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# The Effect of Ultrasonic Waveson the Aged Solar Cell Parameters

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**ABSTRACT:** The current–voltage characteristics of mono-crystalline silicon solar cells under AM1.5 illumination condition were studied before and after the gamma irradiation.The photoelectric parameters of mono crystalline silicon solar cells degraded under gamma radiationcan be significantrecovered by MHz-frequency ultrasonic treatment (UST). The restores of the silicon solar cells parameters such as efficiency(η), open circuit voltage (Voc), short circuit current (Isc) etc. after ultrasonic treatment is related to amount of gamma doses and radiation defects as well as time and frequency of UST.

**KEYWORDS:** silicon solar cells, gamma radiation, ultrasonic treatment, voltage- current characteristics, efficiency, solar cells

## I. INTRODUCTION

The mono-crystalline silicon solar cells are still the mostly used element for photovoltaic solar energy conversion. As is known, when the solar cells exposed to some kind of high energy radiation fields such as natural space and atmospheric, military and civil nuclear environments etc. leads to the accumulation of radiation defects in the solar cells bulk and frequently results in a significant deterioration of the photoelectric parameters of 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[1-3].

When silicon solar cells irradiated with gamma rays, the radiation damage occur within it. These defects mostly act as recombination points that decreased the diffusion length and life time of minority carrier. Photoelectric parameters of silicon solar cell such as maximum output power, open circuit voltage, short circuit current, fill factor and efficiency - Pm, $V_{oc}$, $I_{sc}$, ff, ηrespectively strongly depend on minority carrier life time (τ). Decrease in the life time of minority carrier causes that the output characteristics of solar cells decreased[4, 5].

Using the subsequent ultrasonic treatment on the degraded silicon solar cells, it is possible atoms of crystalline siliconthat have been displaced from their initial place by gamma irradiation, can be removed from their place using UST and return to the previous locationto produce the necessary correction of the cells characteristics. One traditional method of solar cells improvement is thermal annealing, but thermal annealing have received much research in recentyears. According to the results of numerous investigations dedicated to the use of acoustic methods for the recovery of characteristics of semiconductor materials, it is reasonable to expect that ultrasound treatments can be restoration in the properties of degraded silicon solar cells[6-9].

Hence the use of ultrasonic treatment for recovery of photoelectric properties of mono crystalline silicon solar cells deteriorated under gamma radiation is presented in this paper.

## II. EXPERIMENTAL METHODS

In this paper, the tow samples of the commercially mono-crystalline silicon solar cells having same characteristics are used for experimental measurements. The specifications of samples are shown in Table1. The solar cell forms an n-p junction very close to the front surface by diffusing 3µm-thick n-type doping into an approximately 300-µm -thick p-type silicon.

The tow samples were irradiated with $^{60}Co$ gamma source with the energy of 1.23 MeV. The samples A andBwere irradiated with dose 500 and 1000krad respectively. Irradiation of solar cells samples was carried out in professional laboratory at the institute of Radiation Problems of Azerbaijan National Academy of science.

Each of the samples wasconsecutively subjected to a two-stage UST using longitudinal acoustic waves, which were propagated perpendicular to the samples through piezo disk.In the first stage ($UST_1$), the ultrasonic treatment was

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performed in the following condition: frequency, $f_{UST1}$=50 MHZ, duration, t=90 m.The second stage ($UST_2$) was performed in $f_{UST2}$=50 MHZ, duration, t=240 m.

Voltage-current (I-V) characteristics of samples before and after irradiation as well as after Ultrasonic Treatment were measured. To obtain of solar cells I-V characteristics samples were illuminated by reflective lamp with Light intensity equal to 1000 w/$m^2$ (corresponding to AM1.5). The measurements were performed at room temperature with highly accurate measuring equipment.

**Table 1**
Properties of four samples of the experimental solar cells (before irradiation)

| Cells type | $V_{OC}$ [mv] | $I_{SC}$ [mA/$cm^2$] | $P_{mmp}$ [mw/ $cm^2$] | FF | η [%] |
|---|---|---|---|---|---|
| Si-monocrystalline | 570 | 34 | 14 | 0.72 | 13.95 |

Notes: Condition for measurement: 1000 W/$m^2$, AM 1.5, $25^0$C

## III. RESULTS AND DISCUSSION

*3-1. I-V characteristics under gamma radiation*

Voltage-current characteristics of two solar cell samples before and after 500 and 1000 krad doses of gamma radiation at under AM 1.5 illumination conditions have been showed in figure 1. As can be seen, I-V characteristics of cells deteriorated with increasing gamma irradiation.From figure 1, fundamental parameters of solar cells like open circuit voltage ($V_{oc}$), short circuit current ($I_{sc}$), fill factor (ff) and efficiency (η) could be extracted.

The fill factor (FF) parameter for solar cells can be expressed as

$$FF = \frac{V_{mp} \cdot I_{mp}}{V_{oc} \cdot I_{sc}} \quad (1)$$

Where $V_{oc}$ and $I_{sc}$ are the open circuit voltage and short circuit current, $V_{mp}$ and $I_{mp}$ are the voltage and the current at a maximum power point respectively.

The efficiency (η) for a solar cell is given by

$$\eta = \frac{V_{oc} I_{sc} FF}{P_{in}} \quad (2)$$

Where, $P_{in}$ is the incident light power [13, 14].

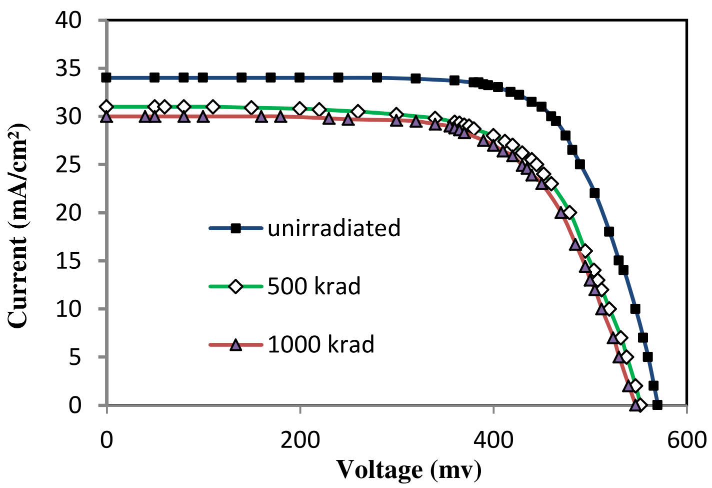


**Figure 1.** The *I–V* characteristics of silicon solar cell irradiated with various doses of gamma radiation

Figure 2 shows the changes in solar cells parameters as a function of gamma dose.The parameters are normalized to the values obtained before samples irradiated.It was found that the degradation of the solar cell parameters is dependent on the gamma radiation dose and the irradiation has affected the solar cell parameters to a certain extent. There is no substantial variation in the fill factor, which in some cases showed increased or relatively steady values. According to

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the results, the gamma radiation causes a significant Reduction in the short circuit current and efficiency while the open circuit voltage is slightly reduced.

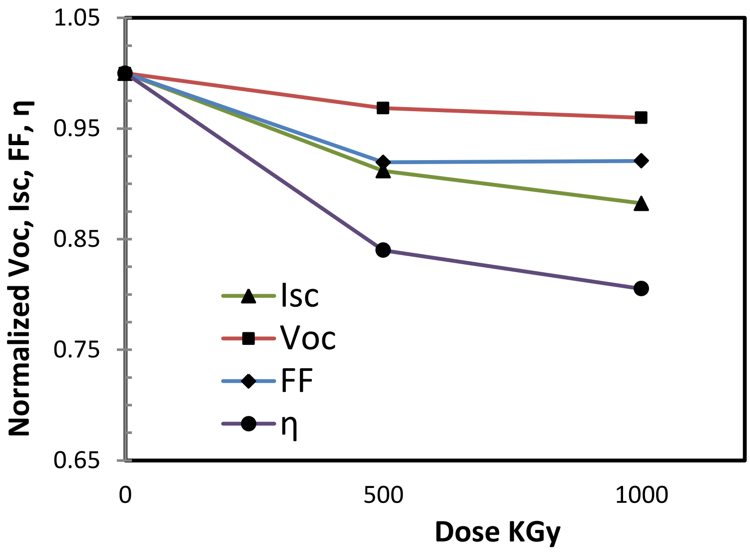


**Figure 2.** Normalized solar cell parameters as a function of gamma radiation dose

The decrease in the efficiency and short circuit current of solar cells under gamma radiation 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 alarge amount of radiation induced defects in the high dose have been formed [11-12]. The detail of solar cells parameters degraded under gamma radiation doses are shown in table 2.

**Table 2**
Degradation of solar cell parameters under gamma radiation doses

| solar cell Sample | ɣ doses $[Krad]$ | $V_{OC}$ $[mV]$ | $I_{SC}$ $[\frac{mA}{cm^2}]$ | $V_{mp}$ $[mV]$ | $I_{mp}$ $[\frac{mA}{cm^2}]$ | FF | η $[\%]$ |
|---|---|---|---|---|---|---|---|
| Mono-crystalline silicon | 0 | 570 | 34 | 450 | 31 | 0.72 | 13.95 |
| | 500 | 552 | 31 | 420 | 27 | 0.662 | 11.34 |
| | 1000 | 547 | 30 | 420 | 25.9 | 0.663 | 10.87 |

*3-1. Ultrasonic Treatment*

Figure 3and 4 shows the effect of gamma-irradiation andeach UST stage on the voltage-current characteristics of solarcells irradiated with 500 and 1000 krad doses of gamma radiation. As can be seen from these data, the subsequent USTs restore the parameters of solar cells, which become substantially closer to the initial values. The subsequent ultrasonic treatments (UST-1 and especially UST-2) improved the characteristics and shifted them toward the initial curves.

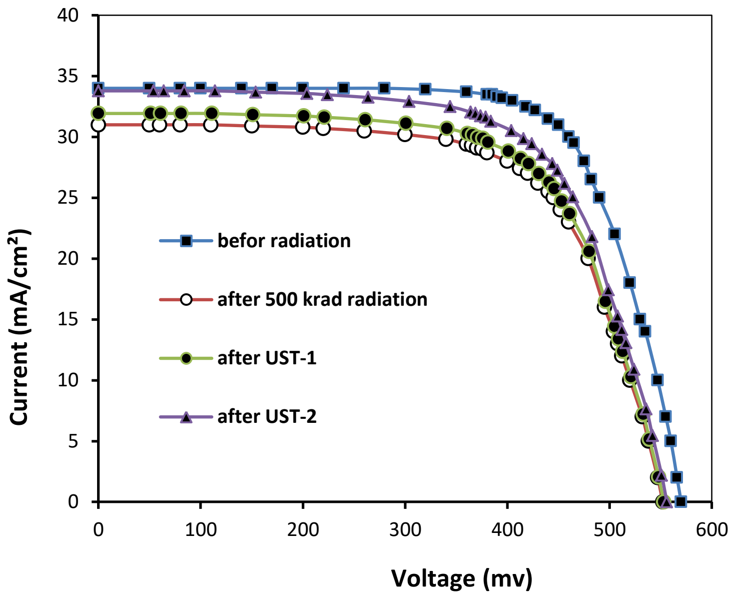


**Fig. 3.** The *I–V* characteristics of silicon solar cell before and after irradiation with 500 krad dose of gamma radiation and each stage of subsequent ultrasonic treatment

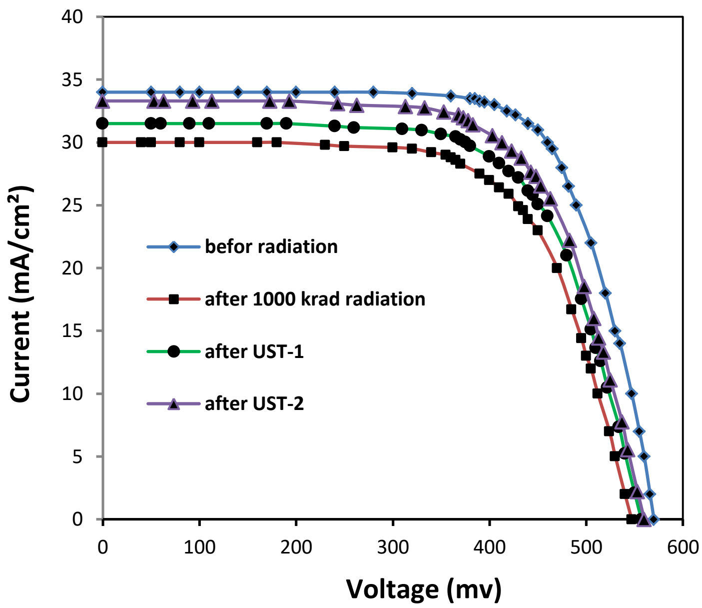


**Fig. 4.** The *I–V* characteristics of silicon solar cell before and after irradiation with 1000 krad dose of gamma radiation and each stage of subsequent ultrasonic treatment

Figure 5 shows the restore in the efficiency of solar cells degraded under gamma radiation by ultrasonic treatment. As can be seen, 10-15% improvement in efficiency was observed after $UST_{1,\ 2}$. The ultrasonic treatment causes the crystalline atoms of the solar cells exposed to gamma rays that have been displaced from their initial place, Can be removed from their place and return to the previous location where the cells showed a recovery from radiation damage [15, 16].

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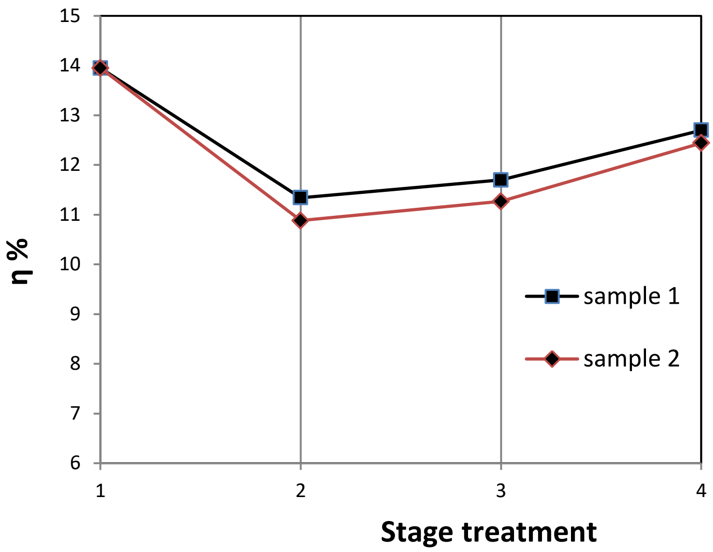


**Fig. 4. The** restore in the efficiency of solar cells degraded under gamma radiation by ultrasonic treatment, sample 1 irradiated with 500 krad and sample 2 irradiated with 1000 krad dose of gamma radiation. Measurements were carried out at room temperature for a silicon solar cell in various states: (1) initial (unirradiated) state; (2) upon gamma-irradiation to a; (3, 4) after UST-1 and UST-2, respectively.

## IV. CONCLUSIONS

Two mono-crystalline silicon solar cell samples were exposed to the different doses of gamma radiation. The effects of different doses of gamma radiation on the properties of silicon solar cells and subsequent ultrasonic treatment of solar cells degraded by gamma irradiation have been studied and the following conclusions were drawn:

- A deterioration of the electric properties of solar cells was observed when the solar cells irradiated by gamma ray (500 and 1000 krad). Except the fill factor, which in some cases showed increased or relatively steady values, gamma radiation causes a significant Reduction in the $I_{sc}$ and η while the $V_{oc}$ is slightly reduced.The decrease in short circuit current and other fundamental parameters 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.
- The ultrasonic results show the si solar cells that their efficiency is missed 20% compared to the initial value, can be recovery by UST.

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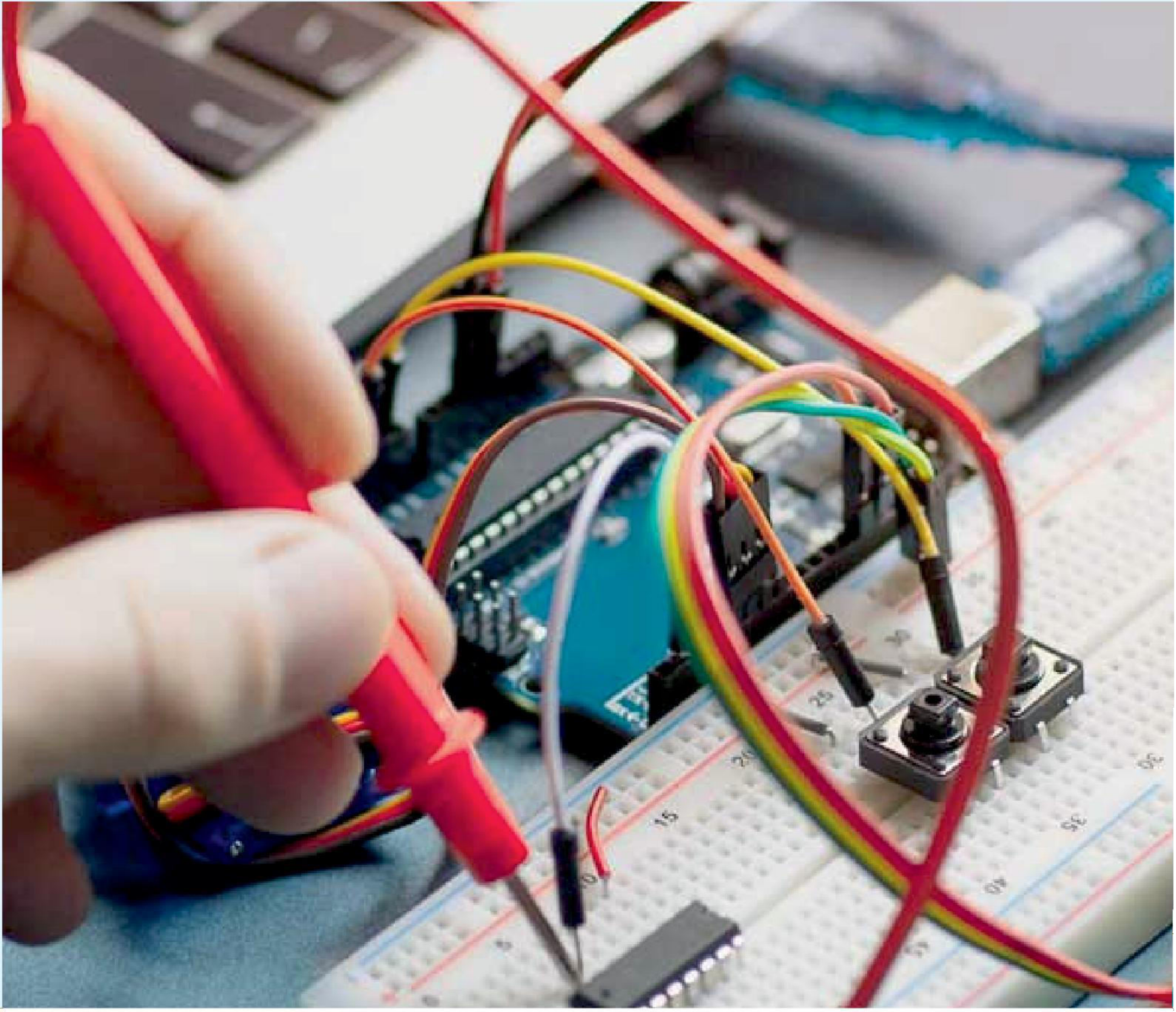


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