LOW LIGHT INTENSITY PERFORMANCE OF N- AND P-TYPE SILICON SOLAR CELLS WITH DIFFERENT ARCHITECTURES

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ABSTRACT

In this work we investigate the relative power output at the maximum power point (mpp) of n-type versus p-type Si solar cells with same architectures operating at low light intensities as compared to 1 sun. This behavior could have a strong impact on the energy yield in kWh/kW$_{peak}$ on module level [1]. Few studies on cell level already exist [2], in our work we compare different cell architectures in more detail. Interestingly we find that cell performance at intensities below 0.2 suns are governed by the shunt resistance of the cell rather than by the base type.

1. INTRODUCTION

The introduction of n-type base material to PV-industry purges numerous challenges but also promises many advantages such as higher bulk lifetimes, stable efficiencies and higher tolerances against common impurities. As has been previously shown [3,4], the effective carrier lifetime at low injection levels of n-type Si wafers is higher as compared to p-type Si wafers in the presence of unavoidable impurities, especially Fe. These higher lifetimes could lead to a better performance of n-type solar cells at low light intensities which will be investigated in the following.

2. EXPERIMENTAL

For our study we measured IV curves of Cz -Si solar cells at different intensities. We chose different n- and p-type cells featuring the same architectures. Firstly, n-type Al rear emitter and p-type standard BSF cells, secondly, n- and p-type bifacial cells.

Our self developed IV setup enables us to measure the IV curve of a solar cell illuminated homogenously at variable intensities without changing the spectrum. The intensities chosen for each tested cell are 1 sun, 0.2 suns, 0.1 suns, 0.05 suns and 0.02 suns. Each cell is measured at least three times at the same illumination and the average taken.

3. RESULTS AND DISCUSSION

Solar cell results are presented separately for both cell structures. Figure 1 shows the relative drop of FF and power output at the mpp for the “standard cells”.

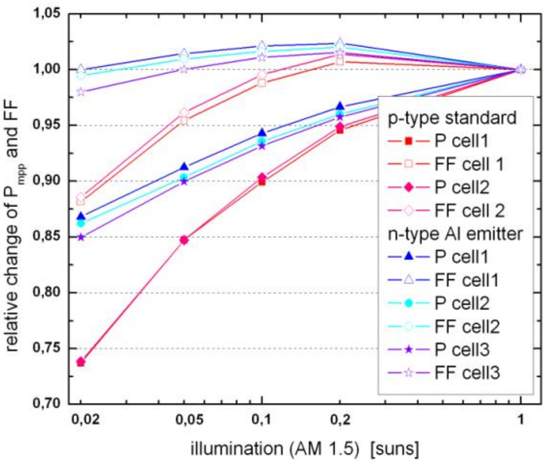

Fig. 1: relative change of P$_{mpp}$ (solid symbols) and FF (open symbols) as compared to 1 sun illumination (for lower intensities P$_{mpp}$ is also scaled to the specific illumination level) for standard n- (blue) and p-type (red) cells

Both cells have an identical structure, only the base material differs. It is remarkable that the power output drops less for the n-type cells, even though their emitter is located at the rear side of the cell. That means that carriers have to travel a longer path before getting separated at the junction. For both cell types the decline of FF and power output show the same behaviour. This leads to conclude that rather the shunt resistance than the lifetime governs the performance at low intensities. The initial increase of the FF for all cells results from a decline in series resistance. At 0.2 suns illumination the transported current is approximately 5 times lower than at 1 sun. That is why the resistance of the metal grid does not decrease cell performance anymore.

For the bifacial cells shown in figure 2, the same trend is observed however vice versa. Here, the p-type cells have a better low light performance. But again the relative drop of the FF suggests that the dependence of the cell performance on the shunt resistance is responsible for the difference in low illumination power output but not the type of the base material.

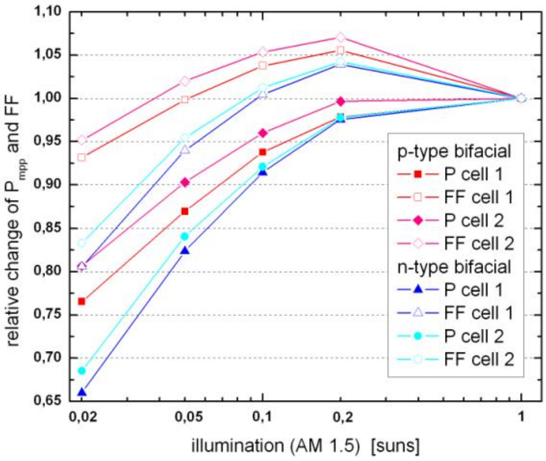

Fig. 2: relative change of P_{mpp} (solid symbols) and FF (open symbols) as compared to 1 sun illumination (for lower intensities P_{mpp} is also scaled to the specific illumination level) for bifacial n-(blue) and p-type (red) cells.

Figure 3 places the results into context with the individual shunt resistance of the solar cells investigated.

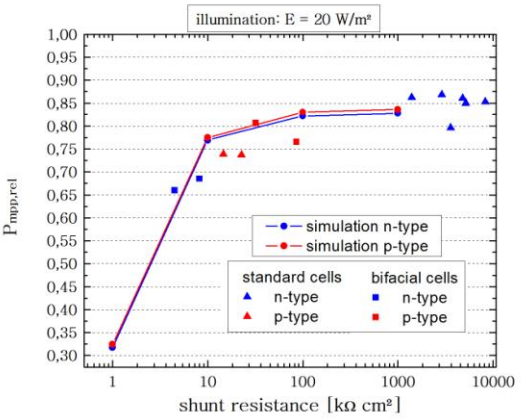

Fig. 3: relative change of P_{mpp} at 0.02 suns versus shunt resistance of the individual solar cells. The pointed curves show simulated results calculated with the Silvaco ATLAS software (symbols: solid sybol: P_{mpp}, blue: n-type, red: p-type, triangle: standard, square: bifacial).

The relative drop of the power output at 0.02 suns for individual cells is plotted versus the shunt resistance of these cells. A clear dependence on the shunt resistance is observed. For low shunt resistances P_{mpp} increases linearly with the shunt resistance until it reaches saturation for values higher than 1 MΩcm². This trend is also backed up by Silvaco ATLAS simulations considering an ideal cell device featuring only series and shunt resistance illuminated at 20 W/m² inputting different values for the shunt resistance. The lowest shunt resistance investigated was 4 kΩcm² which still satisfies industrial standards. For the cells featuring the lowest shunt resistance P_{mpp} drops by 35% relatively compared to only 15% relative for the cells with the highest shunt resistance.

4. CONCLUSION AND OUTLOOK

Our study shows that for light intensities below 0.2 suns the relative drop of the power output strongly depends on the shunt resistance of a solar cell even if industry standards are satisfied. For our Al rear emitter n-type cells featuring a shunt resistance higher than 1 MΩ cm² the FF stays nearly constant even at 0.02 suns compared to a decline by 20% for the cells with the lowest shunt resistance. This leads to the conclusion that properly isolating the junction or optimized firing conditions of a solar cell can drastically increase their low light performance independently of the base type. From these curves the total harvest kWh/kWp could be estimated. An explanation why some modules perform better in field than others could be retrieved.

A positive effect of the higher bulk lifetimes at low injection levels for n-type base compared to p-type base cells could not be observed so far, possibly because this effect has a lower impact than the shunt resistance in our devices.

To continue our work we will compare n- and p-type cells with the same architecture and similar shunt resistance to eliminate its influence on the measurement. With this method the influence of the lifetime on the cell performance should become visible. At the same time we are conducting outdoor measurements of 4 cell mini-modules of the above mentioned architectures to investigate and compare the power output under standard operating conditions.

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