LOW TEMPERATURE PADS ON Al-EMITTER OR Al-BSF

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ABSTRACT: Screen printed Si solar cells are commonly interconnected in modules with straps soldered to their busbars on the front and the AgAl pads on their back. We present a new method for applying AgAl pads on fully covered Al backsides. This method is of great interest because it can be used to apply AgAl pads on screen printed Al rear side emitters of n-type p+nn+ Si solar cells. That makes their industrial production feasible. The method developed here can also be implemented to increase the open circuit voltage of an n+pp+ standard industrial cell due to a fully covering Al-BSF on the rear side.
Keywords: n-type Si solar cell, Al rear side emitter, AgAl pads

1 INTRODUCTION

The overall perspective of our work is finding a cheap and easy applicable way to produce industrial n-type rear side Al-emitter Si solar cells in a standard p-type process line.

In recent time the advantages of n-type base Si cells are being elaborated with respect to lower light induced degradation and higher diffusion lengths. Efficiencies higher than 17% based on the Al rear side emitter concept already have been reported by Mihailetchi et al. [1] and others. Low cost realisation will make the industrial introduction of this process feasible. As pointed out by Kopecek et al. [2] one of the challenges on the way to industrial production is stable cell-cell connection for which we present one solution in this paper.

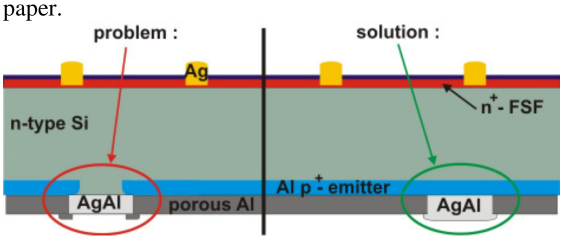

Figure 1: schematics of an Al rear side emitter cell; a standard p-type printing process as shown on the left would lead to shunting of the device below the AgAl pads; for a homogeneous Al emitter AgAl pads have to be applied after emitter formation on the whole cell area

Our new method provides an easy way to produce solderable industrial n-type base Al rear side emitter Si solar cells with high efficiency using a standard p-type process. Figure 1 shows the idea of our new design. To permit contacting of the emitter and soldering connections for module assembly, only two more simple production steps are necessary. This effort must be taken because an AgAl /Al sandwich structure does not stay stable after soldering of a connection strap [2]. Also, Al paste is needed on the whole cell area for uniform emitter formation and avoiding of internal shunts. AgAl pads cover around 7% of the rear cell area. Without this loss in BSF coverage an increase of Voc for p-type screen printed solar cells can be expected.

Our new process can also be applied to use archivated research cells with fully Al covered rear side. They can be put to use again in development aid as suggested in the SLAK-project founded at ISC Konstanz.

2 EXPERIMENTAL METHODS

2.1 Process

A standard p-type Si screen printed solar cell process is run with n-type material. First changes are made after PECVD ARC coating as shown in figure 2. Newly added steps are relevant for n-type Al rear emitter cells and fully Al covered p-type standard cells respectively. For convenience of explanation only n-type cells are mentioned.

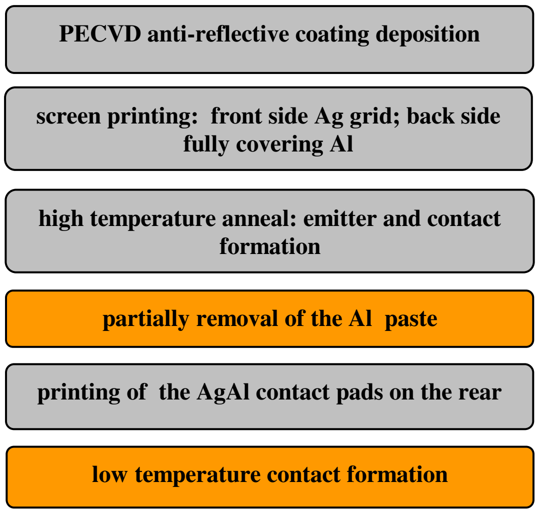

Figure 2: process flow chart after alkaline texture and P-diffusion; orange fields indicate additional process steps

Screen printing is performed as usual on the front side. The rear side is fully printed with Al paste. Then, front contact and rear emitter are formed by co-firing. Next, the porous Al layer on the rear is removed locally where the AgAl pads will be applied. Afterwards, AgAl paste is screen printed on the opened areas. In a subsequent low temperature annealing step of about 700°C the contact between pads and Al-emitter is formed.

2.1.1 Ablation of the pad region

For the removal of the already co-fired porous Al layer various methods can be exploited. Local wet chemical etching, a sand jet or other solutions are possible. In our lab scale experiments we use a multifunction rotary tool mounted with a steel brush.

With the help of a pad shaped stencil structure, 3 mm wide openings are grinded into the Al layer. This process leaves the underlying Si surface polished. Since the screen printed pads are 5 mm wide, there is an overlap of 1 mm on each side. This guarantees the connection between the pads and the Al layer. After the procedure cells are cleaned from dust with an N_2 gun.

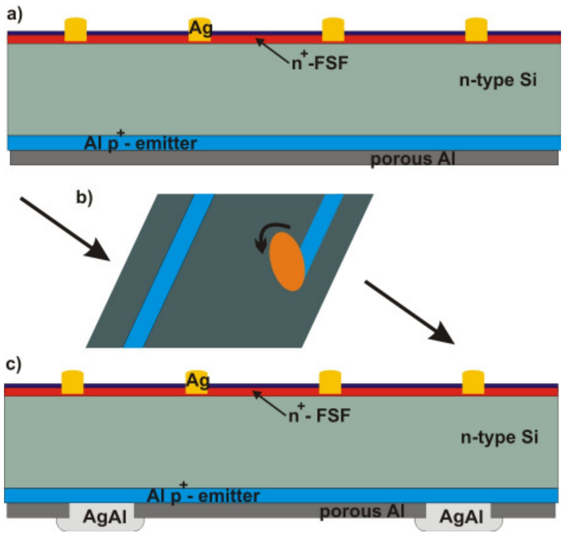

Figure 3: schematic procedure of the pad removal, note that Ag fingers and AgAl pads are drawn parallel a) cross section of the Al rear emitter cell with fully covering Al layer b) to view : ablation of the porous Al layer c) cross section view of the solderable device after pad printing

2.1.2 Pad printing

Equal to a standard process AgAl pads are printed on the cell. As paste we use a commercial AgAl pad paste and one special low temperature paste which is designed for glass as carrier substance. Different than usual, the overlap between Al layer and AgAl pad leaves the latter on top.

2.1.3 Low temperature annealing step

The second firing step is used for contact formation of the AgAl pads with the Si bulk material. Since front contacts and the aluminium silicon alloy are already formed, high temperatures are not desired. Only in respect to soldering stability a temperature treatment is needed. For our experiments we use a six zone IR belt furnace (by Centrotherm).

3 RESULTS AND DISCUSSION

3.1 N-type cells with Al rear emitter

In one first experiment fully Al covered n-type Al rear emitter cells are produced. Wafers are from cz material with a base resistivity of approximately 2 Ωcm and a size of 155.2 x 155.2 mm². Due to edge isolation processed cells are 154 x 154 mm². All IV measurements mentioned in this paper are made with GP sun test equipment under one sun illumination.

An efficiency of 15.9% is reached with this first try on large area fully screen printed cells. 17% percent are in range by enhancing the low fill factor of average 73.7% up to 79%. For the continuation of the experiment 154 x 154 mm² cells are cut to a batch of 50 x 50 mm² cells. After IV measurements the Al layer is removed as described in section 2.2.1. Due to the small substrate size, standard AgAl paste is deposited with brush and spatula.

The second annealing step is performed at three different temperature settings: The last two zones of the IR belt furnace are set to a standard firing temperature, 700 °C and 650 °C. Next, IV measurements are repeated.

Table: IV results; white: before pad removal; yellow: after second annealing step, for each temperature 6 cells are fired

max. firing temp.	η [%]	Jsc [mA/cm²]	Voc [mV]	FF [%]
650 °C	14.6 ± 0.9	33.8 ±0.3	616.9 ± 2.4	69.8 ± 3.6
	14.4 ± 1.3	33.9 ±1.3	614.1 ± 3.8	69.0 ± 3.8
700 °C	15.7 ± 0.3	34.2 ± 0.3	619.6 ± 1.4	74.1 ± 1.2
	15.6 ± 0.3	34.0 ± 0.3	617.5 ± 1.2	74.2 ± 1.2
840 °C	15.0 ± 0.9	33.5 ± 0.4	617.9 ± 2.4	72.4 ± 4.5
	15.0 ± 0.6	33.2 ± 0.6	614.1 ± 0.7	73.4 ± 2.8

The table shows the results before pad removal (white) and after second annealing (yellow). For each temperature setting of the IR furnace six cells are fired. For the two last groups within the errors of measurement no change in cell performance occurs. Figure 4 shows a cross section SEM image of one of the 50 x 50 mm² cells. In the upper half, Si bulk, the Al emitter and porous Al are visible in a stack (left to right).The half below shows the beginning of a AgAl pad. Also here the line of the Al emitter Si bulk interface is straight. This shows the conservation of the emitter structure.

3.1.1 Soldering stability

In order to guarantee stable cell-cell interconnections, soldering experiments have to be conducted. A strap is soldered on the previously applied AgAl pad. The stability of the strap-cell connection is tested by ripping off the strap. If it results in residuent spots of bare silicon and the destruction of the cell, soldering stability is proven. Soldering temperature is 350 °C. Soldering straps are attached with the help of commercial soldering lead and welding flux. Experiments show that a second annealing temperature of 700 °C is sufficient to enable stable connection between AgAl pad and the solar cell.

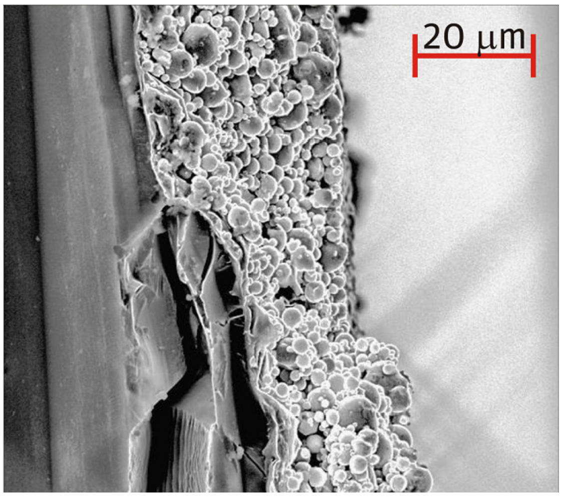

Figure 4: SEM cross section image of an n-type cell with AgAl pad; the vertical line on the left shows the border between Si bulk (left) and Al-emitter (right, grey); the Al-emitter obviously stays unharmed during pad removal

3.2 p-type cells

p-type Cz wafers sized 156 x 156 mm² are processed according to section 2. IV measurements are performed with fully Al covered rear, after pad removal and after pad printing. A total of 60 wafers are divided in ten groups for testing different conditions for the low temperature firing step.

All maximal temperatures are low compared to standard firing parameters. Zone five and six of the IR belt furnace varied between 600 and 700 °C for the low temperature anneal.

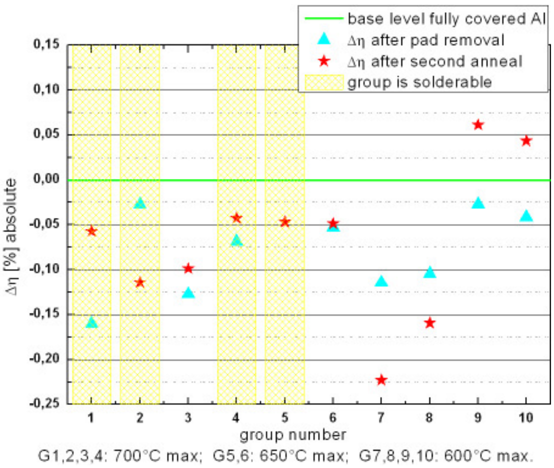

Figure 5: deviation from the first measured efficiency of p-type cells after pad removal (cyan) and after second annealing (red); temperatures on the bottom refer to the maximal annealing temperature for each group; groups inside the yellow bars are solderable

Figure 5 shows the deviation of the average efficiency from the fully Al covered state after pad removal and second anneal. For each group, the average measured efficiency with fully covering Al is set as base level (green line figure 5). The cyan triangles mark the deviation in absolute per cents of the efficiency after pad removal to the first measured vale. The red stars mark the change in absolute per cents between the fully Al covered cells and the same cells after pad printing and firing. The four groups in the yellow bars show a stable strap-cell connection. Soldering is done according to section 3.1.1 at 260°C.

4 CONCLUSIONS

We present a novel method for applying AgAl pads on a prior Al covered area of a screen printed solar cell. This process opens the possibility to industrially produce n-type Al rear emitter solar cells. For both, n- and p-type solar cells with Al-emitter or -BSF further optimisation is needed to exceed the starting efficiency of the fully Al covered cell.

Our results show, that neither the abrasion process nor the low temperature annealing step harm the efficiency of the considered solar cells. With further experiments firing configurations for either n- or p-type cells can be found which could give even more favourable results. Also the use of pure Ag paste for the pads could lead to further improvements.

ACKNOWLEDEGEMT

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