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Research Article

EXCESS EXCITONS DENSITY IN FUNCTION TO THE DOPING LEVEL IN THE SILICON BASE BOUNDARY FOR DIFFERENT COUPLING BETWEEN ELECTRONS AND EXCITONS

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ABSTRACT

The phenomena of excitons generation in the semiconductor such as silicon is observed when interaction between the electrons and the holes become high. This interaction is evidenced by a coupling coefficient denoted b. It takes values 10^{-15} $cm^3.s^{-1}$ to 10^{-7} $cm^3.s^{-1}$ according to the interaction level. In this article, there are studied the variation of excess excitons density in function to the doping level according to the two coupling model between electrons and excitons. This study shows that, near the junction between the base and the space charge region, the excess excitons density is very low. It decreases in function the doping level. Similarly, at the rear face, the higher excitons density in this area decreases as the doping level becomes important. A strong interaction between the charge carriers promotes the excitons generation.

INTRODUCTION

The equations of the excitons transport and excess minority carriers in the silicon base are governed by a system of differential equations [1, 2]. The resolution of this system [2-4] allowed to have an expression of the excess excitons density in the base. The application of these results to a monocrystalline silicon solar cell permit to study the variation of these carriers in function the doping level on acceptor atom. As the excitons density is considered null at the junction, this study was done in its vicinity following the two types of interactions between carriers: high coupling and low coupling (1 nm from the junction). The same study was done at the rear face for find their variation in this region.

Principe of fonctionnement

In this study, we took the homojunction model of a silicon cell. In the calculations, the contributions of the emitter and the espace zone charge have been neglected.

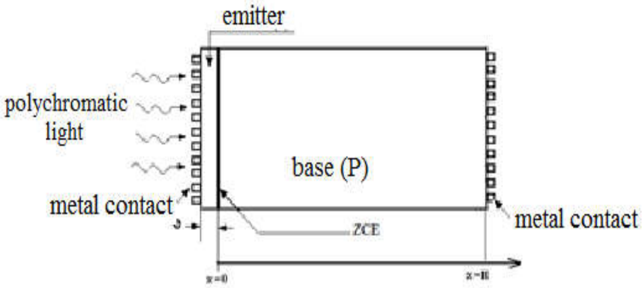

Figure Diagram of the solar cell

When establishing the system of differential equations governing the transport of excess minority carriers and the excitons in the base, the phenomena of conduction due to the electric field in volume have been neglected.

The systems of differential equations is following [1]:

$$D_e \frac{d^2 \Delta n_e}{dx^2} = \frac{\Delta n_e}{\tau_e} + b\left(\Delta n_e N_A - \Delta n_x n^*\right) - G_{oe} \exp\left(-\alpha x\right) \tag{I-1}$$

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$$D_x \frac{d^2\Delta n_x}{dx^2} = \frac{\Delta n_x}{\tau_x} - b\left(\Delta n_e N_A - \Delta n_x n^*\right) - G_{ox}\exp(-\alpha x) \qquad \text{(I-2)}$$

The excess excitons density in the base is given by the following expression [2]:

$$\begin{aligned}
\Delta n_{xL} = &\left[\left(\frac{\alpha_1 + a_2}{\alpha_3 b n^*}\right)\left(bN_A + \frac{1}{\tau_e}\right) - \frac{D_e(\beta_1)^2(\alpha_1 + a_2)}{bn^*\alpha_3}\right]\cosh(\beta_1 x) \\
&+ \left[\left(\frac{\alpha_2 + a_4}{\alpha_3\beta_1 b n^*}\right)\left(bN_A + \frac{1}{\tau_e}\right) - \frac{D_e\beta_1(\alpha_2 + a_4)}{bn^*\alpha_3}\right]\sinh(\beta_1 x) \\
&+ \left[\left(\frac{\alpha_5 + a_6}{\alpha_3 b n^*}\right)\left(bN_A + \frac{1}{\tau_e}\right) - \frac{D_e(\beta_2)^2(\alpha_5 + a_6)}{bn^*\alpha_3}\right]\cosh(\beta_2 x) \\
&+ \left[\left(\frac{\alpha_6 + a_7}{\alpha_3\beta_2 b n^*}\right)\left(bN_A + \frac{1}{\tau_e}\right) - \frac{D_e\beta_2(\alpha_6 + a_7)}{bn^*\alpha_3}\right]\sinh(\beta_2 x) \\
&+ \left[\frac{a_1}{bn^*}\left(bN_A + \frac{1}{\tau_e}\right) - \frac{\alpha^2 a_1 D_e}{bn^*} - \frac{G_{oe}}{bn^*}\right]\exp(-\alpha x) \qquad \text{(I-3)}
\end{aligned}$$

Variation of excess excitons density at the junction in function to the doping level

When the expressions calculated by the Laplace transform method are using, profiles of the excess excitons density are obtained. The different figures obtained below show that the excitons density decreases in function to the doping level on acceptor atom when the cell is in dark and in polarization.

Weak coupling

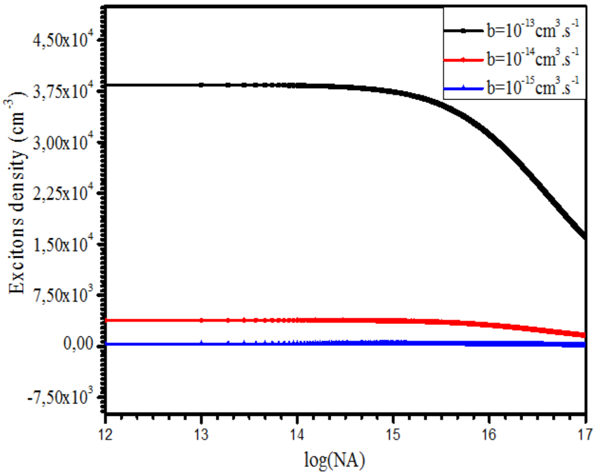

Fig 1 Variation in the excess excitons density in function to the doping level in the vicinity of the junction x = 1 nm n_i=1.5.10^{10} cm^{-3}, D_e=33 $cm^2.s^{-1}$, D_x=17 $cm^2.s^{-1}$, τ_e=4.10^{-6} s, T=300K, τ_x=6.69.10^{-6}s, N_A=$10^{16}$$cm^{-3}$, Va=0.5V.

When the coupling between electrons and excitons is low, the value of the excess excitons density in the base is very negligible. Indeed, the intervention of the electric field in the space charge zone, greatly reduces the excitons density arriving at the junction. Thus, in the vicinity, the excitons become negligible. In addition, the low level of coupling between electrons and holes (10^{-12} $cm^3.s^{-1}$ < b < 10^{-16} $cm^3.s^{-1}$), translates almost nonexistent interactions between electrons and holes. Thereby reducing the excess excitons density [5-8].

When the carbon acceptor density in the base becomes high in the vicinity of the junction, exciton density decreases because of shielding phenomena that occurs between the carriers.

Strong coupling

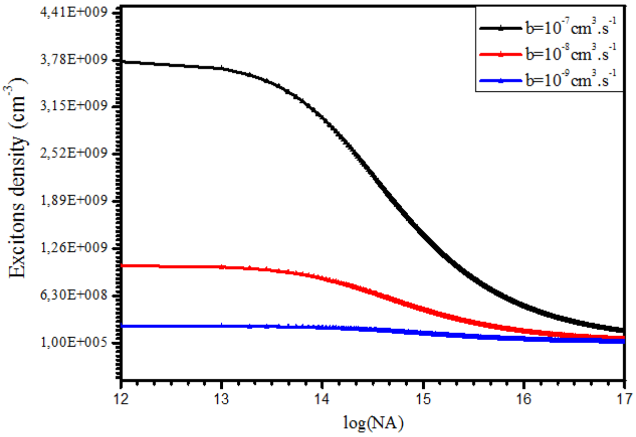

Fig 2 Variation in the excess excitons density in function to the doping level in the vicinity of the junction x = 1 nm n_i=1.5.10^{10} cm^{-3}, D_e=33 $cm^2.s^{-1}$, D_x=17 $cm^2.s^{-1}$, τ_e=4.10^{-6} s,T=300K, τ_x=6.69.10^{-6}s, Sf=3.10^3 $cm.s^{-1}$ et N_A=$10^{16}$$cm^{-3}$, Va=0.5V.

For a strong coupling, the electrical attractions between holes and electrons become very higher, which increases the excitons density in the base. By cons, a strong concentration for acceptor atom in the base leads to the creation of intermediate levels between the valence band of and conduction band constituting recombination sites for minority carriers causing several recombination mostly sheokley-Red-Hall type and the reduction of the excess excitons density in the base [8-13].

Variation of excess excitons density at the metal contact in function to the doping level

The excess minority carriers who are at the rear face are much more related than those lying at the junction

Weak coupling

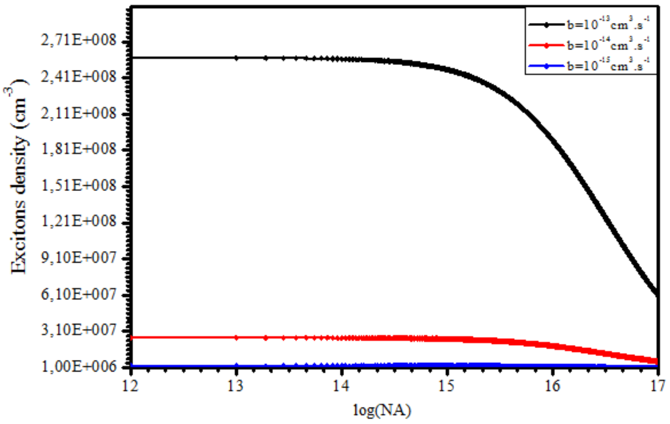

Fig 3 Variation of excess excitons density in function to the doping level at the rear face x=H, n_i=1.5.10^{10} cm^{-3}, D_e=33 $cm^2.s^{-1}$, D_x=17 $cm^2.s^{-1}$, τ_e=4.10^{-6} s, T=300K, τ_x= 6.69.10^{-6} s, N_A=$10^{16}$$cm^{-3}$, Va=0.5V

Strong coupling

In volume, the influence of the electric field created in the space charge region, is almost nonexistent [14]. The interactions between the electrons and holes in that area are more important, resulting in a phenomenon of excitons generation. This phenomenon is observed more when the coupling is strong.

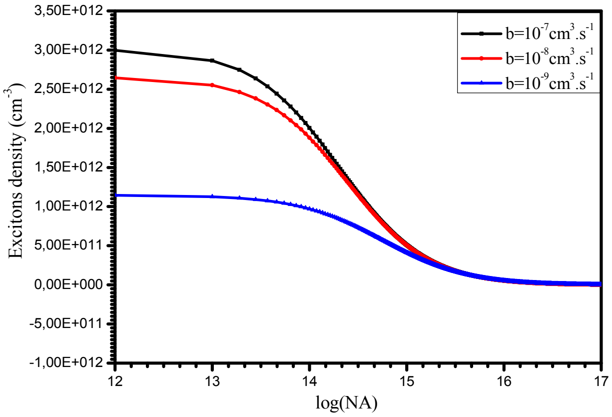

Fig. 4 Variation of excess excitons density in function to the doping level at the rear face x=H, n_i=1.5.10^{10} cm^{-3}, D_e=33 cm^2.s^{-1}, D_x=17 cm^2.s^{-1}, τ_e=4.10^{-6} s, T=300K, τ_x= 6.69.10^{-6} s, Sf=3.10^3 cm.s^{-1} et N_A=10^{16}cm^{-3}, Va=0.5V

It is against reduced when we consider that the interactions between electrons and excitons are low (low coupling). It should be noted that the excitons density in this region decreases with the doping level in acceptor atom becomes high. Both phenomena have resulted in both profiles below:

CONCLUSION

In this article, there are studied the variation of excess excitons density in the base. This study allowed to understand that near the junction, the phenomenon of excitons generation is negligible. This is the result of a dissociation phenomena due to the electric field created in the space charge zone. A weak coupling between the charge carriers leads to a strong decrease of excess excitons density in the silicon base.

At the rear face, the excitons density contracted a slight increase especially when the coupling between electrons and holes is strong to achieve a value 10^{12} cm^{-3}.

A high doping levels results in a reduction of the excess excitons density in the base. This is caused by the increase of impurities in the cell that causes the electron and exciton catch. Hence, the decrease of excess excitons density observed in the base.

Nomenclature

symbols	***Name and unit***
Δn	Excess minority carriers density, cm^{-3}
Δn_x	Excess excitons density, cm^{-3}
b	Binding coefficient, cm^3.s^{-1}
G_{eh0}	direct generation rate of carrier pairs, cm^{-3}.s^{-1}
G_{x0}	Excitons generation rate at the semiconductor surface, cm^{-3}.s^{-1}
Δn_{oe}	Excess minority carriers density at the junction, cm^{-3}
x	The base thickness, 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}

Reference

R. Corkish, Daniel S-p. Chan and M. A. Green, "excitons in Silicon Diodes and Solar Cells - A Three Particle Theory", *Journal of Applied Physics, vol. 79, pp. 195-203, 1996*

Mamadou Niane, Omar. A. Niasse, Moulaye Diagne, Nacire Mbengue, Bassirou Ba, "Laplace transform calculation of dark saturation current in silicon solar cell involving exciton effects", *International Journal of Engineering Sciences & Research Technology*, vol. 4(3), pp.279-285, mars 2015

J. Barrau, M. Heckmann, J. Collet, and M. Brousseau, *J. Phys. Chem. Solids* 34, 1567 (1973)

E. L. Nolle, Sov. Phys. Solid State 9, 90 (1967)

Saliou NDIAYE, Mamadou Niane, Nacire Mbengue, Moulaye Diagne, Omar. A. Niasse, Bassirou Ba," *effects of temperature on the short circuit current of a silicon solar cell while taking into account the excitons ", International Journal of Engineering Sciences & Research Technology*, vol 4(3). pp. 441-444, mars 2015

Modou Faye, Cheikh MBow, Bassirou Ba: Numerical Modeling of the Effects of Excitons in a Solar Cell Junction n$^+$p of the Model by Extending the Space Charge Layer, International Review of Physics (I.RE.PHY), Vol. 8, N. 4 ISSN 1971-680X (August 2014) p102-109.

Marc Dvorak, Su-Huai Wei, and Zhigang Wu1," Origin of the Variation of Exciton Binding Energy in Semiconductors" *Physical Review Letters* 110, 016402 (2013)"

A. Green "Concentration and Minority-Carrier Mobility of Silicon from 77-300K", *Journal of Applied Physics*, Vol. 73, pp. 1214-1225, 1993

EADES W. D and SWANSON R.M, Calculation of surface generation and recombination velocities at the Si-SiO2 interface, *Journal of Applied Physics*, vol. 58, 4267 p**.** 1995

HALL R. N. Electron-Hole Recombination in Germanium, Physical Review, vol. 87, 387 p. 1952

A.G. Aberle, S.J. Robinson, A. Wang, J. Zhao, S.R. Wenham and M.A. Green, "High Efficiency Silicon Solar Cells: Fill Factor Limitations and Non-Ideal Diode Behaviour Due to Voltage-Dependent Rear Surface Recombination Velocity", Progress in Photovoltaics, Vol. 1, No. 2, pp. 133-143, 1993.

Shockley W, READ W.T. Jr. Statistics of the Recombinations of Holes and Electron. Physical. Review, vol. 87, pp. 835-842, 1952.

A.W. Stephens, A.G. Aberle and M.A. Green, "Surface Recombination Velocity Measurements at Silicon/Silicon Dioxide Interface by Microwave-Detected Photoconductance Decay", *J. Appl. Phys*., Vol. 76, pp. 363-370, 1994.

Nawal KORTI-BAGHDADLI, Abdelkrim Elhasnaïne MERAD, and Tayeb BENOUAZ "Adjusted Adashi's Model of Exciton Bohr Parameter and New Proposed Models for Optical Properties of III-V Semiconductors" *Columbia International Publishing American Journal of Materials Science and Technology* 3: 65-73 (2013)