4th International Conference on Automation, Control Engineering and Computer Science (ACECS - 2017)
Proceedings of Engineering and Technology – PET
Vol.19, pp.78-81

STUDY THE EFFECT OF SURFACE RECOMBINATION VELOCITY ON PERFORMANCE OF SOLAR CELLS BASED SiGe

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Abstract **The thin-film SiGe is considered as promising candidate to meet the outstanding need for photovoltaic applications with enhanced adsorption characteristics and improved conversion efficiency [1-6].In this work we propose ,AMPS-1D (Analysis of Microelectronic and photonic structure) developed at Pennsylvania State University program software has been used to study to describe the influence of the front and back surface recombination velocity on silicon (window and BSF) and the doping emitter layer material parameters on the properties of SiGe solar cells the variation of parameters photovoltaic depending. The simulation result shows that the maximum efficiency of 16.91% has been achieved, with short circuit current density of 32.657mA/cm^2, open circuit voltage of 0.66V and fill factor of 0.77. The obtained results show that the proposed design can be considered as a potential candidate for high performance photovoltaic applications.**

Keywords- ***Solar cell; surface recombination velocity; AMPS-1D; silicon; SiGe.***

I. INTRODUCTION

Due to the presence of a high density of defects, such as dangling bonds, and thus traps levels in the band gap, the recombination mechanism is of type recombination Shockley Read Hall (SRH). This type is related to the presence of levels "traps" in the bandgap induced crystalline defects, such as dislocations or impurities in the material matrix. The electrons pass first from the conduction band to the defect associated energy level, eventually reaching the valence band [2-4]. So The surface recombination velocity at a great influence on the electrical and optical parameters of the photovoltaic cell, and therefore to study the surface recombination effect on the electrical characteristics in this work we study the variation of parameters photovoltaic depending on the doping emitter layer P in a solar cell SiGe for different values of the recombination velocity on silicon (window and BSF).

In this paper, a one dimensional simulation program called a analysis of microelectronic and photonic structures (AMPS-1D) [3] is used to simulate the emitter for SiGe solar cell structure. Fig. 1 shows the schematic of solar cell design studied in this work.

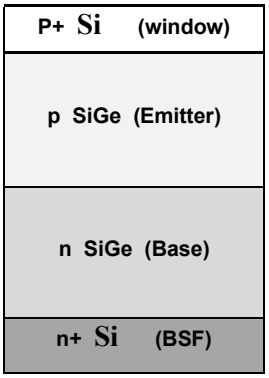

Figure. 1 – Structure of the Solar Cell Study

II. THEORETICAL MODEL

The simulator adopted in this paper is the analyses of microelectronic and photonic structures (AMPS-1D)[11] which is developed by the group from the Pennsylvania State University. It can calculate solar cell parameters such as conversion efficiency (η), short circuit current (Jsc), open circuit voltage (Voc), fill factor (FF), and internal information including carrier recombination profile and electrical field distribution, by solving Poisson's equation and continuity equations for electrons and holes for Maintaining the Integrity of the Specifications.

In on
e dimension case, Poisson's equation is given by :

$$\frac{d}{dx}\left(-\varepsilon(x)\frac{d\psi}{dx}\right) = q[p(x) - n(x) + N_D^+(x) - N_A^-(x) + p_t(x) - n_t(x)] \quad (1)$$

Where, ψ is the electrostatic potential, n, p are the concentrations of free electrons and holes, n_t, p_t are the concentrations of trapped electrons and holes N_D^+, N_A^- are the concentrations of ionized donors and acceptors, ε is the dielectric permittivity of semiconductor, and q is the electron charge.

$$\frac{1}{q}\frac{dj_n}{dx} = R_n(x) - G(x), \quad (2)$$

$$\frac{1}{q}\frac{dj_p}{dx} = G(x) - R_{np}(x) \quad (3)$$

ISSN 2356-5608

Where, J_n, J_p are electron and hole current density, R_n, R_p are electrons and holes recombination velocities for direct band-to-band and indirect transitions, and G is the optical generation rate as a function of x due to externally imposed illumination.

The AMPS-1D can operate in two distinct modes: the density of state (DOS) mode or the lifetime mode. The DOS mode allows the definition of multiple defect states using densities, energy distribution, and capture cross-sections. The lifetime model does not allow the said recombination processes, where inputs are given in the form of carrier life times, which are assumed constant, independent of light and voltage bias. In this work the program was used to study the optimum performance of SiGe solar cell with change the thickness and dopage of emitter layer.

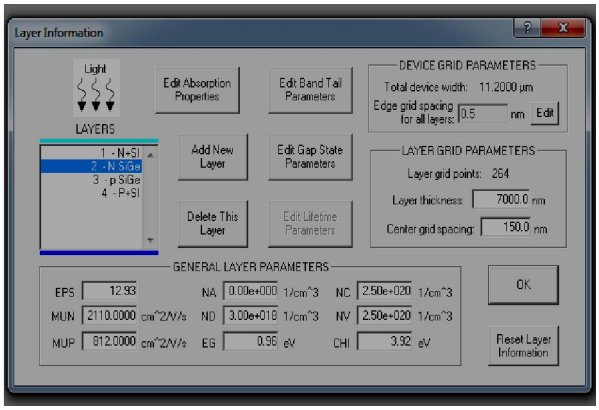

Figure. 2 – AMPS simulation front panel contains the device and layer grid parameters and general layer parameters

III. DESIGN AND SIMULATION

In this study, a one-dimensional numerical analysis tool, AMPS-1D, is used to create various solar cell models and obtain its results. In AMPS-1D, four different layers are required for the modeling. More layers can be added as long as the grid points do not exceed the limitation, viz. 200-grid points. The four layers that are used in this modeling is the P+ Si (window), p- SiGe (emitter), n- SiGe (base) and n+ Si (BSF).

For proper design of SiGe based solar cell, first one have to analyze the equation of material main parameters such as band gap, electron affinity, optical property, carrier mobility, density of states, permittivity, absorption coefficient, electric field distribution and stability at higher operating temperature etc. At room temperature, band gap (eV) of the $Si_{1-x}Ge_x$ material is given by the relation [7-8]:

$Eg(x)= (1.155 – 0.43x + 0.0206x^2)$ eV pour $x < 0.85$

The electron affinity of SiGe is expressed by the relation given below [5]:

$\chi(x) = 4.05\ 1 - x\ + 4.0x$

The effective density of states in the conduction band:

$Nc = 5.3 \cdot 10^{15} x\ T^{3/2}$

The effective density of states in the valence band:

$Nv = 2.\ 10^{15} x\ T^{3/2}$

The relative permittivity:

$\boldsymbol{\varepsilon}_r = 11.8 + 4.2x$

Mobility of electrons:

$\boldsymbol{\mu}n(x) = 1500(\ 1 – x)+ 3900x$

Mobility of hole:

$\boldsymbol{\mu}p(x) = 450\ (1 - x\ ) + 1900x$

The absorption coefficient α(λ) is related to the particular wavelength and band gap of the $Si_{1-x}Ge_x$ material[9-10]:

$$\alpha = A.\left[\frac{(h\gamma - E_g - E_{pkonon})^2}{1 - exp\left(\frac{-E_{pkonon}}{KT}\right)} + \frac{(h\gamma - E_g + E_{pkonon})}{exp\left(\frac{-E_{pkonon}}{KT}\right) - 1}\right]$$

With

$A(x)=3200(1-1.161x+9.581x^2)$

$E_{phonon}=0.050(1+0.026x-1.066x^2)$

In this work, calculations were all performed AM1.5 solar spectrum with P = 100 mW/cm^2, and at room temperature T = 300 K using the one diode ideal model, and for convenience, several simplifying assumptions were made.In this simulation, we take doping for emitter layer between 10^{17} to 10^{18} cm^{-3} and we changed the surface recombination velocity in the front and back contacts to the window and layer BSf from $10^3$to 10^7(cm^{-2}.s^{-1}) [11].

Table 1 shows all the required parameters for the simulation

TABLE I. AMPS-1D PARAMETERS SIGE SOLAR CELL

Layers / Parameters	P+ Si	p - SiGe	n-SiGe	n+ Si
Thickness (µm)	0.1	7	7	0.1
Dielectric constant ε	11.9	12.93	12.93	11.9
Electron mobility μ_n (cm²/Vs)	1350	2110	2110	1350
Hole mobility μ_p (cm²/Vs)	450	812	812	450
Carrier density, n or p (cm^{-3})	P:1E18	P:1E17 – 1E18	n:3E18	n:1E18
Optical band gap, E_g(eV)	1.12	0.96	0.96	1.12
Effective density, N_c (cm^{-3})	2.8E+19	2.5E20	2.5E20	2.8E+19
Effective density,N_v (cm^{-3})	1.04E+19	2.5E20	2.5E20	1.04E+19
Electron affinity , χ(eV)	4.05	3.92	3.92	4.05
Front Contact Windows **PHIBO**	1.12	-	-	-
Back Contact BSF PHIBL	-	-	-	0.020

ISSN 2356-5608

surface recombination velocity ($cm^{-2}.s^{-1}$)	10^3-10^7	-	-	-10^3-10^7

IV. SIMULATION RESULTS AND DISCUSSIONS

The simulation work has been performed aiming to compare the different types of cell structure made by changing doping of the emitter layers SiGe -N and surface recombination velocity of window and BSF layers Si to find out best structure for higher efficiency and more stable SiGe solar cells.

The simulation results can be seen in Fig. 3, 4, 5, and 6. This figure shows the detailed effects of emitter layer that has been increased from 10^7 to 10^8µm on the cell parameters such as VOC, JSC, FF and η from AMPS1D simulation.

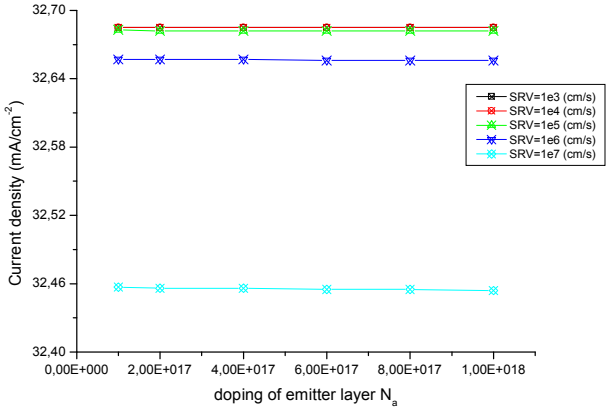

Figure 3- Variation of Jsc on the dopage emitter layer for various surface recombination velocity

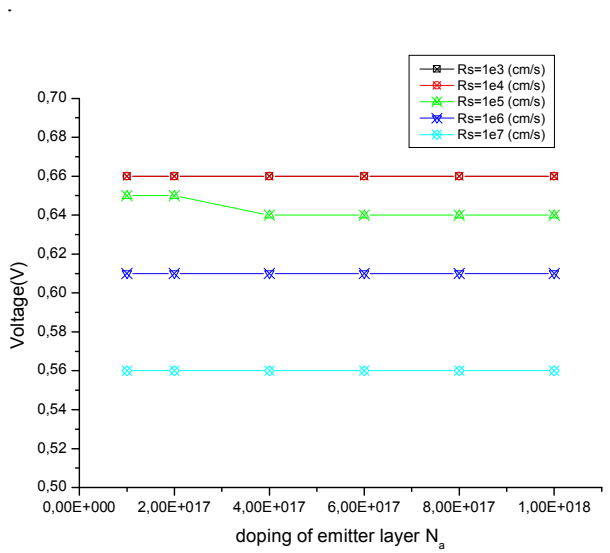

Figure 4 variation of Voc on the dopage emitter layer for various surface recombination velocity

From this figure 3, we also notice that the increase in surface recombination velocity (electron, hole) causes a decrease in the maximum value of the current density and voltage, this is justified by a increase the number of uncollected photo carriers and which is proportional to the surface recombination velocity

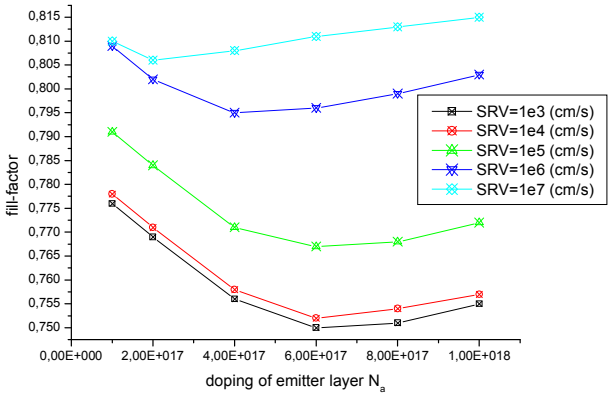

Figure5- Variation of FF on the dopage emitter layer for various surface recombination velocity

Note an increase fill-factor in the more surface recombination velocity (electron, hole) by e increasing the voltage and the current density maximum

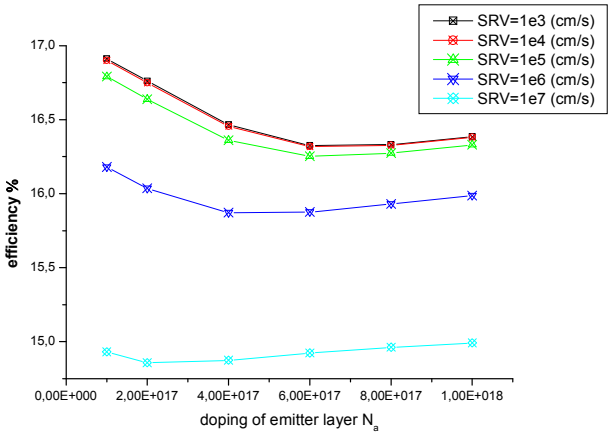

Figure.6: Variation in Performance against depending the Emitter layer for various thicknesses

From the above results are obtain software we can determine the solar cell which has the best performance

ISSN 2356-5608

while giving the doping of emitter layer and surface recombination velocity table II.

TABLE II. THE DOPING OF LAYER EMITTER AND SURFACE RECOMBINATION VELOCITY OF SOLAR CELL OPTIMIZE

surface recombination velocity (cm-2.s-1)	Doping (cm-3)
10^3	10^{17}

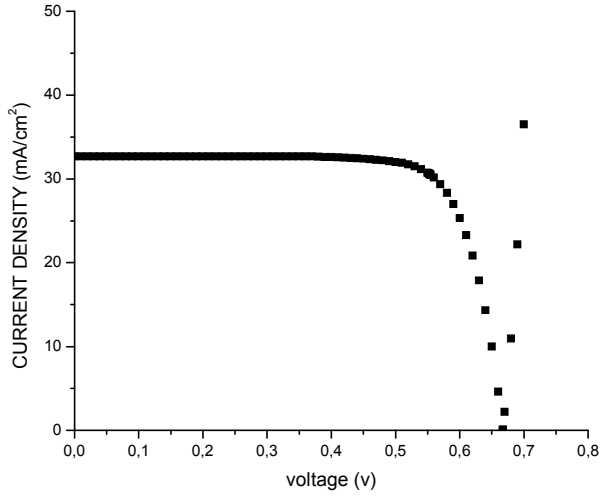

Figure7: current - voltage characteristics of solar cell optimized

The current-voltage characteristics for the device homo-junction $Si_{0.25}Ge_{0.75}$ layers with the optimal concentrations and thickness are shown in Fig.7, and the corresponding parameters PV (V_{CO}, J_{SC}, FF and efficiency) are summarized in Table III.

TABLE III. PHOTOVOLTAIC SOLAR CELL PARAMETERS HETEROJUNCTION OPTIMIZED

V_{CO} (V)	J_{SC} (mA/cm²)	FF (%)	η (%)
0.66	32.65	0.77	16.91

V. CONCLUSION

In this investigation, we have shown that surface recombination velocity at a great influence on the electrical and optical parameters of the photovoltaic cell. An extended spectral coverage due to a careful choice of the materials and optimization of the thickness and doping levels of each layer led to an enhanced overall power output from the SiGe device. Under the standard solar spectrum and one sun, the efficiency of the device is 16.91%, which is much higher than the efficiency .

ACKNOWLEDGMENT

We would like to acknowledge the use of AMPS-1D program that was developed by Dr. Fonash's group at Pennsylvania State University (PSU)..

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ISSN 2356-5608