International Journal of Engineering Applied Sciences and Technology, 2019
Vol. 4, Issue 8, ISSN No. 2455-2143, Pages 224-228
Published Online December 2019 in IJEAST (http://www.ijeast.com)

EFFECT OF GAMMA RADIATION (^{60}CO) ON THE OPTICAL TRANSMITTANCE, ENERGY BAND GAP AND ABSORPTION COEFFICIENT OF ZnSe THIN FILMS

Obasi, C.O.
Department Of Physics And Astronomy,
University Of Nigeria Nsukka, Enugu Nigeria.

Ikhioya, I .L.
Department Of Physics And Astronomy,
University Of Nigeria Nsukka, Enugu Nigeria.

Ahmad, A. S.
Pre-Nd Science Department
Niger State College Of Agriculture Mokwa, Niger Nigeria.

Ramalan, A. M.
Department Of Physics,
University Of Abuja, Gwagwalada, Abuja Nigeria

Abstract - ZnSe thin films prepared on substrate by electrochemical method were deposited at and further irradiated with gamma irradiation of Co-60 source. The optical properties of the films are investigated using UV-VIS measurements. Absorbance of the films are observed to reduce after irradiation with γ- rays of different dose. The wavelength of the optical absorbance (A) decreases as the irradiation dose increases [A(400Gy) > A(300Gy) > A(250Gy) > A(200Gy) > A(0Gy)]. Other Optical properties like Transmittance, Optical band gap, reflectance, absorption coefficient, extinction coefficient and refractive index are determined from the absorbance result. The transmittance increases while the absorption coefficient decreases with increase in wavelength. The energy band gap of the sample decreases as the irradiation doses/fluence increases (0Gy = 3.02eV, 200Gy = 2.68eV, 250Gy = 2.49eV, 300Gy = 2.25eV and 400Gy = 2.0eV). This shows that the increase in gamma irradiation doses (Co-60 source) reduced the band gaps of ZnSe thin films and hence modifies the other physical properties.

Keywords - Gamma irradiation, ZnSe Thin Film, Electrochemical Method, Optical Properties

I. INTRODUCTION

Exposure of semiconductor materials and other materials to ionizing radiations such as x-rays, gamma-rays, beta particles, alpha particles, fission fragments introduces changes in their physical, chemical, mechanical and electrical properties of the materials which they penetrate. This changes can be detrimental or beneficial in tailoring the properties of the materials using different irradiation fluence to enhance the performance of various devices on materials and thereby creating new materials (El Zawawi, et al, 2011, Jasim, 2012).

These changes are strongly dependent on the internal structure of the absorbed substance including the thickness, the source of radiation dose and energy of radiation dose (Abu EL-Fadl, Soltan, Abu-Sehly, 2007, Rigyadh, et al. (2012).

When radiation from solar system hits the solar cell, the incident energy is directly converted into clean electricity without the use of fossil fuel and any other by-products. Solar cells based semiconductor materials are basically used in radiation environment as power sources. They are greatly sensitive to electromagnetic radiation with substantially short wavelengths, such as x-rays and gamma-rays. These types of radiation are abundantly available in space and are widely used to study ionisation-induced damage in devices. The high radiation dose of these types of radiation introduces lattice defects in semiconductor devices, such defects decrease the output power of photovoltaic cells. Any change as a result by gamma rays, neutron in the lattice periodicity produces additional energy levels in the optical band gap. These new energy levels change the optical and electrical properties of solar cells because of the electron-hole pairs produced near the mid gap (Khuram, Sohail, and Matjafri, 2013).

Zinc Selenide (ZnSe) thin film is an intrinsic semiconductor or un-doped semiconductor material i.e it is a pure semiconductor without any dopant. The zinc and selenium elements used for deposition of ZnSe thin film are not toxic in nature. Because this, It is a widely valuable material for applications at large scale in the photovoltaic industry which has attracted replacement of CdS, CdTe- and Cu(In, Ga)Se_2 based thin-film solar cells for reducing environmental polutions, because ZnSe is a less toxic buffer layer material (Yadav, Singh and Pandey, 2019).
It is one of the group II-VI semiconductor with a wide direct band gap of 2.7 eV. This makes it suitable for a variety of applications such as light emitting diodes (LEDS), ultraviolet (UV) detectors, infrared laser gain medium, x-ray and gamma ray detectors, lenses, mirrors. and lasers. It is also suitable for use as a optical window layer of solar cells.

ZnSe thin film has several effective optical applications owing to the high resistance to thermal shock, stability in virtually all environment and extremely low bulk losses (Soonmin, 2016, Raghu, et al. (2013).

The effect of gamma irradiation on other types of photovoltaic materials has been studied by many researchers but few researchers have investigated the effect on ZnSe thin film materials. The aim of this study is to investigate the effect of gamma irradiation on optical properties of ZnSe thin films for purpose of using irradiation to the modify the wide band gap in the material for other uses.

II. EXPERIMENT AND RESULTS

A. Experiment

In this experiment, electrochemical deposition technique (ECD) was used, All chemicals involved such as zinc acetate, hydrazine hydrate, ammonia and hydrochloric acid were of analytical grade without further purification and ITO glass slide was used as substrates. Zinc selenide thin films were prepared from a bath composed of zinc tetraoxosulphate ($ZnSO_4$), selenium oxide(SeO_2), potassium tetraoxosulphate VI (K_2SO_4), and acidified with tetraoxosulphate VI acid (H_2SO_4). 20cm^3 of $ZnSO_4$ was measured out of the 500cm^3, 20cm^3 of SeO_2 was measured out of the 250cm^3 and 5cm^3 of K_2SO_4 was measured out of the 500cm^3 into a 100ml of beaker using burette and acidified with 5cm^3 of dilute and the H_2SO_4 entire mixture was stirred to achieve uniformity. The pH of the entire mixture was 1.8. In the reaction baths, a conducting glass substrate (ITO), carbon electrode to a DC power supply source and the voltage of 3V was maintained for same time intervals. The samples were labelled Z1, Z2 Z3, Z4 and Z5, samples Z2, Z3, Z4 and Z5 were also exposed with ^{60}Co radionuclide with activity of 1109.37MBq and half-life of 5.27 years after synthesis. The irradiation dose rate of 33.626Gy/ hr was used to generate a set of irradiation doses (200, 250, 300, 400) Gy. Then each of the samples Z2, Z3, Z4 and Z5 were placed in a chamber containing ^{60}Co and irradiated at room temperature in different exposure time but sample Z1 was un-irradiated.

Results

The optical properties such as optical transmittance, reflectance, absorbance, absorption coefficient, extinction coefficient and band gap of a thin film material give essential information about the electronic band structures, localized states and the types of optical transitions. These optical properties are very important for the exploration and interpretation of the thin film materials. The obtained results for the electrochemical deposited un-irradiated and irradiated samples of ZnSe thin films were analyzed using UV-Visible spectrophotometer. The UV-Vis spectra indicate that the irradiation effect on the absorbance, transmittance, absorption coefficient and band gap energy at normal range 350 - 1000 mm.

Optical Transmittance

The transmittance spectra for un-irradiated and irradiated samples ZnSe thin films is presented in figure 1. It can be ascertain that from the optical transmittance, in the visible region that the films of un-irradiated film has a great transmission but increase in irradiation dose has lower transmittance.

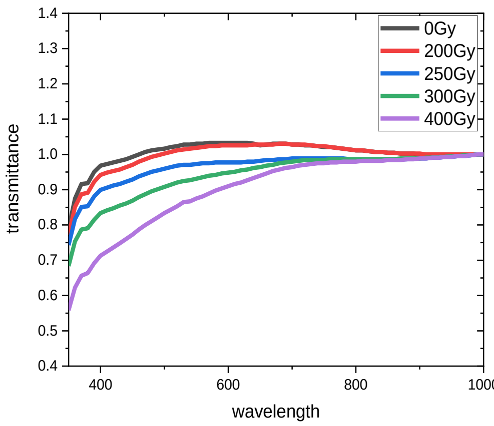

Fig. 1. Plot of Transmittance versus Wavelength for Un-irradiated (0 Gy) and Irradiated Samples of ZnSe thin films.

The values of the transmittance is seen with a great response to the gamma irradiation, there are 100 %, 98 %, 95 %, 94 % and 93 % for un-irradiated (0Gy), 200 Gy, 250Gy, 300 Gy and 400 Gy respectively. The un-irradiated ZnSe thin film shows high transmittance of 100 % but as the dose increase from 200 Gy to 400 Gy the transmittance decreases from 98 % to 93 %. It can be observed that the transmittance increases in shorter wavelength and decreases as the irradiation dose increases in the infrared region for un-irradiated and irradiated films. Also the width of transmission shifted towards higher energy with increasing radiation doses. The behaviour of transmittance of ZnSe thin films with the irradiation doses in the present work is in agreement with results obtained by Rana in 2012.

Optical Reflectance

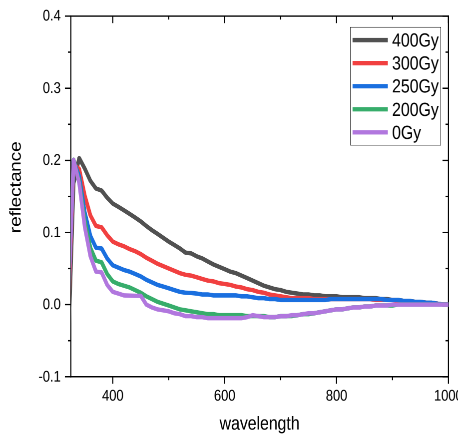

Fig. 2. Reflectance versus Wavelength for un-irradiated and irradiated samples of ZnSe thin films.

From figure 2, It can be seen that reflectance decreases with increasing wavelength in the visible spectrum, and increased below visible spectrum. Irradiation at higher doses increases reflectance of thin film.

Optical Absorbance

The results obtained from both un-irradiated and irradiated samples ZnSe films were analyzed in. Figure 3, which shows the relation between absorbance and wavelength of un-irradiated (0Gy) and irradiated samples with different gamma doses.

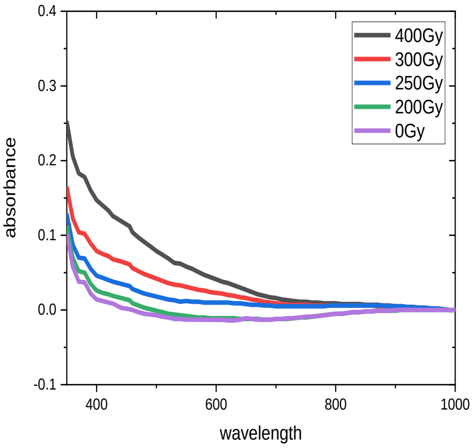

Fig. 3. Plot of Absorbance versus Wavelength for Un-irradiated and Irradiated Samples of ZnSe Thin Films.

The absorbance was high at the shorter wavelength and decreases with increasing wavelength towards the visible region but after exposure to radiation source, the absorbance of the ZnSn thin films increases with increase in the irradiation dose. Also, the effect of gamma dose causes decrease in the wavelength of absorbance as the dose increases. Thus A (400Gy) > A(300Gy) > A(250Gy) > A(200Gy).

Optical Absorption Coefficient

The dependence of absorption coefficient (α) versus wavelength for the thin films is shown in the figure 4 above representing the absorption coefficient (α) for un-irradiated and irradiated thin films with different radiation doses. It can be observed that the increase in wavelength lead to decrease the absorption coefficient.

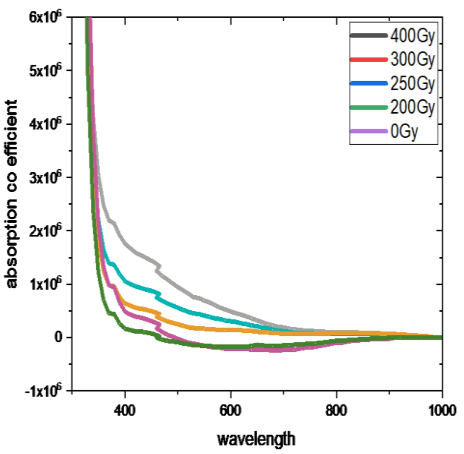

Fig. 4. Plot of Absorption Coefficient versus Wavelength for Un-irradiated and Irradiated ZnSe Samples Thin films.

From an optical absorption plot, the values of the absorption coefficient for un-irradiated and irradiated samples of ZnSe thin films were calculated using the formula (1, 2 and 3) to obtain Beer's law (Abdelnabi, et al, 2019)

$$I = Io e^{-\alpha t} \quad (1)$$

Where 't' is the thickness of the films (cm) and α is the absorption coefficient (cm^{-1}),

$$\alpha t = 2.303 \ \log I/I_o. \quad (2)$$

Where log I/I_o stands for the absorbance (A). Then the absorption coefficient can be evaluated by

$$\alpha = 2.303 \ (A/t) \quad (3)$$

The variation in absorption coefficient with wavelength shows a weak absorption of energy in visible region and great absorption in shorter wavelengths. The spectra also confirm that, as the irradiated dose increases there is increase in absorption coefficient at 350 - 1000nm (Antar, 2014)

Extinction Coefficient

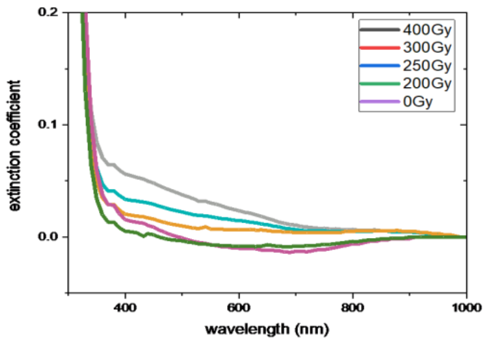

Fig. 5. Plot of Extinction Coefficient versus Wavelength for Un-irradiated and Irradiated ZnSe Samples Thin films.

Extinction coefficient shows very good value near UV region indicating high absorption in the wavelength for both un-irradiated and irradiated samples. It is observed that all the samples have the same value of the extinction coefficient but decreases in wavelength with the increase of irradiation dose which may be as result of similar value of absorption of light. At low wavelength below visible spectrum, all samples have high increasing extinction coefficient, at higher wavelength from (350 – 700) nm, the extinction coefficient decrease with increasing wavelength. It can also be observed that in the visible spectrum, samples with higher gamma doses has higher extinction coefficient.

Optical Band Gap

The best values of the band gap are evaluated by the optical absorption. The direct or indirect transition is measured by using the formula

$$\alpha h v = C(hv - Eg)^n \qquad (4)$$

Where 'hʊ' represents the photon energy, α is the absorption coefficient, Eg is the optical band gap, 'C' is a constant and exponent n is the transition between the valence and conduction band. For direct transition 'n' is equal to 1/2 and indirect transition 'n' is 2 (Ajeel *et al.*, 2014)

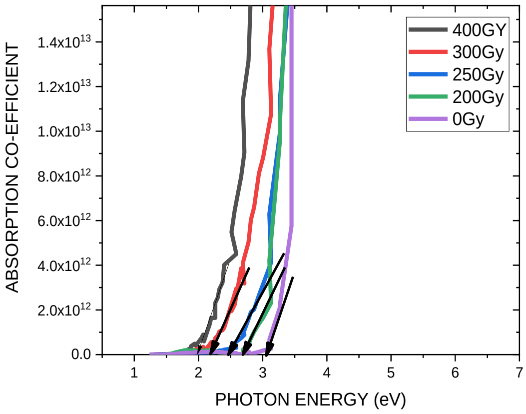

Fig. 4. Plot of Absorption Coefficient $(\alpha h v)^2$ vs Photon Energy (eV) for Un-irradiated and Irradiated Samples of ZnSe Thin Films.

The relation between absorption coefficient $(\alpha h v)^2$ and photon energy (eV) with doses of irradiation is shown in figure 4, the extrapolation in the graph represent the values of the band gap of the un-irradiated and irradiated thin films. The values of band gap are found to be decreasing as irradiation doses increase (0Gy = 3.02eV, 200Gy = 2.68eV, 250G y= 2.49eV, 300Gy = 2.25eV, 400Gy = 2.0 eV). Clearly, the optical band gap decreases from 3.02 eV for un-irradiated thin films to 2.0 eV for the thin films irradiated with the highest irradiation dose of 400 Gy in this research. Maity and Sharma (2008) reported a similar decrease in the optical band gap with increase of irradiation doses of TeO_2 thin films. This indicates that there is high dose of irradiation introduced in the forbidden gap which resulted to radical changes in the carries concentration. This new energy levels may be acceptor at the utmost of the valence band or donor energy levels down the conduction band which in turn decreases the energy needed to transfer the charge carrier from the valence band to the conduction band (Maity and Sharma, 2008).

Effect Of Gamma Irradiation Doses on the Optical Band Gap of ZnSe Thin Films

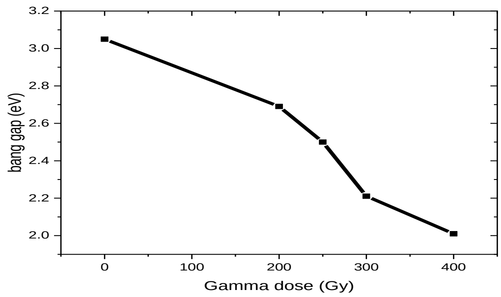

Fig. 5. Plot of Energy Band Gap versus Gamma Dose for Un-irradiated and Irradiated Samples of ZnSe Thin Films.

The plot (figure 5) shows the dependence of band gap energy on irradiated dose. Increasing irradiation dose resulted in decrease of the band gap energy of the ZnSe thin films. It is a known fact that during gamma irradiation, defect are produced within the film. The creation and annihilation of defects in the films coexist together and at greater gamma exposure, the number of defects created due to irradiation becomes more than the number of defect annihilated. This suggests that with irradiation source, high value of energy band gap of this material could be modify for solar cell. It also reveals that the partial linear in the response of the ZnSe thin film to the increase in irradiation dose is possible for dosimeter application.

Table - 1, Experimental Results

ZnSe samples	Optical band gap (eV)	Average transmittance (%)	Absorption coefficient
0Gy	3.02	100	$6x10^6$
200Gy	2.68	98	$6x10^6$
250Gy	2.49	95	$6x10^6$
300Gy	2.25	94	$6x10^6$
400Gy	2.00	93	$6x10^6$

The behaviour of optical band gap (Eg) of ZnSe thin films with the high doses in this research is in agreement with past result for other thin film materials. Table 1, demonstrates the dependence of optical band gap (Eg.) and other optical properties with gamma irradiation dose. It was found the behaviour of optical band gap decreases with increase in irradiation doses and this is due to the irradiation effect which results to bring band gap thinner.

III. CONCLUSION

In this current research, we arrived at the following conclusions after the gamma irradiation by ^{60}Co source on ZnSe thin films:

a) the absorption coefficient spectra, absorbance, extinction coefficient and reflectance as function of wavelength increase with increasing gamma irradiation doses.
b) the optical bang gap showed decreases with increasing gamma irradiation doses.

From the result in this research, the near linearly change in the optical band gap and absorption coefficient of ZnSe thin films indicate it has a promising properties for potential application in the domestic industries.

IV. ACKNOWLEDGMENT

The authors appreciate the staff and management of crystal laboratory unit Department of Physics and Astronomy, University of Nigeria Nsukka, Centre for Energy Research and Training (CERT) University of Nigeria Nsukka and Centre for Energy Research and Training (CERT), Ahmadu Bello University Zaria Nigeria for providing the chemicals, deposition technique, UV-Vis NIR spectrometer and source of gamma radiation during the course of this work. We are highly thankful to Dr. Johnson C. Ibuot for his contributions and encouragement.

V. REFERENCE

[1] Abdelnabi, Alaa, Rwada, and Rawia. (2019). Effect of Gamma Ray on the Optical properties of TiO2 and ZnO Thin Films. Elixir International Journal, (pp. 53386 - 53391).

[2] Abu EL-Fadl, A. Soltan, A.S. Abu-Sehly, A. A. (2007). Effect of Gamma Doses on the Optical Parameters of $Se_{76}Te_{15}Sb_9$ Thin Films, Journal of Physics and Chemistry of Solids, (pp. 1415 - 1421).

[3] Ajeel, H. M., Hussein, T. Z., Thajeel, M. K. and Mekkilf, R. H. (2014). Ajeel, H. M., Hussein, T. Z., Thajeel, M. K. and Mekkilf, Effects of Gamma Radiation on Optical and Structural Properties of Cadmium Telluride Thin Films. Engineering And Technology Journal, (pp. 811-818).

[4] Antar, F. H. (2014). Effect of gamma – ray on Structural and optical properties of cadmium sulphide (CdS) thin films. International Journal of Application or Innovation in Engineering & Management (IJAIEM) , (pp. 89-92).

[5] El Zawawi, K., Mahdy, A., Rabie, N., Sedeek, k., and Adam, A. (2011). Influence of Gamma Radiation on the Optical Properties of ZnSe Nanocrystalline thin Film. Journal Materails Science: Materials in Electronics , (pp. 1195 - 1202).

[6] Jasim, M. A. (2012). Effect of Irradiation on the Optical Properties of PbSe Thin Film Prepared by Thermal Evaporation Method. Diyala Journal for Pure Sciences , (pp. 50 - 58).

[7] Khuram, A., Sohail, A., and Matjafri, M. Z. (2013). 60Co Y-Irradiation effects on the Electrical Characteristics of Monocrystalline Silicon Solar Cell. Internation Journal of Electrochemical Science , (pp. 7831 - 7841).

[8] Maity, T. k., and Sharma, S. L. (2011). Effects of Gamma Irradiation on the Electrical, Optical and structural Properties of Tellurium dioxide Thin Films. Indian Journal of Pure and Applied Physics, (pp. 606 -612).

[9] Raghu, P., Naveen, C. S., Sanjeev, G., and Mahesh, H. M. (2013). Thickness Dependent Optical Properties of ZnSe Thin Films. International Journal of Engineering Research & Technology (IJERT) , (pp. 3568 - 3572).

[10] Rana, M. Y. (2012). Gamma Radiation Induced Changes in the Optical Properties of CdTe Thin Films for Dosimetric Purposes . Iraqi Journal of Physics , (pp. 71-76).

[11] Riyadh,.CH. A , Hussein, F. H. and Adil, A. Al. (2012) the Effect of Gamma-Irradiation on the Absorption Spectra and Optical Energy Gap of selenium dioxide thin films. Science Journal of Physics. (pp. 1 - 4)

[12] Soonmin, H. (2016). Chemical Bath Deposition of ZnSe Thin Films: Investigations of the Growth Conditions. American Chemical Science. Journal , DOI: 10.9734/ACSJ/2016/23356 (pp. 1 - 6).

[13] Yadav, B. K., Singh, P and Pandey, D. K. (2019). Synthesis and Non-Destructive Characterization of Zinc Selenide Thin Films, Zeitschriff fur Naturforschung - Section A, Journal of Physical Sciences - SCimago, DOI: 10.1515/zna-2019-0112, (pp. 993–999).