Vol. 17(3), pp. 96-107, October-December, 2022
DOI: 10.5897/IJPS2022.5010
Article Number: 768CC9970020
ISSN: 1992-1950

http://www.academicjournals.org/IJPS

International Journal of Physical Sciences

Full Length Research Paper

Uncooled PV cell under variable light concentration: Determination of profiles of the temperature, the intrinsic properties and the carrier density

Mahamadi SAVADOGO[1]*, Pegdwindé Ousséni Fabrice OUEDRAOGO[2,3], Adama OUEDRAOGO[1,4], Lamine ZIDA[1], Martial ZOUNGRANA[1] and Issa ZERBO[1]

[1]Laboratory of Thermal and Renewable Energies, Department of Physics, Unit of Training and Research in Pure and Applied Sciences, University Joseph KI-ZERBO, Ouagadougou, Burkina Faso.
[2]Laboratory of Numerical Analysis, Computer Science and Biomathematics. Department of Mathematics, University Joseph KI-ZERBO, Ouagadougou, Burkina Faso.
[3]University of Dédougou (UDDG), PO Box 176, Dédougou, Burkina Faso.
[4]Centre Universitaire Polytechnique de Kaya (CUP-Kaya), P. O. Box 232, Kaya, Burkina Faso.

Received 11 September, 2022; Accepted 21 November, 2022

Studies on concentrated light influence do not take into account the effect of the heating and this proves to be harmful on photovoltaic parameters. The main purpose of this work is to study the effects of light concentration and the heating caused by this concentration on intrinsic properties and carrier density profile. A thermal model of the PV cell is proposed. By applying the power balance at the steady-state, the PV cell thermal equation is determined. The resolution of this equation leads to temperature profile which shows a rapid increase with light concentration. The mobility μ_n and diffusion D_n coefficients of electrons increase to reach their maxima, respectively $(\mu_n)_{\max} = 1895,31\ cm^2V^{-1}s^{-1}$ at C=6,77 Suns where temperature is T=430,92 K and $(D_n)_{\max} = 76,55\ cm^2.s^{-1}$ at C= 12,59 Suns where temperature is T=508,24; before decreasing. However, for the holes these parameters decrease slowly with concentration increase. Silicon gap energy decreases while electrons intrinsic density increases with increasing concentration. The variations of these parameters are explained on one hand by their dependence on temperature but also by temperature profile with concentration. An electrical model of the PV cell under variable concentration is also proposed and from which the carrier's density is determined. It emerges that the carrier density increases significantly with concentration ratio. This fact is explained by the photo-generation increase with concentration. And also, by thermal generation increase linked to temperature increases with concentration increase. Results also show that carriers density is greater in the rear side compared to the zone near the junction in opposite to authors who did not take into account temperature effect and who showed that carriers density is greater at the illuminated face.

Key words: Temperature profile, concentrated light PV cell, intrinsic density, gap energy, carriers density profile.

INTRODUCTION

Since the development of the first photovoltaic cell, the field of photovoltaic energy has obtained encouraging results. However, photovoltaic energy still remains uncompetitive on the market compared to traditional energy sources (Royne et al., 2005). This is an obstacle to its large-scale adoption.

To win this challenge of the market, the photovoltaic sectors have been diversified. Among these, high-efficiency photovoltaic sector can be cited for light concentration. This technique consists of sending on the PV cell an illumination whose intensity can go up to 1000 times that of sunlight. This concentration of the intensity of the incident light on the PV cell is done by using a system of parabolic mirrors or Fresnel lenses (El Chaar et al., 2011).

It is also well-known that most of the solar radiation absorbed by a photovoltaic cell is not converted to electricity but contributes to increase the temperature (Mattei et al., 2006; Cui et al., 2009). It has been shown that this increase of the PV cell's temperature becomes particularly rapid under light concentration (Cui et al., 2009; Swapnil et al., 2013; Wang et al., 2015).

In addition, many works have shown that temperature increase has strong influences on electronic and intrinsic properties of semiconductor materials and photovoltaic cells (Reggiani et al., 2000; Souza and Sousa, 2019; Dhar et al., 2005; Alkuhayli et al., 2021; Amar et al., 2021; Kabbani and Honnurvali, 2021; Medekhel et al., 2022; Santos et al., 2022). Reggiani et al. (2000) showed the strong decrease of the mobility of the electrons and the holes with temperature increase in silicon devices. In the same direction, Souza and Sousa (2019) have shown that temperature increase leads to a decrease of the mobility of the electrons and the holes. They also showed that the intrinsic carrier density and the reverse saturation current density increase with temperature increase. Ravindra and Srivastava (1979) have demonstrated the decrease of the gap energy with the increase of temperature in semiconductor materials such as germanium (Ge), indium arsenide (InAs), phosphide of indium (InP), gallium arsenide (GaAs), gallium phosphide (GaP), silicon carbide (6H-SiC), and silicon (Si).

Thus, a study of light concentration effect on photovoltaic parameters which does not consider the temperature influence cannot lead to realistic results.

The main purpose of this work is to study the effects of light concentration and the heating caused by this concentration on the intrinsic properties and carrier's density in the base of a silicon PV cell under variable light concentration.

A thermal model was proposed and which allows to determine the cell temperature profile versus concentration ratio. Thereafter, an electrical model is proposed. On the basis of this electrical model, the influence of concentration ratio on intrinsic properties and carrier's density in the cell base are studied. This study takes into account the increase in temperature linked to the heating caused by light concentration.

MATERIALS AND METHODS

Thermal model

The solar incident light is concentrated by using an optical system which can be a lens or a reflecting mirror. As shown in Figure 1, the PV cell receives light power which is converted into electrical power. A large part of the concentrated light received by the PV cell is dissipated in thermal forms.

In this model, the following assumptions were made: (1) Heat dissipation is assumed to take place by radiation and natural convection.(2) Heat exchanges are assumed to take place at the front and back surfaces of PV cell.(3) The thermal convection coefficient is assumed to be the same at the front and at the back of the PV cell. (4) The emissivity is also assumed to be the same on the front side and the back side. (5). Because of the cell small thickness, its temperature is assumed to be uniform and the heat exchanges on the lateral surfaces are neglected. Thus, the powers exchanged by the PV cell are:

(1) The absorbed concentrated light power:

$$P_{lum} = \tau_0 \alpha_0 A_0 C P_{in} \tag{1}$$

In Equation 1, τ_0 represents the concentrator transmissivity and α_0 the PV cell surface absorption coefficient. A_0 represents the PV cell surface, C is the concentration ratio and P_{in} the solar illumination power density which is assumed to be $P_{in} = 1000\ W/m^2$ under standard air mass conditions AM 1.5 (Ravindra and Srivastava, 1979; Savadogo et al., 2020).

(2) The PV cell electrical power output:

$$P_{el} = \eta \tau_0 \alpha_0 A_0 C P_{in} \tag{2}$$

where η represents the photo-conversion efficiency and is given by Cui et al. (2009):

$$\eta = a(1 - bT) \tag{3}$$

with a=0.425 and b=0.00176.

(3) The power dissipated by radiation is:

*Corresponding author. E-mail: savadogo.mahamadi1976@gmail.com.

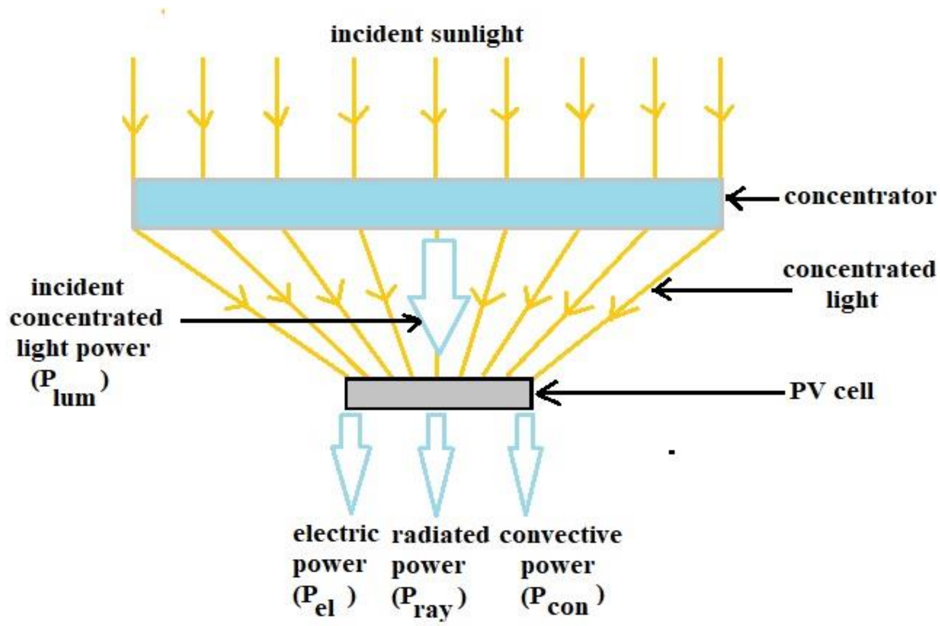

Figure 1. Illustration of the power exchanges in a concentrating PV cell.
Sources: Author's 2022

$$P_{ray} = A_{ray}\varepsilon\sigma(T^4 - T_0^4) \quad (4)$$

where A_{ray} represents the radiative surface and ε its emissivity. $A_{ray} = 2A_0$. $\sigma = 5.67\times10^{-8}\ W/m^2K^4$ is the Stephan-Boltzmann coefficient.

(4) The power dissipated by natural convection is:

$$P_{con} = A_c h(T - T_0) \quad (5)$$

where A_c represents the convective surface and h its convection coefficient: $A_c = 2A_0$.

The PV cell reaches its steady state temperature when the absorbed concentrated light power is equal to the sum of the electrical power output and the powers dissipated in heat forms.

$$P_{lum} = P_{el} + P_{ray} + P_{con} \quad (6)$$

Introduction of the above equations into Equation 6 leads to Equation 7:

$$A_t \cdot T^4 + D_t \cdot T + E_t = 0 \quad (7)$$

where $A_t = -A_r\varepsilon\sigma$; $D_t = \tau_0\alpha_0 A_0 CP_{in} ab - A_c h$ and

$$E_t = \tau_0\alpha_0 A_0 CP_{in}(1-a) + A_r\varepsilon\sigma T_0^4 + A_c h T_0$$

This equation is a polynomial equation of degree four whose numerical resolution by the Newton method leads to the cell temperature profile versus light concentration ratio.

The silicon intrinsic properties

Equations 8 to 15 present the silicon intrinsic electronic parameters.

(1) The electrons and the holes mobility ($m_{n,p}$) coefficients are (Souza and Sousa, 2019; Dhar et al., 2005; Savadogo et al., 2020):

$$m_m(T) = m_m^{\min}(T) + \frac{m_m^L(T) - m_m^{\min}(T)}{1 + \left(\frac{N_m}{N_m^{ref}(T)}\right)^{a_m(T)}} \quad (8)$$

$$m_m^L(T) = m_{m,300}^L\left(\frac{T}{300}\right)^{y_{0,m}} \quad (9)$$

$$m_m^{\min}(T) = m_{m,300}^{\min}\left(\frac{T}{300}\right)^{y_{1,m}} \quad (10)$$

$$N_m^{ref}(T) = N_{m,300}^{ref}\left(\frac{T}{300}\right)^{y_{3,m}} \quad (11)$$

$$a_m(T) = a_{m,300}\left(\frac{T}{300}\right)^{y_{4,m}} \quad (12)$$

The index m is linked to the type of the doping material (type n or type p). In this work the n-type doping concentration of $N_d = 10^{18}$ cm^{-3} and p-type of $N_a = 10^{16}$ cm^{-3} are considered (Souza and Sousa, 2019; Dhar et al., 2005; Savadogo et al., 2020).

Table 1 gives the parameters for the calculation of the carriers mobility in the silicon (Souza et al., 2019; Dhar et al., 2005;

Table 1. Parameters for the calculation of the mobility of the electrons (m=n) and the holes (m=p).

Parameter	$\mu^{L}_{m,300}(cm^2/Vs)$	$N^{ref}_{a,300}(cm^{-3})$	$\mu^{\min}_{m,300}(cm^2/Vs)$	$\gamma_{0,m}$	$\gamma_{1,m}$	$\gamma_{3,m}$	$\gamma_{4,m}$	$\alpha_{m,300}$
Electron	5300	2.5×10^{17}	1520	-19	-2	37	0	5
Hole	200	64×10^{16}	24	-1.2	1.2	0.47	0	1

Sources: Author's 2022

Savadogo et al., 2020).

(2) The electrons and the holes diffusion ($D_{n,p}$) coefficients are given by Souza and Sousa (2019) and Dhar et al. (2005) and Savadogo et al. (2020):

$$D_{n,p}(T) = \frac{kT}{q}\mu_{n,p}(T) \qquad (13)$$

(3) The silicon band gap energy $Eg(T)$ is (Ravindra and Srivastava, 1979):

$$Eg(T) = 1.1557 - \frac{7.021 \times 10^{-4} T^2}{T + 1108} \qquad (14)$$

(4) The intrinsic concentration of electrons in the silicon (Ouedraogo et al., 2021):

$$n_i = A_n \cdot T^{\frac{3}{2}} \cdot \exp\left(-\frac{Eg(T)}{2kT}\right) \qquad (15)$$

with A_n is a specific constant of the material and for the silicon $A_n = 3.87 \times 10^{16}\ cm^{-3}.K^{-\frac{3}{2}}$.

It appears through these equations that the silicon intrinsic parameters are temperature dependent. As the temperature is function of light concentration ratio, the intrinsic parameters and then the PV cell electronic parameters will vary with light concentration.

Electric model

The continuity equation

This study is based on a n^+-p-p^+ silicon PV cell operating under an increasing concentrated light C. The following assumptions are used in this study:

(1) the contribution of the emitter is negligible
(2) we only take into account the base contribution (Savadogo et al., 2020, 2021; Ouedraogo et al., 2021; Saria et al., 2020; Barandja et al., 2021; Soro et al., 2017).
(3) the incident light is assumed to be multispectral and the quasi-neutral base assumption is made (Savadogo et al., 2020, 2021; Ouedraogo et al., 2021; Saria et al., 2020; Barandja et al., 2021; Soro et al., 2017).

Because of light concentration, carrier's distribution within the base is non-uniform. This leads us to take into account the electric field of electrons concentration gradient given by Equation 16 (Pelanchon et al., 1992; Savadogo et al., 2020, 2021; Soro et al., 2017).

$$E(x) = \frac{D_p - D_n}{\mu_n + \mu_p} \cdot \frac{1}{d(x)} \cdot \frac{\partial d(x)}{\partial x} \qquad (16)$$

In Equation 16, $d(x)$ represents carriers' density at the depth x in the base. D_n and D_p respectively represent the electrons and the holes diffusion coefficients. These diffusion coefficients are temperature dependent as shown by Equations 8 to 13. μ_n and μ_p are the electrons and the holes mobility coefficients. As shown by Equations 8 to 12, these mobility coefficients are also temperature dependent.

In steady-state, the following continuity Equation 17 is determined by considering phenomena of generation, recombination and diffusion/conduction of carriers.

$$\frac{\partial^2 d(x)}{\partial x^2} - \frac{d(x)}{(L^c(T))^2} = -\frac{G_n}{D^c(T)} \qquad (17)$$

In continuity Equation 17, $D^c(T)$ and $L^c(T)$ respectively represent the diffusion coefficient and the diffusion length versus temperature T as shown by Equations 18 and 19.

$$D^c(T) = \frac{\mu_n(T)\left[D_n(T) - D_p(T)\right] + \mu_p(T)D_n(T)}{\mu_n(T) + \mu_p(T)} \qquad (18)$$

$$L^c(T) = \sqrt{D^c(T) \cdot \tau} \qquad (19)$$

In Equation 19, τ represents the electron lifetime.

Carriers density

The generation rate of carriers G_n is equal to the sum of two contributions as show by Equation 20 (Savadogo et al., 2020; Dieme et al., 2015; Gökhan, 2016):

$$G_n = G(x) + G_{th} \tag{20}$$

(1) The photo generation rate $G(x)$ at the position x is given by (Barandja et al., 2021; Ouedraogo et al., 2021; Pelanchon et al., 1992; Saria et al., 2020; Savadogo et al., 2020,2021; Soro et al., 2017):

$$G(x) = C \cdot \sum_{i=1}^{3} a_i e^{-b_i x}$$

Coefficients a_i and b_i are deduced from modelling of photo generation rate considering overall solar radiation spectrum:

radiation spectrum.

(2) The thermal-generation rate G_{th} is (Savadogo et al., 2020; Dieme et al., 2015; Gökhan, 2016):

$$G_{th} = C_{th} \times n_i^2 \tag{22}$$

where G_{th} is a coefficient given by $t = \frac{1}{C_{th} N_b}$ and N_b represents the base doping level.

The carriers' density $d(x,T)$ is determined by solving the continuity Equation 17 and is temperature dependent:

$$d(x,T) = A\,ch(a(T)x) + B\,sh(a(T)x) + \sum_{i=1}^{3} K_i(T) \times e^{-b_i x} + \frac{(L^c(T))^2}{D^c(T)} C_{th} A_n^2 T^3 \exp\left(-\frac{Eg(T)}{kT}\right) \tag{23}$$

with $K_i(T) = \frac{C}{D^c(T)} \frac{a_i (L^c(T))^2}{\left[1 - \left(b_i L^c(T)\right)^2\right]}$ and $a(T) = \frac{1}{L^c(T)}$.

RESULTS AND DISCUSSION

Influence of light concentration on temperature profile

The numerical resolution of Equation 7 using Matlab software provides data. These data are used to plot with the OriginPro 8 software the temperature profile given in Figure 3.

Figure 3 shows a rapid increase in cell temperature with increasing light concentration ratio. Indeed, concentration ratio increase leads to increase of heat received by the PV cell and therefore its temperature increases.

The temperature increases from 300 K to more than 1710 K when light concentration increases from C= 1 Sun to C=666.60 Suns. 1710 K represents the melting temperature of the silicon (Talyzin et al., 2019). This result shows that, a concentrated PV system which is not associated to a system of cooling cannot achieve a concentration ratio of C=666.60 Suns.

According to Reggiani et al. (2000), Equations 8 to 13 which give the diffusion and mobility coefficients in silicon remain valid for temperatures below 650K. Also Ravindra and Srivastava (1979) show that the Equations 14 and 15 which give the gap energy and the intrinsic density in the silicon remain valid for temperature $T \le \theta_D = 645\ \mathrm{K}$ ($\theta_D = 645\ \mathrm{K}$ being the silicon Debye temperature).

In continuation of the present work, we will take as maximum value of concentration ratio, C=50 Suns which corresponds according to the temperature profile to a temperature of approximately T=600K.

Influence of concentration ratio on the electrons and the holes coefficients of mobility and diffusion

Figure 4 gives the variations of the mobility of electrons and holes versus light concentration ratio in the silicon.

Figure 4 shows that electrons mobility decreases when light concentration goes from 1 Sun to 3 Suns before increase slightly to reach its maximum $(\mu_n)_{\max} = 1895.31\ cm^2V^{-1}s^{-1}$ at C=6.77 Suns where the PV cell temperature is $T = 430.92\ K$. Beyond C=6.77 Suns, electrons mobility decreases with light concentration increase. Thus, it emerges that the mobility of the electrons globally decreases with light concentration increase in even if a slight increase is observed in the initial zone. However, the holes mobility decreases slightly when light concentration goes from 1 Sun to 50 Suns. Its corresponding value at C=6.77 Suns is $\mu_p = 126.49\ cm^2V^{-1}s^{-1}$.

The decrease of the electrons and the holes mobility with light concentration increase can be explained by the temperature increase with concentration ratio shown earlier.

These results agree with authors such as Reggiani et al. (2000), Souza and Sousa (2019) and Soro et al. (2017) who showed that the electrons and the holes mobility decrease with temperature increase.

The variations of the electrons and the holes diffusion coefficients versus concentration ratio are also plotted as shown in Figure 5.

Figure 5 shows that the electrons diffusion coefficient

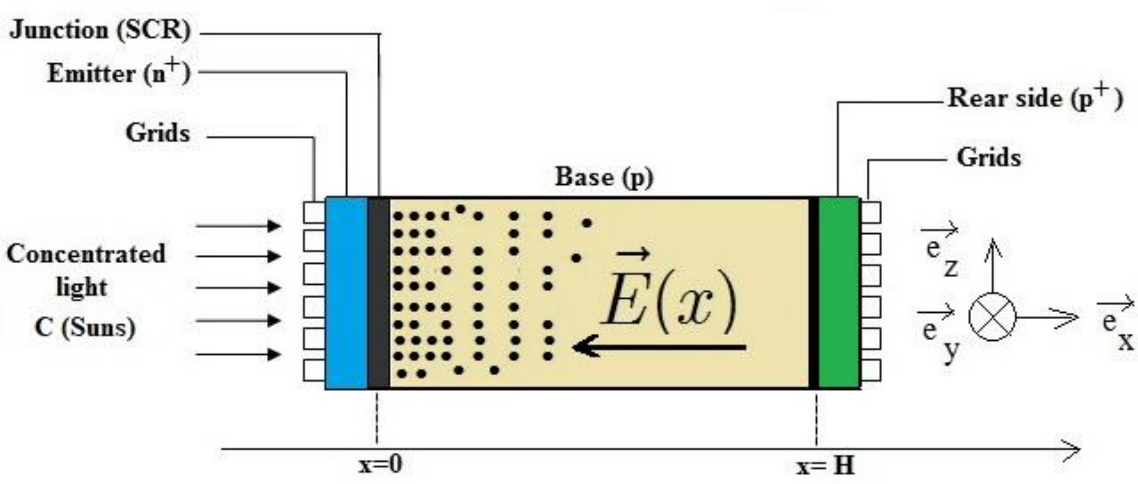

Figure 2. Illustration of a silicon PV cell under concentration.
Sources: Author's 2022

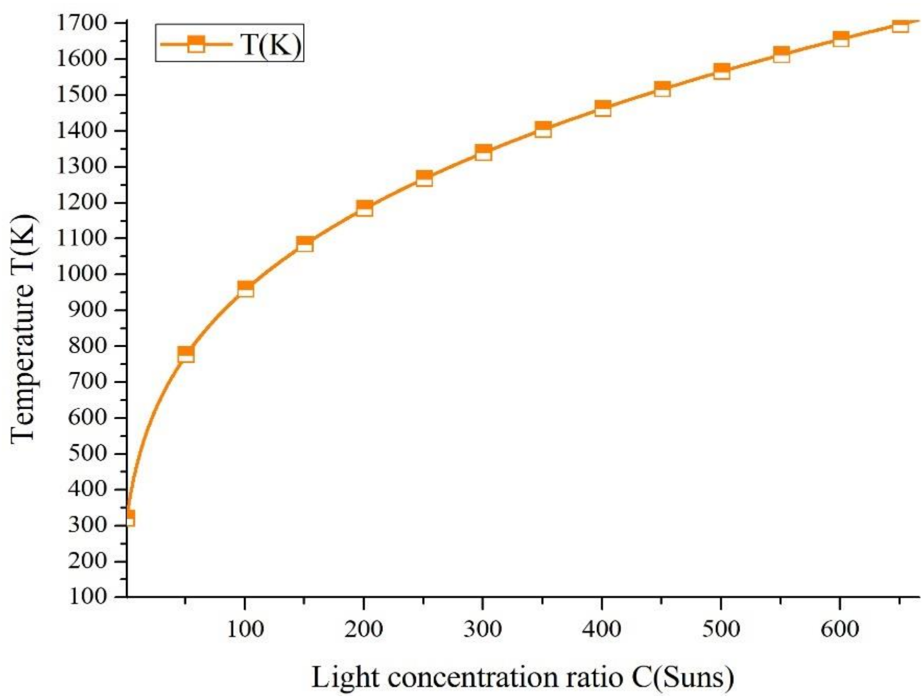

Figure 3. Temperature variation with light concentration ratio.
Sources: Author's 2022

increases with light concentration to reach its maximum $(D_n)_{\max} = 76.55\ cm^2.s^{-1}$ at the concentration C=12.59 Suns, where temperature is T=508.24 K. Beyond C=12.59 Suns, the electrons diffusion coefficient decreases with increasing light concentration ratio. However, the diffusion coefficient of the holes decreases slowly with light concentration increase and its corresponding value at C=12.59 Suns is $D_p = 4.58\ cm^2.s^{-1}$.

Influence of concentration ratio on silicon gap energy

Figure 6 gives the variations of the silicon gap energy with light concentration increase. From Figure 6 it

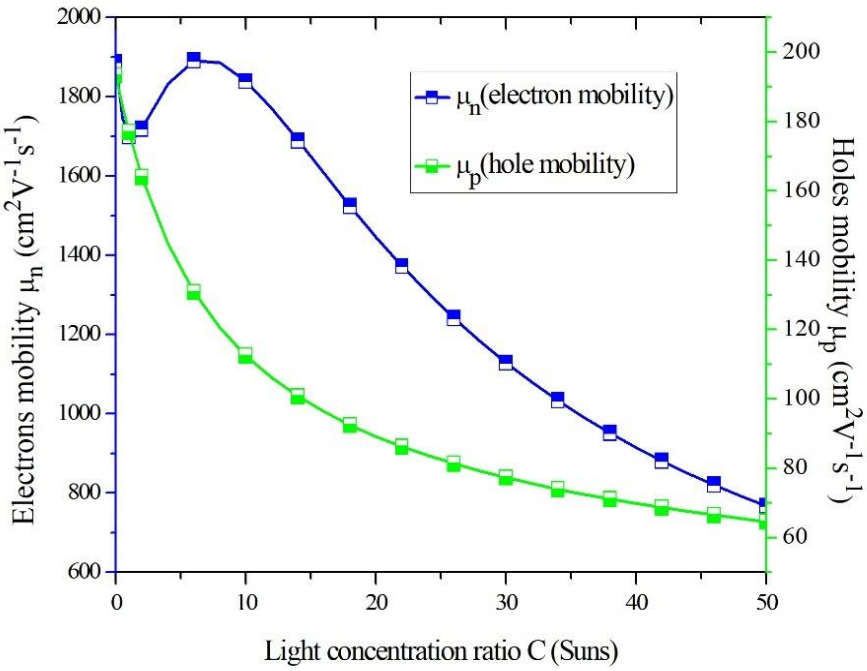

Figure 4. The electrons and the holes mobility versus concentration.
Sources: Author's 2022

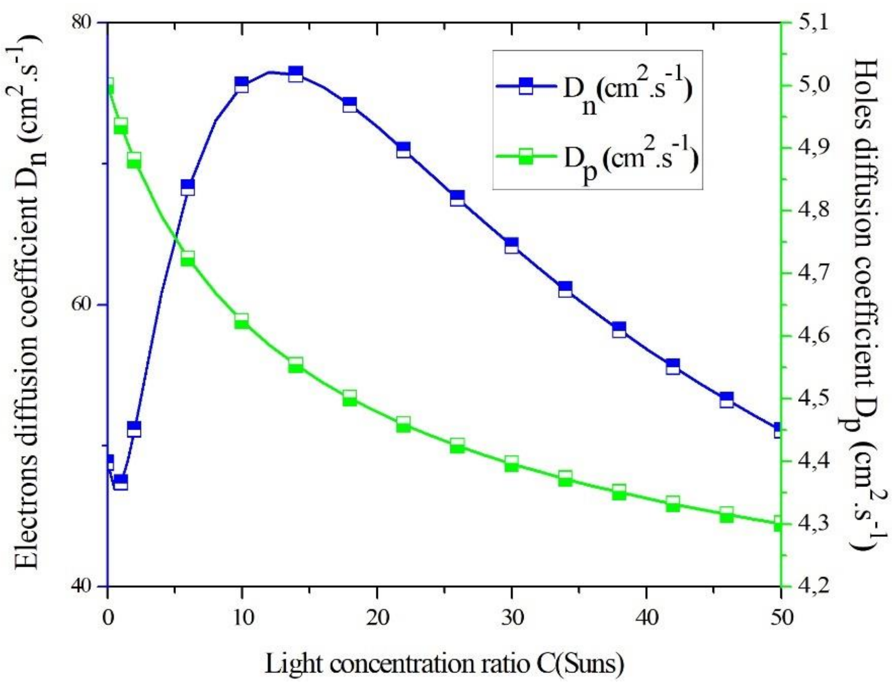

Figure 5. Diffusion coefficients of electrons and holes versus concentration ratio.
Sources: Author's 2022

appears that a decrease of the silicon energy gap with light concentration increases. This decrease of the silicon gap energy with light concentration increase can be explained by: (1) its decrease with the temperature and which has been shown by authors such as Reggiani et al. (2000). (2) The temperature increase with concentration

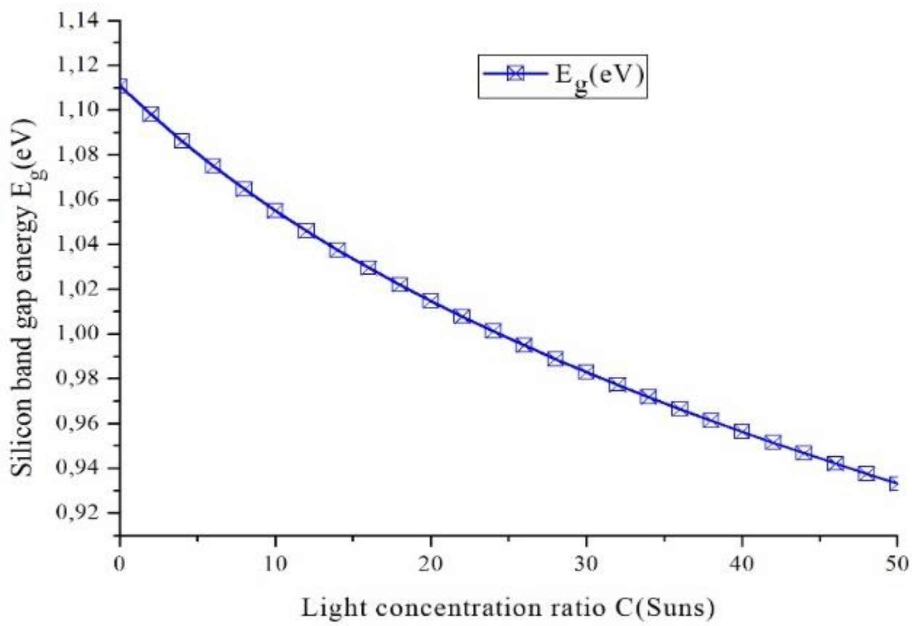

Figure 6. Gap energy versus light concentration.
Sources: Author's 2022

ratio and which is shown by the temperature profile earlier.

Influence of concentration ration on electrons intrinsic density

Figure 7 gives variations of electrons intrinsic density with light concentration ratio. Figure 7 shows that for concentration values lower than 12 Suns $C \leq 12\ Suns$, the electrons intrinsic density is constant and practically null. Beyond C=12 Suns where the cell temperature is T= 501.32 K, this intrinsic density increases exponentially with light concentration.

The electrons intrinsic density increase can also be explained by two facts: (1) its increase with temperature which has been shown by authors such as Ravindra and Srivastava (1979). (2) The temperature increase with light concentration shown by temperature profile earlier.

Influence of concentration ratio on minority charge carrier's density profile

Figure 8 gives, in an intermediate operating point, the carrier density profile for different concentrations ratio.

The curves in Figure 8 show that light concentration increase leads to an increase of carrier density. This result agrees with Pelanchon et al. (1992) and Zoungrana et al. (2012) who did not take into account the effect of light concentration on the temperature.

It was noted that for concentrations C=1 Sun to C=9 Suns, carrier density curves present mainly two (02) parts:

(1) In the zone near the junction (x≤ 0.01 cm): the carrier density increases slowly with the depth x. This variation of the density can be explained by passage through the cell junction of carriers located in this zone.
(2) Beyond x=0.01 cm, carrier density is practically invariable with the position x in the base. This invariance of the density with the position x is linked to the consideration of carriers thermal generation which is done uniformly in the volume of the base. The photo-generation being however preponderant in the zone close to junction and decreases with the position x in the base.

Results therefore show that carrier's density is greater in rear side compared to the zone near the junction. This result is in contradiction with Pelanchon et al. (1992) and Zoungrana et al. (2012) who showed that carriers density is greater at the illuminated face.

This contradiction is due to the fact that Pelanchon et al. (1992) and Zoungrana et al. (2012) did not take into account temperature effect. Indeed, as shown earlier, beyond C=12 Suns where the cell temperature is T= 501.32 K, the carriers intrinsic density increases exponentially with light concentration.

This contradiction is also explained by variations of the gap energy, the mobility and the diffusion of electrons and holes as shown in this study.

The positive slope presented by the carrier density curve at C=12 Suns, shows that all the generated carriers

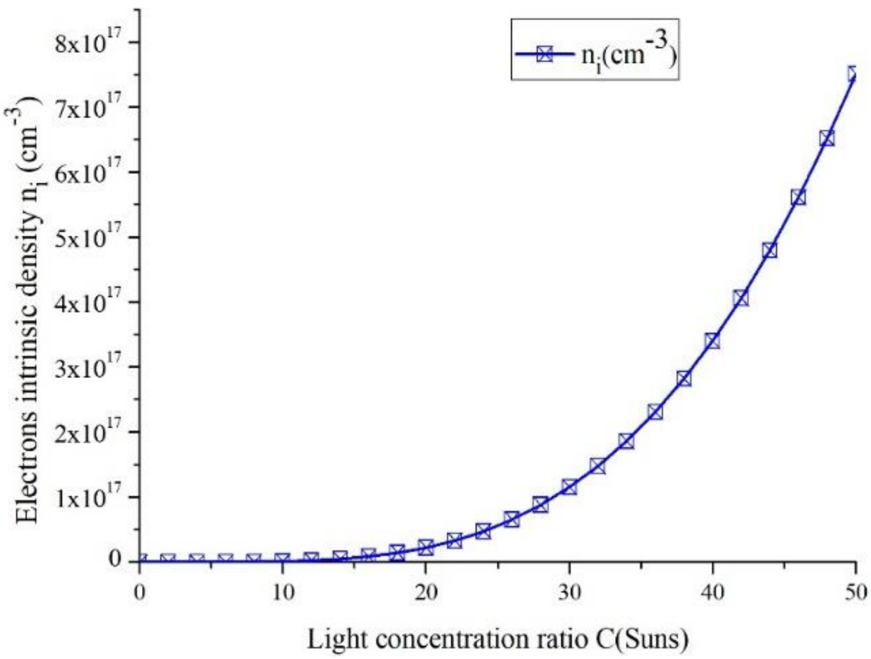

Figure 7. Electrons intrinsic density versus light concentration.
Sources: Author's 2022

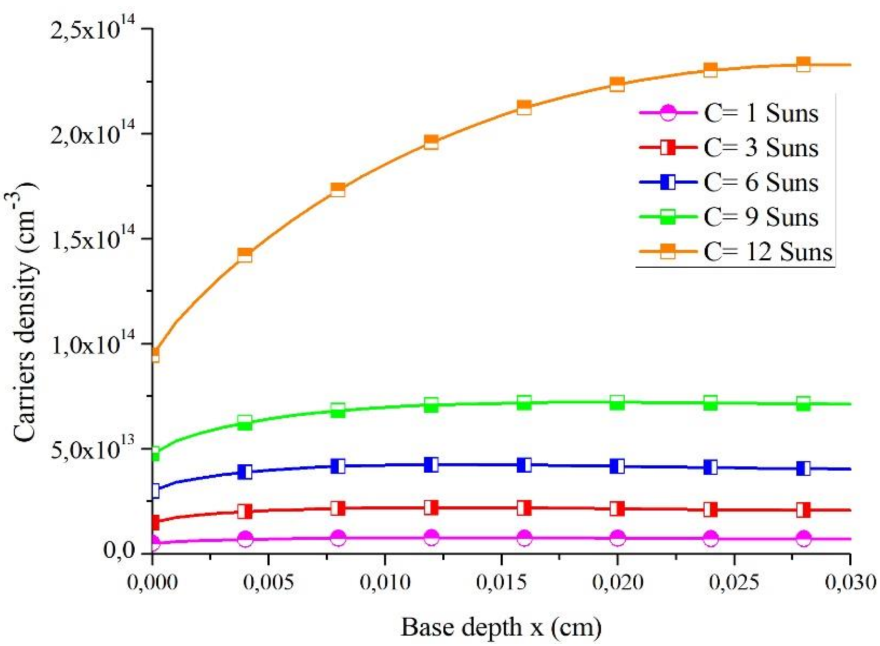

Figure 8. Carrier density profile in an intermediate operating point for different concentrations.
Sources: Author's 2022

will cross the cell junction to participate to the current. We must therefore expect from C=12 Suns very high values for the current density.

The carrier density profile was also plotted in the short-circuit situation and for different concentrations as shown in Figure 9.

Carrier density and slopes of the curves at junction increase with concentration ratio increase. Opposite to Pelanchon et al. (1992) and Zoungrana et al. (2012), the carrier's density is greater in rear side compared to the

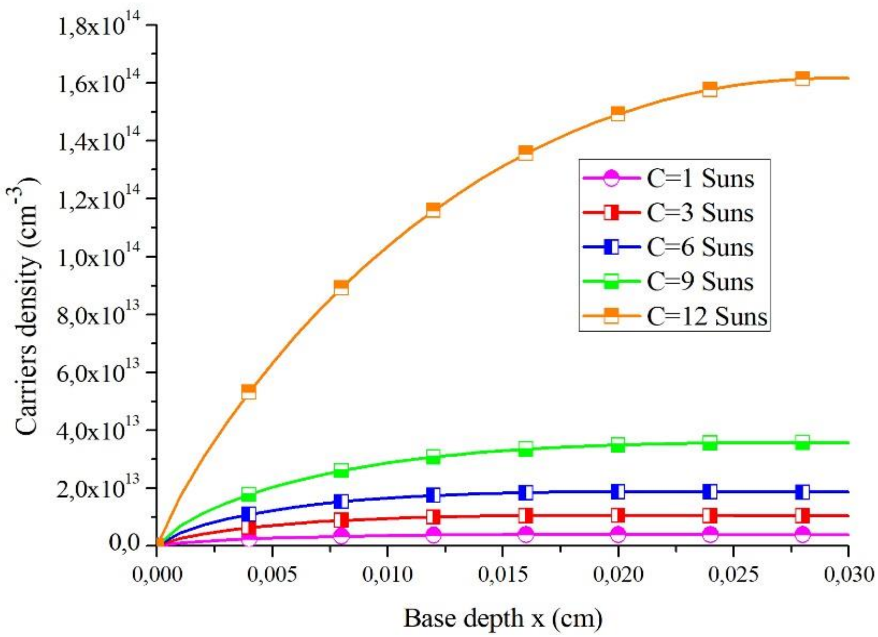

Figure 9. Carriers density profile in short-circuit situation for different concentrations.
Sources: Author's 2022

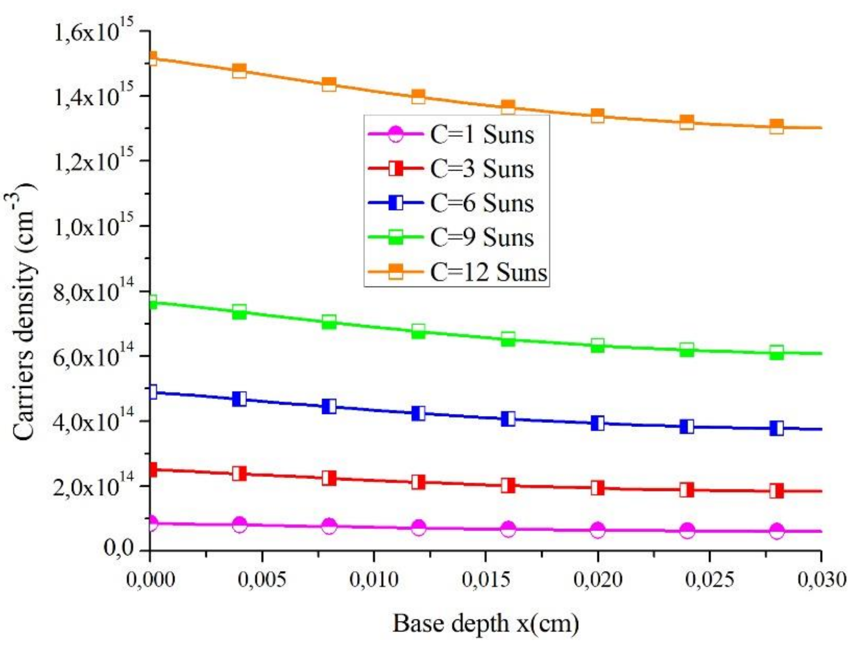

Figure 10. Carriers density profile near the open-circuit for different concentrations.
Sources: Author's 2022

zone near the junction.

The cell being in the short-circuit situation, all the carriers cross the cell junction. There is no carrier storage near the cell junction: at the cell junction, the minority carrier's density is practically null. Also, the augmentation of the slope of curves of carriers density reflects the short-circuit current density increase with the concentration ratio.

Near the open-circuit, the carrier density profile was also plotted for different light concentrations as shown in Figure 10.

For a given concentration, we note that carrier density is maximum at the cell junction and decreases with the position x in the base. It was also noted that carrier density curves present negative slopes at the cell junction.

These negative slopes presented by density curves at the cell junction show that the carriers do not cross the cell's junction; we have carrier's storage at the cell's junction.

Conclusion

In this study, a thermal model of the PV cell under variable light concentration was proposed. In steady state, the PV cell thermal equation was obtained. The resolution of this equation led to the temperature profile.

The results show that the cell temperature goes from 300 K to more than 1710 K when light concentration goes from C= 1 Sun to C=666.60 Suns. However, the silicon melting temperature is 1710 K and this result shows that a concentration of C=666.60 Suns cannot be reached without the association of cooling system to the concentrated PV system.

The mobility and diffusion coefficients of the electrons first increase with the concentration to reach their maximum (at C=6.77 Suns for the mobility coefficient and at C= 12.59 Suns for the diffusion coefficient, respectively) before decrease. However, the mobility and diffusion coefficients of the holes decrease with light concentration increase.

The silicon gap energy decreases while electrons intrinsic density increases with light concentration increase. These results are explained on one hand by dependence these parameters on temperature and on the other hand by temperature increase with light concentration ratio.

An electrical model of the PV cell under concentration is also proposed. This model is used to determine the carrier density.

It emerges that whatever the operating point, carrier's density increases significantly with light concentration.

The results also show that carrier's density is greater in the rear side compared to the zone near the junction. This result is linked to carrier's intrinsic density exponential increase with light concentration. This result is in contradiction with Pelanchon et al. (1992) and Zoungrana et al. (2012) who did not take into account temperature effect and who showed that carrier's density is greater at the illuminated face.

This contradiction is also explained by variations of the gap energy, the mobility and the diffusion of electrons and holes as shown in this study. These intrinsic parameters were assumed to be constant by Pelanchon et al. (1992) and Zoungrana et al. (2012).

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The authors thank the International Science Program (ISP) for supporting their research.

REFERENCES

Alkuhayli A, Telba A (2021). Effect of High Temperature on the Efficiency of Grid-Connected PV System. Proceedings of the World Congress on Engineering 7-9 july.

Amar S, Bahich M, Bentahar Y, Afifi M, Barj E (2021) A Study of the Temperature Influence on Different Parameters of Mono-Crystalline Silicon Photovoltaic Module. Journal of Power and Energy Engineering 9:29-42. https://doi.org/10.4236/jpee.2021.96003

Barandja VDB, Pakouzou BM, Ramdé EW, M'boliguipa J, Saria M, Zoungrana M, Zerbo I (2021). Modeling the response of an illuminated polysilicon solar cell under the influence of radio waves, a 3D approach. Energy Reports 7:2094-2100. https://doi.org/10.1016/j.egyr.2021.04.015

Cui M, Chen N, Yang X, Wang Y, Bai Y, Zhang X (2009). Thermal analysis and test for single concentrator solar cells. Journal of Semiconductors 30(4).

Dhar S, Kosina H, Palankovski V, Ungersbock SE, Selberherr S (2005). Electron Mobility Model for Strained-Si Devices. IEEE Transactions on Electron Devices 52(4):527-533. https://doi:10.1109/ted.2005.844788

Dieme N, Seibou B, Moujtaba MAOE, Gaye I, Sissoko G (2015). Thermal behavior of a parallel vertical junction Silicon photocell in static regime by study of the series and shunt resistances under the effect of temperature; International Journal of Innovative Science, Engineering & Technology 2(1).

El Chaar L, lamont LA, El Zein N (2011). Review of photovoltaic technologies. Renewable and Sustainable Energy Reviews 15:2165-2175.

Gökhan S (2016). Effect of Temperature on the Series and Shunt Resistance of a Silicon Solar Cell under Frequency Modulation. Journal of Basic and Applied Physics 5(1):21-29.

Kabbani A, Honnurvali MS (2021). PV Cell Parameters Modeling and Temperature Effect Analysis. International Journal of Renewable Energy Development 10(3):563-571. https://doi.org/10.14710/ijred.2021.33845

Mattei M, Notton G, Cristofari C, Muselli M, Poggi P (2006). Calculation of the polycrystalline PV module temperature using a simple method of energy balance. Renewable Energy 31:553-567.

Medekhel L, Srairi K, Labiod C (2022). Experimental study of temperature effects on the photovoltaic solar panels performances in Algerian desert. International Journal of Energetica 7(1):18-22

Ouedraogo A, Savadogo M, Honadia PAA, Bathiebo DJ, Kam S (2021). Individual Energetic Processes Efficiencies in a Polycrystalline Silicon PV Cell Versus Electromagnetic Field. Springer Nature B.V. (Silicon), 2021. https://doi.org/10.1007/s12633-021-01480-y

Pelanchon F, Sudre C, Moreau Y (1992). Solar cells under intense light concentration: Numerical and analytical approaches. 11th European Photovoltaic Solar Energy Conference, Montreux 12 to 16 October.

Ravindra NM, Srivastava VK (1979). Temperature Dependence of the Energy Gap in Semiconductors. Journal of Physics and Chemistry of Solids 40:791-793. https://doi.org/10.1016/0022-3697(79)90162-8

Reggiani S, Valdinoci M, Colalongo L, Rudan M, Baccarani G (2000). An Analytical, Temperature-dependent Model for Majority- and Minority-carrier Mobility in Silicon Devices. The Gordon and Breach Science Publishers imprint 10(4):467-483.

Royne A, Dey CJ, Mills DR (2005). Cooling of photovoltaic cells under concentrated illumination: a critical review. Solar Energy Materials and Solar Cells 86:451-483.

Santos LO, Carvalho PCM, Filho COC (2022). Photovoltaic Cell Operating Temperature Models: A Review of Correlations and Parameters. IEEE JOURNAL OF PHOTOVOLTAICS 12(1):179-190. https://doi.org/10.1109/JPHOTOV.2021.3113156

Saria M, Zouma B, Korgo B, Barandja VDB, Zoungrana M, Zerbo I, Bathiebo DJ (2020). Effect of Reverse Polarisation of an Electromagnetic Field on the Performance of a Silicon PV Cell. Hindawi, Advances in Materials Science and Engineering. ID 1320268: 6. https://doi.org/10.1155/2020/1320268

Savadogo M, Soro B, Konate R, Sourabié I, Zoungrana M, Zerbo I, Bathiebo DJ (2020). Temperature Effect on Light Concentration Silicon Solar Cell's Operating Point and Conversion Efficiency. Smart Grid and Renewable Energy 11:61-72. https://doi.org/10.4236/sgre.2020.115005

Savadogo M, Konfe A, Sourabie I, Soro B, Konate R, Zoungrana M, Zerbo I, Bathiebo DJ (2021). Light Concentration Solar Cell: Temperature Proper and Dynamic Effects on Electrical Parameters Determined by using J-V and P-V Characteristics. Global Journal of Pure and Applied Sciences 27:341-347. https://dx.doi.org/10.4314/gjpas.v27i3.10

Soro B, Zoungrana M, Zerbo I, Savadogo M, Bathiebo DJ (2017). 3-D Modeling of Temperature Effect on a Polycrystalline Silicon Solar Cell under Intense Light Illumination. Smart Grid and Renewable Energy 8(9):291-304.

Souza JST, Sousa NCAD (2019). Temperature influence on mobility and charge density model of photovoltaic cells. Revista Brasileira de Ensino de Física 41(3):e20180272.

Swapnil D, Jatin NS, Bharath (2013). Temperature Dependent Photovoltaic (PV) Efficiency and Its Effect on PV Production in the World-A Review. Energy Procedia 33:311-321.

Talyzin IV, Samsonov MV, Samsonov VM, Pushkar MY, Dronnikov VV (2019). Size Dependence of the Melting Point of Silicon Nanoparticles: Molecular Dynamics and Thermodynamic Simulation. Semiconductors 53(7):947-953. doi:10.1134/S1063782619070236

Wang Z, Zhang H, Zhao W, Zhou Z, Chen M (2015). The effect of concentrated light intensity on temperature coefficient of the InGaP/InGaAs/Ge triple junction solar cell. The Open Fuels and Energy Science Journal, 8 106-111.

Zoungrana M, Zerbo I, Ouédraogo F, Zouma B, Zougmoré F (2012). 3D modeling of magnetic field and light concentration effects on a bifacial silicon solar cell illuminated by its rear side. IOP Conferences Series: Materials Science and Engineering 29(012020):1-12.

Zoungrana M, Zerbo I, Savadogo M, Tiedrebeogo S, Soro B, Bathiebo DJ (2017). Effect of light intensity on the performance of silicon solar cell. Global Journal of Pure and Applied Sciences 23:123-129.