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An improved contribution to optimize Si and GaAs solar cell performances

N. Merabtine[a], S. Amourache[c], M. Bouaouina[c], M. Zaabat[b], Y. Saidi[c], C. Kenzai[c]

[a]*Laboratoire Electromagnetisme et Telecommunication. Faculte des Sciences de l'Ingenieur Universite Mentouri Constantine*
[b]*Departement de physique, Institut des science Exactes Centre Universitaire d'Oum el Bouaghi 04000 Oum el Bouaghi, Algeria*
[c]*Laboratoire des couches minces, Faculte des sciences Universite Mentouri Constantine Algeria*
E-mail: na_merabtine@hotmail.com

Abstract. In resent years a considerable effort (experience, numerical simulation and theoretical prediction models) has been devoted to the study of photovoltaic devices characterised by high efficiency and low cost. The present study comes in way to contribute in the optimisation of the performance of Si an GaAs based (*N*/*P*) solar cells by the determination of physical and technological parameters giving the best photovoltaic conversion efficiency and a good spectral response. The four principal parameters that influence the operation of a solar cell are emitter and base doping, junction depth and base thickness. We have also taken into account the recent technique of elaboration of these structures. This study concerns the use of novel optimised values of electronic properties of GaAs and Si materials such as recombination velocity at surface (front and back). All enhancements recently reached: BSF, BSR layers, ARC anti reflection layer with textured surface, surfaces passivation, improved ohmic contacts are taken into account. I–V, P–V, EQE-λ characteristics obtained by PC1D similator on two different cells (Si and GaAs) under the global spectra AM1.5 have allowed us to get optimal cells. The comparison of the cells shows the advantage of given GaAs cells. The effect of solar concentration (1–100 suns) on cell operation has been studied. The later has contributed to the enhancement of the energetic efficiency. The effects different standard spetra such as AM1, AM1, 5G, and AM1.5D have been studied. The optimal values of physical parameters giving the best currents of short-circuit and voltages of open circuit as well as high conversion efficiency have been obtained for these two solar materials.

Keywords: photovoltaic cells, Si, GaAs, high efficiency.

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1. Introduction

Considerable research has been done in the last few years on reducing the manufacturing costs of solar cells, and a big effort (experience, numerical simulation and theoretical prediction models) has been devoted to the study of photovoltaic devices characterisation by high efficiency [1], [2].

The purpose of this work comes to contribute to the optimisation of the performance of Si and GaAs (*N*/*P*) solar cells by the determination of physical and technological parameters giving the best photovoltaic conversion efficiency and good spectral response.

Four principal parameters that influence the operation of a solar cell are emitter and base doping, junction depth and base thickness. We have also taken into account the recent techniques of elaboration of the structures [3].

This study concerns the use of novel optimised values of electronic properties of GaAs and Si materials such as recombination velocity at surface (front and back). All enhancements recently reached: BSF, BSR layers, ARC antireflection layer with textured surface, surface passivation, improved ohmic contacts are taken into account [4].

In this paper the calculated current-voltage characteristics are obtained by PCID program on two different cells (Si and GaAs) under the global spectra AM1.5G, have allowed us to get the optimal cells. The comparison of these two cells shows the advantage given by GaAs cells. The effect of solar concentration (1–100 suns) on cell operation has been studied. For later contributing to the enhancements of the energetic efficiency. The different standards spectra effect such AM1, AM1.5G, and AM1.5D have been studied. The optimal values of physical parameters giving the best current of short-circuit and voltages of open circuit as well high conversion efficiency have obtained for the two solar materials [5].

2. Solar cell new structures

The structures of our study are shown on the Fig. 1 comprising the Si or GaAs based material. A passivation layers and an antireflection layer above the basic material are found the BSF layer and the BSR layer. For a better photon absorption, an ACR layer is deposited and the front surface is textured. The use of optimised values of optoelectrical properties concerning the two materials (Si and GaAs) such as the recombination velocity at surface (front and back) are taken into consideration.

3. Solar cell simulation

The PCID program, designed essentially for the photovoltaic component modelisation and exploitation, has been used for the study parameters that are:

– The doping of the emitter (N_D) and base (N_a) regions, the junction depth X_J and the base thickness X_B.

– The studied cells performances ae strongly affected by the doping levels in the different regions of the cell (N_D-emitter and N_a-base) and by the layer dimensions on the current–voltage (I–V) characteristics, X_b: The base depth, X_J, the junction depth and the cells spectral response.

– The optimised values of optoelectronics properties of the two studied materials (Si, GaAs) such as the recombination velocity (front and back) and at volume have been used in this study.

– On the other hand all the improvements recently provided to the solar cells such as BSF, BSF layers anti reflection layers with a textured surface, surfaces passivation, improved ohmic contacts are taken into consideration.

a) Influence of the base parameters on the photovoltaic efficiency:

In Fig. 2*a*, we present the profile of the photovoltaic conversion efficiency as a function of the base parameters particularly for the weak emitter doping N_a then sturates beyond 5μm, the best efficiency is obtained for $N_a = 5 \cdot 10^{17}$cm^{-3} and a thickness X_B = 5μm for GaAs solar cells. For silicon solar cell Fig. 2*b* as a function of the base thickness and between the doping levels $1 \cdot 10^{16}$ cm^{-3} and $5 \cdot 10^{16}$ cm^{-3} beyond this level, the efficiency will have successive changes until the highest concentration $N_a = 1 \cdot 10^{18}$ cm^{-3} these parameters make a whole size vary such as the resistivity, the diffusion, the saturation current the mobility and the diffusion length. We had to find compromise between these whole parameters in order to obtain optimal values $N_a = 5 \cdot 10^{16}$ cm^{-3} and X_B = 200 μm.

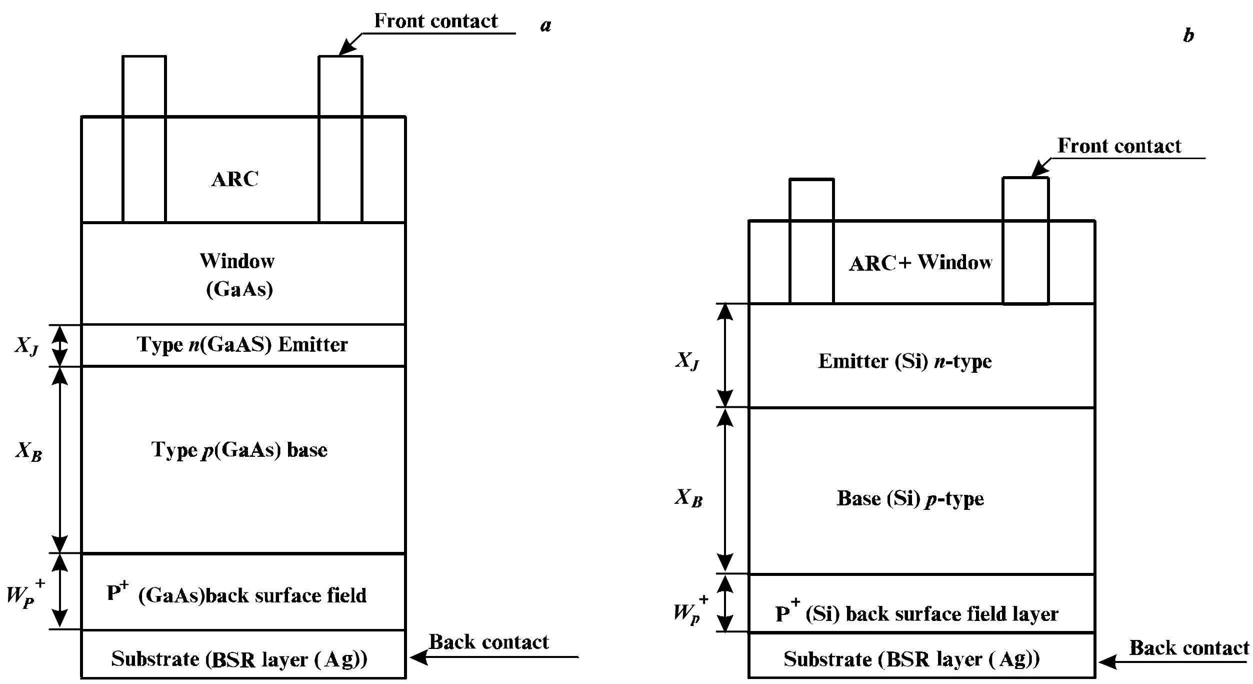

Fig. 1. Solar cells structures GaAs and Si

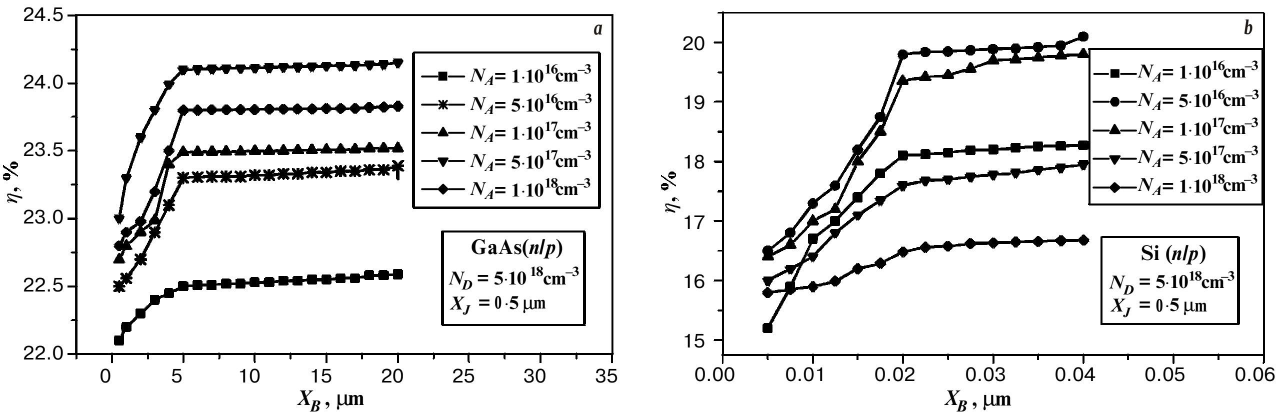

Fig. 2. The influence of the base parameters on the photovoltaic efficiency for Si and GaAs cells.

b) Junction depth influence on the efficiency

In Fig. 3, we present the conversion efficiency as a function of the junction depth. The other parameters being maintained constant the variation decreases rapidly in the sense of the junction depth for GaAs cells and of 0.5 µm for the Si solar cells allows the generated carriers near the surface to be collected. The junction depth increase damages the cell performances this is explained by the carriers in order to reach to collect surface before to recombine and contribute to the photocurrent.

c) The base parameters influence over the spectral response

In Fig. 4, we present the doping effect on the spectral response. In the GaAs case, the spectral response is proved to be independent of the base thickness, it remains constant whatever the thickness X_B this is due to the GaAs material absorption properties besides the spectral response changes as function of the doping N_a Fig. 4*a*. In the silicon case Fig. 4*b* shows the spectral response damage in proportion as the doping increases, a value of 93% is reached. For short wave lengths beyond 950 nm the spectral response begins to decrease.

d) The emitter parameters influence over the spectral response:

The spectral response is damaged with the emitter parameters (Figs 5*a* and 5*b*) this deterioration is due to carriers created far form the surface and do not have a sufficient wavelength to be collected and to contribute to the photocurrent.

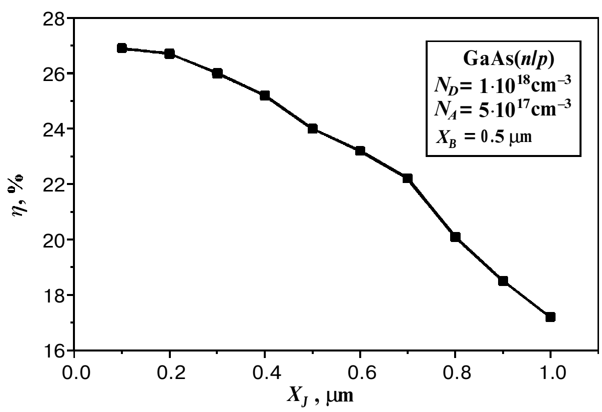

Fig. 3. The junction depth influence on the efficiency.

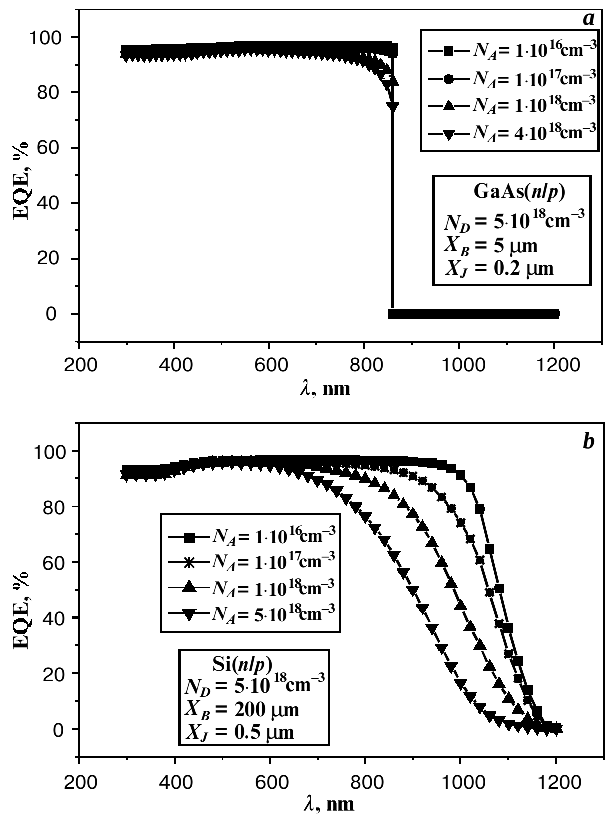

Fig. 4. The base parameters influence on the spectral response.

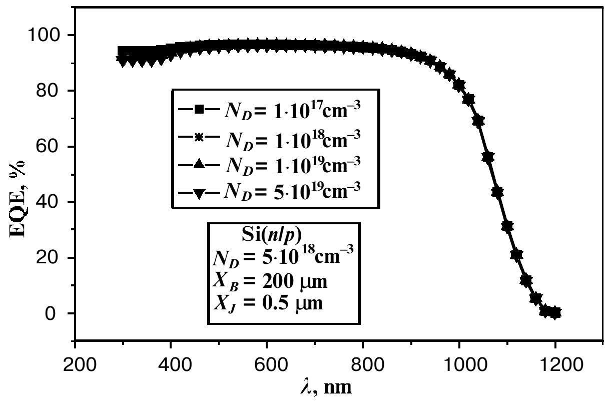

Fig. 5. The emitter parameters influence over the spectral response.

4. The standard spectral effects on the I-V characteristics

In Figs 6*a*, 6*b* we have represented the I–V characteristics concerning the two studied cells as a function of the three standard spectral AM1, AM1.5G and AM1.5D, the best efficiency being the one obtained for the AM1.5 spectral.

5. Results

Based on this study, we have obtained optimal values of the physical and technological parameters offering the best efficiency.

a) GaAs solar cell:

$N_D = 5\cdot10^{18}$ cm^{-3}, N_a=5·10^{17} cm^{-3}, X_B = 5 μm, X_J = = 0.2 μm, $N_a = 4\cdot10^{18}$ cm^{-3}, W_p = 0.2 μm.

b) Si solar cell:

$N_D = 5\cdot10^{18}$ cm^{-3}, $N_a = 5\cdot10^{16}$ cm^{-3}, X_B = 200 μm, X_J = 0.5 μm, $N_a = 8\cdot10^{18}$cm^{-3}, W_p = 25 μm.

These cells offer the following characteristics:

a) GaAs efficiency η = 26,8% a form factor FF = = 87.58%, a short circuit current I_{SC} = 0.03A and open circuit voltage V_{OC} = 1,02V.

b) Si η = 26,8%, FF = 87.58%, I_{SC} = 0.03A and V_{OC} = 1.02V.

The GaAs solar cell has got efficiency greater than that of the Si solar cell in normal working conditions or under concentration. The obtained results are encouraging and we intend pursue the study for more complex structures such as the solar tendencies with three junctions in order to increase the efficiency.

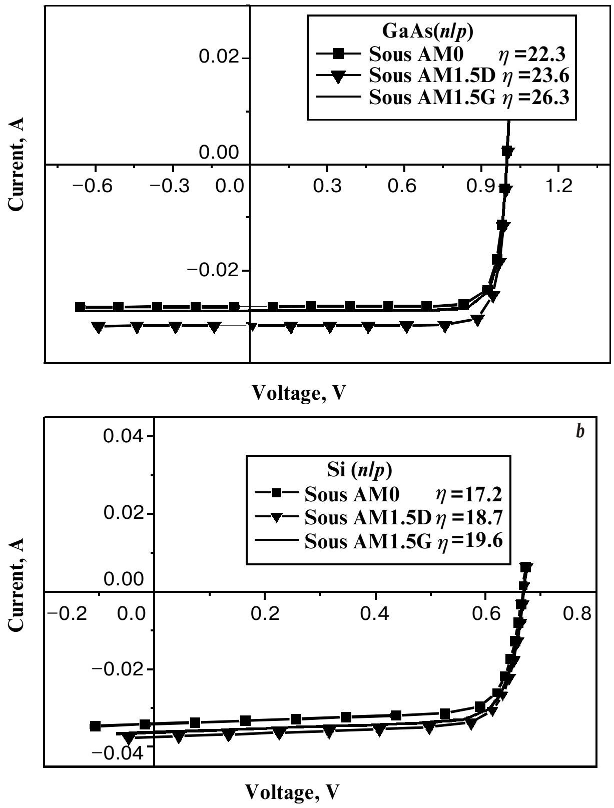

Fig. 6. The standard spectral effects on the I–V characteristics.

6. Conclusions

This study allowed us to work out a synthesis on the photovolatic structure and we have determined the optimal values of the Si and GaAs solar cells which give the best efficiency.

Physical understanding and optimisation of the cell structure is given in all the figures of well established geometrical and electrical cell parameters. Our results are in agreement with the experimental results.

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