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Study and Comparison Of Diffusion Length Effect With Tandem Solar Cells Of Two Levels

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BACKGROUND
The increasing in energy consumption and the price of oil in the recent years has made possible the entry of new energetic options such as solar energy, in which there are multiple studies in order to increase its electrical efficiency, one of the most studied, is the technology of tandem solar cells which provides efficiencies above 30%.

OBJECTIVE
Propose a comparative study between the technology of diffusion length and tandem solar cells technology with two-layer, looking for the best choice in terms of voltage, current, power and energy efficiency.

RESULTS
As a result of the proposed work it was found that the tandem cell model presented an absorbed power (PA) of 6.536 (Watts) higher than that obtained in the model of single cell with which a power of 4,653 was obtained.
Furthermore the energy efficiency (EE) is lower in the tandem cell model with 39.290%, while 56.329% was obtained in the model of single cell.

CONCLUSION
The solar cell electrochemical operation and its efficiency are susceptible to all changes that are performed inside the cell, no matter if they are small, due to in this study was observed that by adding a thin layer of AlGaAs semiconductor it is possible to change the behavior of the cell.

KEY WORDS
Renewable Energy, Solar Energy Efficiency, Multilayer Solar Cells, Semiconductor, PC1D, Air Mass 1.5, Quantum Efficiency, Diffusion Length.

INTRODUCTION

Nowadays as a result of climate change and the exponential population growth in recent years, different goals have been proposed such as the 20-20-20 of the European Union, which aims to increase 20% of renewable energy production, reduce 20% of energy consumption and increase to 20% efficiency in energy use. All of this for 2020 [1], [2].

There are several solutions that have been raised using natural and atmospheric phenomenon such as water, air or even the sun, from which the last one has demonstrated to be a viable solution to implement as an energy source in the coming years. This alternative uses photovoltaic cells as a method of capturing and converting solar rays, which are composed by one or more semiconductor materials, and are capable of generating electricity from electrons motion generated through the interaction with the sun [3], [4].

Photovoltaic cells have a commercial conversion efficiency of 15%, which depends on the semiconductor that is used, which is commonly silicon. As a consequence of its low efficiency there have been sought ways to increase it, like the combination of two or more semiconductors such as germanium, indium-phosphorus (Inp), gallium-arsenic (GaAs) or gallium-aluminum-arsenide (AlGaAs), thereby increasing the converted and the

absorbed energy, using in this way more properly the solar energy [5], [6], [7].

As a consequence of silicon being the most used semiconductor in the manufacturing process of solar cells, there have been studied ways to improve the conversion efficiency by modifying the chemical and physical properties of the semiconductors [8]. The results of these studies have led to increased cell efficiency with this material up to 19% [9].

In the studies of the tandem cells, performed in the papers [10], [11], [12], [13], [14], [15], how solar energy can be used is evidenced using different regions of the wavelength produced by the solar radiation. All of this can be done a cause of each semiconductor has a different value of bandgap, whereby the semiconductor captures different sections of this wavelength and by mixing two or more of these, more sections of the solar spectrum can be absorbed [16], [17], achieving by this way efficiencies between 30 and 68% for theoretical conditions, and 50 to 89% for ideal conditions [18].

Another option that have been analyzed in recent years is the diffusion length, as can be demonstrated in [19], where the degradation of the solar cells performance with copper metallization technique was investigated, revealing that this degradation depends on the effectiveness of the nickel diffusion barrier, being for higher temperature lesser is the effect, assuming that the diffusion length and its effectiveness depends proportionally on the temperature to which is subjected.

Furthermore in [20] a technique for the diffusion of different elements was developed, whereby a minimum diffusion thickness is ensured in order to increase the concentration of charge carriers, increasing by this way the efficiency of the cell directly. In the same way than [21] a front light diffusion cell was developed with the purpose of reducing losses of energy inside the cell.

Of all the papers studied, this work shows the results of a comparative study between the diffusion technology and tandem technology of two layers as a diffusion technique, looking for the best one in terms of voltage, current, power and energy efficiency.

Methodology:

In order to perform a comparison of a single cell based on GaAs that uses forward diffusion technique, with one based on the same semiconductor but instead of a front diffusion a two layers cell it will be studied based on Aluminum gallium arsenic (AlGaAs) as a first layer.

For both developments, it is necessary to define the conditions under which both models are going to be compared. For this, Table 1 shows the properties of both semiconductor at 300K.

The criteria used in PC1D simulation is a constant radiation of 0.1 W / cm^2 under the standard terrestrial solar irradiance AM 1.5 [22], [23], at environment temperature (25 ° C), for a cell dimension of 100 cm^2 and a reflectance factor of 10%, with a textured surface of 3 um depth and an inclination angle of 54.74 °.

Additionally, it is necessary to know what the diffusion length is, which is defined as the average distance that a carrier can move from the point of generation until its recombination [24]. It is also directly related to the quantum efficiency, which affects the likelihood of solar cells bulk collection. Also its relevance to the quantum efficiency is approximately 10% of all 100% [25].

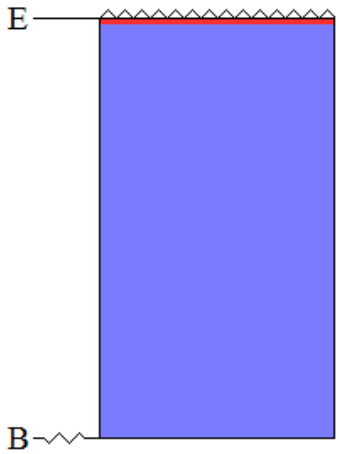

Fig. 1: Solar Cell Design for PC1D Simulation

The design used for the first PC1D simulation is shown in Figure 1, where E and B are the emitter and base of the semiconductor, respectively, wherein the base has a resistance of 10 Ω. The blue area corresponds to P-type doping and the red one, corresponds to the diffusion length of 0.1 um with N type doping, both red and blue doping base on GaAs.

Table 1: Semiconductors properties at 300K

Properties	AlGaAs	GAAS
Thickness	100 um	100 um
Bandgap	1,817 eV	1,424 eV
Lattice constant	5.6767 A	5.653 A
Absorption Range	0 – 684.8 nm	50 – 850 nm
Quantum efficiency (Min-max)	0.5 % - 95.10 %	0% - 95.95%
Front recombination	Sn = Sp = 1e5 cm/s	Sn = Sp = 1e5 cm/s
Rear recombination	Sn = Sp = 1e5 cm/s	Sn = Sp = 1e5 cm/s

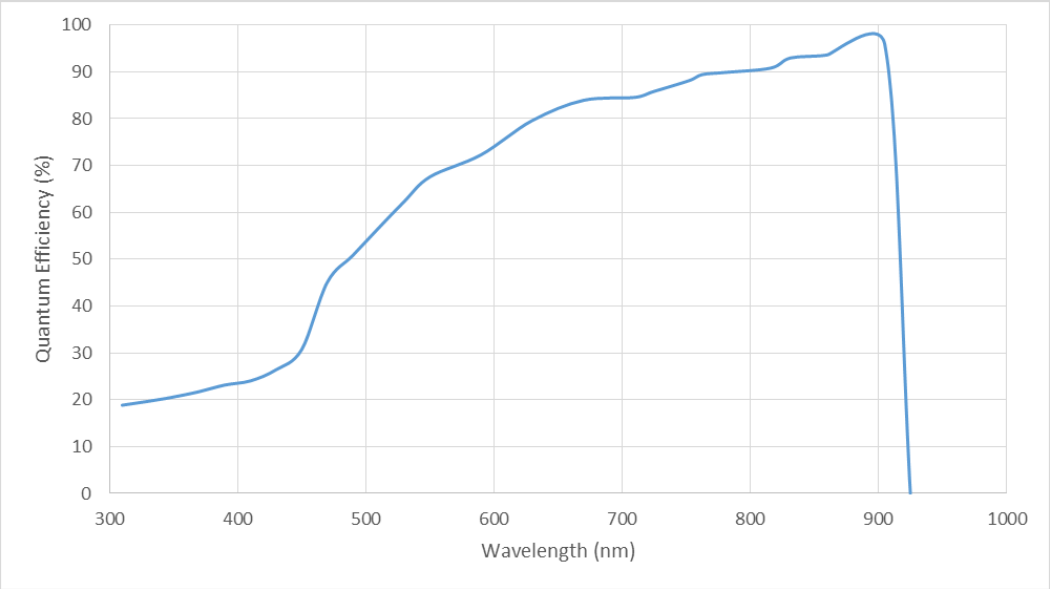

Fig. 2: Quantum Efficiency of First Model

For the second design, the implemented tandem cell is shown in Figure 3, where the red zone is doped with AlGaAs semiconductor at 0.1 um of thickness and the blue zone is the main one based on GaAs semiconductor with 100 um of thickness.

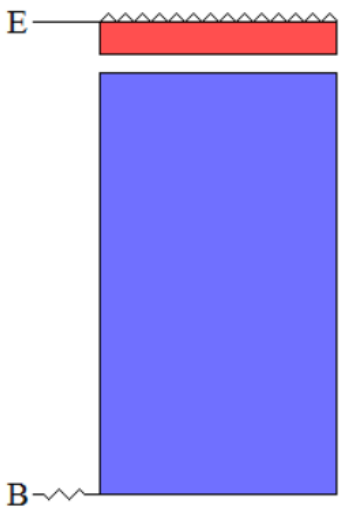

Fig. 3: Tandem Solar Cell Design of two layers in PC1D Simulator

Results:

The first model to simulate was the solar cell based on GaAs as shown in Figure 1, the results are divided into two sections, the first one, consisting of electrical energy results of the model as shown in Table 2.

Table 2: Electrical Results of first Model

Characteristic	GaAs
Isc (Amps)	3,042
Voc (Volts)	1,024
Pm (Watts)	2,621
n (%)	26,210%

Table 2 shows an efficiency of 26% with a cell area of 100 cm^2, using the doping diffusion technique. Likewise the same tests were performed for the second model shown in Figure 3, the results obtained are shown in Table 3.

Table 3: Electrical Results of second Model

Characteristic	AlGaAs/GaAs
Isc (Amps)	3,275
Voc (Volts)	0,958
Pm (Watts)	2,568
n (%)	25,680%

In Table 3 using tandem cells technique under the same conditions, rather than diffusion technique, can be demonstrated that the efficiency diminishes slightly and the current is increased by more than 200 mA.

The second section consists of measuring the quantum efficiency of both models, by the same simulation program, for this purpose how much of the radiation wavelength absorb both models is tested. Starting with the first model the results are shown in Figure 2.

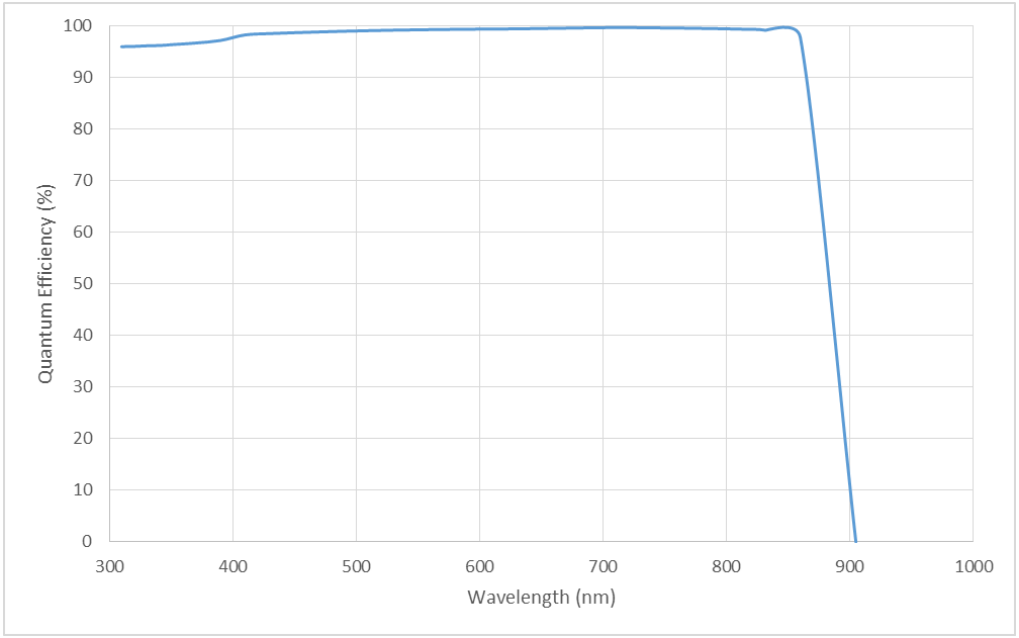

Fig. 4: Quantum Efficiency of Second Model

In Figure 2 the internal quantum efficiency of the cell can be evidenced, where for a length of wave from 300 to 900 nm, the absorption efficiency exceeds 50% after 500 nm, then after 870 nm falls directly to 0% so thereafter no more power is absorbed.

In the same way the simulation is performed using the second model as evidenced in Figure 4, which shows unlike the Model 1, the internal efficiency is over 90% from 300 nm to almost 870 nm, which after this decreases instantly to 0% a cause of the behavior of the semiconductor (GaAs).

With these two graphics a comparison of the energy efficiency and the power consumption is realized, as shown in Table 4.

Table 4: Quantum and Energetic Efficiencies

Characteristic	AlGaAs/GaAs	GaAs
PA (Watts)	6,536	4,653
E.E (%)	39,290%	56,329%

In Table 4 the difference between both models can be appreciated, which lies in the absorbed power (PA),

being higher in the proposed model, so it can be seen that the energy efficiency (EE) which is the relationship between the power consumption vs the converted one (PM) is inferior.

Conclusions:

In first step, the final effect of model 2 was the same as the Model 1, with a little difference in the obtained electrical values, but, on the other hand the greater effect of changing the diffusion method was evidenced, where a significant increase is obtained in the power absorbed due to the change in the bandgap of the resulting cell.

In conclusion, from the obtained results the solar cell electrochemical operation and its efficiency are susceptible to all changes that are performed inside the cell, no matter if they are small, due to in this study was observed that by adding a thin layer of AlGaAs semiconductor it is possible to change the behavior of the cell.

Along all this study it was observed that this technique offers the possibility of implementing the second model in tandem type solar cells as a replacement of the diffusion method in order to increase the overall efficiency.

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