LARGE AREA METALLIZATION WRAP THROUGH SOLAR CELLS USING ELECTROLESS PLATING

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ABSTRACT

In this paper we present a realisation of large area Metallization Wrap Through (MWT) back contact solar cell with electroless plated contacts. The MWT cell is a very promising back contact solar cell concept, since if electroless metallization is used the additional effort required to process MWT compared to conventional buried contact cells is limited to the formation of a small number of holes. In addition, the concept can easily be applied to very large area cells and is suited to thin wafers.

Two different metallization processes are investigated. The best MWT cells of each process reached an efficiency of 16.6% and 17.0% on an area of 140 cm^2. The efficiency difference originates from a difference in bulk lifetime, resulting from the generation of meta-stable defects during the Ni sintering step required for one of the processes.

INTRODUCTION

Back contacted solar cells offer several potential advantages compared to conventional solar cells. Firstly, an increase in photo generated current can be expected from the gain in optically active area due to the removal of parts of the contact grid from the front side of the cell. Secondly, with solar cell production in the near future expected to move towards both thinner and larger area cells, new methods of cell interconnection must be found. Back contacted solar cells may offer a good solution as both polarities are located on the rear side. Interconnection of back contacted solar cells may be realised by attaching the cells to back-sheets with pre-patterned current paths [1]. As handling and thus mechanical stress can be reduced for interconnection of back-contact cells compared to conventional cells, back-contact cell designs are considered to be well suited for thin, fragile wafers. Thirdly, the removal of the busbars from the front side of the cell results in a more homogeneous appearance. This makes back contact solar cells particularly suited for applications with a high aesthetical demand, e.g. building integration.

In this paper, we present two realisations of the Metallization Wrap Through (MWT) solar cell concept [2] with electroless plated contacts (Ni, Cu). A schematic of the cell design is shown in Figure 1. With this cell concept, the collecting emitter and the contact fingers are located on the front side of the cell. The n-type busbars, however, are moved to the rear side of the cell. The electrical connection between the busbars and the fingers is realised through a limited number of laser drilled holes.

This cell concept seems to be particularly suited to large area cells, as the effective finger length can be reduced compared to conventional cells by increasing the number of busbars with negligible increase shadowing losses on the frontside.

MWT SOLAR CELL PROCESSING

For the production of MWT cells, two alternative process sequences were investigated (process flows displayed in Figure 2). Both processes include a screen printed and fired Al-BSF as suggested by Jooss et al. for multi-crystalline cells using electroless plating [3]. This promises a better passivation of the rear side compared to an evaporated and co-diffused Al-BSF as was used in earlier studies [4].

In general, the process sequences for the production of back contact solar cells with electroless metallization are very similar to those used for conventional buried contact cells. This is because the contacts are formed in chemical baths where metal is deposited on catalytic surfaces regardless of the contact geometry. In the case of MWT cells, the metallization of the holes connecting the fingers on the front side of the cell to the busbars on the rear side does not require an additional processing
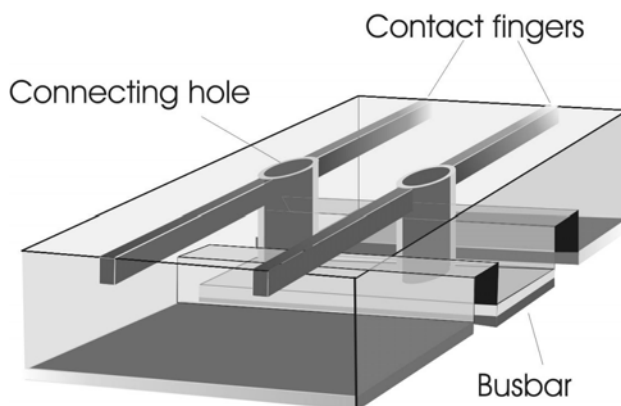

Fig. 1: Schematic drawing of a Metallization Wrap Trough (MWT) solar cell. The n-type busbars are shifted from the front side to the same position on the rear side of the cell. The interconnection to the fingers, which remain on the front side, is realized through holes. With our process, the separation of the n- and p-type regions on the rear side of the cell is realized by diced trenches.
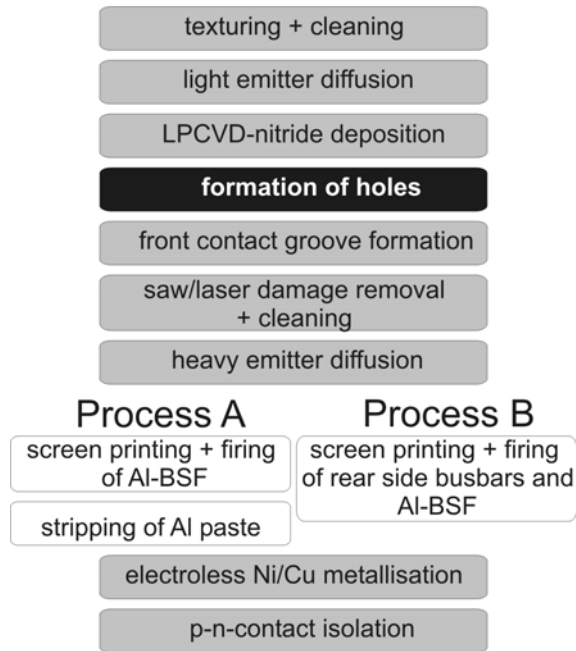
Figure 2: Process flow used for the processing of MWT solar cell with electroless plating.

	J_{sc}	**V_{oc}**	**FF**	**Eta**
	[mA/cm^2]	[mV]	[%]	[%]
Process A	36.1	619	73.0	16.3
Process B	36.5	626	72.4	16.5

Table 1: Average cell parameters of the three best cells produced with process A and B.

	J$_{sc}$	**V$_{oc}$**	**FF**	**Eta**
	[mA/cm^2]	[mV]	[%]	[%]
Process A	35.8	617	75.1	16.6
Process B	36.3	626	74.6	17.0

Table 2: Cell parameters of the best cells produced with process A and B.

step. The only additional effort necessary to process MWT cells with electroless metallization compared to conventional buried contact cells is the formation of a small number of holes (one per intersection of busbar and finger). These holes are drilled using a Nd:YAG laser with 1064 nm wavelength, which is an unproblematic and reliable technology.

The two investigated processes, named A and B, differ in the metallization of the cell. In process A, electroless plating is applied for the metallization of all contacts, namely the front grid, the n-type busbars on the rear side and the base contact. In process B, electroless plating is used only for the front contacts and the rear contacts are formed by separate screen-printing of the emitter and base contacts. For both processes the n-type busbars on the rear side must be electrically isolated from the p-type region. In both cases this is realised by diced trenches.

In Process A, once the screen-printed aluminium has been fired to form a BSF, the excess aluminium must be stripped from the wafers before electroless plating. The final metallization sequence starts with the deposition of a thin nickel film. In order to achieve a satisfactory adhesion of the contacts, particularly in the regions of the n-type busbars, sintering of this nickel film is crucial. After this, a second nickel layer is deposited as a diffusion barrier for the copper, which is deposited as the last. This metallization sequence involves two challenging steps: the first is to obtain a complete, homogeneous and blister-free nickel covering, in particular on the n-type busbar regions of the rear side. The second step, the sintering of the nickel, proved to be challenging in the past. Sintering at too high temperature or in an oxygen-containing ambient can lead to spiking of the nickel

through the emitter, which significantly reduces the fill factor. On the other hand, sintering temperatures that are too low result in an unsatisfactory adhesion of the contacts.

Process B avoids this problem by using screen-printed silver paste for the metallization of the n-type busbars. In this metallization sequence, only the contact fingers on the front side are electrolessly plated.

For a comparison of Process A and B, MWT cells were processed from the same Cz-Si material. Processing was done in parallel except for the different metallization sequences.

CELL RESULTS

The average cell results of the best 3 cells produced with processes A and B are listed in Table 1. Both cell processes result in efficiencies above 16%. Despite the fact that the cells were made from the same material and were processed in parallel where possible, average V$_{oc}$ and J$_{sc}$ differ significantly for the two processes. This indicates that process A leads to a degradation of the Cz-Si used. The degradation also becomes apparent in the EQE measured for two sample cells (see Figure 3). For wavelengths above 800 nm the EQE for the cell produced with process A clearly lies below that of process B. Since no significant difference in reflection was observed for wavelengths below 1000 nm (see Figure 4) this can only be explained by a reduction in effective diffusion length. We suppose that the degradation is caused by meta-stable defects generated during the sintering step (approx. 10 min at 350°-400°C in an infra-red furnace). The defects were found to degenerate with an annealing step at 200°C, which is also shown in Figure 3. After annealing V$_{oc}$ improved from 616mV to 626mV. No significant impact on the EQE was found when annealing the sample of process B. The remaining difference in EQE of the annealed process A sample for wavelength above 1000nm compared to the process B sample is due to different optical reflection on the rear (see Figure 4). The screen-printed Al contact used in process B proves
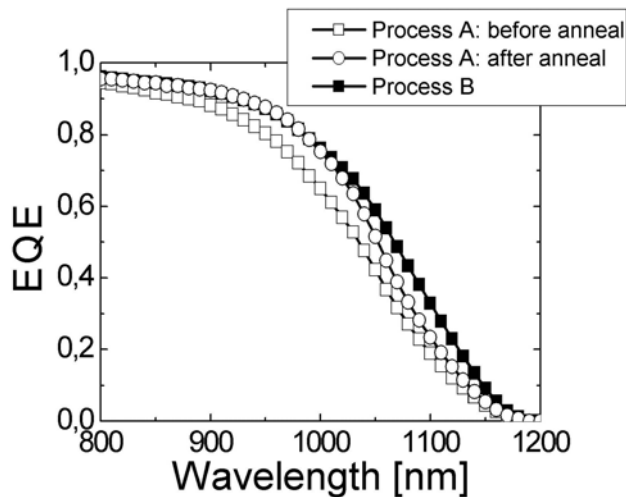
Figure 3: EQE of cells made using processes A and B. EQEs were scaled to compensate for a slightly different shading of the front grids. Process A leads to a generation of meta-stable defects, which cause a decrease in the EQE for wavelengths above 800nm. The defects can be degenerated with an annealing step, leading to an increase in EQE. The remaining difference in EQE is due to different reflectivity of the rear side of the cells.

to be a better reflector than the stripped contact covered with sintered nickel used in process A.

Fitting the parameters of the 2-diode-model from dark and illuminated I-V-curves reveals another interesting difference between the two processes. In both cases, the cells do not fit well to the 2-diode-model. Fitting the curves leads to a quality factor of approximately 4 for the second diode. This indicates the existence of Schottky-shunts. Thermographic log-in measurements for shunt
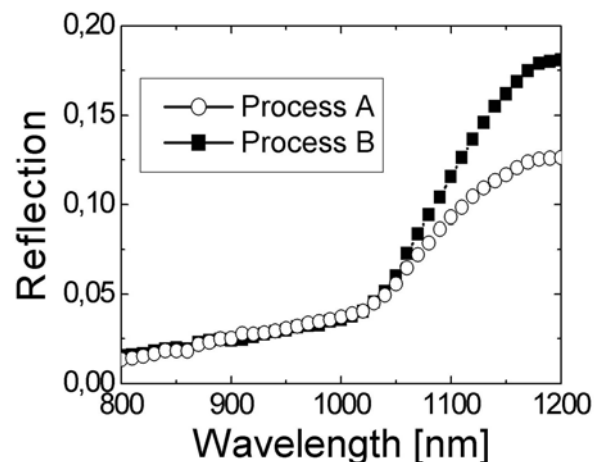

Figure 4: Reflectance measurements of cells made using processes A and B. The reflection of the front grid was subtracted. Below 1000nm the curves hardly differ. Process B results in a higher reflectivity of the rear side of the cell. This increases the measured reflectance for wavelengths above 1000nm.

detection [5] show, that in both cases, heat is mainly generated in the busbar regions. In process A, they are probably formed due to non optimal sintering conditions. In process B, silver paste is screen-printed on bare silicon (without nitride) for busbar metallization. The combination of the paste used and the non-optimised firing parameters probably led to the formation of Schottky-shunts. In process B, however, the problem is less severe and the linear shunt remains unaffected (above 10000 Ωcm^2). This is in contrast to process A, where most linear shunt resistances were below 1000 Ωcm^2, although shunt resistances up to 2000 Ωcm^2 were reached.

Cells made using process B tend to suffer from higher series resistances (above 1.0 Ωcm^2). It is possible that the electrical contact between the plated front contact and the screen-printed busbar is not satisfactory, but could also be explained by a difference in the thickness of copper deposited in the front grooves. With process A, series resistances were fitted to be around 0.8 Ωcm^2, which is very good for a back-contact cell.

Fill factors are limited by different effects for the two processes. Nevertheless, similar fill factors were measured for both cell processes.

CONCLUSIONS

The MWT solar cells obtained from both processes show very good performance (η=16.6% and 17%). Efficiency of the two processes differs probably due to the generation of meta-stable defects in process A. These defects were found to be easily degenerated in an annealing step. Thus, considering only cell performance, neither of the processes can be favoured.

Optimisation of process parameters could lead to a further increase in cell performance for both approaches. In process B, this is mainly the identification of a suited silver-paste and adjustment of firing conditions. Furthermore the contact between the electroless plated finger grid on the front side and the screen-printed busbar needs to be investigated.

The main challenge with process A is the development of a reliable metallization sequence. The formation of contacts that provide both good electrical and mechanical properties remains difficult up to this point.

ACKNOWLEDGMENT

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