Study The Effect of Different Layer Arrangement on Efficiency of Gallium Arsenide Solar Cell

Meor Mohd Ekhwan B Meor Ibrahim
Bachelor of Electrical Engineering (Hons)
Faculty of Electrical Engineering
University Teknologi MARA,
40450 Shah Alam, Malaysia
meor_ekhwan@yahoo.com

ABSTRACT

This research was conducted to study the effect of different layer arrangement of GaAs p/n heteroface solar cell. Three different model of GaAs p/n heteroface solar cell structure were introduced and had been simulated. The analysis focused on spectral response analysis. From spectral response analysis, two parameters were issue, photo current and efficiency. The final result shows that, different layer arrangement can effect on photo current and efficiency.

***Keyword**: Solar cell, GaAs, Heteroface, photo current, Efficiency,*

I. INTRODUCTION

Future photovoltaic space power systems require advanced cells of the highest possible efficiency.
In addition, such photovoltaic power systems must endure space radiation environments with predictable and small degradation. For these reasons, research on advanced light-weight cells is considerable as current interest. Cells made from gallium arsenide (GaAs) are well-suited to these requirements. GaAs cells are very attractive for high-concentration application. Their bandgap is nearly ideal for a single junction solar cell and have better temperature characteristics that silicon cell.

The first high-efficiency GaAs cells were developed by Woodall and hovel using AlGaAs/GaAs heteroface structure grown by LPE [1].

The problem associated with GaAs can be attributed to a combination of factor: a high surface recombination velocity coupled with high absorption coefficient, poor starting material (substrate) cause low lifetimes and diffusion length in both the base and diffused regions and poor fill factor.

The performance of GaAs solar cell has been considerably improved recently by the use of high quality substrate, the use of liquid phase epitaxial method and the growth of thin layer of AlGaAs. GaAs heteroface solar cells are made up by combining several layers. This layer include substrate, buffer layer, mirror layer, base, emitter and window layer [3]. Each of GaAs heteroface solar cell layer have their own doping level, type of dopant and thickness.

The purpose of this research is to investigate the effects of different layer arrangement on efficiency in gallium arsenide (GaAs) heteroface solar cells using SILVACO TCAD TOOLS

.

II. METHODOLOGY

Athena is a simulator that provides general capabilities for numerical, physically-based, two-dimensional simulation of semiconductor processing [5]. The accuracy of this physically based simulation tool depends greatly on the accuracy of the material parameters used in constructing the solar cell model.

Modeling solar cell structure: The solar cell that has been chosen for this test was taken from [3]. An orientation GaAs wafer of <100> with $1x10^{18}$ atom cm^{-2} silicon concentration was chosen.

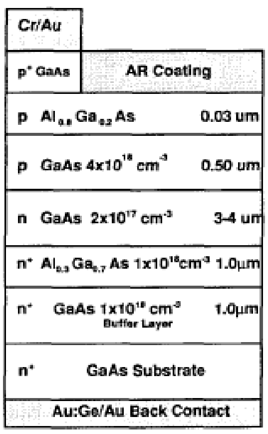

Figure 1: GaAs p/n heteroface solar cell structure

The structure in Figure 1 was obtain from [3]. In this research, the thickness, doping concentration and dopant material of every layer was maintain on every simulation. For both material GaAs and AlGaAs, p-dopant and n-dopant are Magnesium and Silicon respectively [2]. Each layer was constructed one by one. The structure was constructed from bottom to above as shown in Figure 2.

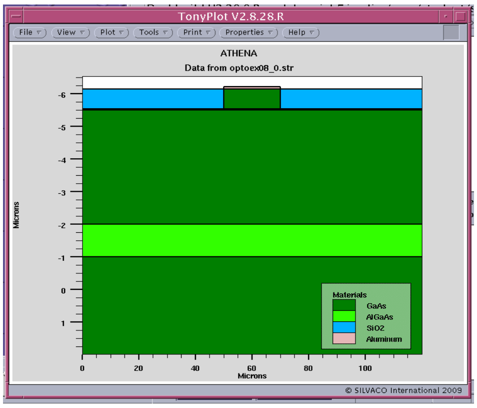

Figure 2: GaAs solar cell simulation structure

The process of making GaAs p/n heteroface solar cell is shown below.

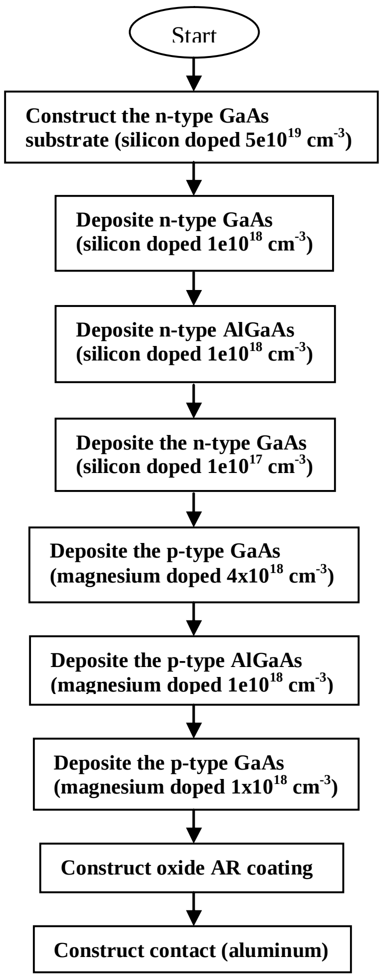

Figure 3: Flow chart of GaAs solar cell

There are three model of GaAs structure was constructed as shown in Figure 4. The model in Figure 4 are used in the simulation. The process in Figure 3 was repeated according to the model in Figure 4.

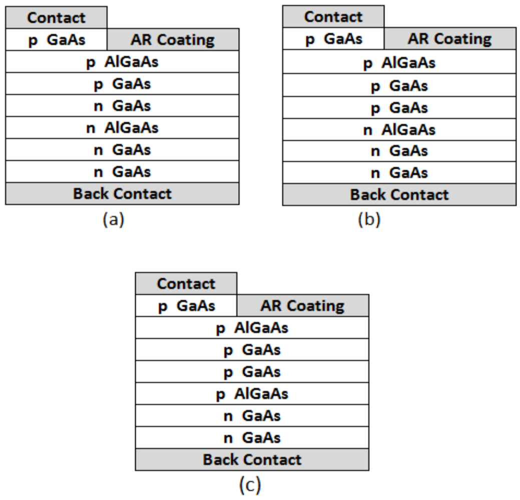

Figure 4(a), (b), (c): Three model structure of p/n GaAs heteroface solar cell used in simulation

Spectral Response Analysis : The spectral response is conceptually similar to the quantum efficiency. The quantum efficiency gives the number of electrons output by the solar cell compared to the number of photons incident on the device, while the spectral response is the ratio of the current generated by the solar cell to the power incident on the solar cell.

The second step is to simulate spectral response of variable structure transition by using ATLAS simulator. In this analysis the beam is fixed to 90^o angle. The result of spectral response analysis was plotted into source photocurrent, available photocurrent and actual cathode current versus wavelength.In this research, we also observe on efficiency of each structure being simulate. By using Tony Plot function, Efficiency versus light energy can be plot. The equation use to obtain Efficiency vs Light energy is [5]:

Light Energy (eV) = hc/q **(1)**

where; h=Planck's constant
c=speed of light
q=electronic charge
where the full equation is

6.6e-34*3.0e+8/ (1.6e-19*Optical wavelength) **(2)**

and the efficiency is defined as power output/power input. In Tony Plot, the function needed was:

Cathode Current/Source photo current **(3)**

III. RESULT AND DISCUSSION

In this project, three models of GaAs solar cell with different layer arrangement have been investigated. The spectral response and collection efficiency will be analyzed and compared.

Figure 4 shows the first GaAs solar cell structure that was used in the simulation. These models have different layer arrangement. Figure 4(a) is the basic structure that was used in [4]. Figure 4(b) and (c) are alternative structure that was created to be used in this experiment.

The simulation result is shown in Figure 5-10, which show the photocurrent effect of the wavelength on gallium arsenide solar cell. The green line on the top shows the photocurrent from the source that being generated by the light source. The red in the middle is available photo current and the blue at the bottom is cathode current. Available photocurrent is the amount of current available for collection by the solar cell and cathode current is the current that be able to collect in the cell [4].

Figure 5 and Figure 6 are the result based on structure from figure 4(a).

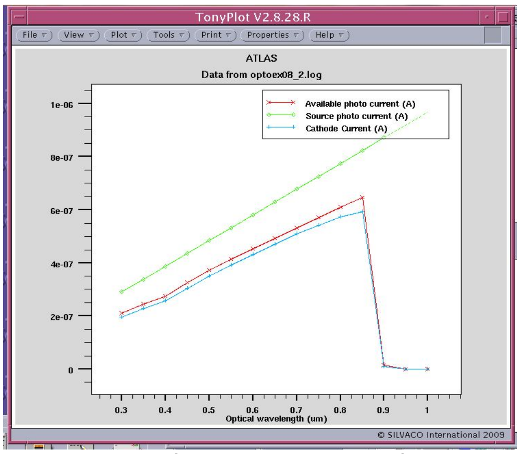

Figure 5: Graph for spectral response for structure Figure 4(a)

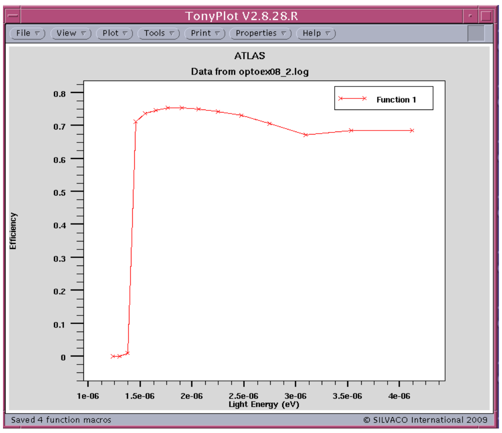

Figure 6: Efficiency graph for structure Figure 4(a)

From Figure 5, the spectral response shows that the cathode curent collection is high. Nearly identical to available photocurrent. At 0.3µm of wavelength, cathode current collect most of the current available for collection and the cell response is very low. At long wavelength, the response fall back to zero. From Figure 5, the current losses due to recombination is low. The simulation has produced all the data needed to create a plot of efficiency vs light enetgy. Figure 6 show the efficiency of 75%

Figure 7 and Figure 8 are the result based on structure from Figure 4(b).

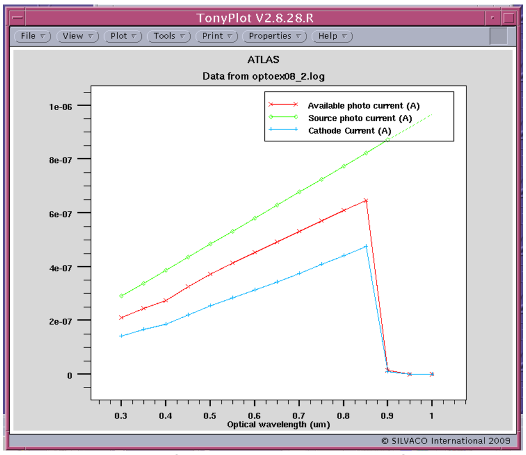

Figure 7: Graph for spectral response for structure Figure 4(b)

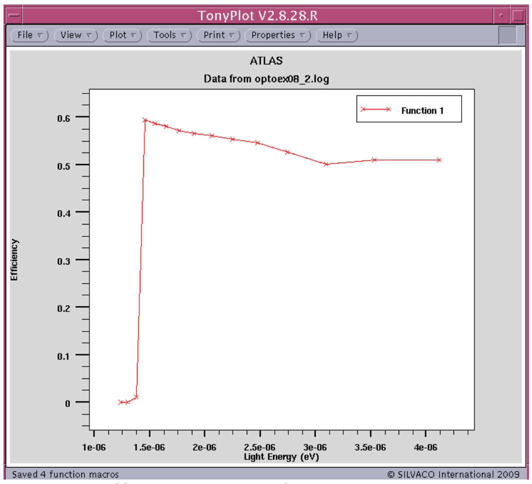

Figure 8: Efficiency graph for structure Figure 4(b)

From Figure 7, the spectral response shows that the cathode current collection of Figure 4(b) structure is lower than Figure 4(a) structure. The efficiency that was plotted is 60%

Figure 9 and Figure 10 are the result based on structure from figure 4(c).

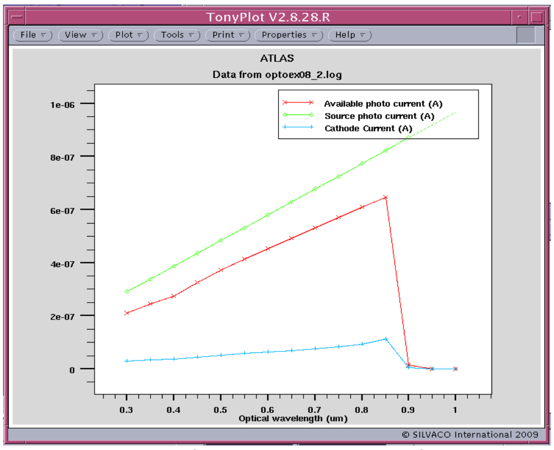

Figure 9: Graph for spectral response for structure Figure 4(c)

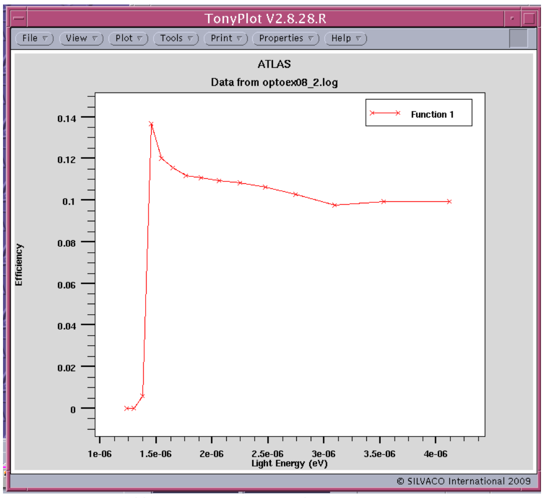

Figure10: Efficiency graph for structure Figure 4(c)

From figure 9, the cathode current collections are much smaller. The efficiency plotted is 14%

The efficiencies of GaAs solar cell with different structure of contact area were summarized in Table 1 below:

Model	Efficiency (%)
Figure 4(a)	70
Figure 4(b)	60
Figure 4(c)	14

Table 1: efficiency of GaAs heteroface solar cell

From Figure 7 and Figure 9, the current losses due to recombination are high. In order for the p-n junction to be able to collect all of the light generated carriers, the carrier must be generating within a diffusion length of the junction. The carrier will be able to diffuse to the junction before recombining.

From Figure 4 (a), (b) and (c), refer to three models, each structures have different location of p-n junction location. The different location of p-n junction will affect in current collection due to recombination.

IV. CONCLUSION

Silvaco Atlas/Athena device simulator was used to design GaAs heteroface solar cell. Three model of structure with different layer arrangement were used to see the performances of GaAs solar cell. The different layer arrangement will affect the current collection and efficiency of GaAs heteroface solar cell. Recombination and location of pn junction of the play main role in the effectiveness of GaAs heteroface solar cell.

V. FUTURE DEVELOPEMENT

Solar cells become popular nowadays because of their ability to provide nearly permanent, uninterrupted power. However in providing the power, they have low power per unit area of sunlight which causes the low efficiencies. Its performance is dependent upon the intensity of the sunlight and also the material used for the solar cell device.

In order to increase performances of GaAs heteroface solar cell, there are several ways to optimize the cell. Decreasing the window layer thickness can increase the efficiency of the cell. Optimizing the doping level of each layer of the cell also can give better conversion of energy of the cell.

ACKNOWLEDGEMENT

This research work has been carried out between January 2009 and November 2009 in the Department of Electrical Engineering Universiti Teknologi MARA Malaysia (UiTM). Many people have helped me in the realization of this work and I would like to take this opportunity to express my gratitude to all of them. I am deeply grateful to my supervisors Dr. Fuziah Sulaiman and Dr. Rusop for their support and guidance. Also thanks to Laboratory staff for allow me to use the facilities.

REFERENCES

[1] H. J. Hovel and J. M. Wooddall, J. Electrochem. Soc. 120, 1246 (1973)

[2] Alan L. Fahrenbruch, Richard H. Bube, Fundamentals of solar cells:Photovoltaic solar energy conversion, academic press, 1983,

[3] Martin a. Green, Operating principles, technology and system applications, prentice-hall, 1982

[4] Tobin, S.P.; Vernon, S.M.; Wojtczuk, S.J.; Bajgar, C.; Sanfacon, M.M.; Dixon, T.M., "Advances in high-efficiency GaAs solar cells," *Photovoltaic Specialists Conference, 1990., Conference Record of the Twenty First IEEE* , vol., no., pp.158-162 vol.1, 21-25 May 1990

[5] Athena User’s Manual

[6] Atlas User’s Manual