

SIMULATION OF THE SOLAR CELLS WITH PC1D, APPLICATION TO CELLS BASED ON SILICON

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ABSTRACT

A way of exploiting the solar energy is to use cells photovoltaic which convert the energy conveyed by the incidental radiation in a continuous electric current. This conversation is based on the photovoltaic effect engendered by the absorption of photons. A part of the absorbed photons generates pairs electron-hole in which an electric field created in the zone of load of space of a junction p-n.

Thus, the junction p-n, its characteristics, its components and its dimensions are the parameters responsible of the efficiency and the performances of a solar cell. To study this, we are going to use a very known software in the mode of the simulation of solar cells, the PC1D, and we are going, at the end, to draw a conclusion around the ideal parameters that a good solar cell has to have.

KEYWORDS

PC1D, Characteristic I-V, Thickness, Doping

1. INTRODUCTION

The numerical simulation software PC1D (Personal Computer One Dimensional) is very used in the simulation of solar cells. This software was developed in Australia at the university South Wales of Sydney. It allows to simulate the behavior of photovoltaic structures based on semi-conductor by respecting to one-dimensional (axial symmetry).

The PC1D contains libraries files with the parameters of the crystalline semi-conductors used in the photovoltaic technology as the GaAs, a-Si, AlGaAs, Si, InP, and Ge. The files of the solar spectrum are also available in this software mainly AM0 and AM1.5 spectrum. The main window of PC1D is as follows:

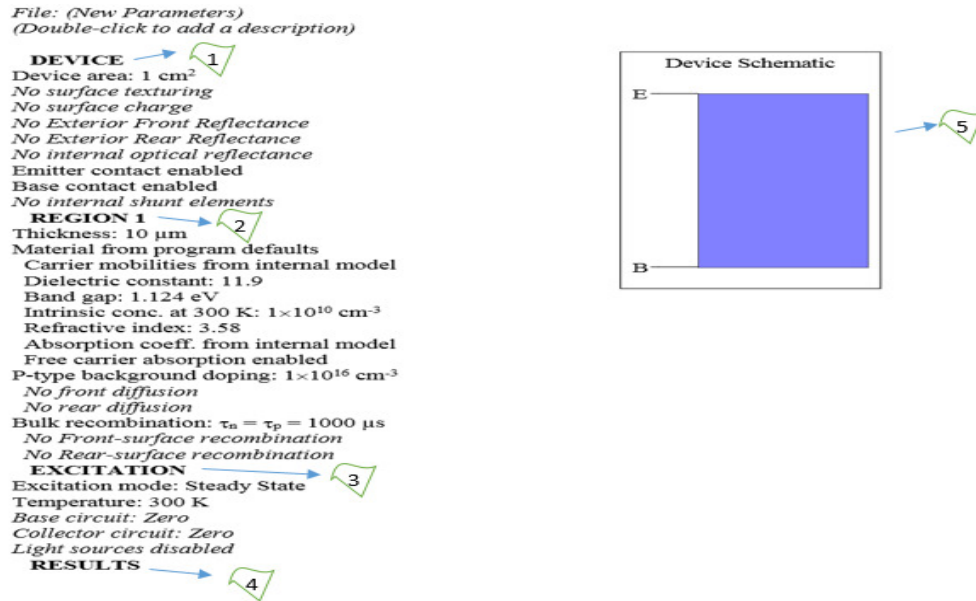


Figure 1. Main window of PC1D

We distinguish essentially 5 parts:

- 1-The part “device”: this part contains the general information on the device which we want to simulate.
- 2-Part 'region': it is in this part that introduces the essential parameters related to component device region (type of materials used, thickness, doping type ... etc.). In the figure above, there is one area but you can add other (maximum one can have 5), as one can remove (at least one must have a single region).
- 3-The part “excitement”: it is into this part that we introduce the parameters of excitement of our device and which will serve us to simulate the behavior of the latter. For example in the case of solar cells, it is in this part that we will solve the irradiation as well as the operating temperature and other parameters.
- 4-The part “results”: it is in this part that we shall have in particular, after the launch of the simulation, the values of I_{cc} , V_{oc} and the power max for the simulation of solar cells.
- 5-The part “device schematic”: it is simply the plan of the dispositive that we create. It can change instantly as soon as one touches to parameters of regions (for instance color changes depending on the doping).

2. SIMULATION AND RESULTS

In fact, we made several simulations to see the influence of various parameters on the efficiency of solar cells. We chose to use the silicon as material composing cells simulated because this is semi-conductor the most used actually in the industry of the photovoltaic.

The basic cell since which we began our simulations is a silicon solar cell. We selected a total thickness of 100 μm and a surface of 100 cm^2 . All settings and parameters of the cell are shown in the following figure:

File: (New Parameters)
(Double-click to add a description)

DEVICE

Device area: 110 cm²
No surface texturing
No surface charge
Exterior Front Reflectance: 10%
No Exterior Rear Reflectance
No internal optical reflectance
Emitter contact enabled
Base contact enabled
No internal shunt elements

REGION 1

Thickness: 10 μm
Material from si.mat
Carrier mobilities from internal model
Dielectric constant: 11.9
Band gap: 1.124 eV
Intrinsic conc. at 300 K: 1×10¹⁰ cm⁻³
Refractive index from si.inr
Absorption coeff. from si300.abs
Free carrier absorption enabled
N-type background doping: 1×10¹⁹ cm⁻³
No front diffusion
No rear diffusion
Bulk recombination: τ_n = τ_p = 1000 μs
No Front-surface recombination
No Rear-surface recombination

REGION 2

Thickness: 100 μm
Material from si.mat
Carrier mobilities from internal model
Dielectric constant: 11.9
Band gap: 1.124 eV
Intrinsic conc. at 300 K: 1×10¹⁰ cm⁻³
Refractive index from si.inr
Absorption coeff. from si300.abs
Free carrier absorption enabled
P-type background doping: 1×10¹⁶ cm⁻³
No front diffusion
No rear diffusion
Bulk recombination: τ_n = τ_p = 1000 μs
No Front-surface recombination
No Rear-surface recombination

EXCITATION

Excitation from one-sun.exc
Excitation mode: Transient, 16 timesteps
Temperature: 25°C
Base circuit: Sweep from -0.8 to 0.8 V

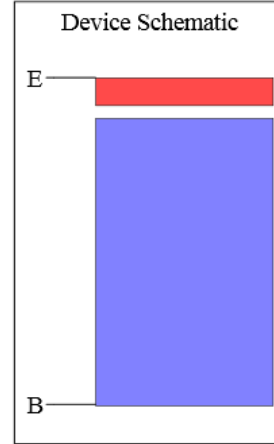


Figure 2. Cell based on Silicon.

As it can be noticed on the figure 02, for the excitement we have chooses a file which is called “one-sun.exc”. In fact, there are already two PC1D ready files that contain standard parameters to be used during the simulation of solar cells, these two files are:

- 1- The “one-sun.exc” file which gives us the following results:
 - ✓ The value of short circuit current.
 - ✓ The value of the open circuit voltage.
 - ✓ The value of the maximum power.
- 2- The file 'scan-qe.exc' which gives us the following results:
 - ✓ The value of short circuit current.
 - ✓ The value of the maximum power.

In fact, the second file gives us, at the level of curves representing the quantum efficiency of 1 cell. As we are only interested in the characteristics $I-V$ of cells solar simulated as well as their powers, we preferred to use only 1 file 'one-sun.exc' during our work. For this first example, we had the following results:

$$I_{CC} = 1.735 \text{ A}$$

$$P_{MAX} = 0.9529 \text{ W}$$

$$V_{OC} = 0.6567 \text{ V}$$

2.1. Characteristic $I-V$

The figure shows the $I-V$ curve of the obtained characteristic of the first example:

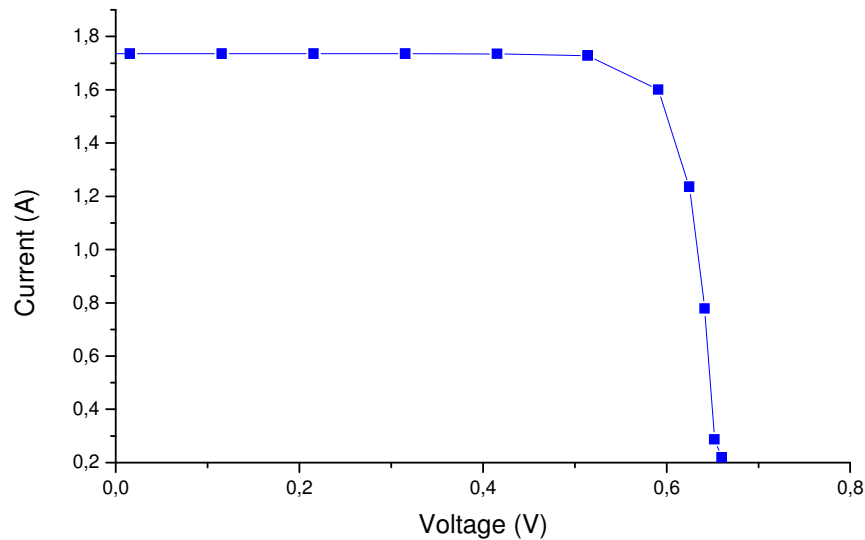


Figure 3. $I-V$ characteristic of the basic cell.

2.2. Influence of the surface on the $I-V$ characteristic

For this example, we took the same parameters as the basic cell and we changed the surface of the latter as follows:

- (a) Surface of 120 cm^2
- (b) Surface of 150 cm^2
- (c) Surface of 200 cm^2

P_{Max} Values are found, respectively, of: 1.039 W, 1.299 W and 1.732 W. The three curves $I-V$ characteristics are shown in figure 4.

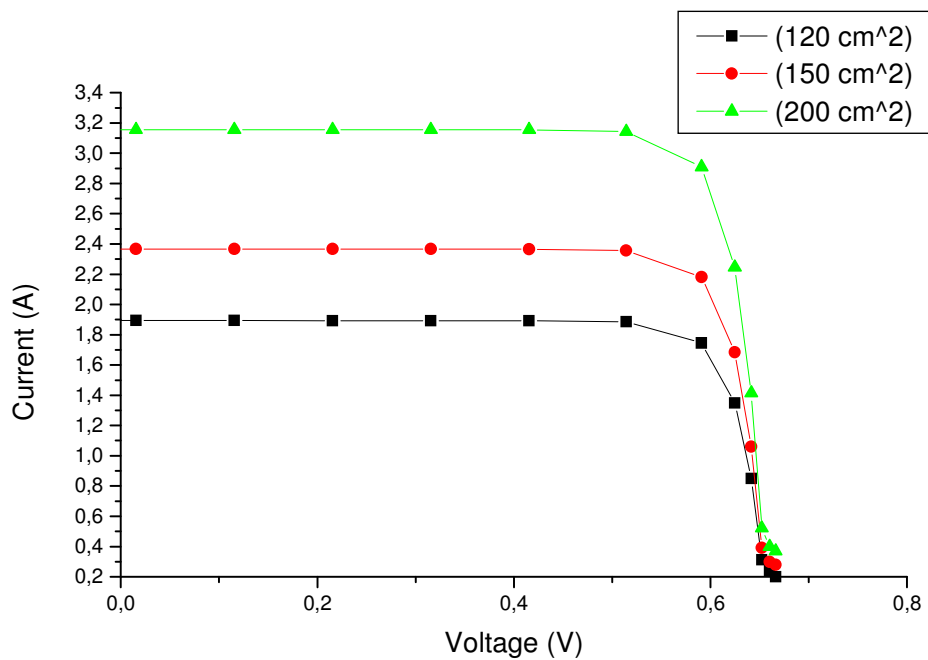


Figure 4. Influence of the surface on the $I-V$ characteristic.

2.3. Influence of the thickness of the region n on the $I-V$ characteristic

For this example, we took the same parameters that the basic cell and we changed the thickness of the region n, that is to say the region 1.

- (a) Thickness $6 \mu\text{m}$
- (b) Thickness $8 \mu\text{m}$
- (c) Thickness $12 \mu\text{m}$

P_{Max} Values are found, respectively, of: 1.476 W, 1.185 W and 0.778 W. The three curves $I-V$ characteristics are shown in figure 5.

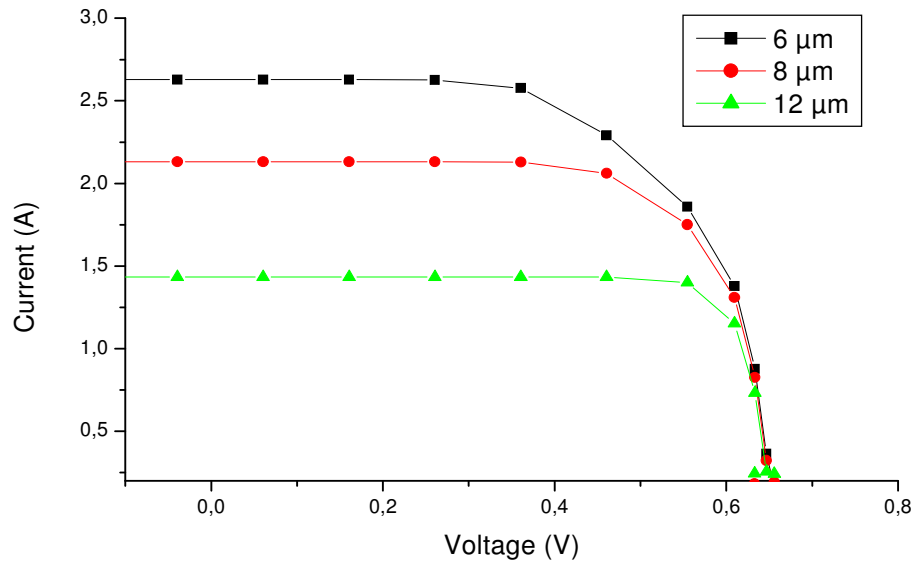


Figure 5. Influence of the thickness of region n on *I-V* characteristic.

2.4. Influence of doping of the region n on the *I-V* characteristic

In a pure semiconductor the number of carriers being low in ordinary temperature, the conductivity is mediocre. The silicon is treated in a way, we say doped, this technique allows the silicon to play the role of a diode, that is to say, electrons can "pass" only in a unique sense.

The doping is a means to increase the electrical conductivity of the material. The atoms of the material of doping, or dopant (donors or acceptors of electrons), and those of the host have a number different from peripheral electrons. The doping so produces electric particles positively charged (type P) or negatively (type N).

For this example, we took the same parameters that the basic cell and we changed the doping of the region n, that is to say the region 1.

- (a) Doping 10^{17} cm^{-3}
- (b) Doping 10^{20} cm^{-3}

P_{Max} Values are found, respectively, of: 2.366 W, 0.4358 W. The two curves *I-V* characteristics are shown in figure 6.

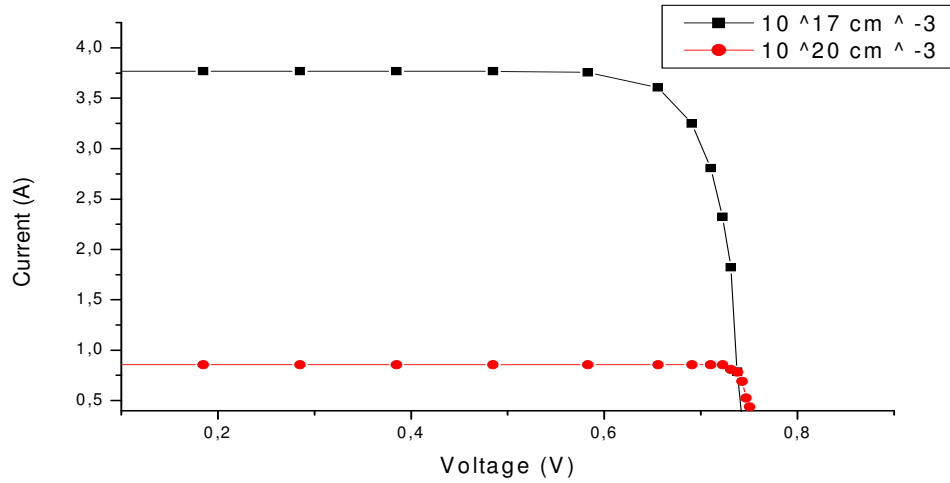


Figure 6. Influence of doping of region 1 on *I-V* characteristic.

2.5. Influence of doping of the region p on the *I-V* characteristic

For this example, we took the same parameters that the basic cell and we changed the doping of the region p, that is to say the region 2.

- (a) Doping 10^{15} cm^{-3}
- (b) Doping 10^{19} cm^{-3}

P_{Max} Values are found, respectively, of: 0.9321 W, 0.5401 W. The two *curves I-V* characteristics are shown in figure 7.

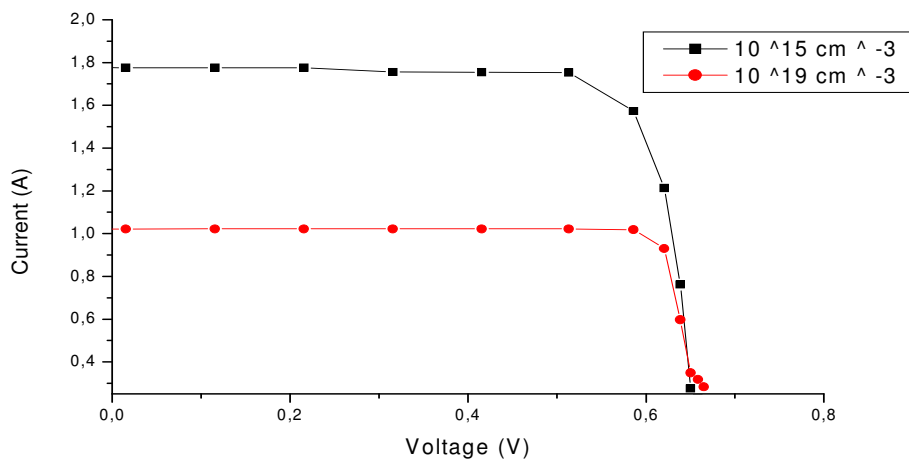


Figure 7. Influence of doping of region 2 on *I-V* characteristic.

3. DISCUSSION

In this section we will try to discuss the results that we had in the previous section and most importantly, try to give the reasons and causes which have led to such results. Of course, the basic results we take for comparison with the results of the basic cell described at the beginning of Section 2, from there we go gradually to draw conclusions about the ideal settings to build an efficient solar cell.

We began first of all to see if yes or not the surface enlightened by the solar cell can influence on the power delivered by the latter, and as we can notice it on the found results and the figure 04, the more the surface is big, the more there will be a better output. Of the characteristic $I-V$ we also see that the cause of this increase of power is especially the increase of the value of the current (which is influenced by the photo-current which is itself influenced by the irradiance) according to the increase of the surface because the tension is not too much influenced by the change of the order of greatness of the latter.

We also played on the thickness of the active region, which is other than the region 1 in our example (doped region n). Every time we increased the thickness of this region was issued or the power decreases and this may explain the fact that, as this is the region that is responsible for generating the major part of the electrons which will contribute to the electrical condition, once these they generated their need to travel some distance to reach the external circuit through the cathode, thus the more this distance is short (i.e the thickness of region 1) the more we have of chance that a large number of electrons leave the cell and contribute to the conduction.

For the doping, as regards the region 1, we see according to the results obtained in sub-section 2.4 that the increase of the doping beyond a certain value of the active part, n-doped, negatively affects on the performance of the solar cell. This can express itself by the fact that the level-rise of doping of the transmitter (Region 1) decreases the height of the barrier, we studied the influence of the doping region 2 (p-doped region) on the power output of the cell (Section 2.5), and we see as well in this case that the increase of the doping influenced negatively on the performances of the cell.

4. CONCLUSION

As conclusion, in this modest work which we made, we can give in the following table the ideal characteristics that it is necessary to change the basic cell in order to have a very good efficiency:

Table 1. The ideal characteristics for a very good efficiency

Surface	Thickness of the region n	Doping of the region n	Doping of the region p
200 cm ²	6 μm	10 ¹⁷ cm ⁻³	10 ¹⁵ cm ⁻³

5. REFERENCES

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