



Purposeful scientific research is a basic pillar for the advancement of Iraq



Effect of Electromagnetic Radiation at Vs, IR, UV on the Properties of Ordinary Si Diode with an Exposed Device

Abdullah H. Ibrahim¹, Faris S. Atallah¹, Musab S. Mohammed²

¹Department of Physics, College of Science, University of Tikrit, Salahaddin, Iraq.

²Department of Physics, Faculty of Education, University of Mosul, Nineveh, Iraq.

abdallh.hussen@uomosul.edu.iq, f-s.atallah@tu.edu.iq wesamusab_67@uomosul.edu.iq

ABSTRACT

The effect of electromagnetic radiation on the properties of ordinary Si diode with exposed device, studied in was the framework of using visible light sources (VS), of wavelength (630-650nm), wavelength (532±10nm) and wavelength (405nm), i.e. red laser, green laser and blue-violet laser, respectively. As well as ultraviolet (UV) and infrared (IR), where sources with wavelengths (395nm) (850 nm) were used, respectively. As well as to using transistor (2N3773) as diode, by using base and emitter pins. Then we calculate and scheme the $V-I$ in-state forward bias characteristic curve for the diode in two states with and without the effect of radiation, and compared between them. Where we getted to barrier potential is equal to (13.548 V) for exposed diode device without effect for electromagnetic radiation where (12.885 V), (12.626 V), (11.818 V), (13.425 V) and (13.366 V), the first three values are for visible light, the fourth value for ultraviolet radiation, and the fifth value for infrared radiation, According to the order of wavelengths above. The frontal resistance was also calculated from the curve for the knee region, and the regions before and after the knee.

Keywords: Radiation; Diode; Exposed Device; Characteristic Curve; Visible light; Ultraviolet; Infrared.

1. Introduction

Numerous researchers have looked into semiconductor devices' radiation effect. Numerous papers that offer experimental data on the impact of radiation on silicon devices have been published [1-3]. Irradiation has a significant impact on the characteristics of semiconductor diodes and other semiconductor devices. The $(V-I)$ characteristic curve is altered as a result, changing both branches. The type of semiconductor, the device's design, and the operating circumstances all affect how big such changes will; As a result, the degree of forward $(V-I)$ characteristic deformation and changes in reverse characteristics can occasionally be used to predict the radiation stability of diodes. Consequently, it is challenging to develop a comprehensive criterion for the radiation, stability of diodes, in contrast to transistors [4].

The maximum allowable saturation current or its permissible percentage rise is often the radiation stability criterion for germanium diodes, for which the reverse branch experiences the majority of changes. The criteria for radiation stability for silicon diodes also include a specific maximum allowable change, either in the voltage drop on the forward branch or the forward resistance, as these parameters are affected by radiation and exhibit changes in the forward $(V-I)$ characteristics [4].

Electronics and their parts and components have become increasingly popular in recent years. Evidently, there is a chance that injecting external electromagnetic fields will cause the electrical system to produce unsettling indications. The danger posed by electromagnetic, pulse radiation, which might inadvertently cause or purposely, because of their proximity to electronic devices, pair into the high-frequency environmental signal—typically in the need for a microwave to get more attention. It would be tragic and unthinkable if the electronic systems malfunctioned or were destroyed. The semiconductor devices could sustain long-term harm from the electromagnetic radiation [5-10].

It's one of the fundamental components of all contemporary the $(p-n)$ junction is a semiconductor device. It serves as the foundation for the majority of optical devices and field effect transistors (light-emitting diodes, and lasers). Therefore, accurate $(p-n)$ junction characterization is essential for the creation of electrical devices for each new material system [11].

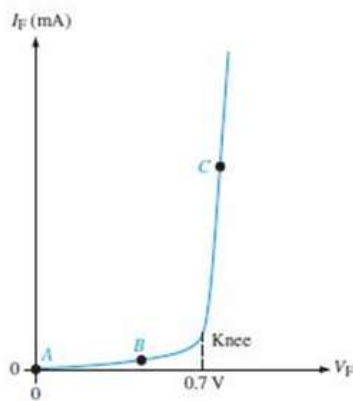
The performance of the semiconductor diode with an exposed device is discussed in this study in terms of the various electromagnetic pulse (EMP) impacts and damage processes [12].

2. Theory

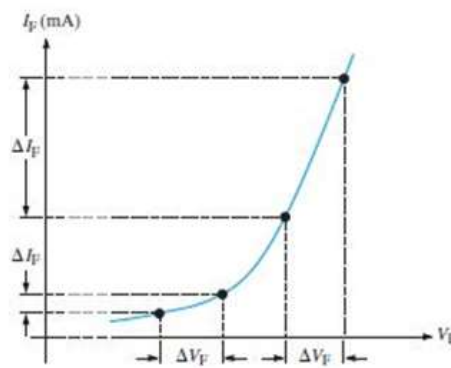
2.1. The characteristic diode's curve.

When a forward-bias voltage is applied across a diode, there is current. This current is called the forward current and is designated " I_F ". The resistor is used to limit the forward current to a value that will not overheat the diode and cause damage.

With 0 V across the diode, there is no forward current. As you gradually increase the forward-bias voltage, the forward current and the voltage across the diode gradually increase. A portion of the forward-bias voltage is dropped across the limiting resistor. When the forward-bias voltage is increased to a value where the voltage across the Si diode reaches approximately 0.7 V (barrier potential), the forward current begins to increase rapidly[13].



(a)



(b)

Fig. 1: Relationship of voltage and current in a forward-biased diode

(a) V-I characteristic curve for forward bias. (b) Expanded view of a portion of the curve in part (a). Resistance of forward for diode R_f decreases as you move up the curve, as indicated by the decrease in the value of $\Delta V_F / \Delta I_F$.

As can see in **Fig. 1(a)**, the forward current increases very little until the forward voltage across the pn junction reaches approximately 0.7 V at the knee of the curve. After this point, the forward voltage remains nearly constant at approximately 0.7 V, but " I_F " increases rapidly. As previously mentioned, there is a slight increase in " V_F " above 0.7 V as the current increases due mainly to the voltage drop across the dynamic resistance. The " I_F " scale is typically in mA, as indicated[13].

Three points A, B, and C are shown on the curve in **Fig. 1(a)**. Point A corresponds to a zero-bias condition. Point B corresponds to **Fig. 1(a)** where the forward voltage is less than the barrier potential of 0.7 V. Point C corresponds to **Fig. 1(a)** where the forward voltage approximately equals the barrier potential. As the external bias voltage and forward current continue to increase above the knee, the forward voltage will increase slightly above 0.7 V. In reality, the forward voltage can be as much as approximately 1 V, depending on the forward current[13].

The barrier potential in terms of the density of the impurity atoms that prove its existence is [14]:

$$V_B = \frac{KT}{q} \ln \left(\frac{N_A N_D}{n_i^2} \right) \dots \dots (1)$$

The minority-carrier densities and the current densities for the forward-bias and reverse-bias conditions. It is interesting to note that the hole current is due to injection of holes from the p-side to the n-side [14].

The hole diffusion current in the n-side

$$I_p = I_0 \left[\exp \left(\frac{qV}{KT} \right) - 1 \right] \dots \dots (2)$$

Similarly, we obtain the electron diffusion current in the p-side

$$I_n = I_0 \left[\exp \left(\frac{qV}{KT} \right) - 1 \right] \dots \dots (3)$$

Where $I_0 = \frac{qD_p p_{n0}}{L_p}$ in the n-side and $I_0 = \frac{qD_n n_{p0}}{L_n}$ in the p-side

The total current is given by the sum

$$I = I_p + I_n = I_0 \left[\exp \left(\frac{qV}{KT} \right) - 1 \right] \dots \dots (4)$$

2.2. Resistance of Forward For Diode.

Fig. 1(a) depicts the (V – I) characteristic curve, in part (b) the resistance of forward for diode. The

resistance of the forward-biased diode is not constant along the entire curve, in contrast to a linear resistance. The obstruction of a forward-biased diode is so named because it varies as you move along the $(V - I)$ characteristic curve. Instead of the normal R , diode resistances are typically identified by the letter R_f . Forward diode resistance is abbreviated R_f [13].

For a given change in voltage. Because the current increases so little below the curve's knee, the resistance is highest.

$$R_f = \frac{\Delta V_F}{\Delta I_F} \dots (5)$$

The resistance starts to drop around the curve's knee, and is at its lowest above the knee, where there is a significant for a specific change in voltage, the change in current [13].

3. Results and Discussion.

Fig. 2 displays the circuit diagram for the operation, which includes a variable power supply, a voltmeter, an ammeter, a 470Ω resistor, (2N3773) NPN power transistor, electromagnetic radiation sources and wires.

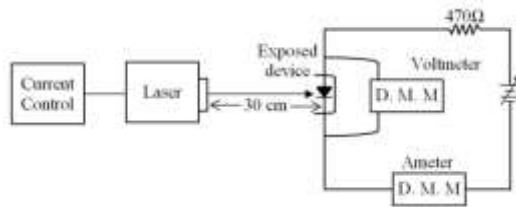


Fig. 2: The circuit diagram of the operation

Electromagnetic radiation's impact on the characteristics of ordinary Si diode with the exposed device, was first studied without any effect except at pre-illumination of the laboratory room, V_F and I_F starting from $0.001V$ and $0.1 \mu A$ at zero voltage bias,

as shown in **Fig. 3(a)** where the barrier potential approximately equal to $13.548 V$. The resistance of forward of a diode is $9089.233 K\Omega$ before the knee of the curve's area, and after it is $1.825 K\Omega$.

V Fig. 3 (b) shown the diode's $V - I$ characteristic curve under effect the ultraviolet of wave length (395 nm) whose agree with the diode's $V-I$ characteristic curve without effect, where V_F and I_F starting from $0 V$ and $1.1 \mu A$ at zero voltage bias, the barrier potential approximately equal to $13.425 V$. As well as the effect of infrared of wave length (850 nm), with barrier potential approximately equal to $13.366 V$, We note that the characteristic curve up to the current axis, by increasing the voltage even reaches approximately barrier potential the region of the knee become consist, that also happen for visible light of wave length (630-650 nm), and power of sores $5 mW$. the barrier potential approximately equal to $12.885 V$ for last effect.

Also from the **Fig. 3 (b)**, we note that both infrared and ultraviolet radiation do not affect the shape of the curve, as they are completely compatible with the original curve without any effect, where the effect is on the voltage barrier and the forward resistance of the curve, before and after the knee, While the effect of the red laser light is also in the shape of the curve, where the knee area has a wider arc than it is in the previous effects.

Now the resistance of forward of a diode for effects it find in **Fig 3(b)**, we can calculated for region before the knee region it equal to $6874.601 K\Omega$, $1030.842 K\Omega$ and $541.665 K\Omega$ for ultraviolet, infrared and laser of red light respectively. but the resistance of forward of a diode after the knee region for ultraviolet is $2.137 K\Omega$, infrared is $0.441 K\Omega$ and laser of red light is $0.885 K\Omega$.

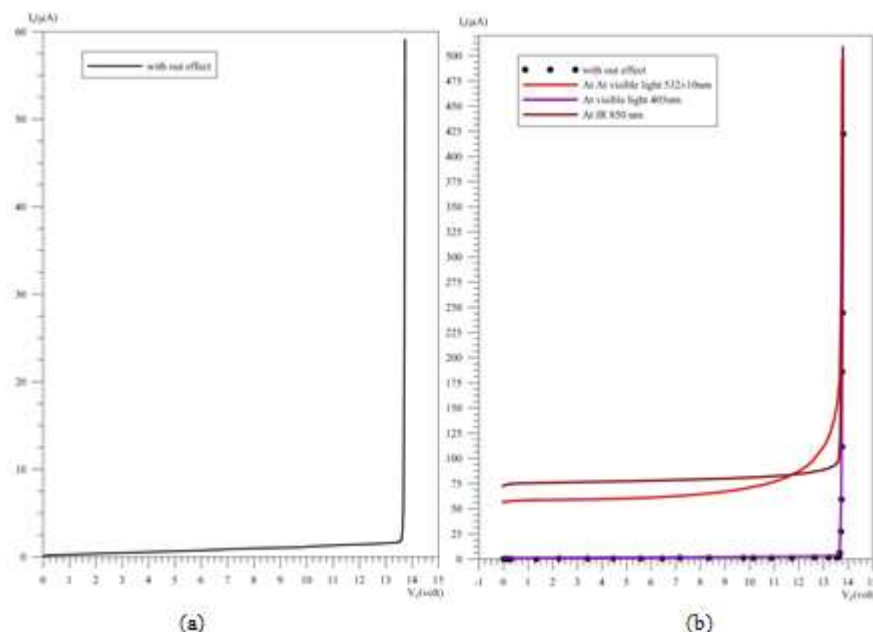


Fig. 3: Electromagnetic radiation has an impact on the relationship between voltage and current in a forward-biased diode.

In **Fig. 4** comparison between effect of lasers green light and blue-violet light with general state at power of source 100 mW, the barrier potential approximately equal to 12.626 V and 11.818 V for blue-violet light and green light respectively.

The resistance of forward of a diode for effects it find in **Fig. 4** is 59.737 K Ω and 65.789 K Ω for blue-violet light and green light respectively, for region before the knee region, and after region the knee 0.192 K Ω and 0.117 K Ω .

The effect of electromagnetic radiation for all sources it used was on the barrier potential and the resistance

of forward of a diode before the knee region, where we have noticed that the barrier voltage is less than what it is in the normal case, as well as the forward resistance of the diode in the knee region and before and after the knee region, except for one case in which the front resistance is higher than the normal case, which is the region after the knee under the effect of ultraviolet radiation.

The V_F and I_F in **Fig. 4** starting from -0.2 V and 366.2 μ A for green light, and -0.414 V and 1209 μ A for blue-violet light at zero voltage bias.

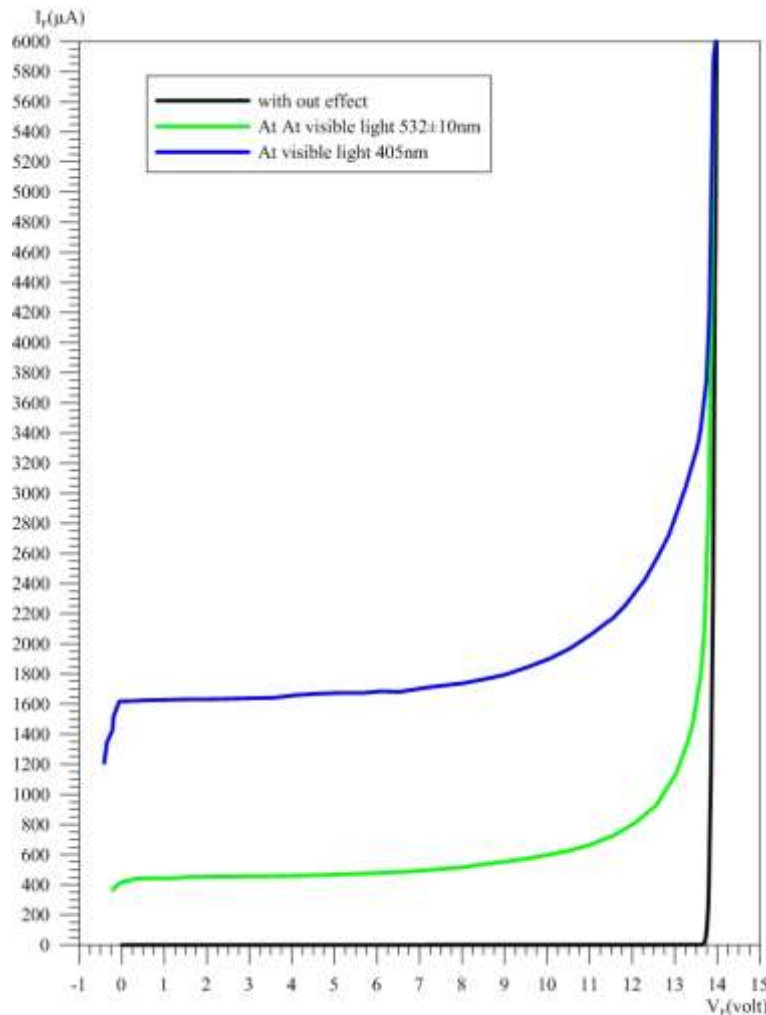


Fig. 4: Electromagnetic radiation has an impact on the relationship between voltage and current in a forward-biased diode.

3. Conclusions

In this paper and as demonstrated in fig.3(a), fig. and fig.3(b), the effects of UV, IR and laser of red light on the curve agreement with the normal case in terms of behavior, where in fig. 4 the behavior was different. The effect of electromagnetic radiation was changed the barrier potential of the pn junction,

where this change can be considered as a measure of wavelength. As well as to the sliding of the bias current to up on the current axis, which magnitude varies from one wavelength to another. This is another parameter that can be used to measure or detect electromagnetic radiation.

References

- [1] N.A. Hastas. et al. Effects of gamma-ray irradiation on polycrystalline silicon thin-film transistors. *Microelectron Reliab.* 43.1. (2003) 57.
- [2] S. Zhang. et al. The effects of operating bias conditions on the proton tolerance of SiGe HBTs. *Solid-State Electron.* 47. 10. (2003) 1729.
- [3] Sanaa A. Kamha, F.A.S. Solimanb. Environmental conditions effect on characteristics of some unijunction and bijunction semiconductor devices. *Nuclear Instruments and Methods in Physics Research. A* 564 (2006) 463–470.
- [4] V. S. Vavilov and N. A. Ukhin. Radiation Effects In Semiconductors and Semiconductor Devices. Library of Congress Catalog Card Number 76-17409.(1977) chap. 2.
- [5] C. Kopp and R. Pose. The Impact of Electromagnetic Radiation Considerations on Computer System Architecture. Dept. of Computer Science, Monash University, Clayton, Victoria, Australia.
- [6] S. Krishnan . G. Sanjeev. M. Pattabi. Electron irradiation effects on the Schottky diode characteristics of p-Si. *Nuclear Instruments and Methods in Physics Research. B* 266 (2008) 621–624.
- [7] High Power Microwave Technology and Effects, University of Maryland Short Course Presented to MSIC Redstone Arsenal, Alabama August 8-12, 2005.
- [8] S. M. Hwang. J. I. Hong. and C. S. Huh. Characterization of the susceptibility of integrated circuits with induction caused by high power microwaves. *Progress In Electromagnetics Research. PIER.* 81. (2008) 61-72.
- [9] V.V. Shurenkov. On the physical mechanism of interaction of the microwave radiation with the semiconductor diodes. *Advanced Materials Research.* 1016. (2014) 521-525.
- [10] X. Fei, C. Bing and L. Chenglong. Damage efficiency research of PCB components under strong electromagnetic pulse. *Applied Mechanics and Materials.* 130-134. (2012) 1383-1386.
- [11] J. U. Lee, P. P. Gipp, and C. M. Heller. Carbon Nanotube P-N Junction Diodes. *Applied Physics Letters.* 85.1. (2004) 145-147.
- [12] V. V. Shurenkov, V. S. Pershenkov. Electromagnetic Pulse Effects And Damage Mechanism On The Semiconductor Electronics. *Electronics and Energetics .*(2016).621 – 629. *Electronics and Energetics .* 29. 4. (2016) 621 – 629.
- [13] T. L. Floyd. *Electronic Devices.* Tenth edition, Conventional current version. Boston : Prentice Hall, (2017) chap. 2 .
- [14] S. M. Sze and Kwok K. Ng. *Physics of Semiconductors Devices.* Library of Congress Cataloging-in-Publication Data is available. (2017) chap.2.