Impact of 1.33 MeV Gamma ray irradiation on the energy gap modification of CdSe thin films prepared by spray pyrolysis at different temperatures

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Abstract
In this study, CdSe thin films were prepared using Spray Pyrolysis method at different substrate temperatures and then subjected to gamma rays from a (Co-source) with an energy of about 1.33MeV for two hours. The effect of gamma rays on the energy gap values was examined at the temperatures mentioned above. There was a significant modify the energy gap value by about (0.15)eV at 200ºC and 250ºC.

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Keywords: CdSe, Spray pyrolysis, gamma ray, irradiation

1. Introduction

Cadmium Selenide (CdSe) is a notable wide bandgap semiconductor [1]. Its band gap of 1.74eV and high exciton binding energy of 15 meV has recently garnered considerable attention [2]. CdSe-based nanostructures are widely applied in solar cells [3], transistors, light-emitting diodes (LEDs) [4], UV detectors, and thin-film transistors [5, 6]. These materials exhibit a direct bandgap nature with an optical energy gap around 1.75 eV, contributing to a high responsively of 4.9A/W in CdSe film photodetectors, making them promising for nanoscale applications [7]. Moreover, CdSe's high absorption coefficient near the band edge and direct bandgap make it a promising material for photovoltaics [8, 9].

CdSe is an n-type semiconductor with significant electrical conductivity [10], and it crystallizes in three forms: rock salt (cubic), sphalerite (cubic, zinc blende), and wurtzite (hexagonal) structures [11]. Recently, CdSe thin films have gained attention due to their unique physical properties. The technique of chemical spray pyrolysis, which involves depositing thin films by spraying a precursor solution onto a heated surface, has become widely utilized [12]. This method is prominent in electronics, energy applications, and materials science for producing coatings and thin films. The films prepared via chemical spray pyrolysis, characterized by small grains tens to hundreds of nanometers in size, find diverse applications such as in solar energy for manufacturing photovoltaic cells, gas sensors, and for studying various physical properties.

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]. Thin film semiconductors exposed to radiation (like the Cobalt) may be degraded in their properties especially for higher dose radiation and thinner films, while some thin films have shown an enhancement of their optical properties in another dose rate of radiation [16, 17]. Cobalt-60 is a radioactive isotope widely utilized as a gamma-ray source due to its high-energy emission gamma rays (1.17 and 1.33) MeV. These gamma rays are highly penetrating and interact with materials through processes such as Compton scattering and photoelectric absorption [18]. CdSe thin films are semiconductor materials with applications in optoelectronics, including solar cells and sensors. When exposed to Co-60 gamma rays, CdSe thin films undergo various changes [19]. Understanding the gamma-ray-induced modifications in the energy gap of CdSe thin films is crucial for applications such as radiation detection devices and solar cells. This study aims to fabricate CdSe films via chemical spray deposition at varying substrate temperatures (100-300)°C. Additionally, the research investigates the impact of gamma ray exposure from a Co-source emitting at 1.33MeV on the energy gap of the CdSe films.

2. Materials and Methods

Thin films of cadmium selenide (CdSe) were deposited onto soda lime glass (SLG) substrates using the spray pyrolysis method at various substrate temperatures (100°C, 150°C, 200°C, and 250°C). Before deposition, the SLG substrates underwent a thorough cleaning process to eliminate surface contaminants. This process involved sequential ultrasonic baths in deionized water, ethanol, and acetone, followed by rinsing with distilled water and a final rinse with acetone under ultrasonic conditions. Subsequently, the substrates were dried using an air dryer to prepare them for the deposition process.

For the preparation of the CdSe films, a solution was prepared by dissolving 0.8gm of selenium in 10 ml of distilled water along with 1.2gm of sodium sulfide, which was boiled for an hour to achieve dissolution. This solution served as the selenium source. Subsequently, 1gm of cadmium chloride was mixed with 20ml of distilled water and 1 ml of ammonia, and this mixture was added to the selenium solution. The combined solution was stirred on a magnetic stirrer for an hour at 90°C to ensure complete dissolution, followed by a two-minute settling period to allow heavy particles to precipitate. Care was taken to prevent nozzle clogging during the solution separation process. Some of the prepared samples were irradiated by a Cobalt (Co) source with 1.33 MeV energy at 2hour intervals of gamma radiation. Optical measurements were taken using a spectrophotometer (UV spectrophotometer 721-2000) within wavelengths (320-900) nm.

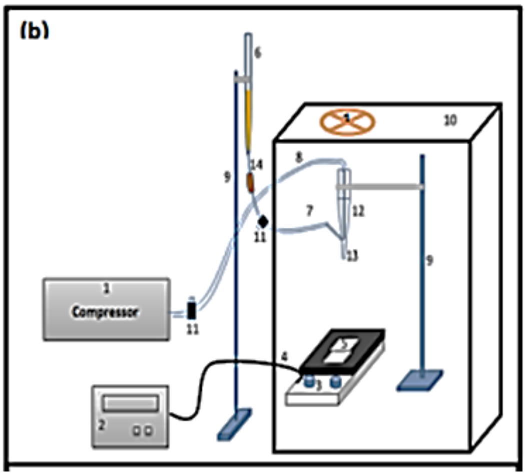
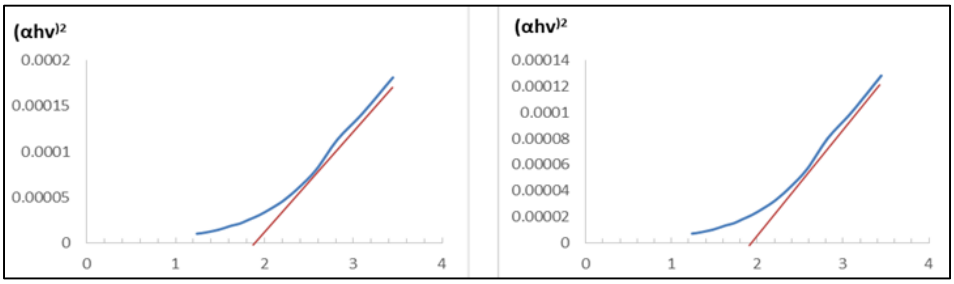


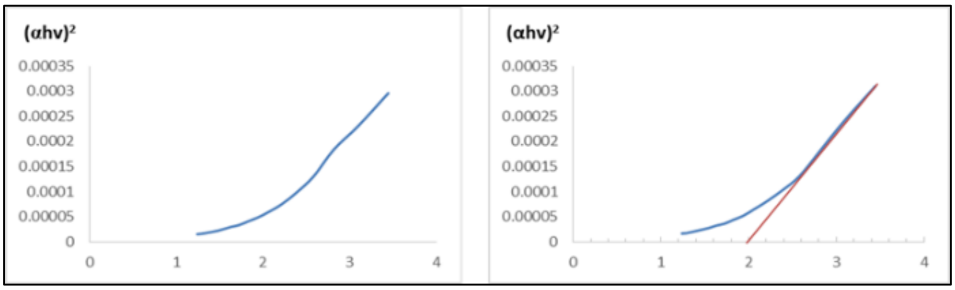
Fig 1: The chemical spray system

3. Results and discussion

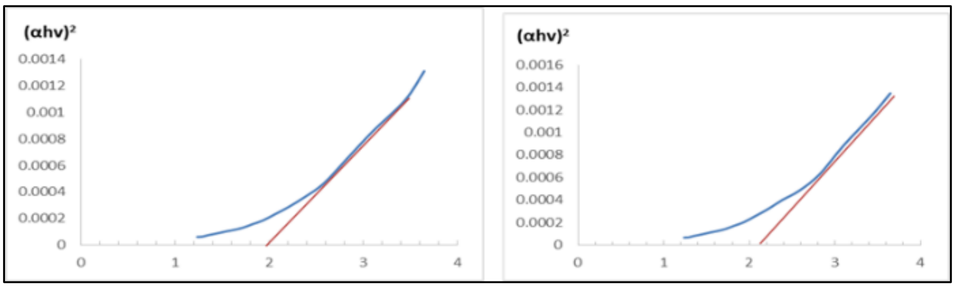
The following relation can be used to calculate the optical band gap from experimental results of the absorption coefficient (α) as a function of photon energy ($h\nu$), [20]: $\alpha h\nu = A(h\nu - Eg)^n$, where A is the constant, and E_g is the band gap of the film. $h\nu$ is the photon energy, n= 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°C. The following Figure (1, A to E), illustrates the energy gaps before and after irradiation:



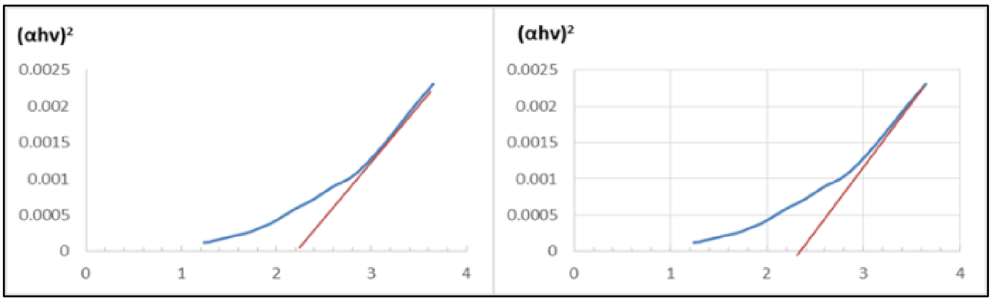
A: at (100ºC) before (left) and (right) after irradiation



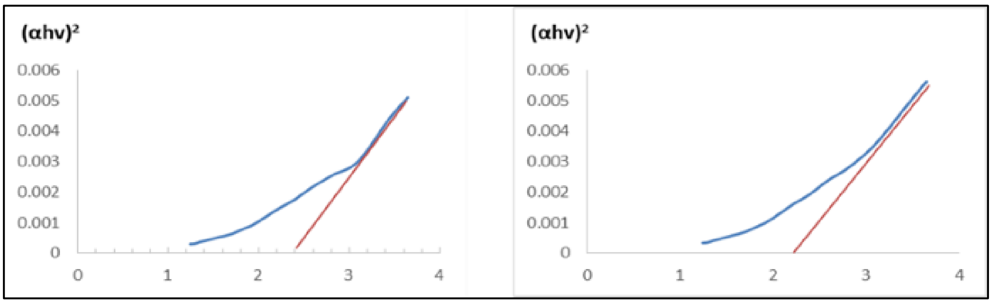
B: at (150ºC) before (left) and after (right) irradiation



C: at (200ºC) before (left) and after (right) irradiation



D: at (250°C) before (left) and after (right) irradiation



E: at (300°C) before (a) and after (b) irradiation

Fig 1: Absorption coefficient (α) –*vertical*- vs photon energy (*h*ν) –*horizontal*-, for CdSe samples before and after gamma 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 °C	Eg (eV)	
		Before	**After**
#1	100	1.9	1.95
#2	150	1.95	2.0
#3	200	2	2.15
#4	250	2.2	2.35
#5	300	2.37	2.37

4. Conclusion

Gamma rays from Co-60 interact with the atoms in CdSe thin films through ionization and excitation processes, which leads to the creation of defects within the crystal lattice of CdSe. Gamma-ray irradiation can alter the energy gap by introducing additional energy states within the band gap region. These states can act as traps for charge carriers, according to Brik [21]. Thereby increasing the effective energy required for electron transitions. So experimentally, this study has demonstrated that exposure of CdSe thin films to gamma rays from Co-60 sources increases the energy gap. This increase is attributed to the creation of deep-level traps or defect states that affect the band structure and electronic properties of the material. At temperatures of 200 and 250 °C, it is the best in adjusting the value of the energy gap of the CdSe thin film by (0.15 eV).

5. Acknowledgments

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