Effect of Contact Resistive Variations of Screen Printed Si Solar Cell

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Abstract: - In this paper, single crystalline silicon solar cell was analyzed using quasi-one-dimensional transport of electrons and holes in crystalline semiconductor, PC1D. Effects of the resistance of the emitter and base contact have been investigated with a view to find the best resistive combinations. The short circuit current Isc, the open circuit voltage Voc, the maximum power Pm and the fill factor are the observed parameters due to the variations of the resistance on the emitter and base contact. As the two variable factors that take into the account, while evaluating one factor, the other was set to constant value. It is found that as the contact resistance goes higher, the values of the parameters deceased. From the evaluation, the lowest emitter resistance that will give highest value of parameter in the selected ranged is 1mΩ while for the base contact will be 15mΩ. The overall investigation on single crystalline silicon solar cell base and emitter contact were done, gives potential parametric suggestion that may assist in the fabrication of high efficiency single crystalline silicon solar cells.

Key-Words: - base, emitter, contact, crystalline silicon, PC1D

1 Introduction

There are many aspects to be look on in order to produce a high efficiency energy conversion solar cell, mostly the single crystalline silicon solar cells. The energy conversion efficiency of a solar cell can be significantly increased with the improvement of material properties and the design of structures of the cells [1]. Solar cell in the market nowadays comes with various type, sizes and efficiencies. The commercially available module made using crystalline silicon typically have solar conversion efficiencies in the range of 10-16%, with more sophisticated cell design having efficiency at the higher end of this range [2]. One of the factors that required increasing the efficiency of a solar cell is by optimising its emitter and base contacts. The silicon solar cell contacts nowadays are commonly realized by screen printing method. Solder pastes were printed on both surface of the cell before it was annealed. Metal semi conductor contact resistance depends beyond the metal involved, on the fabrication process of metallic contact [3]. Metal pastes that usually used for the contacts are aluminium for the back contact and silver for the front contact.

Due to its robust process technology and high throughput, screen printing is the most common technology for metallization of today's industrial solar cells [4]. One of the other new options is Hot-Melt screen printing. Advantages of Hot-Melt technology over the conventional screen printing is the possibility of the front contact with high aspect ratios and the use of ink that release significantly less amount of volatise organic compound then the conventional metal paste [5].

These contacts give resistance that affect the efficiency of the solar cell. Optimising it mostly during firing is a must in order to reduce the contact resistance. A contact resistance could also be included by adding a thin resistive layer, which would also model the effects of the current crowing at the contact [6]. The effect of contact resistance can be evaluated using physic-mathematical approach.

A complete physic-mathematical approach to the I-V characteristic can be presented by two diodes model where the diffusion current and the recombination current are presented by the diode with different exponential behaviour and become more closely related to the physical phenomenon [7]. In this study, the physics-mathematical software used was PC1D.

2 Methodology

In this work, the one dimensional numerical analysis software, PC1D simulator has been employed to model and analyze two parameters which are the emitter resistance and base resistance. The figure 1 below is the model of solar cell in this study. The design parameter like open circuit voltage (Voc), short circuit current (Isc), maximum power (Pmax) and fill factor (FF) have been investigated by taking variation value of these parameters.

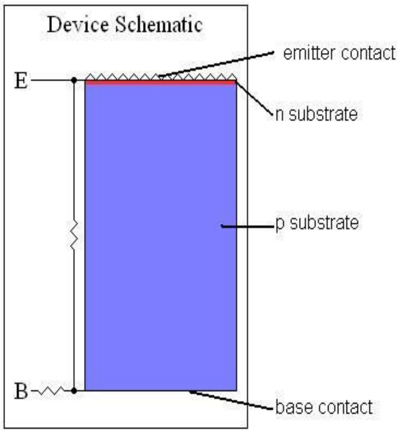

Fig. 1 PC1D model

The investigations were done towards the two type of resistance, one type at a time. As the emitter resistance was evaluated, the base resistance was left constant. Two scales were taken to account; the large scale is to determine the resistance with the best result, while the small scale was to study the effect of the resistance towards the parameters. As the base contact was kept constant at 0.015Ω, emitter contact was evaluated in large scale from $1x10^{-6}$ to $1x10^{2}$ Ω with 10 steps. It is then evaluated in small range, $1x10^{-3}$ to $1x10^{-2}$ Ω, with 10 steps too.

Similar method applied to base resistance as the emitter resistance was kept at $1x10^{-6}$ Ω. Large scale base resistance value implicated were from 0.00015Ω to 15Ω, while the small scale was from 0.015Ω to 0.15Ω with 10 steps each.

3 Results and Discussion

3.1 Emitter Contact

When evaluating the emitter contact, the base contact value was kept constant at 0.015Ω. From the large scale evaluation, it is found that emitter resistant at $1x10^{-6}$ Ω give the highest value of all the parameters as shown in figure 2. However all the parameters will only start to show an obvious change from the resistance at $1x10^{-3}$ Ω. Figure 4 below show the effect of the increasing resistance from $1x10^{-3}$ Ω to $1x10^{-2}$ Ω.

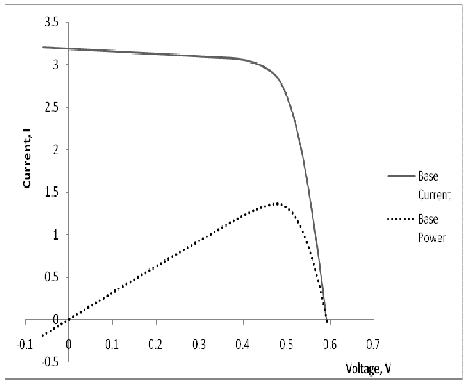

Fig. 2 Best IV in emitter contact.

Within that range, 10 steps were taken into evaluation. As the resistance was increasing, all parameters were decreasing. This is a nature in electronics that the fill factor varies resistance. In this range, with emitter contact at $1x10^{-3}$ Ω, the short circuit current (Isc) is 3.182A, maximum power (Pmax) is 1.353W, the open circuit voltage is (Voc) 0.592V and the fill factor (FF) is 0.7183.

The open circuit voltage, Voc was remained constant through all the evaluation since Voc doesn't varies with resistance.

3.2 Base Contact

When evaluating the base contact, the emitter contact value was kept constant at $1x10^{-6}$ Ω. From the large scale evaluation, it is found that base resistant at 0.00015 Ω give the highest value of all the parameters as show in figure 3. However all the parameters will only start to show an obvious change from the resistance at 0.015 Ω. Figure 5 below show the effect of the increasing resistance from 0.015 Ω to 0.15 Ω.

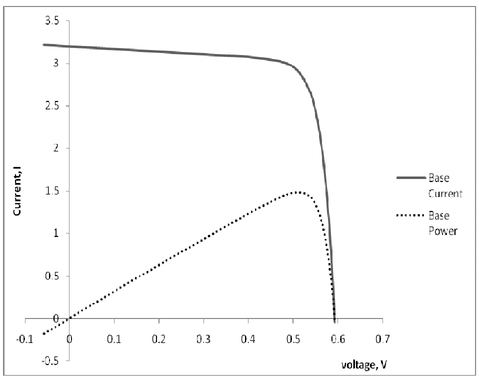

Fig. 3 Best IV in base contact.

Within that range, 10 steps were taken into evaluation. As the resistance was increasing, all parameters were decreasing. Just like in emitter contact testing, the fill factor varies resistance. In this range, with base contact at 0.015 Ω, the short circuit current (Isc) is 3.183A, maximum power (Pmax) is 1.362W, the open circuit voltage is (Voc) 0.592V and the fill factor (FF) is 0.7228.

Like in emitter contact, the open circuit voltage, Voc was remained constant through all the evaluation since Voc doesn't varies with resistance.

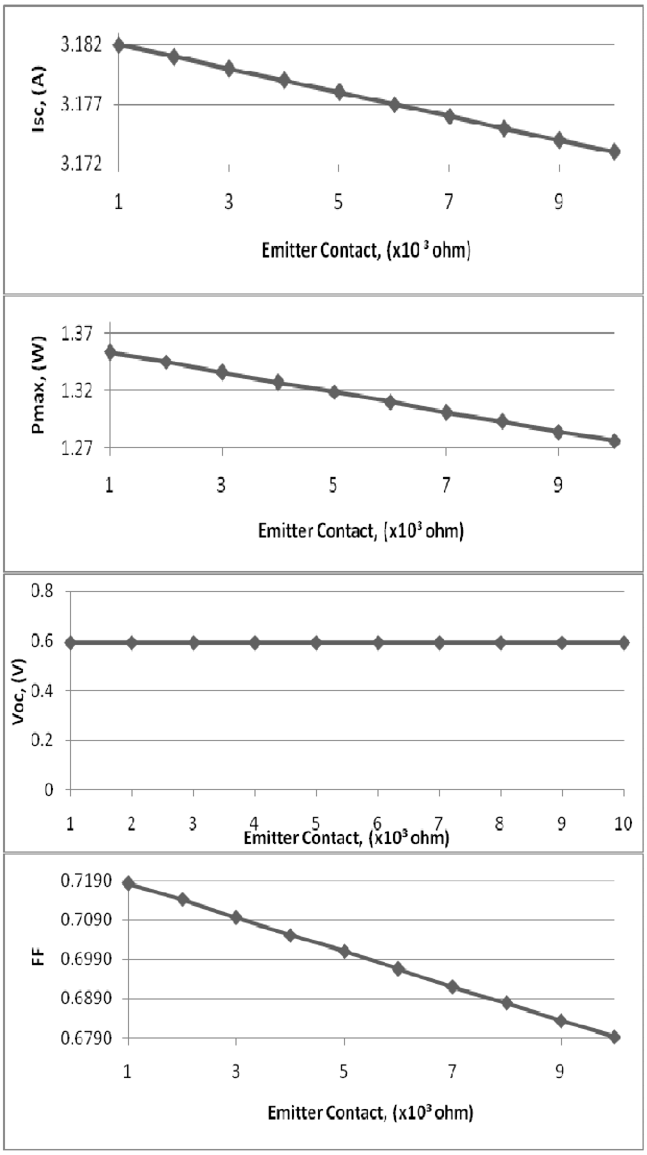

Fig. 4 Effect of emitter contact resistance.

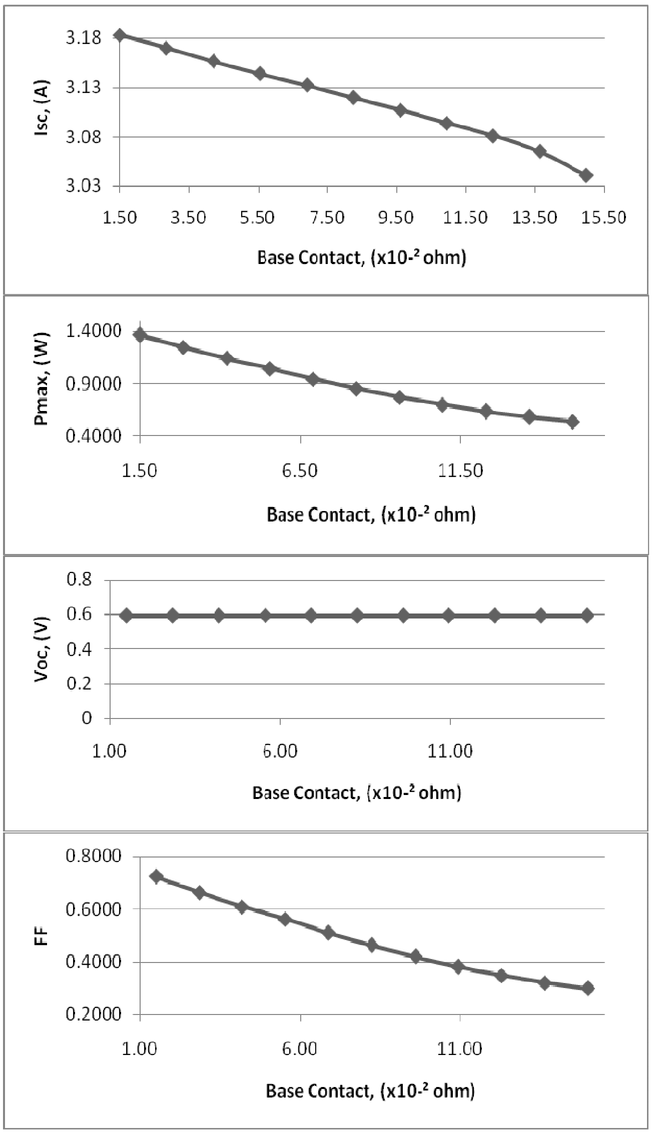

Fig. 5 Effect of base contact resistance.

4 Conclusions

In this work, we have evaluated the effect of emitter contact and also base contact towards the major parameters in Si solar cells using the physic-mathematical PC1D. The lowest emitter contact resistance that gives higher value in the result would be $1x10^{-6}$ Ω. Meanwhile for base contact resistance, the lowest contact resistance that gives higher value is 0.00015Ω. From the graph generated, it is shown that all parameter, mostly that related to the fill factor are varies with the resistance, in our case is the contact resistance. However, the open circuit voltage doesn't varies with the resistance but it varies with surface concentration and also surface recombination velocity. Since those parameters are not in our evaluation (also are kept constant by default), the value of Voc is remain constant too. The simulation results corroborate the established fact that resistance give an important impact of designing solar cells. The outputs from this study are hopefully to help future purposes.

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