement of their optical properties in another dose rate of radiation [16, 17].

The objective of this study is to produce CdSe films using chemical spraying at different substrate temperatures (100, 150, 200, 300 and 250)ºC, and to investigate how the energy gap of the cadmium selenide films are affected by exposure to gamma rays from a Caesium (Cs) source with an low energy of 0.66 MeV.

Materials and Methods

Thin films of cadmium selenide CdSe have been deposited on soda lime glass (SLG) substrates by the Spray pyrolysis method at different substrate temperatures (100, 150, 200, and 250)ºC. The cleaning process of glass substrates includes several steps using deionized water, ethanol, and acetone ultrasonically to remove any contamination from the substrate's surfaces. It is then washed again with distilled water for two or three minutes, followed by a wash with an acetone solution for two or three minutes using ultrasonic waves. After that, it is washed again with distilled water for two minutes and finally dried with an air dryer. This prepares it to enter the deposition process.

Cadmium selenide films are prepared by mixing 0.8 gm of selenium in 10 ml of distilled water with 1.2 gm of sodium sulfide. Then we boil the mixture for an hour to obtain a solution in which the cadmium selenide is dissolved. This last solution was used as a source of the element cadmium selenide. Then mix this solution with 1 gm of cadmium chloride in 20 ml of distilled water with 1 ml of ammonia. The solution is placed over the magnetic mixer for an hour at 900°C temperature to ensure the dissolution process. Then we leave the solution for two minutes to precipitate. Heavy particles, the solution is separated after two minutes to avoid clogging the nozzle opening, which impedes the sedimentation conditions. The mechanism of CdSe preparation can be expressed in the following reactions [18]:

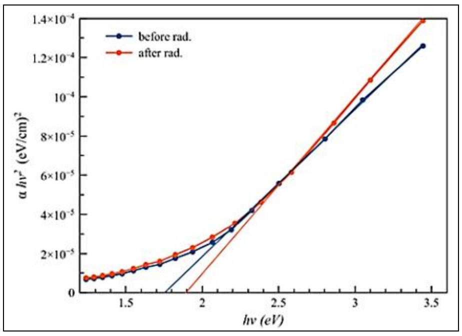
$$2CdCl_2 + 4NH_3 \rightarrow [Cd(NH_3)_4]^{+2} + CdCl_4^{-2}$$
$$[Cd(NH_3)_4]^{+2} \rightarrow Cd^{+2} + 4NH_3$$
$$Na_2SeSO_3 + 2OH^- \rightarrow Na_2SO_4 + H_2O + Se^{-2}$$
$$Cd^{+2} + Se^{-2} \rightarrow CdSe$$

Some of the prepared samples were irradiated by a Selenium (Cs) source with 0.660 MeV energy at 2hour intervals of gamma radiation. Optical measurements were taken using a spectrophotometer (UV spectrophotometer 721-2000) within wavelengths (320-900)nm.

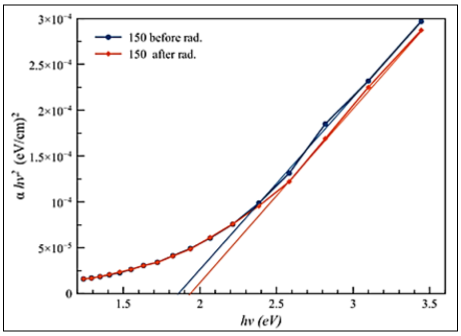
Results and discussion

The following relation can be used to calculate the optical band gap from experimental results of the absorption coefficient (α) as a function of photon energy ($h\nu$), [19]: $\alpha h\nu = A(h\nu - Eg)^n$, where A is the constant, and E_g is the band gap of the film. $h\nu$ is the photon energy, n= 2 or 1/2 for indirect or direct transition.

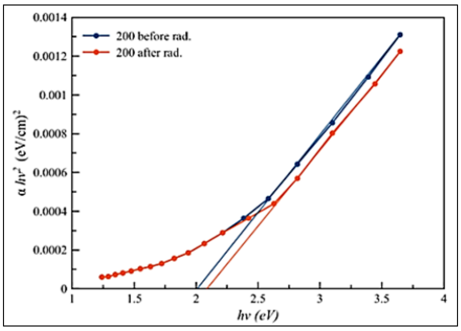
The energy gap (E_g) of CdSe film was determined from the experimental investigation at 100, 150, 200, 250 and 300. The following Figure (1, a-e), illustrate the energy gaps before and after irradiation:



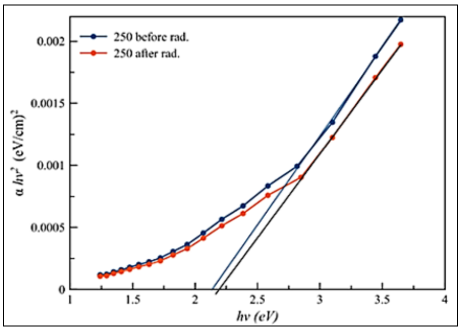
a



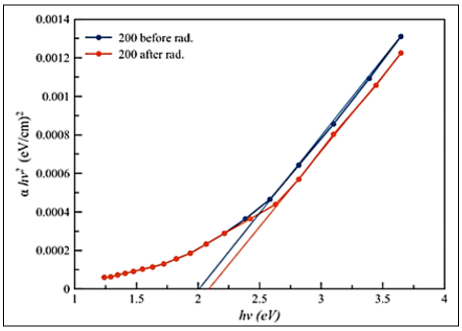
b



c



d



e

Fig 1: Absorption coefficient (α) vs photon energy ($h\nu$), for CdSe samples before and after γ-irradiation at*:* *a*- 100°C, *b*- 150°C, c- 200 °C, *d*- 250 °C, *e* -300°C

Then the energy gap values for CdSe thin films before and after irradiated were listed in Table 1.

Table 1: The energy gap values for CdSe thin films before and after irradiation at different temperatures

sample	T ºC	Eg (eV)	
		before	after
#1	100	1.75	1.9
#2	150	1.85	1.95
#3	200	2	2.15
#4	250	2.1	2.15
#5	300	2	2.1

Conclusion

The exposure of cadmium selenide semiconductor films to gamma rays increases the energy gap of the material, which various physical mechanisms can explain. One proposed explanation is based on the effect of radiation-induced distortion on the material's electronic structure, According to the study by [20]. An analysis of the effect of gamma radiation on CdSe nanocrystals suggests that the increase in the energy gap of these materials may be attributed to the distortion effect caused by radiation. Gamma rays interact with the material's crystal lattice, leading to various distortions in the network structure, which affects the band gaps and energy levels within the energy gap. This interaction may also result in the formation of different compounds or a change in the crystal structure due to the reorganization of atoms within the lattice, ultimately causing a change in the energy gap value.

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