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IMPACT OF SILICON THICKNESS ON ELECTRICAL PERFORMANCE OF SOLAR CELL IN SUBMICRON TECHNOLOGY

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Abstract

In the field of new technologies for energy, solar photovoltaic in submicron technology is becoming an axis of development industrially important. In this paper, we present the results of the study of the influence of silicon thickness T_{Si} on the characteristics of a solar cell based to silicon and in submicron technology using the 2D-Atlas SILVACO software. We simulate the Current-Voltage (I-V) and Power-Voltage (P-V) characteristics as a function of silicon thickness in the range of 120nm to 900nm at room temperature and under global AM1.5G illumination spectra. Then we calculate the values of the form factor FF for the different values of the silicon thickness. The simulation results show that the solar cell in silicon without defect and in submicron technology is characterized by good electrical characteristics and high performance.

Keywords:

Solar Cell, I-V Characteristic, P-V Characteristic, Form Factor FF, Submicron Technology

1. INTRODUCTION

Energy is one of the most important factors in the development of societies. Therefore, the scientific research is interested in the study of energy in terms of sources, how to produce and their different types. Given the irrational consumption of energy from various countries and the negative effects of these energies, such as pollution, scientific research sought to find renewable energy because of their constant availability [1]-[2] and non-polluting [3]. Among the most important of these energies, the photovoltaic energy [3]-[4]. Solar energy is the most promising and most powerful energy source among renewable energies. Photovoltaic electricity (PV) is obtained by direct conversion of sunlight into electricity [5]-[7], using the PV cell. In 1839, the French physicist Edmond Becquerel discovered the photovoltaic effect by observing the change of the voltage of a platinum electrode under the effect of illumination with light [8]. Einstein explained this mechanism in 1912. The world then witnessed a remarkable development in the field of photovoltaic energy, which included various fields, including ground-based power plants, satellites and hybrid systems.

During the last decade, the concepts of micro and nanotechnology have addressed different areas of science and technology [9], among these areas photovoltaic conversion [10]-[11]. So that several recent researches have focused on the study of the solar cells in Micro and Nanotechnology [5], [12]-14], so that this technology has contributed to the improvement of the different electrical parameters and the conversion efficiency of these cells.

In this work, we will study the silicon solar cell in submicron technology. To carry out a good study of this cell, we will study the effect of silicon thickness on the different characteristics and important parameters that define the electrical performance of the solar cell. To realize this study, we will present the structure of this cell according to the different dimensions and doping technologies, then on the basis of this structure of the solar cell, we will simulate their characteristics Current-Voltage (I-V) and Power-Voltage (P-V) for a range of silicon thickness ranging from T_{Si} = 125nm to T_{Si} = 900nm. We will exploit these characteristics to find the parameters of our cell, such as short circuit current I_{SC}, open circuit voltage V_{OC} and form factor FF. We will use in this study the 2D-Atlas SILVACO software as a simulation tool.

2. SUBMICRON SOLAR CELL STRUCTURE

The Fig.1 and Fig.2 show the silicon solar cell structure proposed in this work and the simulation structure of this cell in submicron technology respectively. This structure contains a silicon layer without defects of a thickness T_{Si}, this layer is deposited on an electrode of indium oxide and tin (ITO) (cathode). On the Silicon layer, there is the second electrode (anode) of the same material. The thickness of the electrodes is the same T_{ITO} = 50nm. Doping of the adjacent areas of the anode and cathode electrodes are *p* and *n* types respectively, with the same concentration of 1 E18cm^{-3} and the same thickness of 10 nm. The remaining area (Ln = T_{Si}-20)(nm) is characterized by *n*-type doping with the concentration of 1 E14cm^{-3}. The length of this cell is 1μm. In addition, the different basic parameters of silicon which are presented in Table.1 are employed as inputs in Atlas-SILVACO. In this work, the solar cell is studied according to five different values of the silicon thickness T_{Si} = 125nm, 250nm, 500nm, 750nm and 900nm. These solar cells are illuminated by a spectral illumination source of AM1.5G.

Table.1. Basic parameters of Silicon

Parameters	**Si**
Eg (ev) Energy gap	1.12
μe (cm^2/Vs) Electron mobility	1500
μh (cm^2/Vs) Hole mobility	505
ni (cm^{-3}) Intrinsic carrier concentration	1.45×10^{10}
Dielectric permittivity (ε)	11.8

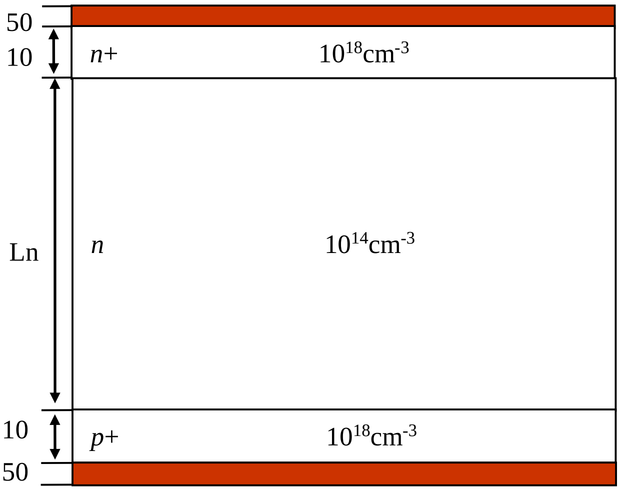

Fig.1. Silicon solar cell structure proposed

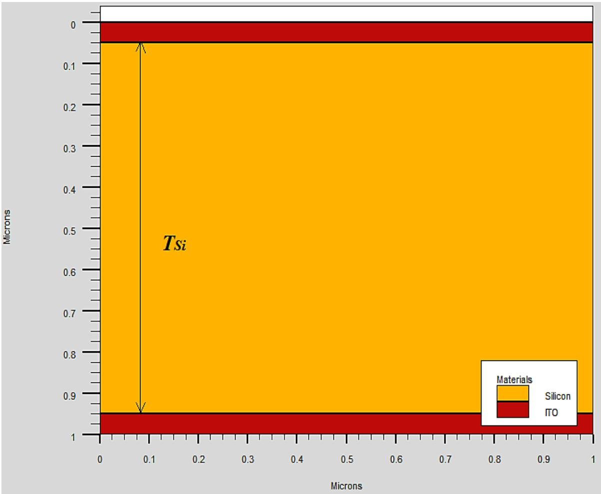

Fig.2. Simulation structure of the silicon solar cell

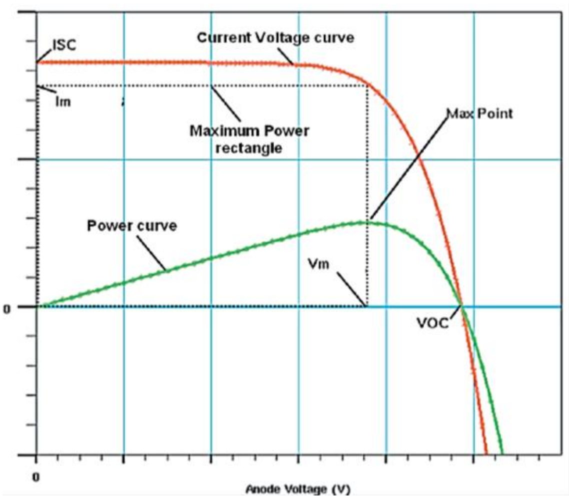

Fig.3. I-V and P-V characteristics of the solar cell [15]

In theory, photovoltaic cells possess characteristics that evolve as a function of the voltage variation. The Fig.3 shows the different characteristics Current-Voltage (I-V) and Power-Voltage (P-V) with the different electrical parameters of the photovoltaic cell. In Fig.3, I_{SC} is the short circuit current; I_m and V_m are the maximum cell current and voltage respectively at the maximum power point and V_{OC} is the open circuit voltage.

3. RESULTS AND DISCUSSIONS

3.1 I-V CHARACTERISTIC

To characterize solar cells in direct polarization mode according to the different silicon thicknesses, we have varied the anode voltage V_{Anode} from 0 to 1.2V for both cases of darkness and lighting. The values of the voltage V_{Anode} were chosen so as to distinguish the different operating regions. After simulation, we obtained the characteristics shown in Fig.4 and Fig.5.

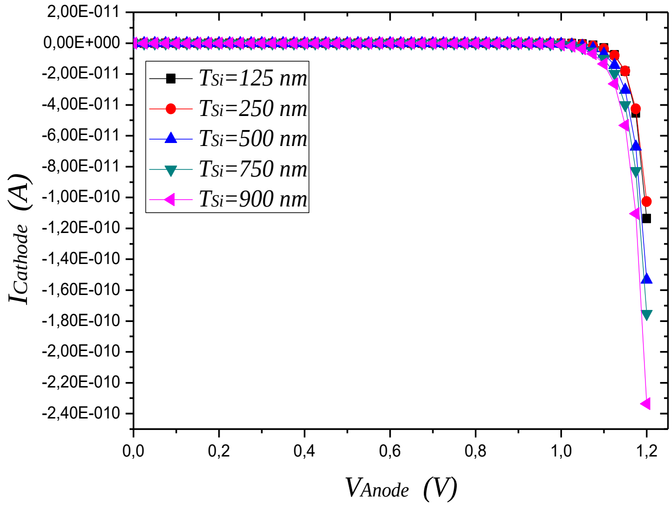

Fig.4. Current-Voltage characteristic in the case of darkness

The Fig.4 and Fig.5 show the evolution of the I-V characteristic of the solar cell for different silicon thicknesses ranging from T_{Si} = 125nm to T_{Si} = 900nm in the case of darkness and lighting respectively. For a solar cell, the I-V characteristic is described by the Shockley equation as follows [16]-[17].

$$I = I_{ph} - I_0 \left(e^{\frac{qV}{e^{nK_BT}}} - 1 \right) \quad (1)$$

where, I_{ph} is the photogenerated current, I_0 is the saturation current of the diode, q is the electron charge, V is the voltage on the terminals of the cell, n is the ideality factor, K_B is the Boltzmann constant and T is the absolute temperature. The ideality factor n is assumed to be 1 in this paper.

In the case of darkness and when the anode voltage is less than 1V the current of the solar cell is very small and it is independent of the variation of the silicon thickness as shown in Fig.4. The absence of incident photon flux on the cell leads to a lack of photogenerated current I_{ph} = 0A in this case. Therefore, the solar cell in the dark is simply a current rectifier semiconductor, or a diode.

In the solar cell and in the case of lighting, this cell absorbs the sunlight. The photogenerated current I_{ph} is closely related to the incident photon flux on the cell [18]. This phenomenon increases the photogenerated current in the case of lighting contrary to the case of darkness as shown in Fig.5.

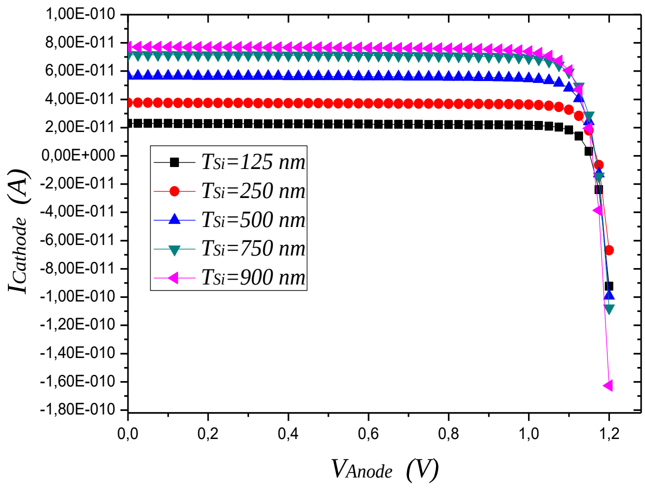

Fig.5. Current-Voltage characteristic in the case of lighting

The figures of the I-V characteristic show that the silicon solar cell structure in submicron technology proposed in this paper is correctly working according to the operating principle of the solar cells.

The simulation results show that the photogenerated current of the silicon solar cell in submicron technology is directly proportional to the silicon thickness T_{Si} as shown in Fig.5. When the silicon thickness increases in the solar cell and their exposure to light, the concentration of the pairs (electrons-holes) produced is increased, the latter increases the generated current. In the nanocrystals, the electron particles (negative electrons and positive holes) produce unique optical and electronic properties that can improve the power conversion efficiency of the solar cells [5], because the nanoparticles will fluoresce in distinct colors [10], and this is consistent with our results.

3.2 P-V CHARACTERISTIC

I-V characteristic of the solar cell in the case of lighting shown in Fig.4 is exploited to find the P-V characteristic. The Fig.6 shows the evolution of the power as a function of the anode voltage of the solar cell for different silicon thicknesses ranging from T_{Si} = 125nm to T_{Si} = 900nm.

The P-V characteristic of the silicon solar cell submicron technology shows that the power is directly proportional as a function of the anode voltage up to the voltage of V_m which corresponds to the maximum value of the power P_{max}, and then the power is decreased as shown in Fig.6. The simulation results that are presented in the graph of the P-V characteristic show that as the silicon thickness increases the power in the linear region increases. The P-V characteristic is exploited to find the maximum power values. The Fig.7 shows the evolution of the maximum power P_{max} as a function of the thickness of the silicon T_{Si} of the solar cell.

The results of our work show that the maximum current I_m is increased as the silicon thickness increases. However, the maximum voltage is not significantly affected by the variation in silicon thickness T_{Si} (Fig.6). From the following power relation [17],

$$P_{max} = I_m \cdot V_m \tag{2}$$

The maximum power is directly proportional to the variation of the silicon thickness T_{Si} as shown in Fig.7. According to this figure and with the use of the Fitting Analysis of this graph, the expression which shows the evolution of the maximum power as a function of silicon thickness is written as follows:

$$P_{\max} = \left(-6.01\times10^{-5}T_{Si}^{2} + 0.13T_{Si} + 7.7\right)10^{-12} \tag{3}$$

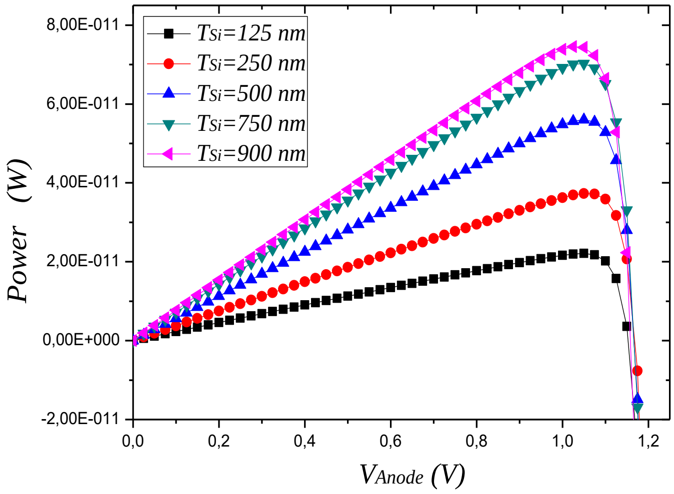

Fig.6. P-V characteristic of the solar cell

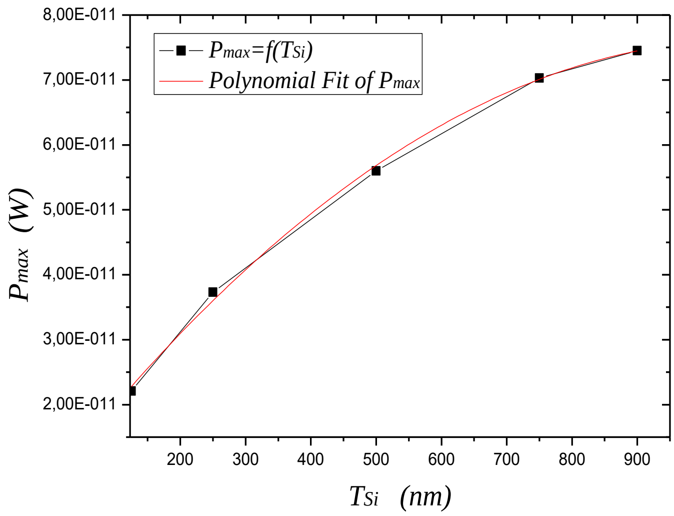

Fig.7. Maximum power P_{max} as a function of T_{Si}

In addition to the I-V and P-V characteristics of the solar cell, there are several important parameters that can determine the electrical performance of this cell [19]. Among the most important of these parameters, the form factor *FF* determines the ideality of the solar cell [6], and given by the following relationship.

$$FF = \frac{P_{\max}}{I_{SC}V_{OC}} \tag{4}$$

According to Table.2, the solar cell in silicon without default and in submicron technology can be considered as an ideal cell, because the value of the form factor FF is roughly of the order of 85% for the different values of the thickness of silicon. Therefore, the losses of carriers at the junction interface are neglected and then, the intrinsic junction recombination velocity is null [20].

The simulation results show that the open circuit voltage V_{OC} is slightly affected by the variation of the silicon thickness, and cannot make a judgment on the evolution of the form factor *FF* as a function of the silicon thickness T_{Si}, because the open circuit voltage V_{OC} does not vary regularly as a function of the silicon thickness as shown in Table.2.

The results show that the performance becomes better of our cell while increasing the silicon thickness. The silicon thickness overly is not increased, since the solar cells are subjected to industrial conditions. Optimum performance has been found out at 900nm thickness of silicon as shown in the figures and Table.2.

Table.2. Electrical parameters of the solar cell

T_{Si}	Parameters		
	I_{SC} (10^{-11}A)	V_{OC} (V)	*FF* (%)
125nm	2.30	1.15375	83.4
250nm	3.76	1.16875	84.9
500nm	5.66	1.16625	84.8
750nm	7.16	1.16687	84.2
900nm	7.71	1.15875	83.4

4. CONCLUSION

In this work, we studied the influence of silicon thickness on the characteristics and parameters of the silicon solar cell in submicron technology. We have shown, according to the simulation results, that the different characteristics and parameters of our cell are affected by the thickness of submicron-scale silicon, whose increase in silicon thickness leads to an increase in short-circuit current and power. The submicron technology and flawless silicon are responsible for increasing the form factor of our solar cell, which necessarily leads to the increase in ideality of this cell. The solar cell in flawless silicon and in submicron technology has given us very satisfactory results.

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