RECENT RESULTS IN LOW COST BACK CONTACT SOLAR CELLS

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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 **E**mitter **W**rap **T**hrough 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 (**M**etalized **W**rap **T**hrough) 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.

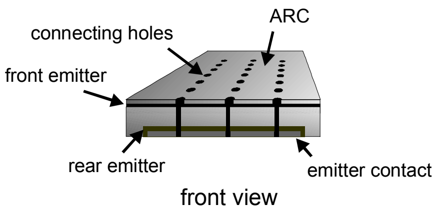

Figure 1: Schematic view of the EWT cell design (front view). The grid free front side of the cell is shown with the small holes which connect the front emitter to the emitter contact at the cell rear.

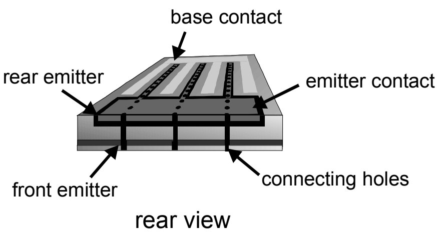

Figure 2: Schematic rear view. The interdigitated emitter- and base-grid at the cell rear is shown. Base and emitter area at the cell rear are separated by a SiN diffusion barrier.

In order to determine the influence of the connecting holes, high-resolution LBIC studies have been performed. 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 $POCl_3$ 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 exepted

$POCl_3$ - 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.

# of fingers	holes/finger	R_{serie} [Ω cm^2]
38	1	1.8
27	1	2.1
20	1	2.2
20	2	2.1
20	3	2.1

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).

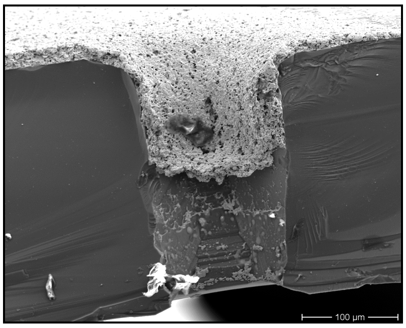

Figure 3: SEM image of a connecting hole. The hole is only partially filled with metallisation paste due to the reduction in volume during drying and firing. The hole diameter is 150 µm.

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_{sc} and V_{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 wavelenth 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 Jsc and Voc (no ARC).

base met. paste	J_{sc} [mA/cm^2]	V_{oc} [mV]
A	24.3	580
B	24.6	582

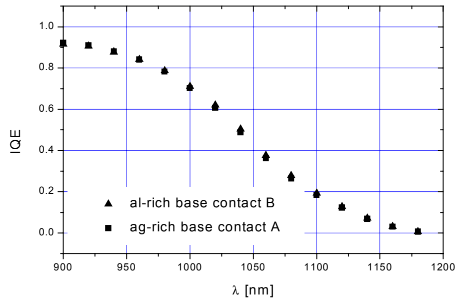

Figure 4: IQE of base metallization paste A and B in the long wavelength range. The Al-rich paste B shows a slightly increased IQE (both EWT-cells, 25 cm^2 Cz-Si).

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 $POCl_3$ - diffusion

LPCVD SiN as ARC

plasma etch of rear emitter

This process enabled the record efficiency of 14.2 % on a 25 cm^2 Cz-silicon cell, J_{sc} = 37.7 mA/cm^2, V_{oc} = 597 mV and a moderate fill factor of 63 % due to the high series resistance. The spectral response shows an increase of 1.5 mA/cm^2 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.

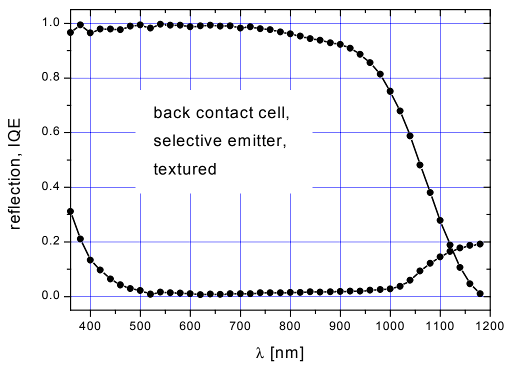

Figure 5: IQE and reflection of a screen printed EWT-cell with a selective emitter on the alkaline textured front side. The high-ohmic emitter increases J_{sc} by about 1.5 mA/cm^2 due to the increased IQE in the short wavelength range.

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_{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 $2*10^4$ cm/s for the back contact cells compared to 10^3 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].

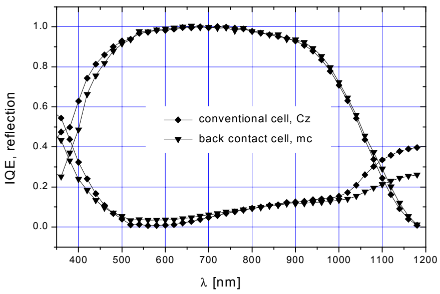

Figure 6: IQE and reflection of a conventionally processed Cz-cell (untextured) and a multicrystalline low-cost back contact cell. The thickness of the ARC of the mc cell is to small, the reflection is only hardly reduced by the alkaline texturing. The IQE of the back contact cell is slightly increased in the long wavelength range due to the rear emitter.

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.

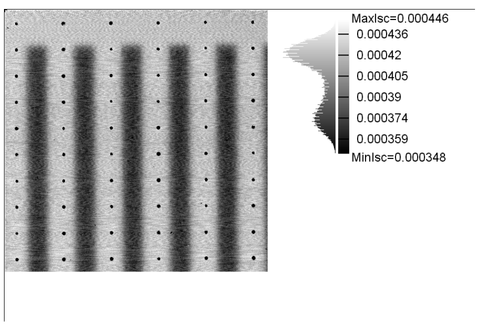

Figure 7: LBIC scan of an EWT back contact cell under front illumination at 905 nm (arbitrary units). The doping structure of the cell rear is easily distinguished. The rear emitter increases the collection probability of light generated carriers by up to 20 %.

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 cm^2 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:

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