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Optimizing the Emitter Layer for Higher Efficiency Solar Cell Based SiGe Using AMPS1D

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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 paper, we simulated a solar cell type SiGe using AMPS1D (Analysis of Microelectronic and photonic structure) developed at Pennsylvania State University, to analyze emitter layer (thickness, doping) and we studied their influence on the photovoltaic solar cell. The simulation result shows that the maximum efficiency of 16.181 % has been achieved, with short circuit current density of 32.657 mA/cm², open circuit voltage of 0.61 V and fill factor of 0.809. The obtained results show that the proposed design can be considered as a potential candidate for high performance photovoltaic applications.

Keywords: SiGe, AMPS-1D, Emitter, Simulation, Conversion, Efficiency.

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1. INTRODUCTION

Recently, solar cell technology attracts much attention for reliable and high efficiency renewable energy applications.

The increase in the photovoltaic market needs the development of new materials and designs based on the optimization of cost / efficiency ratio for larger scale mass production. However, solar cells based on crystalline silicon-germanium alloys (SiGe) or multiple bandgap materials have gained much interest in recent years [1-5].

It has been shown that by using alloy material ($Si_{1-x}Gex$ alloy) in silicon solar cell modifies material's characteristic and bandgap (E_g). This alloy is also a lattice match with the substrate [1]. Hence, by using $Si_{1-x}Ge_x$ alloy, this solar cell can extend the spectrum of light that being absorbed.

Emitter formation is the very basic step of solar cell process sequences. The higher conversion efficiency of a solar cell much more depends on the type and quality of the emitter.

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.

Note that the structure has been studied under o AM1.5 solar spectrum with $P = 100$ mW/cm², and at room temperature $T = 300$ K.

2. THEORETICALY 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 (J_{sc}), open circuit voltage (V_{oc}), fill factor (FF), and internal information including carrier recombination profile and electrical field distribution,

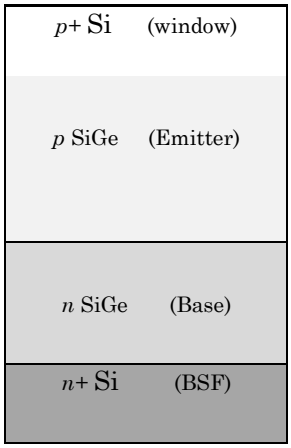

Fig. 1 – Structure of the solar cell study

by solving Poisson's equation and continuity equations for electrons and holes.

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

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

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.

The continuity equations for the free electrons and holes in the delocalized (band) states of the conduction band and valence band, respectively, have the forms:

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

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

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.

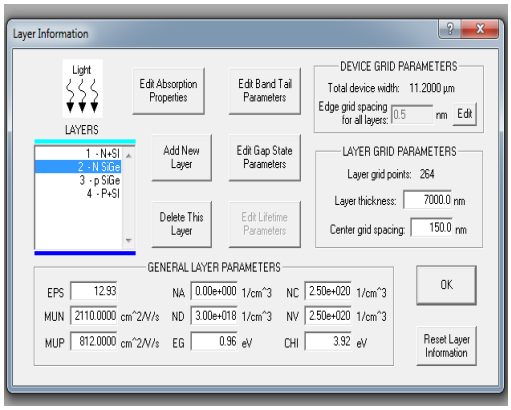

Fig. 2 – AMPS simulation front panel contains the device and layer grid parameters and general layer parameters

3. EXPERIMENTAL

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).

In this simulation, emitter's thickness is increased from 3 µm to 7 µm based on the step size of 1 µm, and emitter's dopage layer from 1E 17 to 1E 18 cm^{-3}.

The main parameters used in the simulations are summarised in Table 1.

4. SIMULATION RESULTS AND DISCUSSIONS

The performance of modeled solar cells was designed and analyzed in respect to the open circuit voltage (V_{oc}), short circuit current density (J_{sc}), fill factor (FF) and efficiency (η) by incorporating the layer parameters into AMPS- 1D. In this study we have chosen a range the hole doping concentration was varied from 10^{17} to 10^{18} (cm^{-3}) for emitter layer, and your thickness from 3 to 7 µm. The simulation results can be seen in Fig. , 4, 5, 6 and 7.

Table 1 – AMPS-1D parameters SIGe solar cell

Parameters \ Layers	p+ Si	p-SiGe	n-SiGe	n+ Si
Thickness (µm)	0.1	3-7	7	0.1
Dielectric constant ε	11.9	12.93	12.93	11.9
Electron mobility μ_n (cm^2/Vs)	1350	2110	2110	1350
Hole mobility μ_p (cm^2/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, Nv (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		Back Contact BSF	
PHIBO	1.12	PHIBL	0.020
SNO	1.00E+06	SNL	1.00E+06
SPO	1.00E+06	SPL	1.00E+06
RF	0	RB	1

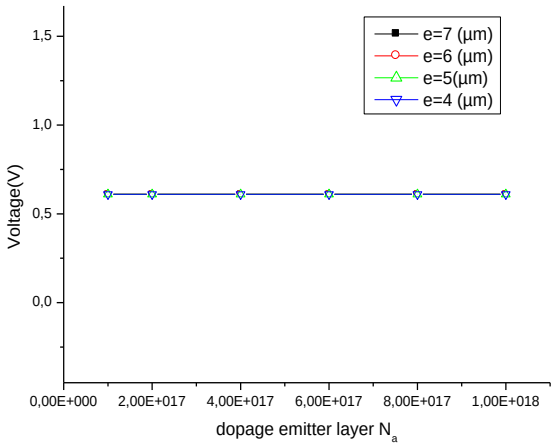

Fig. 3 – variation of V_{oc} on the dopage emitter layer for various thicknesses

Figure 3, 4, 5 and 6 shows the variation of performances (J_{sc}, V_{oc}, η and FF) as a function of thickness and dopage emitter layer on the cell parameters.

In Figure 3, we note that the short-circuit current is the highest value when larger thickness of a layer emitter and interprets what he will be a great absorption on photons.

In Figure 4, we note that the open circuit voltage with no change of changing the thickness and doping of the layer emitter and see this because Vco does not have the biggest of E_g.

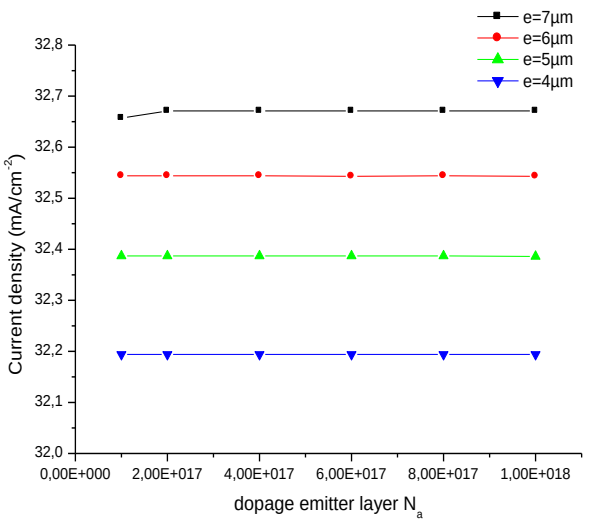

Fig. 4 – Variation of J_{sc} on the dopage emitter layer for various thicknesses

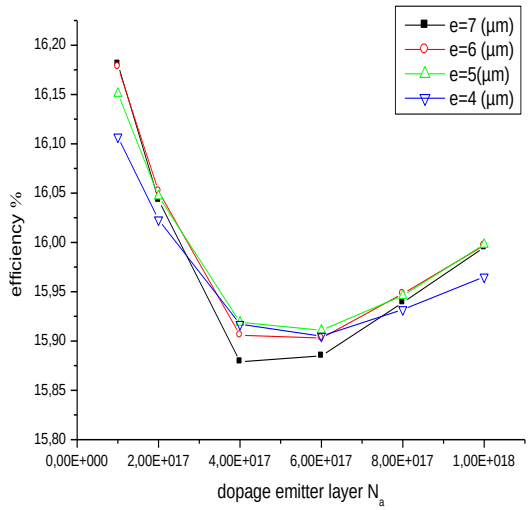

Fig. 5 – Variation of FF on the dopage emitter layer for various thicknesses

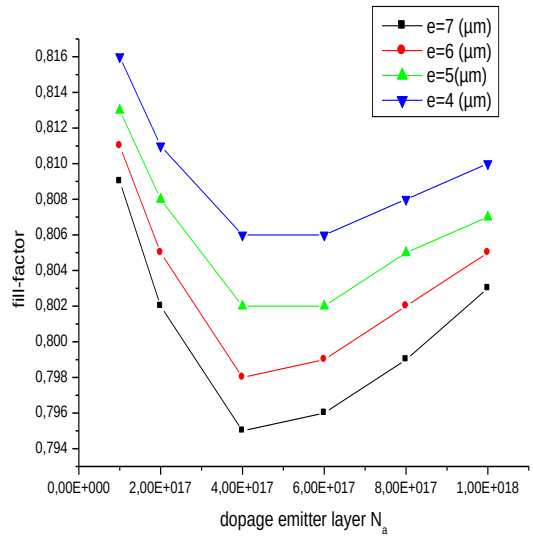

Fig. 6 – Variation of efficiency η on the dopage emitter layer for various thicknesses

5. OPTIMIZATION RESULTS

From the above results are obtain software we can determine the solar cell which has the best performance while giving the thickness of each layer of the cell table 2.

Table 2 – The thickness and doping of layer emitter of solar cell optimize

Thickness (µm)	7
Doping(cm^{-3})	$2e^{17}$

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 3.

Table 3 – Photovoltaic solar cell parameters heterojunction optimized

V_{CO} (V)	J_{SC} (mA/cm^2)	FF (%)	η (%)
0.61	32.65	0.80	16.05

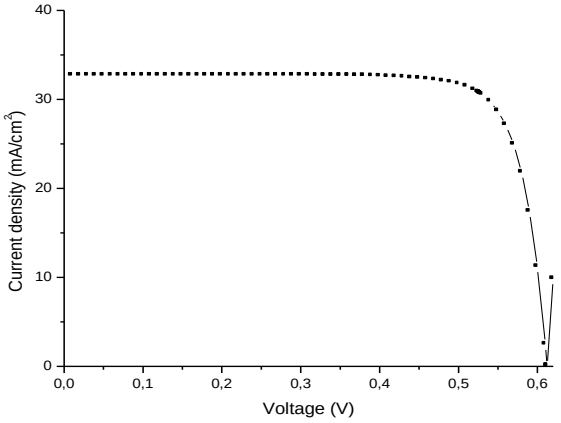

Fig. 4 – Current-voltage characteristics of solar cell optimized

6. CONCLUSION

The calculation of the photovoltaic parameters of the $Si_{0.25}Ge_{0.75}$ p-n single junction solar cell width layer window and BSf layer, for the cases of different doping concentrations and different thicknesses of each layers, has allowed to achieve the best solar cell structure with optimum performances. Optimal parameter values depend, of course, the structure of the solar cell, the quality of the material, the surface recombination velocity (front and rear), etc. The optimization of the solar cell therefore comprises the study of the influence of these parameters on the performance to obtain a structure leading to maximum efficiency. The results show that the thickness of the solar cell is an important parameter for the absorption of photons.

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