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Comparative Study of Gamma Ray and Neutron Radiation on Some Electrical Properties of n-CdSe/p-Si Photodiodes

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ABSTRACT

Cadmium Selenide (CdSe) thin films were prepared on silicon(p-type) substrates using the pulsed laser deposition technique (PLD). They were then annealed at 300 ºC for one hour to get diodes used as a visible light detector. Four diodes were subjected to four different intervals of gamma radiation emitted from the ^{226}Ra source. For comparison, four of these diodes were subjected to four different intervals of neutron radiation using a (^{241}Am - ^{10}Be) source; the other diodes were kept without exposure to irradiation. I-V measurements studied the electrical properties of these samples. Results of gamma-irradiated devices show that dark current decreases for the irradiated thin films. Forward current under illumination increases when exposed to small gamma radiation values and then decreases with higher exposure values. While the value of reverse current increases with the irradiation. The results of I-V characteristics for neutron irradiation devices show that the value of current under illumination increases when exposed to small values of neutron radiation, then it decreases with higher values of exposure. However, dark current decreases significantly with irradiation. The effect of the gamma and neutron irradiation was clear on the response/recovery period for all irradiated devices. However, it was more profound in the response/recovery time of pristine devices. Also, the photo-responsivity of the pristine device was larger than that of the irradiated devices, and it decreased with increasing absorbed doses of gamma and neutron radiation.

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1. INTRODUCTION

Cadmium Selenide has been studied as an N-type compound semiconductor material [1]; it has important optoelectronic properties due to its direct band gap [2]. CdSe thin films can be used in solar cells [3], heterojunction cells of n-CdSe/p-Si [4], photosensors and photodetectors [5]. Several techniques are available for preparing CdSe thin films, such as chemical bath deposition (CBD) [6], vacuum evaporation [7], pulsed laser deposition [8], spray pyrolysis deposition [9] and spin-coating [10]. When CdSe thin film devices are exposed to ionising radiation, it can negatively impact some electrical properties of the device [11-13]. Gamma irradiation can create modifications in the lattice periodicity because of high-energy photons [14,15], and Neutron radiation can interact with the nucleus, causing an atomic displacement [16-18]. As a result, altering the electrical properties of a material because of ionising radiation gives rise to some additional energy levels in the forbidden band gap [19,20]. Modification in the device properties exposed to radiation depends on the radiation energy, the amount of dose and the material structure [21,22]. The current study is an attempt to investigate the impact of gamma and neutron radiation on the electrical properties of the CdSe photodetectors subjected to irradiation.

2. RESEARCH METHOD

Silicon substrates are cleaned by immersing them in 1:9 HF (40% purity) for 30 seconds, followed by distilled water and alcohol. After drying, the substrate is placed at a distance of 3.5 cm from the CdSe target (laboratory prepared), which has been irradiated by Nd: YAG laser (1064 nm) with an angle of 45º (with a 6Hz repetition frequency and 10 ns pulse duration). The energy of the laser beam was 80 mJ. All samples are annealed at 300ºC for one hour. Silver electrodes are made on the top of the CdSe thin films to obtain a photodiode device structure. Four of these devices were subjected to gamma rays from a ^{226}Ra source (1.96μci with 186 keV energy) with intervals (10, 20, 30, 40) days of gamma's radiation. While the other four devices were exposed to neutron radiation using a (^{241}Am -^{10}Be) source with a flux of 3×10^5n/cm^2.s and an energy of 5.7MeV with intervals (5,7,9,12) days of the neutron's radiation, some of the diodes were still without any radiation exposure. Electrical measurements were carried out by a Keithley source meter 2400 in conjunction with a band–pass optical filter (λ=460nm) and (p=10mW/cm^2) tungsten halogen light source. Figures (1), (2), and (3) show Diagrams of (I-V) characteristic measurement, switching behaviour measurement, and spectral response measurements, respectively

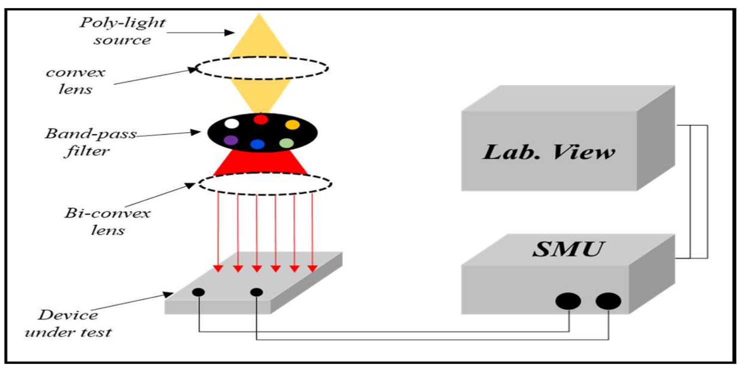
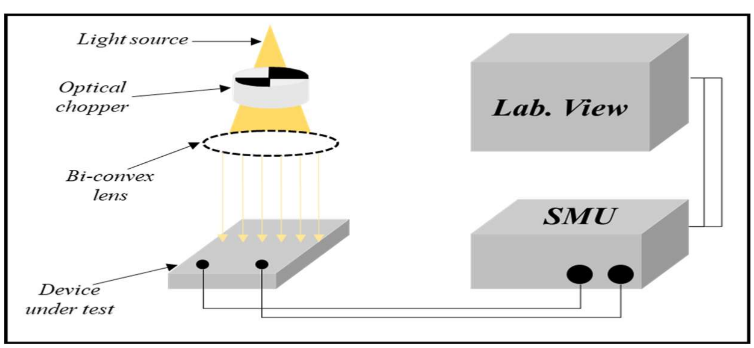
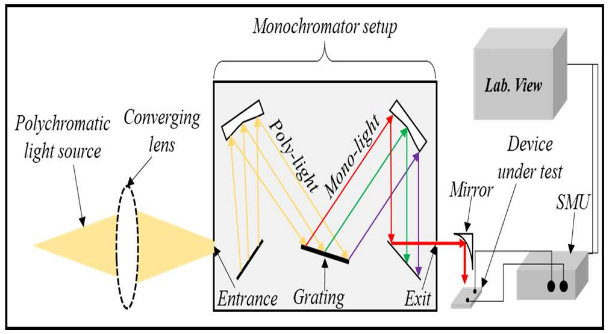


Figure (1): The diagram of the (I-V) characteristic measurement



Figure(2): The diagram of switching behaviour measurement



Figures(3): The diagram of spectral response measurements

3. RESULTS AND DISCUSSIONS

Table 1 shows the time of gamma and neutron irradiation of the prepared photodiodes.

Table 1: Time of irradiated photodiodes

Sample name	Time of radiation(day)
pristine(pure)	0
G1	10
G2	20
G3	30
G4	40
N1	5
N2	7
N3	9
N4	12

Figure (4) shows the I-V characteristics (light and dark current curves) for a pristine "pure" photodiode, while Figures (5) and (6) show the light and dark current curves for irradiated photodiodes, respectively exposed to (10,20,30,40) days of gamma radiation doses. The light/dark currents were measured in forward and reverse bias; it was clear from these curves that the semiconducting behaviour of the fabricated diodes. It is also shown that the current under illumination increases when subjected to small values of gamma radiation, while decreasing with higher values of gamma-ray exposure; however, the dark currents decrease significantly with irradiation.

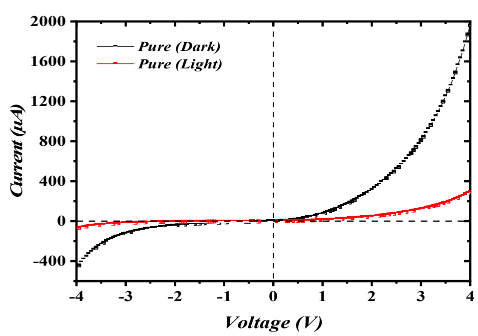


Figure (4): The I-V characteristics of pristine photodiodes

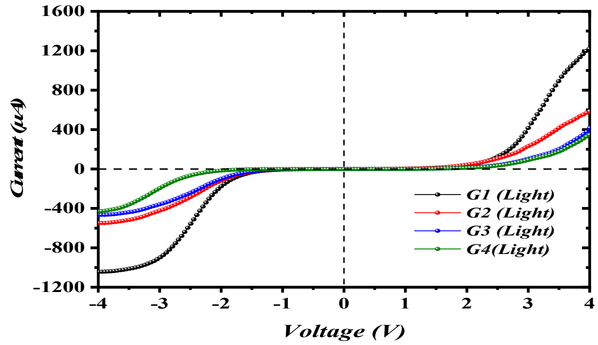


Figure (5): The I-V characteristics of the gamma-irradiated photodiodes (in the illumination case)

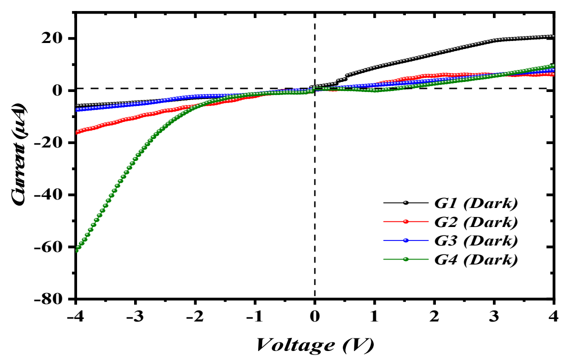


Figure (6): The I-V characteristics of the gamma-irradiated photodiode (in the dark case)

Figures (7) and (8) show the I-V characteristics (light and dark current curves) for irradiated photodiodes, respectively exposed to (5,7,9,12) days of neutron radiation. The light-dark currents are measured in forward and reverse bias; it was clear from these curves that the semiconducting behaviour of the fabricated devices. It is also shown that the current under illumination increases when exposed to small values of neutron radiation, while decreasing with higher values of exposure; however, the dark currents decrease significantly with the values of irradiation.

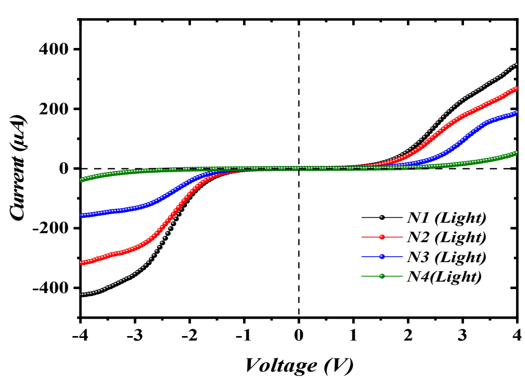


Figure (7): The I-V characteristics for irradiated photodiodes exposed to various levels of neutron radiation (in the illumination case)

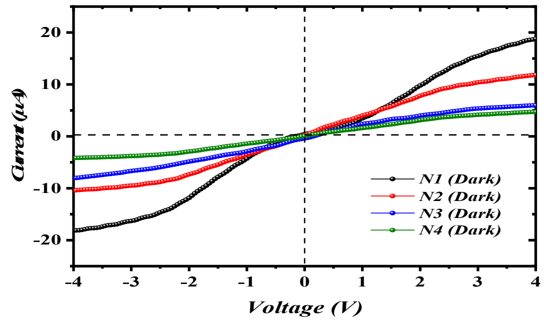
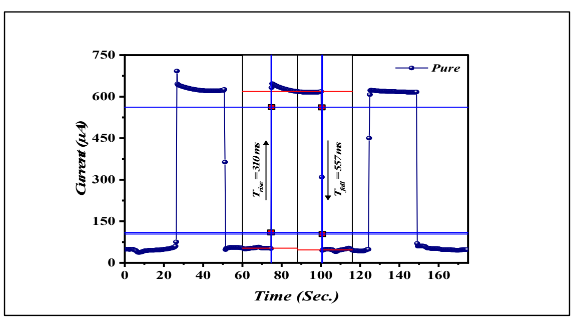
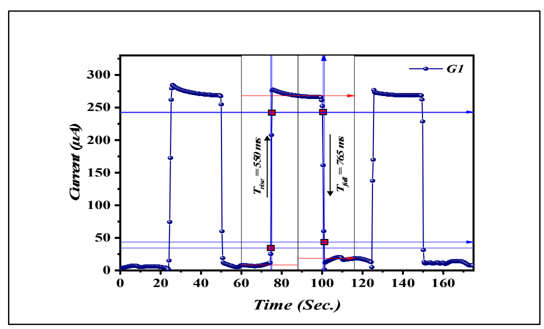
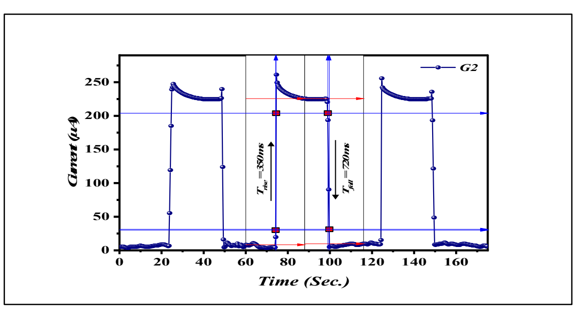


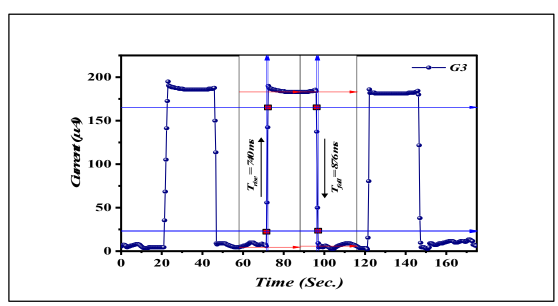
Figure (8): The I-V characteristics for irradiated photodiodes exposed to various levels of neutron radiation (in the dark case)

Figures (9) and (10) show measurements of response/recovery time for all photodiode devices, which were calculated (from 10-90% of the peak amplitude) using a 460 nm monochromatic light source, P=10 mW/cm^{2,} with biasing the photodetectors at 2V. These photodiodes have exhibited a stable profile for 3 complete cycles (~25sec pulse width). It can distinguish the impact of gamma irradiation on the irradiated photodiodes. As shown in the table(2), the response time of the pristine was 310 mSec, but the recovery time was 557 mSec, while the response time of the 10-day irradiated device was 550 mSec and the recovery time was 765 mSec. The response time of the 20-day irradiated device was 350 msec, and the recovery was 720 msec. Whereas the response time of the 30-day irradiated device was 740 mSec, the recovery time was 876 mSec; the response time of the 40-day irradiated device was 400 mSec, but the recovery time was 560 mSec. The response time of the 5-day irradiated device was 445 mSec, and the recovery time was 860 mSec. While the response time of the 7-day irradiated device was 370 mSec, the recovery was 775 mSec. Whereas, the response time of the 9-day irradiated device was 650 mSec, but the recovery was 550 mSec. Finally, the response time of the 12-day irradiated device was 440 mSec, and the recovery time was 370 mSec.









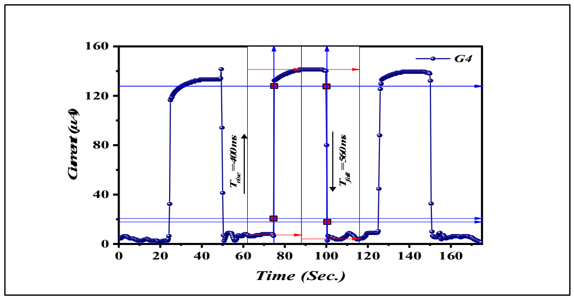


Figure (9): Response/Recovery time measurements for pristine and (10,20,30,40) days gamma irradiated photodiodes

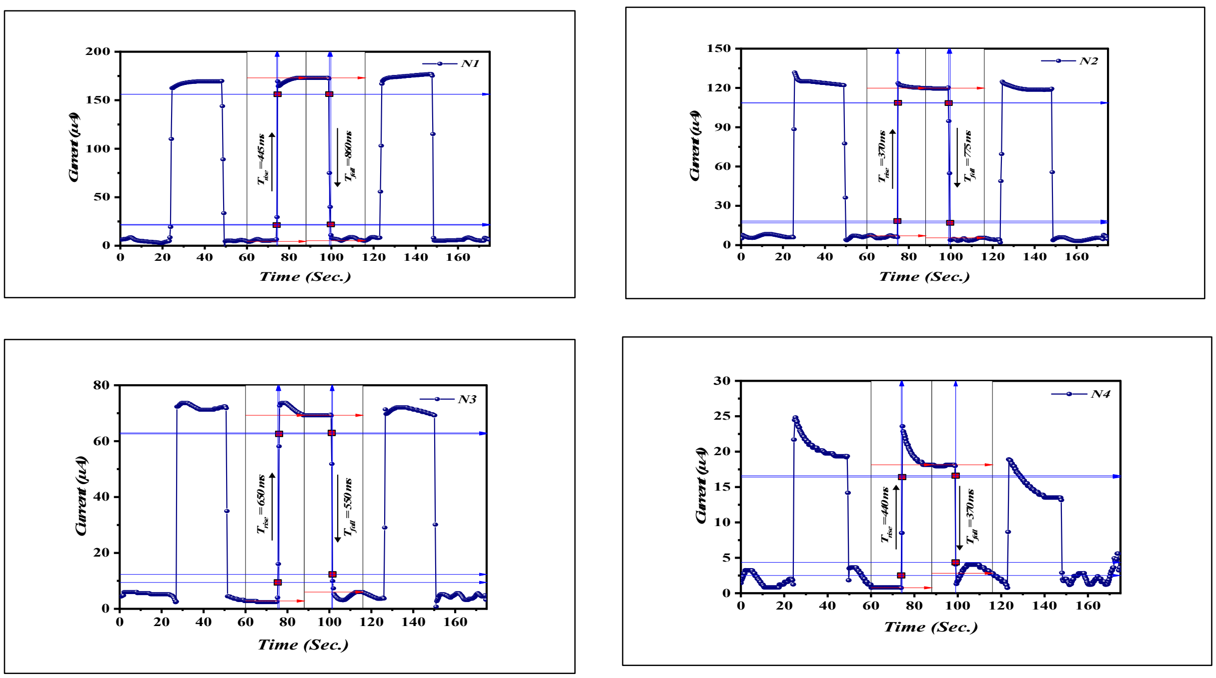


Figure (10): Response/Recovery time measurements for (5,7,9,12) days neutron irradiation photodiodes

Table (2) Response/Recovery time for pristine and irradiated devices

Sample name	Trise (ms)	Tfall (ms)
pure	310	557
G1	550	765
G2	350	720
G3	740	876
G4	400	560
N1	445	860
N2	370	775
N3	650	550
N4	440	370

The photoresponsivity for all photodiodes was measured at (320-800) nm using a monochromator device. Table 3 shows the values of photoresponsivity for pristine and irradiated devices. Figure (11) shows the photoresponsivity curves of the pristine and (10,20,30,40) days gamma irradiated devices, while Figure (12) shows the photoresponsivity curves of the pristine and (5,7,9,12) days neutron irradiated devices. It was clear that the photo-responsivity of the pristine device was larger than that of the gamma or neutron-irradiated devices, and it decreased with increasing absorbed doses.

Table(3): The photoresponsivity values for pristine and irradiated devices

Wavelength (nm)	Pure (mA/W)	G1 (mA/W)	G2 (mA/W)	G3 (mA/W)	G4 (mA/W)	N1 (mA/W)	N2 (mA/W)	N3 (mA/W)	N4 (mA/W)
310	2.00	1.10	0.60	0.30	0.30	0.854	0.597	0.427	0.155
340	2.50	1.15	0.65	0.33	0.33	0.950	0.609	0.365	0.194
375	3.30	1.500	0.80	0.40	0.33	1.002	0.701	0.500	0.256
405	3.00	2.00	1.50	0.75	0.39	1.124	0.721	0.431	0.233
460	4.10	1.80	1.60	0.80	0.52	1.212	0.848	0.605	0.318
500	6.80	2.50	1.62	0.81	0.65	1.941	1.152	0.690	0.527
530	9.50	5.50	3.50	1.75	1.94	2.145	1.421	1.015	0.736
575	15.00	7.50	4.50	2.25	1.96	3.752	2.405	1.440	1.163
625	20.00	10.40	5.80	2.60	2.26	5.124	3.993	3.769	1.550
720	12.00	3.40	2.50	1.67	0.33	3.145	2.235	1.338	0.930
808	15.00	8.80	3.00	3.00	2.61	4.214	2.947	1.403	1.163

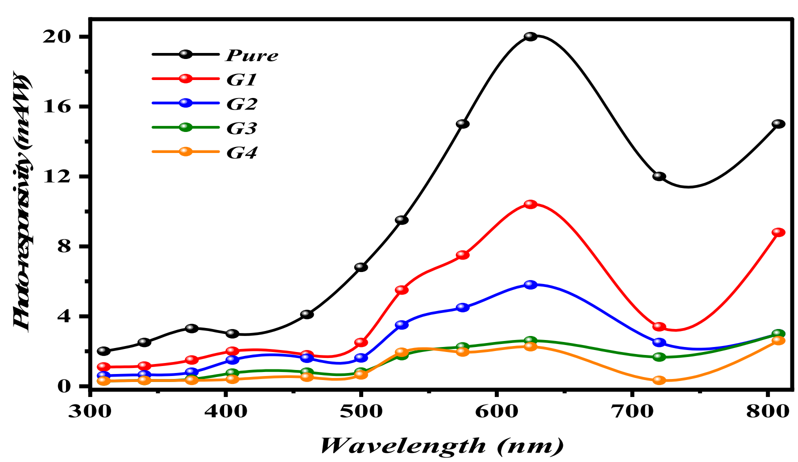


Figure (11): The photoresponsivity curves of the pristine and (10,20,30,40) days gamma irradiated devices

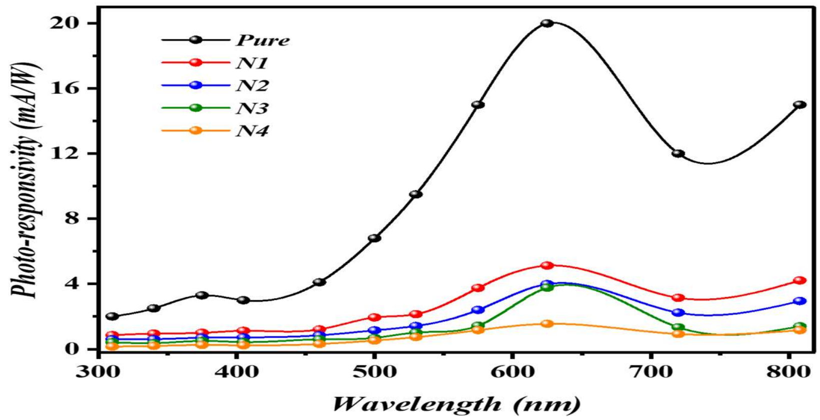


Figure (12): The photoresponsivity curves of the pristine and (5,7,9,12) days neutron irradiated devices.

4. CONCLUSION

Results show these conclusions:

- The current value under illumination decreases for gamma and neutron-irradiated photodiodes under forward biasing,
- The larger decrease in current values was in neutron irradiation in the forward bias case
- The current value under illumination in the reverse case increases for gamma-exposed photodiodes while decreasing for neutron-irradiated devices.
- The values of dark current decrease greatly with increasing gamma irradiation time.
- The current value under illumination increases when exposed to small values of neutron radiation and then decreases with higher values of exposure
- The values of dark current decrease greatly with neutron irradiation.
- The response time of pristine devices was smaller than that of gamma or neutron-irradiated devices generally.
- The recovery time of pristine photodiodes was smaller than that of irradiated photodiodes; in the gamma-irradiated devices, the values of recovery increase significantly in the (10,20,30) days of radiation, but they decrease clearly in the 40 days of gamma irradiation.
- The recovery time for neutron-irradiated devices was so large in the 5-day irradiation, and decreased with increasing the time of neutron exposure to the 12-day neutron irradiation, the recovery time became smaller than the recovery value of the pristine device.
- The photoresponsivity for the pristine device was larger than for gamma and neutron-irradiated devices.
- The neutron-irradiated devices have smaller photoresponsivity than the gamma-irradiated devices.

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