Recent Results in Low Cost Back Contact Solar Cells

A. Kress, P. Fath, E. Bucher
Universität Konstanz, Fachbereich Physik, Fach X916, 78457 Konstanz, Germany
Tel: +49-7531-88-3731, Fax:+49-7531-88-3895
e-mail: Andre.Kress@uni-konstanz.de

Abstract: In order to increase the cost effectiveness of solar cells, module production should be treated more comprehensively. Back contact cells offer distinct advantages in the interconnection of cells to modules. The Emitter Wrap Through concept allows in addition to combine low cost material, low cost processes and easy cell interconnection in a very efficient way [1]. The frontside emitter is connected through small laser drilled holes to the rear emitter contact which is very appropriate for low cost material with relatively small diffusions lengths. Apart from these advantages the short circuit current is distinctly increased due to the grid free frontside. Despite the work of several groups on the subject of EWT or MWT (Metalized Wrap Through) cells the final and optimal grid design has not yet been found.

Keywords: back contact - 1: low cost - 2: EWT - 3

1 Introduction:

In the presented work we will describe the optimisation of the rear grid design. The number and length of the contact fingers has been varied in order to minimise the series resistance [2, 3, 4]. An optimum between large fingers and small finger distances was found. Two different screen printing pastes (paste A and paste B) for the base contact have been compared. One of the advantages of the EWT-concept is that an selective emitter can be applied easily without any further alignment steps. Spectral response- as well as IV- measurements are presented.

The increased collection probability due to the rear side emitter is very well visible in the LBIC scan.

2 Process:

The developed production process is briefly presented: the connecting holes are drilled by a laser which is a very flexible method for experimental studies. The rear side p - and n+ - regions are defined using SiN as local diffusion barrier. The n+-diffusion is carried out in a POCl3 furnace. PECVD-SiN is applied as an ARC. The metallized contacts are screen printed using an automatic alignment system.

- hole drilling by laser
- alkaline damage etch
- SiN-deposition at the cell rear
- screen printing of etch resist
- plasma etch of rear SiN, resist covered regions excepted
- POCl3 - diffusion
- PECVD-SiN ARC
- screen printing of contacts
- contact co-firing

We hope to be able soon to replace the SiN/etch resist step by a screen printable diffusion barrier.

3 Results:

3.1 Grid optimisation

Unlike in conventionally processed cells, the design of the metallisation in EWT-cells is not restraint by shadowing losses. So several different grid geometries have been investigated experimentally (Table I) as it is very difficult to simulate the highly 3-dimensional structure.
Table I: IV-results of 3 different grid designs. The series resistance is very high, but depends little on the grid design.

<table>
<thead>
<tr>
<th># of fingers</th>
<th>holes/finger</th>
<th>$R_{\text{serie}};\Omega,\text{cm}^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>38</td>
<td>1</td>
<td>1.8</td>
</tr>
<tr>
<td>27</td>
<td>1</td>
<td>2.1</td>
</tr>
<tr>
<td>20</td>
<td>1</td>
<td>2.2</td>
</tr>
<tr>
<td>20</td>
<td>2</td>
<td>2.1</td>
</tr>
<tr>
<td>20</td>
<td>3</td>
<td>2.1</td>
</tr>
</tbody>
</table>

In order to reduce the series resistance, the emitter contacts are printed into the holes. For both, the contact resistance and the resistance in the emitter, metal filled holes are favourable. Due to the volume reduction of the paste during drying and firing the holes are only filled half as a SEM-image shows (Fig. 3).

Figure 3: SEM image of a connecting hole. The hole is only partially filled with metallization paste due to the reduction in volume during drying and firing. The hole diameter is 150 µm.

So finally, a grid design with 2.4 mm fingerspacing between equal fingers was choosen. This spacing allows a relaxed alignment and a metal coverage ratio of 65 % to keep the contact resistance low.

3.2 Base metallization paste

Tow different base metallization pastes have been investigated. Paste A is less rich in aluminum content than paste B. Compared to conventionally processed cells with completely metallized rear surface $J_{\text{sc}}$ and $V_{\text{oc}}$ of EWT-cells show a smaller difference for paste A or B (Table II). Spectral response measurements indicate a slightly better IQE in the long wavelength range (Fig. 4) of paste B, and also in an LBIC scan paste B is favourable [5]. However, the conductivity of paste A is by a factor 3 - 5 higher than of paste B, so finally paste A was choosen.

Table II: Comparison between base metallization paste A (Ag-rich) and paste B (Al-rich) for $J_{\text{sc}}$ and $V_{\text{oc}}$ (no ARC).

<table>
<thead>
<tr>
<th>base met. paste</th>
<th>$J_{\text{sc}};\text{mA/cm}^2$</th>
<th>$V_{\text{oc}};\text{mV}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>24.3</td>
<td>580</td>
</tr>
<tr>
<td>B</td>
<td>24.6</td>
<td>582</td>
</tr>
</tbody>
</table>

Figure 4: IQE of base metallization paste A and B in the long wavelength range. The Al-rich paste B shows a slightly increased IQE (both EWT-cells, 25 cm² Cz-Si).

3.3 Selective emitter

The grid free frontside can be completely covered by a high ohmic shallow emitter which shows an excellent spectral response in the short wavelength range. Nevertheless the rear side emitter contact can be carried out by screen printing on a highly doped emitter. The following steps are carried out before drilling of the holes (effectuated by BP-Solarex):

alkaline texture etch

high ohmic POCi₃ - diffusion

LPCVD SiN as ARC

plasma etch of rear emitter

This process enabled the record efficiency of 14.2 % on a 25 cm² Cz-silicon cell, $J_{\text{sc}} = 37.7\;\text{mA/cm}^2$, $V_{\text{oc}} = 597\;\text{mV}$ and a moderate fill factor of 63 % due to the high series resistance. The spectral response shows an increase of 1.5 mA/cm² due to the increased IQE in the short wavelength range (Fig. 5) compared to a homogeneous 35 Ω/sqr emitter. The weighted reflexion losses are below 4 % due to alkaline texturing of the front surface.

Figure 5: IQE and reflection of a screen printed EWT-cell with a selective emitter on the alkaline textured front side. The high-ohmic emitter increases $J_{\text{sc}}$ by about 1.5 mA/cm² due to the increased IQE in the short wavelength range.
3.4 Multicrystalline silicon

During the optimisation process Cz-Si was used for unadulterated comparison. Spectral response measurements show, that diffusion length and rear surface recombination velocity are similar for Cz and mc-silicon within this process (Fig. 6). Fitting with IQE-1D results in \( L_{\text{base}} \) of 230 µm for a mc back contact cell and 250 µm for a Cz-back contact cell. The rear surface recombination velocity was fitted to \( 2 \times 10^4 \text{cm/s} \) for the back contact cells compared to \( 10^3 \text{cm/s} \) for conventionally processed cells with Al-BSF. The increased surface recombination velocity for the back contact cells is due to the enhanced recombination at the rear surface pn-junctions [6].

![Figure 6: IQE and reflection of a conventionally processed Cz-cell (untextured) and a multicrystalline low-cost back contact cell.](image)

3.5 LBIC measurements:

In order to determine the influence of the connecting holes, high-resolution LBIC studies have been performed [5]. The increased collection probability due to the rear side emitter is very well visible in the LBIC scan (Fig. 7). Depending on the kind of metallisation paste used for the base contact, the collection probability due to the rear emitter is increased by up to 20 % at 905 nm compared to the base contact. The collection probability is not increased next to the holes as was expected due to the vertical junction in the connecting holes.

![Figure 7: LBIC scan of an EWT back contact cell under front illumination at 905 nm (arbitrary units).](image)

4 SUMMARY:

Several results of the optimisation process of a low-cost back contact cell have been presented. The IQE of a multicrystalline back contact cell is slightly enhanced compared to a conventionally processed Cz-cell. The fill factor is strongly affected by high series resistances, whose origin has still to be investigated. An EWT back contact cell efficiency of 14.2 % was reached on a 25 cm² Cz-Si cell in a low cost process without any photolithographical steps. This is to our knowledge the highest efficiency reported so far for a low cost screen printed EWT cell.

5 ACKNOWLEDGMENT:

Many thanks to R. Tölle and BP Solar for wafer preparation. This work was supported by the German BMWI within the project „Neuartige kristalline Silizium Solarzellen“ and within the ACE designs project of the European Commission under contract number JOR3-CT98-0269.

REFERENCES: