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The Effect of γ-irradiation on the Structural and Physical Properties of CdSe Thin Films

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Thin film of CdSe has been deposited on to clean glass substrate by using CBD technique at room temperature. The samples are irradiated by γ-ray with various doses (25,50,100,150) rad. These films are characterized by XRD, which indicated that as-deposited CdSe layers and irradiated films at 25 & 50 rad of γ- ray grew in cubic phase having preferred orientation along (111) plane in c-direction. Further the irradiated films at 100 & 150 rad of γ- ray show polycrystalline in nature and with a mixture of cubic along with hexagonal structures. Optical absorption spectra of these thin films have been recorded using spectrophotometer. The energy band gap has been determined using these spectra. It is found that energy band gap of CdSe film is 2.09 eV and it is increased as increasing γ- ray irradiation does. The electrical conductivity measurements gave a decrease in conductivity with the increase of γ- irradiation does.

Keywords: CdSe, Thin films, γ-irradiation, Optical properties.

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1. INTRODUCTION

The II-VI semiconducting compounds, especially the cadmium chalcogenides, have been extensively studied due to their potential applications in semiconductor devices and solar cells fabrication [1-3].

Cadmium Selenide with some additives is nowadays attracting a great deal of attention owing to its potential, fundamental, experimental and applied interests in a variety of thin film devices such as laser screen materials, projection colour TVs, nuclear radiation detectors, light emitting diodes, etc. [4-9].Many studies have focused on cadmium selenium, because of its high luminescence quantum yield, suitable band gap and a variety of optoelectronic conversion properties [10].

Several physical and chemical techniques are available for the growth of CdSe thin films. CdSe thin films have been deposited using different techniques such as electrodeposition [11-12], molecular beam epitaxy [13], spray pyrolysis [14], successive ionic layer adsorption and reaction method [15], vacuum deposition and chemical bath deposition [16].

Among these methods chemical bath deposition has several overriding advantages with other techniques such as uniform film deposition, control of thickness, precise maintenance of deposition temperature, low cost [17-18]. In this paper, CdSe thin films deposited on the glass substrates by chemical bath deposition, then we demonstrated the effect of γ-irradiation on the optical, electrical and structural properties of CdSe films. The synthesized films were characterized and analyzed with scanning electron microscope (SEM), X-ray diffraction (XRD) patterns and ultraviolet- visible (UV–vis) spectrophotometer.

2. EXPERIMENTAL DETAILES

Solutions were prepared by dissolving an appropriate amount of analytically Selenium metal and Sodium sulphite in 10 ml distilled water. Sodium selenosulphite (Na_2SeSO_3) can be synthesized by refluxing selenium powders in a sodium sulphite. In the experiments, (0.5M) Cadmium Chloride dissolved in 10 ml distilled water and ammonia was used as complexing agent. The temperature of the solution was allowed to rise slowly up to 35˚C. The substrates were removed from the beaker after about 20 h. After the deposition, the substrates were taken out of the bath, rinsed with distilled water, dried in air and kept in a desecrator.

In order to accelerate the irradiation process, the strongest of the available γ-ray source was used, namely a 137Cs source with the activity of 0.132 Ci, emitting 662 keV γ rays. The dose average at the irradiation was (6 Gy/h) and the irradiation time was (2.5, 5, 10, 15) min at doses (25, 50, 100, 150) rad respectively. The samples were on the distance 8 mm from the radiation source. The samples were characterized by X-ray diffraction patterns employing in 2θ range from 20˚ to 80˚, using CuKα radiation ($\lambda = 1.5418$ Å) at 40 kV and 20 mA. The morphology and particle sizes were determined by Scanning Electron Microscopy (SEM). UV-vis spectroscopy was carried out at room temperature using spectrophotometer in the range 400-1100 nm. The conductivity of these films (as-deposited and irradiation) have been determined by I-V measurements using the electrometer.

3. RESULTS AND DISCUSSION

The crystal form of the CdSe film was characterized with XRD patterns and results are shown in Fig. 1. XRD studies revealed that these samples are polycrystalline in nature exhibiting the hexagonal (wurtzite) and cubic (zinc blende) structures. Fig.1 shows XRD patterns of as-deposited and irradiated

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CdSe thin films at different doses (25, 50, 100, 150) rad of γ-radiation. As-deposited CdSe thin films were cubic structure, which showed only one intense reflection peak at $2\theta = (29)$, corresponding to cubic (111) plane, which coincide well with JCPDS data No. (8-459). The thin films irradiated at 25 rad of γ-ray were cubic with slight improvement in crystallinity, whereas films irradiated at 50 rad of γ-ray becomes polycrystalline with cubic structure. Further, CdSe thin films irradiated at 100 rad of γ-ray were polycrystalline with a mixture of cubic along with hexagonal structure with highest intense reflection peaks at $(2\theta = 29)$ corresponding to cubic (111) and with lowest reflection peaks corresponding to cubic and hexagonal structures . The film irradiated at 150 rad of γ-ray were also polycrystalline with a mixture of cubic along with hexagonal structures with highest intense reflection peaks at $(2\theta = 29)$ & $(2\theta = 56.5)$ corresponding to cubic (111) & (311) planes respectively.

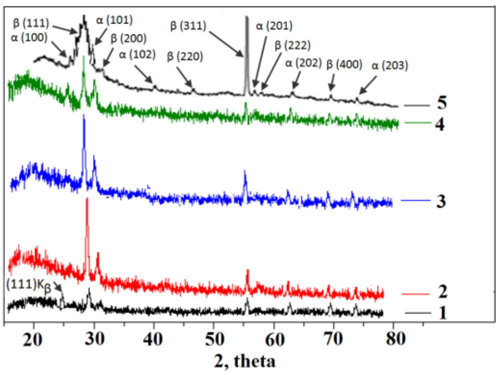

Fig. 1 – XRD pattern of CdSe thin films 1 – as-deposited without ray, 2 – 25 rad, 3 – 50 rad, 4 – 100 rad, 5 – 150 rad

Scanning electron microscopy (SEM) is a convenient technique to study microstructure of thin films. Fig. 2 shows the SEM micrographs of as-deposited and irradiated with γ-ray CdSe thin films. It is observed that the as-deposited CdSe films are non homogeneous, The grains are densely packed, well defined and quasi-spherical having different sizes. Whereas the film irradiated at 25 rad of γ-ray was nearly similar that as-deposited CdSe films with presence simple distortion in picture. Further, films irradiated at 50 rad of γ-ray clearly show that the effect of γ-irradiation on CdSe and observed that the grains becomes nearly similarity the crystals. In fig. (2-4)was observed that the distortion in the crystals and non homogenous. The SEM of CdSe thin film irradiated at 150 rad of γ-ray clearly shows microcrystals of larger size, more crystalline behavior and well covered to the glass substrate.

The transmittance spectrum of the CdSe film was recorded using UV-vis spectrophotometer at room temperature in the wavelength range 400-1100 nm. Optical transmittance of the film is shown in Fig. 3. From the optical transmittance spectra, it is observed that the transmittance of CdSe thin films increases as increasing the irradiation at doses (25, 50, 100, 150) rad.

The optical band gap energy Eg can be determined from the experimental values of absorption coefficient α

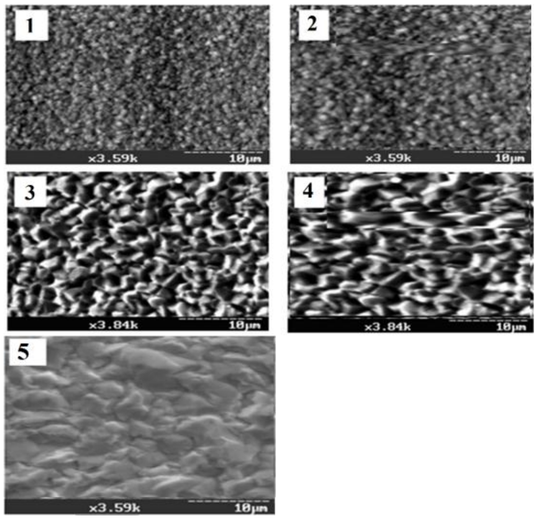

Fig. 2 – SEM of as-deposited & irradiated with γ-ray CdSe thin films, 1 – without γ-ray, 2 – 25 rad, 3 – 50 rad, 4 – 100 rad, 5 – 150 rad

as a function of photon energy hν, using the following relation [19].

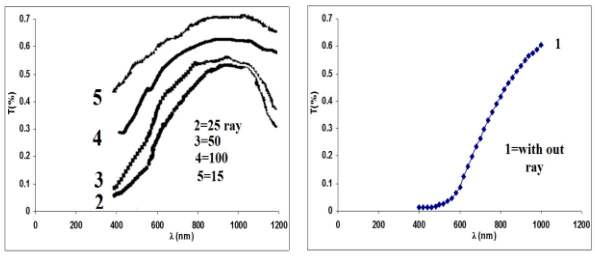

Fig. 3 – Optical transmittance spectra of as-deposited and irradiated CdSe thin film 2 – 25 rad, 3 – 50 rad, 4 – 100 rad, 5 – 150 rad

$$\alpha h\nu = A(h\upsilon - E_g)^n \qquad (3.1)$$

where hν is photon energy, Eg is band gap and A is constant. Now n can have values 1/2 for direct transition. The value of absorption coefficient is found to be of the order of 104 cm^{-1}. The plot of $(\alpha h\nu)^2$ versus $(h\nu)$ is shown in fig. 4a which is linear at the absorption edge, indicating a direct allowed transition.

Table 1. – Band gap energy calculations of CdSe thin film for; 1 – without irradiation, 2 – 25 rad, 3 – 50 rad, 4 – 100 rad, 5 – 150 rad

No	Band gap energy, E_g (eV)
1	2.09
2	2.15
3	2.3
4	2.33
5	2.35

The straight line portion was extrapolated to the energy axis and when $(\alpha h\nu)^2 = 0$, the intercept gives the band gap energy of CdSe. It is found to be in the range of 2.09 eV for as- deposited CdSe thin film and in the range of 2.15-2.35 eV for irradiated samples respectively. It is believed that the increasing in the band gap after irradiation due to the increasing in the grain size as shown in SEM pictures and expectation of forming CdS material, as shown in XRD pattern. Then the variation is depicted as in fig. 4b-4d and the band gap energy calculations are shown in table 1.

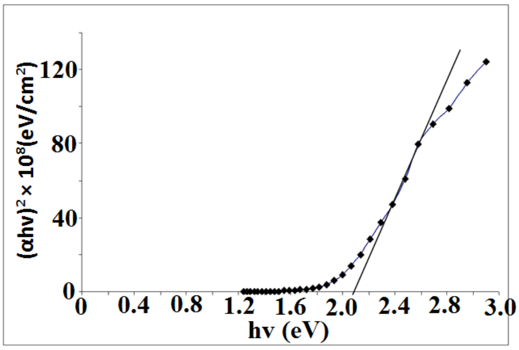

Fig. 4 – Variation of $(\alpha h\nu)^2$ versus hv of as deposited CdSe films

Electrical conductivity of CdSe thin films is determined using four- point prop measurements at room- temperature as shown in table 2. It is found that the conductivity decreases with the increase in irradiation dose. This is explained in terms of structural changes and defects creation occurring in the irradiated films. In as-deposited CdSe films, there is some lattice defects, geometrical, and physical imperfections randomly distributed on the surface and within the volume of the film [20]. The roughness of the surface, grain boundaries and inclusions in the volume are the main components of the geometrical imperfection. The important factor, which is responsible for the physical properties of thin film, is the structure. So it expected that the decrease in the conductivity is due to increase in the mean size of the grain [21] and a decrease in the grain boundary area as shown in SEM pictures in addition to the increase of defects like vacancies and interstitial. Also our expectation of forming CdS which is added factor of decreasing in conductivity.

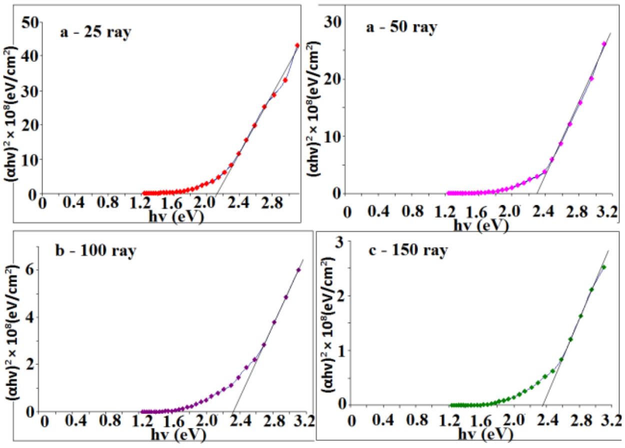

Fig.4b – Variation of $(\alpha h\nu)^2$ versus *hν* of irradiated CdSe films: 25 γ ray b - 50 γ ray c - 100 γ ray d - 150 γ ray

Table 2 – Conductivity of thin film CdSe for ;1-without irradiation, 2- 25 rad, 3- 50 rad , 4- 100 rad , 5- 150 rad

№	σ (Ωcm)$^{-1}$
1	1.3×10^{-2}
2	0.5×10^{-2}
3	2×10^{-3}
4	0.3×10^{-3}
5	7×10^{-4}

CONCLUSIONS

In summary, the influence of irradiation on the optical, structural and electrical properties of the chemically deposited CdSe thin films were investigated. The optical energy band gap has been increased from 2.09 to 2.35 eV with the increasing irradiation doses. The structure of the films has been transformed slightly from cubic to mixture of cubic and hexagonal structure at 100 & 150 rad of γ-ray. The films show typical semiconductor characteristics with conductivity of the order 1.3×10^{-2} (Ω cm)$^{-1}$ at room temperature and the electrical conductivity decreases down to 7×10^{-4} (Ω cm)$^{-1}$ at 150 rad of γ-ray.

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