Optimizing the Efficiency of Solar Cells based on GaAs

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Abstract

Nowadays thin-film solar cells are increasingly used mainly because of their low cost. In recent decades the performance of these cells were significantly improved. In this work, we simulated a solar cell type GaAs using software (PC1D) to analyze certain parameters, in particular the properties of the window layer, base, emitter and BSF layer (thickness, doping ...), these parameters play a crucial role in the performance of the cell, and to optimize them, we studied their influence on the photovoltaic solar cell sizes. In order to highlight the importance of depositing a layer window type Ga_{1-x}Al_x on GaAs solar cells, a comparison between two cells, one with no window layer, the other with a layer window, was made. The energy efficiency is increased from 24.9 registered in a cell% to 26.7% for GaAs cell Ga_{1-x}Al_x As / GaAs.

Keywords: Solar Cell, Heterojunction, Yield, Layer Window, BSF layer, GaAs, PC1D

1. Introduction

In recent years, solar cells based on gallium arsenide have been widely used, particularly for space applications, and this owing to their high efficiency and a low degradation in the face of irradiation space. However, a significant problem precluded the development of GaAs solar cells, namely the rate of surface recombination. This is why the performance achieved for the first solar cell was only about 10% [1-2]. This problem was partially solved by growing a layer of Ga_{1-x}Al_x on the surface of GaAs [3]. The two materials having similar crystal parameters, few defects and the recombination centers may exist in the interface between the two semiconductors. [4] Thus the performance of GaAs cells exceeded 20% the first time in the late 70s when Woodall and Hovel fabricated cells to hetero structures with a yield of 22% [5]. Nowadays, these solar cells have achieved efficiencies of around 20-25% [6-7]. The solar cell that has been studied, is a structure np: Ga_{1-x}Al_x (n) -GaAs (n) - GaAs (p) -GaAs (p), for the highly efficient photovoltaic conversion, and for the reduction of and the series resistance of the surface recombination velocity attributed to the use of the heterojunction across avant. Pour it was used a one-dimensional numerical simulation software PC1D (personal computer one-dimensional).

2. Presentation of the Structure

The appropriate structure is comprised primarily of a cell np GaAs based on what is deposited a layer of n-type window Ga_{0.3}Al_{0.7} As. Between the substrate and the cell is inserted a layer BSF (Back Surface Field) doped p+, which has the function of creating an electric field delayed rear face, thereby lowering the effective value of the recombination rate for and hence improve the electrical characteristics of the cell. A diagram of the structure illustrated in Figure (1).
Figure 1. Structure of the Solar Cell Study

Note that the structure has been studied under AM1.5 solar spectrum, with $P = 100$ mW/cm$^2$, and at room temperature $T = 300$ K. Measurements of photovoltaic parameters were performed in the case of a zero series resistance and larger shunt resistance infinitely.

2.1. Current Density of Short Circuit

Basically the relations governing the operation of a silicon solar cell are valid for gallium arsenide. The density of the monochromatic photocurrent is given by [8]:

$$J_{n,ph}(X_i) + J_{p,ph}(X_i) + J_{scr,ph}(W)$$

(1)

$J_{n,ph}$: the photocurrent density of the emitter
$J_{p,ph}$: the photocurrent density of the base
$J_{scr,ph}$: photocurrent density of the space charge zone
$W$: the thickness of the space charge zone.

The equations previously photocurrents densities for a given wavelength ($\lambda$) specific are approximately valid in a narrow band width ($\approx 100$ Å). The total photocurrent density can be calculated by summing the densities of the photocurrent by the fraction of 100 Å [9].

$$J_{ph} = \sum_{i=1}^{63} J_{ph}(\lambda_i)\lambda_i = 0.24 + 0.01 (i - 1)$$

(2)

It should be mentioned that the total current density photo shows the current density $J_{sc}$ shorting.

2.2. Open-circuit Voltage

The dark current density is given by [10, 11]:

$$J_d = J_{n,d}(X_i) + J_{p,d}(W_b) + J_{scr,d}$$

(3)

$J_{n,d}$: density of the dark current of the emitter
$J_{p,d}$: density of the dark current of the base
J_{scr, d}: density of the dark current of the space charge zone
W_B: the thickness of the neutral zone near the base.

The open circuit voltage is calculated using the feature:

\[ J = J_{sc} - J_d (V) = 0 \]  \hspace{1cm} (4)

\[ V = V_{oc} \]  \hspace{1cm} (5)

\section*{2.3. Form Factor and photovoltaic conversion efficiency}

\[ P = J \cdot V = (J_{sc} - J_d) \cdot V \]  \hspace{1cm} (6)

\[ P_n = J_n \cdot V_n = J_n \left[ V_{oc} - V_T (1 + \ln (1 + V_n / V_T)) \right] \]  \hspace{1cm} (7)

\[ V_m = V_{oc} - V_T \cdot \ln (1 + V_m / V_T) \]  \hspace{1cm} (8)

\[ FF = \frac{J_n \cdot V_m}{J_{sc} \cdot V_{oc}} \]  \hspace{1cm} (9)

\[ \eta = \frac{P_n}{P_m} \]  \hspace{1cm} (10)

P: power output,
P_m: maximum power,
V_{oc}: maximum voltage,
J_{sc}: maximum current density,
V_T: thermal potential,
FF: form factor,
\eta: photovoltaic conversion efficiency,
P_n= 100 mW / cm^2: incident power on condition AM1.5.

\section*{3. Optimization Technique}

By optimizing the main problem is as follows:

\[ F (X_1, X_2, ..., X_N) \text{\ rendementphotovoltaïque} \]

Optimize the function:

\[ G_k (X_1, X_2, ..., X_N) \text{\ variation range} \]

\begin{table}[h]
\centering
\begin{tabular}{|l|c|}
\hline
Variables & Range \\
\hline
X_1 = doping window (cm^3) & $[10^{14}-10^{19}]$ \\
X_2 = doping of the emitter (cm^3) & $[10^{14}-10^{19}]$ \\
X_3 = doping of the base (cm^3) & $[10^{14}-10^{19}]$ \\
X_4 = doping BSF (cm^3) & $[10^{14}-10^{19}]$ \\
X_5 = thickness of the window (um) & [0-10] \\
X_6 = thickness of the emitter (um) & [0-10] \\
X_7 = base thickness (um) & [0-10] \\
X_8 = BSF thickness (um) & [0-10] \\
\hline
\end{tabular}
\end{table}
4. Results

**Figure 2.** Change in Performance Depending on the Thickness of the Window Layer

**Figure 3.** Variation in Performance against Doping the Layer Window

**Figure 4.** Change in Performance Depending on the Thickness of the Emitter
Figure 5. Variation in Performance against Doping of the Emitter

Figure 6. Change in Performance Depending on the Thickness of the Base

Figure 7. Variation in Performance against Doping Base
Figure 8. Change in Performance Depending on the BSF Thickness

Figure 9. Variation of Performance against Doping BSF

Table 2. Results of Our Optimization

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Heterojunction cell</th>
<th>Homojunction cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>$N_{\text{window}}$ ($\text{cm}^3$)</td>
<td>$10^{15}$</td>
<td>$10^{17}$</td>
</tr>
<tr>
<td>$P_{\text{Base}}$ ($\text{cm}^3$)</td>
<td>$10^{17}$</td>
<td></td>
</tr>
<tr>
<td>$N_{\text{emitter}}$ ($\text{cm}^3$)</td>
<td>$2.10^{18}$</td>
<td>$2.10^{18}$</td>
</tr>
<tr>
<td>$P_{\text{BSF}}$ ($\text{cm}^3$)</td>
<td>$2.10^{18}$</td>
<td>$2.10^{18}$</td>
</tr>
<tr>
<td>$X_{\text{window}}$ (um)</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>$X_{\text{Base}}$ ($\text{cm}^3$)</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>$X_{\text{emitter}}$ ($\text{cm}^3$)</td>
<td>0.04</td>
<td>0.04</td>
</tr>
<tr>
<td>$X_{\text{BSF}}$ ($\text{cm}^3$)</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>$I_{sc}$ (mA/cm)</td>
<td>31.2</td>
<td>29.9</td>
</tr>
<tr>
<td>$V_{oc}$ (V)</td>
<td>0.9975</td>
<td>0.9708</td>
</tr>
<tr>
<td>$\text{FF}$ (%)</td>
<td>85.79</td>
<td>85.79</td>
</tr>
<tr>
<td>$\eta$ (%)</td>
<td>26.7</td>
<td>24.9</td>
</tr>
</tbody>
</table>
Conclusion

We were interested to show the influence of the thickness and doping of the window layer, the emitter, base, BSF layer and the substrate on the photovoltaic parameters of the cells and heterojunction homojunction GaAs.

The optimum conditions to obtain the best conversion efficiencies are:

1. For the heterojunction cell:
   \[ X_w = 0.01 \text{ um}, \ N_w = 10^{18} \text{ cm}^{-3}, X_E = 0.04 \text{ um}, N_E = 2.10^{18} \text{ cm}^{-3}, X_B = 3\text{ um}, P_B = 10^{17} \text{ cm}^{-3}, X_{BSF} = 3\text{ um} \text{ and } P_{BSF} = 2.10^{18} \text{ cm}^{-3} \]

2. For the homojunction cell:
   \[ X_E = 0.04 \text{ um}, N_E = 2.10^{18} \text{ cm}^{-3}, X_B = 3\text{ um}, P_B = 10^{17} \text{ cm}^{-3}, X_{BSF} = 3\text{ um} \text{ and } P_{BSF} = 2.10^{18} \text{ cm}^{-3} \]
Solar cells based on GaAs give a current density of small short circuit, open circuit voltage greater circuit and perform better than the solar cells based on Si.

References