Advancement in Science and Technology Research
Vol. 2(3), pp. 54-66, August 2015
ISSN: 2437-1319
Review

A novel look on the materials effect on the characteristics and applications of solar systems

H. A. Ashry[1], A. Abdel Magid Abu Talib[2], M. I. M. Mahdi[2] and F. A. S. Soliman[3]*

[1]National Center for Radiation Research and Technology, Nasr-City, Cairo, Egypt.
[2]Physics Department, Faculty of Women for Art, Science and Education, Ain Shams University, Egypt.
[3]Nuclear Materials Authority, P. O. Box 530, Maadi-11728, Cairo, Egypt.

Accepted 20 August, 2015

ABSTRACT

This paper describes how measurement techniques can be used to characterize the electrical properties of solar cells made of different materials. In this concern, cells and panels made of monocrystalline, polycrystalline, amorphous and polymers were investigated. It describes how electrical characterization products can be used to evaluate the different materials to be used for manufacturing solar cells. Common techniques such as current-voltage (I-V) -, and capacitance- voltage (C-V) – characteristics, as well as photo-induced open circuit voltage decay, were shown to yield valuable information regarding the devices under test. Finally, temperature effects on the proposed different cells and panels were investigated.

Keywords: Photovoltaic cells, solar cell, impedance, I-V, C-V, materials, polycrystalline, mono-crystalline, polymer.

*Corresponding author. E-mail: fouad.saad.soliman@gmail.com.

INTRODUCTION

The history of photovoltaic energy started way back in 1876. William Grylls Adams along with a student of his, Richard Day, discovered that when selenium was exposed to light, it produced electricity (Reece, nd). An electricity expert, Werner von Siemens, stated that the discovery was "scientifically of the most far-reaching importance". The selenium cells were not efficient, but it was proved that light, without heat or moving parts, could be converted into electricity.

In 1953, Calvin Fuller, Gerald Pearson, and Daryl Chapin, discovered the silicon solar cell (Fuller, nd). This cell actually produced enough electricity and was efficient enough to run small electrical devices. The New York Times stated that this discovery was "the beginning of a new era, leading eventually to the realization of harnessing the almost limitless energy of the sun for the uses of civilization. Three years later, that is, in 1956, the first solar cells are available commercially. The cost however is far from the reach of everyday people. At $300 for a 1 watt solar cell, the expense was far beyond anyone's means. 1956 started showing us the first solar cells used in toys and radios. These novelty items were the first item to have solar cells available to consumers.

In the late 1950's and early 1960's satellites in the USA's and Soviet's space program were powered by solar cells and in the late 1960's solar power was basically the standard for powering space bound satellites (USA Space Foundation, nd). Also, in the early 1970's a way to lower to cost of solar cells was discovered. This brought the price down from $100 per watt to around $20 per watt. This research was spearheaded by Exxon. Most off-shore oil rigs used the solar cells to power the waning lights on the top of the rigs. Noting that, the period from the 1970s to the 1990s saw quite a change in the usage of solar cells. They began showing up on railroad crossings, in remote places to power homes, Australia used solar cells in their microwave towers to expand their telecommunication capabilities. Even desert regions saw solar power bring water to the soil where line fed power was not an option. Finally, today we see solar cells in a wide variety of places. You may see solar powered cars. There is even a solar powered aircraft that has flown higher than any other aircraft with the exception of the Blackbird. With the cost of solar cells well within everyone's budget, solar power has never looked so tempting. Recently new technology has given us screen printed solar cells, and a solar fabric that can be used to side a house, even solar shingles that install on our roofs. International markets have opened up and solar panel manufacturers are now playing a key role in the solar power industry.

SOLAR SYSTEMS

Silicon solar cells

In the basic unit of a crystalline silicon solid, a silicon atom shares each of its four valence electrons with each of four neighboring atoms**.** Silicon, which was used to make some the earliest photovoltaic (PV) devices, is still the most popular material for solar cells. Outranked only by oxygen, silicon is also the second-most abundant element in the Earth's crust. However, to be useful as a semiconductor material in solar cells, silicon must be refined to a purity of 99.9999%. In single-crystal silicon, mono-crystalline (Figure 1a), the molecular structure – the arrangement of atoms in the material – is uniform, because the entire structure is grown from the same crystal (Saga, 2010). This uniformity is ideal for transferring electrons efficiently through the material. To make an effective PV cell, however, silicon has to be "doped" with other elements to make it n-type and p-type. On the other hand, polycrystalline silicon is an aggregation of small silicon crystals. As a result, silicon molecules are irregularly aligned within the crystals, and do not allow a regular flow of current even if electricity is charged (Figure 1b). On the other hand, another method of producing solar panels uses amorphous silicon instead of crystalline and was developed in the 1970s (Figure 1c) (Tester, 2005).To produce these modules silicon is deposited on an inexpensive supportive background (Carlson and Wagner, 1993). Because amorphous silicon absorbs light more completely, the thickness of the silicon in amorphous modules is orders of magnitude less than that in crystalline modules.

Among all kinds of solar cells we started with silicon solar cells, for they are the most widely used. Their efficiency is limited due to several factors. The energy of photons decreases at higher wavelengths. The highest wavelength when the energy of photon is still big enough to produce free electrons is 1.15 μm (valid for silicon only). Radiation with higher wavelength causes only heating up of solar cell and does not produce any electrical current. Each photon can cause only production of one electron-hole pair. So, even at lower wavelengths many photons do not produce any electron-hole pairs, yet they effect on increasing solar cell temperature. The highest efficiency of silicon solar cell is around 23%, by some other semiconductor materials up to 30%, which is dependent on wavelength and semiconductor material. Self loses are caused by metal contacts on the upper side of a solar cell, solar cell resistance and due to solar radiation reflectance on the upper side (glass) of a solar cell.

The efficiency of amorphous solar cells is typically between 6.0 and 8.0%. Besides, their lifetime is shorter than the lifetime of crystalline cells. Besides, they have current density and open circuit voltage values of about 15 mA/cm^2 and 0.80 V, respectively, which are more compared to crystalline cells. Their spectral response reaches maximum at the wavelengths of blue light therefore, the ideal light source for amorphous solar cells is fluorescent lamp.

Advantages of amorphous silicon

1. It requires much less silicon. Amorphous silicon is a direct-band gap material, and therefore only requires about 1.0% of the silicon to produce a crystalline-silicon based solar cell.
2. The substrates can be made out of inexpensive materials such as glass, stainless and steel.
3. Can be made flexible and lightweight. They can be placed on curved surfaces and will probably in the future be incorporated into clothing.
4. Thin-film solar cells perform relatively well under poor lighting conditions and are not affected as much by shading issues.
5. Amorphous silicon can be deposited onto substrates at temperatures below 300°C, which makes the technology a good candidate for flexible substrates and roll-to-roll manufacturing techniques. (Maehlum, 2013; Collins et al., 2003; Myong et al., 2006; Wronski et al., 2004)

Disadvantages

1. Amorphous thin-film solar cells have lower efficiency rates. The technology is new, and efficiency rates are thought to increase with technological breakthroughs in future.
2. Thin-film solar panels tend to degrade faster and not last as long as mono- and poly-crystalline solar panels.
3. You would have to cover a larger surface with amorphous silicon solar panels than crystalline-based solar panels for an equal output of electrical power.

Gallium arsenide solar cells

Gallium arsenide (GaAs) is a mixture of two elements, gallium (Ga) and arsenic (As). Gallium is a by-product of the smelting of aluminum and zinc, and is extremely rare (Figure 2a). A rare element is certainly not an advantage if we want to bring the energy production of GaAs solar cells to a TW level. Besides that, the element Arsenic is

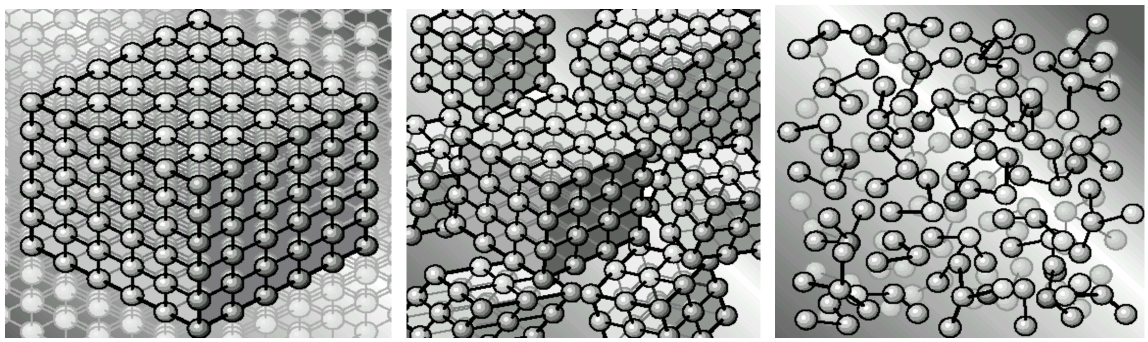


Figure 1. (a) Monocrystalline silicon materials; (b) polycrystalline-silicon materials; (c) amorphous-silicon materials.

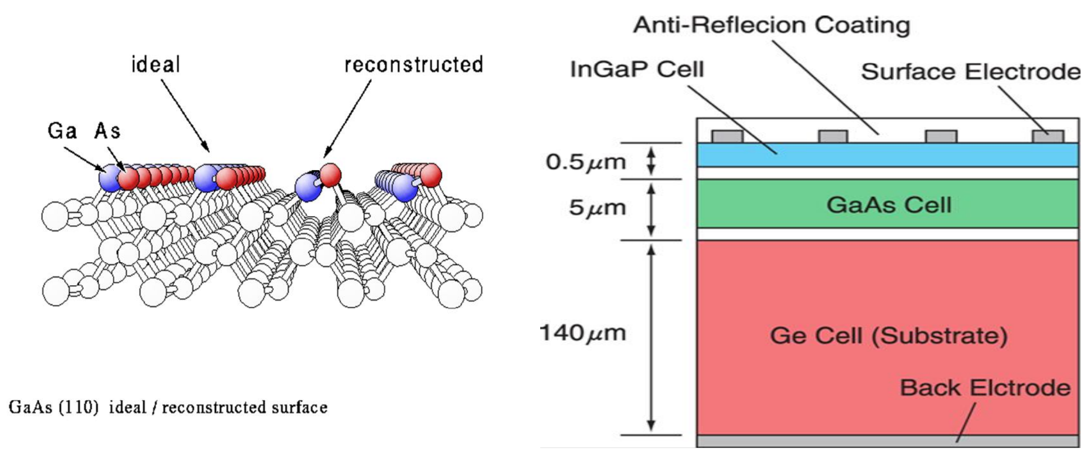


Figure 2. GaAs (110) ideal/reconstructed surface and solar cell.

poisonous. Not quite the ideal elements for solar cells, which ideally would be abundant and non-toxic. Finally, GaAs solar cells certainly have advantages as well (Figure 2b) (Hannon, 1993). Efficiency is very good lab tests have reach efficiencies of up to 26% under un-concentrated sun-light. Solar cells in commercial production reach as high as 20%.

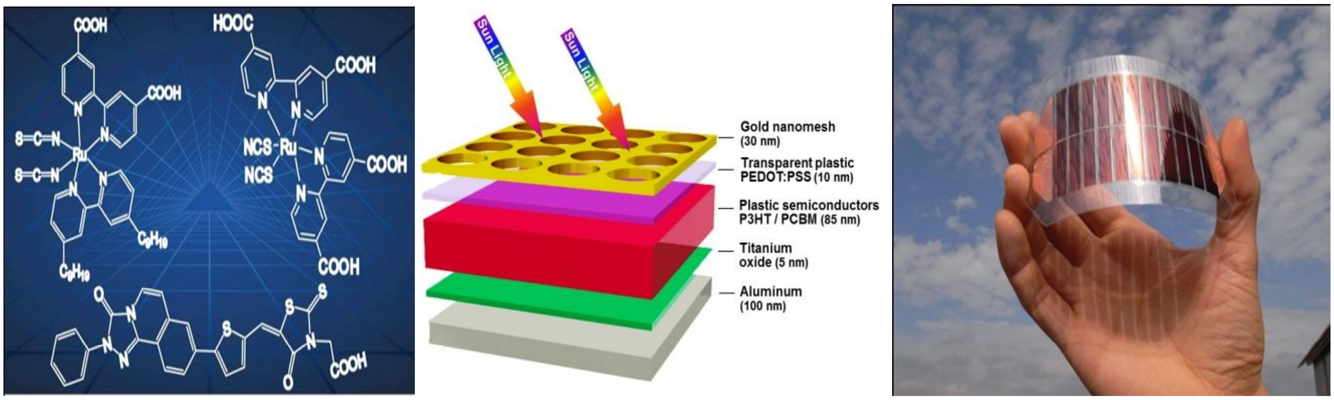
Advantages of GaAs

1. Thickness: GaAs solar cells can be extremely thin. They already absorb sunlight when it is made of a few microns thick. If one compares this with crystalline solar cells, that need at least 50 to 100 microns, GaAs solar cells need only little material.
2. Band gap: GaAs band gap is very near to the ideal for single-junction solar cells: 1.43 eV.
3. Heat insensitivity: GaAs cells are relatively insensitive to heat, which makes it more suitable for Concentrated Photovoltaic (CPV) as such design involves higher temperatures. The insensitivity to heat is a major advantage compare to silicon, which is quickly affected by high temperatures.

Organic/plastic solar cells

An organic solar cell or plastic solar cell is a type of polymer solar cell that uses organic electronics, a branch of electronics that deals with conductive organic polymers or small organic molecules (McGehee and Topinka, 2006; Nelson, 2002) for light absorption and charge transport to produce electricity from sunlight by the photovoltaic effect (Figure 3).

The plastic used in organic solar cells has low production costs in high volumes. Combined with the flexibility of organic molecules, organic solar cells are potentially cost-effective for photovoltaic applications. Molecular engineering (e.g. changing the length and



a b c

Figure 3. Organic solar cell material (a), structure (b) and flexibility (c).

a b c d

Figure 4. Sargent-Si-solar cell (a), Konarka polymer solar panels (b) and polycrystalline, and GaAs.

functional group of polymers) can change the energy gap, which allows chemical change in these materials (Pandey and Holmes, 2010). The optical absorption coefficient of organic molecules is high, so a large amount of light can be absorbed with a small amount of materials. The main disadvantages associated with organic photovoltaic cells are low efficiency, low stability and low strength compared to inorganic photovoltaic cells.

Advantages of organic solar cells

1. Low weight and flexibility of the PV modules.
2. Have a semi transparent characteristic.
3. Easy to integrate into other products.
4. New market opportunities, due to their design features such as flexible solar modules.
5. Lower manufacturing costs compared to conventional silicon solar cells.
6. Can be produced in a continuous process using printing tools.
7. Have a low environmental impact and short energy payback times.

Disadvantages of organic solar cells

In order for organic solar cells to match and exceed the performance of silicon based solar cells, it is necessary for both donor and acceptor materials in an OPV to have good extinction coefficients (referring to several different measures of the absorption of light in a medium), high stabilities and good film structure.

Chosen of solar cell samples and panels

Mono-crystalline silicon solar cells

The proposed mono-crystalline silicon solar cells are manufactured by Sargent-Welch, Inc., USA. It is of standard n/p type with its negative terminal soldered on the light sensitive side of the cell, while the positive terminals soldered on the back (Figure 4a). The specifications of the cells are rectangular with 2.0 cm × 1.0 cm, in dimensions, short circuit current (I_{sc}): 36 mA, open circuit voltage (V_{oc}): 0.45 V and output maximum power (P_{max}): 16 mW.

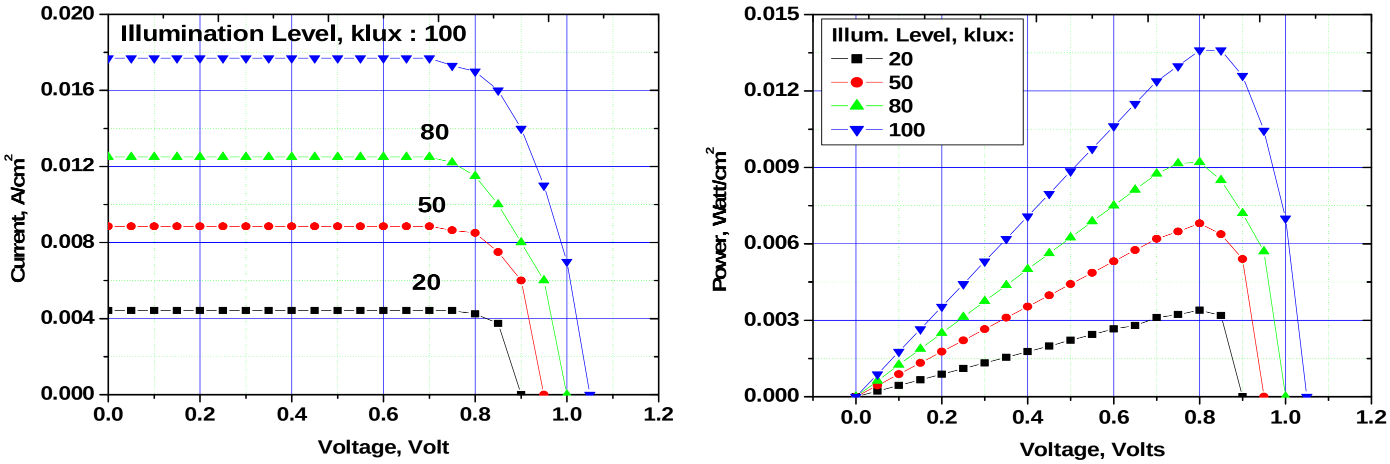


Figure 5. Output (I-V) –and (P-V) –characteristic curves of GaAs solar cells, plotted at different illumination levels.

Polycrystalline silicon solar panels

Poly-silicon solar panel with 1.10 to 1.25 W, with dimension of 112 mm × 84 mm, input voltage/current: 6.0 V, 200 mA, transfer efficiency not less than 17%, and packed with anti-deformation PCB, resistant to corrosion eUV, high transmission EPOXY (Figure 4b).

Polymer solar panels

Konarka polymer solar panels with different areas were investigated. The samples were 20 Series comes in a standard width of 340 mm, and lengths ranging from 273 to 1553 mm (Figure 4c). Finally, the general characteristics of the samples are: V_{MP}: 7.90 V, V_{OC}: 11.30 V, and P_{OUT}: from 1.20 W up to 8.60 W (depending on panel size).

GaAs solar cells

SunPower GaAs solar cells were investigated (Figure 4d). The samples have short circuit current density (J_{SC}): 17.77 mA.cm^{2}; V_{OC}: 1.085 V, Fill-Factor (FF): 0.745, and Efficiency (Eff.): 13.25%.

SOLAR SYSTEMS CHARACTERIZATION

Output electrical characteristics

Solar illumination

The output (I-V) and (P-V) characteristics of different GaAs and silicon solar cells and panels, as well, the effects of illumination level on their main electrical parameters were presented in Figures 5 to 8. From which, typical points on solar cell characteristics are open circuit voltage, short circuits, efficiency, fill factor and maximum power point were determined. As a matter of fact for the solar cell, an increase in short circuit current was observed, as the light intensity increase, while as open-circuit voltage is largely unaffected all over light intensity range and wavelengths incident, which means that, V_{oc} increase up to around 20 to 30 kux. For higher incident light intensity, more than 20 to 30 klux, V_{oc} stays fairly constant. Finally for most studied solar cells, the short-circuit current density shows a linear relationship with the incident light intensity. The open-circuit voltage and fill factor are much weaker dependent on the light intensity (Soliman et al., 1995; Abd El-Basit et al., 2013; El-Ghanam et al., 2015).

Concentrated solar illumination levels

A concentrator is a solar cell designed to operate under illumination greater than 1.0 sun. The incident sunlight is focused or guided by optical elements such that a high intensity light beam shines on a small solar cell. Concentrators have several potential advantages, including a higher efficiency potential than a one-sun solar cell and the possibility of lower cost. The short-circuit current of the proposed silicon solar cell with 10 mm × 5.0 mm in dimensions was shown to be depends linearly on light intensity (Figure 9), where such cell whenever operated under 2.8 suns would have approximately 2.8 times the short-circuit current as it operates under one sun operation. However, this effect does not provide an efficiency increase, since the incident power also increases linearly with concentration. Instead, the efficiency benefits arise from the logarithmic dependence of the open-circuit voltage on short circuit. On the other hand, V_{oc} increases logarithmically with light intensity, following Equation 1:

$$V'_{OC} = \frac{nkT}{q}\ln\left(\frac{XI_{SC}}{I_0}\right) = \frac{nkT}{q}\left[\ln\left(\frac{I_{SC}}{I_0}\right) + \ln X\right] = V_{OC} + \frac{nkT}{q}\ln X \quad (1)$$

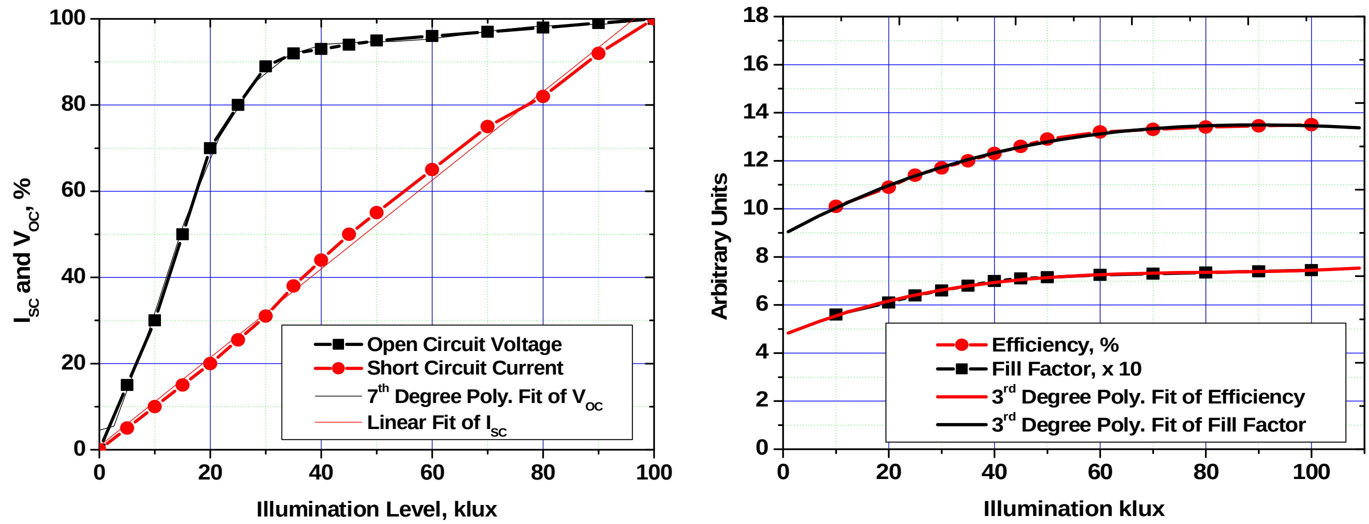


Figure 6. Dependence of short circuit current and open circuit voltage (a), and efficiency and fill factor (b) of GaAs photovoltaic cells on illumination level.

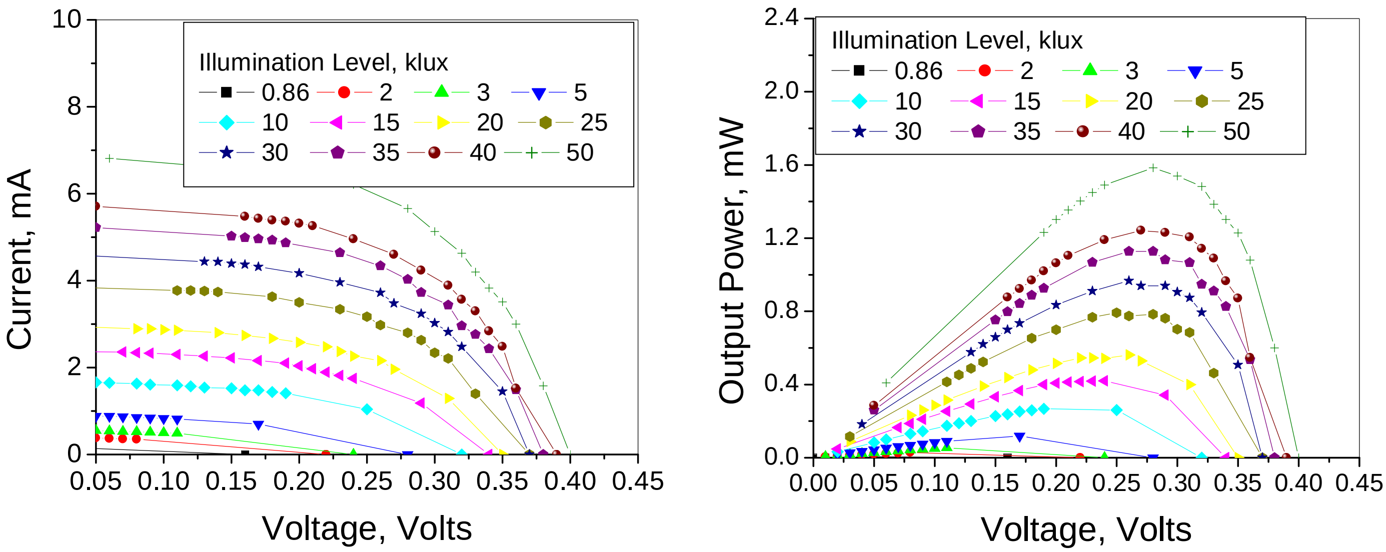


Figure 7. Output (I-V) and (P-V) characteristic curves of mono-crystalline silicon solar cell, plotted at different illumination level.

Where, X is the concentration of sunlight.

Spectral response

The spectral response is conceptually similar to the quantum efficiency. The quantum efficiency gives the number of electrons output by the solar cell compared to the number of photons incident on the device, while the spectral response is the ratio of the current generated by the solar cell to the power incident on the solar cell. In this concern, spectral response curves of GaAs, monocrystalline-, polycrystalline- and amorphous-silicon solar cells are shown in Figure 10, in comparison with day light spectrum.

The ideal spectral response is limited at long

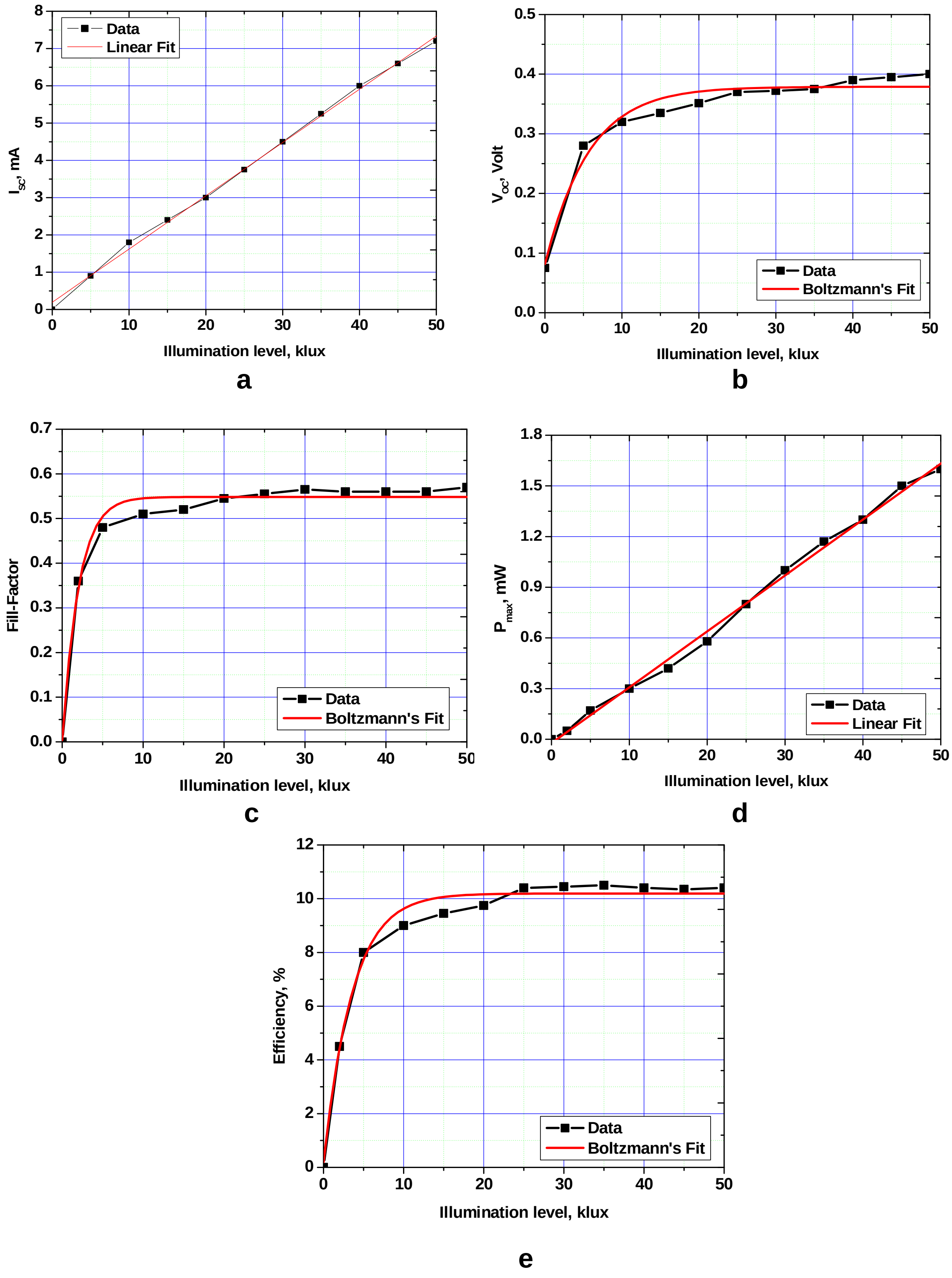


Figure 8. Dependence of (a) I_{SC}, (b) V_{OC}, (c) P_{MAX}, (d) F.F and (e) Efficiency of mono-crystalline silicon solar cell on illumination levels.

wavelengths by the inability of the semiconductor to absorb photons with energies below the band gap. This limit is the same as that encountered in quantum efficiency curves. However, unlike the square shape of QE curves, the spectral response decreases at small photon wavelengths. At these wavelengths, each photon has a large energy, and hence the ratio of photons to power is reduced. Any energy above the band gap

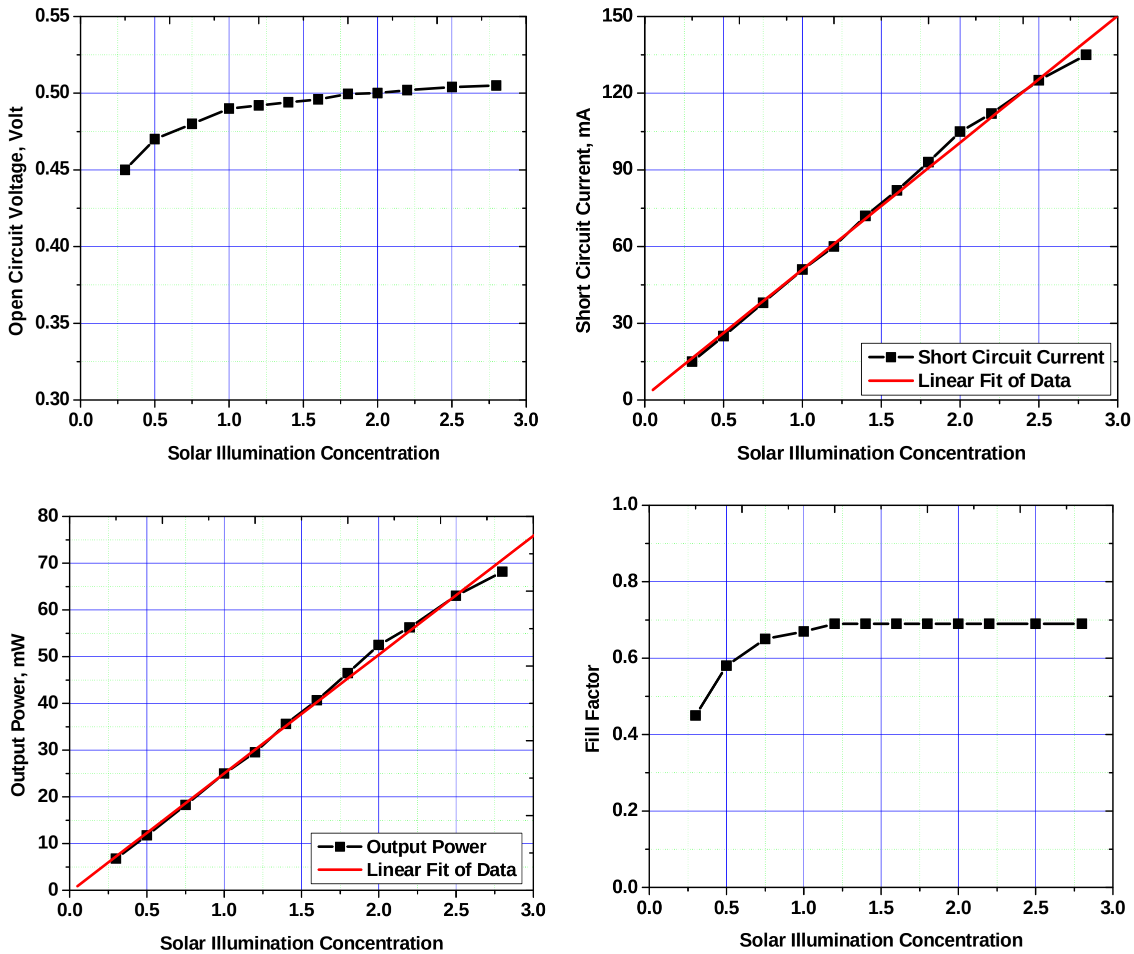


Figure 9. Open circuit voltage short circuit current, output power and fill factor dependence on high illumination levels, for mono-crystalline silicon solar.

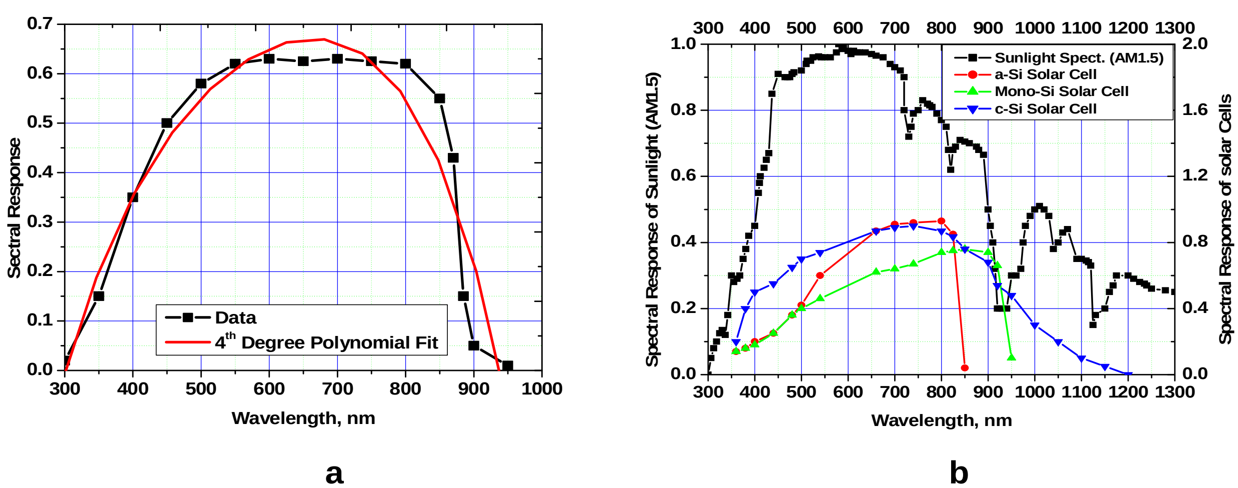


Figure 10. Spectral response of GaAs solar cell (a), mono-, poly-, and amorphous -silicon, and sunlight (b).

energy is not utilized by the solar cell and instead goes to heating the solar cell. The inability to fully utilize the incident energy at high energies and the inability to absorb low energies of light represents a significant

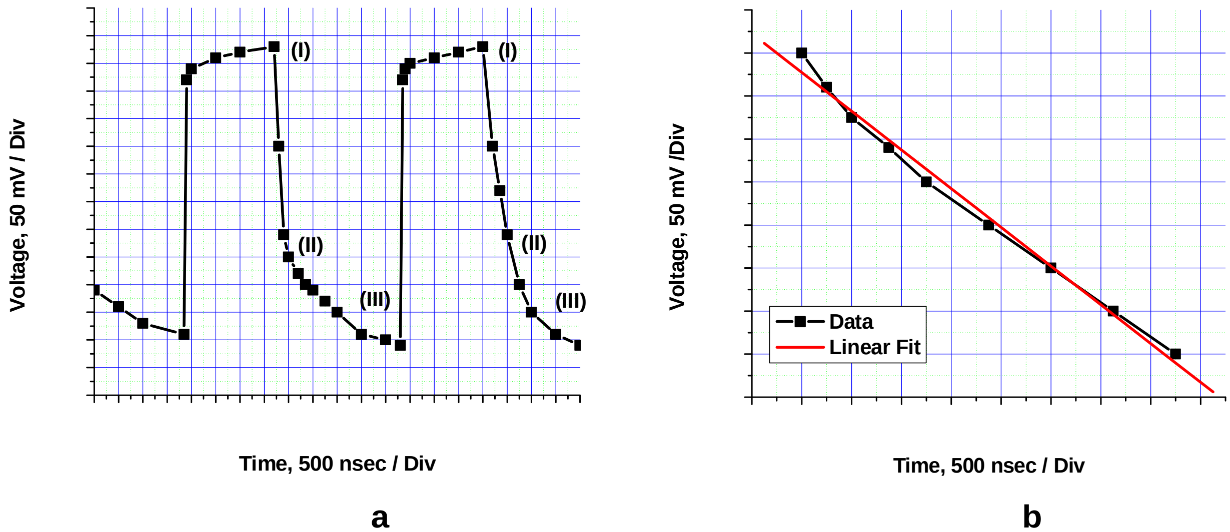


Figure 11. Open circuit voltage decay (a) and linear fit of the decay portion (b) of mono-crystalline silicon solar cells with 5 mm × 10 mm in dimensions.

power loss in solar cells consisting of a single p-n junction.

Spectral response (SR) is important since it is the spectral response that is measured from a solar cell, and from this the quantum efficiency is calculated. The quantum efficiency can be determined from the spectral response by replacing the power of the light at a particular wavelength with the photon flux for that wavelength, where:

$$SR = (q\lambda/hc).QE \quad (2)$$

where:
QE: quantum efficiency of the cell,
q: electric charge,
λ: wavelength,
h: Planck's constant, and
c: speed of light.

Minority carrier's lifetime determination

Minority carrier's lifetime was calculated applying the open circuit voltage decay technique (Soliman, 1996; Hyvarinen and Karila, 2003; Mahan et al., 2005). In this concern, Figure 11 shows the photo induced open circuit voltage decay of the mono-crystalline cell. From which, it is clear that the decay curve consists of three distinct regions, which can be described as:

Region (I): is observed in rather high base resistivity cells for which the source intensity is sufficient to produce the high injection condition.
Region (II): can be masked by a slow rate of discharge of the stored charge in the junction depletion region. Its discharge rate is inversely proportional to the effective time constant of the cell.
Region (III): normally observed in silicon solar cells, the matter is due to that, although the source intensity is not sufficient to reach the high injection condition, it is usually enough to excite the cells to an injection level substantially higher than that at which the discharge of the junction capacitance limits the open circuit voltage decay rate. The decay rate is determined from the slope of the linear or semi-linear part of the open circuit voltage decay curve.

The decay transient can be analytically obtained by set-ting the sum of the diode current and displacement current in the capacitor to zero, and thus writing the recombination current as Soliman (1996), Hyvarinen and Karila (2003), Mahan et al. (2005):

$$-C(dV_{oc}/dt) = I_0.[\exp(V_{oc}/n_X V_T) -1] \quad (3)$$

where:
C: geometrical capacitance,
I_0: dark saturation current,
n_x: ideality factor, and
V_T: t hermal voltage (kT/q).

The solution can be readily given as:

$$V_{oc}(t) = n_x.V_T.\ln\{-1[1- \exp(V_i/n_x.V_T)].\exp(-\alpha_t)\} \quad (4)$$

where:
V_i: initial voltage at t = 0, and
α: $I_0/n_x.C.V_T$

It is straight forward to fit the measured data to Equation 4 with the ideality factor n_x, and the dark saturation current I_0 as parameters to obtain extremely reliable values for the two quantities. It is also physically instructive and fairly easy to see that the most significant part of the decay, i.e., linear decrease with ln(t) during inter mediate times, is given by the requirement that exp $[Vi/n_x V_T] << \alpha_t << 1$, and that it can be expressed as:

$$V_{oc}(t) = -n_x.V_T.\ln(\alpha) - n_x.V_T.\ln(t) \quad (5)$$

Hence, the ideality factor, n_x, can be inferred from the slope alone quite reliably without using other experimental parameters such as the capacitance value (Hellen, 2003). The parameters α (hence I_0) and n_x can be obtained using either Equation 4 or Equation 5 with equal ease.

Charge carriers lifetime is very important term in semiconductor devices because it indicates the time required for the excited hole and electron concentrations to return to their equilibrium values. In practice, the open circuit voltage decay technique is commonly used, where (Soliman, 1996; Hyvarinen and Karila, 2003; Mahan et al., 2005; Mahan et al., 1979; Soliman et al., 1990; Graff, 1979):

$$p_n(0) = p_{no} + \Delta p = \exp(qV/KT) \quad (6)$$

Solving for V, one obtains:

$$V = (qV/KT)\ln[1 + (\Delta p/ p_{no})] \quad (7)$$

In case of Δp = 0, then:

$$p = p_{o}.\exp(-t/\tau) = p_{no}\exp[(qV_0/KT)-1] \quad (8)$$

Assuming $V_0 >> KT/q$, and $t << \tau$, then:

$$V(t) = V_0 - (KT/q).t \quad (9)$$

From which, and referring to the linear part of the open circuit voltage decay curve, one obtains:

$$\tau = 2KT/q\,[1/dV_{OC}/dt)] \quad (10)$$

At the intermediate injection, the decay curve is again linear and the lifetime can be computed as (Soliman, 1996):

$$\tau = KT/q\,[1/dV_{OC}/dt)] \quad (11)$$

In order to test the validity of the proposed technique, solar samples were gamma-irradiated up to around 30 kGy, at the National Center for Radiation Research and Technology, Atomic Energy Authority of Egypt, the matter which expected to make a pronounced changes on the minority carriers lifetime (Figure 12). The degradation of minority carrier lifetime results in change in the device properties. The importance of effective minority carrier lifetime to a silicon solar cell's efficiency is reflected in its crucial impact on both short circuit current and open circuit voltage.

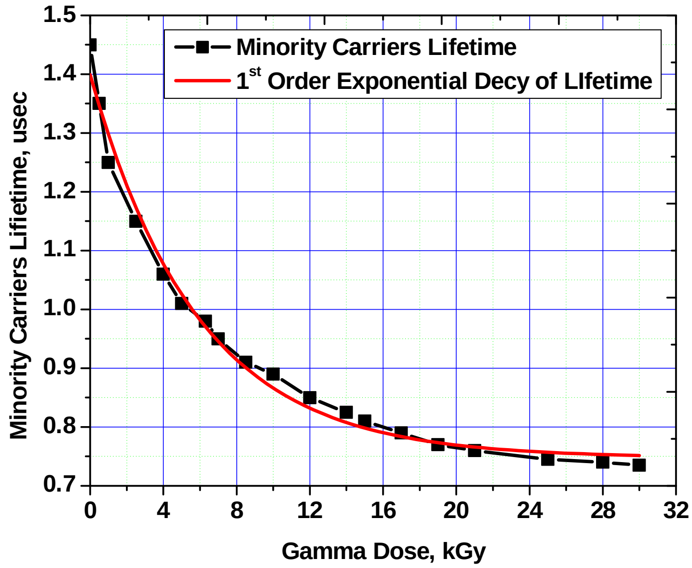


Figure 12. Minority carrier lifetime of monocrystalline silicon solar cells dependence on gamma-dose and its exponential decay.

Capacitance-voltage characteristics

Capacitance-voltage (C-V) measurements for solar cells were made either forward-biased or reverse-biased**.** In this concern, Figure 13 shows the capacitance–voltage relationships of the silicon solar cells with 10 mm × 5.0 mm in dimensions, plotted at different frequencies (a), illumination levels (b). However, when the cell is forward-biased, the applied DC voltage must be limited; otherwise, the conductance may get too high. The maximum DC current cannot be greater than 10 mA; otherwise, the DC voltage output will not be at the desired level (Keithley, nd; Zeyrek et al., 2013).

Temperature effects on solar cells and panels

Effects on silicon solar cells and panels

There have been a number of studies into the way that silicon solar cells react at different temperatures. There is one study on the way CIS cells perform at different temperatures. Meneses-Rodriguez et al. (2005) compares one CIS cell to several types of silicon cells over the range of 25 to 800°C. One of the silicon cells is an amorphous silicon cell tested from 25 to 800°C. Carlson (1977) examined amorphous silicon cells from 20 to 100°C and Carlson et al. (2000) has information about

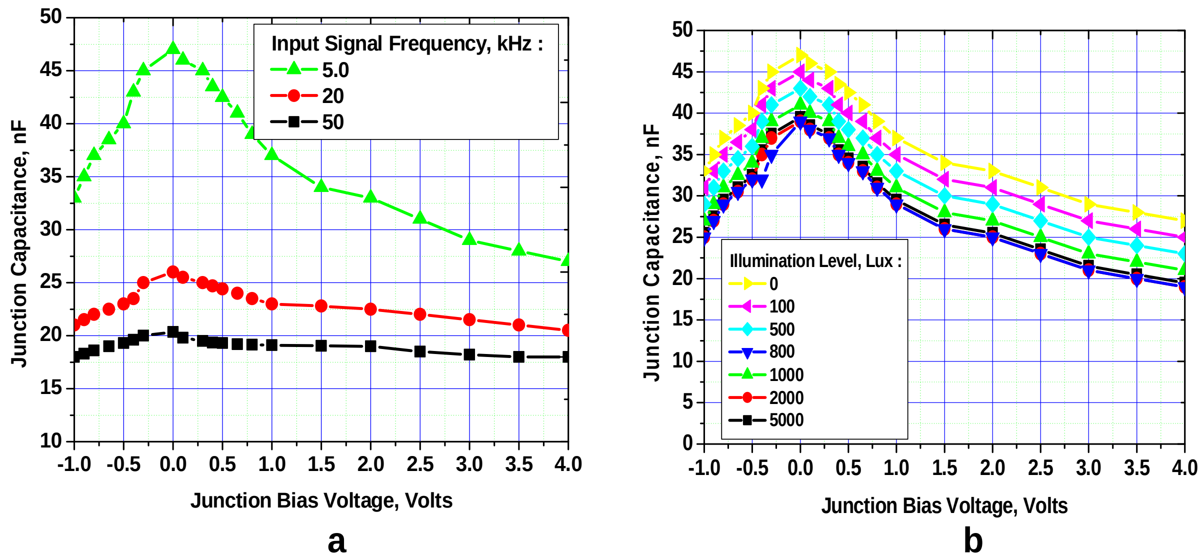


Figure 13. Capacitance–voltage relationships of the monocrystalline silicon solar cells, plotted at different frequencies (a), and illumination level (b).

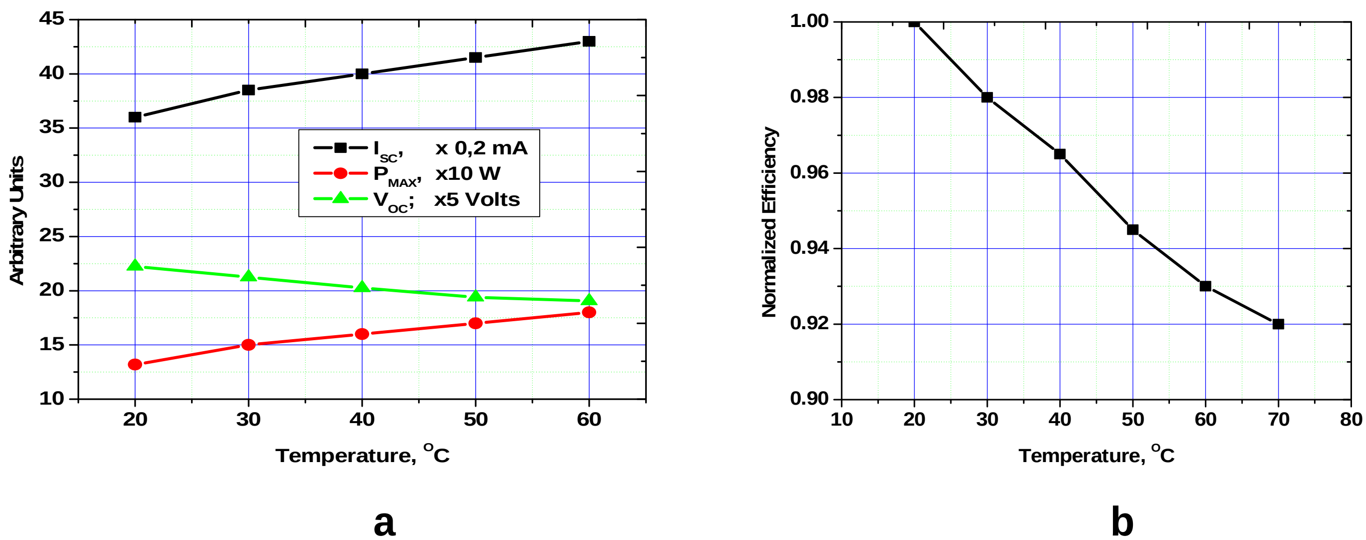


Figure 14. Temperature effects on the some of the electrical characteristics of mono (a)-poly (b)–crystalline and amorphous (c) -Si-solar cells.

amorphous silicon performance from 100 to 300 K, -173 to 23°C that includes open circuit voltage and short circuit current, but not fill factor, maximum power or efficiency.

The performance of silicon solar cells is dependent on environmental conditions and their output parameters such as output voltage, current, power, and fill factor vary by temperature (Singh and Ravindra, 2012; Cuce and Cuce, 2013; Yadav and Chandel, 2013; Abd El-Azeem, 2014; Wilfried et al., 2012; Vos, 1988). Experimental results showed that the most significant changes by temperature is voltage which decreases with increasing temperature while output current slightly increase by temperature (Figure 14). Reduction in the open-circuit voltage for silicon solar cells is about 2.30 mV/°C. As well as the effect of temperature on the maximum power output is -0.006 mW/°C. The best performance of solar panels in sunny and cold day has been suggested.

Temperature effects on polymer panels

For the 500 W/m^2 (irradiance: 50,000 lux), two current-voltage (I-V) characteristic curves were plotted for polymer solar panel at two different panel temperature

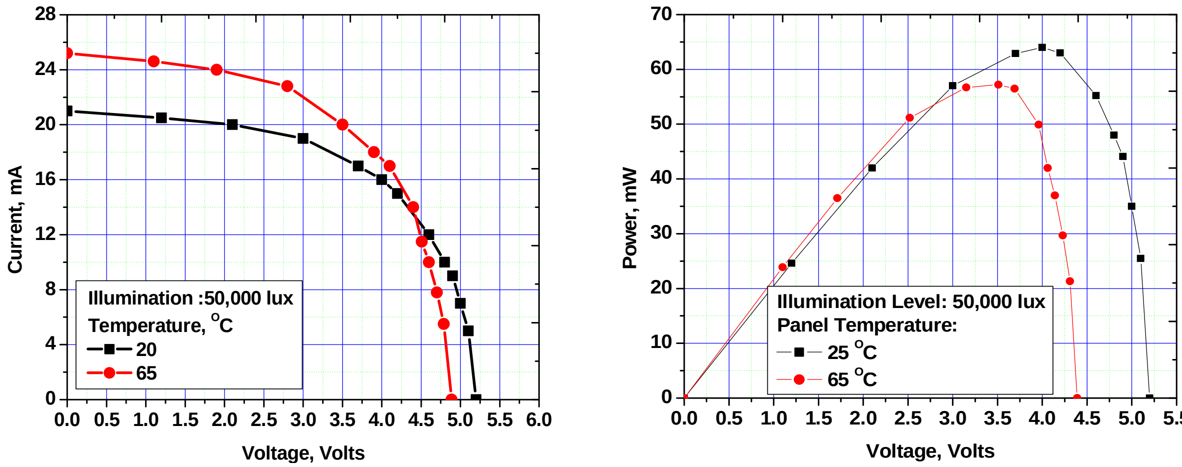


Figure 15. Temperature dependence of polymer solar cell parameters.

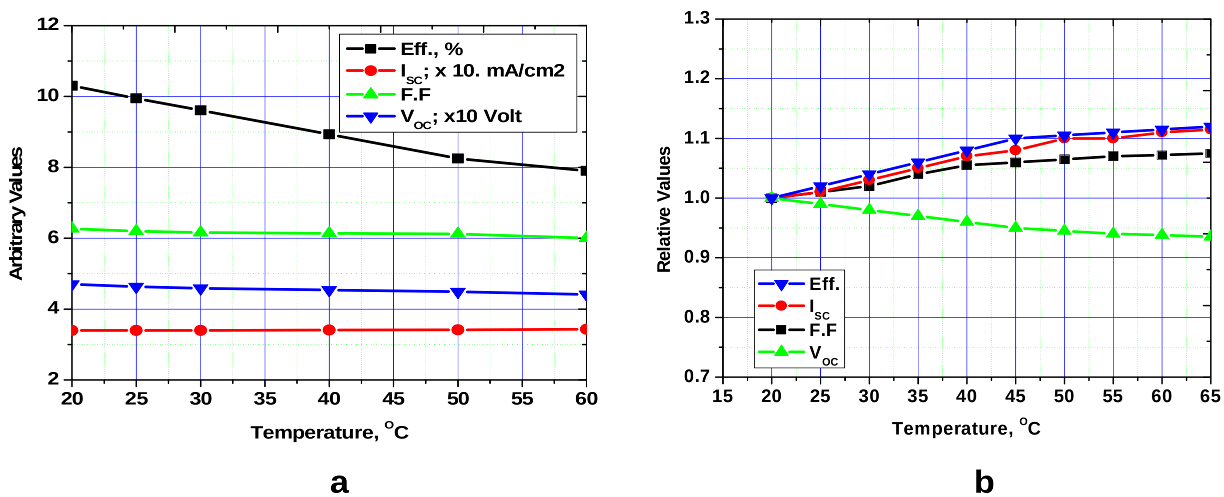


Figure 16. Temperature dependence of the electrical parameters of monocrystalline (a) and polymer solar panels (b).

levels of 25 and 65°C (Figure 15). From which, it is clearly shown that as the temperature rises above 25°C, V_{OC} falls while I_{SC} gets higher. As well, the graph shows that the maximum voltage decreases was decreases from 3.46 V down to 2.93 V, because of the decrease of V_{OC}. Therefore, to get the maximum current output, modules should be mounted so that air can circulate around them freely to keep the cell cool. Finally, (I-V) curves are usually shown for the cell at the temperature of 25°C. From the previous factor, we know that the amount of sunlight can affect the current generated from the module. It is possible to increase the irradiance above 1000 W/m^2 using mirrors or lenses to concentrate sunlight on the cells. However, the irradiance may be uneven over the module which will cause overheating and damage in cells. Besides, the whole module will become hotter and extra cooling is needed. Therefore, it is not advisable to concentrate sunlight on standard modules in any way.

Figure 16 shows the changes in some of the electrical parameters of monocrystalline solar cells and polymer solar panels as a function of temperature. It was found that the solar cell parameters are dependent on the temperature level, and the temperature 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 the results, the temperature causes a slight increase in the short circuit current and efficiency while the open circuit voltage is slightly reduced.

CONCLUSION

From the experimental work, results, analysis and interpretation, it could be concluded that measuring the electrical characteristics of a solar cell is critical for determining the device's output performance and efficiency. From which it is clear that crystalline silicon is the dominant photon-absorbing material in conventional solar cell technology. Also, conventional crystalline silicon solar cells are a time-tested technology with some of the highest commercial conversion efficiencies. Finally, crystalline silicon installations are reliable over a long lifetime – 25 years or more – and the modules are fairly rugged.

REFERENCES

Abd El-Azeem S, **2014**. Novel techniques for improvement of solar energy conversion. M.Sc. Thesis, Faculty of Girls, Ain-Shams Univ., Cairo, Egypt.

Abd El-Basit W, Abd El-Maksood AM, Soliman FAS, **2013**. Mathematical model for photovoltaic cells. Leonardo J Sci, 23:13–28.

Carlson DE, **1977**. The effects of impurities and temperature on amorphous silicon solar cells. IEEE, pp. 214-217.

Carlson DE, **Wagner** S, **1993**. Amorphous Silicon Photovoltaic Systems. Renewable Energy: Sources for Fuels and Electricity. Ed. Burnham, Laurie, Thomas Johansson, Henry Kelly, Amulya Reddy, and Robert Williams. Washington, D.C.: Island Press. pp. 403-436.

Carlson DE, Lin G, Ganguly G, **2000**. Temperature dependence of amorphous silicon solar cell PV parameters. IEEE, pp. 707-712.

Collins RW, Ferlauto AS, Ferreira GM, Chen C, Koh J, Koval RJ, **2003**. Evolution of microstructure and phase in amorphous, proto crystalline, and microcrystalline silicon studied by real time spectroscopic ellipsometry. Solar Energy Mater Solar Cells, 78(1-4):143-180.

Cuce E, **Cuce** PM, **2013**. An experimental analysis of illumination intensity and temperature dependency of photovoltaic cell parameter. Appl Energy, 111:374-382.

El-Ghanam SM, Abd El-Basit W, Soliman FAS, **2015**. Simulating of the silicon photovoltaic's operation at outer space environments. Adv Sci Technol Res, 2(3):42-53.

Fuller CS, **nd**. The Birth of the Solar Cell. Technica, Journalism Experience, www.technicacommunications.com/calvin-fuller-soalr-cell/.

Graff K, **1979**. Carrier lifetime in silicon and its impact on solar cell characteristic. Topics in Applied Physics , 31:173-211.

Hannon MH, **1993**. Light-weight, light - trapped, thin GaAs cells for spacecraft applications. Official Website of the United States Government, http://www.sbir.go v/sbirsearch/ detail/98971.

Hellen EH, **2003**. Verifying the diode-capacitor circuit voltage decay. Am J Phys, 71(8):797-800.

Hyvarinen J, **Karila** J, **2003**. New analysis method for crystalline silicon solar cells. Photovoltaic Energy Conversion, 2003, Proc. of 3rd World Conf. Renewable Energy, pp:1521 – 1524.

Keithley, **nd**. Making I-V and C-V measurements on solar/photovoltaic cells using the model 4200 - SCS semiconductor characterization system. Application Note Series, www.keithley.com/data?asset=50913.

Maehlum MA, **2013**. Amorphous silicon solar panels. Energy Informative, USA.

Mahan JE, Ekstedt TW, Frank RI, Kaplow R, **1979**. Measurement of minority carriers lifetime in solar cells from photo-induced open circuit voltage. IEEE Trans Electron Devices, 26(5):98-105.

Mahan JE, Ekstedt TW, Frank RI, Kaplow R, **2005**. Measurement of minority carrier lifetime in solar cells from photo-induced open-circuit voltage decay. IEEE Trans Electron Devices, 26(2):733–739.

McGehee DG, and **Topinka** MA, **2006**. Solar cells: Pictures from the blended zone. Nat Mater, 5(9):675–676.

Meneses-Rodriguez D, Horley PP, González-Hernández J, Vorobieva YV, Gorley PN, **2005**. Photovoltaic solar cells performance at elevated temperatures. Solar Energy, 78:243-250.

Myong SY, Kwon SW, Kwak JH, Lim KS, **2006**. Good stability of proto crystalline silicon multilayer solar cells against light irradiation originating from vertically regular distribution of isolated nanosized silicon grains. 4th World Conf. on Photovoltaic Energy Conversion Proceedings, p. 492.

Nelson J, **2002**. Organic photovoltaic films. Curr Opin Solid State Mater Sci, 6:87–95.

Pandey R, **Holmes** RJ, **2010**. Organic photovoltaic cells based on continuously graded donor-acceptor heterojunction. IEEE J Selected Topics in Quantum Electronics, 16(6):1537-1543.

Reece W, **nd**. History of Solar Power. https://www.experience.com/alumus/article?

Saga T, **2010**. Crystalline and polycrystalline silicon PV technology. NPG Asia Materials, 2(3):96-102.

Singh P, **Ravindra** NM, **2012**. Temperature dependence of solar cell performance-an analysis. Solar Energy Mater Solar Cells, 101:36–45.

Soliman FAS, **1996**. Application of open-circuit voltage technique for the characterization of photovoltaic devices. Intr. Jour. of the Ambient Energy, Ambient Press, Limited, Hornby Lancaster, U.K.

Soliman FAS, El-Fouly M, El-Ashry M, **1995**. Photovoltaic devices: Simulation, properties and the effect of physical parameters. Intr. Jr. of Perspectives in Energy, Moscow Intr. Center, Russia. 3:35-46.

Soliman FAS, Saleh MB, El Fouly MH, El Ashry M, **1990**. Fabrication and characterization of silicon photovoltaic cells for solar energy conversion. 1st World Renewable Energy Cong., Reading, U.K., 23-28 Sept., Pergamon Press, ISBN-008-0375313, Vol. 1, pp. 135-140, 1990.

Tester JW, **2005**. Sustainable Energy: Choosing Among Options. Cambridge, Massachusetts: MIT Press.

USA Space Foundation, **nd**. U.S. Government Space Program. www.spacefoundation.org. Introduction to Space Activities.

Vos AD, **1988**. Detailed balance limit of the efficiency of tandem solar cells. J Phys D: Appl Phys, 13(5):839.

Wilfried GJ, van Sark WG, Korte L, Roca F, **2012**. Physics and technology of amorphous-crystalline silicon solar cells. Engineering Materials, Springer Link.

Wronski CR, Pearce JM, Deng J, Vlahos V, Collins RW, **2004**. Intrinsic and light induced gap states in a-Si:H material and solar and solar cells - effects of microstructure. Thin Solid Films, 451-452: 470-475.

Yadav AK, **Chandel** SS, **2013**. Tilt angle optimization to maximize incident solar radiation: A review. Renewable Sustainable Energy Rev, 23:503–513.

Zeyrek S, Turan A, Bülbül M, **2013**. The C–V and G/ω–V electrical characteristics of ^{60}Co γ-ray irradiated $Al/Si_3N_4/p\text{-}Si$ (MIS) structures. Chin Phys Lett, 30(7):234-241.

Citation: Ashry HA, Abdel Magid Abu Talib A, Mahdi MIM, Soliman FAS, 2015. A novel look on the materials effect on the characteristics and applications of solar systems. Adv Sci Technol Res, 2(3): 54-66.