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Effect Irradiation time of Gamma Ray on MSISM ($Au/SnO_2/SiO_2/Si/Al$) Devices Using Theoretical modeling

Marwa Abdul Muhsien Hassan[a], Mahasin F. Hadi Al-Kadhemy[b] and Evan T. Salem[c]

[a, b] *Department of physic, College of Science, Al-Mustansiriyah University, Baghdad, Iraq,*
[c]*Laser and Optoelectronic Branch, School of Applied Sciences, University of Technology, Baghdad, Iraq*

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Abstract

An experimental and theoretical analysis of the effect of irradiation time to Gamma ray on the SnO_2/n-Si hetero-junction devices have been carried out. The time of exposure to Gamma ray was taken as (t= 0, 50, 100, and 150 min.) at room temperature. The power intensity of illumination was 9.5 mw/cm^2. Increasing irradiation time led to increase in photo current. We estimate theoretical model for this effect to obtain (J –V) curve for any irradiation time that we do not take experimentally. "Table curve 2D, version 5.01" program was used to make the fitting curve for all experimental data. The best estimated theoretical equation was :$Y= a + b x +c e^x$. Theoretical (J- V) curve has been achieved for test irradiation time (t= 75 and 125 min.) and plotted with experimental data, there is a good similarity between them. In this work we have demonstrated an experimental study and theoretical analysis of the effect of power intensity of illumination on the SnO_2/n-Si Hetero-junction devices that have been irradiated with Cs 137 for 150 min. Gamma ray. The (J-V) characteristic was plotted as function of power intensity of illumination (1.95, 2.88, 3.78, 5.9, and 9.5) mw/cm^2. There was an increase in efficiency of this device until maximum efficiency reached at 9.5 mw/cm^2 represents optimal case. Theoretical analysis of this process was achieved by using "Table Curve 2D version 5.01" program leading to estimate theoretical modeling equation : $Y= a + b x +c e^x$. We have calculated these parameters (a, b, and c) as function of power intensity and tested the equation for power intensity (4 and 8 mw/cm^2). Theoretical (J- V) curves have been plotted with experimental data. There is a good agreement between them and the behavior of these two curves contains linear term and exponential term.

Keywords: Thin films; SnO_2; Effect of Gamma ray.
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1. Introduction

TIN dioxide, a wide band gap semiconductorwith high chemical stability, along with excellent optical and electrical properties [1]. The wide band gap oxide is a semiconductor compounds such as In_2O_3, SnO_2 etc have a band gap more than 3 eV and therefore are transparent to the radiation with the wavelength more than 0.4 μm, i.e for the wavelength from the region of the maximum solar intensity. Now SnO_2 thin films have

become an integral part of modern electronic technology, such as a window layer and heat reflectors in solar cells, various gas sensors, liquid crystal displays etc [2]. There are various methods such as spray pyrolysis, electron beam evaporation, chemical vapour deposition, magnetron sputtering and the Pechini method, etc., for the preparation of doped or undoped SnO_2 films [3]. The SnO_2 films are n-type semiconductors [4–6]. Their conductivity can be changed within wide limits, from 10^{-1} ohm^{-1}. cm^{-1} up to 10^{4} ohm^{-1}. cm^{-1}. The above mentioned property permits to use this material in solar cell fabrication as frontal layer in SIS (semiconductor-insulator-semiconductor) structures. The investigation of silicon based SIS structures began in 1979 [7-8]. Hetero-junction device consisting of a wide band gap semiconductor (usually an oxide semiconductor) mated to a much narrower band gap (active) semiconductor have gained considerable prominence during the past few years. The performance of these devices is strongly controlled by the presence of a thin interfacial insulator layer [9-10], since the Si represents semiconductor in the metal-insulator-semiconductor structure, the SiO_2 thin layer represents the insulator and the reduction of SnO_2 will produce the metal. A high resistance at the SnO_2 - Si interface is attributed to the presence of a semi-insulating interface layer existing at least in the silicon part as SiO_2 layer, which plays an important role in determining the device efficiency, i.e., enhancing the photovoltaic characteristics [11-12]. Gamma rays in the energy range up to 3 MeV primarily interact with matter by three distinct processes. These are Compton Scattering, the Photoelectric Effect and Pair Production. Two additional processes that can occur are not significant at the energies of interest in this experiment. These are Bremsstrahlung and Cerenkov radiation. For energies less than 1.022 MeV, Compton and Photoelectric effects are possible.
For energies greater than 1.022 MeV, Pair Production is also possible.

Theoretical Spectrum of a Gamma Ray:

In photoelectric effect, the gamma ray gives up all its energy to an electron. The electron has a lot of energy to lose in the scintillator and will thus produce a large pulse of light. This in turn will produce a voltage pulse at a particular value. In Compton Effect, electrons have a variety of energies in the scintillator and should produce voltage pulses of varying heights up to a maximum value (Compton edge). In Pair production electrons produce light at varying energies with positrons creating 0.511 MeV gamma rays. If we have pair production, we ought to see photoelectrons at this energy. Of course there will also be Compton Effect electrons as well. The ideal gamma ray spectrum might look like figure 1.

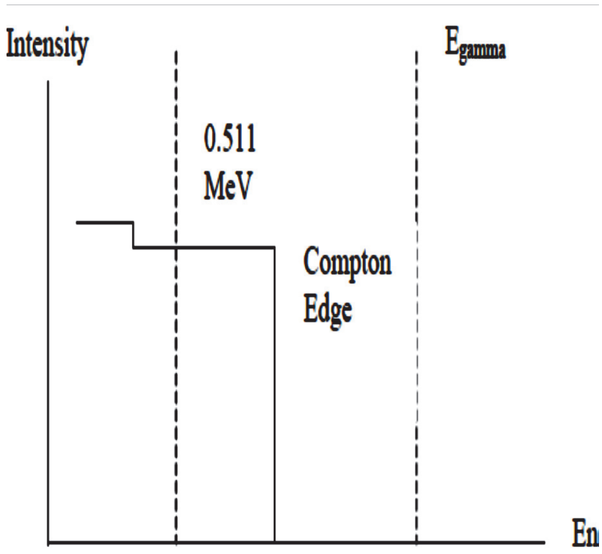

Fig. 1: The photoelectron peak from gamma rays.

Fig. 1 shows the photoelectron peak from the gamma ray, two Compton edges and a range of Compton electron energies and a peak from the gamma rays resulting positron annihilation. There are other complications however. Some of the gamma rays from the source will interact with other materials in the neighborhood. This will produce additional Compton scattering and those Compton gamma rays will introduce gamma rays of different energies into the scintillator crystal. Electronic noise will also tend to spread out the signals. This is a Cs-137 gamma ray spectrum. The energy of the primary gamma ray is 662 keV. Since this is less than 1.022 MeV, there is no pair production.

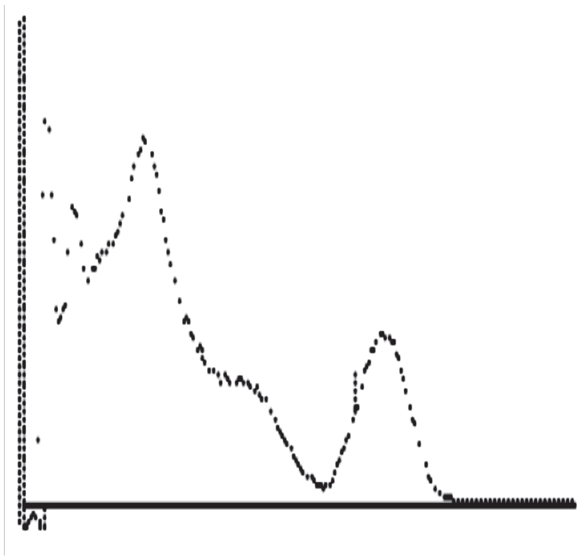

Fig. 2: The photopeak (due to the photoelectric effect).

The photopeak as shown in fig. 2 (due to the photoelectric effect) is the rightmost feature of this spectrum. To the left of the peak, you can see the Compton edge. Further left are some other peaks which arise from Compton gammas scattered from surrounding materials (lead, aluminum, etc.) [13-16]. So that, in the present work, the J-V characteristic under illumination of SnO_2/n-Si Hetero-junction devices has been investigated and analyzed after irradiation of γ-rays at different irradiation time. An analysis study of experimental (J-V) curves was demonstrated to obtain theoretical modeling equation for the effect of γ-rays at di fferent irradiation time and effect of changeable of power intensity of illumination by using "Table Curve 2D version 5.01" program.

2. Experimental setup

The substrate used was (111) n-type single crystal silicon, each of 1×1 cm^2 area, of (1.5-4) Ω.cm resistivities were prepared using a wire-cut machine. The silicon substrates were etched with CP4 solution consisting of (HNO_3, CH $_3$COOH, HF) of ratios (3:3:5) to remove oxides. They were then cleaned by alcohol and ultrasonic machine (Cerry PUL 125 device) for 15 minutes then they were cleaned by water and ultrasonic waves for another 15 minutes. High purity of tin (Sn) thin film was deposited on silicon substrate using thermal evaporation technique at room temperature under vacuum pressure of 10^{-6} Torr. SnO_2 film was obtained with aid of rapid thermal oxidation system with halogen lamp as oxidation source. The oxidation condition used to form SnO_2 film was 600 ^oC/90 s. The silicon sample was used as substrate for TCO's/Si heterojunction. Ohmic contacts were fabricated by evaporating 99.999 purity aluminum wires for back contact and 99.999 pure gold were used as front contact using Edwards coating system.

"Table Curve 2D version 5.01" program was used to estimate theoretical equation for the effect of γ-rays at different irradiation time and effect of power intensity of illumination on the (J- V) curve for SnO_2/n-Si Hetero-junction devices irradiated by 150min. Gamma ray.

3. Results and discussion

The results in this work classified into two parts; practical part and theoretical modeling part:

A- Practical Data

The effect of γ-rays at different irradiation time and effect of illumination on the (J-V) characteristics for SnO_2/n-Si Hetero-junction devices irradiated by 150 min (Cs 137) Gamma ray was discussed extensively elsewhere [17].

B- Theoretical Modeling Part

We use "Table curve 2D" to estimate theoretical model by fitting curve for these experimental results, as demonstrated in figure 3. (a, b, c and d). The best fitting equation for each figure is given by:

$$Y = a + bx + ce^x \quad (1)$$

where the values of the parameters (a, b and c) are shown in table 1 for each irradiation time.

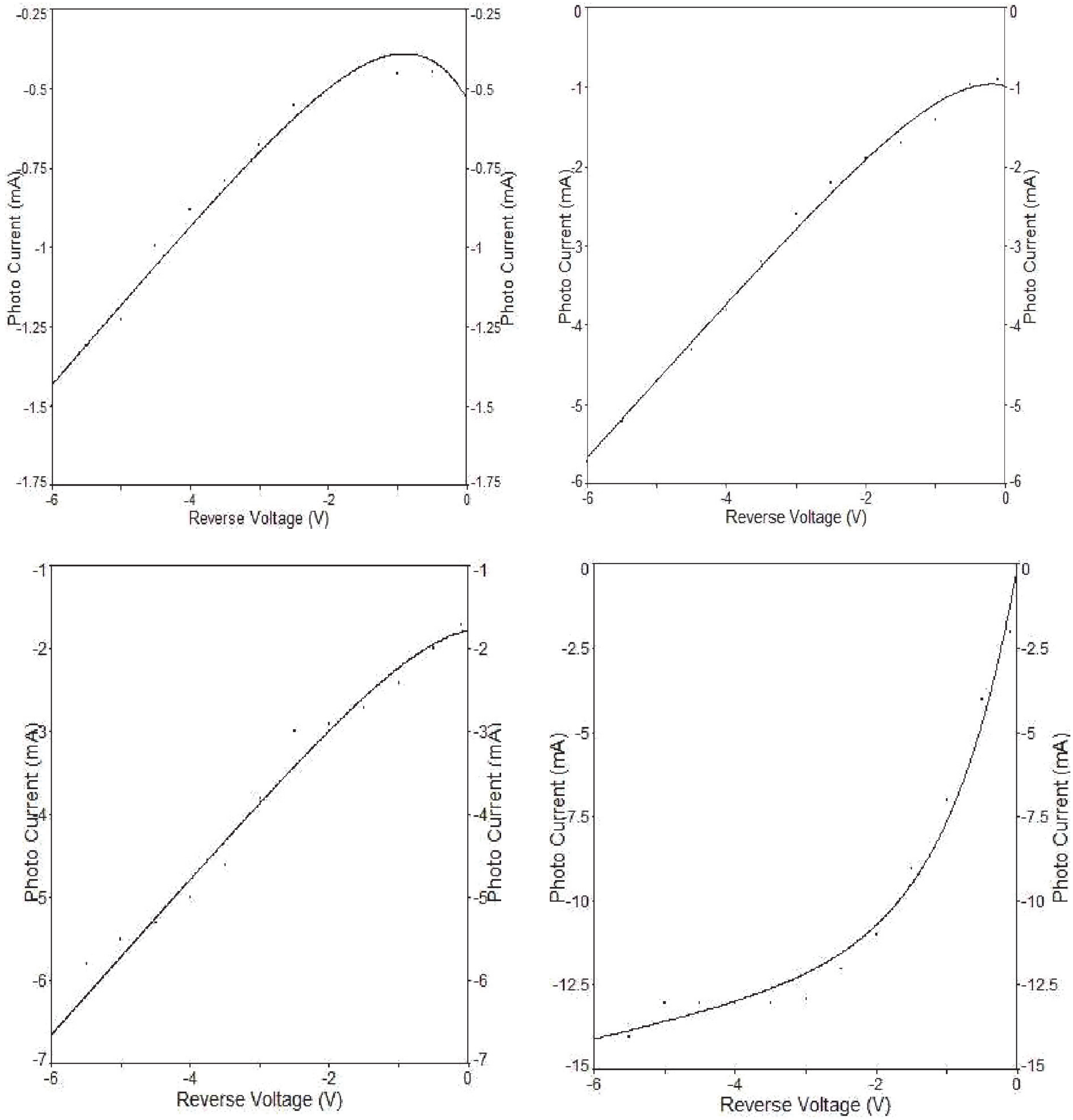

Fig. 3: Fitting curve for (J- V) characteristics of SnO_2/n-Si hetero- junction at different irradiation time of Gamma ray under illumination 9.5 mW/cm^2 (a)t=0 (b) t=50min. (c) t=100min. (d) t=150 min.

Table 1: The parameters of estimated theoretical equation for each

Parameter	t=0	t=50min.	t=100min.	t=150min.
r^2	0.98238324	0.99554651	0.97945149	0.98240537
a	0.092584638	0.19556622	-0.991842	-11.273046
b	0.25439975	0.97807204	0.94331305	0.47470885
c	-0.61885915	-1.1749158	-0.7871057	11.140469

Where r^2 represents correlation factor between practical curve and fitting curve. Each parameter are plotted against irradiation time as illustrated in figures (4- 6), and we take the fitting curves.

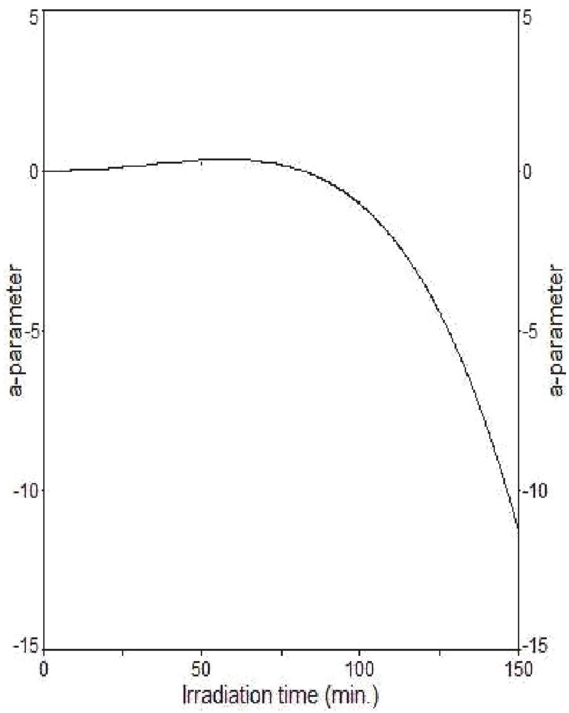

Fig.4: The relation between irradiation time and a-parameter

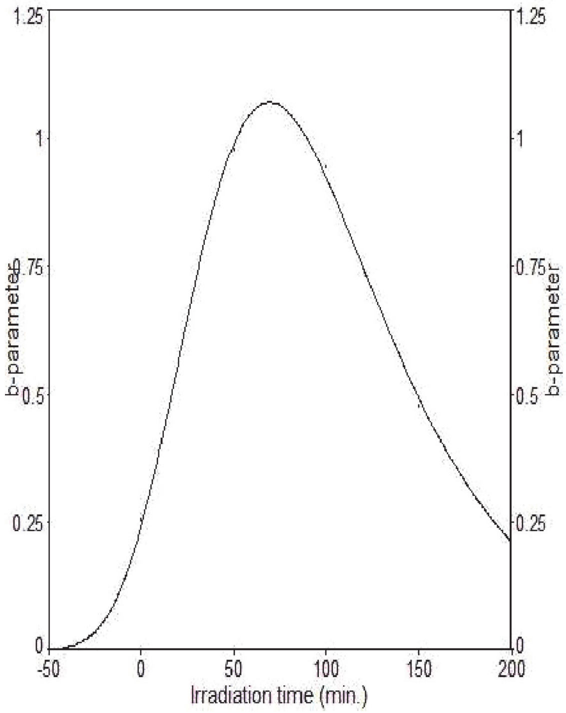

Fig.5: The relation between irradiation and b-parameter

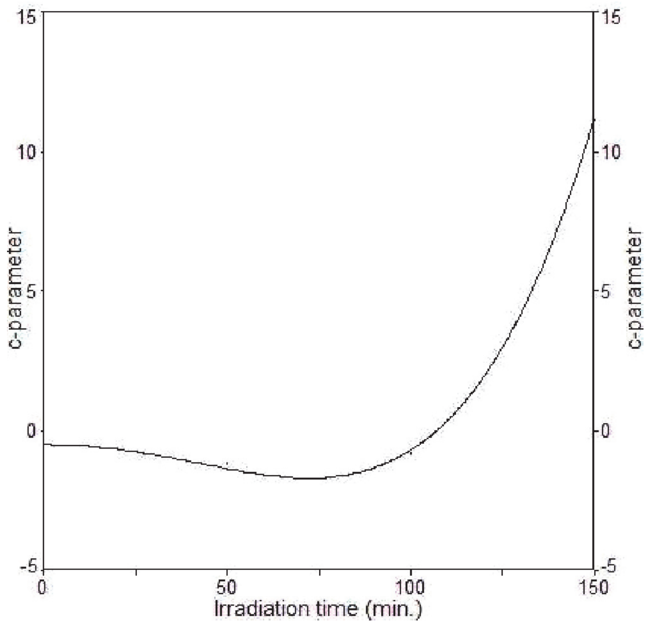

Fig.6: The relation between irradiation time and c-

The fitting equations above figures are given as follows:

Fitting equation for a-parameter:

$$Y = 0.0010280888 + 0.00021192571x^2 - 3.1670611e^{-8}x^4 \quad (2)$$

Fitting equation for b-parameter:

$$Y = 1.0699296exp\left(-exp\left(-\left(\frac{(x-69.134544)}{51.678836}\right) - \left(\frac{(x-69.134544)}{51.678836}\right) + 1\right)\right) \quad (3)$$

Fitting equation for c-parameter:

$$Y = -0.49653988 - 0.00045241676x^2 + 4.3069934e^{-8}x^4 \quad (4)$$

In order to calculate the final parameters of estimated theoretical equation (eq. (1)), we choose two test irradiation times (t=75 and 125 min.) in eqs. (2, 3 and 4).

At t=75min., theoretical modeling equation is:

$$Y = 0.19103228 + 1.0633123x - 1.6786245e^{x} \quad (5)$$

At t=125min., theoretical modeling equation is:

$$Y = -4.4197155 + 0.7028081x + 2.9495688e^{x} \quad (6)$$

Then, the theoretical (J- V) curves for these two test irradiation time of Gamma ray were plotted with experimental data as shown in figure 7. The theoretical photo current of SnO_2/.n-Si hetero-junction devices was observed to be increased with increasing reverse voltage and increasing the time of exposure to irradiation with Gamma ray. There is a good matching between the behavior of theoretical and experimental curves.

As well as this modeling enable us to study (J- V) characteristics of SnO_2/.n-Si hetero-junction devices irradiated with Gamma ray at any time of exposure under illumination 9.5 mW/cm^2 at room temperature that will not take experimentally.

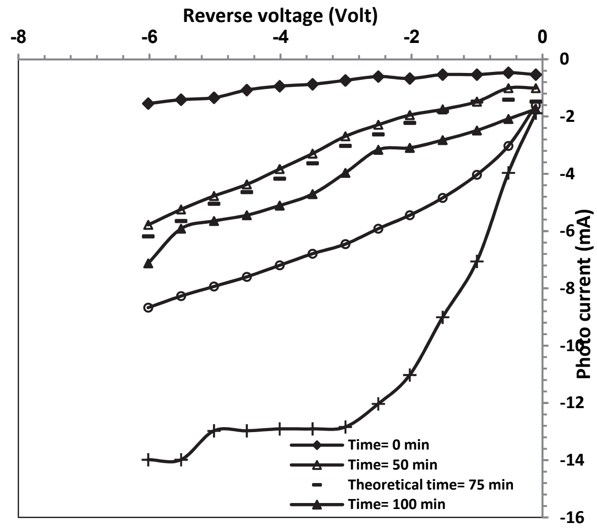

Fig.7: Effect of irradiation time of Gamma ray (theoretically and experimentally) on the (J-V) curve for SnO_2/n-Si hetero-junction devices

To estimate theoretical modeling equation, we take first the fitting curves and fitting equation for (J- V) curve at each case of power intensity of illumination. Figures 8. (a, b, c, d and e) show the fitting curves for (1.95, 2.88, 3.78, 5.9, and 9.5) mw/cm^2, respectively. The fitting equation that is described to estimate theoretical equation is given as follow

$$Y= a+ b\,x +c\,e^x \qquad (7)$$

The parameters (a, b and c) of this equation are given in table 2.

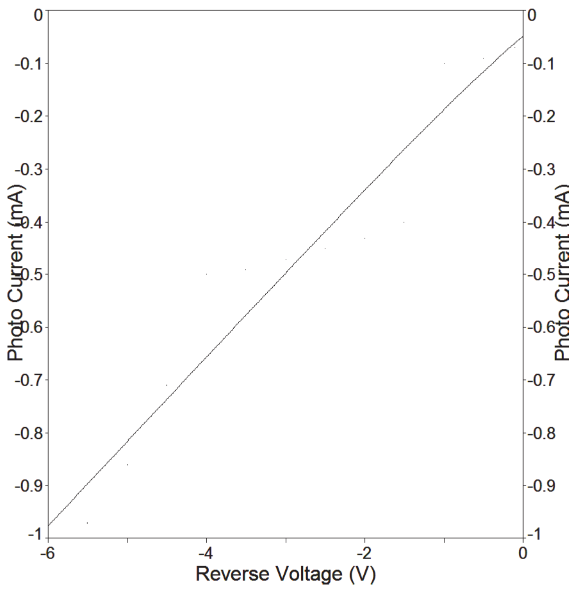
Photo Current (mA)
Photo Current (mA)
Reverse Voltage (V)
0
-0.1
-0.2
-0.3
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-0.6
-0.7
-0.8
-0.9
-1
-6
-4
-2
0

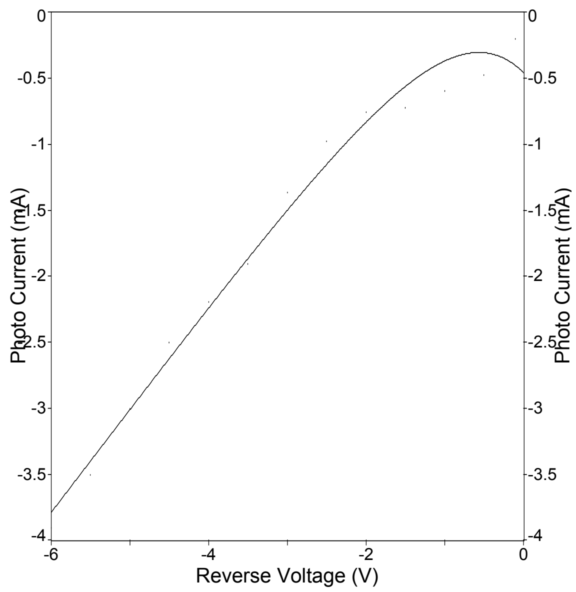
Photo Current (mA)
Photo Current (mA)
Reverse Voltage (V)
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-2
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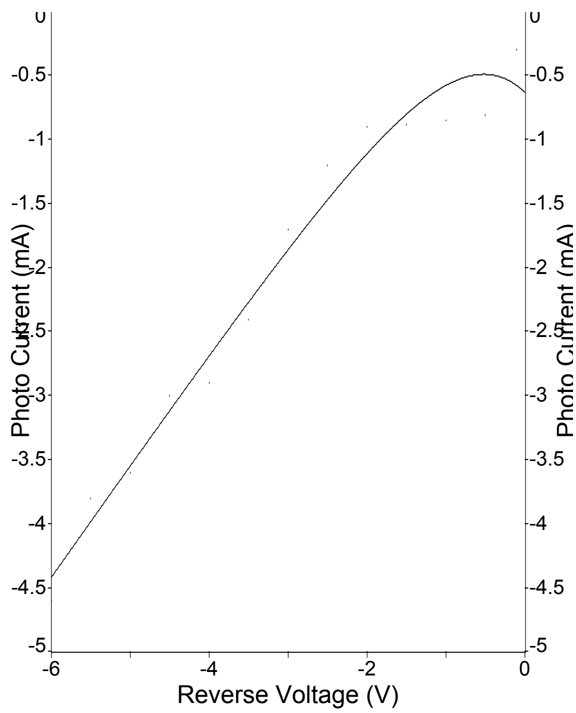
Photo Current (mA)
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-2
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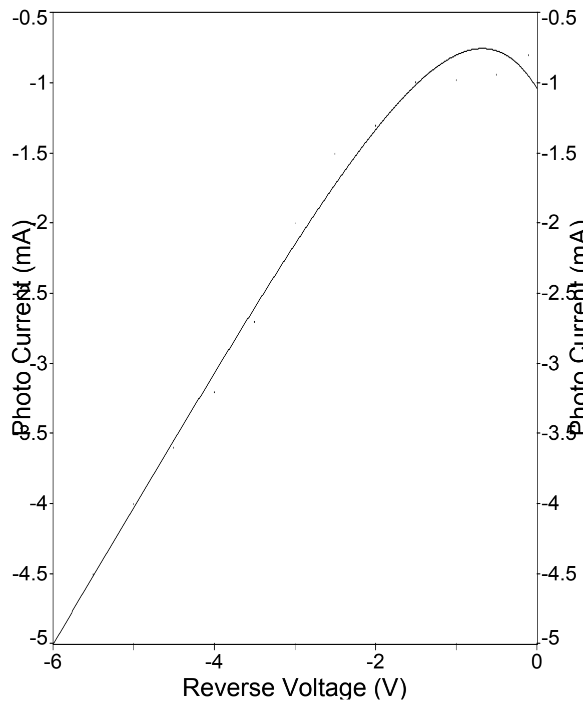
Photo Current (mA)
Photo Current (mA)
Reverse Voltage (V)
-0.5
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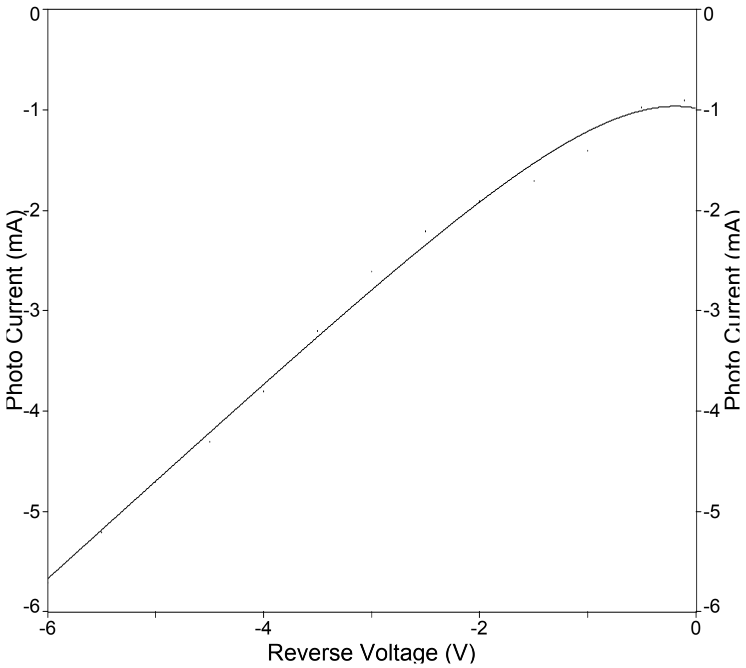

Fig. 8: Fitting curve of (J- V) characteristic of SnO_2/n-Si Hetero-junction at different power intensity of illumination (a-1.95mw/cm^2 b-2.88mw/cm^2 c-3.78mw/cm^2 d-5.9mw/cm^2 e-9.5mw/cm^2)

Table 2: The parameters of theoretical modeling equation

parameter	**1.95mw/cm^2**	**2.88 mw/cm^2**	**3.78 mw/cm^2**	**5.9 mw/cm^2**	**9.5 mw/cm^2**
r^2	0.93394781	0.98654198	0.97648263	0.99303263	0.99554651
a	-0.014660442	0.92650509	0.83815806	0.88976577	0.19556622
b	0.16030628	0.785382	0.87562762	0.98119679	0.97807204
c	-0.033342193	-1.3830564	-1.47349	-1.9280001	-1.1749158

The r^2 represents correlation factor between practical curve and fitting curve. Each parameter was plotted as function of power intensity of illumination as shown in figures (9-11). The fitting curve was taken for each curve and the fitting equation is writing over the curve.

Fitting equation

$$y = -3.7053158 + 0.55405702\ x^2 - 0.40330694\ x^{2.5} + \frac{14.835513\ \ln x}{x}$$

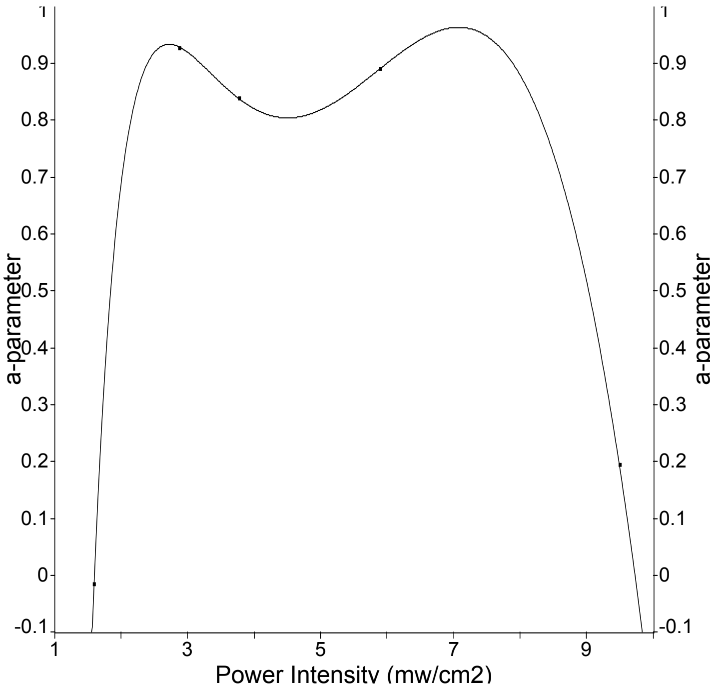

Fig. 9: The relation between a-parameter and the power intensity of illumination

Fitting equation

$$y = 8.7488762 + 0.059424533\ x^{1.5} - \frac{1.6985123\ x}{\ln x} - \frac{9.8879756\ \ln x}{x}$$

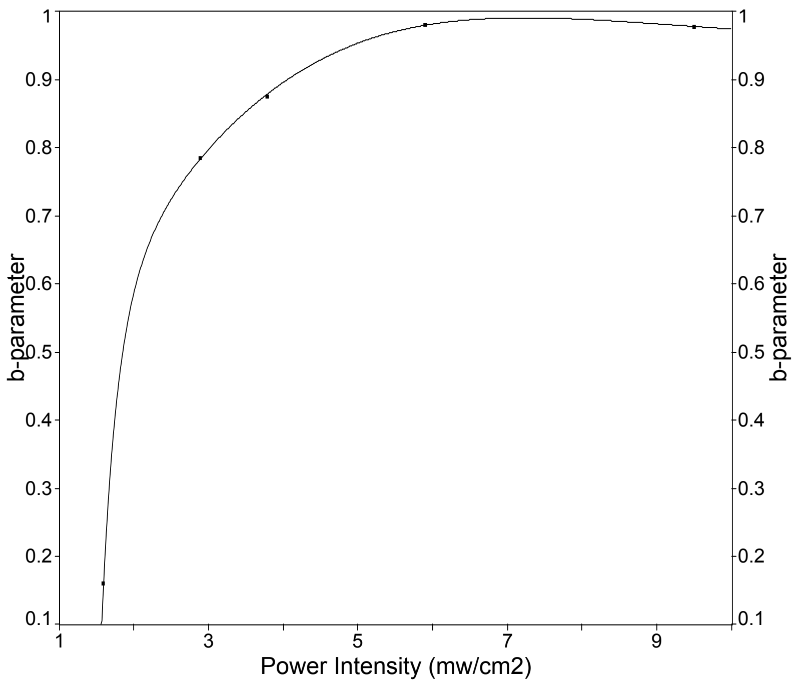

Fig.10: The relation between b-parameter and the power intensity of illumination

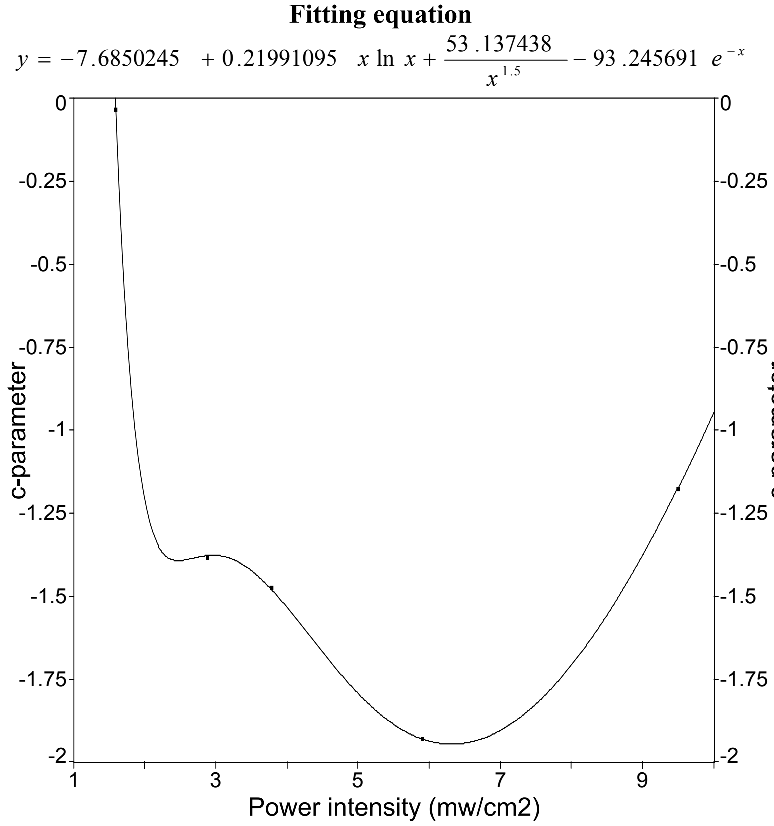

Fig.11: The relation between c-parameter and the power intensity of illumination

After that, we have calculated the parameters (a, b and c) to estimate theoretical equation (eq.7) by substituting test power intensity of illumination first 4mw/cm^2 and second 8mw/cm^2 in the above fitting curve and equation so that we get the theoretical modeling equation as follows

For test power intensity 4mw/cm^2

$$Y = 0.81983693 + 0.89649072x - 1.5312539e^{x} \quad (8)$$

For test power intensity 8mw/cm^2

$$Y = 0.88079493 + 0.98882241x - 1.709604e^{x} \quad (9)$$

These theoretical modeling equations are plotted with experimental data as shown in figure 12. We noted that the behavior of both curves is symmetrical and there is a good matching between them.

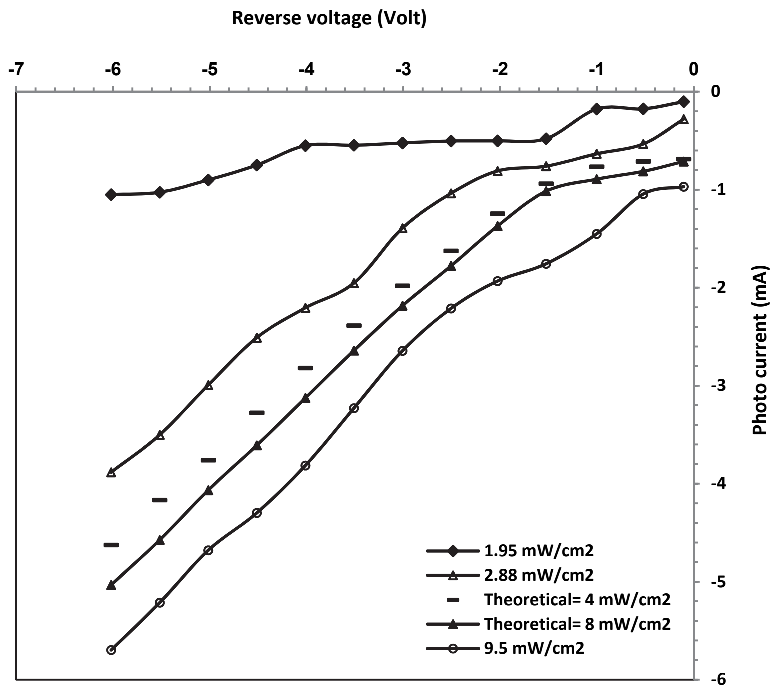

Fig.12: Theoretical and experimental (J- V) curve for SnO_2/n-Si Hetero-junction device irradiated with 150min. Gamma ray at different power intensity of illumination

4. Conclusion

From the analysis for the effect of irradiation time to Gamma ray on the SnO_2/.n-Si hetero-junction devices under power intensity 9.5mW/cm^2 at room temperature, we conclude that there is positive proportionality between photo current and reverse voltage and irradiation time. So, we obtain a good SnO_2/.n-Si hetero-junction device at irradiation time 150min. which has greater photo current passing through the device. For the importance of the effect of irradiation time to gamma ray and its effect on efficiency of solar cell, we estimate theoretical model for this experimental data by using "Table curve 2D, version 5.01"and make fitting curve for all (J- V) curve. The theoretical modeling equation is as follows: **Y=a + bx +c e^x**. We have achieved this equation for two test irradiation times T=75 and 125min. This equation is not achieved experimentally and plotted the (J- V) curve for these theoretical curves with experimental curves. We obtain a good symmetry between these two behaviors. In addition modeling give us the ability to plot (J –V) curve at any irradiation time to Gamma ray which is not taken experimentally. The effect of illumination on the SnO_2/n-Si Hetero-junction devices irradiated with 150min Gamma ray was achieved in this work experimentally and theoretically. A highly symmetric behavior between experimental and theoretical (J-V) characteristics of this device is obtained. The theoretical modeling equation was: **Y=a + bx +c e^x** contains a linear term and an exponential term. This is similar to experimental curve.

References

[1] R. Riveros, E. Romero, and G. Gordillo, "Synthesis and Characterization of Highly Transparent and Conductive SnO_2: F and In_2O_3: Sn thin Films Deposited by Spray Pyrolysis", Brazilian Journal of Physics, **36** (3B), September, (2006)

[2] Th Diana, K. Nomita Devi and H. Nandakumar Sarma, "On the optical properties of SnO_2 thin films prepared by sol-gel method", Indian Journal of Physics, **84** (6), pp. 687-691, (2010)

[3] Woon-Seop Choi, "Effects of Seed Layer and Thermal Treatment on Atomic Layer Deposition-Grown Tin Oxide", Transactions on Electrical and Electronic Materials, **11** (5), pp. 222-225, October 25, (2010)

[4] Viviany Geraldoa, Luis Vicente de Andrade Scalvib, Evandro Augusto de Moraisa, Celso Valentim Santillic, Sandra Helena Pulcinellic, "Sb Doping Effects and Oxygen Adsorption in SnO_2Thin Films Deposited via Sol-Gel", Materials Research, **6** (4), 451-456, (2003)

[5] Smritimala Sarmah and A. Kumar, "Optical properties of SnO_2 nanoparticles", Indian Journal of Physics, **84** (9), (2010)

[6] Novinrooz, Abdoljavad, Sarabadani, Parvin, Garousi, Javad, "Characterization of Pure and Antimony Doped SnO_2 Thin Films Prepared by the Sol-Gel Technique", Iran. J. Chem. Chem. Eng. **25** (2), (2006)

[7] J. Shewchun, J. Dubow, C. W. Wilmson, J. F. Wager, "The operation of semiconductor–insulator–semiconductor solar cells. Experiments", J. Appl. Phys., **50**, 2832-2839, (1979)

[8] R. Plattner, W. Stetter and P. Kohler, "Transparent Conductor Tin– Oxide Layers for Thin–Film Solar Cells", Siemens Forsch- Entwick – Ber Bd. 138-146, (1988)

[9] S. J. Fonash, "Metal-Insulator-Semiconductor solar cells: theory and experimental results", Thin Solid Films, PP 387-392, (1976)

[10] K. L. Chopra, "Transparent conductors-a status review", Thin Solid Films, **102**, 1-46, (1983)

[11] G. William, "Intensity effects in SnO_2-Si heterojunction solar cells", Transaction on Electron Devices, ED-**24** (4), (1977)

[12] Keshaw Singh and R. Y. Tamakloe, "Power output of Al/ SnO_2/n-Si solar cell", Solar Energy, **56** (4), PP 343-348, (1996)

[13] J. Gerl, Nuclear Physics A, **752**, pp.688c–695c, 2005

[14] Theodore A. Rapach and Melanie A. Pelcher, Department of Physics and Astronomy, University of Rochester, Rochester, NY 14627

[15] Arthur H. Compton, the Physical Review, **21** (5), May, 1923

[16] Kogan, R.M., Nazarov, I.M., Fridman, S.D, Israel Programme for Scientific Translations, 1971

[17] Marwa A .Hassan, Evan T. Salem and Ibrahim R. Agool, "Effects of Gamma Radiation on Optoelectronic properties Of Au/SnO_2/n-Si (MIS) Heterojunction Devices", International Conference on Mathematical Applications in Engineering (ICMAE'10), Kuala Lumpur, Malaysia, 3-5 August (2010)