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Influence of Pulsed Nitrogen Laser on Silicon Solar Cells Efficiency

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Abstract: *This study focuses on the effect of pulses Nitrogen laser (N_2) on the electrical properties and the efficiency of silicon - solar cells. A nitrogen laser light (λ = 337.1nm) wavelength and (400mJ) energy was used to irradiate the solar cells for different periods of time. The current and voltage (I–V) were measured at room temperature. In addition, the short circuit current (I_{sc}), the open circuit voltage (V_{oc}), the fill factor (FF) and the efficiency of the solar cells were studied. The present results show that the solar cells efficiency was increased with time exposure increased. The efficiency of unirradiated solar cell was 13.5% while it increased by 46% after irradiate for 20 minutes. In view of this remarkable intensity increase, it is recommended to use pulse N_2 laser to influence the efficiency of Silicon solar cells.*

Keywords: Solar cell, Silicon, N_2 laser, efficiency, radiation intensity

Introduction

A solar cell, or photovoltaic cell, is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect, which is a physical and chemical phenomenon .(Mohammed *et all*,2016) It is defined as a device whose electrical characteristics, such as current, voltage, or resistance, vary when exposed to light(Christiana, Stuart, 2013). Solar cells are the building blocks of photovoltaic modules, otherwise known as solar panels. Solar cells are described as being photovoltaic irrespective of whether the source is sunlight or an artificial light. (Dobrzanski, Drygala, 2008). They are used as a photo detector (for example infrared detectors), detecting light or other electromagnetic radiation near the visible range, or measuring light intensity (Costas, Grigoropoulos, 2009**)**. The main objective of solar cell industry is focused on improving cell efficiency and lowering the cost of production (Konica, 2015). One of the most important requirements for enhancing power conversions efficient light energy absorption is over the entire solar spectrum causing carrier generation in a material (Kaisa, 2011). The main task of photovoltaic is to reduce the cost of electricity produced by solar panels. The most obvious trend in the manufacture of solar cells is replacing most expensive technologies with new ones (Matthew, Craig 2010). That is why the investigations are currently being carried out to use the laser technologies in different stages of solar cells fabrication: creation of contact structures (laser scribing for buried contacts, laser-fired contacts, depth-selective laser ablation, and thin film selective removal), surface texturing to reduce reflection, deposition of transparent conductive oxides, laser doping,(Tiwari, Mishra 2012).The application of laser radiation for crystalline silicon solar cells manufacture is especially prospective for the following reasons. The technologies of silicon solar cells production are almost perfected, and the struggle for fractions of a percent in their efficiency improvement is carried out (Matthew, Craig 2010). The silicon solar cells are the basis of photovoltaic power engineering. If a wire is connected from the cathode (N-type silicon) to the anode (P-type silicon) electrons will flow through the wire. The electron is attracted to the positive charge of the P-type material and travels through the external load (meter) creating a flow of electric current (abdalsakhi, *et all* ,2016). The hole created by the dislodged electron is attracted to the negative charge of N-type material and migrates to the back electrical contact (Ahmeed,*et all*, 2020). As the electron enters the P-type silicon from the back electrical contact it combines with the hole restoring the electrical neutrality (Rawia, *et all,* 2021). After the absorption of short laser pulses of high peak intensities silicon is heated up so that the surface is partially molten. If the absorbed energy is sufficiently high some of the material is explosively evaporated from the molten layer. Many trials have been performed to adjust etch concentration and thickness of removed layer. It can be observed that with the increase of thickness of removed layer efficiency of solar cell grows but at the same time the effective reflectance increases as well. Laser texturing of semiconductor surfaces can be utilized to capture as much of the incident light as possible. To decrease reflections and increase absorption for enhanced device performance without altering bulk properties. Light enters through the air–material interface, where a discontinuity in the index of refraction causes a portion of the wave to reflect and carry off a fraction of the incident power equal to the reflectivity. While the reduction of reflection is an essential part of achieving a high efficiency solar cell, it is also essential to absorb all the light in the silicon solar cell. (Dobrzanski, Drygala, 2008). The amount of light absorbed depends on the optical path length and the absorption coefficient. (Bunea, 2006). This paper aims to enhance Efficiency of Silicon solar cells by irradiate to pulsed Nitrogen laser.

Experimental

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Four silicon solar cells were chosen. The current –voltage (I-V) of solar cell were measured after connected the circuit which contained (Voltmeter, Ammeter, Rheostat, lamp and Silicon solar cell) as in figure (1). The solar cells were irradiated by pulse N2 laser (337.1 nm) wavelength and (400mJ) energy for different time (5, 10, 15 and 20 minutes). The open circuit voltage (V_{oc})and short- circuit current (I_{sc}) were determined were measured before and after irradiation in addition to that the fill factor and efficiency of solar were calculated. The enhancement of efficiency of solar cells also calculated.

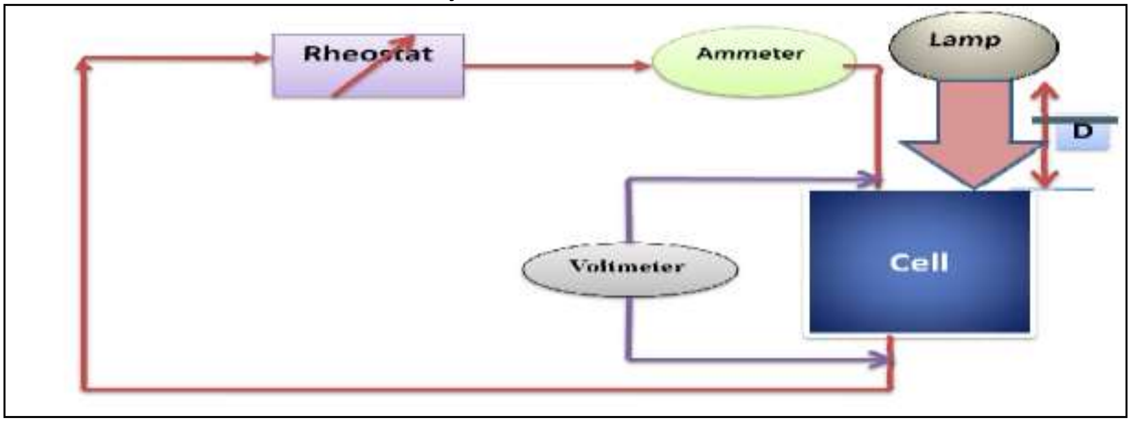

Figure (1) Schematic diagram of (I-V) characteristic experimental setup

Results and Discussion

The fill factor (FF) and efficiency(η) of all samples was calculated before and after irradiation using following relations

$$FF = \frac{P_m}{V_{oc} \times I_{sc}} = \left(\frac{I_{max} \times V_{max}}{I_{sc} \times V_{oc}}\right)$$

While efficiency of solar was calculated by using:

$$\eta_{ec} = \frac{P_{\max}}{P_{in}} = \left(\frac{V_{oc} \times I_{sc} \times FF}{I_t \times A_c}\right)$$

Characteristic curve results

Figures (2) to (5) illustrated the (I-V) curve characteristic of solar cells before and after exposure by N2 laser.

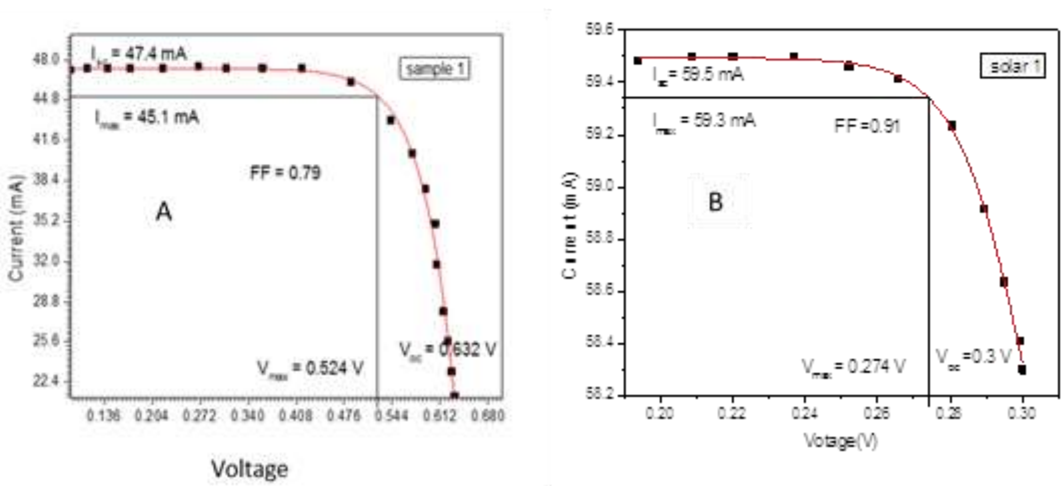

Fig (2) plot of the I-V characteristics for cell (a) before irradiation (b) irradiated for 20minutes.

Figures (2(a), (b)) illustrate that, the values of I-V curve characteristics for solar cell (sample 1). It was notes that as the influence of N_2 pulse laser, for exposure time 20 minutes, the value of Short Circuit Current (I_{sc}) was decreased from (59.5) to (47.4 mA), which related to decrease of I_{max} (59.3 -45.1 mA), it was recorded that the fill factor (ff) was decreased (0.91-0.79) as result for increasing of volts of open circuit (V_{osc}) from (0.3-0.632 v) and increasing of V_{max} (0.274-0.524v).

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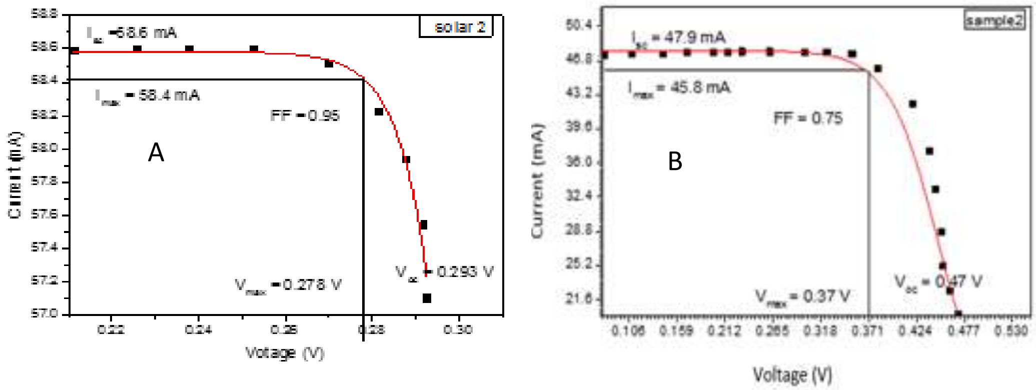

Fig (3) plot of the I-V characteristics for cell (a)before irradiation (b) irradiated for 5 minutes.

Figures (3(a), (b)) show that, the values of I-V curve characteristics for solar cell (sample 2). It was observed that, as the results of effect of N_2 pulse laser, for exposure time 5 minutes, the value of Short Circuit Current (I_{sc}) was decreased from (58.6 to 47.9 mA), as response to decrease of I_{max} (58.4 -45.8 mA), the value of fill factor (ff) was decreased (0.95-0.75) which affected by increasing of volts of open circuit (V_{osc}) from (0.293-0.47 v) and increasing of V_{max} (0.278-0.37 v).

Fig (4) plot of the I-V characteristics for cell (a) before irradiation (b) irradiated for 15 minutes.

Figures (4(a), (b)) indicate that, the current and voltage (I-V) curve characteristics for solar cell (sample 3).It was found that, as the results of effect of N_2 pulse laser, for exposure time 15minutes, the value of Short Circuit Current (I_{sc}) was decrease from (57.4 to 46.1 mA), as result of decreasing of I_{max} (57.3 -43.9 mA), the value of fill factor (ff) was found changed in range of (0.94-0.81) which affected by increasing of volts of open circuit (V_{osc}) from (0.32-0.524 v) and increasing of V_{max} (0.3-0.444 v).

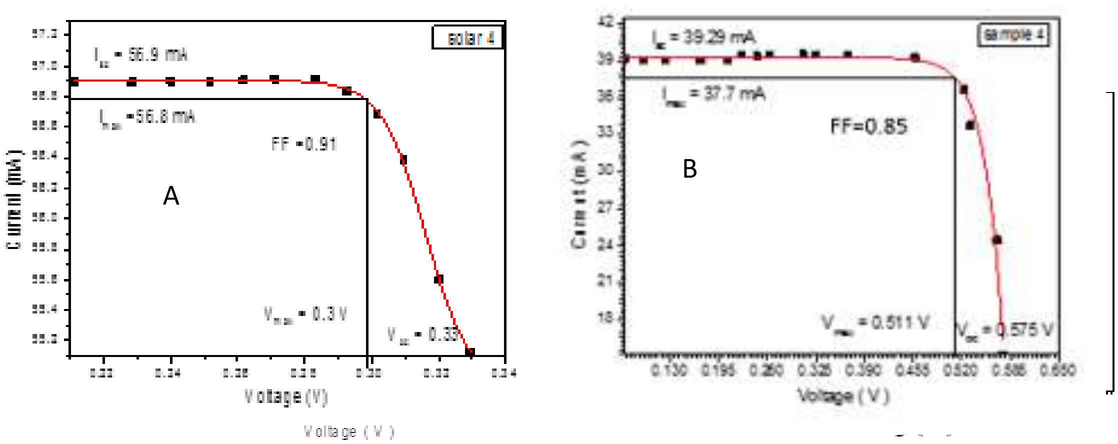

Fig (5) plot of the I-V characteristics for cell (a) before irradiation (b) irradiated for 10 minutes.

Figures (5(a), (b)) indicate that, the current and voltage (I-V) curve characteristics for solar cell (sample 4). It was found that, as the results of effect of N_2 pulse laser, for exposure time 10 minutes, the value of Short Circuit Current (I_{sc}) was decrement from (56.9 to 39.3 mA) as result of decreasing of I_{max} (56.8 -37.7 mA), the value of fill factor (ff) was found changed in range of (0.91-0.85) which affected by increasing of volts of open circuit (V_{osc}) from (0. 33-0.575 v) and increasing of V_{max} (0.30-0.51 v). In figure (1b – 4b) note that the value of fill factor was decreased for cells after exposure by pulse N_2 laser, because some of Silicon layer was evaporated.

Table (1): efficiency of solar cell before and after exposure to N_2 laser

sample	Irradiation time(s)	**η %**Un irradiated cell	**η %** irradiated cell	Enhance%
Solar 2	5	13.7	14.4	5%
Solar 4	10	14.2	16.1	13%
Solar 3	15	14.4	16.3	13%
Solar 1	20	13.5	19.7	46%

Table (1) explain the efficiency of solar cell before and after irradiated, note that the increase of time exposure (5 -20 minute) by N_2 pulse laser lead to increase of efficiency of solar cells in ranged from 5% up to 46%, these enhancement in solar cell because the light intensity incident on a solar cell play a excellent role in the decreasing of energy gap and reflectivity of silicon. Laser processing is a very good technique for texturing silicon structures due to the contactless treatment. Moreover, textures of different patterns can easily be implemented on the treated surface without any additional masking (Dobrzanski&ADrygala,2008).

Conclusions

Pulsed N_2 laser have clear effect on silicon solar cells efficiency, the highest efficiency achieves when exposed for 20 mints.

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