EUROPEAN COMMISSION

HORIZON 2020 PROGRAMME
TOPIC H2020-LCE-07-2016-2017
Developing the next generation technologies of renewable electricity and heating/cooling

GA No. 727523

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

NEXTBASE
THE NEXT GENERATION BASELINE

NextBase - Deliverable report

D5.3- IBC-SHJ device with efficiency ≥ 26.0% on 6-in wafer

Deliverable No.	NextBase D5.3	
Related WP	WP5	
Deliverable Title	IBC-SHJ device with efficiency ≥ 26.0% on 6-in wafer	
Deliverable Date	2019-09-30	
Deliverable Type	DEM	
Dissemination level	Public	
Author(s)	Bertrand Paviet-Salomon	2019-09-09
Checked by	Frank Versluis	2019-09-18
Reviewed by	Ding Kaining (Jülich, coordinator)	2019-09-20
Approved by	Ding Kaining (Jülich, coordinator)	2019-09-20
Status	Final	2019-09-23

Disclaimer/ Acknowledgment

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727523. The information and views set out in this publication does not necessarily reflect the official opinion of the European Commission. Neither the European Union institutions and bodies nor any person acting on their behalf, may be held responsible for the use which may be made of the information contained therein.

Contents

List of acronyms, abbreviations and definitions

Table 1. *Acronym table*

Abbreviation	Explanation
ARC	Anti-reflection coating
***a*-Si:H**	Hydrogenated amorphous silicon
***c*-Si**	Crystalline silicon
Eff.	Conversion efficiency
FF	Fill factor
IBC	Interdigitated back contact
ITO	Indium tin oxide
$\mathbf{J_{sc}}$	Short-circuit current density
***nc*-Si:H**	Hydrogenated nano-crystalline silicon
$\mathbf{R_{series}}$	Series resistance
SHJ	Silicon heterojunction
SiNx	Silicon nitride
TCO	Transparent conductive oxide
$\mathbf{V_{oc}}$	Open-circuit voltage

1 Introduction

D5.3 provides a status of the champion IBC-SHJ devices processed in the frame of NextBase. The final IBC-SHJ architecture – featuring a tunnelling electron contact – is presented, as well as its process flow with a single PECVD patterning step via shadow mask. The best demonstrated efficiencies with this approach are of 25.4 % on 25 cm^2 FZ wafer, and of 25.35 % on 92 cm^2 Cz wafer. A loss analysis explaining the deviation to the targeted 26.0 % efficiency is provided, and the path to achieve higher efficiency is discussed.

Deliverable Number	Deliverable name	Lead partner	Type	Dissemination level	Due date
D5.3	IBC-SHJ device with efficiency ≥ 26.0% on 6-in wafer	CSEM	DEM	PU	M36

1 NextBase's champion IBC-SHJ devices

Figure 1 plots the evolution of the efficiency of the IBC-SHJ champion devices obtained using the different patterning techniques and associated process flows under investigation in WP5 (see D5.1 report for details) during the whole duration of the NextBase project.

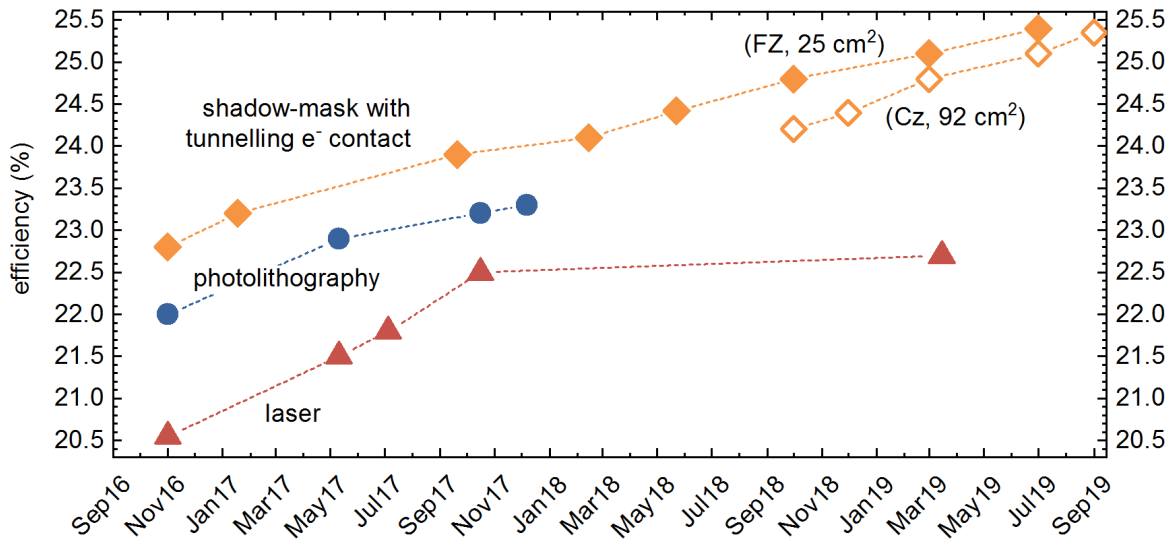

Figure 1. Evolution of the efficiency of the champion devices for each patterning technique under investigation in WP5 during the NextBase project.

As can be seen, even if regular progresses were recorded with all investigated patterning schemes, the efficiencies are eventually topped by IBC-SHJ devices processed using the combination of shadow mask as a patterning technique and a tunnelling electron contact [1]. The architecture of these devices is depicted in Figure 2, and their process flow in Figure 3. Such devices demonstrated efficiencies close to 25.5 % both on 25 cm^2 FZ wafers and on 92 cm^2 Cz wafers. Note that the transfer of this technology on full M2 Cz wafers is ongoing and already reached 24.25 % efficiency. Figure 4 below presents the full I-V curves of these best devices.

Remarkably, note that this approach – combining shadow mask patterning with a tunnelling electron contact – allows to reach > 25 % efficiency with only 9 process steps, probably making it one of the leanest process flows for IBC-SHJ devices.

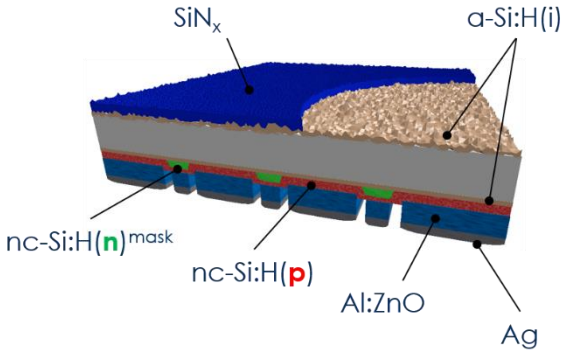

Figure 2. Architecture of an IBC-SHJ device with tunnelling electron contact.

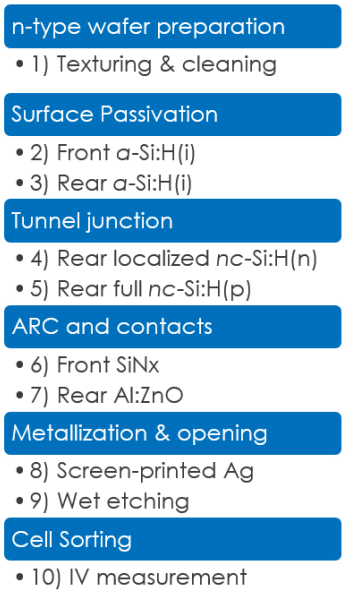

Figure 3. Process flow of IBC-SHJ devices with tunnelling electron contact patterned via shadow mask.

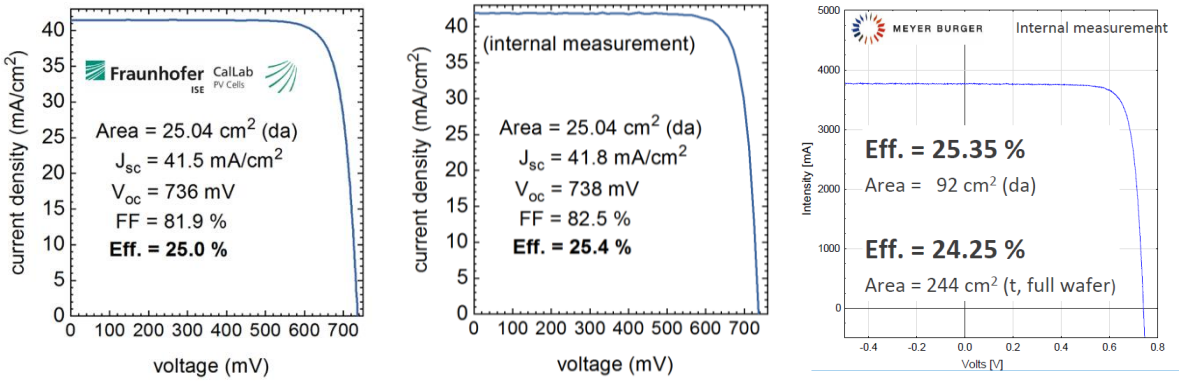

Figure 4. Champion IBC-SHJ devices obtained in the frame of NextBase.

2 Loss analysis & roadmap towards higher efficiency

In spite of the impressive results presented in Section 1 above, the highest demonstrated efficiency falls short to the 26.0 % value targeted in NextBase. Table 2 below compares the key performance indicators for the 25.4 % efficient IBC-SHJ device (presented in Figure 4 middle) to those required for a 26.0 % efficient device.

Table 2. Comparison of the key performance indicators for the 25.4 % efficient IBC-SHJ device (presented in Figure 4 middle) to those required for a 26.0 % efficient device.

	J_{sc} (mA/cm^2)	V_{oc} (mV)	FF (%)	Eff. (%)
26.0 % target	42.0	730	85	26.0
25.4 % NextBase's best device	41.8	738	82.5	25.4

As can be seen from Table 2, the J_{sc} of the champion device falls a bit short to the 42.0 mA/cm^2 target, but this small loss is entirely compensated by the over-performing V_{oc} of the NextBase's champion solar cell (738 mV *vs.* an anticipated value of 730 mV). In contrast, the major reason for the final efficiency to fall short to the 26.0 % targeted value is to be found in the FF value, which is 2.5 $\%_{abs}$ lower than the targeted one. To explain the reasons for this deviation, Figure 5 plots the R_{series} loss analysis of our champion device using the latest series resistance modelling for IBC-SHJ devices [2].

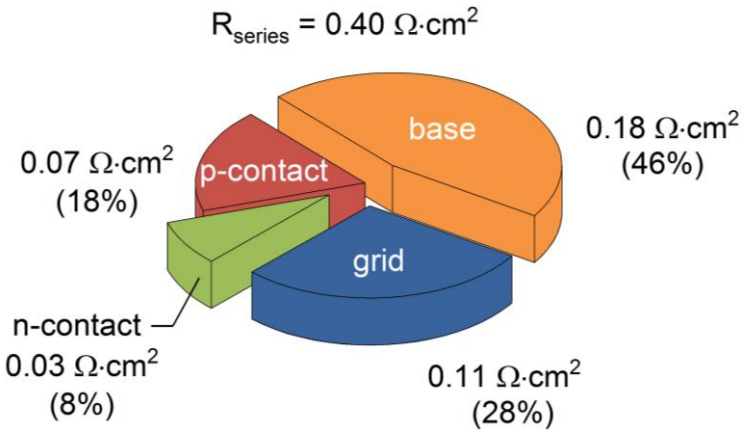

Figure 5 clearly pinpoints that the major contribution to the overall R_{series} of our IBC-SHJ champion device lies in the lateral base resistance owing to the 2.5 mm pitch currently used in this best device. Numerical simulations performed in WP8 already provided the reduced pitch values expected to unlock the path to higher FF values (see D8.5 report). Their practical implementation into IBC-SHJ devices is ongoing, but is yet hindered by technical challenges.

3 Conclusion & outlook

This deliverable reports on the champion IBC-SHJ solar cells demonstrated in the frame of NextBase. Up to 25.4 % efficiencies were demonstrated on 25 cm^2 FZ wafers and on 92 cm^2 industrial Cz wafers. These results are the European record to date for such solar cells technology. The path towards even higher efficiency has been clearly identified – especially regarding the need to mitigate the lateral transport losses – and the technological building blocks required to reach this goal are under development.

4 References

[1] A. Tomasi *et al.*, “Simple processing of back-contacted silicon heterojunction solar cells using selective-area crystalline growth,” *Nat. Energy*, vol. 2, no. April, p. 17062, 2017.

[2] D. Lachenal *et al.*, “Optimization of tunnel-junction IBC solar cells based on a series resistance model,” *Sol. Energy Mater. Sol. Cells*, 2019.