Effect of different radiations on Silicon Solar Panels

M.A.Iqbal, Wafa Awais and M. Naveed Iqbal*

Department of Physics,University of The Punjab, Lahore, Pakistan, iqbalma@yahoo.com
*Department of Electronics & Communication,
University of Lahore, Pakistan, munaveed2002@yahoo.com

ABSTRACT

The characteristics of different solar pannels were measured and analyzed by using their different electrical circuits. The external parameters like open-circuit voltage, fill factor, short-circuit current, maximum power point and efficiency are calculated experimentally before and after radiation. The internal parameters like shunt resistance, series resistance, ideality factor and saturation current were also evaluated before and after radiation. The external parameters are calculated from the I-V characteristics curve of the solar cell for X-rays and gamma rays of different intensities. During measurements environmental temperature was kept constant. Plots of current-voltage have been drawn in both illuminated and non-illuminated conditions and the parameters are abstracted from the corresponding graphs. It was concluded from the results that the designed parameters of the silicon solar cells under study were deteriorated when exposed to radiation.

Keywords: solar cells, current-voltage characteristics, open-circuit voltage, short-circuit current, radiation effect.

1 INTRODUCTION

Silicon cells are of two types, Mono-crystalline and Polycrystalline. Mono-crystalline cells are obtained from silicon crystal ingots that can easily be grown in 10cm diameter or 50cm in length. Silicon cells are made by different junction formation methods [1].The crystalline silicon solar cells were developed very earlier and are still most widely used [2]. Silicon solar cells are being in production since 1955.Until 1958, this production was oriented towards open-circuit voltage of the cell. It has been observed that shunt resistance (R_s) decreases more rapidly with temperature in polycrystalline silicon solar cells and less rapidly in mono-crystalline silicon solar cells. Moreover, R_S increases with temperature and ideality factor decreases with temperature [9]. Utilizing the “free energy” from the sun for the prosperity of mankind [3], single crystal silicon solar cells are the only cells available commercially having efficiencies in the range needed for photovoltaic solar energy conversion systems [4].

The properties of silicon solar cells are affected on changing the environment. Some of the environmental effects that degrade the characteristics of the silicon solar cells are discussed.

The presence of dust on the surface of the solar cells deteriorates their performance. For example, the deposition of cement particles which are present in the air reduces the short-circuit current and power of the solar cell. Similarly, presence of carbon particles also degrades the performance of the solar cell [5].Concentration of the dust and velocity of wind also produces a drop in the performance of the cell. The performance drop is larger in heavy winds as compared to light winds [6].

Solar cells, like all other semi-conducting materials are subjected to an electrical degradation Generally, solar cells are exposed to temperatures changing from 10 to 50 ^{0}C. The output parameters, open-circuit voltage, fill factor, short-circuit current and efficiency of the solar cell are temperature dependent [7]. It has been seen that V_{OC} decreases at a value of approximately2.3 mV/K whereas I_{SC} increases a little with temperature. Fill factor also decreases and so the efficiency of the cell is decreased [8].

The internal parameters of the solar cell, ideality factor (n), shunt resistance (R_{Sh}), series resistance (R_S) and reverse saturation current (I_0) control the temperature effect on the fill factor, conversion efficiency. This produces a reduction in the power, voltage and output current of the cell [10].

Different radiations like gamma ray, protons, electrons etc produce defects in the solar cell. These defects mainly act as recombination centers, as a result of which, the diffusion length of the carriers is decreased [11]. When a photon is incident on silicon, there are three phenomena may occur, 1) the photon passes through silicon, 2) the photon is reflected back, 3) the photon is absorbed which either produces heat or produces electron-hole pairs. This happens only in the case when the energy of the photon is larger than the band gap of silicon.

When a photon is absorbed, it gives its energy to the electron in the crystal lattice. This electron is present in the valence band and is unable to move because it is tightly bound in covalent bonds. The photon gives energy to this electron and it excites to the conduction band where it is free to move. In this way, the covalent bond now has one fewer electron which is called a hole. Due to the presence of a missing covalent bond, the bonded electrons of the neighboring atoms move into the hole and leave another hole behind. In this way, a hole moves through the lattice. In short, when photons are absorbed by semiconductors mobile electron-hole pairs are generated [12].

This paper deals with the effect of X-ray and gamma radiation on the output parameters of monocrystalline silicon solar cells.

1. EXPERIMENTAL DETAILS

Six batches of samples each batch contain 5 solar panel/cells were studied and these samples have a monocrystalline structure. Six samples batches (A, B, C, D, E, F) were investigated. All the sample characteristics were measured at room temperature. A degradation was observed in the dark I-V curve. samples were same having an output current of 100mA and voltage 1.5V. Sample A was not exposed to any radiation. Samples B, C and D were irradiated with energetic Co^{60} gamma radiation with a dose rate of 5Gy/min and absorbed doses 4Mrad, 6Mrad and 8Mrad respectively. Batches of samples E and F were irradiated with X-rays having energies 6.15 Mev and 11 Mev respectively.

To study the deterioration in the performance of silicon solar cells experimentally I-V characteristics were investigated in dark and light conditions before and after irradiation.

1.1 Light I-V Characteristics

To measure the illuminated I-V characteristics, a photocell was used. At one end of the box, a 60 Watt solar simulator (bulb) was clamped which can be moved in order to change the illumination intensity. Solar cell was placed on the other end of the box. The solar cell was connected to a resistance, voltmeter and an ammeter in series to measure the values of current and voltage at different illumination intensities.

The other parameters like maximum power point, fill factor and efficiency were extracted from the corresponding graphs of current and voltage.

1.2 Dark I-V Characteristics

The measurement circuit was designed to measure the dark IV characteristics before and after radiations. During measurement it the solar cell was covered to keep out the ambient light in the laboratory. Computer control variable DC power supply was used and current was monitored in the circuit and high impedance voltmeter was used to record the voltage across the solar cell.

2. RESULTS AND DISCUSSION

The I-V characteristics for batch solar cell A (non-irradiated) under both illuminated and dark were measured. Same devices characteristics were measured with the different radiation dose both using X-rays and gamma rays. High energy radiation in solar cell produces defects in semiconductor diode that causes reduction in the solar-cell output power. The reduction in the short-circuit current is a non-linear function of radiation dose. It is observed that short-circuit current is decreased rapidly with increasing radiation dose. Solar cells undergo an atomic process called ionization, when exposed to el gamma and X-rays radiation. The irradiation of solar cells produces a photocurrent, which is similar to the light generated current, proportional to the number of photons and incident particles. The amount of excess energy present in the radiations is so great that their energy is converted into heat causes defects in solar cells. Moreover, this extra energy may displace the atoms present in the crystal lattice from their regular positions and causes displacement damage.

In silicon, the dislodged atoms are subjected to some other atomic processes that proceed at a value depending on the cell temperature until equilibrium is established. The dislodged sites are electrically active and cause a reduction in the diffusion lengths and life times of the minority carriers in the cell.

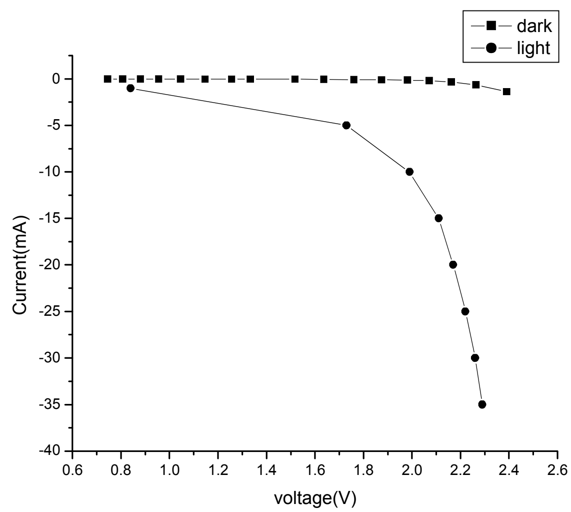

Fig.1: I-V curves of cell A under both light and dark conditions.

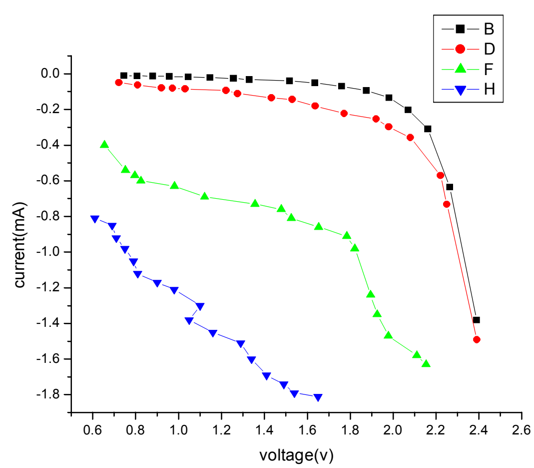

Fig.2: I-V curves of cells when exposed to gamma radiations.

Lifetime of solar cell is important for successful operation of the satellite. The current decreases with decreases diffusion lengths. The lifetime of the excess minority carrier at any point during the bombardment of high energy particle is

$$\frac{1}{\tau} = \frac{1}{\tau_0} + K\varphi \quad (1)$$

The recombination rate of the minority carriers is proportional to the initial number of the recombination centers present plus the numbers introduced introduces during bombardment. Figure 3 shows the current -voltage curves of the solar cells when exposed to X-rays radiation of energies 6.15Mev and 11Mev. It also shows a degradation in the curves as the energy is increased.

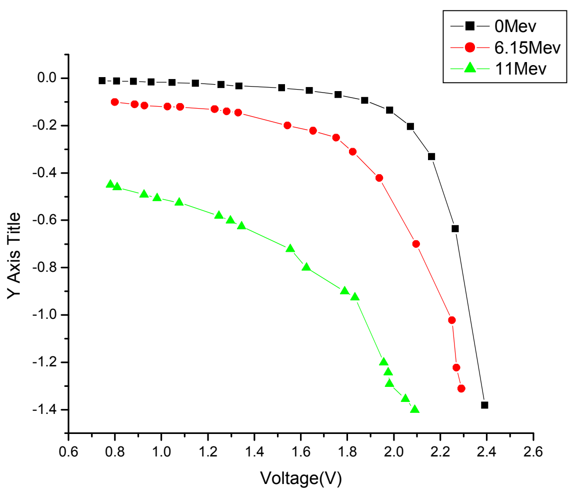

Fig.3: I-V curves of cells when exposed to X-rays

Recombination centers also proporational to flux of radiation. The diffusion length varying function with bombardment therefore

$$\frac{1}{L^2} = \frac{1}{L_0^2} + K\emptyset \quad (2)$$

In order to reduce the effect of radiation a transparent microsheet may be placed over the front surface to minimize the number of high energy particles that reach the device. We are trying to develop new transparent sheet that reduce the radiation effect o device and not effects the efficiency of the solar cell.

The effect of illumination intensity is also observed. It has been seen that there is a direct relation between the illumination intensity and voltage and current of the solar cell. Solar spectral irradiance in free space and function of solar constant also depends upon the AM0 and AM1.

3. CONCLUSION

The deterioration in the characteristics of six silicon solar cells was studied under gamma and X-ray radiation doses. A deterioration was seen for all the external parameters of the solar cell as the radiation dose is increased. The current decreases due to decreases diffusion length and also proportional to the initial number of recombination centers. Substrate diffusion length effect may be reduces by using antireflection coating.

Acknowledgements

The authors are thankful to the INMOL hospital, Lahore for providing the irradiation facility and their cooperation.

REFERENCES

[1] H. S. Rauschenbach," The principles and Technology of photovoltaic energy conversion", 161, 2001

[2] E. Radziemska, "The effect of temperature on the power drop in crystalline silicon solar cells"1-12, 2003.

[3] William C. Dickinson, Paul N.Cheremisinoff, "Solar energy Technology Handbook",517, 2002

[4] William C.Dickinson,Paul N.Cheremisinoff, "Solar energy Technology Handbook",558, 2005

[5] Mohammad S.El-Shobokshy,Fahmy M.Hussein, "Effect of dust with physical properties on the performance of photovoltaic cells",505-511,1993

[6] Dirk Goossens,Emmanuel Van Kerschaever,"Aeolian dust deposition on photovoltaic solar cells:The effects of wind velocity and airbone dust concentration on cell performance"277-289, 1999.

[7] Priyanka Singh,S.N.Singh, M.Lal ,M.Hussain, "Temperature dependence of I-V characteristics and performance parameters of silicon solar cell",1611-1616, 2008.

[8] S.M.Sze,"Physics of semiconductor devices",Wiley,New York,1981.

[9] Priyanka Singh, S.N.Singh, M.Lal,M.Hussain, "Temperature dependence of I-V characteristics and performance parameters of silicon solar cell",1611-1616, 2008.

[10] H.S.Rauschenbach,"The principles and Technology of photovoltaic energy conversion",190-19,1 2006.

[11] M. Y. Feteha,Moataz Soliman,Naima G.Gomaa,MoustafaAshry, "Metal-insulator semiconductor solar cell under gamma

irradiation”,113-120, 2002.
[12] Eduardo Lorenzo,Solar electricity: Engineering of photovoltaic systems,Progens, 1994