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Role of surface recombination in multi-crystalline silicon solar cells

C. Pugazhenthi[1], A. Vigneshwaran[2]
[1]*(Nano electronics, SASTRA university, India)*
[2]*(Nano electronics, SASTRA university, India)*

Abstract: *Multi-crystalline silicon solar cell was fabricated using crystalline p-substrates with emitter front contact of n-type crystalline silicon. This paper reviews that an efficiency of the Multi-crystalline silicon solar cell which was analysed to demonstrate the surface recombination of the substrate that affects the performance of the solar cell, was investigated in detail by computer simulation using PC1D software. The surface recombination was found to be a key factor to affect the performance of the solar cell. A detailed simulation studies were analysed. Accordingly, the optimization of the multi-crystalline silicon solar cell on c-Si substrates was provided.*

Keywords: *Efficiency, Multi-crystalline, Simulation, solar cell, Surface Recombination,*

I. Introduction

Majority of the world's electricity was produced by fossil fuel such as coal, oil and natural gas, thus increasing demand for energy and scarcity of fossil fuel turns the people to think about the alternative way of electricity production such as renewable energy sources [1]. Solar power generation is one of the most rapidly developing renewable energy resources for electricity and it operates under the mechanism of photovoltaic. Photovoltaic devices consist of different semiconductors materials which are arranged on different structures, by using those semiconductors materials one can convert photon (solar radiation) to electron (electrical energy) for electricity generation. The reasons for selecting silicon are: (i) silicon is the most abundant element in earth crust, about 25.7% by mass (ii) it is non-toxic and safe (iii) proven efficiencies of 23% in manufacturing, with theoretical potential of approximately 30% [2].

Silicon solar cells are classified into amorphous and crystalline Silicon. Amorphous silicon (a-Si) is the non-crystalline form of material and it can be deposited at low temperature due to Staebler-Wronski effect [3], It has low performances of the device output compared to crystalline silicon. Crystalline silicon (c-Si) solar cell share the market ranges from 80-90% [4] has been used in light absorber, but it absorbs low light radiation. According to increases the thickness of crystalline silicon as thinner material to gain the efficiency. However multi-crystalline silicon solar cell will be dominant in future, hence mono-crystalline silicon solar cell could be used in low solar radiation and limited space region with cost effective.

In this paper we use crystalline silicon(c-Si) as both n and p type semiconductor by optimizing the solar cell layer. Here, surface recombination plays a crucial role that affects the performance of the device. Then surfaces recombination values are reported and combined with the result of cell simulation using the PC1D software.

II. Simulation

PC1D is a computer program written for IBM-compatible personal computer and it is a user-friendly program which solves the quasi-one dimensional transport of electron and holes from fully coupled time-dependent nonlinear equation in the crystalline semiconductor devices [5]. This device plays a dominant role for understanding the physics of solar cell, especially silicon solar cell of photovoltaic devices. The solar AM1.5 radiation was adopted as the illuminating source with steady state intensity of $0.1Wcm^{-2}$ and simulating parameters are given in the initial value as shown in Fig 1. During the simulation process all the parameters given below was analysed as the setting values.

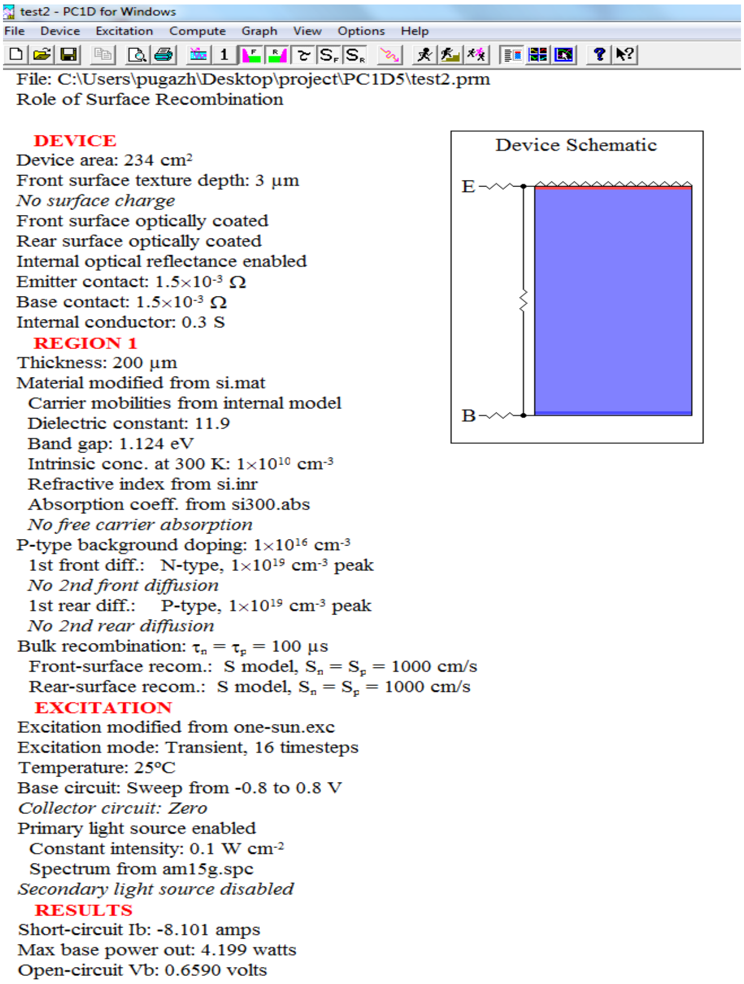


Figure 1: summary of simulation parameters for PC1D model.

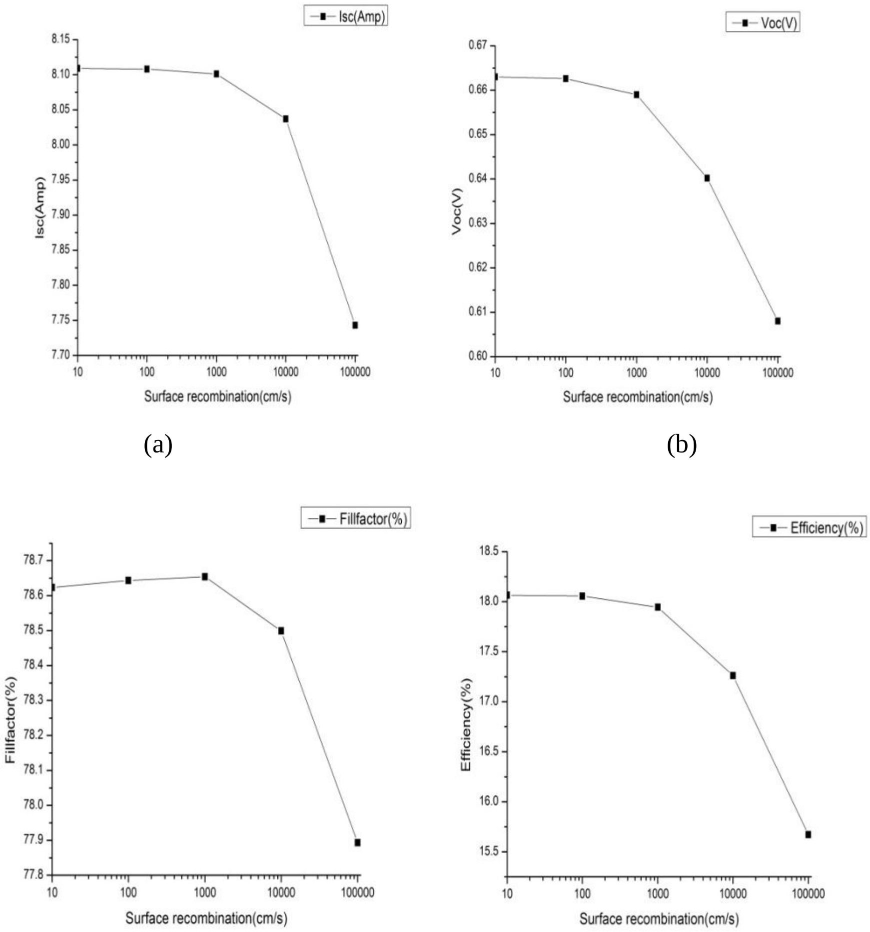
III. Results And Discussion

The characterization of surface recombination should take into account, it may be give rise to band bending. The cell parameters values like short circuit current (I_{sc}), open circuit voltage (V_{oc}), maximum power (Pmax), fillfactor and efficiency for various surface recombination conditions apply (10 to 10^5cm/s), the output values of our modelled structure is shown in Table 1.

Table 1: Simulated values of cell parameters

Surface recombination (cm/s)	I_{sc} (Amp)	V_{oc} (V)	Pmax (W)	Fillfactor (%)	Efficiency (%)
10	8.109	0.6630	4.227	78.62	18.06
100	8.108	0.6626	4.225	78.64	18.05
1000	8.101	0.6590	4.199	78.65	17.94
10000	8.037	0.6402	4.039	78.49	17.26
100000	7.743	0.6080	3.667	77.89	15.67

Surface recombination (S_n,S_p) set for the conditions 10 to 10^5 cm/s and the remaining parameters are set as constant, the I_{sc} value decreases with the increase of surface recombination. In surface recombination I_{sc} will be largely affected, high recombination rates at the top surface have particularly detrimental impact on the short circuit current (I_{sc}) because top surface also corresponds to the highest generation region of carriers in the solar cell and this impact can be shown in fig 2(a). When surface recombination increases then the carrier starts to recombining at the defect surfaces which reduces the cell performance, effect of surface recombination at the back surface is very low because the generation rate at the back surface is very small. Surface recombination largely affects the whole performance of the solar cell.



(a) (b)

(c) (d)

Figure 2: Effect of surface recombination in cell parameters

The V_{oc} value decreases with the increase of surface recombination. For high V_{oc} the recombination should be 10^3 cm/s [6]. Unlike I_{sc}, the V_{oc} does not approach saturations recombination speed becomes smaller but rises continuously and it is shown in fig 2(b). Fillfactor is in conjunction with V_{oc} and I_{sc}. Fillfactor decreases with the increase of surface recombination. The fillfactor is directly affected by the value of the cell's series and shunt resistances. Increasing the shunt resistance (R_{sh}) and decreasing the series resistance (R_s) lead to a higher fill factor, thus resulting in greater efficiency, and bringing the cell's output power closer to its theoretical maximum [7]. Fill factor decreases with the increase of surface recombination is shown in fig 2(c). The efficiency of a solar cell related with V_{oc} and $I_{sc.}$ So, it decreases with the increase of surface recombination. The majority of the electronics industry relies on the use of a thermally grown silicon dioxide layer to passivate the surface due to the low defect states at the interface [8]. The industries have moving towards to use thinner wafers for fabrication of solar cells to reduce cost [9] The effect of surface recombination in the efficiency of solar cells is shown in fig 2(d).Surface recombination is the important parameter which affects the performance of the solar cells. Multi-crystalline silicon solar cells are modelled and simulated using PC1D software. It has shown that PC1D was able to design the experimental results for different multi-crystalline silicon solar cells that have been proven by number of research groups. The proposed structure for modelled multi crystalline silicon solar cell gives I_{sc} = 8.101 amps, V_{oc} = 0.6590 V, fill factor = 78.65%, efficiency = 17.94%.

IV. Conclusion

The defects at a surface of solar cells is the reason for surface recombination, which is caused by the interruption to the periodicity of the crystal lattice which forms dangling bonds at the surface of solar cells. The surface recombination can be decreased by defect free surface, which can be achieved by passivation. The rate depletion of minority carriers can be reduced by limiting the surface recombination. It also helps to extend the lifetime of the material. Heavy doping at rear surface called back surface field (BSF) keeps minority carriers away from high recombination at rear contact. In multi-crystalline silicon solar cells, the front and rear surface recombination vary from 10 to105 cm/s was analysed. Finally, we simulate the role of surface recombination and its effects was analysed and provided.

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