Cost reduction by using micro-fingers in thin film silicon modules

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***Abstract* — A finite element electrical model is described that can be used to calculate the performance of monolithic thin film photovoltaic modules. The model is suitable for all type of thin film modules, like e.g. p-i-n a-Si:H, CIGS and polymer based modules and it includes losses due to interconnection. Using this model a parameter study is performed for a-Si:H cells with the aim to reduce metal consumption in the cell and interconnection. It is shown that a reduction in metal consumption by a factor 1.3 can be achieved with only marginal loss in performance if short cell are used with very short fingers.**

***Index Terms* — amorphous materials, charge carrier lifetime, photovoltaic cells, silicon.**

I. Introduction

Potential scarcity of Ag is a major issue for the long term perspective of solar cells.[1] Increasing scarcity will lead to increasing Ag price and in the end a higher euro/Wp price of solar energy. Modeling of solar cells is becoming increasingly important in searching for higher power conversion efficiencies and strategies to decrease the Ag consumption in solar cells. Other groups have reported on electrical models to calculate the performance of n-i-p thin film silicon solar cells[2] and polymer solar modules.[3,4] They reported on variation in finger length and cell length to optimize the performance. In this paper an Finite Element electrical model is presented that calculates the performance of a monolithic interconnected a-Si:H solar cell. It is shown that for a specific cell length, the finger length can be strongly reduced while maintaining the power conversion efficiency. This will help to reduce the Ag consumption in this type of solar cell.

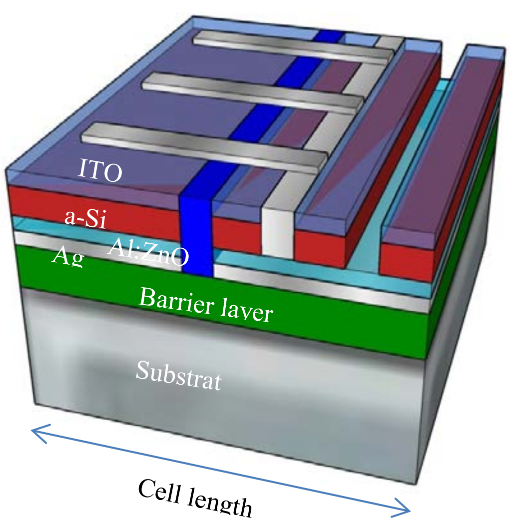

Figure 1: Schematic presentation of the cell and interconnection as used in this paper.

II. MODEL

A finite element model was developed that describes the thin film solar cell and its metal contacts as well as the interconnection from the top contact of one cell to the back contact of the next cell in a module. In this paper this will be called a single cell module. A schematic presentation of the device layout is shown in Fig.1. In the model it is assumed that the isolation scribe (blue in Fig. 1) is isolating good enough so that there will be no direct current flow between the active layer and the metal of the interconnection. For this reason the isolation and material between the isolation and the metal of the interconnection were omitted in the model. In this way the device can be treated as a quasi 2-dimentional system.

The model cell module contains several layers: the top metal, the active layer and the back contact layer. The active layer is determined by the diode equation with its diode parameters, a conducting top as defined by the ITO and a conducting bottom as defined by the backside contact. It is assumed that the ZnO:Al between the a-Si and the back contact is not contributing to the lateral transport and that its contribution to the resistance can be neglected. The voltage is applied to the Ag contact at the right side of the device, while the Ag edge on the left side is kept at 0V. The model then calculates the voltage in the model using the Poisson equation for both the metallization layers and the active layer. These layers are coupled via their contact resistance. Iterations are done to make the voltages between the layers consistent.

Table I. PARAMETERS USED IN THE CALCULATIONS.

finger width	0.0125 cm
Ls P1 width (isolation under finger)	0.002 cm
interconnection width	0.002 cm
Ls P3 width (isolation between cells)	0.002 cm
distance lsP1 and interconnection	0.01 cm
distance interconnection and lsP3	0.01 cm
Pitch	0.2 cm
photon current density	25.5 mA/cm^2
dark saturation current under finger	0.0020 mA/cm^2
dark saturation outside finger	0.0025mA/cm^2
n under finger	2.033
n outside finger	2.000
shunt resistance under finger	2400 Ohm cm^2
shunt resistance outside finger	110 Ohm cm^2
Contact resistance Ag/ITO	0.005 Ohm cm^2
Sheet resistance ITO	30 Ohm sq
Ag conductivity	1.59e-8 Ohm m
Contact resistance in interconnection	0.01 Ohm cm^2

III. RESULTS

The model was used to perform a parameter study for device optimization. First calculations were done for various cell lengths, while maintaining a pitch (distance between two fingers) of 0.2 cm. All other parameters are given in Table I. For the diode characteristics of the cell, values were used as determined on cells made previously at the Energy research Center of the Netherlands.

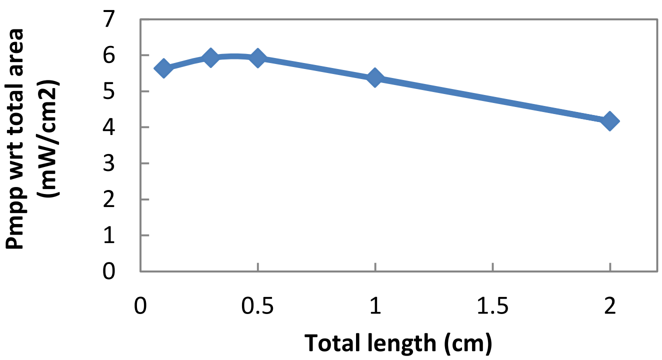

Figure 2: Calculated power at maximum power point versus module length for single cell a-Si:H module (including interconnection).

Figure 2 shows the power at maximum power point (Pmpp) for cells of 0.1, 0.3, 0.5, 1 and 2 cm length. As can be seen, the cell performance improves upon decreasing the cell length from 2 to 0.3 cm and decreases for smaller cells. Small cells have a relative large dead zone, i.e. the area that does not contribute to the current and consists of the interconnection and the isolation scribes between the interconnection and the active area. As a result, upon increasing the cell length, the performance will increase. On the other hand, the series resistance increases upon increasing the cell length. The combined contributions cause an optimum in cell performance around 0.4 cm.

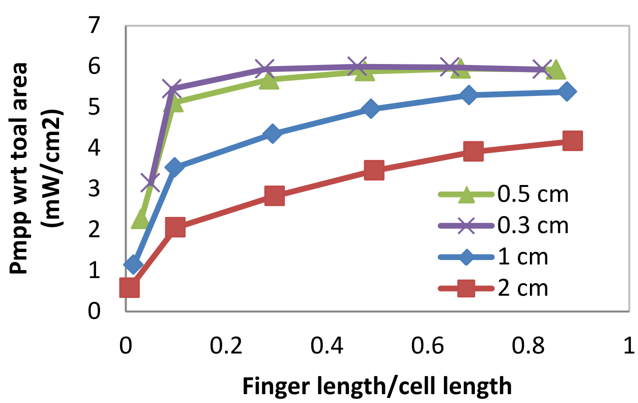

Figure 3: Calculated power at maximum power point versus relative finger length for a single cell a-Si:H module of various lengths.

Next the finger length was varied. The result is plotted in Fig. 3. Again a decrease in cell performance is seen upon increasing cell length. More interesting is the fact that there is only a very small difference if the finger length of the small cells, 0.3 and 0.5 cm length, is reduced from maximum finger length to about half the cell length. So if short cells are used, the finger length can be half the cell length without losing efficiency. On the other hand, more interconnection area per unit of length is needed if short cells are used. This means also more metal for the interconnection. To see if it is beneficial to reduce the cell length and finger length with respect to metal consumption and power, Fig. 3 was re-plotted using the Pmmp divided by the metal volume per unit of length, i.e. the metal volume in de cell and interconnection, divided by the total length of the cell and interconnection. In this way a comparison can be made between different cell lengths.

Figure 4 shows the effect of taking into account the metal volume. Increasing the cell length strongly reduces the power per volume of metal. But the most striking is that reducing the finger length gives a better performance with respect to metal consumption. Even though a module based on 0.3 cm cells needs more metal for the interconnections compared to the 0.5 cm long cell, there is still a benefit because the finger length can be reduced further, reducing the metal consumption by a factor 1.3, without losing performance.

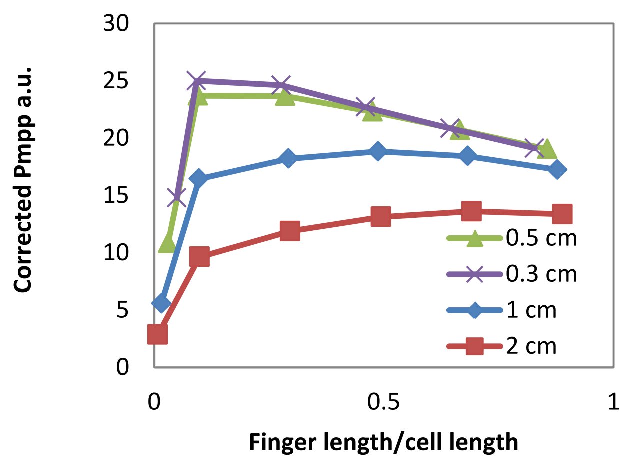

Figure 4: Calculated power at maximum power point per metal volume per module length versus the relative finger length. Calculation are plotted for several module lengths.

CONCLUSIONS

An electrical model is presented that calculates the performance of single cell thin film modules based on a monolithic interconnection. Both cell and interconnection are taken into account into the model. Calculations for a-Si:H cells show that an optimum in performance can be found for a cell length of 0.3-0.5 cm. For these narrow cells, the finger length can be reduced without losing performance. An important result, as it opens the way to reduce metal consumption in these modules. Even when taking into account the increased metal consumption due to the increased number of interconnections, the 0.3 cm long cell shows better performance to metal consumption ratio than the 0.5 cm long cell. These results are very valuable for full cost-of-ownership calculations in which also other costs like (additional) laser scribing are taken into account.

ACKNOWLEDGMENT

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