International Journal of Engineering and Applied Physics (IJEAP)
Vol. 4, No. 2, May 2024, pp. 977~983
ISSN: 2737-8071

Gamma Radiation Effects on The Performance of The CdSe Thin Film for Photodetector Application

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Article Info

Article history:

Received Feb 02, 2024
Revised April 16, 2024
Accepted April 30, 2024

Keywords:

CdSe,
Thin film,
PLD,
Gamma radiation,
Photodetector.

ABSTRACT

Cadmium Selenide thin films were deposited on glass substrates and p-type silicon substrates using pulsed laser deposition technique (Nd: YAG laser). Some of these samples were exposed to different intervals (10,20,30,40) days of gamma radiation using a ^{226}Ra source emitting 186 KeV γ-ray. For comparison purposes, the other diodes were kept without any irradiation. Results have shown all these thin films exhibit a hexagonal structure. However, there is a new (102-SiO_2) peak appeared in the irradiated thin film pattern. The crystallite size of pristine and irradiated CdSe thin films were (26.9,25.8,28.4,35.3 and 22.2) nm respectively, whereas the average grain size of the pristine film was (112.3-29.24) nm whereas for the irradiated films (45.58-33.72) nm, (61.16-42.8) nm, (55.7-36.03) nm and (53.31-43.45) nm. Results also show that the band gap increased from 2.17eV for pristine thin films to 2.28, 2.45, 2.2, and 2.28 eV for the irradiated thin films. also, I-V characteristics show the dark current decreases for the irradiated thin films. The forward current under illumination increases when exposed to small gamma radiation values and then decreases with higher exposure values. In contrast, the reverse current increases with the irradiation.

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1. INTRODUCTION:

Cadmium Selenide materials are one of the II-VI group, which can convert light energy into electrical energy in devices (such as photodetectors, solar cells and transistors) [1,2] due to its large bandgap, high optical absorption coefficient and very good photosensitivity [3,5]. Pulse laser deposition (PLD) has been used to deposit thin films of II-VI group successfully with very good control of the film properties [6,8]. Generally, semiconductors are so sensitive to ionizing radiation such as γ–ray [9,10]. The high energy photon of γ-ray may cause ionization and displacement damage in the semiconductor material [11,12] which can modify the material parameters [13]. Thin film semiconductors exposed to radiation 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 [14,16]. The current study aims to prepare some of the CdSe thin films on glass and p-type silicon substrates by PLD Technique and investigate the effects of gamma radiation in different intervals of exposure on the surface morphology, structural and electrical properties using FE-SEM, XRD, UV and I-V measurements.

2. EXPERIMENTAL DETAILS

2.1 CdSe powder preparation

CdSe powder is collected from depositing thin films of CdSe on glass slides in dimensions (7.5cm×2.5cm×0.1cm) as a substrate. Before the deposition, the substrate was rinsed well with deionized water then it was put in an alcoholic solution. Later, it was immersed in acetone and dried in room Temperature. In chemical bath deposition, to make CdSe films, 0.876 gm Se and 2.65 gm Na_2So_3 dissolved in 10 ml of deionized water in a reflux system, and it was heated with stirring for about 90 min to obtain the Na_2SeSo_3 solution. 1.75 gm $CdCl_2$ was dissolved in 10 ml of deionized water with 2 ml NH_3 and three drops from TEA (Tri ethanol amine). then the Na_2SeSo_3 solution is added to the $CdCl_2$ solution by adding deionized water until we get 100 ml of the final solution (PH=9). Finally, it was heated with the aid of stirring for 15 min. Afterwards, glass slides are placed vertically in the solution in the chemical bath at 70 ºC for 3 hours. The glass slides were removed carefully and dried at room temperature for 7 days at least. The CdSe powder was collected from these slides and was pressed mechanically with a force of 7 tons to get a disk of 1.3cm in diameter and 2mm in thickness as a PLD target.

2.2 PLD film deposition

CdSe thin films with thicknesses of 300-400 nm were deposited on 7.5cm×1.3cm×0.1cm glass substrates and 1 cm^2 p-type silicon [100] (1-10 Ω.cm) substrates after cleaned well. Silicon substrates were immersed in 1:9 HF (40% purity) for 30 Sec, followed by distilled water and alcohol. After drying, the substrate is placed at a distance of 3.5cm from the CdSe target which has been irradiated via 1064 nm by Nd: YAG laser with an angle of 45º (with a repetition frequency of 6HZ and pulse duration of 10 sec). The energy of the laser beam used during the deposition was 80 mJ. These samples are annealed at 300ºc for one hour. Silver electrodes are made on top of the thin films to obtain the device structure.

2.3 Experimental Techniques

Some of the prepared samples were irradiated by ^{226}Ra source (1.96µci with 186 KeV energy) with intervals (10, 20, 30, 40) days of gamma's radiation. Structural and morphological properties of samples were examined using XRD-6000 SHIMADZU and (FE-SEM JSM7600F). The optical and electrical measurements were carried by (SHIMADZU, UV-3600) and Keithley source meter 2400 in conjunction with a band–pass optical filter (λ=460nm) and (p=10mW/cm^2) tungsten halogen light source. Figure 1 illustrates the diagrams of the (I-V), response/recovery, and photo-responsivity measurements.

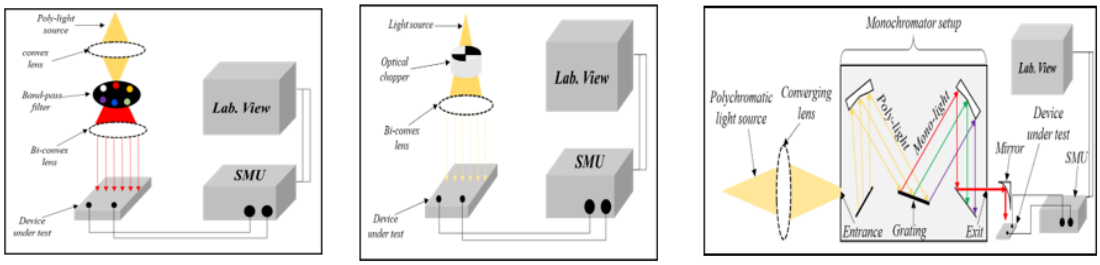

Figure 1. Diagrams (a) (I-V) characteristic measurement, (b) switching behaviour measurement, (c) spectral response measurements

3. Results and Discussion

Table 1 shows the time of irradiated fabrication samples. The XRD patterns of the pristine "pure" and irradiated CdSe thin films on (p-type) silicon substrates reveal that all the thin films exhibit the hexagonal structure. Figure 2 shows the obtained pattern that matched (JCPDS-00-008-0459).

Table 1. Time of irradiated samples

Sample name	Time of radiation(day)
pristine(pure)	0
G1	10
G2	20
G3	30
G4	40

The preferred orientation of all these films was [100] plane corresponding to 2θ=23.93º, 23.83º, 23.73º, 23.57º and 23.5º for pristine and (10,20,30,40) day γ- irradiated respectively as shown in table 2. It was clear that the main diffraction peaks were slightly shifted from 23.93º to 23.5º. Also, it is clear that no diffraction peak disappeared in all these films but instead (102- SiO_2) peak emerged in all the irradiated thin films that corresponding to 2θ=38.08º, 37.98º, 37.8º and 37.67º for (10,20,30,40) days irradiate, respectively. This peak may be formed during the irradiation process in the presence of oxygen in the ambient. The crystallite size was calculated using Debye-Scherrer formula [17-18]:

$$D=0.9\lambda/\beta \cos\theta \quad (1)$$

where D: is crystallite size, is the wavelength of X-ray(1.54Aº),β is the (FWHM) of the peak intensity and θ is the diffraction angle.

The crystallite size was 26.9 nm for pristine film while they were 25.8, 28.4, 35.3 and 22.2 nm for (10,20,30,40) days irradiated films respectively. The fluctuation of the crystallite size for irradiated films as well as in the micro strain reveal the degradation of crystalline structure caused by irradiation.

Table 2. some of the factors obtained from XRD results of pristine and irradiated samples

Sample	2-theta (deg.)	d-spacing (Å)	FWHM (deg.)	Crystallite (Å)	Crystallite (nm)	Micro Strain
Pure	23.936	3.715	0.277	269	26.9	0.691
G1	23.833	3.73	0.281	258	25.8	0.724
G2	23.735	3.746	0.275	284	28.4	0.658
G3	23.571	3.771	0.192	353	35.3	0.534
G4	23.507	3.782	0.343	222	22.2	0.852

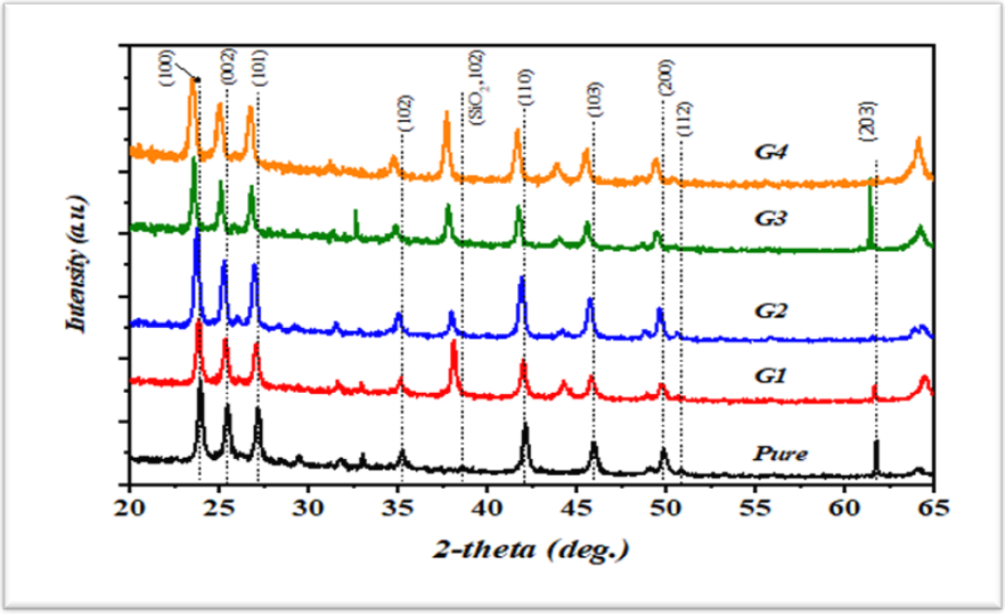

Figure 2. XRD pattern of pristine(pure) and irradiated samples

Figure 3 shows the FE-SEM images for pristine and irradiated thin films. The grain size of the pristine film range was (112.3-29.2) nm while in irradiated films was (45.58-33.72) nm, (61.16-42.8) nm, (55.7-36.03) nm and (53.31-43.45) nm respectively. The images obtained from FE-SEM show that the surface morphology was influenced by γ-radiation and reveal differences in the shape and size of crystallites for each dose.

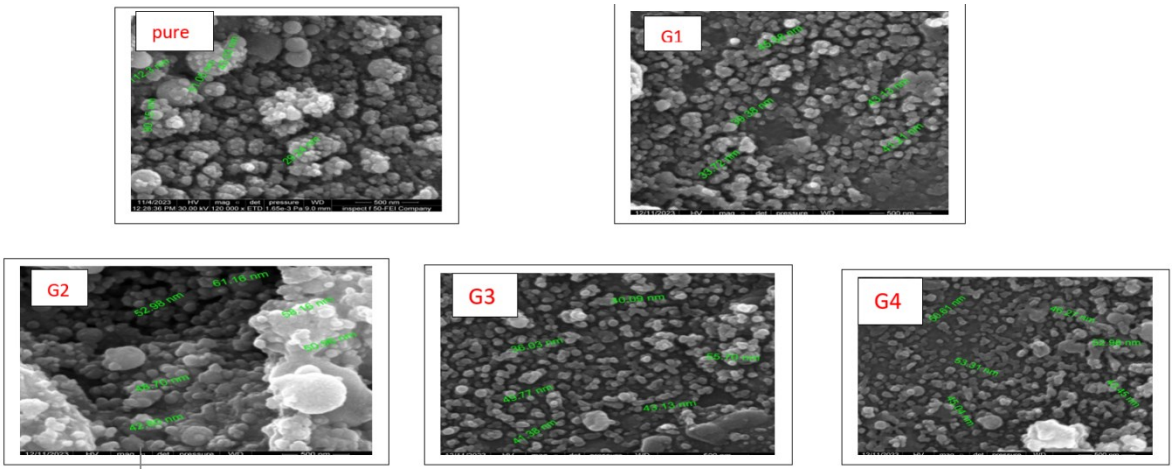

Figure 3. FE-SEM images for pristine "pure" and 10,20,30,40 days irradiated samples

The optical measurements were carried out in the wavelength range of 300-800 nm. Figure (4a) shows that there was a blue shift of the absorption edge of the irradiated films towards a lower wavelength. This indicates an increase in the optical band gap. As shown in figure (4b), The absorption coefficient α as well as the investigated optical band gap using the Tauc relation:

$$\alpha h\nu = A(h\nu - Eg)^n \quad (2)$$

where A is constant, hν is the photon energy, n=1/2 for direct transition [19-20]. The band gap energy values increase from 2.17eV for a pristine thin film to (2.28, 2.45, 2.2, 2.28) eV for irradiated thin films as shown in Table 3 the γ-irradiate thin films have resulted in higher optical band gap which led to low detection of UV light. this may be due to the decrease in particle diameter as illustrated in the FE-SEM measurement.

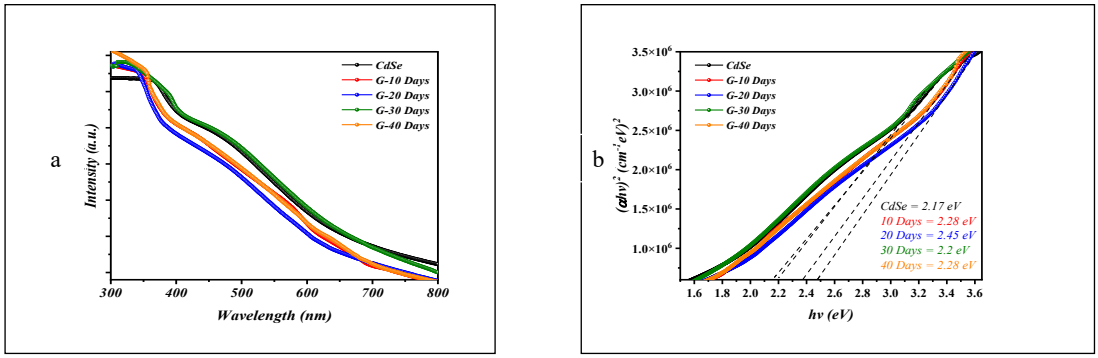

Figure 4. optical properties of samples. (a)the absorbance versus wavelength of pristine and irradiated samples, (b) the variation of $(\alpha h\nu)^2$ as a function of photon energy hν for all samples

Table 3. band gap energy values of samples

Sample name	Bandgap (Eg)
pure	2.17eV
G1	2.28eV
G2	2.45eV
G3	2.2eV
G4	2.28eV

Figure (5) shows the I-V characteristics for pristine "pure" and irradiated thin films exposed to various levels of gamma radiation doses. The light/dark currents were measured in forward and reverse directions, it was clear from these plots the semiconducting behaviour of the CdSe thin film deposited on (p-type) silicon. It is also shown that the current under illumination increases when exposed to small values of

gamma radiation and then decreases with higher values of exposure, however, the dark currents decrease greatly with irradiation.

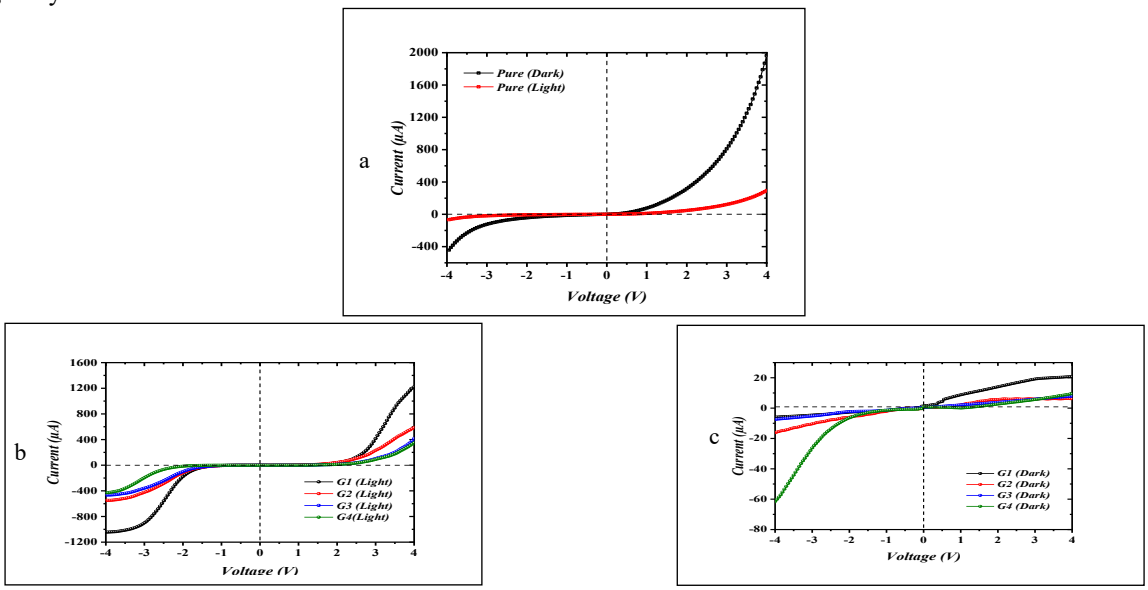

Figure 5. The I-V characteristics of pristine and irradiated samples under (a) dark and light current of the pristine sample, (b) light current of irradiated samples, and (c) dark current of irradiated samples.

As inset in figure 6, The response and recovery time for all the fabricated photodetectors were calculated from 10-90% of the peak amplitude using 460 nm monochromatic light source, P=10mW/cm^2 with biasing the photodetectors at 2V. These fabricated photodetectors have exhibited a stable profile under 3 complete cycles with ~25sec pulse width evidencing the consistency of the fabricated devices under testing protocol. It can distinguish the effect of γ-irradiation on the devices. The response time of pristine was 310 mSec and the recovery time was 557 mSec while the response time of the (10) days irradiated device was 550 mSec and the recovery time was 765 mSec. On the other hand, the response time of the (20) days irradiated device was 350 mSec and the recovery was 720 mSec. However, the response time of the (30) days irradiated device was 740 mSec and the recovery was 876 mSec, finally, the response time of the (40) days irradiated device was 400 mSec and the recovery time was 560 mSec.

the photo-responsivity for all fabricated devices was measured at (320-800) nm using a monochromator device. Fig 7 shows that the photo-responsivity of the pristine device was larger than the other devices and it decreases with increasing absorbed doses.

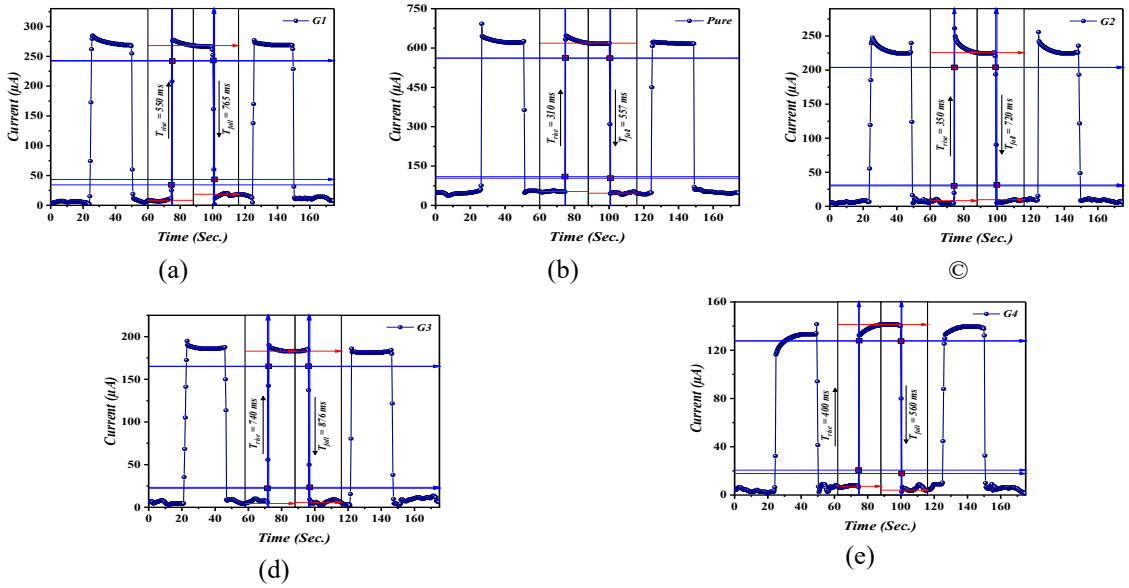

Figure 6: Response/recovery time of (a) pristine sample, (b) 10 days irradiated sample (c) 20 days irradiated sample, (d) 30 days of irradiated sample and (e) 40 days irradiated samples.

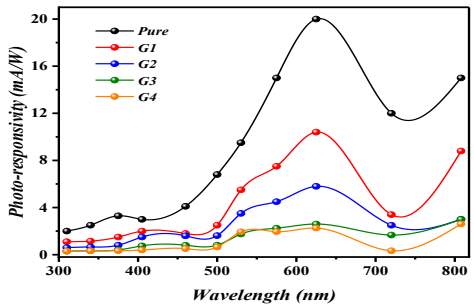

Figure 7. Photo-responsive characteristics of pristine and irradiated samples

4. Conclusion:

CdSe thin films fabricated by the PLD technique on the p-type silicon substrates were employed in fabricating efficient photodetectors. Photodetectors were exposed to gamma radiation from (^{226}Ra) source for (10,20,30,40) days. The last one was kept without any radiation to identify radiation damage through several measurements. Our results have shown the conclusion as below:

- XRD measurements show that the structures of all pristine and irradiated films were hexagonal.
- Irradiation by γ-ray causes the appearance of (102-SiO_2) peak in all irradiated thin film patterns.
- The band gap is also affected by γ-radiation and becomes larger than its initial value.
- Crystalline and grain size are also affected by gamma radiation.
- Finally, the electric properties coincided with the typical semiconductors as well as showed significant changes after radiation.

5 . References:

[1] Yadav, A. A., Barote, M. A., & Masumdar, E. U. Studies on cadmium selenide (CdSe) thin films deposited by spray pyrolysis. *Materials chemistry and physics*, *121*(1-2), (2010). 53-57.

[2] Kumara, P., Kumara, D., Kumar, A., & Katiyarc, R. S. Effect of post-growth annealing process on optical properties of CdSe thin films on Si p-type substrate deposited by pulsed laser deposition technique. *The International Journal of Analytical and Experimental Modal Analysis*, *13*(6), (2021). 3016-3028.

[3] Ashry, M., & Fares, S. Electrical characteristic measurement of the fabricated CdSe/p-Si heterojunction solar cell under radiation effect. *American Journal of Materials Science*, *2*(3), (2012). 72-76.

[4] Shelke, N. T., Karle, S. C., & Karche, B. R. Photoresponse properties of CdSe thin film photodetector. *Journal of Materials Science: Materials in Electronics*, *31*(18), (2020). 15061-15069.

[5] Elisa, M., Iordache, S. M., Iordache, A. M., Rusu, M. I., Socol, G., Filipescu, M., ... & Enculescu, M. Pulsed laser deposition films based on CdSe-doped zinc aluminophosphate glass. *JOM*, *73*, (2021). 495-503.

[6] Hernandez-Perez, M. A., Aguilar-Hernandez, J., Contreras-Puente, G., Vargas-Garcia, J. R., & Rangel-Salinas, E. Comparative optical and structural studies of CdSe films grown by chemical bath deposition and pulsed laser deposition. *Physica E: Low-dimensional Systems and Nanostructures*, *40*(7), (2008). 2535-2539.

[7] Hernandez-Perez, M. A., Aguilar-Hernandez, J. R., Vargas-García, J. R., Contreras-Puente, G. S., Rangel-Salinas, E., Hernandez-Santiago, F., & Vargas-Ramírez, M. Influence of the fluence and substrate temperature on the Structural and Optical properties of CdSe thin films prepared by Pulsed Laser Deposition. In *Materials Science Forum* (Vol. 691, pp. 134-138). Trans Tech Publications Ltd. (2011, August).

[8] Salih, E. Y., Bashir, M. B. A., Rajpar, A. H., Badruddin, I. A., & Bahmanrokh, G. Rapid fabrication of NiO/porous Si film for ultra-violate photodetector: The effect of laser energy. *Microelectronic Engineering*, *258*, 111758. (2022).

[9] Jamil, N. Y., Najim, S. A., & Muhammed, A. A. K. M. The Effect of γ-Irradiation on the Structural and Physical Properties of CdSe Thin Films. *Rafidain journal of science*, *25*(3E). (2014).pp90-98

[10] Johnston, A. H. (2000, October). Radiation damage of electronic and optoelectronic devices in space. In *Proceedings of the 4th International Workshop on Radiation Effects on Semiconductor Devices for Space Application* (pp. 11-13).

[11] Kumari, M., Rana, P., & Chauhan, R. P. Modifications in structural and electrical properties of gamma irradiated CdSe nanowires. *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, *753*, (2014).116-120.

[121] Nikolić, D., Vasić-Milovanović, A., Obrenović, M., & Dolićanin, E. Effects of successive gamma and neutron irradiation on solar cells. *Journal of Optoelectronics and Advanced Materials*, *17*(3-4), (2015). 351-356.

[13] Sudha, A., Maity, T. K., & Sharma, S. L. Effects of gamma irradiations on structural and electrical properties of indium oxide thin films prepared by thermal evaporation. *Materials Letters*, *164*, (2016). 372-375.

[14] Elttayef, A. K. Improvement of physical properties of SnO 2 By Gamma Irradiation. (2012).

[15] Souli, M., Nefzi, C., Seboui, Z., Mejri, A., Vidu, R., & Kamoun-Turki, N. Improved structural properties, morphological and optical behaviours of sprayed Cu2ZnSnS4 thin films induced by high gamma radiations for solar cells. *Materials Science in Semiconductor Processing*, *83*, (2018). 50-57.

[16] Choudhary, R., & Chauhan, R. P. Gamma irradiation induced modifications in spin-coated CdSe thin films. *Journal of Materials Science: Materials in Electronics*, *27*, (2016). 11674-11681.

[17] Al Refaei, D. H., Najam, L. A., & Al Taan, L. M. The Effect of Neutron Irradiation on Optical, Structural and Morphological Properties of Cadmium Selenide Thin Films. (2021).

[18] Pogrebnjak, A. D., Jamil, N. Y., Abdulla, S. N., & Muhammed, A. M. The effect of γ–irradiation on the structural and physical properties of CdSe thin films. In *Proceeding of the International Conference Nanomaterials: Application and Properties* (Vol. 2, No. 1). (2013).

[19] Abed, H. H., Abduljalil, H. M., & Abdulsattar, M. A. Structural, Optical and Humidity Sensitivity for CdSe Nanocrystalline Thin films. *Journal of Advanced Pharmacy Education & Research*| *Oct-Dec*, *8*(4). (2018).

[20] Abdulghani, S. O., Salih, E. Y., & Mohammed, A. S. Fabrication and photo-responsive characteristics of GeO2 doped SnO2/porous Si film for ultraviolet photodetector application. *Materials Chemistry and Physics*, *303*, 127859. (2023).