IJESRT: 9(7), July, 2020 ISSN: 2277-9655

International Journal of Engineering Sciences & Research Technology

(A Peer Reviewed Online Journal)
Impact Factor: 5.164

IJESRT

Website: www.ijesrt.com Mail: editor@ijesrt.com

RESEARCHERID
THOMSON REUTERS

ISSN: 2277-9655
[NIANE *et al.*, 9(7): July, 2020] Impact Factor: 5.164
IC™ Value: 3.00 CODEN: IJESS7

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

EXCITONS IN FUNCTION TO THE BINDING COEFICIENT IN MONOCRISTALLINE SILICON BASE

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DOI: https://doi.org/10.29121/ijesrt.v9.i7.2020.9

ABSTRACT
The exciton is a particle formed between one or more electrons intermediate levels with one or more holes in the valence band. These two particles are bonded by electrical interactions. These interactions are modeled by a coupling coefficient denoted b. Thus in this article, a study of the variation of the excess excitons density in the base in function to the binding coefficient was done. This study shows that, the excess excitons density is zero at the junction of the base and the space charge zone. By cons, in depth, the excitons density increases as a function to the coupling coefficient. Indeed, when one enters deep, interactions between holes and electrons become very important modeled by a high coupling coefficient. These result a reduction of the excess minority carriers mobility in the base and the formation of exciton complexes, hence the increase of the excess excitons density in the base. The reduction of the excess excitons density at the rear face is due to a very high excitons recombination in this region. This is due to a lack adhesion of the metal contact and disruption of the crystal lattice in this region. When the cell is under polychromatic light, the excess excitons density in the base is very high compared to that obtained when the cell is in dark.

KEYWORDS: Excess excitons density, Excess minority carriers density, binding coefficient, base thickness.

1. INTRODUCTION
This study was carried in the base of the monocrystalline silicon solar cell in the steady state. We have considered in this study that the field in volume is neglected and the transport of carriers is done by diffusion. The coupling coefficient is materialized interactions between electrons and holes. In this study, the variation of the excess excitons density in the base was performed. To do this, in first, the study of the excitons density in the base in function to the level of interaction between the carriers is made according to different positions in the base (at the junction, close to the junction and the rear face). Then we studied the influence of the doping level on the excess excitons density. In the end, when the cell is under polychromatic illumination, we studied the variation of the excess excitons density in the base following different doping levels in atom acceptor function of the binding coefficient.

2. VARIATION OF EXCESS EXCITONS DENSITY IN FUNCTION TO THE BINDING COEFFICIENT: CELL IN DARK
When we apply a forward voltage in the silicon base, we note the following profiles of the excess excitons density. In this part, we have studied there variations following different positions in the base. Recall that the expressions used to map these profiles were calculated from the resolution by the Laplace transform [1] of the differential transport equations of the carriers in the base [2].

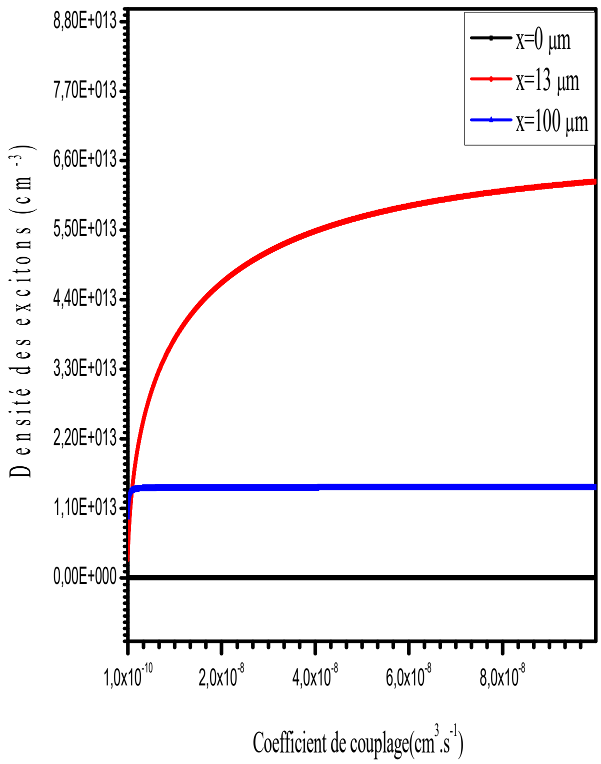

Fig.1: Variation of excess excitons density in function to the binding coefficient following different in the depth n_i = 1.5.10^{10} cm^{-3}, D_e=33 cm^2.s^{-1}, D_x=17 cm^2.s^{-1}, τ_e=4.10^{-6} s, T=300K, τ_x= 6.69.10^{-6} s, Sc=3.10^3 cm.s^{-1} et N_A=10^{16} cm^{-3}, Va=0.5V

Analysis of these profiles above shows, as established in the boundary conditions, at the junction the excitons density is zero. Gradually, as we enter deeply, we see that one gets a very significant increase of the excitons density. This density is function to the binding coefficient. In the strong coupling, the excitons density is increases due by the very strong interaction between electrons and holes. The electrons are not free and many pairs of electron and holes form giving rise to the excitons generation [3]. With the approach of the rear face, exciton density starts to decrease gradually and stabilizes at the rear face to a value of about 10^{13} cm^{-3}. This density reduction is the result of a high rate recombination existing in this region. At the junction, we get a zero excitons density when the cell is in darkness. Which makes it almost impossible, under these conditions, the study of excitons density variation according to the coupling coefficient in this region. To do this, we will consider a region very close to the junction such as X = 1nm where the study will be done. For the study is more complete, we will study the behavior of the excitons density to particular positions of the cell as the junction, in the rear face and in a one deep position.

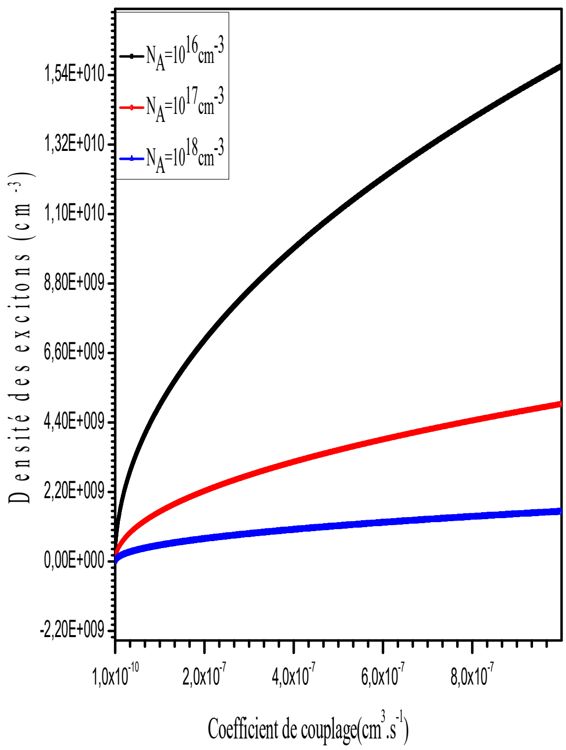

Fig.2: Variation of excess excitons density in function to the binding coefficient following different doping level near the junction X=1nm, n_i=1.5.10^{10} cm^{-3}, D_e=33 $cm^2.s^{-1}$, D_x=17 $cm^2.s^{-1}$, τ_e = 4.10^{-6} s, T=300K, τ_x= 6.69.10^{-6} s, Va=0.5V

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

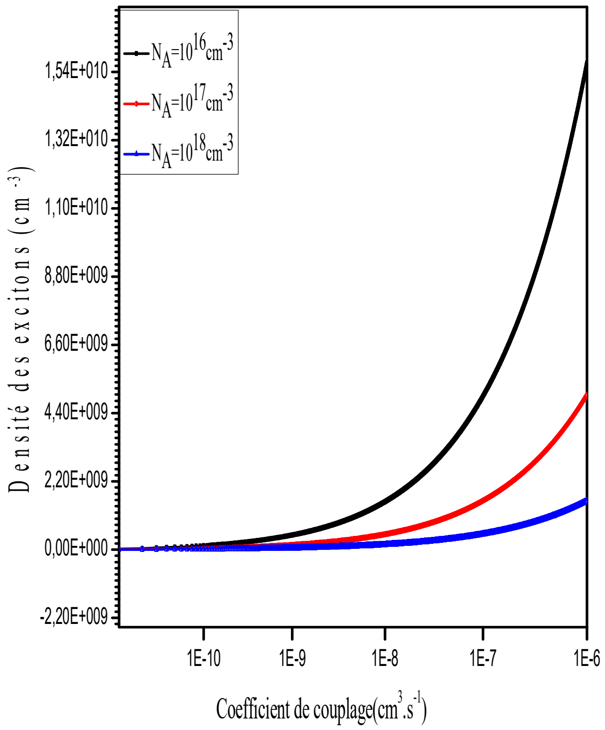

Fig.3: Variation of excess excitons density in function to the binding coefficient following differents doping level near the junction X=1nm, n_i=1.5.10^{10} cm^{-3}, D_e=33 cm^2.s^{-1}, D_x=17 cm^2.s^{-1}, τ_e = 4.10^{-6} s, T=300K, τ_x= 6.69.10^{-6} s, Va=0.5V

Analysis of these profiles shows that when the coupling level between the electron and hole is small, the excess excitons density is almost zero. For a strong coupling, the density of the excitons increases as a function to the coupling coefficient. Indeed, when the coupling is strong into the charge carriers, the electrical connections become important [4]. This causes an increase of the excess excitons density in the base. An increase in the doping level leads to a shielding phenomenon between the carriers. This promotes the recombination volume, hence the decrease of the excess excitons density [5].

3. VARIATION OF EXCESS EXCITONS DENSITY IN FUNCTION TO THE BINDING COEFFICIENT: CELL IN POLYCHROMATIC ILLUMINATION

By illuminating the cell with polychromatic light, we get the following profiles of the excess excitons density in the base.

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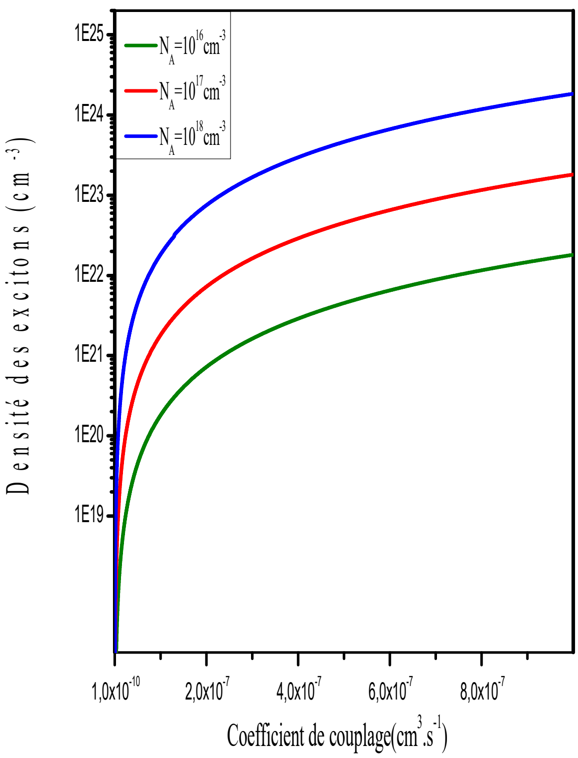

Fig.4: Variation of excess excitons density in function to the binding coefficient following different doping level near the junction X=1nm n_i=1.5.10^{10} cm^{-3}, D_e=33 $cm^2.s^{-1}$, D_x=17 $cm^2.s^{-1}$, T=300 K, τ_e=10^{-5} s, τ_x=4.45.10^{-5} s, G_{eh0}=5.$10^9$$cm^{-3}.s^{-1}$, G_{x0}=5.$10^9$$cm^{-3}.s^{-1}$, Sc=5.$10^5$ $cm.s^{-1}$

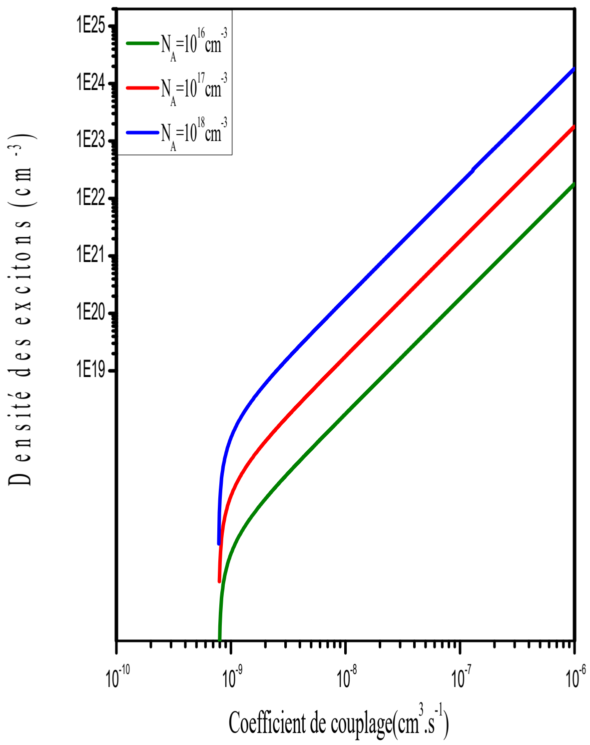

Fig.5: Variation of excess excitons density in function to the binding coefficient following different doping level near the junction X=1nm n_i=1.5.10^{10} cm^{-3}, D_e=33 cm^2.s^{-1}, D_x=17 cm^2.s^{-1}, T=300 K, τ_e=10^{-5} s, τ_x=4.45.10^{-5}s, G_{eh0}=5.10^{9}cm^{-3}.s^{-1}, G_{x0}=5.10^9 cm^{-3}.s^{-1}, Sc=5.10^5 cm.s^{-1}

The profiles obtained from the excitons density in illumination show that it has a very high concentration of excitons in the base. This density is order to 10^{22} cm^{-3} (almost equal to the volume density of silicon atoms) is explained by the fact that, when the cell is illuminated by a polychromatic light [6-8], more electrons atoms silicon migrate to excited states. Thus, Coulomb interactions between the majority carriers and minority carriers are exercised increasingly in the base, which would cause an important exciton generation. We should also remember that when the holes generation rate is very high, an electron in the base can interact with several holes and thus contribute to the formation of several excitons. Similarly, a hole may interact with many more electrons to form excitons. In other words, if we have N electrons in a Fermi level M and holes in the valence band, the maximum number of excitons created is equal to NM. Density exciton obtained is actually less than this value because of the volume recombination phenomena [9].

4. CONCLUSION

This study showed that the excess excitons density in the base in dark, remains substantially equal to that excess minority carriers. A high doping level of acceptor atoms causes a reduction of the excess excitons density due to the increased shielding phenomenon that occurs between these charge carriers. An increase of the interaction level between the electrons and the holes modeled by an increase of the coupling coefficient value promotes excitons generation. When the cell is under polychromatic light, the excess excitons density is almost 10^7 times greater than the excess electrons in the base. The observation of these phenomena leads us to the following postulat:

An electron in a Fermi level or the permitted levels, can interact with several holes in the valence band through electrical interactions. Hence a hole can interact with many electrons and participate in the multiple excitons generation.

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NOMENCLATURE

symbols	***nd unit***
B	Binding coefficient, $cm^3.s^{-1}$
G_{eh0}	direct generation rate of carrier pairs, $cm^{-3}.s^{-1}$
G_{x0}	Exciton generation rate at the semiconductor surface, $cm^{-3}.s^{-1}$
X	the base depth, cm
N_A	Doping level, cm^{-3}
D_e	Diffusion coefficient for electron, $cm^2.s^{-1}$
D_x	Diffusion coefficient for excitons, $cm^2.s^{-1}$
T_e	Electrons lifetime, s
T_x	Excitons lifetime, s
H	Base thickness, cm
$n*$	Equilibrium constant, cm^{-3}
α	Absorption coefficient, cm^{-1}