PATHS TO ACHIEVE EFFICIENCIES OVER 20% WITH MWT SILICON SOLAR CELLS

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ABSTRACT

This work focuses on the latest developments from research on MWT (metal wrap through) solar cells at Fraunhofer ISE. An overview of the current cell results for FZ-Si, Cz-Si and mc-Si material with both Al-BSF and passivated rear side (PERC approach) is presented. Recent progress in cell technology and the challenges in order to reach efficiencies for pilot-line processed large area MWT solar cells over 20% are discussed. Several paths in order to reach such cell efficiency are presented in this paper. Up to now cell efficiencies up to 20.6% for FZ-Si and up to 20.1% for Cz-Si are achieved with large-area 125 x 125 mm² psq. MWT cells in our PV-TEC [1] lab. To our knowledge this are the highest cell efficiencies reported for p-type mono-crystalline silicon material so far. Furthermore, 18.2% are reached on 156 x 156 mm² mc-Si wafers.

1. INTRODUCTION

The common industrial cell and module production is mainly based on screen-printed H-patterned silicon solar cells. Therefore today's modules suffer from high front surface shading and from series resistance losses in the tabbing material. Both loss mechanisms are caused by the presence of an external contact, the so called busbar, on the front surface. To reduce these losses significantly, the busbar has to be transferred to the rear surface.

This can be realized by the metal wrap through (MWT) technology [2] while using only industrial applicable production technologies. The main advantage of the MWT technology among the rear contact cell technologies is the need of only two additional process steps for cell production in comparison to the conventional technology: laser via drilling and rear contact isolation. The via-metallization can be done in the same process step as the rear solder pad metallization. Hence, the MWT technology allows high efficiencies [3-5] while production costs are still on a low level. Therefore the costs per Wp can be reduced at low economical risks. The transfer of the MWT technology from laboratory to industry is already ongoing and has been successful so far [6-8].

The combination of the MWT technology and the rear surface passivation (PERC approach) allows a further efficiency improvement [9, 10]. A schematic cross section of a typical MWT cell with rear side passivation (so called MWT-PERC cell) is shown in Figure 1.

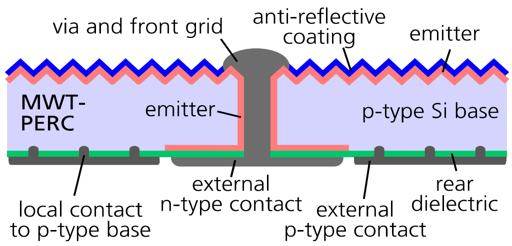

Figure 1: Schematic cross-section of a typical MWT-PERC solar cell.

2. APPROACH

Several paths to achieve cell efficiencies over 20% with large-area MWT cells are discussed and combined:

First, different approaches for the passivation of the rear and front side are investigated. A clear increase of the short circuit current J_{SC} mainly due to improved rear side reflectance and of the open circuit voltage V_{OC} mainly due to improved front and rear side passivation is demonstrated.

Second, a selective emitter process based on laser doping is introduced. The selective emitter process allows low contact resistances and therefore high fill factors as well as an increase in JSC and VOC due to the possibility to use lowly doped and passivated emitters between the contact fingers.

Third, different front metallization technologies are focussed. The common screen printing process is compared with a newly developed dispensing process as well as different seed and plate approaches. For seed layer formation different printing technologies are discussed. Dispensing as well as seed and plate approaches lead to higher J_{SC} and V_{OC} values mainly caused by less front metallization area and to higher FF values due to increased finger conductivity. Both effects are caused by improved finger geometry: The finger width is decreased while the aspect ratio is increased.

3 RESULTS

Table 1: Maximum cell efficiencies of large-area MWT cells. Cell area: 156*156 mm² fsq. for mc-Si; 125*125 mm² psq. for Cz- and FZ-Si. All IV measurements on Cz-Si are done after annealing.

Cell type	*Si mat*	V_{OC} *[mV]*	J_{SC} *[mA/cm²]*	*FF [%]*	η*** [%]*
PERC-	mc	637	36.9	77.3	18.2*
HIP-	Cz	635	39.3	77.3	19.3
HIP	Cz	647	39.7	76.2	19.6
PERC	Cz	647	39.3	76.2	19.4*
PERC+	Cz	651	40.3	76.6	20.1*
PERC	FZ	655	39.0	78.4	20.1*
PERC+	FZ	661	39.9	78.3	20.6*

*independently confirmed by Fraunhofer ISE CalLab
**Measurement uncertainty is ±3% relative

An overview of current cell results achieved with boron doped multi- (mc) and mono-crystalline (Cz and FZ) silicon material is given in Table 1. Cell processing was mainly performed on pilot-line equipment in the PV-TEC lab of Fraunhofer ISE [1].

Application of an Al_XO_Y based rear side passivation [11] and a homogenous emitter on the front as well as screen printed contacts on both sides yield efficiencies up to 18.2% on mc-Si (cell type: PERC-). A simplified and improved cell process [10] for screen printed MWT cells with a thermally grown silicon oxide based rear side passivation and a homogenous emitter allows for efficiencies up to 19.3% on Cz-Si (cell type: HIP-). The introduction of the selective emitter process in combination with a passivated lowly doped front emitter [12] leads to efficiencies up to 19.6% on Cz-Si (cell type: PERC and HIP).

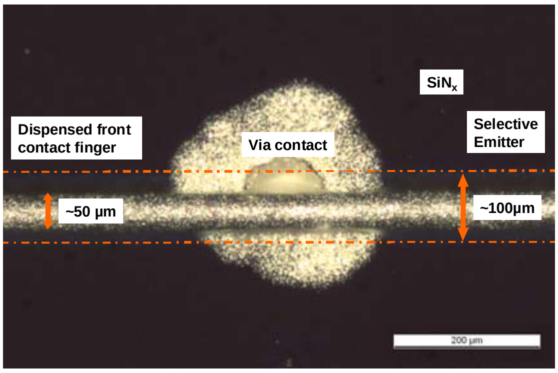

Figure 2: Microscope picture of the crossing point of a dispensed front contact finger and a via contact. The selective emitter region is also visible.

The use of dispensed front contacts [13] instead of screen printed contacts enhances the maximum cell efficiency to 20.1% on Cz-Si and 20,6% on FZ-Si (cell type: PERC+). In Figure 2 an example for a dispensed front contact finger on top of a laser doped selective emitter crossing a via contact is shown. Contact finger widths down to 50µm and aspect ratios close to 1 are reached.

A direct comparison of the cell results (cell type: PERC) achieved with Cz- (1.5-2.5 Ωcm) and FZ-Si (~0.5 Ωcm) shows that the use of high-quality low base resistivity material such as FZ-Si allows an efficiency gain of at least 0.5% absolute.

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