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Research Paper

Influence of Gamma Radiation on Electric Properties of Silicon Solar Cells

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Abstract: *The change in electric properties of silicon solar cells was investigated under the irradiation of different doses of gamma ray. Experimental results showed that the external and internal parameters of silicon solar cell changed to different extent with increasing the gamma radiation doses from 50 krad to 2000 krad. At low dose, 50krad, electrical properties of silicon solar cells was improved. From 100 to 2000 krad I_{sc} and η parameters decrease proportionally with the increase of the gamma radiation doses whereas V_{oc} is only slightly decreased. Large amount of radiation induced defects in the high dose have been formed. Obtained results could lead to new designs of silicon solar to increasing their applications in radiation environments.*

Keywords: Silicon Solar cells, gamma radiation, open circuit voltage, short circuit current.

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1. Introduction:

Using the clean and free energy from the sun mono-crystalline silicon solar cells are still the best options for photovoltaic solar energy systems. The electrical characteristics of silicon solar cells are affected by environment condition. During operation of photovoltaic solar cells, they are exposed to radiation such as used in space systems and satellites. The irradiation of solar cells by high-energy levels of radiation in the form of gamma rays, neutrons, charged particles, etc. leads to radiation defects and electrical damage in the solar cells bulk and results a significant degradation of the electrical parameters of silicon solar cells [1, 2]. The lifetime and performance of the solar cells is

limited by the amount of radiation damage in solar cells. We have experimentally showed the electrical performance of solar cells using 50–2000 krad doses of cobalt 60 gamma radiation to simulate the effect of space radiation on silicon solar cell.

When silicon solar cells irradiated with gamma rays, two types of radiation damage occur within it: displacement damage and ionization effects. Displacement damage is the movement of atoms from their initial location in the crystal lattice to another placement 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 [4-6]. These defects mostly act as recombination points that decreased the diffusion length and lifetime of minority carrier.

output parameters of solar cell such as maximum output power, fill factor, efficiency, short circuit current, and open circuit voltage-P_m, ff, η, I_{sc}, V_{oc} respectively strongly depend on internal parameters of solar cells such as series resistance, Rs, saturation current, I_0 and ideal factor, n. it has been proved that increasing each of above internal parameters of solar cell causes that the output parameters of solar cells decreased [3].

The aim of this paper is to investigate output parameters of mono-crystalline silicon solar cells before and after exposed to different doses of gamma radiation.

2. Experimental Method:

In this paper, the five samples of commercially available solar cells are used for experimental measurements. The solar cells were fabricated mono-crystalline structure with using phosphorus diffusion into a p-type silicon wafer. The front surface n-type layer thickness (d_n) was 0.3 μm and the p-type base thickness (d_p) was 300 μm. All five samples were irradiated with Co60 gamma source with energy of 1.25MeV. The samples 1, 2…, 5 were irradiated with dose 50, 100, 500, 1000, 2000 krad respectively. Irradiation of cells was carried out in professional laboratory at the institute of Radiation Problems of Azerbaijan National Academy of science.

Voltage-current (I-V) characteristics and as well as Spectral Response 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 1000 w/m^2. The measurements were performed at room temperature with highly accurate measurement equipment.

3. Results and Discussion:

Voltage-current characteristics of five samples before and after gamma radiation have been showed in figure 1. As can be seen, electrical Characteristics of solar cells at low doses of gamma radiation (50 krad) improved. This means that by low doses of gamma ray aging and declined solar cell can be recovered. At higher doses (100-2000 krad) high energy of gamma radiation produces defects in solar cells that causes to deterioration in solar cell's characteristics. The measurements are normalized to the values obtained before samples irradiated.

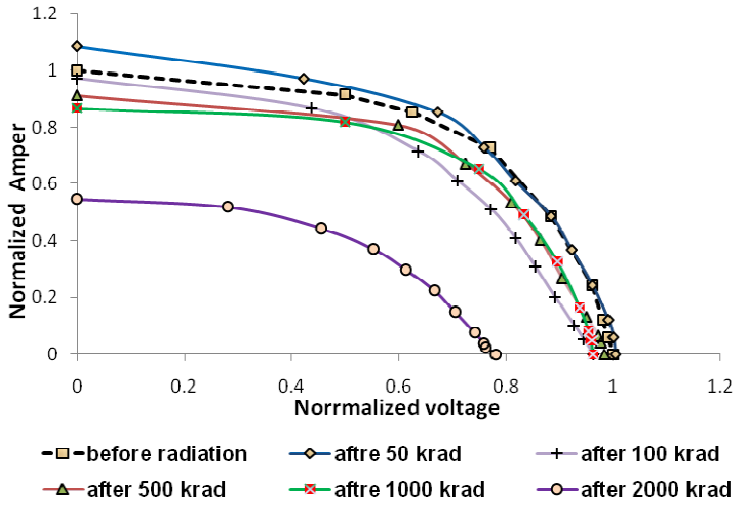

Fig 1: V-I characteristics of solar cells before and after irradiation

From figure 1, output and fundamental parameters of solar cells like maximum output power(P_m), fill factor(ff), efficiency(η), short circuit current(I_{sc}), and open circuit voltage(V_{oc}), can be extracted. Figure 2, shows the influence of gamma radiation on output parameters of five samples solar cells. As can be seen, except at low doses, gamma radiation causes a significant Reduction in the I_{sc}, Pm and η while the V_{oc} is slightly reduced. Gamma Radiation also causes changes in the fundamental and inner parameters of solar cells such as diffusion length and lifetime of minority carriers decreased and reverse saturation current(I_0) and ideal factor increased(n) [7,9].

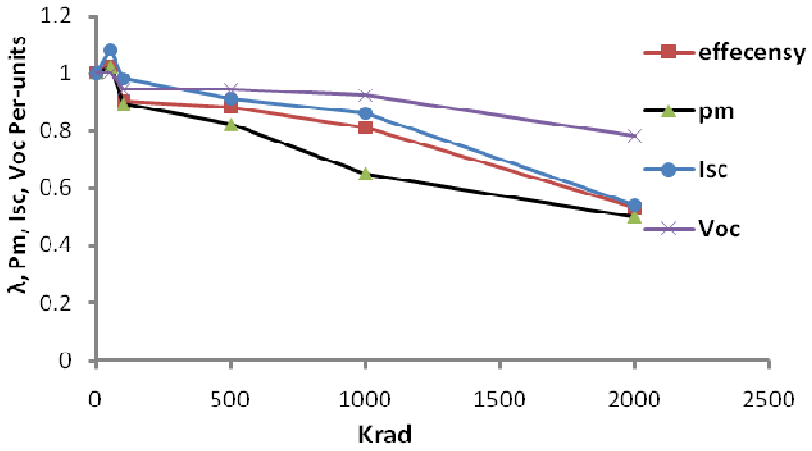

Fig 1: Output parameters of solar cells affected by gamma irradiation

The short circuit current is because of the generation and collection of light-generated carriers so it was determined as:

$$I_{sc} = q.G.P \qquad (1)$$

Where q is electron charge, G is number of carriers generated in the solar cell, and P is the collection probability of carriers. Since the amount of G remains approximately constant [10], decrease in the Isc essentially relevant to the reduced P. the collection probability of carriers depends on the surface passivation and the minority carrier diffusion length in the base. Gamma radiation causes the activation of solar cell surface and also increase defects near the upper surface ultimately

recombination is increased in the upper layer of solar cell so P is decreased. In the base layer, irradiation of ɣ ray reduces the diffusion length of minority carrier (in this layer, $L_n \langle\langle d_P$). The P value was determined as:

$$P = \frac{\alpha L_n}{\alpha L_n + 1} \qquad (2)$$

Where α is Light absorption coefficient and L_n is diffusion length of minority carrier

The open circuit voltage can be obtained using the following equation:

$$V_{oc} = \frac{nkT}{q} \ln \frac{I_{sc}}{I_0} \qquad (3)$$

According to Eq. 3, V_{oc} does not change significantly with increasing, n and I_0 and also with decreasing I_{sc}.

To further investigation of the high doses of gamma radiation effect on the solar cells, the spectral response of the samples before and after irradiation has been obtained. Silicon solar cells display acceptable spectral response to visible radiation (0.4-0.8 μm wavelength) [8]. Spectral response of three samples According to wavelength has been illustrated in Figure 3.

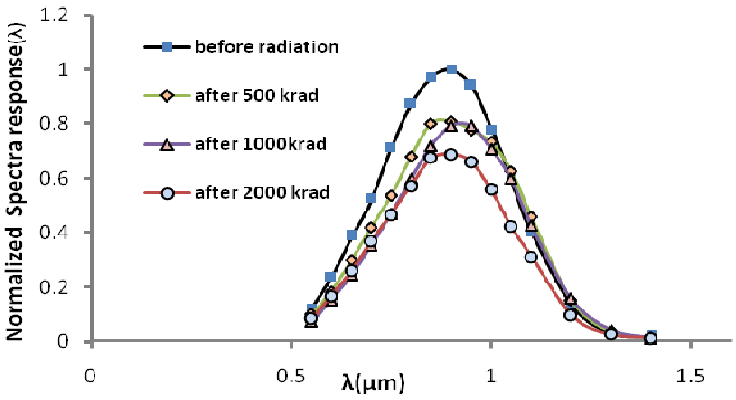

Fig 3: Spectral response of samples before and after irradiation

As can be seen, with increasing irradiation dose, reducing the current of solar cells occurred at lower wavelengths, almost blue light wavelength. This means that the effect of gamma radiation on silicon solar cells and production defects is greater in very close to the surface region. Also according to fig 3, large amount of radiation induced defects in the high dose have been formed and radiation damage occurred in the all bulk of cell.

4. Conclusions:

The changes on output parameters of five samples mono-crystalline silicon solar cells under gamma irradiation were investigated. Experimental results showed at low doses of gamma radiation the I-V characteristics of samples have improved. This means that using low doses of gamma ray the aging and declined solar cells can be recovered. A deterioration of output parameters of solar cells was observed when the gamma dose was increased (100-2000 krad). According to the results, except at

low doses, gamma radiation causes a significant Reduction on the Isc, Pm and η while the V_{oc} is slightly reduced.

Also the spectral response results showed that the more defect due to gamma irradiation was occurred very close to the solar cells surface. Obtained results could lead to new designs of mono-crystalline silicon solar cells for development of their application in different conditions.

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