International Journal of Scientific Research & Engineering Technology (IJSET)
Vol.7 pp. 4-7

# Optimization the concentration doping of emitter layer for InGaP /GaAs hetero-junction solar cell using the SILVACO ATLAS software

Dennai Benmoussa*1,Fillali Mostefa#2,Atouani Toufik *3

*Matter Sciences Departement, Faculty of Exact Sciences, Université Tahri Mohammed Béchar
#Laboratory of Semiconductor Devices Physics,University of Bechar, Algeria
1deennai_benmoussar@yahoo.com
2filali_mustapha@yahoo.fr
3toufikatouani1972@yahoo.fr

***Abstract*— The photovoltaic power (PV) is obtained by direct conversion of sunlight into electricity by means of PV cell. Performance optimization of InGaP/GaAs heterojunction solar cell can be done by acting on some components and parameters of this cell. The main objective of this work is to optimize the efficiency by varied the concentration doping of emitter layer of this type of solar cell, which is limited by multiple losses in particular those related to photons and carriers. The performances of the chosen model, of this InGaP/GaAs heterojunction, are obtained by using Silvaco-Tcad.**

**The optimisation result shows that the maximum efficiency of 21.68% % has been achieved, with short circuit current density of 32.29mA/cm$^2$, open circuit voltage of 0.82V and fill factor of 0.81%.**

***Keywords*—Performance,Solar cells, heterojunction, InGaP/GaAs. Silvaco-Tcad.**

## I. INTRODUCTION

The use of solar cells is currently one of the best solutions to the energy problems. Solar cell design stared with the simple single junction ones and later moved on to multijunction cells that are used in space applications [1]. There has been considerable interest in recent years in heterojunction device such as the solar cell. At present time, the GaAs /AlGaAs and InGaP/GaAs heterojunction represent a great interest. As shown in Fig.1, This type of cells are made up of materials with different band-gap which are connected back to back and cover a wide range of sun's spectrum.

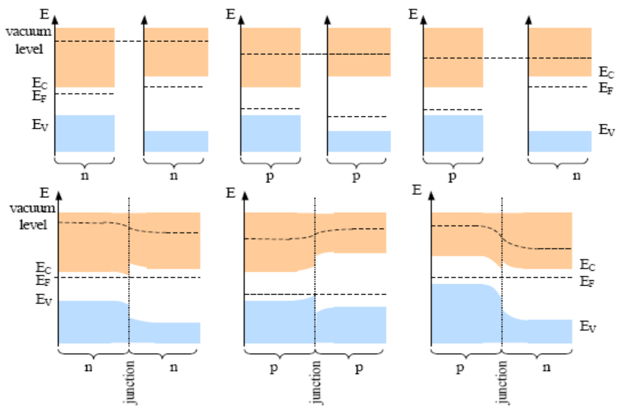


Fig 1 : Band diagram of heterojunction formation[2].

The major goal of heterojunction solar cell design is to maximize the output power for a given solar spectrum. High efficiencies could be obtained by stacking together different absorbers with different band-gaps to maximize the light absorption.[3]

Numerical modelling and simulation help to optimize the solar cell structure in understanding of main physical phenomena, thus decreasing the time and cost for development [4]. The SILVACO ATLAS can be used for the design of III-V heterojunction solar cell. The doping layer concentration of the solar cell is a very important parameter. But the obtaining of the optimal values of the latter, often depends on many complicating factors.

In this work, we report the optimum design of InGaP/GaAs heterojunction solar cell by varying the concentration doping of the emitter layer using the SILVACO ATLAS software. The results obtained show that all output parameters (Isc ,Vco , FF ,ɳ) are influenced and vary with the concentration doping of the base layer.


ISSN 1737-9296

## II. DEVICE STRUCURE

Figure 1 shows the schematic diagram of the heterojunction solar cell used in the simulation. The device consists of four regions which are ZnO (cathode), n-InGaP (emitter), p-GaAs (base) and Molybdenum (anode). The effects of heterojunction are manifested because the materials used do not have the same parameters as the band gap, the electronic affinity, the density of states and the mobility of the charge carriers. The dominant recombination mechanism in this study is Shockley - Read - Hall and Auger, similar to Si [5].

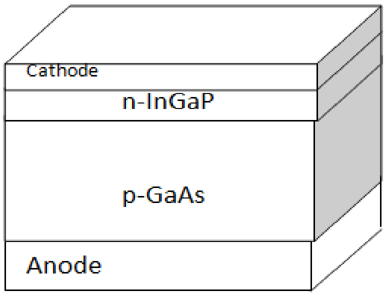


Fig 2 – Schematic representation of the sample structure.

The following table (I) summarizes the parameters of the solar cells used in the simulation [6, 7].

TABLE I
PARAMETERS OF THE INGAP/GAAS HETEROJUNCTION SOLAR CELL

| **layer** | **Cathode** | **emitter** | **base** | **Anode** |
|---|---|---|---|---|
| material | ZnO | GaInP/n | GaAs/p | Molybdenum |
| Thickness( µm) | 0.0001 | 0.5 | 5 | 0.0001 |
| Bandgap Eg (eV) | / | 1.75 | 1.41 | / |
| doping densities ($cm^{-3}$) | / | $1x10^{16}$ to $1x10^{21}$ | $2x10^{16}$ | / |

## III. - MODELING PROCESS

The simulator used works on mathematical models to calculate a solar cell structure; ATLAS solves Poisson's equation, carrier continuity equation, the drift-diffusion transport model and the energy balance transport model [8].

Poisson's equation relates variations in electrostatic potential to local charge densities. The continuity and transport equations describe the way that electron and hole densities evolve as a result of generation, recombination and transport processes [9].

In this work, the models used to optimize the structure are [10]:

**AUGER** specifies Auger recombination;

**CONMOB** specifies that a concentration dependent mobility model be used for silicon and gallium arsenide. This model is a doping versus mobility table valid for 300K only;

**OPTR** selects the optical recombination model. When this parameter is specified, the COPT parameter of the **MATERIAL** statement should be specified;

**SRH** specifies Shockley-Read-Hall recombination using fixed lifetimes;

**FERMIDIRAC** specifies that Fermi-Dirac carrier statistics be used;

**SRH** specifies Shockley-Read-Hall recombination using fixed lifetimes;

The major parameters of the solar cell which are given as [11]:

The total current ($I_{total}$) is calculated by the following equation:

$$I_{tot} = I_0\left[exp\left(\frac{qV}{nKT}\right) - 1\right] - I_l$$

where $I_L$ is the light generated current. The open circuit voltage (Voc) is given by:

$$V_{co} = \frac{nKT}{q}\ln\left(\frac{I_L}{I_0}+1\right)$$

However the Fill factor (FF) is illustrated by:

$$FF = \frac{V_{oc} - L_n(V_{oc}+0.72)}{V_{oc}+1}$$

and the conversion efficiency ($\eta$) by:

$$\eta = \frac{V_{oc}I_{sc}FF}{P_{in}}$$

## IV. RESULTS AND DISCUSSIONS

Optimization of the solar cell has gone through two essential steps. The first is the creation of a model of the cell using the appropriate structural and material characteristics. The second step is an iterative routine to adjust the doping concentration of the emitter layer (from $10^{16}$ $cm^{-3}$ to $10^{21}$ $cm^{-3}$).

Figure 3 shows Atlas regions with materials defined:

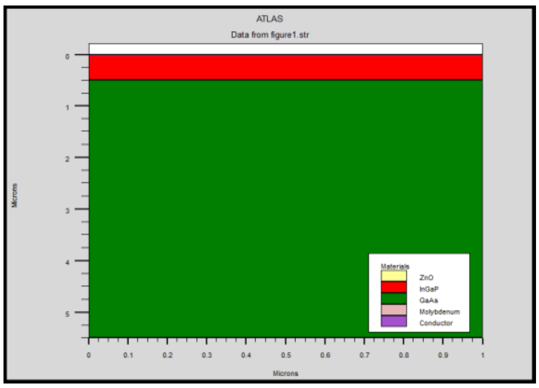


Fig.3. Atlas regions with materials defined

As shown in the figure 4, the first step is specifying the mesh on which the device will be constructed.


ISSN 1737-9296

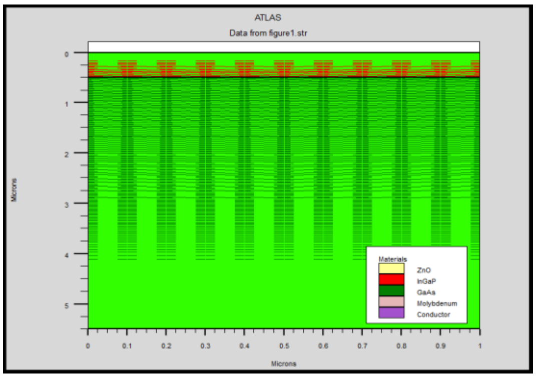


Fig4. Mesh structure of the model.

The physical and optical parameters of the materials used to build the solar cell, were obtained from the SILVACO ATLAS software.

*A. The effect on short circuit current :*

The effects of the InGaP (n) doping concentration on the short circuit current of the solar cell are shown in Fig.5. The results show the short-circuit current are both increased due to higher the doping concentration but a slight increase by any percentage and this indicates that there is no significant effect to focus on and this due to the increase of the electric field but there is a lack of thickness of space charge area.

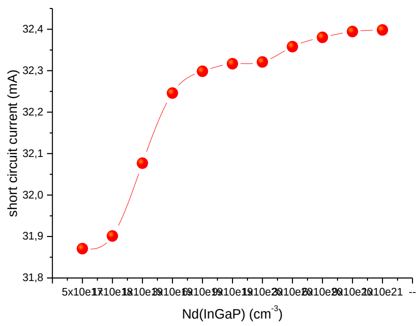


Fig5. Effects of the emitter doping concentration on the short circuit current of the solar cell.

*B. The effect on open circuit voltage:*

Figure 6 shows the variation the open circuit voltage versusof emitter doping concentration o heterojunction solar cell optimesed.The remarks there are three phases:

- First there is a decrease in open circuit voltage every increasedoping concentration.
- The second phase is an increase open circuit voltagefor each increasedoping concentration.
- The third phase decreasesin open circuit voltage.

This is explained by the great value of Voc= 0.8199 V when Nd=$6x10^{19}cm^{-3}$, If it is Nd<$6x10^{19}cm^{-3}$ less than the electric field is weak and if it is Nd>$6x10^{19}cm^{-3}$ the thickness ofspace charge areais small.

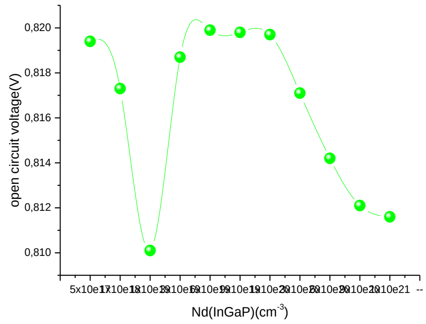


Fig5. Effects of the emitter doping concentration on the open circuit voltage of the solar cell.

*C. The effect on fill factor:*

The fill factor as a function of the doping concentration of emitter layer is represented in Fig. 6.We observedfor the maximum value of FF=81.88% for Nd= $6x10^{19}cm^{-3}$.

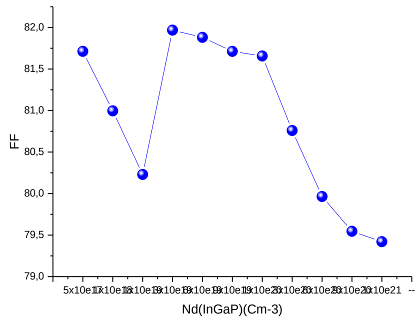


Fig6. Effects of the emitter doping concentration on fill factor

*D. The effect on efficiency:*

Fig.7 is the efficiency of the solar cell accordingn-type doping concentration. We can distinguish three different behaviours; the first,for Nd<$6x10^{17}cm^{-3}$, where a significant decrease of efficiency is obtained decrease of Voc. The second behaviour is observed for $6x10^{17}$<Nd<$6x10^{19}$ increase of efficiency.The thirdbehaviour is observed for $6x10^{19}$<Nd<$6x10^{21}$decrease of efficiency is obtained decrease of fill factor.


ISSN 1737-9296

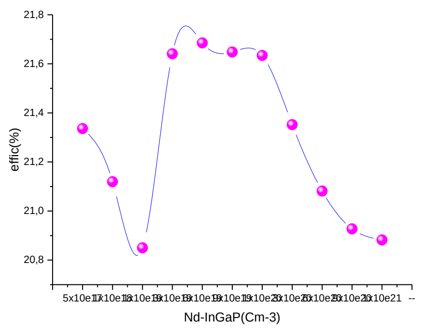


Fig7. Effects of the emitter doping concentration on the efficiency

### *E. Optimal Structure*

From the above results are obtained using the SILVACO ATLAS software.we can determine the best performance of heterojunction solar cell(InGaP/GaAs) which has while giving the doping concentration of emitter layerof the cell.

In Table Ii, we recapitulate the photovoltaic parameters of optimised cells.

TABLE III
OPTIMISED PHOTOVOLTAIC PARAMETERS

| **Doping level ($cm^{-3}$)** | **Isc($mA/cm^{-2}$)** | **Voc(V)** | **FF(%)** | **$\eta$(%)** |
|---|---|---|---|---|
| $6x10^{19}$ | 32.2986 | 0.8199 | 81.8810 | 21.6850 |

The current-voltage characteristics for the device heterojunction solar cell layers with the optimal efficiency for PN structure are shown in Fig. 7,

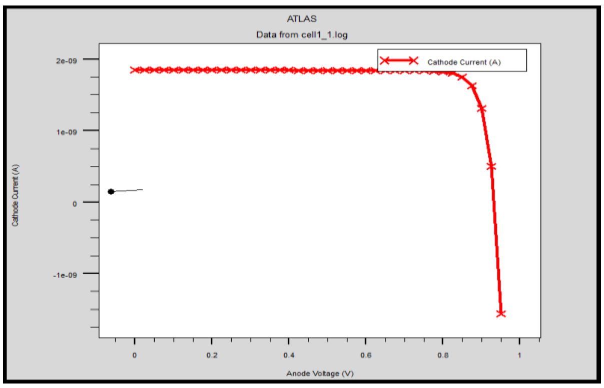


Fig. 7 – I(V) characteristic of the heterojunction solar cell with the optimum performance Silvaco ATLAS simulation

## V. CONCLUSIONS

In this paper, we studied InGaP/GaAsheterojunction solar cell device. Modelling and simulation were performed by using ATLAS-TCAD simulator. Our simulations prove the quality and validity of our model for modelling electronic characteristic of the InGaP/GaAs heterojunction solar cellstudied.

In this design, it has been found that the inclusion of a heterojunction InGaP/GaAs solar cell due. The efficiency has been optimised by changing the doping concentration of the emitter layer.Optimizedemitter material results in Jsc = $32.2986mA/cm^2$, Voc = 0.82 V with significant enhancement in conversion efficiency up to 21.65% (1sun).

## REFERENCES

[1] B. Dennai et al., "Modeling of Cascade Solar Cell Ga0.5In0.5P /GaAs Using AMPS-1D", Advanced Materials Research, Vol. 685, pp. 174-178, 2013

[2] Panayiotis Michalopoulos, A NOVEL APPROACH FOR THE DEVELOPMENT AND OPTIMIZATION OF STATE-OF-THE-ART PHOTOVOLTAIC DEVICES USING SILVACO, THESIS ser. Lecture Notes in Statistics. NAVAL POSTGRADUATE SCHOOL Monterey, California, 2002,

[3] Fuhs, W., Korte, L., Schmidt, M., 2006. Heterojunctions of hydrogenated amorphous silicon and monocrystalline silicon. Journal of Optoelectronics and advanced materials 8, 1989-1995.

[4] *ATLAS User's Manual* – Device SimulationSoftware, SILVACO, Santa Clara, USA 2009.

[5] Atanu Bag, “Heterojunction Solar Cells,” Computer Aided Design of Micro- and Nanoelectronic DevicesEdition: 1Chapter: 13, Nov. 2016.

[6] ] S.Adachi, “GaAs, AlAs, and Al x Ga1−x As: Material parameters for use in research and device applications”, J. Appl. Phys, Vol. 58, pp.R1-R29, 1985..

[7] I. Vurgaftman, J.R. Meyer, L.R. Ram-MohanBand parameters for III–V semiconductors and their alloysJ. Appl. Phys., 89 (2001), p. 5815

[8] ***ATLAS*** *User's Manual*. Device simulation Software. Volumes I and II. Silvaco International (2002).

[9] S. Selberherr, Analysis and Simulation of Semiconductor Devices, Springer-Verlag, Wien-New York, 1984.

[10] Atlas User's Manual Device Simulation Software ; Silvaco, Inc. 4701 Patrick Henry Drive,Bldg. 2 Santa Clara, CA 95054 October 2, 2013.

[11] Hemmani Abderrahmane, B. Dennai, H. Khachab, A. Helmaoui,” Effect of Temperature on the AlGaAs/GaAs Tandem Solar Cell for Concentrator Photovoltaic Performances” J. Nano- Electron. Phys. 8 No1,01015(2016)


ISSN 1737-9296