



## *Experimental study of the gamma dose effects on silicon solar cells*

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### **Abstract**

In this study, the effect of gamma ray degradation on silicon solar cells at different doses was investigated and then the aging effect after irradiation was studied. In this study, solar cells were irradiated by gamma rays of the Gamma cell system of the Atomic Energy Organization of Tehran at doses of 0.5, 1, 2, 4, 8, 16 and 32 kGy (dose in water). The dose rate used here was 1.35 Gy/s and the source was cobalt 60 (5,770 Ci). The  $I_{SC}$  reduction rate was faster than the  $V_{OC}$  reduction rate, and between 4 to 8 kGy, the most changes were observed in the  $V_{OC}$  of the cells. After 32 kGy, the average open-circuit voltage and short-circuit current of the cells decreased by 5.38% and 26.16%, respectively. The aging effect over time was investigated in this study and no significant changes were observed in the electrical parameters of the cells.

**Keywords:** Displacement Damage Dose, Total Ionizing Dose, Ionization, Radiation Damage

### **Introduction**

Solar cells are one of the main candidates for power generation in missions and industry. In some missions and special situations, there is dangerous ionizing radiation that can affect the performance of the solar cell. Ionizing radiation can cause ionization damage and atomic displacement by ionizing and colliding with the atoms of the target material [1].

Gamma rays are important in terms of the depth of penetration and the discrete interactions they have with the atoms of the target material. Electromagnetic radiation interacts with the electrons of the target material, ionizing and exciting the atoms of the target material. Usually, the primary electrons separated from the atoms have enough energy to cause secondary ionization in the crystal structure of the target material. In fact, total ionization dose to the structure of the target material is due to the secondary electrons of the primary charged particles. Therefore, the study of gamma radiation damage to solar cells is a purposeful study for the resistance of solar cells to ionizing radiation [2-4].

### **Experimental**

A discrete wavelength solar simulator with 4 different LEDs (white, blue, red and infrared) was used [5-9]. This simulator has a stable light intensity of about 10 mW/cm<sup>2</sup>. Figure 1 shows the final view of the built-in simulator.

Autolab-PGSTAT101 was used to measure I-V diagram of solar cells. Figure 2 shows an overview of the Autolab system. The I-V test is the first and most

basic analysis of solar cells. In this analysis,  $V_{OC}$  and  $I_{SC}$  are determined.

The solar cell which was studied in this project is made of polycrystalline silicon, which has dimensions of 1.8×5.3 cm<sup>2</sup>. The thickness of this cell is about 150 um. The  $I_{SC}$  and  $V_{OC}$  of these cells are normally about 20 mA and 540 mV, respectively, under the discrete LED solar cell simulator light.

In this study, the gamma radiation system of the Tehran Atomic Energy Organization was used. Gamma cell is a gamma irradiation system using a cobalt 60 source. Gamma cell of Tehran Atomic Energy Organization has an activity of 5770 Ci and a dose rate of 1.5 Gy/s. Irradiation error in this system is less than 10%.

Four solar cells were irradiated in each of the doses of 0.5, 1, 2, 4, 8, 16 and 32 kGy. The reason for choosing this dose range for irradiation is the limitations of the Gamma cell device at doses higher than 32 kGy (long irradiation time) and lower than 0.5 kGy (shortest irradiation time by the device leads to this dose). Before and after irradiation, the electrical parameters of solar cells were measured by the Autolab device and the solar simulator. The I-V curves plotted by the cell analysis system indicated the  $I_{SC}$  and  $V_{OC}$  of the cells. The trend of short circuit current and open circuit voltage of cells was recorded in different doses. The effects of time after irradiation up to 10 days after irradiation were measured.

## Results and discussion

The amount of changes in open circuit voltage and short circuit current of solar cells with increasing dose received from cobalt 60 is shown in Figure 3. As shown in Figure 3, in gamma irradiation, the short-circuit current decreases faster than the open-circuit voltage. This result indicates that many of the amplifiers produced by the landing photons at the semiconductor junction are recombination centers that prevent the collection of the minority carriers produced. Gamma irradiation also reduces the forbidden energy band and thus reduces the open circuit voltage of the cells. The reduction of the forbidden band is due to the creation of permanent surface traps in the forbidden band of energy, which reduces the distance between the electrons to the conduction band. Gamma radiation has the greatest effect on the short-circuit current of solar cells.

After two weeks, the changes in the damage caused to the cells were examined by re-measuring their current-voltage curve, and no change in electrical parameters was observed. Therefore, it can be said that the damage caused by gamma irradiation in the structure of solar cells is almost permanent.

Relative voltage error for doses of 0.5, 1, 2, 4, 8, 16 and 32 kGy are 2.24, 0.79, 0.23, 1.01, 0.46, 0.60 and 0.77 percent, respectively. Also, the relative error values for current in these experiments are 2.37, 2.04, 3.70, 3.31, 7.82, 10.38 and 7.50 percent, respectively.

## Figures

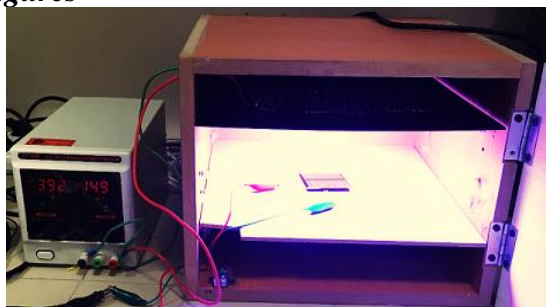


Figure 1 View of a built-in solar simulator



Figure 2 Overview of the Autolab-PGSTAT101

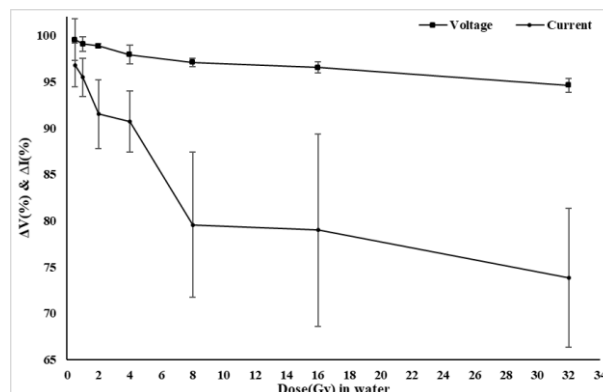


Figure 3 The amount of changes in open circuit voltage and short circuit current with increasing dose received in gamma irradiation

## Conclusions

In the study of total ionization dose, irradiation was performed for doses of 0.5, 1, 2, 4, 8, 16 and 32 kGy using cobalt 60 source located in Gamma cell of Tehran Atomic Energy Organization. The changes in gamma irradiation on the  $I_{sc}$  were much greater than the  $V_{oc}$ . As a result, gamma irradiation creates many recombination centers and traps in the semiconductor crystal, which has a significant effect on the life of minority carriers produced by visible photons. The changes in the electrical parameters of the solar cells did not change after two weeks, indicating an almost permanent effect in gamma irradiation.

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