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Preparation of CdSe Thin Films at Different Temperature by Chemical Spraying Method and Study of the Effect of (Se-0.660 MeV-Gamma γ) Radiation on the Energy gap (Eg)

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Abstract: Cadmium selenide (CdSe) thin film fabrication by chemical spraying method occurred at different temperatures from 100°C to 300°C while the research analyzed gamma radiation (0.660 MeV) effects on their energy gap (Eg). Scientists did a spectral analysis of CdSe films, which rested on glass substrates using UV-Vis spectroscopy when the investigation started and when it finished. Film crystallinity increases following temperature elevation in deposition, which results in decreased defects and eventually develops a progressive Eg increase from 2.17 eV at 100°C to 2.365 eV at 300°C. All film specimens underwent increased Eg values after gamma irradiation, but the value variation extended from 0.08 eV to 0.125 eV based on their original deposition temperature. Scientists trace the energy gap expansion produced by the gamma radiation process to two components: ionisation effects and defect alterations altering the electronic structure. enhanced deposition temperature resulted in enhanced radiation sensitivity of films as improved crystalline quality formation produced more obvious alterations. Because of their importance to optoelectronic devices and radiation-resistant material development, the study shows how temperature and radiation exposure influence the optical properties of CdSe thin films. A bibliometric analysis conducted using Scopus coupled to VOS viewer to the most published authors and countries contributing in the field of “Cadmium selenide”.

1. Introduction

The creation of cutting-edge gadgets like cellphones, smart windows, flexible high-resolution screens, and solar cells has advanced significantly in the last several decades. Transparent conductive oxides (TCO) are fundamental components of many electronics. These semiconductors show very low electrical resistance and great optical transparency in the visible part of the light spectrum. Correctly developed TCO layers are conductors with a 10^{-4} Ω.cm resistance and a light transmission rate above

85%, claims (Lewis *et al.*, 2008). Indium tin oxide is the most often utilised transparent conductive oxide in a range of applications, including in solar panels, displays, and touch-sensitive devices, thanks in great part to its outstanding optical clarity and robust electrical performance. With its low resistance, most visible light can pass through Indium Thin Oxide (ITO) and performs perfectly as a see-through electrode (Arshad *et al.*, 2020; Habis *et al.*, 2022; Minami *et al.*, 2023; Pal *et al.*, 2024). Although indium tin oxide is employed in most industrial manufacturing, according to (Arshad *et al.*, 2020) it presently suffers with low resource availability and breakability. Classed as a wide band gap semiconductor (Uslu, 2021), cadmium selenide is recently attracted much interest is CdSe with its 1.74 eV band gap and its exciting binding energy of 15 meV (Pawade *et al.*, 2022). Solar cells (Zhao and Fang, 2012), transistors, light-emitting diodes (LED), ultraviolet (UV) detectors, and thin-film transistors (He *et al.*, 2012) among other uses find applicability in CdSe-based nanostructures.

High responsiveness of 4.9 A/W in CdSe film photodetectors is produced by the optical absorption qualities displaying a straight bandgap with an optical energy gap of around 1.75 eV (Al-Taan *et al.*, 2024). The results imply that CdSe sheets might enable nanoscale photodetectors (Shelke *et al.*, 2020). High absorption coefficient, close band edge, and direct band gap make CdSe a solar material (Hone *et al.*, 2015).

Electrical conductivity is displayed by the CdSe n-type semiconductor (Habte *et al.*, 2019). Three crystalline forms of cadmium selenide: three hexagonal (wurtzite), sphalerite (cubic, zinc blende), and cubic (rock salt). The physical properties of CdSe thin films generated major research interest (Al Abbas *et al.*, 2023). The thin coating deposition process known as Pyrolysis relies on spray treatment where a precursor solution distribution occurs across a heated surface (Kumari *et al.*, 2014; Naciri *et al.*, 2009). This technique enables production of thin films and coatings which serve various applications in electronics and both energy-related domains and material research fields. The thin films that result from chemical spray pyrolyses are utilized for testing physical properties while also serving in solar energy applications and photovoltaic cell manufacturing and operating gas sensors and detectors. A strong air pressure method for precursor solution application ensures solution retention on substrates which allows particles to attach to the surface and form a uniform distribution of nanoscale grains extending between tens and hundreds of nanometres. Semiconductor materials experience two distinct changes in their characteristics due to γ-ray high-energy photons as they produce both ionisation events and displacement damage (Sudha *et al.*, 2016).

Bibliometric analyses are widely used to show more indicators as the authors implied, their affiliations, countries and collaboration inter-institutions or between countries. The data can be extracted from Scopus, Web of Science, Scholar google… and may be coupled to VOS viewer to build cartography analysis (maps) (Ullah *et al.*, 2023; Salim *et al.*, 2022; N'daye *et al.*, 2022). VOS viewer, researchers can promptly investigate and analyze bibliometric networks such as authors, publications, countries, organizations, and journals

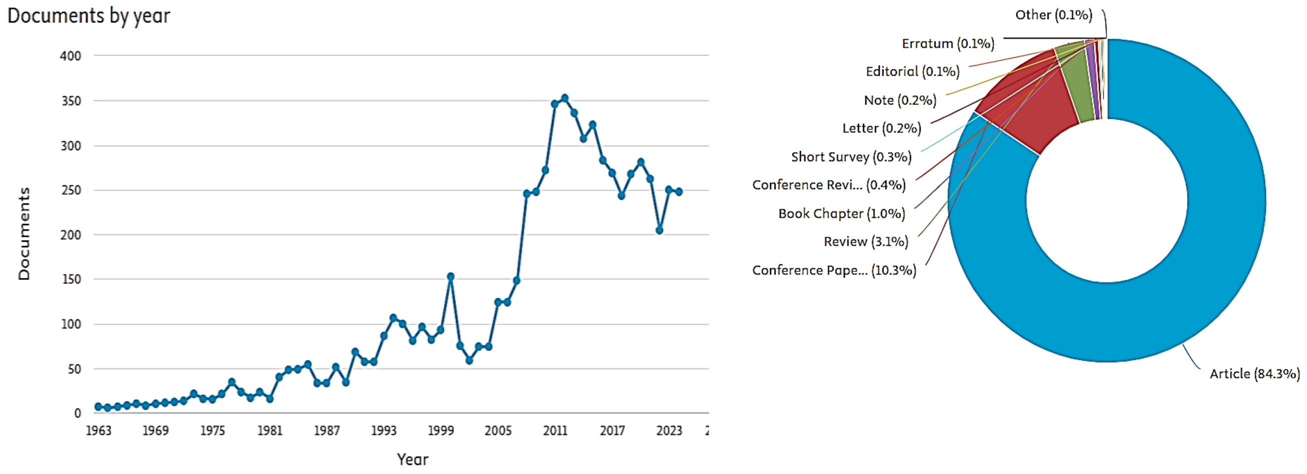
This research focused on creating cadmium selenide (CdSe) films through chemical spraying method under different temperature conditions to examine gamma ray effects from 0.660 MeV cesium emitter sources on film energy gap (Eg). The paper proceeds to create an original case study using bibliometrics to explore the development made on "cadmium selenide" using Scopus data and VOSviewer to examine authors and their countries contributing this field. This research tackles crucial Eg enhancement development for wide application areas including optoelectronics and sensors because radiation studies of materials lead to better device performance alongside environmental harshness resistance. Analysis of material changes can result in making devices function better when using these materials.

2. Methodology

We discussed first, the evolution of the publication on CdSe from 1963 to 2024 as gathered from the Scopus database, and we also use the VOS viewer to show the most authors and their cooperation nationally and internationally using the various materials CdSe-based. the thorough processes involved in preparing the videos and analyzing their qualities. The procedure began with selecting 1 mm thick glass slides as a basis for film deposition. Hot distilled water was used in multiple stages to clean these substrates; next, methanol and acetone were used with ultrasonic aid to guarantee eliminating contaminants and efficiently drying them. The cadmium selenide films were deposited using prepared solutions whereby (0.8 g) selenium was combined with (1.2 g) sodium sulphide in distilled water and cadmium chloride was added. To guarantee the quality of the deposition process, the solutions were heated at 90°C on a magnetic mixer for a set duration then filtered to eliminate heavy particles. The films were deposited on glass substrates using thermal spraying technique, in which components like a nozzle, air compressor, and heater were integrated into the system. To investigate the influence of temperature on the characteristics of the films, the samples were made at many degrees ranging from (100°C, 150°C, 200°C, 250°C, and 300°C). The optical characteristics of the films were investigated upon deposition under a spectrophotometer spanning wavelengths between 320 and 900 nm. To investigate the influence of radiation on the optical and structural characteristics of the films, the produced samples were finally irradiated for two hours under gamma rays from a cesium source with an energy of (0.660 MeV-Se source).

3. Results and Discussion

The analysis of Scopus data indicated that researchers' interest in CdSe began since 1963, with 7 papers, to reach an average of 250 papers per year, recently, to collect 5566 documents from 1963 to 2024 (Figure 1a). (Figure 1(b) shows that more than 84% are research articles. The industrialized countries were more concentrated on the various applications of CdSe films as the US (1714 documents), China (1216 documents), India (828 documents, Japan (403 Documents), Germany (402 documents), etc, as shown in Figure 1.



(a) **(b)**

Figure 1 Evolution of the scientific publication (a) and the kind of documents (b) .

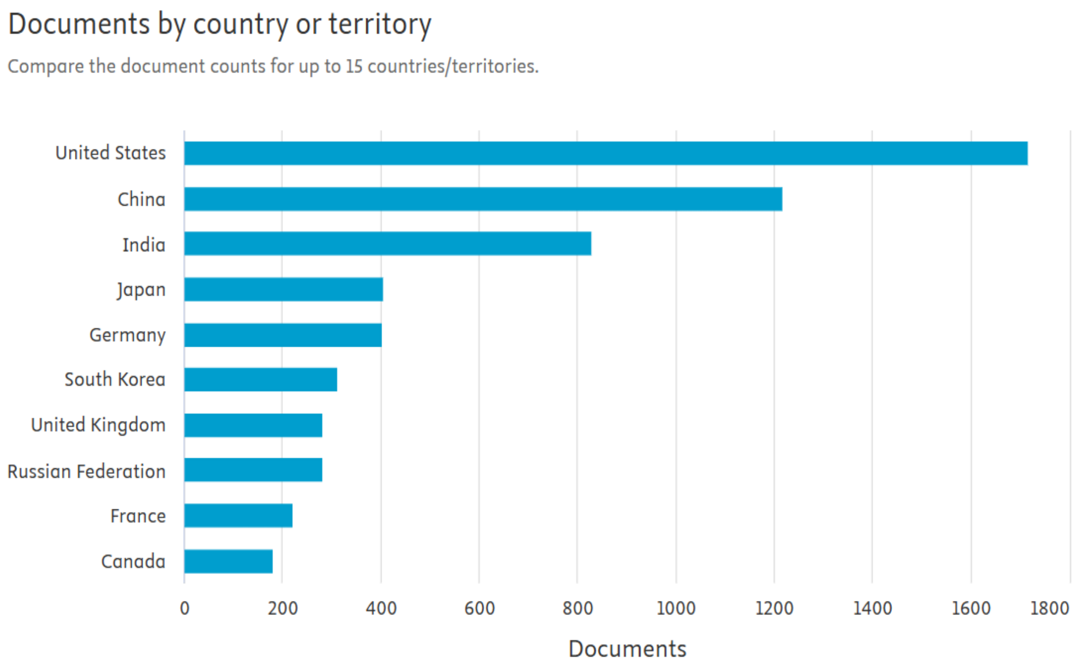


Figure 2. Countries interesting on CdSe materials

The best authors contributing on this topic are summarized on Figure 3. Alivisatos, A.P. (55 documents), awendi, M.G. (45 documents), Peng, X. (37 documents), Rosenthal, S.J. (33 documents), Ellis A.B. (32 documents), etc… the network visualization obtained via the VOSviewer the most published authors and their team collaborations on this topic (Figure 4).

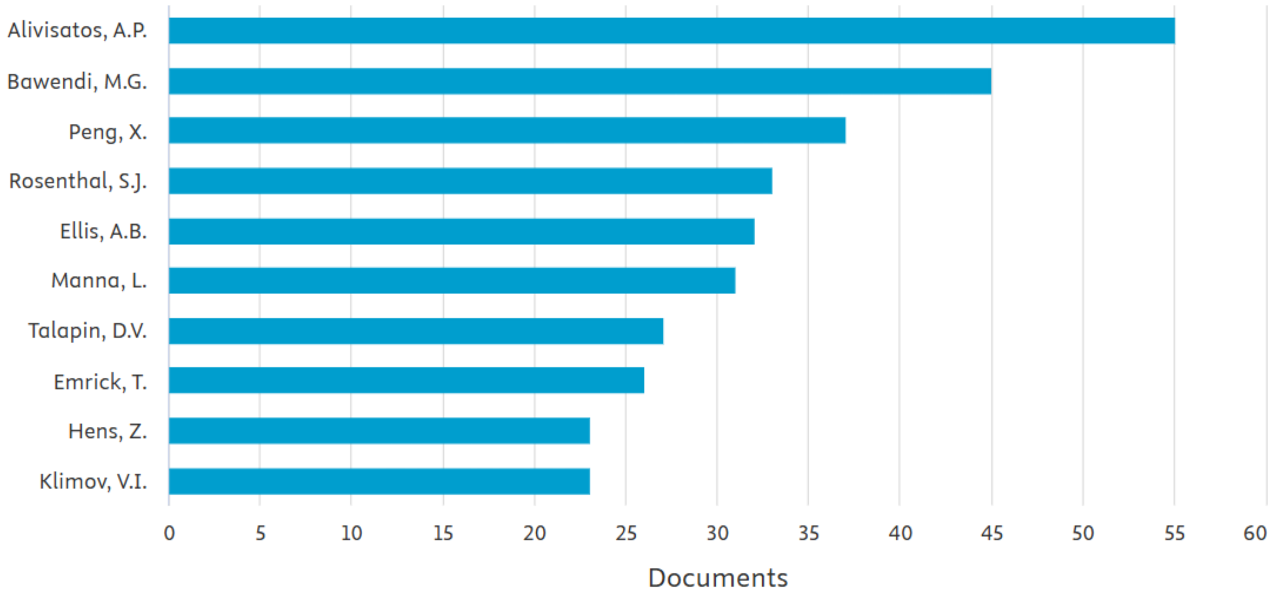


Figure 3 Ten most authors publishing on CdSe (Scopus data from 1963 to 2024)

Cadmium selenide (CdSe) research has seen a remarkable growth in recent years, with data from scientific databases such as Scopus indicating a continuous increase in the number of publications related to this material. The great interest in CdSe began in the 1960s, when publications were relatively few, but over time, a significant increase in the number of published papers has been observed annually. In the past two decades, the number of papers related to CdSe has increased significantly, reflecting the growing interest in the optical and electrical properties of this material in the fields of electronic applications and solar energy.

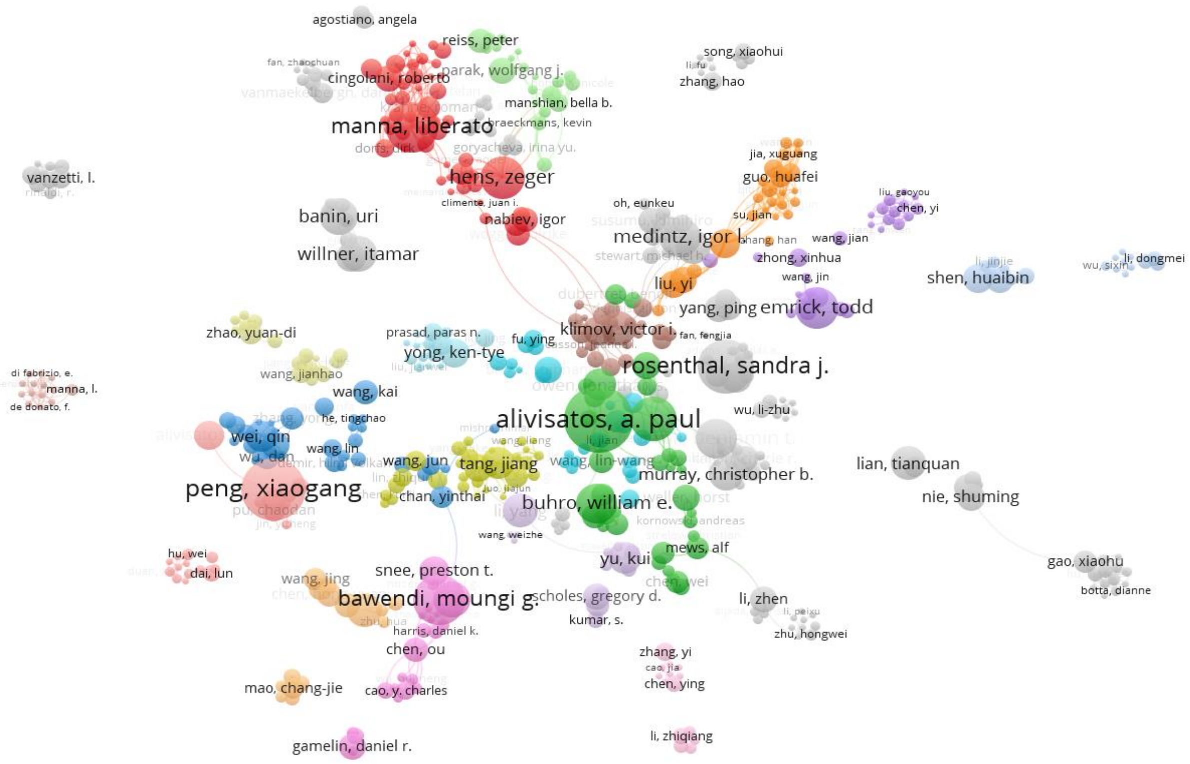


Figure 4. Network visualization of authors contribution on CdSe (1963 to 2024)

The data show that most of the research in this field is concentrated in industrialized countries such as the United States and China, as these countries contribute a large share of publications. For example, the United States has accounted for more than 30% of publications related to CdSe since 1963, followed by China and India, indicating knowledge exchange and international cooperation in this field (Zhao and Fang, 2012; Pawade *et al.*, 2022; Al-Taan *et al.*, 2024).

The bibliometric analysis also indicates that the use of scientific tools and techniques such as ultraviolet-visible (UV-Vis) spectroscopy has become increasingly popular in the study of CdSe properties, especially in investigations of radiation effects such as gamma radiation. This technique represents a pivotal point in understanding how the energy bandgap (Eg) of these thin film's changes after exposure to radiation, which enhances their potential in applications related to sustainable technology and electronic devices. By tracing these research trends over the past decades, it can be observed that radiation effects, especially gamma radiation, have become a focal point for many recent studies investigating the improvement of material performance in environmental and industrial applications. This development reflects the importance of CdSe applications in areas ranging from optical sensors to solar cells (Kumari *et al.*, 2014; Habte *et al.*, 2019; Arshad *et al.*, 2020).

By analyzing collaborative research networks, VOSviewer data show that collaboration among researchers in this field reflects close interaction between academic and industrial institutions at the international level. For example, institutions in the United States, China, and India have the highest rates of collaboration in CdSe research, indicating that these countries are major hubs for the development of innovative technological applications related to CdSe. In addition, collaborative networks between these countries are an important feature of the success of this research field, as researchers from different nationalities collaborate to exchange knowledge and enhance a common understanding of the physical and chemical properties of CdSe. This global collaboration reflects the commitment of scientists to advance the applications of this material in many industries (Al Abbas *et al.*, 2023 ; Minami *et al.*, 2023).

Bibliometric analysis shows that future trends in CdSe research will increasingly focus on improving performance in environmental and solar energy applications. With the growing global concern for sustainability, CdSe research is expected to see further development in thin film preparation techniques for this material, making them more cost-effective and more efficient in energy conversion. Expectations also indicate that there will be an increasing focus on improving material properties using radiation techniques such as gamma radiation and modification of experimental conditions such as temperature. These developments may contribute to enhancing future applications of CdSe in areas such as flexible devices and technologies that require radiation-resistant materials (Shelke *et al.*, 2020; Uslu, 2021).

In our study, at various temperatures (100°C, 150°C, 200°C, 250°C, and 300°C) the influence of gamma radiation (0.662 MeV) from a cesium source on the energy gap (Eg) of CdSe thin films was investigated. UV-Vis spectroscopy was used to detect the energy gaps before and after irradiation; Table 1 and Figure 5 show the data. After gamma irradiation, the energy gap for all samples increases; the degree of this change depends on the temperature the films were made at.

The energy gap of the CdSe thin films exhibits a temperature-dependent rise before irradiation, spanning 2.17 eV at 100°C to 2.365 eV at 300°C. As the temperature rises, flaws decrease and crystallinity improves, which helps to explain this rise. Usually improved atomic rearrangement and grain development made possible by higher preparation temperatures enable more organised crystalline structure. Less imperfections mean a greater band gap as the crystallinity of the movie gets better. The energy gap at 100°C is 2.17 eV, which reflects rather reduced crystallinity and perhaps existence of lattice defects or contaminants. The energy gap approaches 2.365 eV at 300°C, suggesting a notable enhancement in film quality with reduced electronic structural flaws.

For all samples, the energy gap grows following gamma radiation exposure. The range of increase is 0.08 eV to 0.125 eV; the degree of change varies according to the starting temperature of the sample. In two primary respects, gamma radiation can influence the electrical characteristics of thin films. Radiation can first cause lattice atoms to be displaced, resulting in point defects including vacancies or interstitials. But the widening energy difference implies that radiation-induced flaws might lower shallow defect states close to the band margins. Second, the high-energy gamma photon ionisation can spread charge carriers and change the band structure, thereby expanding the energy gap by lowering electron-hole recombination.

The temperature-dependent behaviour of the films reveals that samples made at higher temperatures show more variations in the energy gap following irradiation. For example, whilst the 300°C sample shows a greater rise of 0.125 eV (from 2.365 eV to 2.49 eV), the energy gap of the 100°C sample increases by 0.08 eV. Higher temperature-produced films are more crystalline and have fewer initial flaws, which improves the interaction between gamma radiation and the film structure and thereby causes a more notable change in the energy gap. This implies that better-ordered films are more susceptible to alterations generated by radiation.

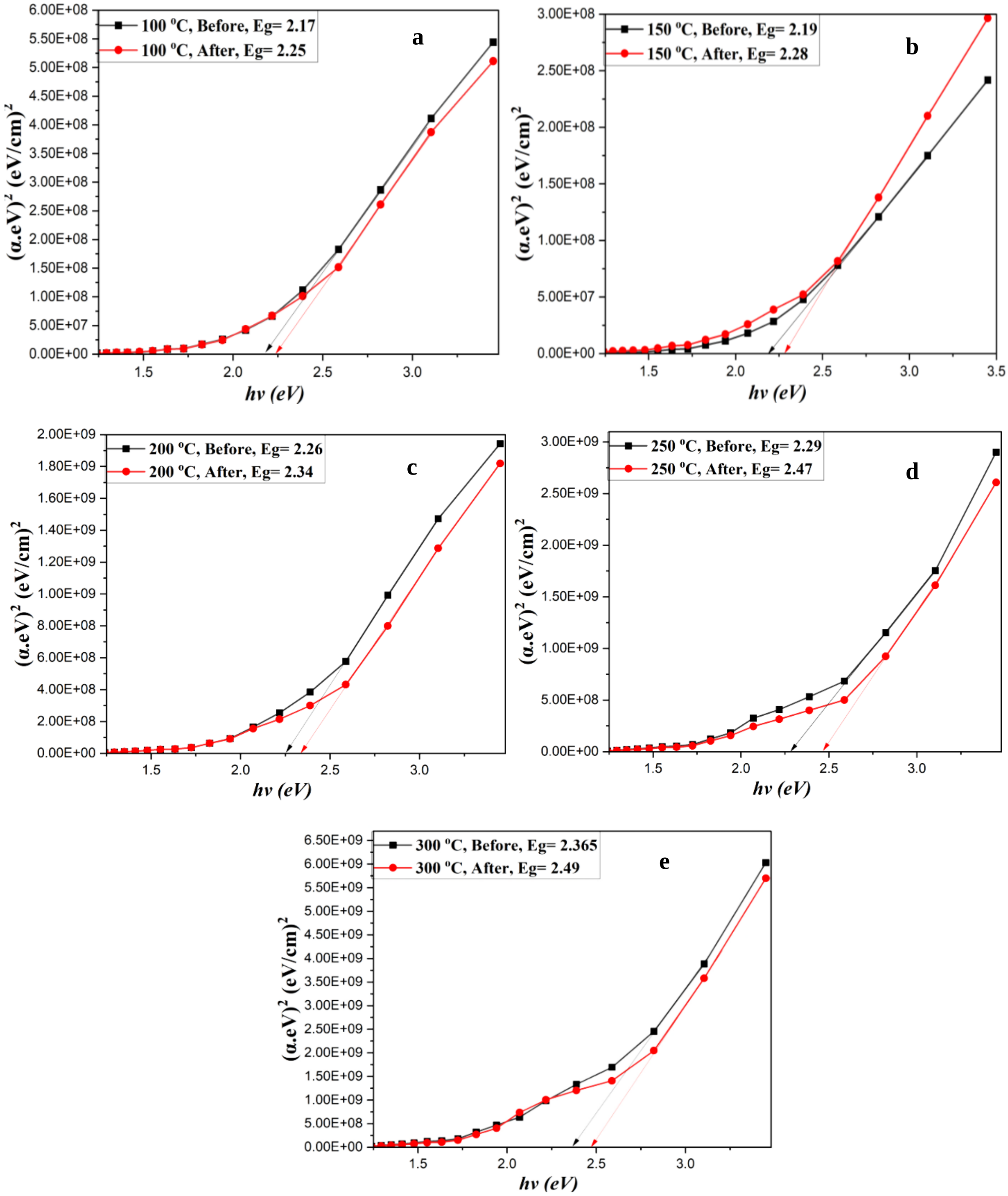


Figure 5. Absorption coefficient (a) vs photon energy (hv) for CdSe samples at a-100, b-150, c-200, d-250, and e-300 degrees Celsius, before and after irradiation by Gamma Ray (Se-0.662 MeV).

Table 1. The CdSe thin film energy gap (Eg) values at various temperatures before and after irradiation by Gamma Ray (Se-0.662 MeV).

No. Sanple	The Degree of Temperature °C	Energy gap (E_g) eV	
		Before irradiation	After irradiation
1	100 °C	2.17	2.25
2	150 °C	2.19	2.28
3	200 °C	2.26	2.34
4	250 °C	2.29	2.47
5	300 °C	2.365	2.49

Conclusion

The research investigated how temperature and gamma radiation affected the energy gap magnitude (Eg) in CdSe thin films. Film production occurred at different temperatures from 100°C to 300°C before subjecting them to gamma radiation at 0.662 MeV. Research findings proved that temperature variation and radiation dosage significantly affected the films' optical characteristics. The energy gap of the CdSe thin films exhibited an upward trend with rising temperature before irradiation until it reached 2.365 eV at 300°C. These films seem to have an energy gap elevation connected with improved crystallinity together with reduced flaws resulting from higher preparation temperatures. All films had an energy gap increase between 0.08 eV and 0.125 eV by gamma irradiation. The most notable change in the energy gap of films made at 300°C was 0.125 eV from 2.365 eV to 2.49 eV. Since higher crystallinity enhances their structure to absorb radiation better, films become more sensitive to gamma radiation. The study shows that the energy gap modification of CdSe thin films is crucially influenced by both gamma radiation and preparation temperature. Higher temperature manufactured films with greater crystalline purity show more notable changes in their optical characteristics during irradiation.

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