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Study of the Diffusion Coefficient D*(B, T) of the Minority Carriers of a Silicon Photopile under Magnetic Field and Temperature Influence

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Abstract This paper aims to present the influence of magnetic field and temperature on diffusion coefficient of minority carriers of silicon photopile. Also, for the value of given magnetic field, we determined the optimal temperature to obtain the maximum diffusion coefficient.

Keywords Photopile, diffusion coefficient, magnetic field, temperature

Introduction

The performance of a photopile depends on several parameters, the most important of which are: the diffusion coefficient D (in relation to the doping of the base), the diffusion length of the charge carriers L (i.e. the average distance travelled by the charge carriers before succumbing to a recombination process), the recombination rates (at the junction Sf, at the rear face Sb, at the grain joints Sg) and the lifetime τ

Several characterization methods have been developed in static or dynamicmode to better understand the effects of these parameters on the functioning of solar cells [1-5].

In this paper the study focuses on the diffusion coefficient of silicon photopile in static mode under monochromatic illumination under the influence of magnetic field and temperature.

Presentation of the photopile

The silicon photopile to be investigated is monofacial of the n^+, p, p^+ type (Figure 1).

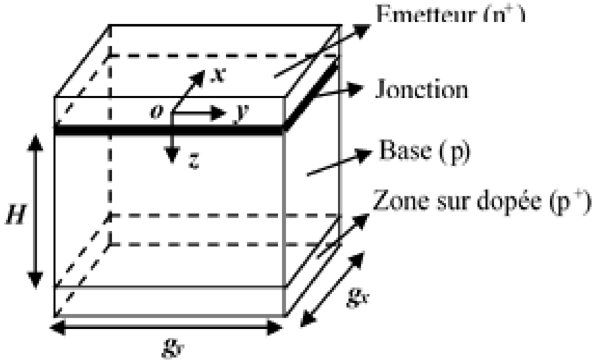


Figure 1: Grain or crystallite of a solar cell

The photopile is illuminated by its front face and the junction of the photopile will be taken as the origin of the z axis, the center of this plane containing the junction will be considered as the origin of the xoy axis. Also we will neglect the contribution of the emitter to the photocurrent in relation to that of the base and assume that the theory of near-neutrality of the base (Q.N.B) is satisfied, i.e. that the crystalline field will be neglected at the base of the photopile, only the electric field at the junction will be taken into account.

Diffusion Coefficient

The diffusion coefficient D*(B, T) of the minority carriers in the base under the influence of the temperature T and the applied magnetic field B is given by equation 1. [1]

$$D^*(B,T)=\frac{D(T)}{1+(\mu(T)B)^2} \qquad (1)$$

Avec $D(T)=\mu(T)\frac{kT}{q}$ $\mu(T)=1{,}43.10^{9}T^{-2,42}\ \mathrm{cm}^2\ \upsilon^{-1}\mathrm{s}^{-1}$

Graphical Analysis

The relationship (1) allows us to plot the profile of the diffusion coefficient. It reflects the diffusion of carriers from the most concentrated area to the least developed area.

Figure 2 below shows the profile of the logarithm of the diffusion coefficient as a function of the logarithm of the magnetic field for different temperature values.

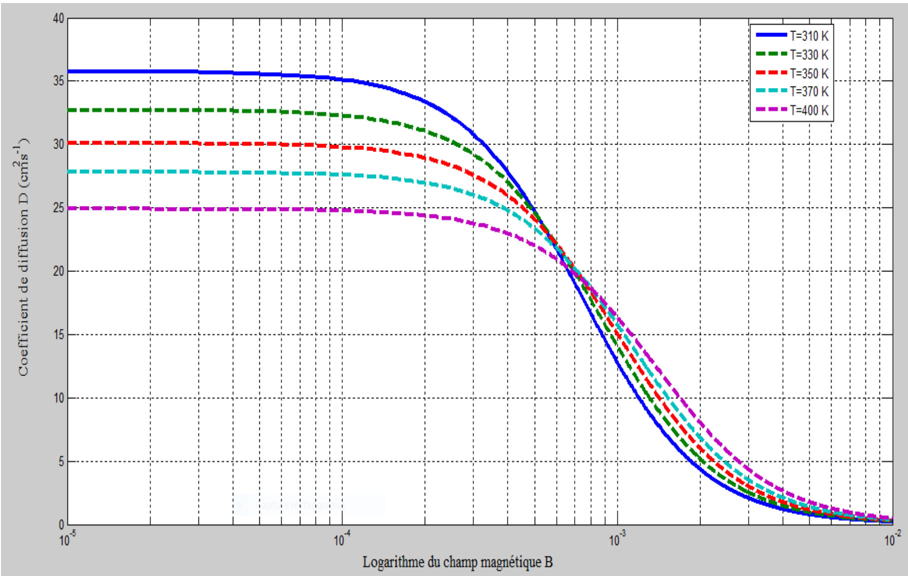


Figure 2: Profile of the diffusion coefficient as a function of Log (B) for different temperatures

We can see from this profile that at low magnetic field values (B ≤ 10-4 T) the diffusion coefficient is practically constant and we can affirm that the low magnetic field values have almost no effect on the diffusion of minority charge carriers; however, the influence of the magnetic field is visible beyond values above 10-4 T. When the magnetic field becomes very strong (around 10-2 T) the diffusion of the carriers becomes almost impossible. This decrease in the diffusion coefficient when the magnetic field increases is due to the fact that the charge carriers moving at a velocity are deflected from their trajectory by the action of the magnetic field. This action, which increases with the magnetic field, considerably reduces the diffusion of the carriers.

Also we notice that the diffusion coefficient decreases with increasing temperature. Therefore, a very high value of the magnetic field and temperature leads to a degradation of the intrinsic properties of the photopile.

The diffusion coefficient is more temperature sensitive when the magnetic field is weak. At around 10-3 T, it increases with temperature, so we will determine a relationship between the optimal temperature and the magnetic field for maximum diffusion in this area. For this purpose, we have plotted the profile of the diffusion coefficient as a function of temperature for different magnetic field values as shown in Figure 3 below.

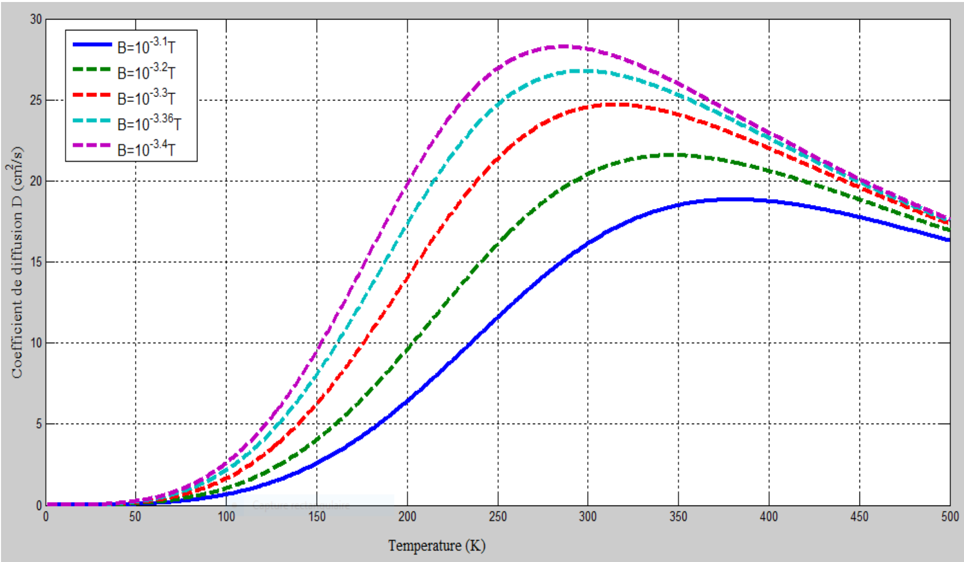


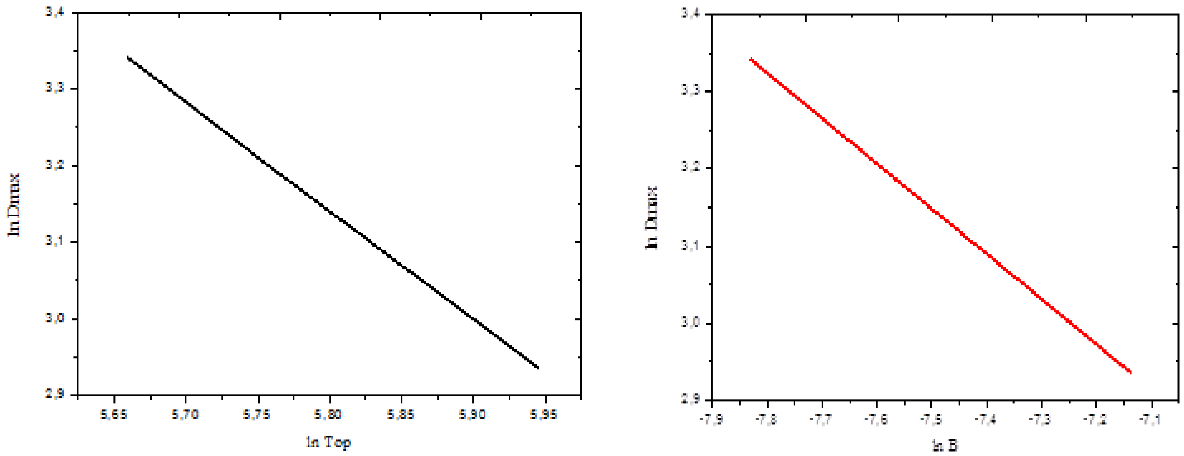
Figure 3: Profile of the diffusion coefficient as a function of temperature for different magnetic fields

For the value of a given magnetic field, the optimal temperature is obtained when the diffusion coefficient reaches its maximum; thus we give in Table 1 the graphically recorded values.

Table 1: Maxima of the diffusion coefficient and the optimal temperature for different magnetic fields obtained by the graphical method

Magnetic fields B (T)	$10^{-3,1}$	$10^{-3,2}$	$10^{-3,3}$	$10^{-3,36}$	$10^{-3,4}$
Optimal temperature Top (K)	382	347	315	298	287
Maxima of the diffusion coefficient Dmax (cm^2/s)	18.84	21.57	24.69	26.77	28.26
Ln (Top)	5.945	5.849	5.753	5.697	5.659
Ln (Dmax)	2.936	3.071	3.206	3.287	3.341
Ln (B)	-7.138	-7.368	-7.599	-7.737	-7.829

From the results of Table 1 we obtained the profiles in Figure 4.



(a) (b)

Figure 4: Logarithm of the maximum diffusion coefficient maxima, a) as a function of the logarithm of the optimal temperature, (b) as a function of the logarithm of the magnetic field

From the results obtained in Table 1, we have represented in Figure 4 the logarithm of the maximum scattering coefficient as a function of the logarithm of the optimal temperature and that of the magnetic field respectively. These linearization curves allow us to write the relationships below.

$$\ln(D_{max} = a_1.\ln(Top) + \ln(b_1)$$

$$\ln(D_{\max} = a_2.\ln(B) + \ln(b_2)$$

Where a_1, b_1, a_2, b_2 are real coefficients obtained from the curves in Figure 4.

$$\begin{cases} 3{,}341 = 5{,}659a_1 + \ln(b_1) \\ 3{,}206 = 5{,}753a_1 + \ln(b_1) \end{cases} \begin{cases} 3{,}206 = 5{,}753a_1 + \ln(b_1) \\ 3{,}071 = 5{,}849a_1 + \ln(b_1) \end{cases}$$

This gives: $D_{\max} = 8{,}7741.10^{4}T^{-1{,}42121}$ (2)

$$\begin{cases} 2{,}936 = -7{,}138a_2 + \ln(b_2) \\ 3{,}287 = -7{,}737a_2 + \ln(b_2) \end{cases}$$

This gives: $D_{\max} = 28{,}745.10^{-2}B^{-0{,}586}$ (3)

From equations (2) and (3) we obtain the optimal temperature as a function of the magnetic field.

$$T_{op}(B) = \sqrt[4{,}85]{5{,}2349.10^{18}.B^2} = \sqrt[4{,}85]{2{,}56(1{,}43.10^9)^2.B^2} \quad (4)$$

Analytical Analysis

This result can be verified by the analytical method. Indeed, the derivative of the diffusion coefficient as a function of temperature by maintaining the constant magnetic field is given by equation 5.

$$\frac{\partial D^*}{\partial T} = 1{,}7513925T^{-2{,}42}.\frac{10^5\left[4{,}925.10^{18}B^2T^{-4{,}84} - 1\right]}{\left[1 + 2{,}0449.10^{18}B^2T^{-4{,}84}\right]^2} \quad (5)$$

The temperature is optimal when the derivative is zero, so Top (B) is given by expression 6.

$$T_{op}(B) = \sqrt[4{,}84]{4{,}925.10^{18}.B^2} = \sqrt[4{,}84]{2{,}41(1{,}43.10^9)^2.B^2} \quad (6)$$

This relationship allows us to calculate the optimal temperature for different magnetic fields and to deduce the maximum diffusion coefficient. Table 2 below represents the results obtained.

Table 2: Maxima of the diffusion coefficient and the optimal temperature for different magnetic fields obtained by the analytical method

Magnetic fields B (T)	$10^{-3,1}$	$10^{-3,2}$	$10^{-3,3}$	$10^{-3,36}$	$10^{-3,4}$
Optimal temperature Top (K)	381.18	346.6	315.13	297.64	286.53
Maxima of the diffusion coefficient Dmax (cm^2/s)	18.843	21.569	24.689	26.774	28.261

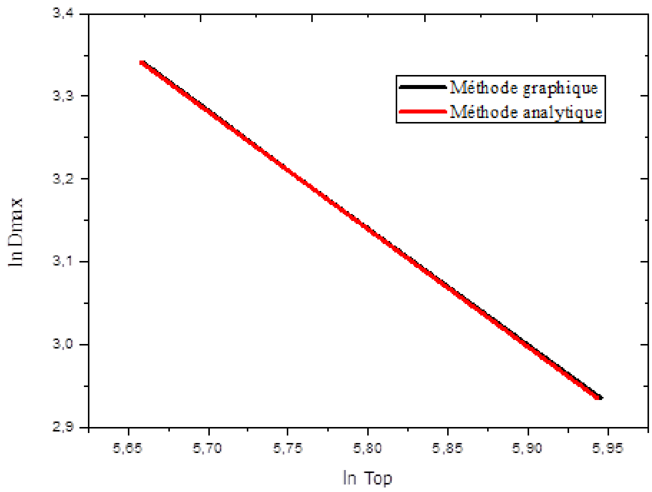


Figure 5: Logarithm of the maximum diffusion coefficient as a function of the logarithm of the optimal temperature

The representation of the results obtained by the graphical and analytical methods in the same reference frame is given in fig 5. We notice that the two curves are practically confused. This study will avoid the arbitrary choice of temperatures for the study of the effect of temperature on the different parameters of the photopile.

Conclusion

The diffusion coefficient is practically constant for low magnetic field values; however, when the magnetic field becomes very large, the diffusion of the carriers becomes almost impossible. Also we notice that the diffusion coefficient decreases with increasing temperature. Therefore, a very high value of the magnetic field and temperature leads to a degradation of the intrinsic properties of the photopile. The diffusion coefficient is more temperature sensitive when the magnetic field is weak.

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