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Next – generation interdigitated back-contacted silicon heterojunction solar cells and modules by design and process innovations

NEXTBASE
THE NEXT GENERATION BASELINE

NextBase - Deliverable report

D6.3 IBC HJT cells processing with a throughput > 10 wafers/hour.

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Publishable summary

The objective of this deliverable consists of transferring the IBC tunnel technology developed in WP5 in a mass production scalable form. This report presents a 23.8% cell (V_{oc}=730mV; FF=79.72%; J_{sc}=40.8mA/cm^2) on an industrial CZ wafer over large area (90.25 cm^2) using an industrial compatible shadow masking technology for the PECVD deposition of microcrystalline silicon. An efficiency gap of 1% absolute remains with the record lab-scale device mainly attributed to FF loss (1.5%) due to non-optimum contact resistance and J_{sc} loss (0.9mA/cm^2) due to lower infrared absorption when using thinner wafer. An optimum backside reflector allows the recovery of the J_{sc} loss, even if this optimization has not been able to maintain yet the same level of FF and V_{oc}. Finally, we show the capability of the developed PECVD tool using the shadow masking technology to reach a throughput of twelve wafer per hour. The next focuses will be the process stabilization, the upscaling to full 6 inches area and the transfer of the produced IBC SHJ solar cells to the module activities.

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List of acronyms, abbreviations and definitions

Table 0.1 Acronym table

Abbreviation	Explanation
***a*-Si:H**	Hydrogenated amorphous silicon
FF	Fill factor
IBC	Interdigitated back contact
***nc*-Si:H**	Hydrogenated nano-crystalline silicon
SHJ	Silicon heterojunction
TCO	Transparent conductive oxide
V_{oc}	Open-circuit voltage

1 Introduction

The final goal of WP6 is to transfer and upscale the tunnel IBC technology developed by EPFL & CSEM from small area devices to industrial PECVD reactors and large area solar cells. The work package is split in three tasks, namely the tool specifications for high quality silicon patterned layers (T6.1, due in M6), the tool upgrade and mask manufacturing to reach the best patterned tunnel junctions (T6.2, due in M18) and the development of IBC SHJ solar cells on large area silicon wafers (T6.3). Moreover, in order to identify the key points towards a mass production of such new technology, the tunnel IBC technology, expected the masking step, is deployed using large area tools (PECVD & PVD) from Meyer Burger.

Deliverable Number	Deliverable name	Lead partner	Type	Dissemination level	Due date
D6.3	IBC SHJ cells processing with a throughput > 10 wafers/hour	MBR	DEM	CO	M24

2 Results

1.1 Efficiency results

The best cell efficiency measured on industrial N-type 155um Czochralski wafer achieved an encouraging 23.8% on a defined 90.25cm^2 area. This intermediate step size towards a full 6 inches solar cell is an important and successful milestone demonstrating the technology potential on industrial and thin wafer.

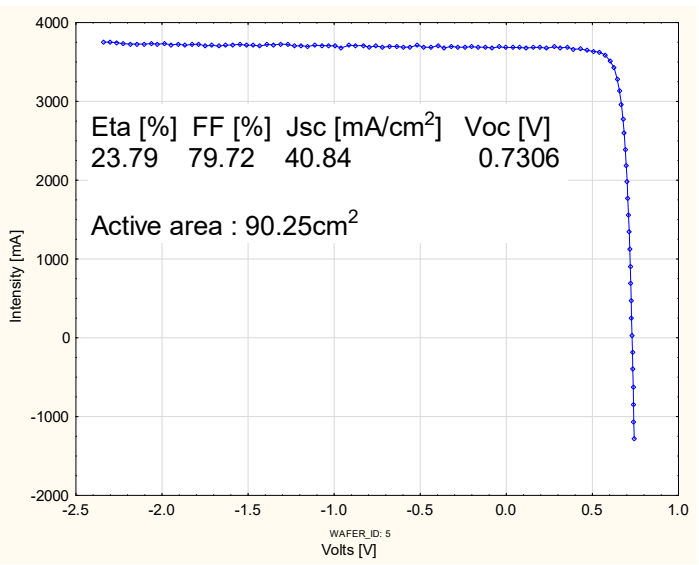


Figure 1. left: IV curve and main IV parameters of the best device produced in WP6 using the novel masking technology developed. Right: front and rear side pictures of IBC HJT on 6 inches wafer.

This achievement has been obtain by optimizing both processes and the mask technology. The list below presents the main modifications:

- A redesign of the mask to improve the layer nc-Si:H transfer.
- An optimization of the nc-Si:H layer to improve the emitter contact resistance.
- A front and rear side a-Si:H(i) optimization to decrease both the front parasitic absorption and the rear transport losses.
- A process optimization of the SiN front side layer to maintain high passivation quality.
- A modification of the rear IBC design to decrease the contact resistance losses.

1% absolute efficiency gap remains between lab-scale record device presented by WP5 and the present result:

	Wafer, size	Eta(%)	FF(%)	J_{sc}(mA/cm^2)	V_{oc}(mV)
Record Lab scale device (WP5)	FZ, 280um, 25cm^2	24.8	81.2	41.7	733
Record WP6	CZ, 155um, 90.25cm^2	23.8	79.7	40.8	730
Delta		***1***	***1.5***	***0.9***	***3***

In order to reduce the efficiency gap between lab-scale device and the intermediate size developed in WP6, the focus will be on the next following items:

- V_{oc}: Previous IBC SHJ solar cells developed in WP6 reached already the same level than lab-scale devices demonstrating the feasibility. The delta V_{oc} of this record cell is attributed to the amount of scratches let by the manual handling during the wafer processing. A difference of 3 mV in Voc is insignificant.
- J_{sc}: A difference of 0.9mA/cm^2 is observed between both solar cells, due to less absorption of the infrared light on the thin 155um wafer. This effect can be recover using an optimum backside reflector as shown in the IQE/EQE below (90.25cm^2 IBC SHJ solar cell) where a J_{sc} of 41.8mA/cm^2 was measured (155um thick wafer).

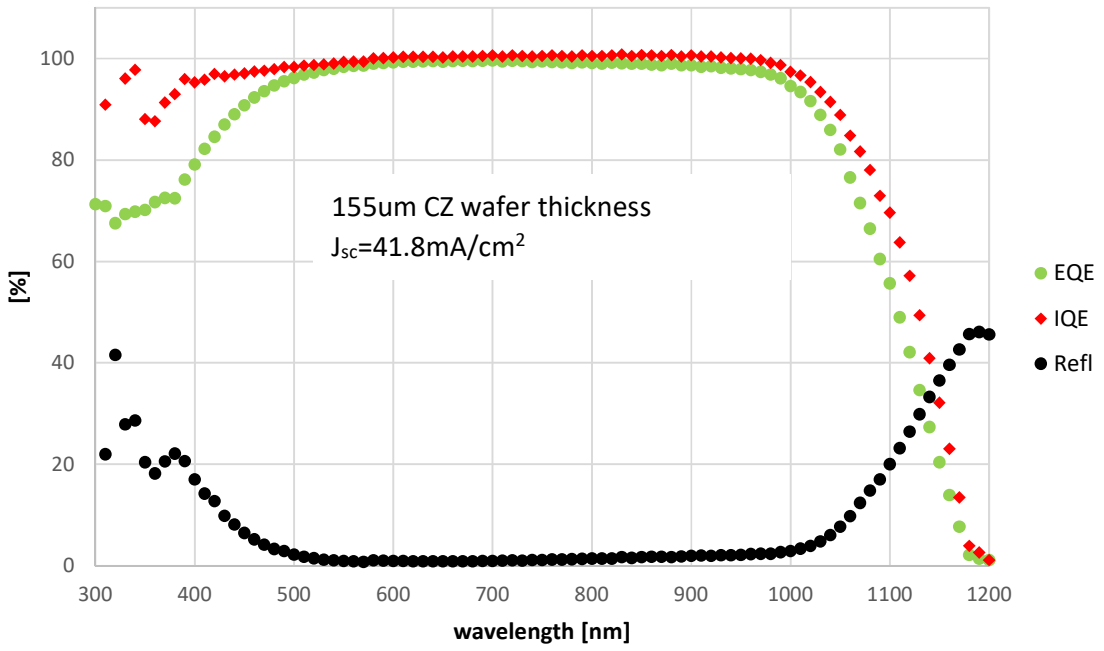


Figure 2. IQE/EQE of 90.2cm2 IBC HJT using an optimum backside reflector allowing the recovery of the infrared loss in thin wafer.

- FF: 1.5% absolute difference remains; mainly attributed at that time to a non-yet perfect masking solution and a still higher contact resistance value for the emitter. Both items need further improvement to reduce the gap between lab scale device and the intermediate size of 90.25cm^2 solar cell developed in WP6.

1.2 In situ masking PECVD throughput

The target of the task 6.3 was to transfer the IBC SHJ tunnel technology to industrial size PECVD and PVD production platform; expected the masking solution developed on lab-scale PECVD platform during this project.

Figure 3. Large view of the modified AK-1000 PECVD tool from Meyer Burger.

The tool has a low throughput of only 12 wafers per hour, mainly due to the absence of automation. Thus, the tact-time is not fully representative of what can be expected in mass production, but is sufficient to develop and demonstrate the feasibility of the new mask technology.

To monitor the real PECVD throughput, we present in the figure 4 below the trend of the PECVD pressure over sixty minutes when IBC HJT solar cells where manufactured. Each of the run correspond to a load of four wafers; thus, twelve wafers were processed within the target of sixty minutes.

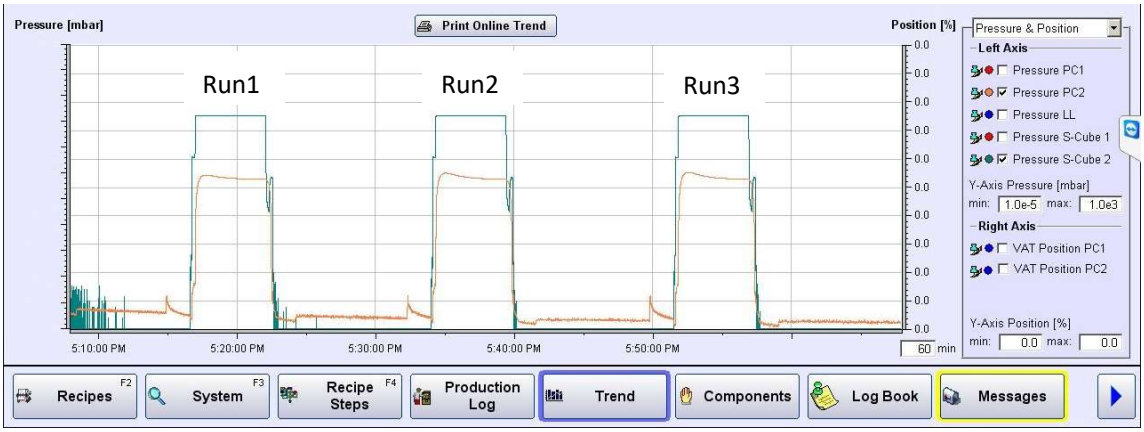
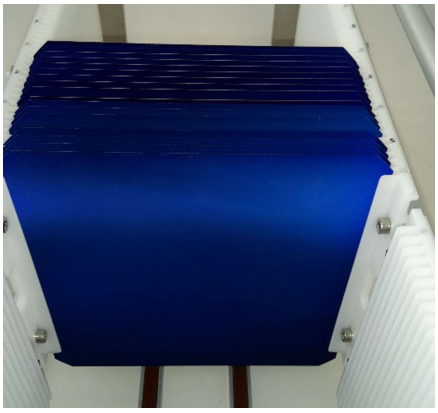


Figure 3. screen shot of the PECVD pressure (arbitrary unit) reactor trend during three consecutive runs of IBC HJT solar cells.

The last picture shows a typical IBC SHJ daily small production (25 cells) in the MBR facilities. Forty to sixty solar cells/week are manufactured depending on the experimental plan.



2 Risks and interconnections

2.1 Risks

Despite good progress on the solar cell efficiency, the process stabilization of nc-Si:H layers is not yet finalized. Ongoing work started to understand the deposition and stability over time of those layers that are critical to reach high efficiency solar cells.
New masks have shown better results than previous months and continuous work is running to improve the design and alignment when moving to full area solar cells. The risk associated to the mask decreases compared to the previous period but cannot considered as null.

2.2 Interconnections

All solar cells are transferred to WP8 for the encapsulation tests (actually 90.25cm^2). Their quick feedback will be used as a guide for the improvement of the back-end of solar cell if required. Full area solar cells are planned beginning of October 2018 for single cell encapsulation. If successful, mini-module (4x4 or 9x9 cell) are planned to demonstrate the interconnection concept.

3 Conclusions

The last task 6.3 showed good progress on the IBC SHJ efficiency with a record efficiency of 23.8% on a 90.25cm^2 solar cell. The monitoring of the modified AK platform including the in-situ masking solution demonstrated the capacity to reach twelve wafers per hour. Next challenges during the coming months are the process optimization to push the FF above 80%, stabilize the efficiency and move the solar cell size to a full 6 inches area. All the solar cells are transferred to WP8 for the first tests of IBC SHJ encapsulation despite a reduced area.
We can conclude that the task 6.3 “IBC HJT cells processing with a throughput > 10 wafers/hour“ was successful.