SABC back-contact cell technology

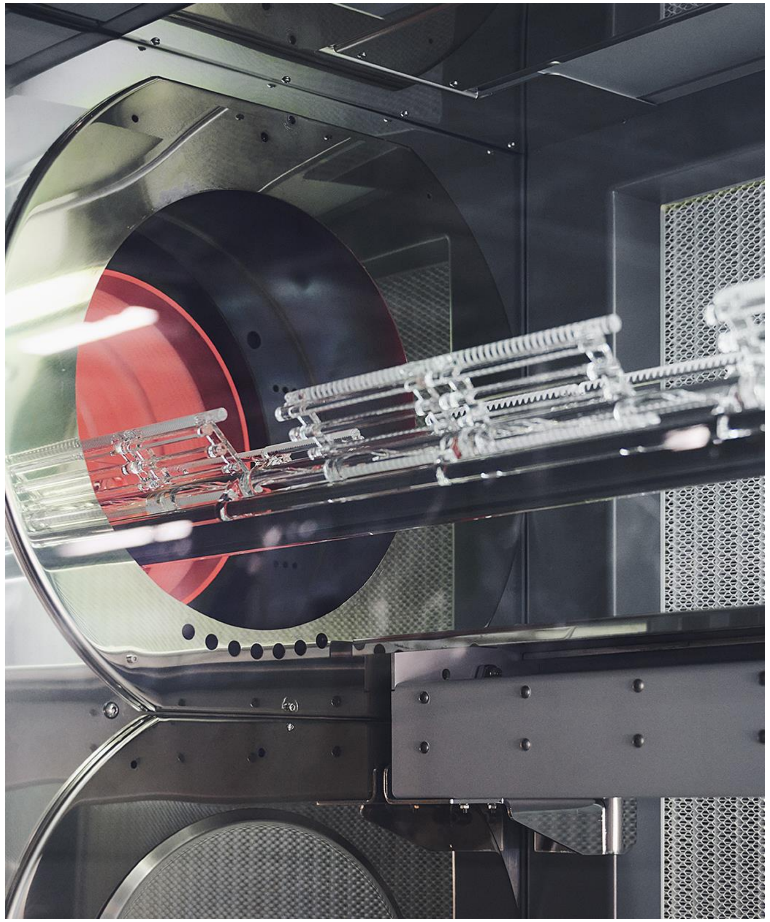
Massimo Centazzo, EnPV GmbH

PV CELLTech USA 2024, San Francisco, October 8th 2024

Content

EnPV: founded by a utility company consistently focusing on renewables

- EnPV GmbH is a subsidiary of EnBW Energie Baden-Württemberg AG, a leading European utility company.
- Based in Germany, EnBW puts a strong focus on renewable energy in Europe, currently operating 3.5 GW_p wind and solar parks – with 22 GW_p in the pipeline.
- EnPV is part of EnBW's research portfolio. EnPV is focused on next-generation PV-technology:
  - in Sep 2017 EnBW started a project in collaboration with University of Stuttgart to develop a cost-effective IBC cell;
  - at the end of 2017 EnBW transferred the project to EnPV GmbH, to exploit commercially the project's results;
  - in 2024 EnPV presents its proprietary technology SABC[1], a highly competitive TOPCon IBC cell architecture with significantly reduced production cost compared to TOPCon.
- **EnBW wants EnPV to industrialise its assets with an exclusive partner**.



[1] Self-Aligned Back-Contact, patent pending.

Highly motivated team of leading experts in back-contact cell technology

International team with 75+ years of accumulated experience in solar cell device and production technology

- Development of SABC is driven by a dedicated team around the inventors of SABC, led by M. Centazzo
- 7 people strong team, of which 3 PhD’s in physics/electrical engineering, and 4 M.Sc. in Physics/Electrical Engineering
- international team with diversified backgrounds from Europe, Asia, and the USA
- 75+ years of accumulated experience in solar cell device and production technology
- experimental work done at ISFH[1] (Hamelin, Germany) under the leadership – and with the support of – EnPV’s team.

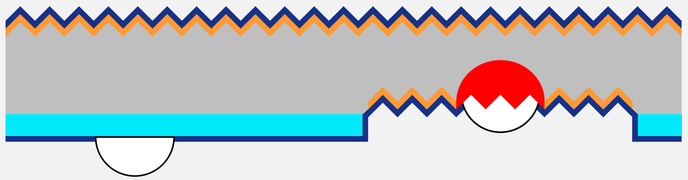
Expertise and experience in:

- LASER Physics and application;
- thermal processes and sputtering;
- wet-chemical processes;
- Quokka simulation;
- technology transfer into mass production;
- financial modelling of cell production;
- project management and funding acquisition.

[1] With the exception of the photo in this slide (source: Gorodenkoff, stock.adobe.com), all other photos in this document were taken at ISFH, with friendly permission of the same.

Capabilities for next-gen cell technology were built up in three stages

Al BSF IBC cell (2018 – 2021)
n-type IBC cell with LASER diffused base contact

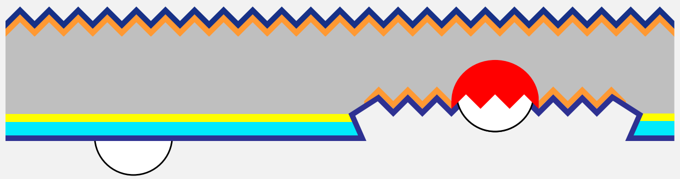


- *n*-type Si wafer
- Front/Back Surface Field
- Base contact
- B diffused emitter
- Passivating layer
- Metallisation

Boron diffused emitter
LASER diffused base contact

Potential V_{oc} = 702 mV
Achieved V_{oc} = 700 mV

HyBC (2022 – 2023)
n-type IBC cell with passivated emitter

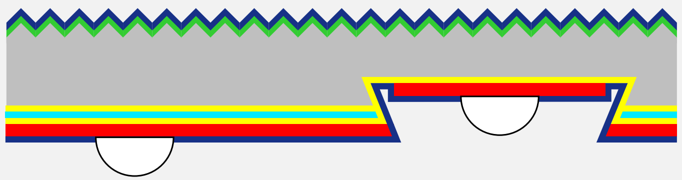


- *n*-type Si wafer
- Front/Back Surface Field
- Tunnelling oxide
- Base contact
- *p*-type poly-Si
- Passivating layer
- Metallisation

***p*-type poly-Si emitter**
LASER diffused base contact

Potential V_{oc} = 727mV
Achieved V_{oc} = 702 mV before migrating to SABC

SABC (2024 – present)
fully passivated *n*-type IBC cell with self-aligned (trench-less) phase insulation (TLI[1])



- *n*-type Si wafer
- Front Floating Emitter
- Tunnelling oxide
- *n*-type poly-Si
- *p*-type poly-Si
- Passivating layer
- Metallisation

***p*-type poly-Si emitter**
***n*-type poly-Si base contact**

Potential V_{oc} = 740 mV
Status 08/2024 V_{oc} = 708 mV

[1] Trench-Less Insulation™.

How to enable TOPCon IBC

EnPV

Zhong Baoshen, Chairman at LONGi

"

Of course, we know that efficiency and **cost are critical** factors in cell technology, but there should be a balance between the two. After exhaustive research, out of all the technologies we have explored, the objective of achieving the highest efficiency has ultimately led us to BC cells. Whether it's IBC, our own HPBC, HBC as an evolution of HIT or TBC, you can see that all these technologies ultimately lead to the BC structure. That said, **the BC structure has historically been complex in terms of the manufacturing process** and also high in cost terms, which has proven a fundamental obstacle to BC cell development.

SNEC PV+ 2023[1]

How does SABC remove these complexities?

SABC exploits self-alignment. Hence:

- SABC removes the complexity
- SABC takes care of the cost challenge

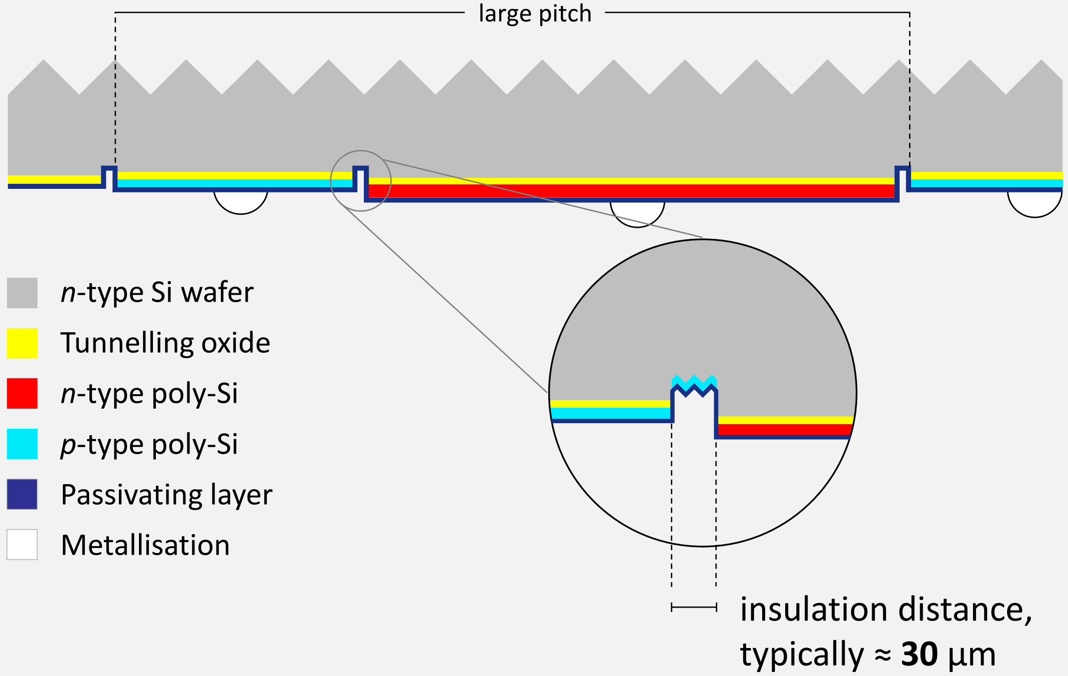
SABC‘s wafer-to-cell conversion cost are 15% lower than TOPCon‘s

[1] Source: PV-TECH.ORG.

Conquering complexity I

Self-aligned phase insulation on IBC back-side

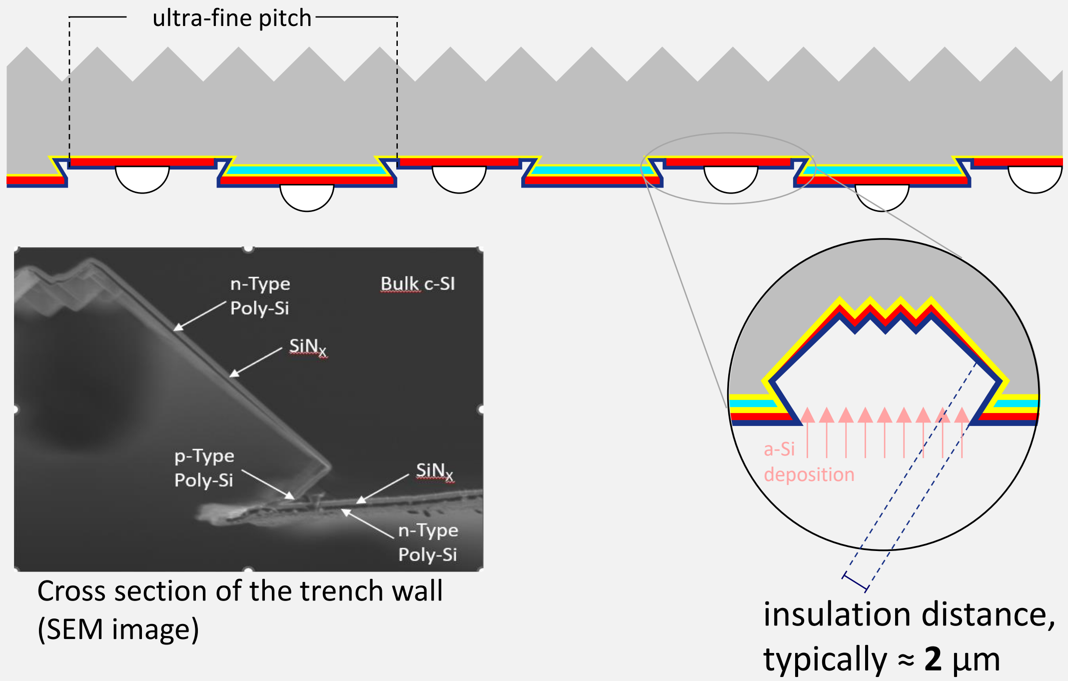
Typical IBC insulation
(simplified sketch)



Traditional trench insulation:

- complexity in terms of manufacturing;
- expensive.

SABC self-aligned insulation, TLI
(simplified sketch)



Cross section of the trench wall
(SEM image)

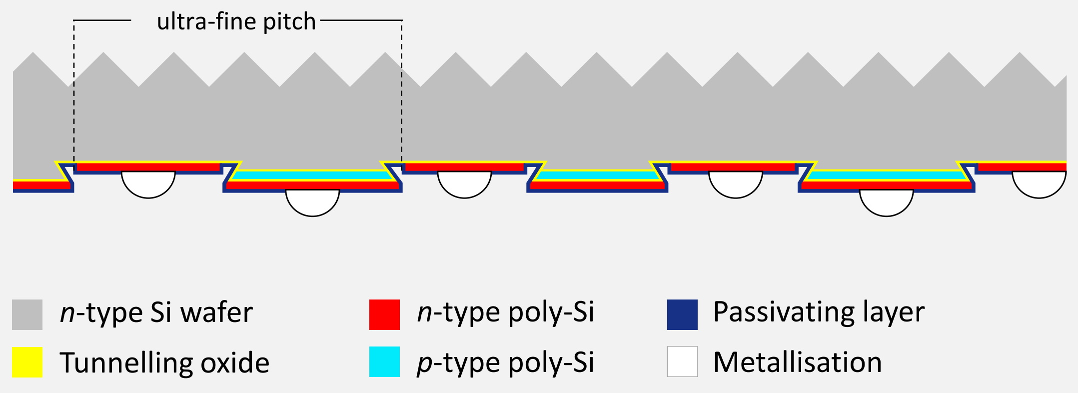
Self-alignment works through two main features:

- under-etching of a-Si, shadowing the trench walls;
- PVD a-Si deposition.

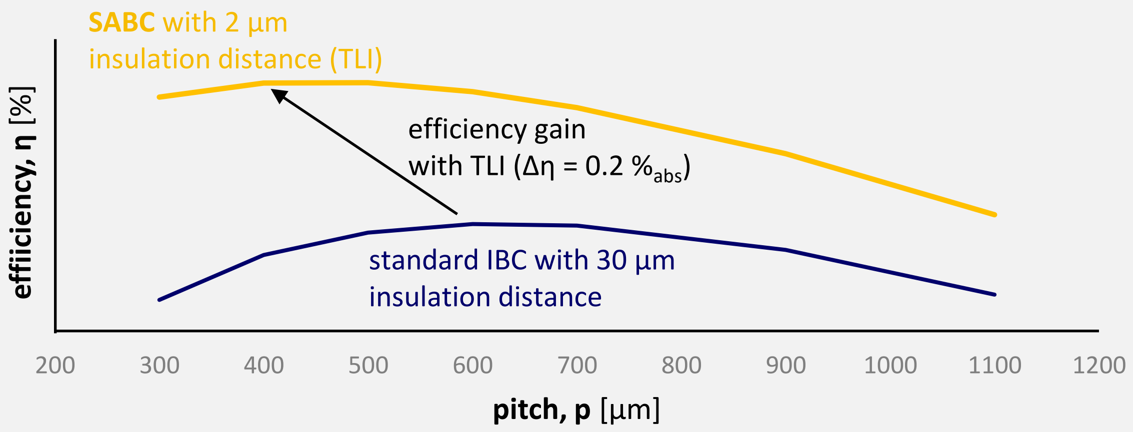
Conquering complexity II

Laser structuring combined with TLI enables ultra-fine pitch and very small insulation distance

SABC's ultra-fine pitch of 400 µm (simplified sketch)



Reducing insulation distance from 30 µm to 2 µm leads to 0,2%$_{abs}$ more efficiency



On-the-fly laser structuring (ultra-fine pitch) technology:

- 526 lines for M12 wafer;
- 451 lines for M10 wafer;
- 0,6 J/cm^2 energy density;
- 150 m/sec (> 500 km/h) laser spot speed;
- 2 sec per wafer scan time;
- ± 8 µm (3σ) scanned line-pattern congruence to drawing.

On-the-fly laser structuring (ultra-fine pitch) advantages:

- reliable;
- high efficiency through small pitch;
- cost effective;
- virtually no environmental impact.

Easy upgrade TOPCon to SABC thanks to only two additional tools

SABC manufacturing sequence: adding two tools[1]

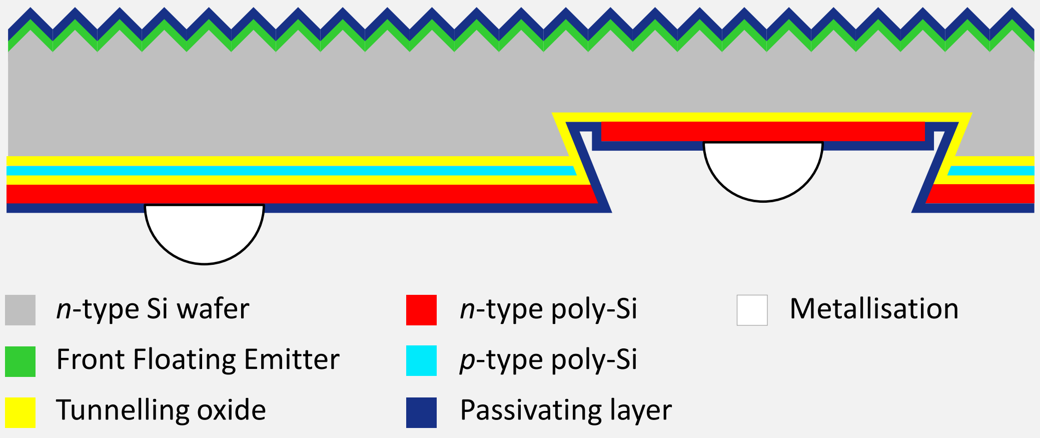
Pos	Measure/Equipment
1	alkaline texture
2	BCl_3 diffusion
3	BSG etch + SDE rear + 1st tunneling oxide
4	*p*-poly deposition
	etch barrier deposition
5	LASER structuring
6	SDE + BSG + barrier etch rear + 2nd tunneling oxide
7	*n*-poly deposition
8	*n*-/*p*-poly annealing + oxidation
9	cleaning
10	front side SiN_x
11	rear side SiN_x
12	back-end

SDE = Saw-Damage Etch

BSG = BoroSilicate Glass

Additional equipment

Recipe adjustments when upgrading from TOPCon[1] to SABC:

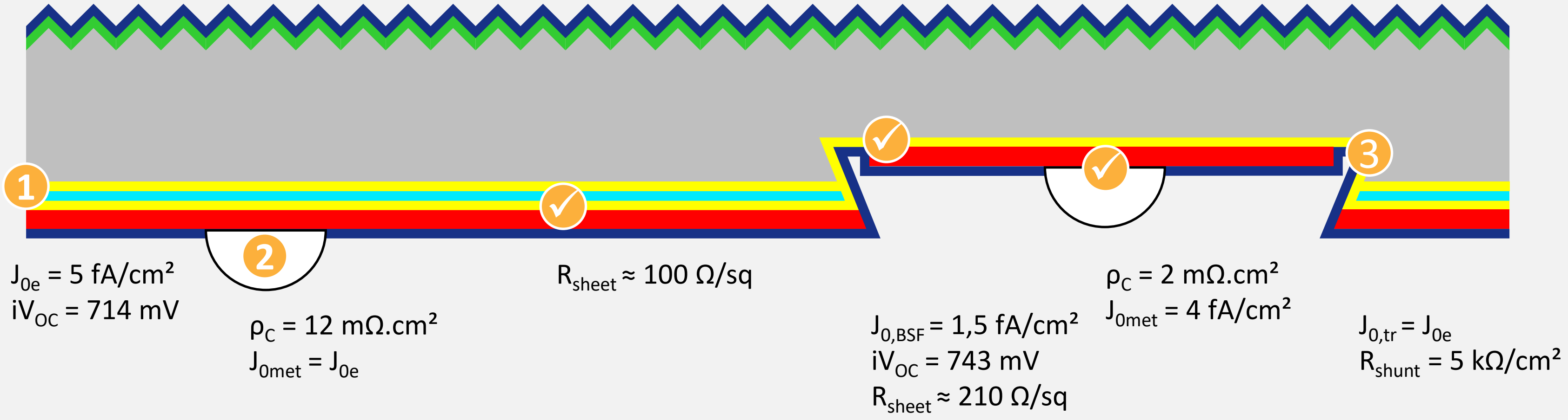


- convert *n*-poly deposition (step 4) to *p*-poly deposition, add etch barrier deposition (SiN_x)
- add LASER structuring and PVD deposition of *n*-poly
- change recipes, in particular for second wet bench (step 6)
- metallisation needs two printing steps (Ag and Cu) only, sequence would change (Ag print, fast-firing, Cu-print, curing)
- chuck in cell tester is replaced by back-contact chuck
- train personnel on additional equipment

[1] Depending on TOPCon line specification.

Key steps towards top efficiency have been made …

EnPV



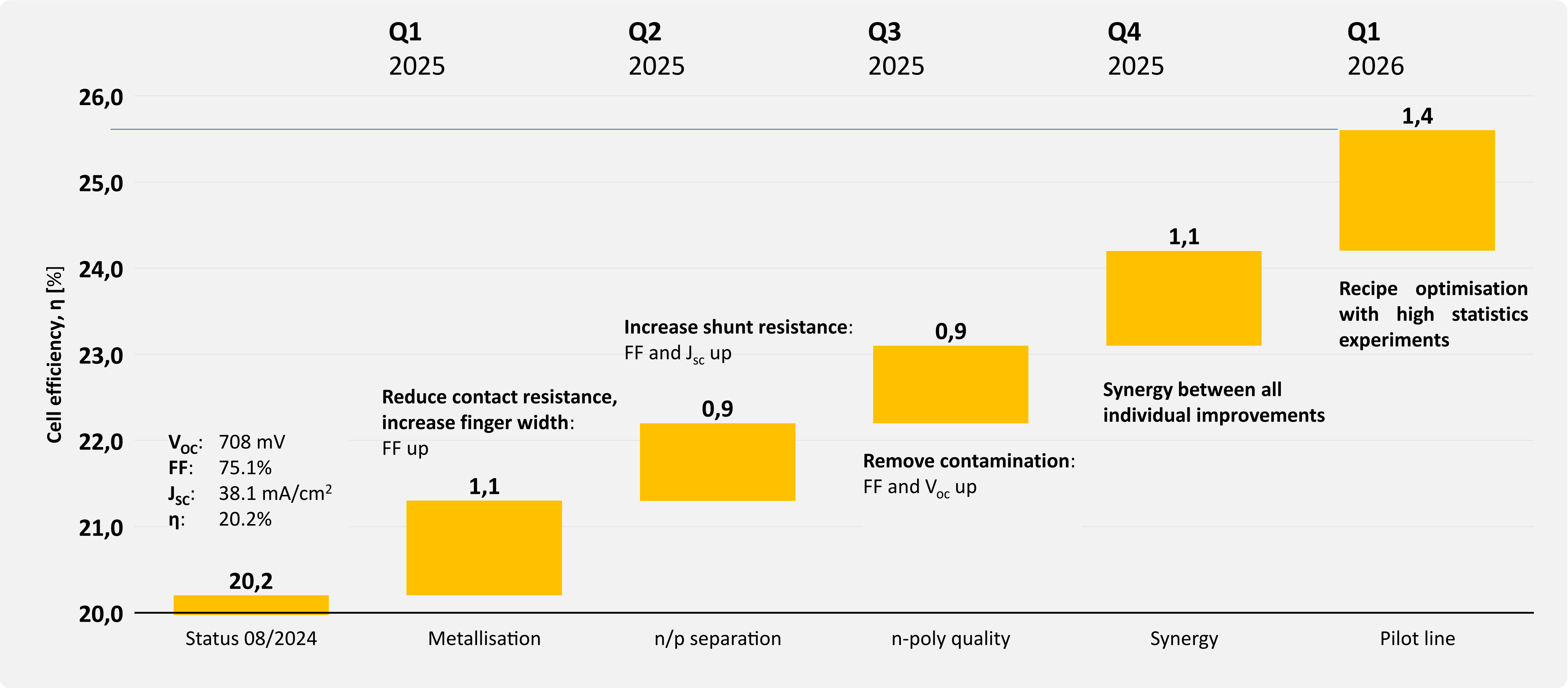
✓ **Features at target-level**

n **Features needing further optimisation in lab and pilot line:**

1. optimisation of *n*-poly Si quality
2. metallisation
3. *n*/*p* phase separation

- *n*-type Si wafer
- Front Floating Emitter
- Tunnelling oxide
- *n*-type poly-Si
- *p*-type poly-Si
- Passivating layer
- Metallisation

… and a clear plan has been devised



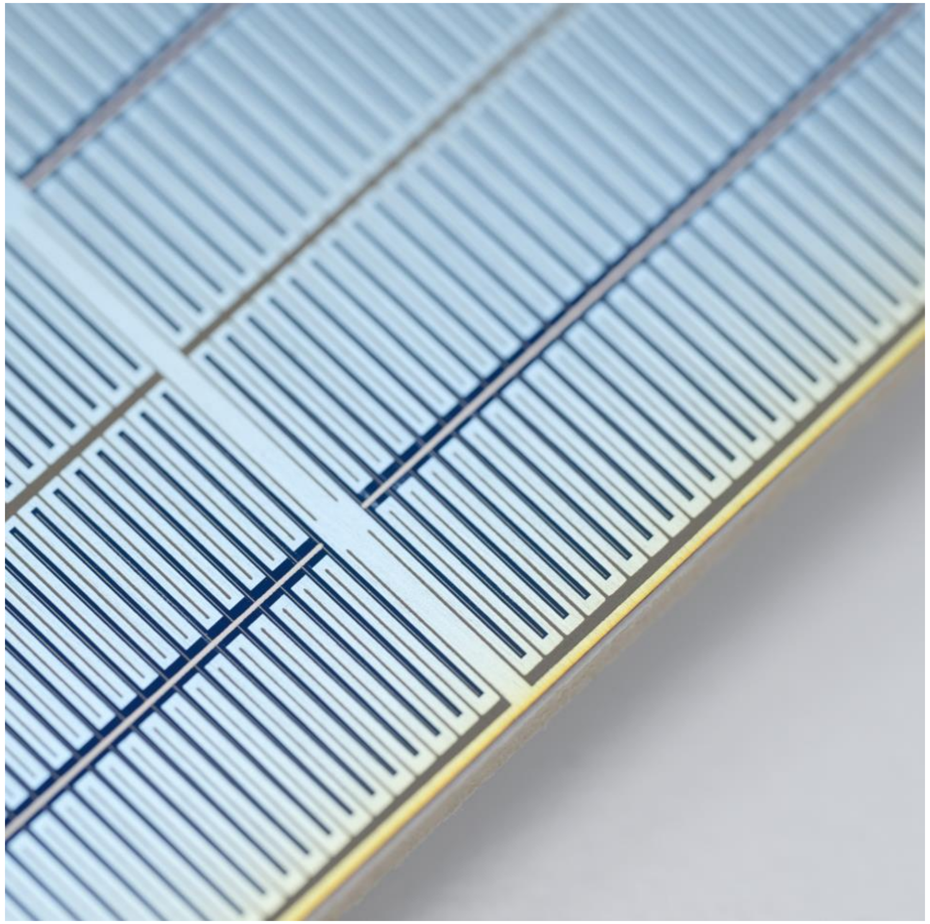
Technology readiness level TRL6 is achieved

- SABC's underlying technology concepts are proven
- all process steps can be demonstrated
  on industrial mass-production equipment
- prototype cells can be produced in small quantities[1]
- the efficiency potential (> 0,5%$_{abs}$ higher than the best TOPCon cell performance) is proven in Quokka simulations fed with trustworthy data known from TOPCon production and experiments of EnPV's
- an exemplary production line including equipment has been specified. Due to the proximity to TOPCon production the equipment specifi-cation is highly reliable. The additional equipment (LASER and PVD, to be added to upgrade TOPCon to SABC) is extensively tested in the suppliers' laboratories

[1] With Ag-only metallisation.

Riding the wave:
SABC is ready for the up turn-cum-technology change

- EnPV GmbH developed SABC[1], a novel proprietary back-contact cell (IBC) technology
- SABC dramatically simplifies all IBC fabrication methods existing to-date by the reduction of typical number of productions steps resulting in greater production efficiency
  - **SABC decreases wafer-to-cell conversion cost by > 15% compared to TOPCon.**
- Essential parts of SABC (TLI[2]) are protected IP
- **EnPV is looking for an exclusive partnership to implement SABC into a pilot production.**



[1] Self-Aligned Back Contact.
[2] Trench-Less Insulation.

Contact

Any inquires or communication should be directed to the following contact:

Massimo Centazzo
Managing Director
+49 151 547 76896
m.centazzo@enpv.de

EnPV GmbH
Durlacher Allee 93
76131 Karlsruhe
Germany