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Modeling of PERC Solar Cell using Atlas-TCAD

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Abstract

The objective of this research work was to design, simulate and model PERC (Passivated Emitter and Rear Cell) by using TCAD (Technology Computer Aided Design) simulations. Firstly, a PERC is designed in a process simulator Athena. The parameter included in coding are doping, diffusion, its temperature and time, sheet resistance, series resistance, lifetime, passivation layers and their thicknesses. The final structure is then incorporated into Atlas for device simulation. This simulated PERC cell is then modelled to a real experimental PERC device by fitting their I-V parameters, which are in close agreement with each other with only a minor difference of 0.83%, confirming the modeling of simulated PERC cell.

Keywords: *PERC, TCAD, Al-BSF, modeling, efficiency, emitter*

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I. INTRODUCTION

In the upcoming two decades, a major share of the global energy demand will comprise of electricity consumption. Satisfying this increasing demand is a significant challenge. In regard to overcome this challenge, silicon photovoltaic cells play significant role [1]. Being Ist generation cells, Si based solar cells still have many problems e.g. recombination losses, low-conversion efficiency, less absorption of light and huge production costs [1]. To overcome these issues a PERC (passivated emitter and rear cell) concept (1st proposed by UNSW in 1984 [2,3,4]) plays a vital role. It is considered a promising candidate in Photovoltaics. It offers many advantages such as minimizing the carrier recombination at the back surface, increases internal reflectivity at rear side hence increasing light absorption of light and also reduces heat absorption thus consequently increasing efficiency [4]. A lot of research is being carried out on PERC solar cell regarding the ARC [5], passivation, degradation, electrical characteristics, recombination and optical losses etc. But still there is a room for the improvement of the conventional PERC cells which mainly lies in many factors (e.g. optical & recombination losses, less passivation, series & contact resistance etc.) that affect the important parameters i.e. maximum power, short circuit current, fill factor, open circuit voltage & conversion efficiency. Hence the purpose of this work is to design and model PERC solar cell using Silvaco Atlas.

II. DEVICE SIMULATIONOF PERC

Using computer simulation for studying, designing and optimizing semiconductor devices is referred to as technology computer aided design (TCAD) [6][7]. Atlas is a TCAD tool that performs physically-based two and three-dimensional simulations [6] therefore predicting electrical properties. Athena (process simulator) is used for structure specification. The structure created in Athena is then considered as input in Atlas simulation program. The combination of Athena and Atlas determines that how process parameters affect device properties. [6][7].

The structure of PERC solar cell was created in Athena. The cell [8] comprises of polycrystalline p-type base with a thickness of 200 µm, <100> oriented, 0.2 Ω.cm resistivity and phosphorus doped n-type emitter with a corresponding sheet resistance of 130 Ω/sq. and a 65 nm thick Si_3N_4 passivation layer at front and back as well. The parameter included in coding are doping, diffusion, its temperature and time, sheet resistance, series resistance, lifetime, passivation layers and their thicknesses. The final structure was then used as input for ATLAS. The simulations were performed at room temperature i.e. 300 K. AM1.5 spectrum with effective wavelength range between 300 nm-1400 nm with an angle of 90° (i.e. normal to the cell) with an irradiance of 100 mW/cm^2 was used [9].Thecell parameters are listed in Table 1.

Table 1: Cell parameters used for the modelling and simulation of PERC (cell 06) given in [8]

Parameter	Value	Reference
Wafer thickness	200 µm	[8]
Base resistivity	0.2 Ω.cm	[8]

Emitter sheet resistance	130 Ω/sq	[8]
Front & back Si_3N_4 thickness	65 nm	[12][13]
Recombination velocity at front	2.5 x 10^4 cm/s	[8]
Recombination velocity at back	100 cm/s	[11]
Series resistance	0.85 Ω.cm	[14][15]
Metallization fraction	4%	[8]

III. MODELING OF PERC CELL

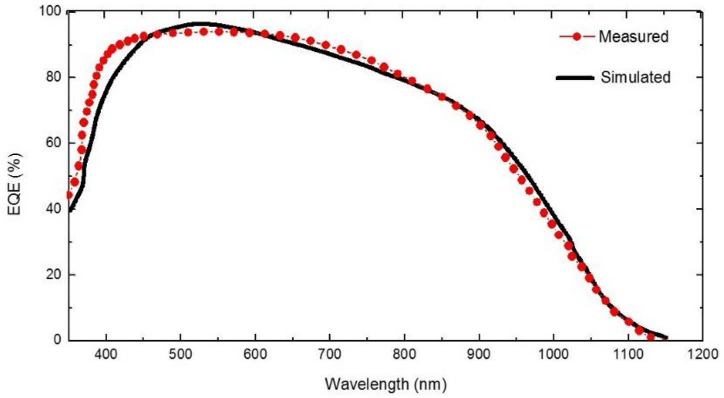

Figure 1: Fitting of the EQEs of both experimental and

It has been found that the parameters of the simulated PERC solar cell and that of the experimental PERC photovoltaic cell (cell 6) of Kerr et al [8] are in close agreement with one another with a minor average difference of approximately 0.83% only. This has showed that, the simulated PERC cell is closely based on the experimental PERC, in such a way the simulated cell has been modelled. The comparison of the I-V parameters of both the cells is listed in Table 2. The structure of the modelled PERC is plotted in Fig 1.

Table 2: Comparison of the J-V parameters of the Modelled PERC and that of the Experimental PERC cell given in [8]

Parameter	**Experimental** [8]	**Simulated**	**% Difference**
V_{oc} (mV)	655.4	655.87	0.07%
J_{sc} (mA/cm^2)	31.0	30.36	2.06%
Fill Factor	78.9	79.66	0.96%
Efficiency (%)	16.1	16.06	0.24%

IV. RESULTS AND DISCUSSION

All the input parameters required for the device and process simulation were included in the coding program. Incorporating all the required parameters and considering the crucial parameters related to solar cell's device simulation, as a whole they have contributed to the design, simulation and accurate modelling of the PERC solar cell.

The external quantum efficiencies (EQE) fitting of the simulated and actual experimental PERC photovoltaic cell is shown in Fig 2. Both are in close agreement with one another with a small difference in lower wavelength, due to poor passivation at the front (as can be seen from the slight difference of ~2% in their short circuit current, where the simulated short circuit current is less than the experimental one) surface of the simulated PERC. The EQE of the experimental PERC was taken from the Kerr's Thesis [10] because its EQE was not given in their paper [8] directly. The fitting of the EQEs of both experimental and simulated PERC solar cells is shown in Fig 2.

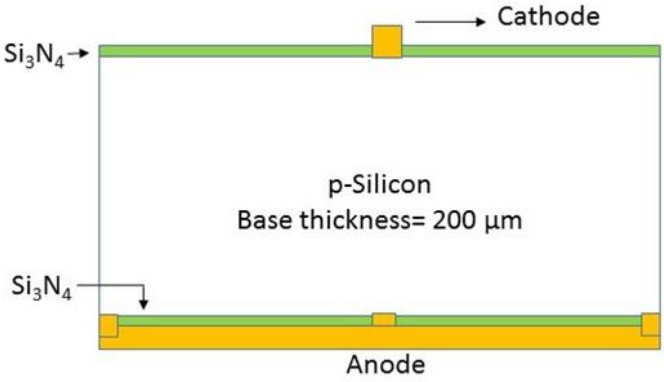

Figure1: Structure of modeled PERC

The I-V parameters of the of the experimental and the simulated (modelled PERC) solar cell are given in Table 2. Comparing their I-V parameters, the individual differences between short circuit current is 2.06%, 0.07% between open circuit voltage. 0.96% in fill factor and 0.24% in the efficiencies with a commutative average difference of 0.83%.This has confirmed that, the simulated PERC cell is closely based on the experimental PERC, in such a way the simulated cell has been modelled. The I-V curve of the modelled PERC is presented in Fig 3

V. CONCLUSION:

This paper has presented simulation and modeling of PERC solar cell using ATLAS software. Firstly, a PERC solar cell was designed and then modelled to real experimental PERC device by fitting I-V parameters with minor difference of 0.83%, the individual differences between short circuit current was 2.06%, 0.07% between open circuit voltage. 0.96% in fill factor and 0.24% in the efficiencies. It has been found that the carrier recombination whether at front or rear surface or at the cell contacts, must be reduced and kept low using passivation layers for increasing short circuit current and open circuit voltage.

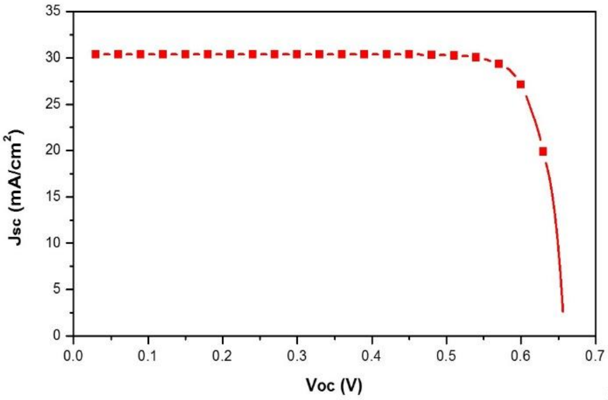

Figure 3: I-V curve of the modelled PERC

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