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SECTION 6. Metallurgy and energy.

Nfally Dieme
Laboratory of Semiconductors and Solar Energy,
Department of Physics,
Faculty of Science and Technology,
Cheikh Anta DiopUniversity,
Dakar, Senegal
nfallydieme@yahoo.fr fallydieme@gmail.com

Moustapha Sane
LSSE, DP, FST, Cheikh Anta DiopUniversity,
Dakar, Senegal
moustaphasane2003@yahoo.fr

Idrissa Fabe Barro
LSSE, DP, FST, Cheikh Anta DiopUniversity,
Dakar, Senegal
fabebarro@gmail.com

PHOTOCURRENT AND PHOTOVOLTAGE UNDER INFLUENCE OF THE SOLAR CELL THICKNESS

***Abstract**: A theoretical study of a parallel vertical junction silicon solar cell under a multi-spectral illumination in static regime has been done under impact of the thickness of this solar cell. Based on the diffusion-recombination equation, the expression of excess minority carrier density in the base was established according to the thickness. Photocurrent density and photovoltage are then deduced. The objective of this work is to show the effects of solar cell thickness on these electrical parameters.*

***Key words**: photocurrent density, photovoltage, thickness, Vertical junction.*

***Language**: English*

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1. Introduction

The vertical junction solar cell is manufactured by an alternative junction base -emitter-base-emitter. Both sides have the same thickness [1]. The incident rays simultaneously touch the base, the junction and the emitter. Each base and emitter is bordered by an aluminum collector as shown in the following figure1.

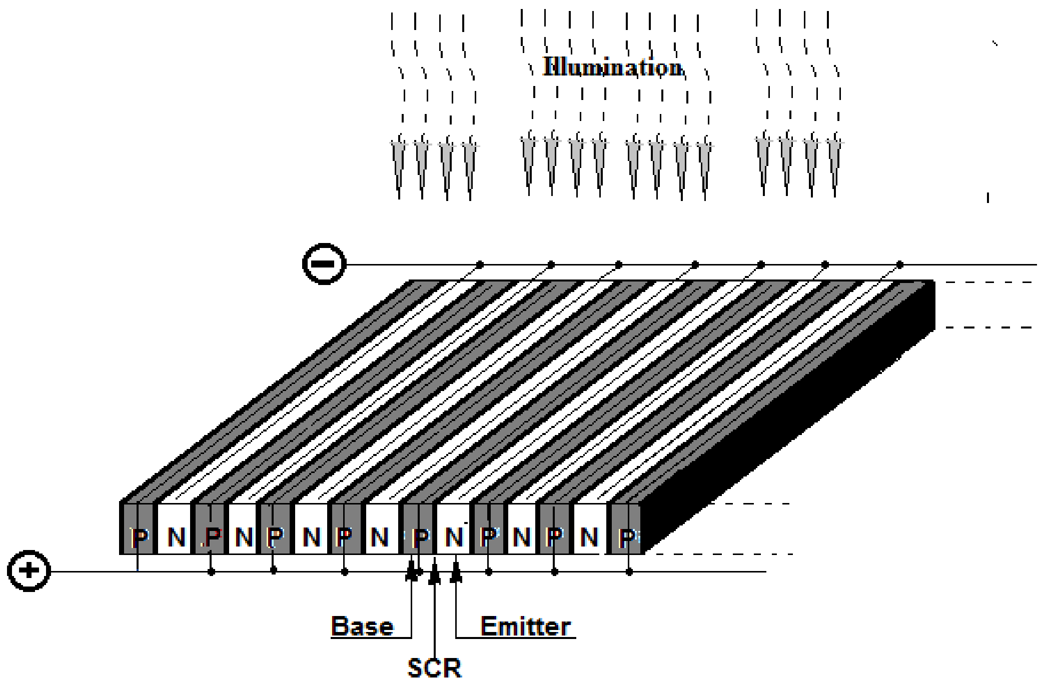

Figure 1 - Parallel vertical junction solar cell.

The bases are interconnected by a connecting wire to define the positive electrode and the emitters are connected together to form the negative electrode. The aim of this work is to investigate the influence of The thickness of the solar cell on electrical parameters such as photocurrent and photovoltage. Knowing the evolution of these two quantities based on the thickness is a good indicator for us to comment on the impact on the performance of solar cells.

2. Mathematical study

2.1. Hypotheses

We assume that the following hypotheses are satisfied.

The solar cell is illuminated along the z axis.

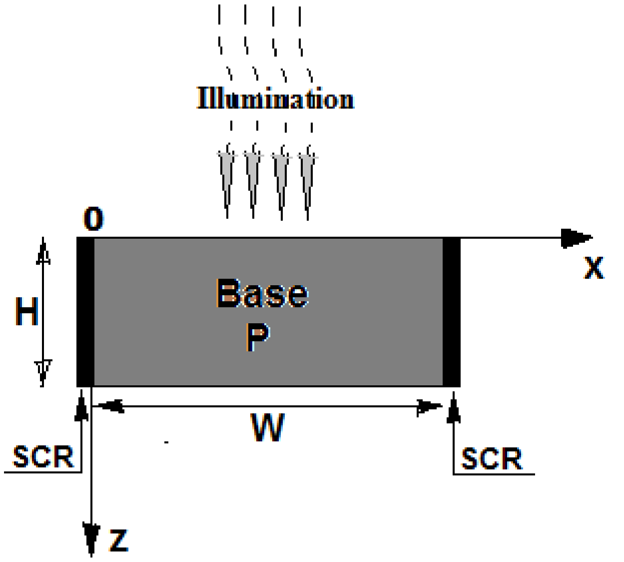

Figure 2 - Base of parallel vertical junction solar cell (thickness: H; width:W =0,03cm).

- The contribution of the emitter is neglected.
- Illumination is made with polychromatic light in steady state, and is considered to be uniform on the z = 0 plane.
- There is no electric field without space charge regions.

2.2. Density of minority charge carriers

When the solar cell is illuminated, there are simultaneously three major phenomena that happen: generation, diffusion and recombination.

These phenomena are described by the diffusion-recombination equation obtained with:

$$\frac{\partial^2 n(x)}{\partial x^2} - \frac{n(x)}{L^2} = -\frac{G(z)}{D} \quad (1)$$

D is the diffusion constant and is related to the operating temperature through the relation [2], [3]

$$D = \mu . \frac{K}{q} . T \quad (2)$$

with q as the elementary charge, k the Boltzmann constant and T temperature.

G(z) is the carrier generation rate at the depth z in the base and can be written as

$$G(z) = \sum a_i e^{-b i z} \quad (3)$$

a_i and b_i are obtained from the tabulated values of AM1.5 solar illumination spectrum and the dependence of the absorption coefficient of silicon with illumination wavelength.

n(x), L, τ, and μ are respectively the density of the excess minority carriers, the diffusion length, lifetime and mobility.

The solution to the equation (1) is:

$$n(x) = A\sinh(\frac{x}{L}) + B\cosh(\frac{x}{L}) + \sum \frac{a_i}{D} L^2 e^{-biz} \quad (4)$$

Coefficients A and B are determined through the following boundary conditions:

at the junction (x=0):

$$\left.\frac{\partial n(x)}{\partial x}\right|_{x=0} = \frac{S_f}{D} n(0) \qquad (5)$$

This boundary condition introduces a parameter S_f which is called recombination velocity at the junction; Sf determines the flow of the charge carriers through the junction and is directly related to the operating point of the solar cell. The higher Sf is, the higher the current density will be.

in the middle of the base (x=W/2) [5]:

$$\left.\frac{\partial n(x)}{\partial x}\right|_{x=\frac{w}{2}} = 0 \qquad (6)$$

Equation 8 illustrates the fact that excess carrier concentration reaches its maximum value in the middle of the base due to the presence of junction on both sides of the base along x axis (figure 1).

2.3. Photocurrent density

The photocurrent Jph is obtained from the following relation given that there is no drift current [5]:

$$J_{ph} = 2qD\left.\frac{\partial n(x)}{\partial x}\right|_{x=0} \qquad (7)$$

2.4. Photo-voltage

The photo-voltage derives from the Boltzmann relation [6]:

$$V_{ph} = \frac{k.T}{q}\cdot \ln\left(N_B\cdot\frac{n(0)}{n_i^2}+1\right) \qquad (8)$$

with

$$n_i = A_n.T^{\frac{3}{2}}.\exp\left(\frac{Eg}{2KT}\right) \qquad (9)$$

n_i refers to the intrinsic concentration of minority carriers in the base,

A_n is a specific constant of the material (**A_n=3.87x10^{16}** for silicon)

N_B is the base doping concentration in impurity atoms

Eg is the energy gap; it is given by [3]; [4]:

$$Eg = Eg_0 - \frac{a.T^2}{b+T} \qquad (10)$$

(Eg_0=1.170 eV; a=4.9 10^{-4} eV.K^{-2}; b=655K for silicon)

3. Results and discussion

In this section of our work, we present the results obtained from simulations.

3.1. Photocurrent density

The figure3 and Figure4 show the impact of the solar cell thickness on the photocurrent density.

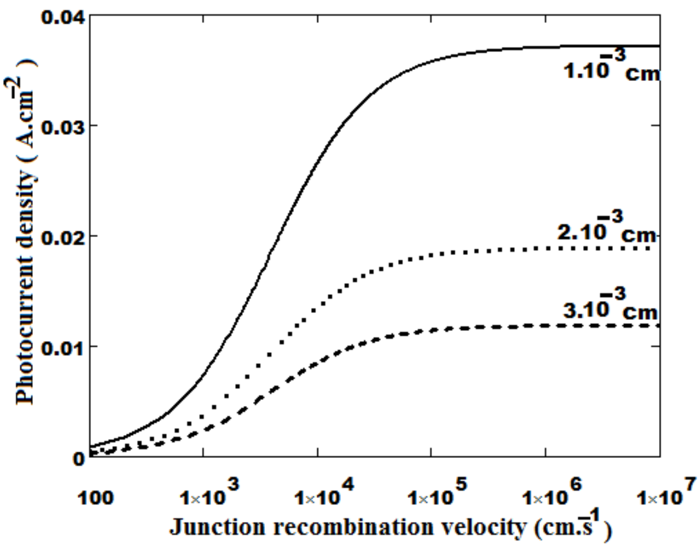

Figure 3 - Photocurrent density versus junction recombination velocity. T=300K

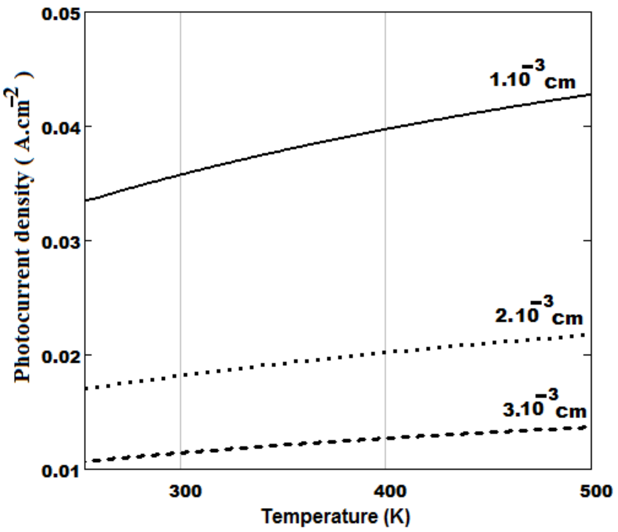

Figure 4 - Photocurrent density versus temperature Sf=10^5cm.

La figure3 shows the evolution of the photocurrent density versus junction recombination velocity for various values of solar cell thickness. It can be seen that the photocurrent increase with the junction recombination velocity. The recombination velocity at the junction reflects the stream of carriers crossing the junction [7]. For higher Sf, the carrier flow through the junction increases so that the generated photocurrent also increases: the solar cell operates near short circuit [10].

It can also be seen that the increase in the solar cell thickness causes a decrease in the photocurrent density. This same Remark is noticed in the figure5 that shows the profile of the photocurrent density versus temperature for various values of the solar cell thickness. In this figure we note that photocurrent density increases as operating temperature increase [8], [9].

3.2. Photovoltage

The figure5 and Figure6 show the impact of the solar cell thickness on the photocurrent density.

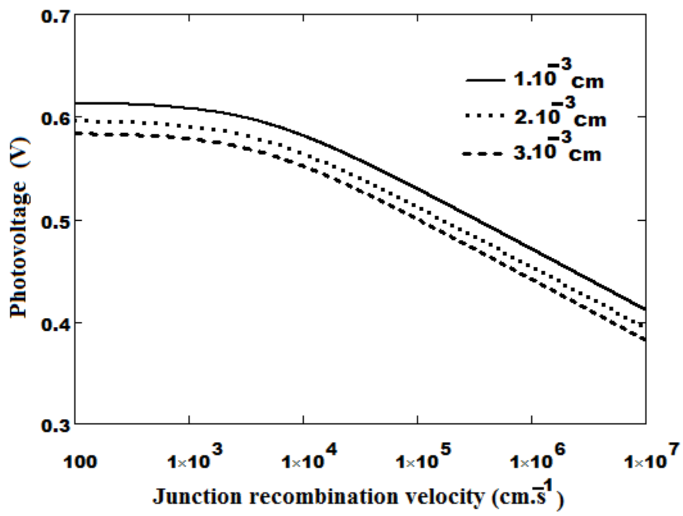

Figure 5 - Photovoltage versus junction recombination velocity T=300K.

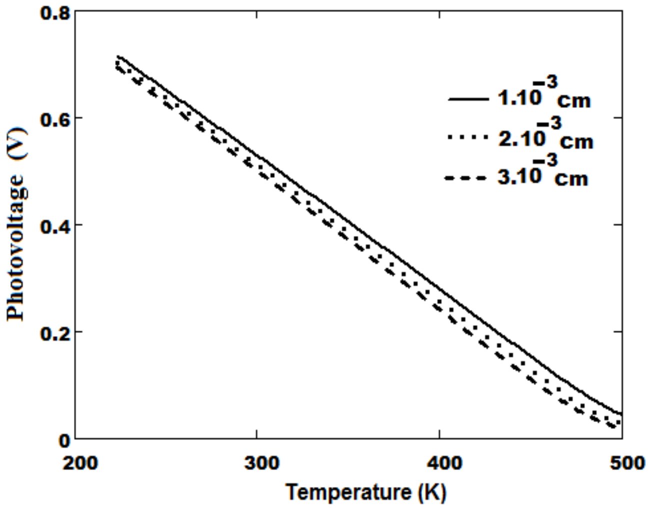

Figure 6 - Photovoltage versus temperature Sf=10^5cm.

For lower junction recombination velocities, carriers flow through the junction is neglectable since carriers are stored across the junction: the photovoltage is at the maximum value (open-circuit voltage) [10]. For increasing Sf value, carriers flow through the junction increase and the stored charge cross the junction leading to a decrease of the photovoltage [7]. This decrease is all the more important than solar cell thickness is high. This simple remark is observed in the figure6. In this figure we note that photvoltage decreases as operating temperature increase [8], [9].

3.3. Characteistc current-voltage

Figure 7 shows the evolution of photocurrent density for different values of the solar cell thickness and in relation to photo-tension.

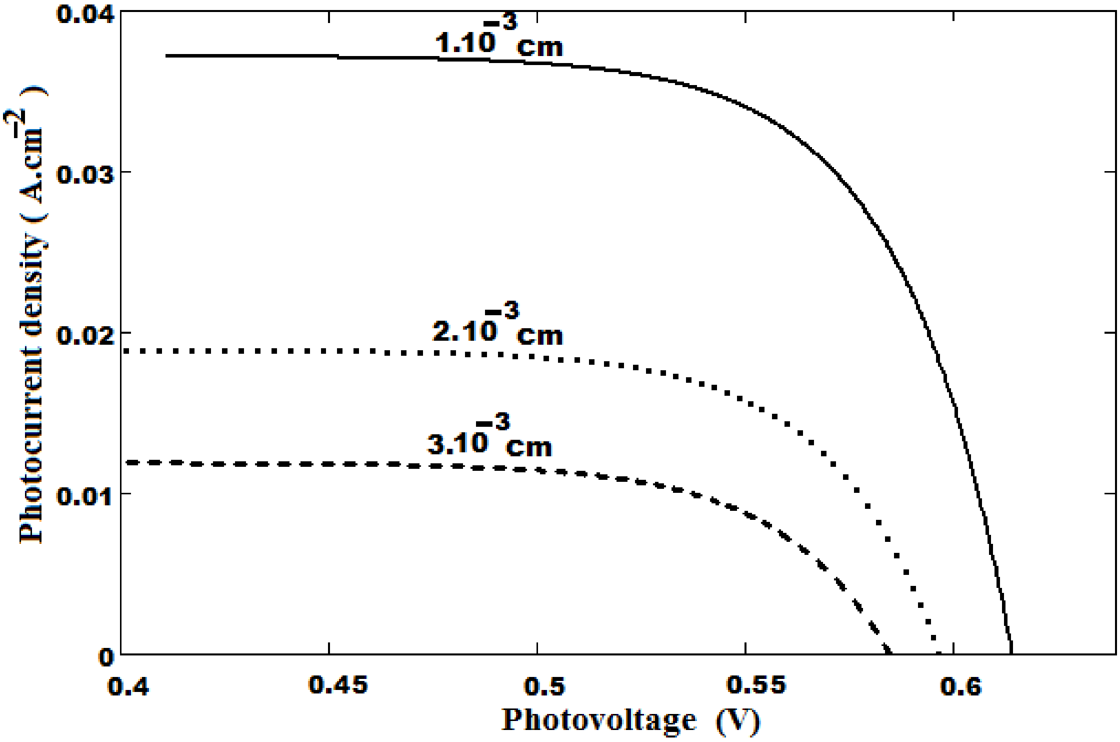

Figure 7 - Photocurrent density versus photovoltage.

Figure 7 shows that when photo-courant is maximized, photo-tension nears the zero level and vice versa. It can be noted that this figure perfectly confirms variation of the two physical quantities (photovoltage and photocurrent) in relation to solar cell thickness.

Indeed the increase in thickness increases defects in structuring and traps center for photogenerated electrons. Moreover high thickness increases rate imperfection of the junction. All these malfunctions are the reals causes of the decrease of photocurrent and photovoltage.

It can also be seen that when there is an increase in thickness of ΔH = 10^{-3}cm, photovoltage can decrease by almost 3% while photocurrent can decrease by about 49%.

4. Conclusion

A theoretical study of a vertical junction solar cell has been presented. Electrical parameters such as photocurrent density, photovoltage, have been determined and we showed the effects of solar cell. This study exhibit the fact that photocurrent density and photovoltage depend on solar cell thickness. An increase in the thickness of ΔH = 10^{-3}cm can prompt a decrease in photovoltage of almost 3% and a decrease in photocurrent of about 49%. We can estimate that high solar cell thickness decreases performance solar panels. This study can be confirmed by studying the power under the influence of thickness.

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