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STUDY OF A SILICON SOLAR CELL IN DYNAMIC FREQUENCY REGIME: EFFECT OF TEMPERATURE AND IRRADIATION ENERGY ON SURFACE RECOMBINATION RATE SB WITH MATLAB / SIMULINK

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ABSTRACT

The aim of this article is to study the effect of temperature and irradiation energy on the surface combination rate of a silicon solar cell, in dynamic frequency regime under monochromatic illumination. We derived the expression of the diffusion length from the diffusion coefficient of the minority carriers and that of the rear surface recombination rate from the equation of continuity of the density of the minority carriers of excess charge in the base. The study showed that the recombination rate increases regardless of the value of the depth H.

KEYWORDS: Solar cell - recombination rate - Irradiation energy - temperature.

1. INTRODUCTION

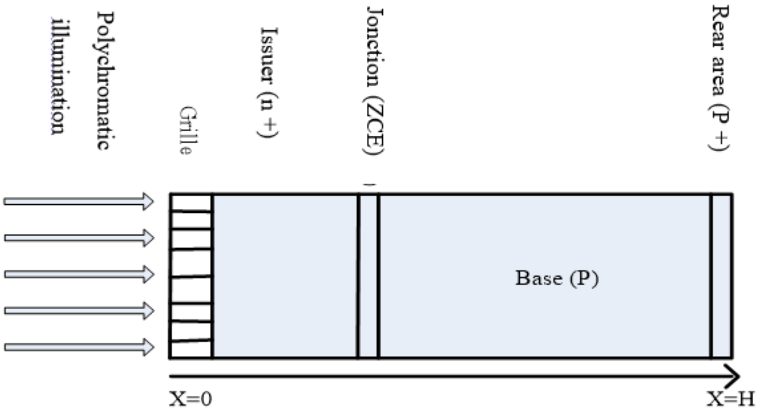
Conventional energy sources are unable to meet the demand for energy around the world. In this context, photovoltaic energy is an interesting source of energy; it is renewable, inexhaustible and non-polluting, and it is used as an energy source in various applications [1]. But for reasons of efficiency and high cost, it is therefore essential to have efficient and flexible models, to allow us an easy manipulation of certain electrical parameters [2,3] or phenomenological parameters [4,5] of solar cells. . These solar cells operate under different static [6], transient [7] and frequency dynamic [8] regimes. Their operation can take place under different conditions under the effect of temperature [9], under the effect of irradiation energy [10] etc.

When we illuminate the solar cell, we observe that a diffusion of minority charge carriers that travel a distance called the diffusion length before recombining on the surface (front face or back face) or in volume [11,12]. Several studies concerning the rate of recombination on the rear face of minor carriers have been carried out by different methods [13,14]. With matlab / simulink, we will try to make a study of the surface recombination rate by modeling its equation and by simulating it for different values of the temperature and the irradiation energy in dynamic frequency regime.

2. MATERIALS AND METHODS

The solar cell considered is of the n + -p-p + type and its structure is presented in figure 1 [15].

Figure: 1



Structure of an n + -p-p + silicon solar cell

The solar cell being under monochromatic illumination, the expression of the rate of generation of charge carriers is given by the following relationship [16].

$G_n(x,t) = g_n(x).\exp(jwt)$ (1)

With $g(x) = \Phi(\lambda).\alpha(\lambda).(1 - R(\lambda)).\exp(-\alpha(\lambda)x)$ (2)

We assume a base with great defects in which we have strong generations, due to the lighting mode.

The light enters the $p^+ - n$ junction in the plane x=0 and travels down the base to the position, where the position x=H, where the rate of recombination is estimated to be Sb.

Taking into account the phenomena of generation, recombination and diffusion in the base volume, the electron continuity equation can be written as on the abscissa x in dynamic frequency regime is given by the following equation [17, 18]:

$D^*.\frac{\partial^2 \delta_n(x,t)}{\partial x^2} - \frac{\delta_n(x,t)}{\tau} - \frac{\partial \delta_n(x,t)}{\partial t} = -G_n(x,t)$ (3)

Where □ (x) is the density of electrons generated in the base at position x
Where D * is the diffusion coefficient

The general solution of equation (3) is:

$\delta(x,\omega,kl,\phi_p,T) = A(\phi_p,kl,\omega,T).\cosh\left(\frac{x}{L(\phi_p,\omega,kl,T)}\right) + B(\phi_p,\omega,kl,T).\sinh\left(\frac{x}{L(\phi_p,\omega,kl,T)}\right) + \sum_1^3 Ki.\exp(-bi.x)$ (4)

The expressions of A and B are determined from the following boundary conditions [19,20]:

i) At the junction ($x = 0$)

$\left.\frac{\partial\delta(x,\omega,kl,\phi_p,T)}{\partial x}\right|_{x=0} = \frac{S_f}{D(x,\omega,kl,\phi_p,T)}\delta(x,\omega,kl,\phi_p,T)\Big|_{x=0}$ (5)

ii) In the back (x=H)

$\left.\frac{\partial\delta(x,\omega,kl,\phi_p,T)}{\partial x}\right|_{x=H} = -\frac{S_b}{D(x,\omega,kl,\phi_p,T)}\delta(x,\omega,kl,\phi_p,T)\Big|_{x=H}$ (6)

Simulink model of the diffusion coefficient

The diffusion coefficient D * is a very important parameter in the characterization of the semiconductor material [21].

This coefficient, which describes the diffusive character of minor carriers in the material, is represented as a function of temperature, irradiation energy and damage coefficient.

$$D(T) = \mu(T) \cdot \frac{Kb \cdot T}{q} \qquad (7)$$

The diffusion length before irradiation Lo is given by:

$$L_0(T) = \sqrt{D(T).\tau} \qquad (8)$$

The diffusion length of excess minority carriers in the base of the solar cell denoted L is related to the flow of irradiating particles as well as to the damage coefficient by the following relationship [22]:

$$L(kl, \phi_p, T) = \sqrt{\frac{1}{\frac{1}{L_0(T)^2} + kl.\phi_p}} \qquad (9)$$

From equation 3, we give the expression of the diffusion coefficient depending on the temperature, the irradiation energy and the damage coefficient in the following equation 4 [23,24]: $D^*(kl, \phi_p, T) = \frac{L(kl,\phi_p,T)^2}{\tau}$
(10)

The diffusion length dependent on the pulsation, the temperature, the damage coefficient is given by the following equation (10):

$$L^*(\omega, kl, \Phi p, T) = L(Kl, \Phi p, T)\sqrt{\frac{1 - j.\omega.\tau}{1 + (j.\omega)^2}} \qquad (11)$$

Simulink model of the recombination rate at the rear face Sb

Sb denotes the rate of recombination of the carriers on the rear face; it reflects how carriers are lost at the rear interface of the solar cell.

This rear face recombination rate represents the area where the photocurrent gradient is zero [25,26,27]. This allows us to write:

$$\frac{\partial J_{Ph}(\omega, Kl, \phi_p, T)}{\partial Sf} = 0 \qquad (12)$$

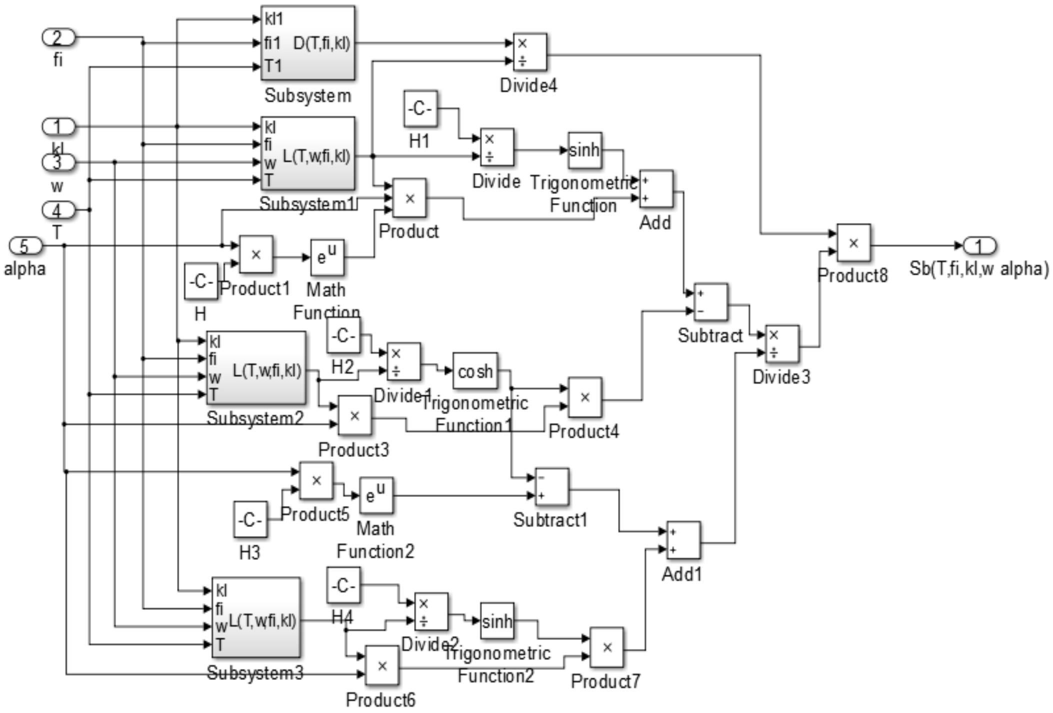
and give the expression of the recombination rate to the rear face.

$$S_b(\omega, Kl, \Phi_p, T) = \frac{D(\omega, Kl, \Phi_p, T)}{L(\omega, Kl, \Phi_p, T)} \cdot \frac{\left(\sinh\left(\frac{H}{L(\omega, Kl, \Phi_p, T)}\right) - \alpha_t.L(\omega, Kl, \Phi_p, T)\right)\left(\cosh\left(\frac{H}{L(\omega, Kl, \Phi_p, T)}\right) - \exp(-H.\alpha_t)\right)}{\alpha_t.L(\omega, Kl, \Phi_p, T).\sinh\left(\frac{H}{L(\omega, Kl, \Phi_p, T)}\right) - \left(\cosh\left(\frac{H}{L(\omega, Kl, \Phi_p, T)}\right) + \exp(-H.\alpha_t)\right)} \qquad (13)$$

3. RESULTS AND DISCUSSION

The simulink model of the recombination speed at the rear face is given in the figure above:

Figure : 2



Simulink model of Sb rear face recombination rate

We present in Figure 3 the curve of the rear face recombination speed as a function of depth

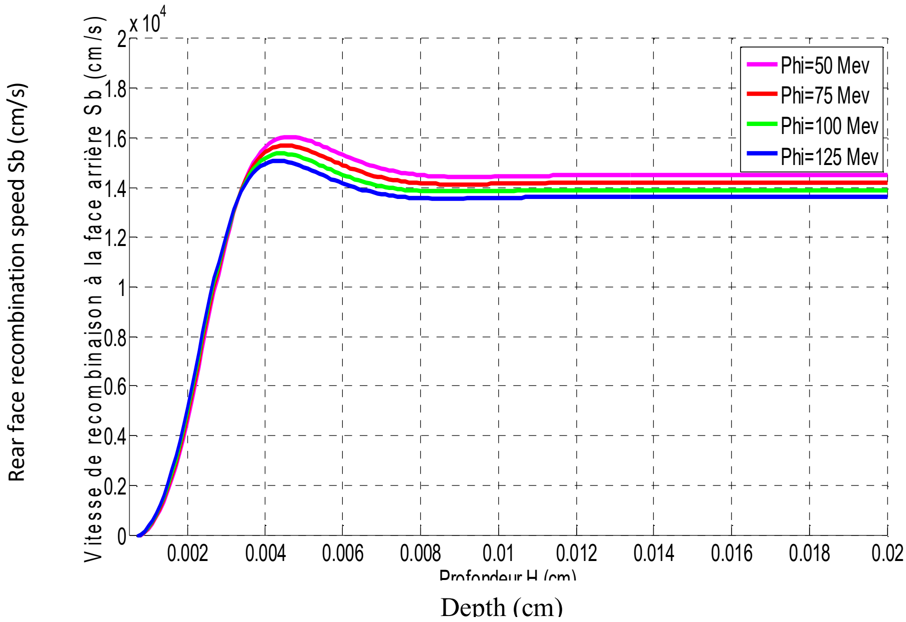
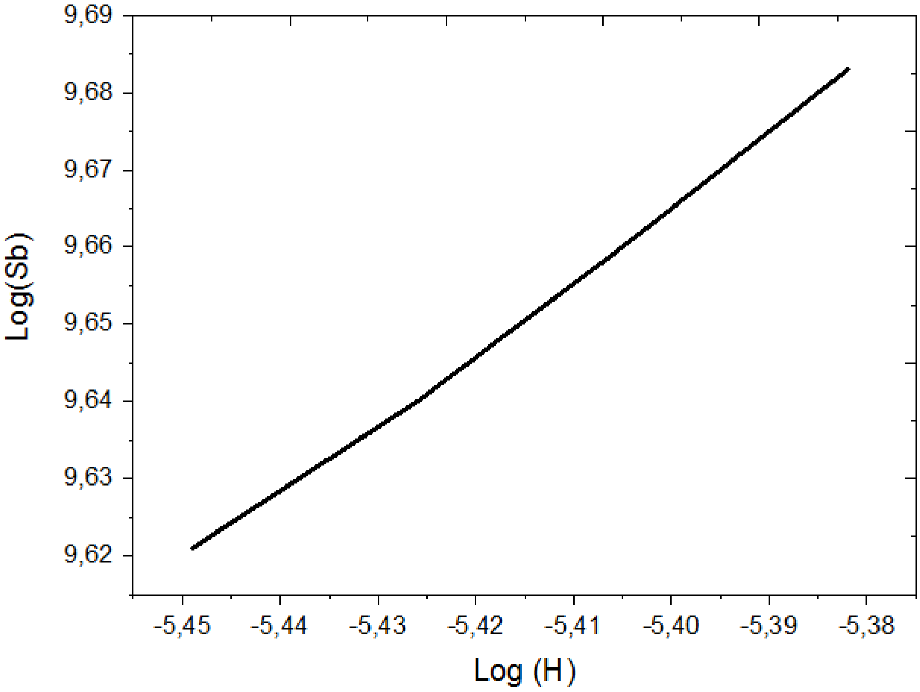


Figure 3 Curve of rear face recombination rate as a function of depth
T=250K ; $K_l = 10cm^2/s$; $\omega = 10^7 rad/s$

We notice that the rate of recombination increases for low values of the depth until reaching a maximum then decreases until a certain value and becomes linear throughout the depth. We also observe that the rate of recombination decreases as the irradiation energy increases. The increase in irradiation energy is accompanied by an increase in the number of particle-matter interactions and the density of the carriers is affected, which decreases the number of carriers stored on either side of the rear face. .

In Figure 4 below, the maximums in Figure 3 have been plotted as a function of depth
The equation line: Log(Sb)=alog(H)+b

Figure 4



Courbe du logarithme de la vitesse de recombinaison Sb en fonction du logarithme de la profondeur H

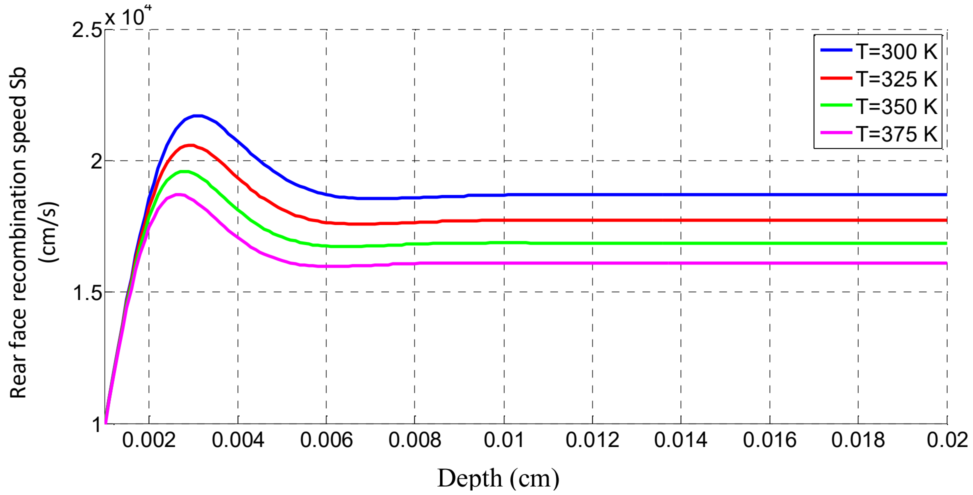
Figure 4 shows two affine lines whose guide coefficients and their ordinates at the origin are calculated and listed in Table 1 below:

Table 1: Value of slopes and coordinates at the origin

Coefficients Dept H (cm)	a(s^{-1})	b(cm/s)
H< 4.401*10^{-3}	0,857	14,269
H>4.401*10^{-3}	0,955	14,822

We notice whatever the value of H the recombination speed increases.

Figure 5



Curve of rear face recombination rate as a function of depth $K_l = 10cm^2/s$; $\omega = 10^7 rad/s$ $\Phi_p = 100\ Mev$

In this figure, we note three parts: a first part corresponding to an increase in the recombination speed at the rear face for low values of the depth, a second corresponding to peak of the recombination speed at the rear face and finally a third part corresponding to a rapid decrease to a certain value and a constant rate of recombination throughout the depth. For an applied temperature, we note a decrease in the rate of recombination at the rear face as the temperature increases. Indeed, the increase in temperature causes thermal agitation, the solar cell will no longer have time to relax and therefore many carriers will be recombined in volume.

4. CONCLUSION

In this work the expression of the rear face recombination rate is determined and its evolution as a function of the depth in the base for different values of temperature and for different values of irradiation energy is presented. From this expression we have proposed a simulink model of the rear face recombination rate. Thus, as the irradiation energy increases, the rate of rear face recombination decreases as well as when the temperature increases. On the other hand, this same speed increases when the depth increases.

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