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Investigation of the changes in the electrical parameters of solar panels with the passage of operation time

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Abstract

After several years of using solar cells, its electrical parameters are degraded. in this paper, to simulate of aging, solar cells were exposed to the different doses of gamma radiation. The (I–V) characteristics of silicon solar cells were studied before and after gamma irradiation. Experimental results showed that the electrical parameter of solar panel such as short circuit current, open circuit voltage, and efficiency decrease with the increase of the gamma doses. As well as, dependence of V_{oc} and I_{sc} according to the absorbed dose for different illumination levels has been investigated.

Keywords: Silicon Solar Cell; Current–Voltage Characteristics; Short Circuit Current; Open Circuit Voltage; Gamma Radiation

1. Introduction

Crystalline silicon solar cells are still the mostly used element for photovoltaic solar panel. Regardless of the high standards in the production of solar panel, it has been proved that under ordinary working conditions, solar cells are prone to the effects of aging. [1]. stability of output parameters and lifetime of solar panel are of great significance. Because of radiation and aging produces similar effects in solar cells, studying radiation resistance of solar cells is interesting not only for the purpose of predicting lifespan and end-of-life output characteristics of solar cells, but also to improve design of solar cells used in high radiation environments. In this paper, to simulate and accelerate of the effects of aging on solar cells parameters, solar cells were exposed to the different doses of gamma radiation [2,3].

The irradiation of solar cells by high-energy levels of radiation in the form of gamma rays, neutrons, etc. leads to radiation defects and electrical damage in the solar cells bulk and results a significant degradation of the solar panel parameters [4].

When solar cells irradiated with gamma rays, displacement damage and ionization effects occur within it. Displacement damage is the movement of atoms from their initial location to another placement in the crystal lattice that results a defect in the crystal lattice of solar cells. Ionization effect is the generation of electron-hole pairs in the bulk of solar cell that results radiation effects. These defects mostly act as recombination centers that decreased the diffusion length and life time of minority carrier as well as increased internal parameters of cells. Output parameters of solar cell such as maximum output power (P_m), short circuit current (I_{sc}), and open circuit voltage (V_{oc}), strongly depend on internal parameters of solar cells. It has been proved that increasing each of above internal parameters of solar cell causes that the output characteristics of solar cells decreased [5-7].

Also this paper investigates output parameters of silicon solar cells in working mode, which corresponds to increased average cloud cover during the year, after being exposed to different doses of gamma radiation. Experimental results

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show that lower illumination lead to reversible changes in measured characteristics of solar cells, while higher illumination results irreversible degradations.

2. Experimental Methods

In this paper, the three samples of the silicon solar cells having same characteristics are used for experimental measurements (shown in Figure 1). The solar cells were fabricated mono-crystalline silicon structure using phosphorus diffusion into a p-type silicon wafer. The solar cell forms an n-p junction very close to the front surface by diffusing 3-4-μm-thick n-type doping into an approximately 350-μm -thick p-type silicon.

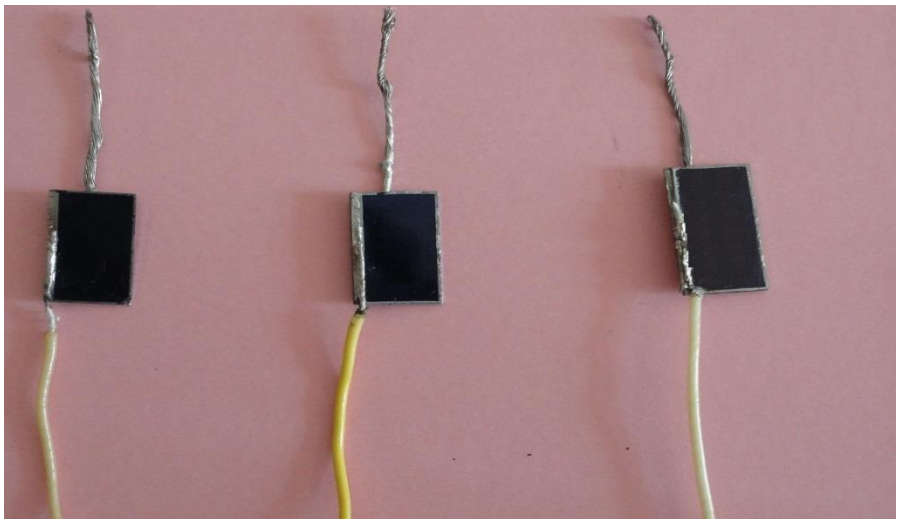

Figure 1 Mono-crystalline silicon solar cells samples

Properties of experimental solar cells samples before irradiation are:

$V_{OC} = 580\ [mv]$, $I_{SC} = 34\ [mA/cm2]$, $P_{mmp} = 34\ [mw/\ cm2]$, $\eta = 13.9\ [\%]$

All samples were irradiated with Co^{60} gamma source. The samples 1, 2, 3 were irradiated with dose 100, 1000, 2000 krad respectively. measurement of cells was carried out in 1000 W/m^2, AM 1.5, 25^0C condition.

Voltage-current (I-V) characteristics of all samples before and after irradiation were measured. To obtain of solar cells I-V characteristics samples were illuminated by reflective lamp with Light intensity equal to 1000 $\frac{w}{m^2}$.

I_{SC} and V_{OC} curve of all solar cell samples under 80 and 800 W/m^2 illumination levels before and after gamma irradiation was measured. Illumination intensity was varied by changing the distance of samples from the light source, and was controlled using a calibrated lux-meter. The measurements were carried out at room temperature with highly accurate measuring equipment.

3. Results and discussion

3.1. I-V characteristics

Voltage-current characteristics of silicon solar cell samples before and after gamma radiation doses at under AM1.5 illumination condition have been showed in figure 2. As can be seen, I-V characteristics of cells deteriorated with increasing gamma irradiation. From figure 1, fundamental parameters of solar cells such as open circuit voltage (V_{oc}), short circuit current (I_{sc}) and efficiency (η) could be extracted.

According to the results, the gamma radiation causes a significant Reduction in the short circuit current and efficiency while the open circuit voltage is slightly reduced [8,9]. The decrease in the short circuit current of solar cells under gamma radiation exposure could be related to the minority carrier life time. The minority carrier life time is sensitive

to the radiation induced defects and the decrease in the minority carrier life time reduced the electric properties of solar cells. According to results a large amount of radiation induced defects in the high dose have been formed [11-13].

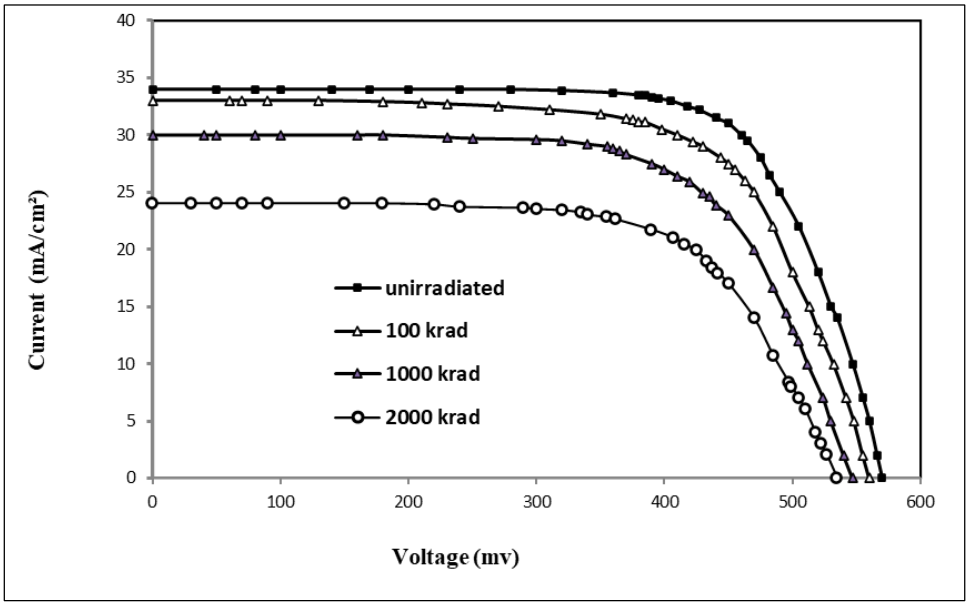

Figure 2 The *I–V* characteristics of mono-silicon solar cell irradiated with various gamma doses

3.2. solar cells parameters under working mode

The effects of gamma irradiation on measured solar cell samples was degradation of fundamental parameters but mostly these effect is on the short circuit current, since gamma radiation induced defects mainly affects the transport mechanisms in the solar cells, finally leads to the decrease of the output power of solar cells. [10]. Dependence of the short circuit current on the absorbed dose for different illumination level (80-8000 w/m^2) was shown in Figure 3. Steeper decrease of the I_{sc} for higher illumination levels demonstrate that recombination centers could be both optically activated and activated by irradiation.

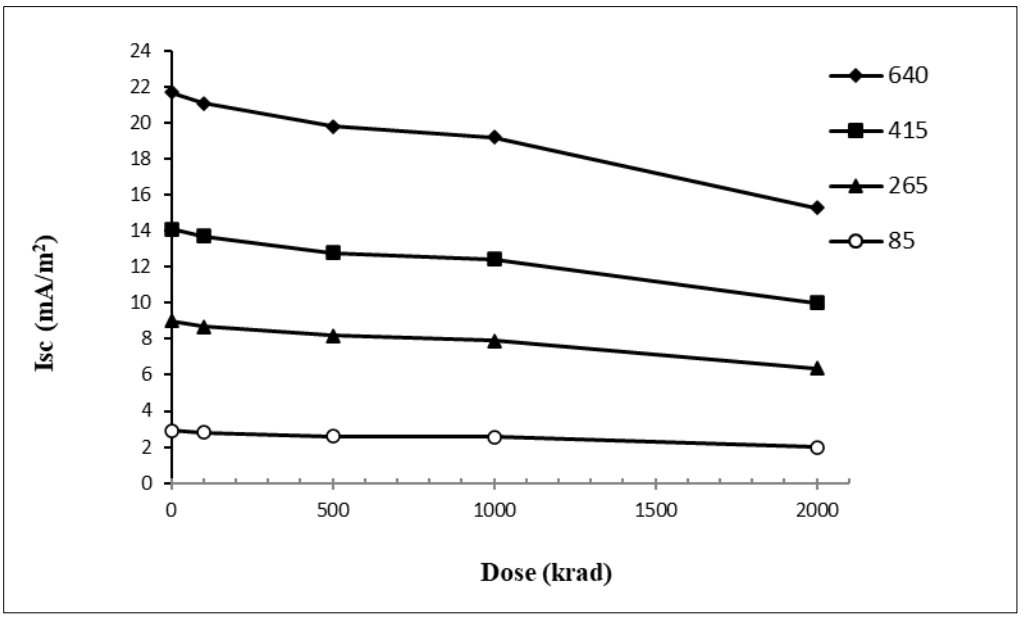

Figure 3 Dependence of the I_{sc} on doses for different illumination

The solar cells samples exposed to the higher values of solar irradiation during their performance could exhibit greater decrease in the initial, open circuit voltage value. this action was observed for the V_{oc}, Figure 4.

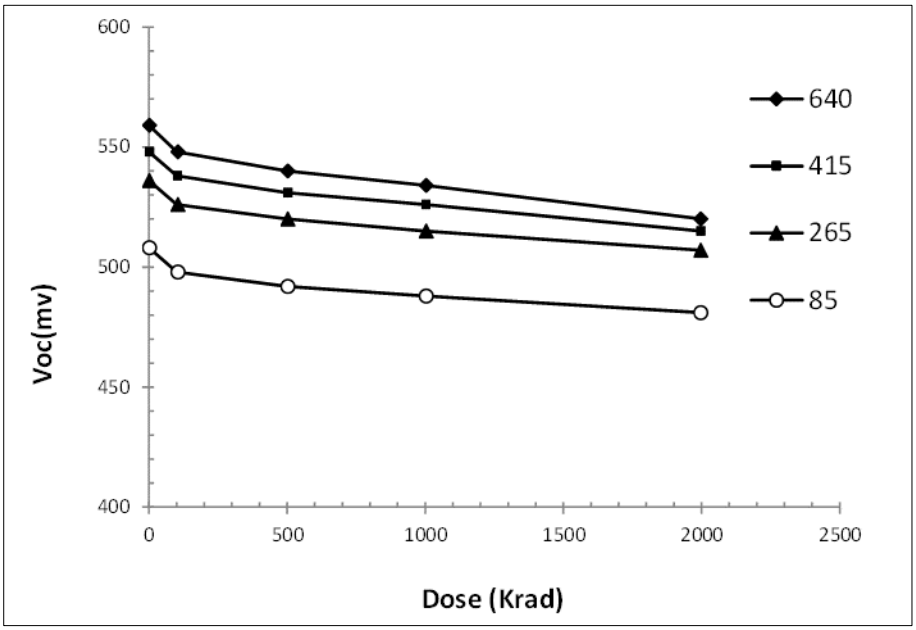

Figure 4 Dependence of the V_{oc} on doses for different illumination

4. Conclusions

Gamma irradiation and aging produces similar effects in the solar cell, to simulate of the aging effects on solar cells parameters, three solar cell samples were exposed to the different doses of gamma radiation. The effects of different doses of gamma radiation on the parameters of silicon solar cells and also output characteristics of cells in working mode after being exposed to different gamma doses have been studied and the following results were drawn:

deterioration of the electric properties of solar cells was observed when the gamma dose was increased. gamma radiation causes a significant Reduction in the I_{sc} while the V_{oc} is slightly reduced. The decrease in short circuit current is mainly related to the minority carrier life time. The life time of minority carriers is sensitive to the radiation induced defects that mostly act as recombination points, and the decrease in the minority carrier life time reduced the solar cells parameters. Examination of silicon solar cells performance in working mode showed that the aged solar cells exposed to the higher values of solar irradiation during their performance could exhibit greater decrease in the initial their parameters.

Compliance with ethical standards

Acknowledgments

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