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Optimization of GaInP Solar Cell Performances

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Abstract: One of the most important problems in the design of modern photo-voltaic cells is increasing their efficiency. In this study we study a BSF layer structure of GaInp solar cell, windows layer, the effect of surface texturisation, surface recombines speed and we search for technological parameters of this leading to its optimized performance (using PC1D simulator). The optimized structure gives the following results: 18.1% and FF = 84.80%.

Key words: GaInP, solar cell, BSF Layers and external quantum efficacies

INTRODUCTION

Starting from the 1953 year, when the semiconductor Solar Cells (SC) were invented, SCs were mainly applied in space satellite energy systems. Only after international oil crisis in 1973, the decision of exploring the solar cell technology potential for terrestrial applications appeared. Until this period the Photovoltaic (PV) technology was extensively investigated, developed and is still in progress now (Coiante and Barra, 1992; Grilikhes, 1986). Up to 1990, the solar cells were mainly created using single crystal, polycrystalline and amorphous Si. The latter was caused by the comparatively high efficiency of these solar cells (h = 13-16%) and relatively cheap technology. Prices of GaAs SC, for example, were around ten times higher than those of Si SC. Only beginning from 1990 when the GaAs SC technology moved into volume production the prices of GaAs SC dropped to five times of the Si SC ones. Sharp rise of GaAs SC volume production was connected with revolution in the satellite industry (Meyer and Metzger, 1997). The latter stemmed from the improvements in III-V solar cell design, coupled with demands for satellites to have higher on-board power (Torchynska and Polupan, 2002).

In this study we study a BSF layer structure of GaInp solar cell, windows layer, the effect of Surface texturisation, surface recombines speed and we search for technological parameters of this leading to its optimized performance (using PC1D simulator).

GAINP SOLAR CELLS MODEL

Schematic drawing of basic structure of a mono-crystal GaInp solar cell is shown in Fig. I. It is known that

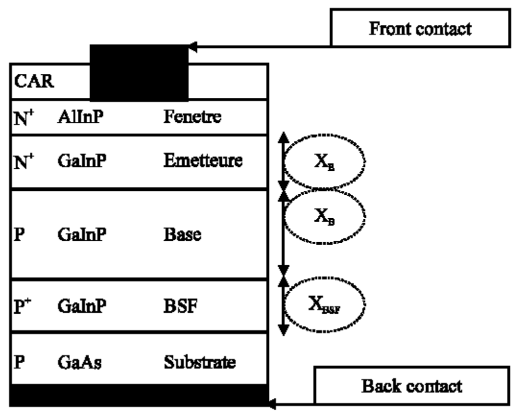

Fig. 1: Basic structure of solar cell

the efficiency of the GaInp solar cells depends on n+-p junction depth. There is an optimal value of this parameter where solar cell operates most efficiently. This is caused, on the one hand, by a specificity of photon processes taking place in the materials which are contained in the solar cells andon the other hand, by the features of their designs (Ustyantsev *et al*., 2000). For optimization of a solar cell we used its mathematical model possessing an abrupt n+-p junction as well as the constant levels of doping on each side of the n+-p junction. As a result, we can suppose that electric field outside of depletion layer of the n+-p junction is equal to zero (Fig. 1).

For the incident light of the wavelength\and intensity or flux F(•), electron-hole pairs are generated at the distance×from the surface at a rate:

$$G(x,\lambda) = \alpha(\lambda)\, F(\lambda)\, [1 - R(\lambda)]\, \exp(-\alpha(\lambda)x) \qquad (1)$$

Where a (•) is the local absorption coefficient; R(•) is the surface r eflectivity; F(•) is the density of photons.

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Under low injection conditions 1D stationary equation are written as (Ustyantsev *et al*., 2000):

$$(1/q)\ (d J_p / dx) - G_p + \Delta p_n / \tau_p = 0 \quad (2)$$

$$(1/q)\ (d J_n / dx) + G_n - \Delta n_p / \tau_n = 0 \quad (3)$$

With:

$$\bullet\ p_n = P_n - P_{no} \text{ et } \bullet\ n_p = n_p - n_{po} \quad (4)$$

Here, expressions for the photo-current contributions in the p- and n-region, J_n and J_p are therefore given by the diffusive currents:

$$J_p = q\mu_p p_n E - q D_p (dp_n / dx) \quad (5)$$

$$J_n = q\mu_n n_p E + q D_n (dn_p / dx) \quad (6)$$

Where, q is the electron charge; D_p, D_n is diffusion factor. For n+-p region we can obtain integro-differentual equation which describes distribution of holes in n-layer

$$D_p \frac{d^2\Delta p_n}{dx^2} + \alpha\ F(1-R)\ \exp(\alpha x) - \frac{\Delta p_n}{\tau_n} = 0 \quad (7)$$

A similar integro-differentual equation for the electron distribution in the player can be written as:

$$D_p \frac{d^2\Delta N_p}{dx^2} + \alpha\ F(1-R)\ \exp(\alpha x) - \frac{\Delta N_p}{\tau_p} = 0 \quad (8)$$

Taking into account that Eq. 7 and 8 have no analytical solution we used the numerical methods with the following initial conditions:

$$D_p \frac{d\Delta p_n}{dx} = S_p \Delta P_n \text{ at } x = 0 \quad (9)$$

$$D_p \frac{d\Delta n_p}{dx} = S_n \Delta n_p \text{ at } x = H$$
$$n_p - n_{po} = 0\ P_n - P_{no} = 0 \text{ at } x = x_i \quad (10)$$

The photo-generated excess hole density in the n region is given by

$$J_p = -q D_p \left(\frac{dp_n}{dx_j}\right) = \left[q F(1-R)\ \alpha\ L_p / (\alpha^2 L_p^2 - 1)\right] \times \left[\frac{\left(\frac{S_p L_p}{D_p} + \alpha L_p\right) - \exp(-\alpha x_j)\left(\frac{S_p L_p}{D_p}\cosh\frac{x_j}{L_p} + \sinh\frac{x_j}{L_p}\right)}{\frac{S_p L_p}{D_p}\sinh\frac{x_j}{L_p} + \cosh\frac{x_j}{L_p}} - \alpha L_p \exp(-\alpha x_j)\right] \quad (11)$$

The photo-generated excess hole density in the p region is given by

$$J_n = \frac{q F(1-R)\alpha L_n}{\left(\alpha^2 L_n^2 - 1\right)} \exp\left[-\alpha(x_j + w)\right] \times \left[\alpha L_n - \frac{\left(\frac{S_n L_n}{D_n}\right)\left(\cosh\left(\frac{d'}{L_n}\right) - \exp(-\alpha d')\right) + \sinh\left(\frac{d'}{L_n}\right) + \alpha L_n \exp(-\alpha d')}{\frac{S_n L_n}{D_n}\sinh\left(\frac{d'}{L_n}\right) + \cosh\left(\frac{d'}{L_n}\right)}\right] \quad (12)$$

The total photo-current as a function of wavelength is then given by the sum of diffusion currents in the p-, n- regions and depletion region (Ustyantsev *et al*., 2000):

$$J_E(\lambda) = J_p(\lambda) + J_n(\lambda) + J_{dr}(\lambda) \quad (13)$$

$$J_{dr} = q F(1-R) \exp(-\alpha x_j)\left[1 - \exp(-\alpha w)\right] \quad (14)$$

The most important SC parameter is conversion efficiency •

$$\bullet = P_m P_{in} = FFU_{oc} J_{sc}/P_{in} \quad (15)$$

Where Pm = Im Um is the maximum output power of SC, P_{in}-the integral solar incident power on front contact, Uoc-the open circuit voltage, Jsc-the short circuit current density, FF-the fill factor of I-U characteristics.

SIMULATION RESULTS

We point out that the thickness of the transmitter must be low for a good collection of the carriers and that the doping of this area should not exceed 5.10^{18} cm•^{3}, to minimize the dark current. The doping of the base must be higher than 10^{16} cm•^{3}, in order to reduce the resistive losses due to the base, by keeping the values of the parameters of the base, constants. We chose a oping of 1.5 10^{17} Cm^3, a thickness xB = 0,6 µm, a strongly doped layer BSF (NA = 2×10^{18} cm•^{3}), thickness xBSF = 0,5 µm and a layer fenestrate thin and strongly doped (ND = 2×10^{18} cm•^{3}), thickness xf = 0,03 µm. We vary the thickness (Xe) transmitter between 0.01 and 0.1 µm andthe concentrations ND between 5×10^{17} and 3×10^{18} cm•^{3}, for the results concerning spectrum AM1.5G. Let us note that the choice of the optimal parameters of each area of the cell was carried out in order to carry out the best compromises between the output of conversion ç and the factor of form FF. We took these two characteristics like selection criteria of the parameters. Results of PC1D simulation (using these assumptions) are shown in Fig. 2 and 3. Witch represent the conversion efficiency (•) of the GaInp cell on the emitter

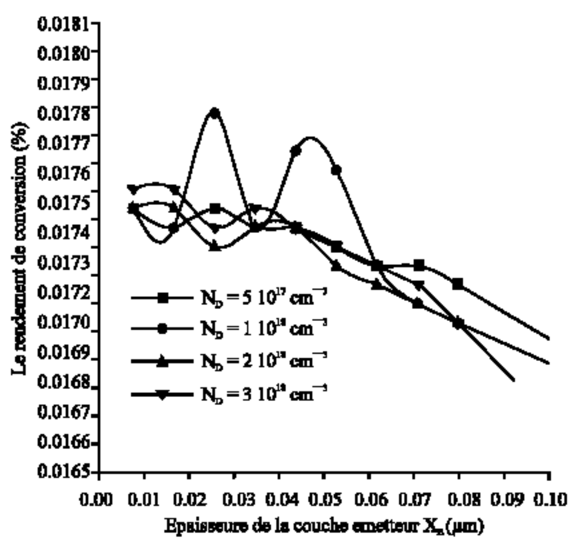

Fig. 2: The conversion efficiency (•) of the GaInp cell on the emitter device

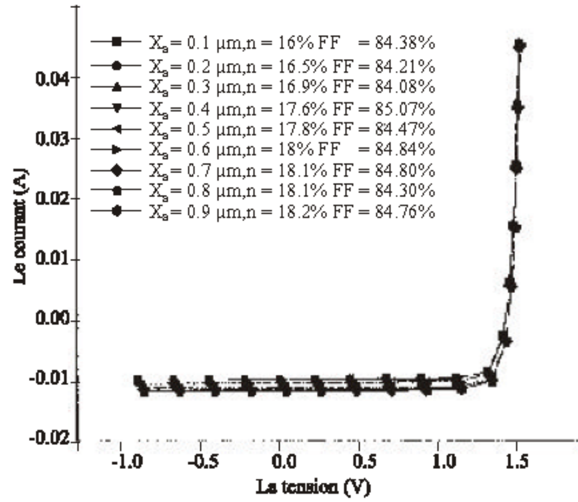

Fig. 3: Variation of the courant via voltage

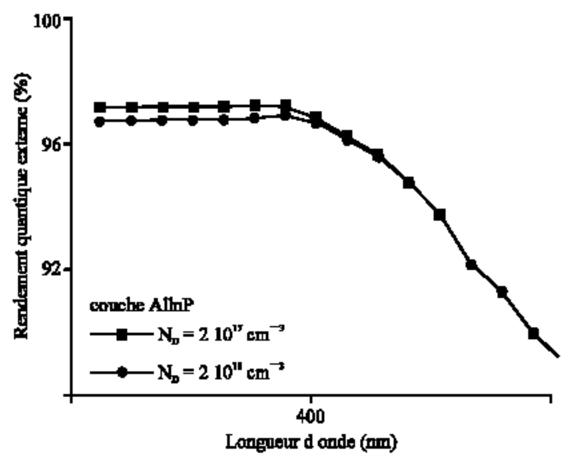

Fig. 4: Effect of the doping of the window layer on the external quantum yield of a GaInP cell

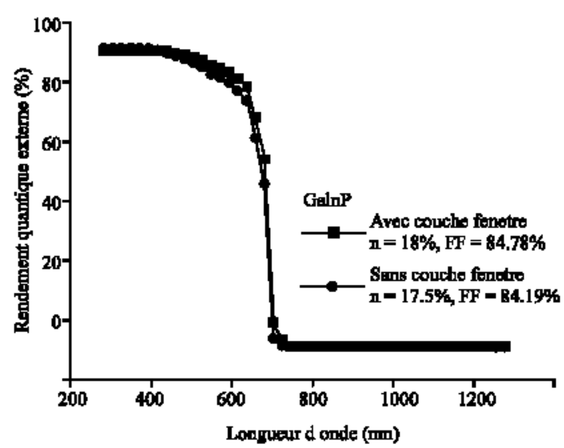

Fig. 5: Influence window layer on the external quantum yield of the GaInP cell

device and the variation of the courant via voltage, who gives us the best results for a thickness and specific doping of the emitter and the base.

Figure 4 and 5 show, respectively that a strong doping the window layer affects the spectral answer negatively (a doping of 2×10^{17} cm•^{3} gives the best result) and that this same layer has According to Fig. 6, one sees that the presence of a BSF layer slightly improves the energetic efficiency and the factor of form.

The texturisation of front surface allows the containment of the solar radiations in solar material. This layer must have an optimal angle (54.74°) for trapping the light well, in order to optimize the photo generation in front surface. Figure 7 shows a positive effect on the electric characteristics of the photovoltaic cell; it

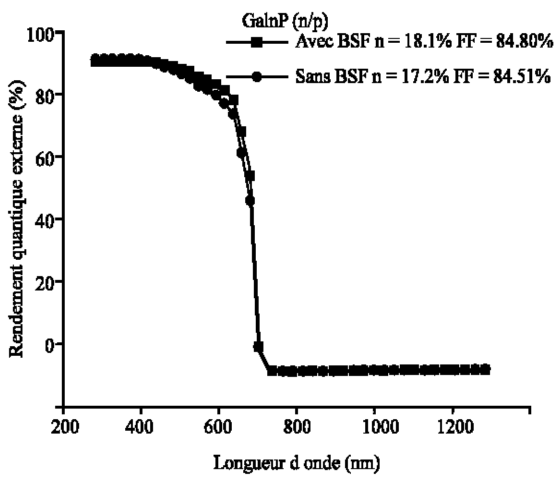

Fig. 6: Influence of BSF layer on the external quantum yield of the GaInP cell

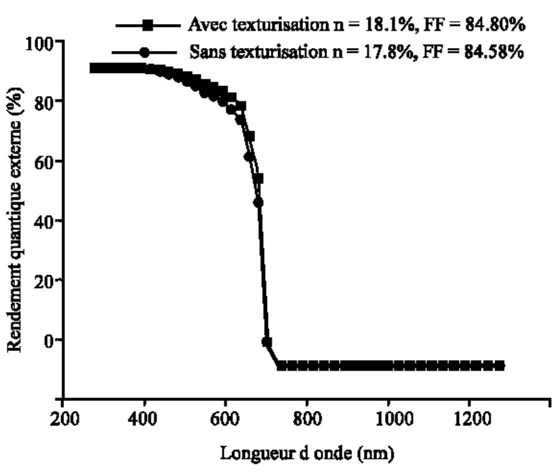

Fig. 7: Influence texturisation on the external quantum yield of the GaInP cell

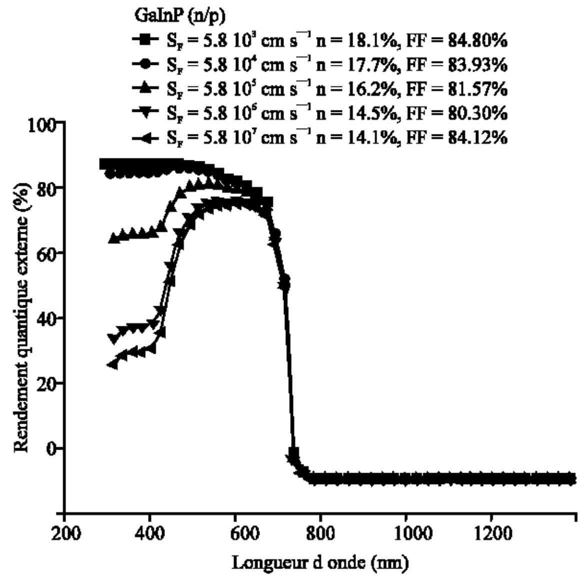

Fig. 8: the Effect of a speed recombination on external quantum efficacies in the surface of a GaInP cell

Table 1: Solar cell parameter

				BSF		Emitter		BASE	
FF (%)	• (%)	V_{OC} (V)	I_{SC} (A)	X_{BSF} (µm)	N_A (cm•^{3})	X_E (µm)	N_D (cm•^{3})	X_B (µm)	N_A (cm•^{3})
84.80	18.1	1.278	0.0167	0.5	2×10^{18}	0.03	1.0×10^{18}	0.7	1.5×10^{17}

minimizes the effect of surface recombination andimproves the external quantum Influence texturisation on the external quantum yield of the GaInP cell. Figure 8 show that the high speed of the recombination on the front surface strongly degrades the electric performances and the spectral response of the solar cell.

The Table 1 summarizes the parameters of the various layers of the studied cell, aswe ll as the corresponding characteristics of exit (according to the results of simulation).

CONCLUSION

From these studies, we saw that the performances of the studied cells are very sensitive to the variations of the technological parameters of the cell (doping and thickness) and of various layers (window, texturusation, BSF). This analysis enabled us to obtain the values of the physical and technological parameters, offering the best outputs.

We have found technological parameter of a emitter, base and BSF layer to its optimized performance (• = 18.1and FF = 84.80%).

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