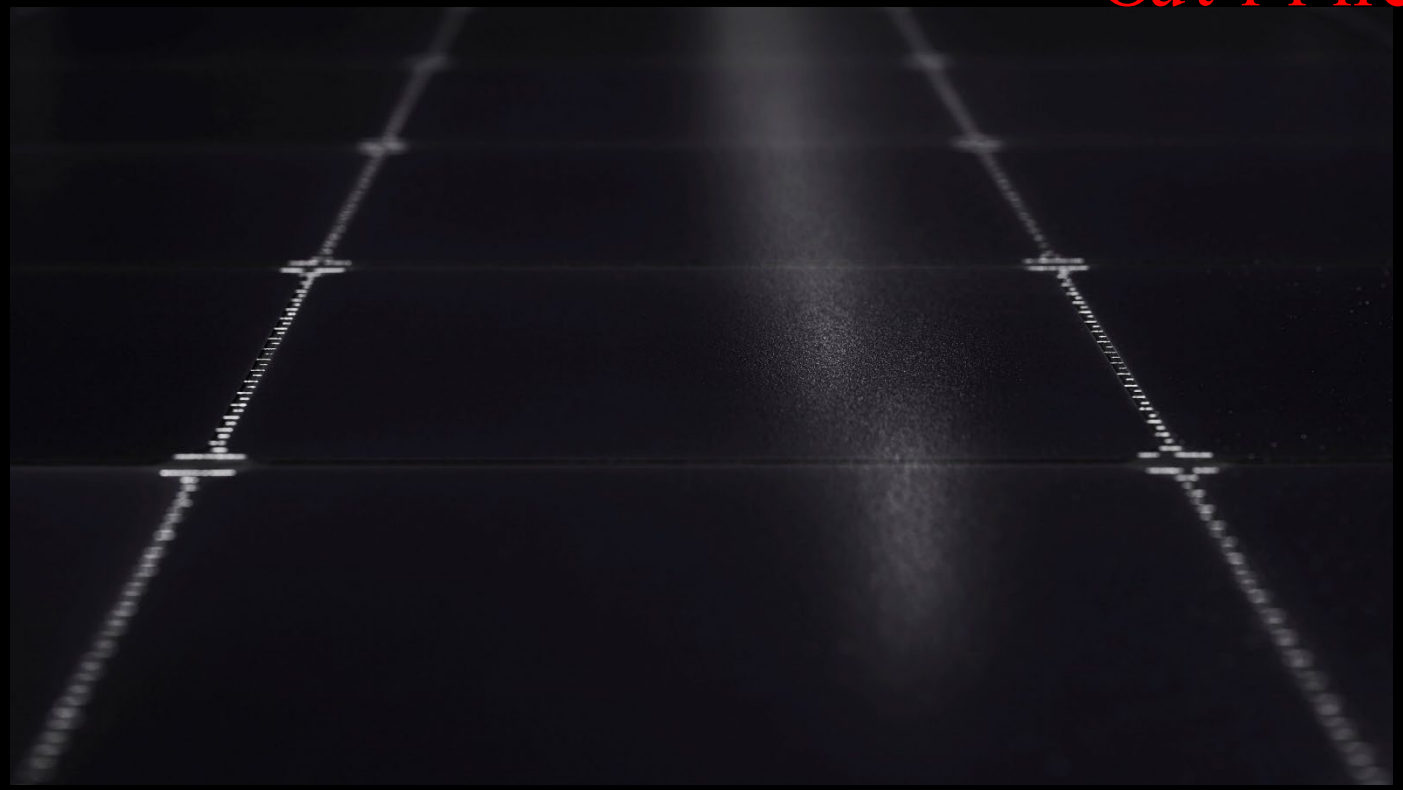
Industrial Tunnel-IBC solar cells based on Heterojunction technology

Gizem Nogay
Innovation Project Manager at Meyer Burger Switzerland

12th Workshop on Back Contact Solar Cells and Module Technology

04.12.2024 - Delft, Netherlands

Outline



1 Introduction of Development Sites

2 Tunnel IBC Solar Cells

3 Tunnel IBC Modules & SWCT

4 Reliability Results

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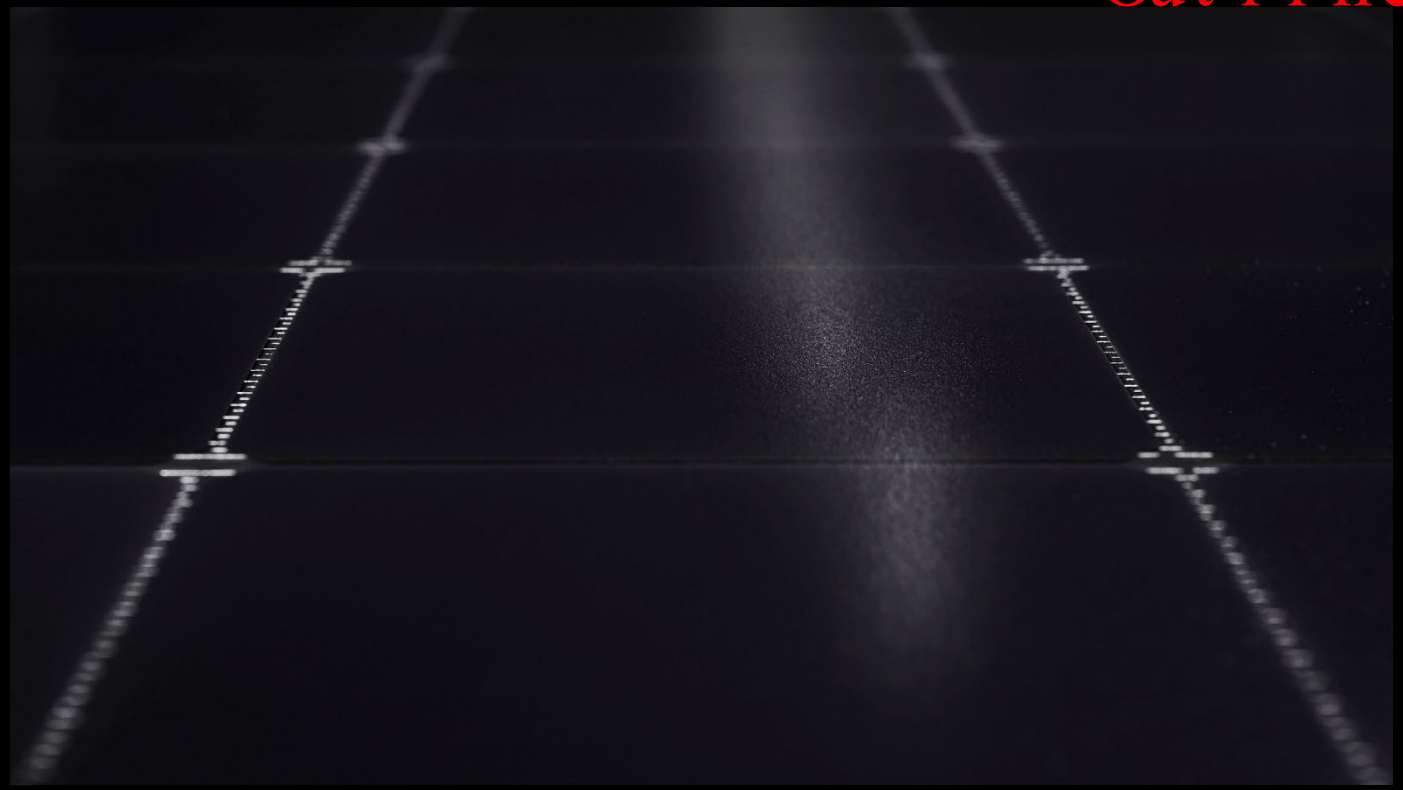

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Tunnel IBC Development Sites

CSEM

Proof of Concepts
TRL (1-4)

Meyer Burger Research

Upscaling
TRL (4-7)

Meyer Burger Germany

Industrialization
TRL (7-9)

Meyer Burger Switzerland

Module R&D Team

Tunnel IBC Cell developments

- Engineering thin film depositions
- Electrical and Optical Analysis
- Simulations and Software development

Tunnel IBC Module Production in Pilot Scale

- SWCT development
- BOM optimization
- Quality Control
- Software development & Automation

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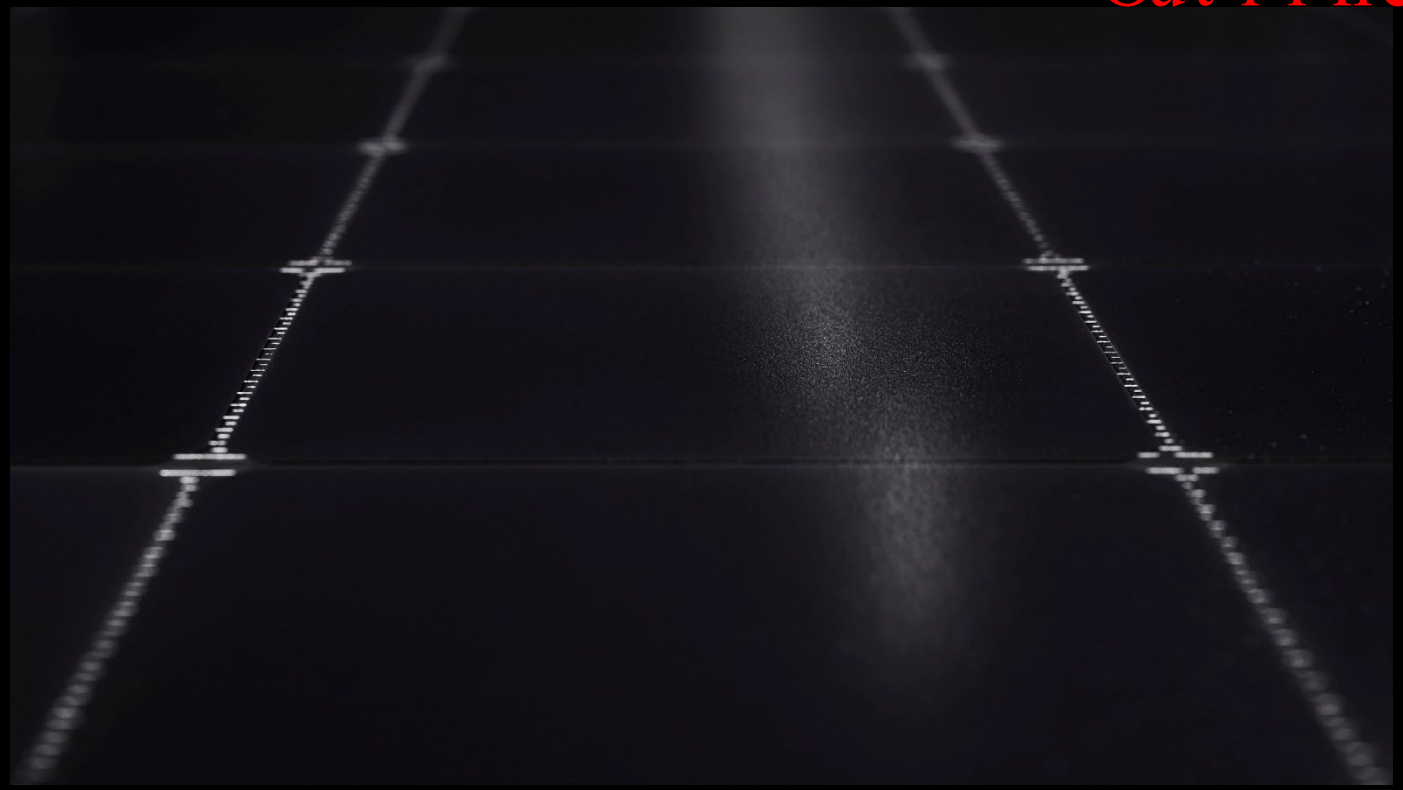
Outline



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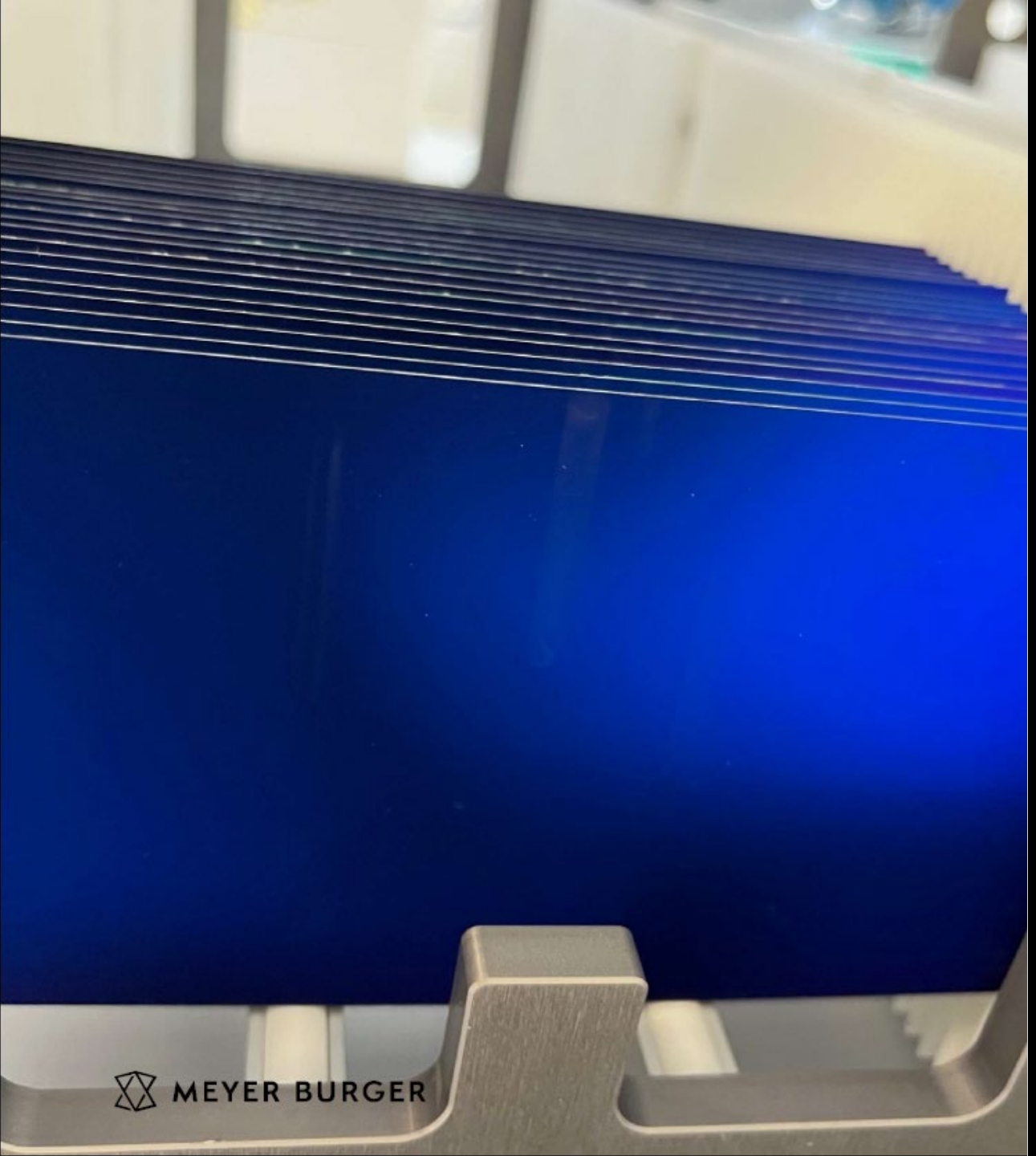

Why tunnel IBC solar cells ?

Next challenge at TW scale

Silver market will remain firmly in deficit over the next five years supporting further price increases

Source : CRU precious metals outlook

Design considerations for multi-terawatt scale manufacturing of existing and future photovoltaic technologies: challenges and opportunities related to silver, indium and bismuth consumption

Yuchao Zhang, †*a Moonyong Kim, †a Li Wang, a Pierre Verlinden abcd and Brett Hallam a

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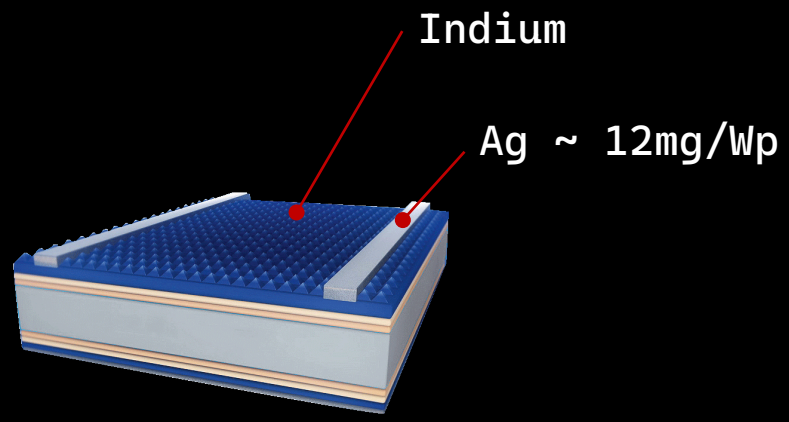
Next challenge at TW scale

- Upcoming technologies must reduce / remove
- Use inexpensive / abundant TCO's



HJT

Design considerations for multi-terawatt scale manufacturing of existing and future photovoltaic technologies: challenges and opportunities related to silver, indium and bismuth consumption

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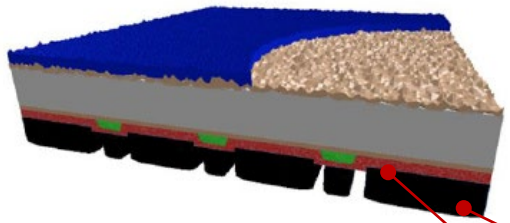

IBC HJT

Indium free TCO
Ag 3.3mg/Wp

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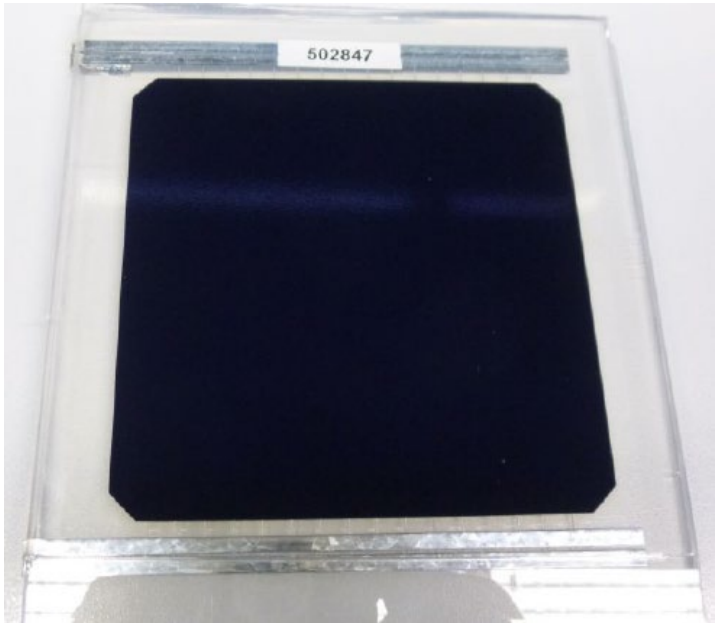
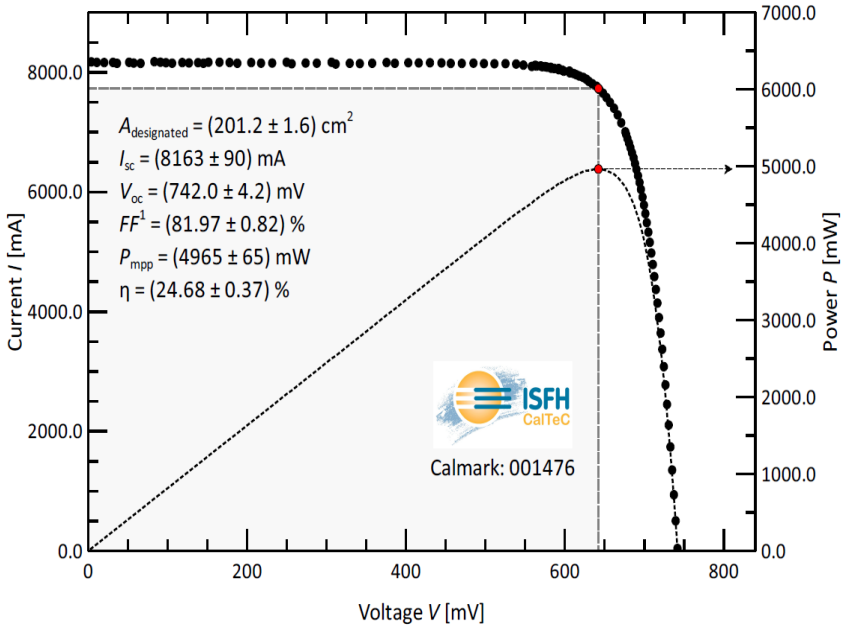
Tunnel IBC solar cells

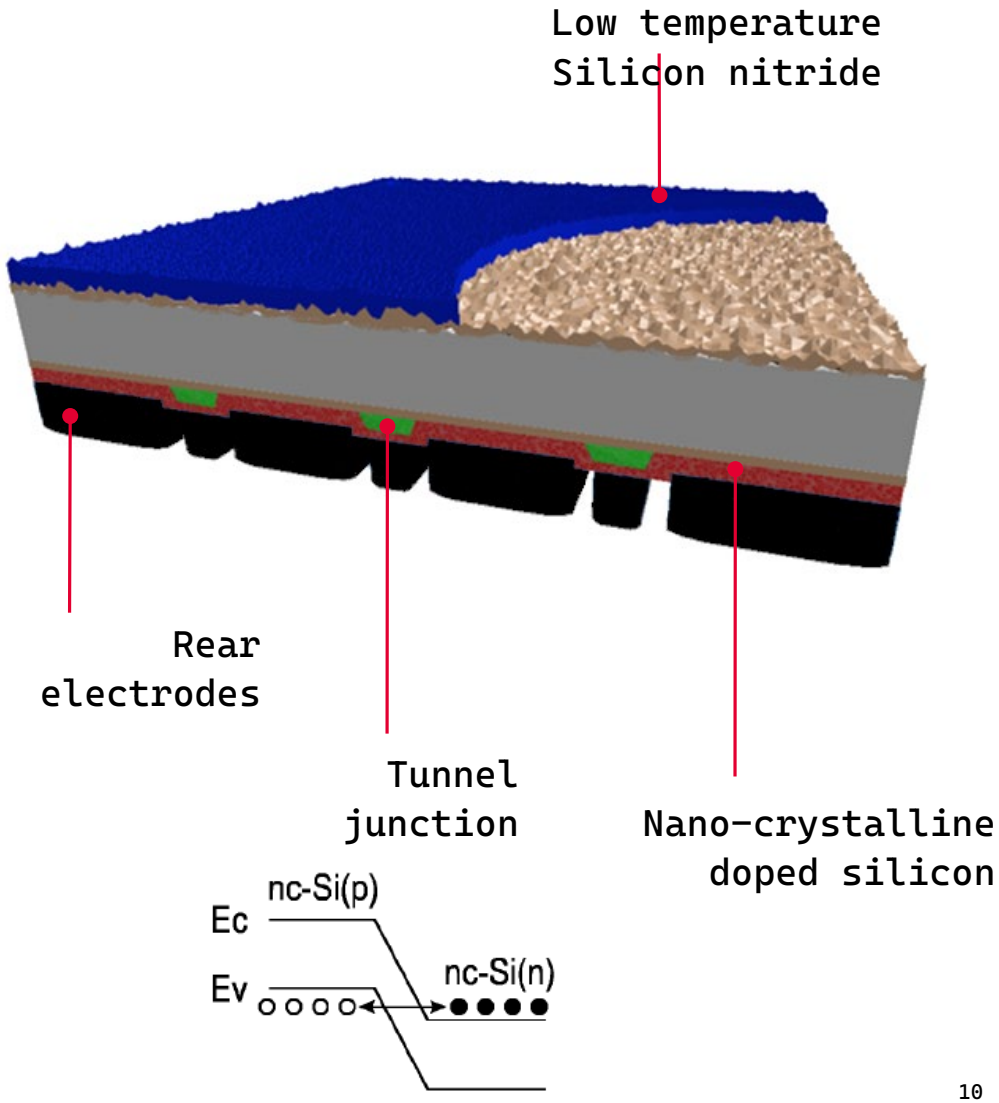
- Co-developed initially at EPFL and CSEM
- Can reach very good performance with SWCT encapsulation (24.7 % certified on 201 cm²)





Tunnel IBC as the next big step

- Performance >25%, industrial potential >26%
- Tunnel-IBC technology merges both advantages of HJT and IBC architecture
- No front shading and highly transparent front side layers
- Innovative self aligned tunnel junction manufacturing
- Radically new electrodes offering an ultimate reliability



TopCon

WIS

1

SDE + Text + Clean

Boron diffusion

BSG & rear side etch

PECVD TO + poly Si(n)

High T anneal

PSG removal + RCA

Front ALD Al2O3

PECVD SiNx front & back

Screen Printing front (2-steps)

Screen Printing rear (2-steps)

Firing

Light Soaking /Elec. pumping

LECO

TLS half cell cutting

Edge passivation for full size cut

14

Cell Tester & sorter

➢ **24.2 - 25.5%**

WIS

1

Dual sided polishing

LPCVD: Rear side i-poly

Boron diffusion

Laser removal of n-area BSG

Polishing: Removal p-poly on n area

LPCVD: Rear side i-poly

Dual sided boron diffusion

Laser removal of p-area BSG

Acid etching + texturing+ acid cleaning

Dual sided ALD

Front + Back SiNx

Screen Printing

Firing

Light Soaking/Electrical Pumping

TLS half cell cutting

Edge passivation for full size cut

16

Cell Tester & sorter

➢ **26%**

Tunnel TBC Technology

WIS

1

Tex & Clean

PECVD F&R a-Si:H(i)

PECVD SiNx(i) & puc

PVD TCO/metal

PECVD SiNx (Front)

SP resist – pads (2steps)

Contact separation

10

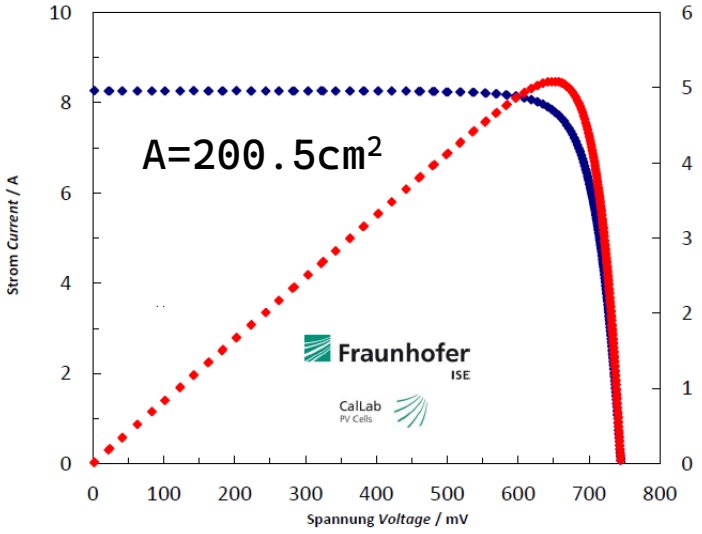
Cell Tester & Sorter

➢ **26% potential**

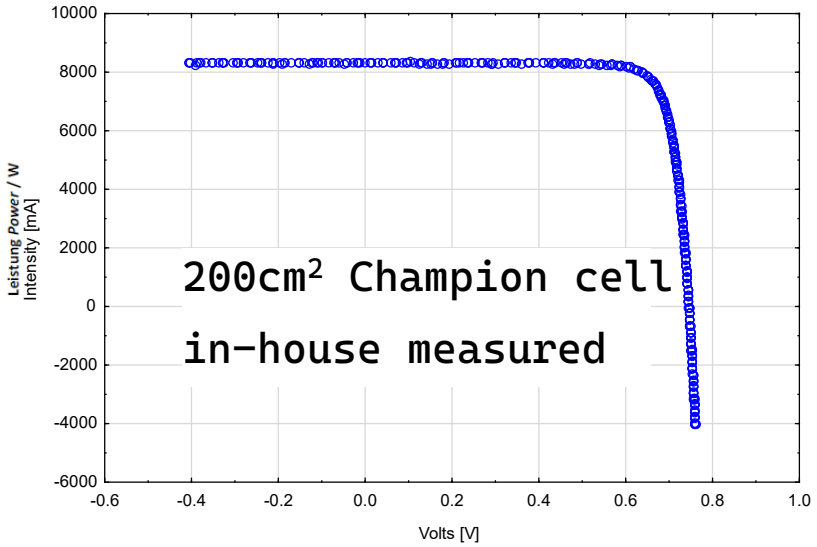
- Compact process flow
- Secured IP portfolio : 9 core patents on both on processes and machine (4 granted, 5 pending)

Tunnel IBC solar cells reach > 25%

V_{OC} [mV]	J_{SC} [mA/cm²]	FF [%]	Eta [%]
744.9	41.2	82.6	25.35



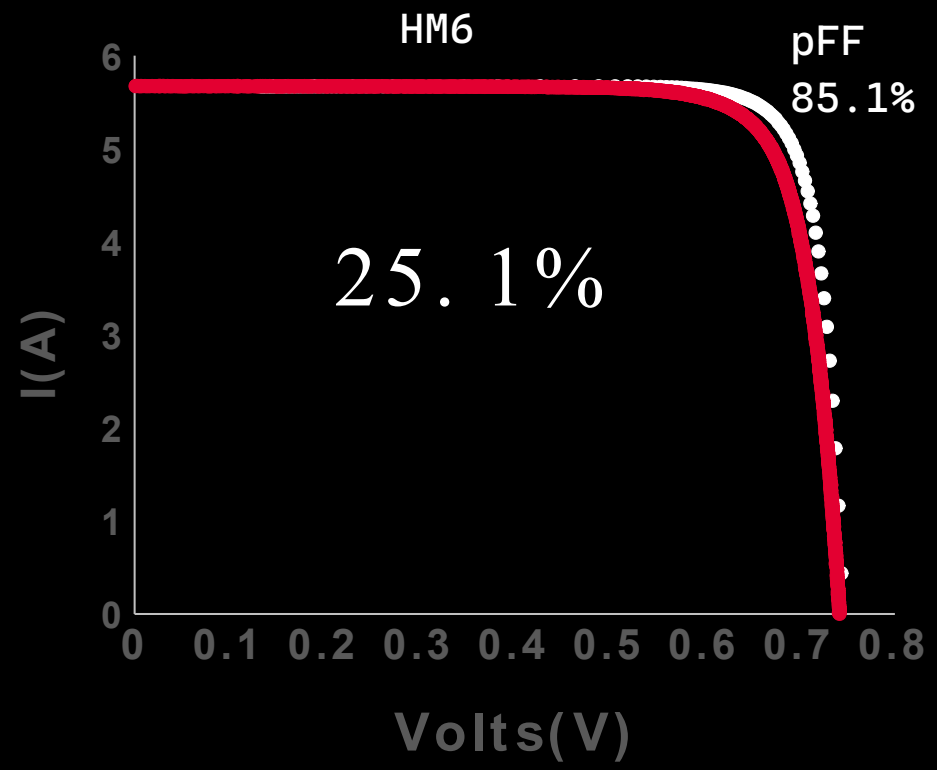
V_{OC} [mV]	J_{SC} [mA/cm²]	FF [%]	Eta [%]
745	41.7	82.9	25.75



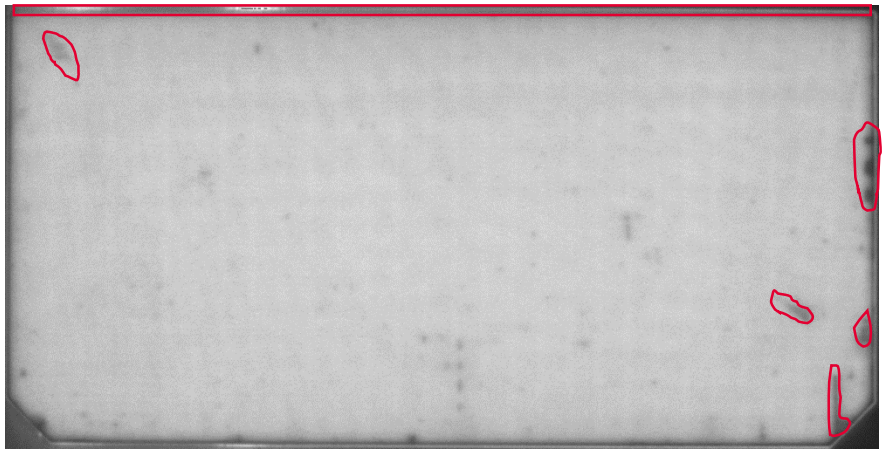
- Cell processed in Lab PECVD reactors (50x50cm²)
- 6mm edge exclusion allows to reach cell efficiency above 25% on 200cm² cells despite manual handling

Tunnel IBC solar cells reach > 25%

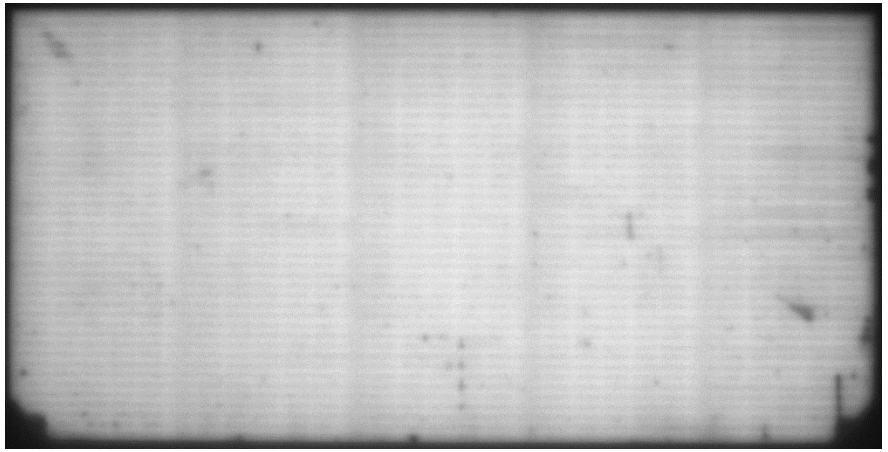
V_{OC} [mV]	J_{SC} [mA/cm²]	FF [%]	Eta [%]
741.8	41.4	81.9	25.14



Photoluminescence



Electroluminescence



Several marks remains due to manual wafer positioning in process tools

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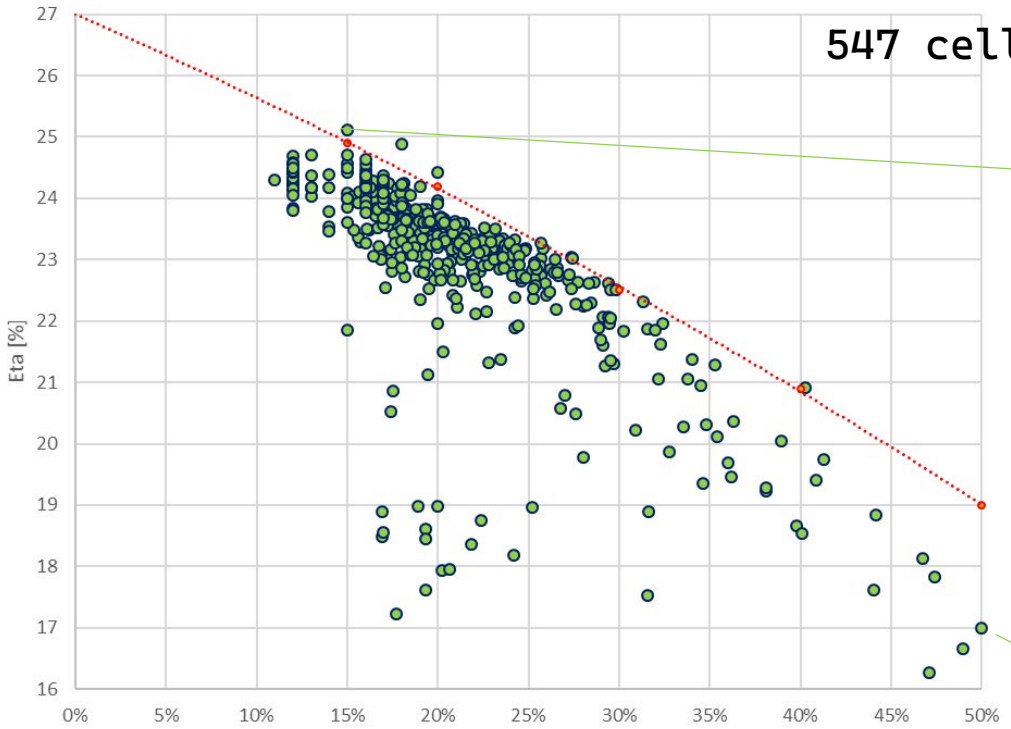
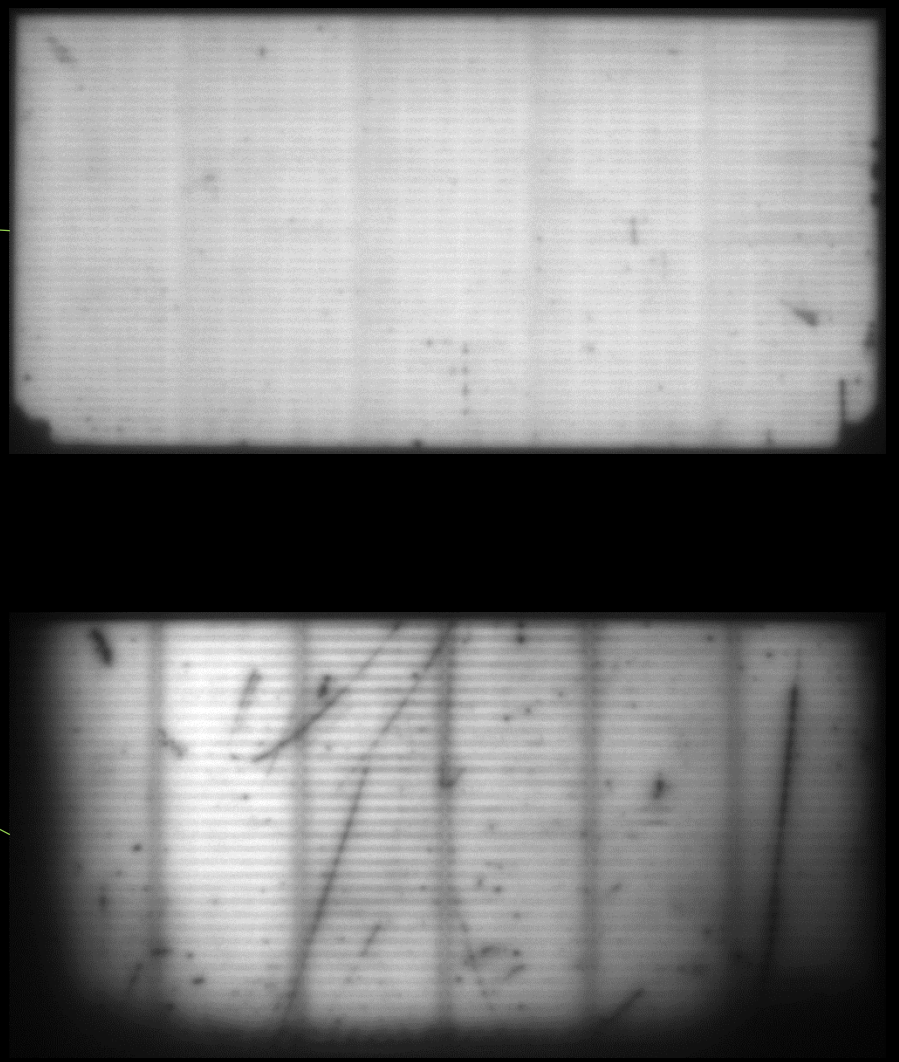
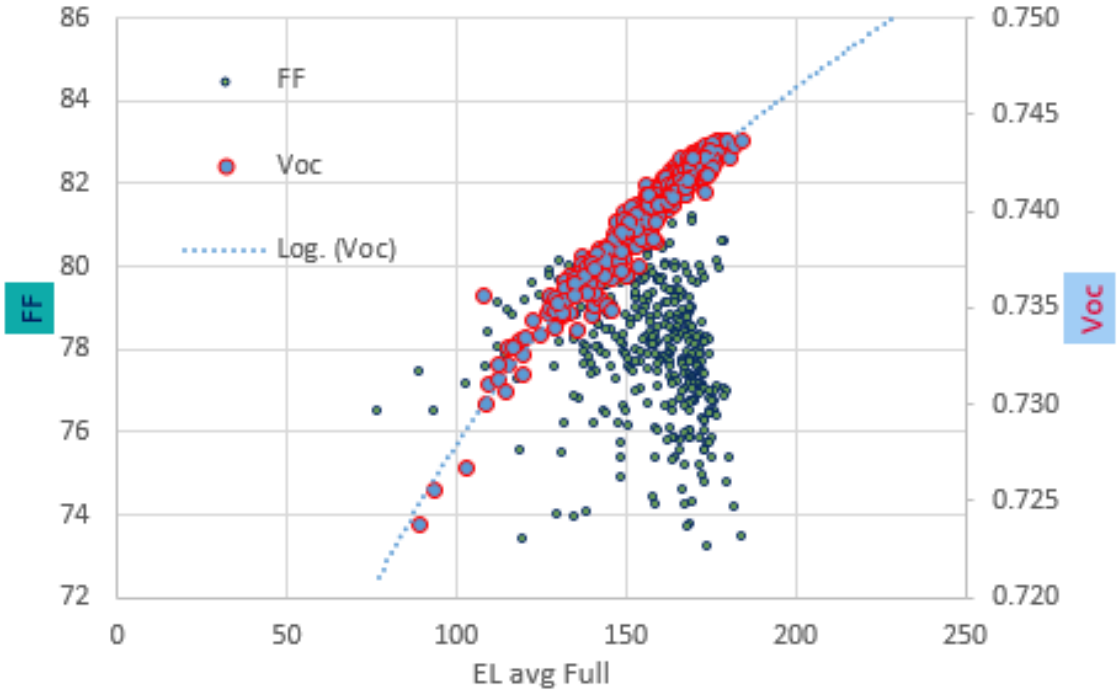
EL as a simple monitori efficiency





EL absolute signal & signal uniformity



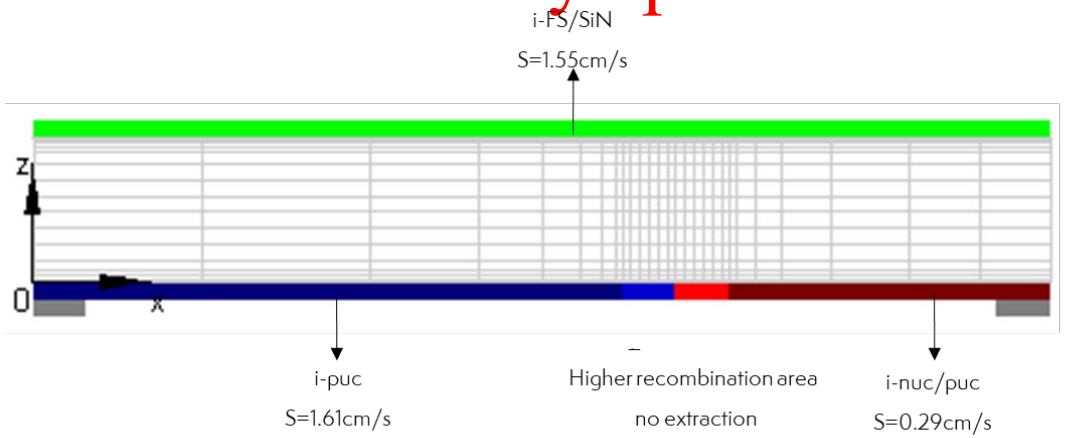
- The absolute EL signal is dominated by passivation quality if the cells are ‘sufficiently’ good, meaning uniform passivation and low series resistance
- Voc & log (EL signal) correlates well, however no correlation with FF

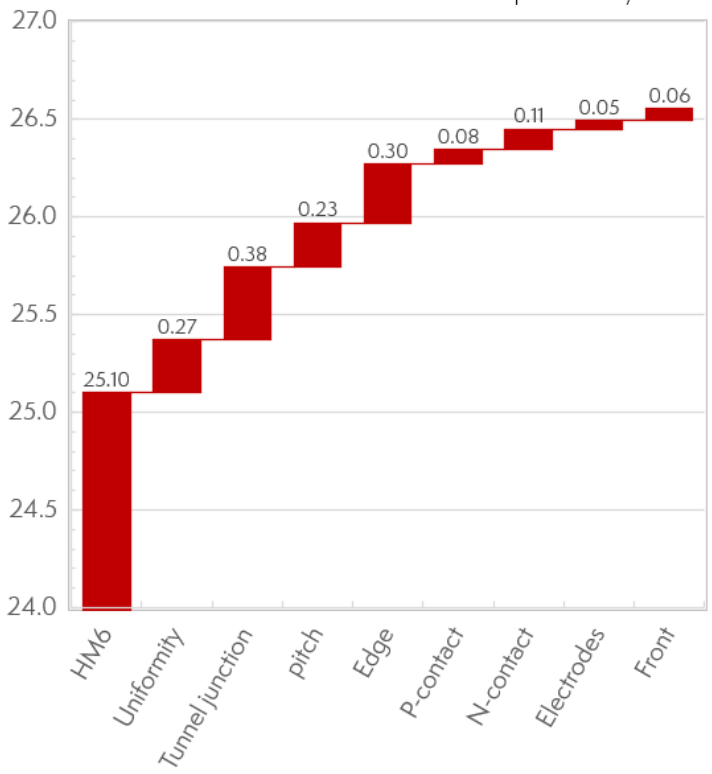
Power loss analysis and efficiency potential

Main sources for power losses:

- Uniformity (lack of automation)
- Tunnel junction recombination (PECVD process)
- IBC design & pitch (Base transport)
- Edge passivation (un-passivated edge after TLS)

Tunnel IBC has the potential to reach up to 26.5%-26.6%





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Bifi Tunnel IBC

Structure	Ag laydown [mg/Wp]	Eff [%]	Voc [mV]	Jsc [mA/cm²]	FF [%]	Bifaciality I_{sc} [%]
Monofacial	3.3	25.1	741.8	41.4	81.9	12
Bifacial Gen1	46.8	23.6	739	39.5	81	78
Bifacial Gen2	3.1	23.8	738.8	40.9	78.7	40

complex patterning process & high Ag consumption

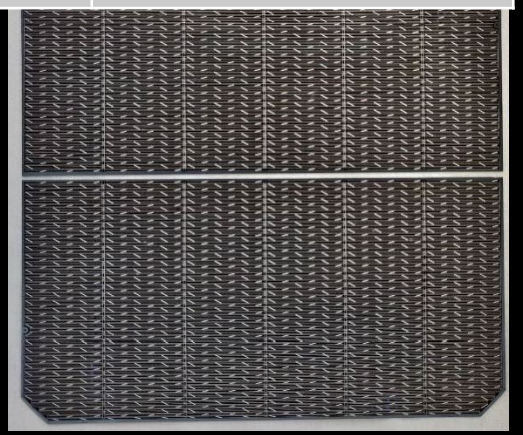
- Gen2 can reach up to 40% bifaciality while keeping Ag at ~3mg/Wp

Challenge:

Keep a compact process flow

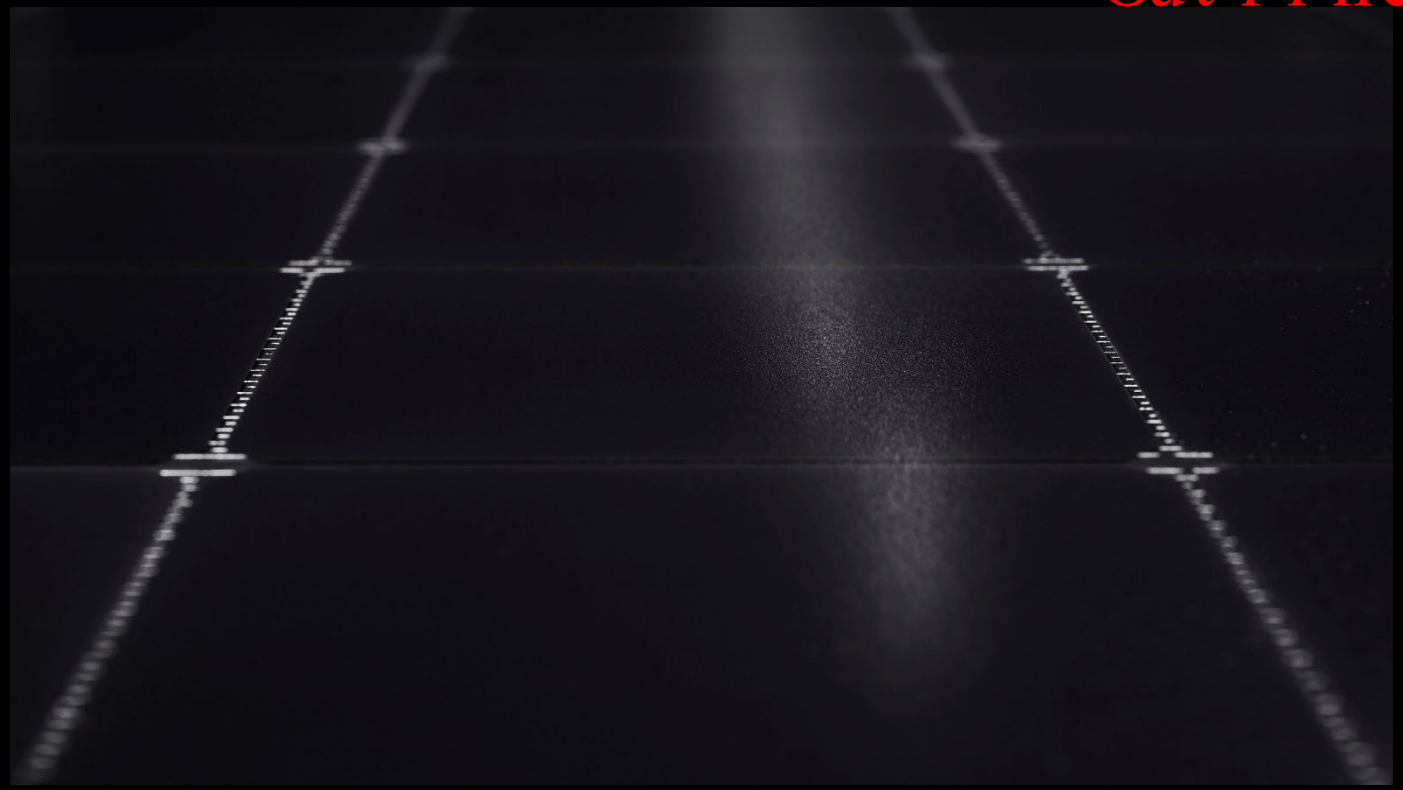
Keep low Ag laydown

Reaching IBC bifi factor above 40%



Gen1 Tunnel IBC

Outline



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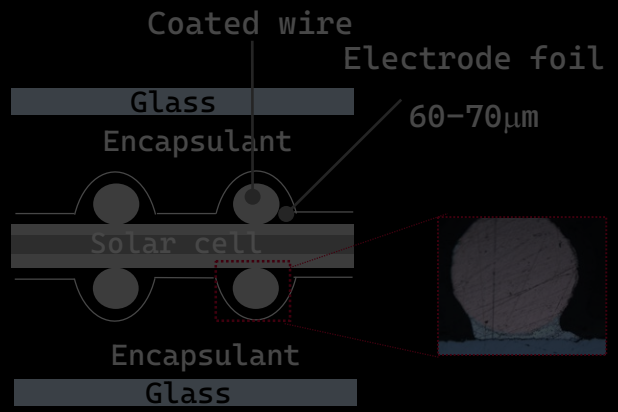
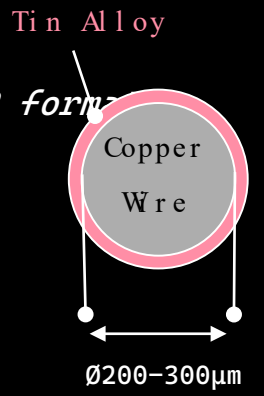
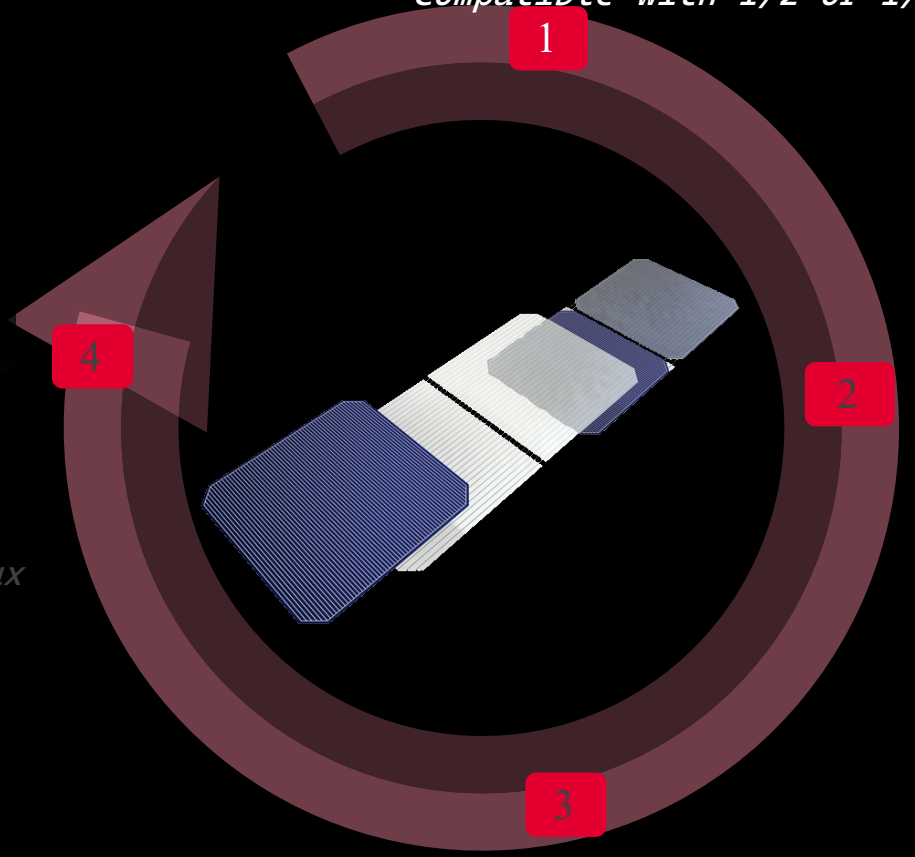


Cu wires coated with Sn-alloy with low melting T (<140°C)

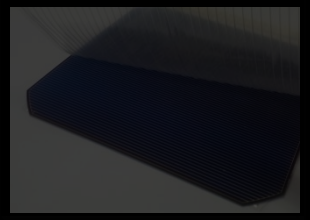
- *Currently 16 x 250µm wires for M10hc*
- *Compatible with 1/2 or 1/3 cells in M12 & G12R formats*





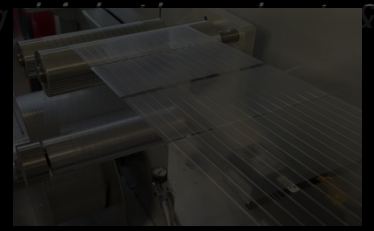
Electrical connection to cell takes place during laminating

- *No need for conventional high temperature soldering entirely flux and lead free*
- *Low T soldering reduces thermo-mechanical stress*



Foil Wire Assembly (FWA) - Wires embedded in a polymer foil

- *High transparent foil with optical loss <0.3%*
- *FWA avoids single wire handling on stringer leading to higher yield*



Cell to Cell Stringing - FWA is attached to cell with automated stringer

- *Foil holds wires in place without a need of alignment → no ribbon shift*

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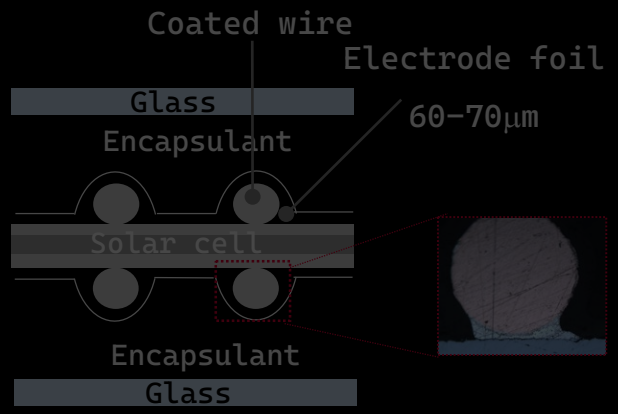
SWCT Concept



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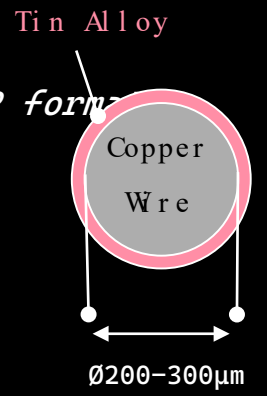

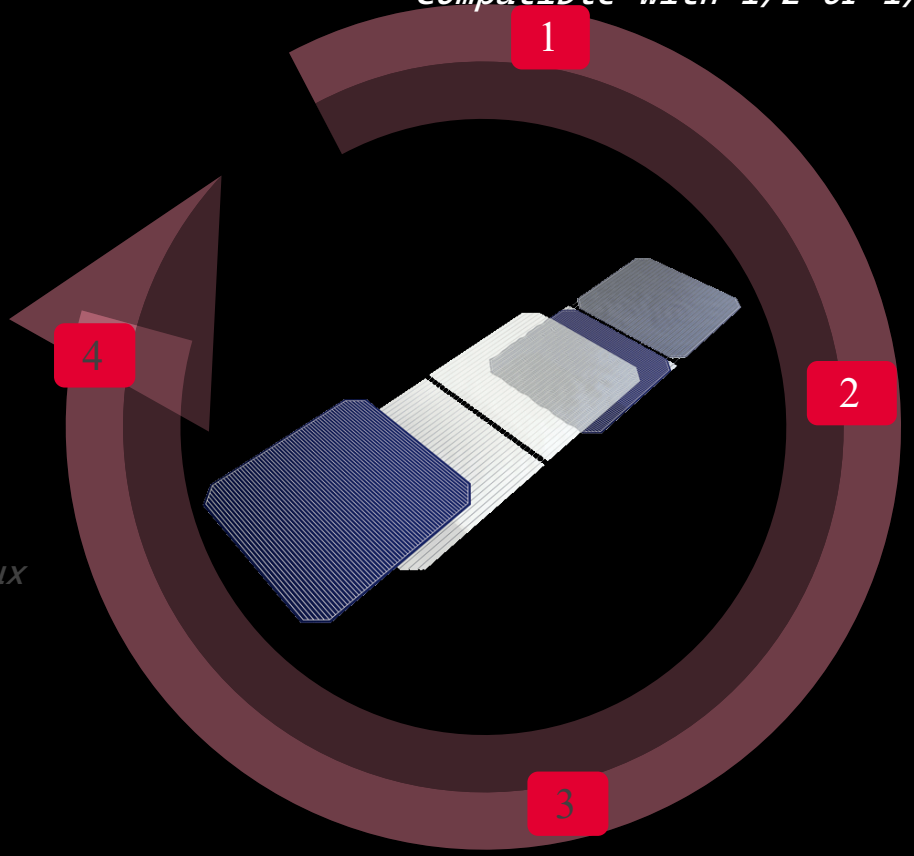

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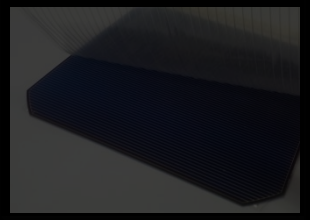

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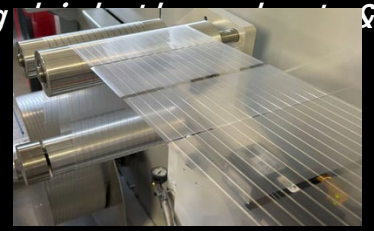

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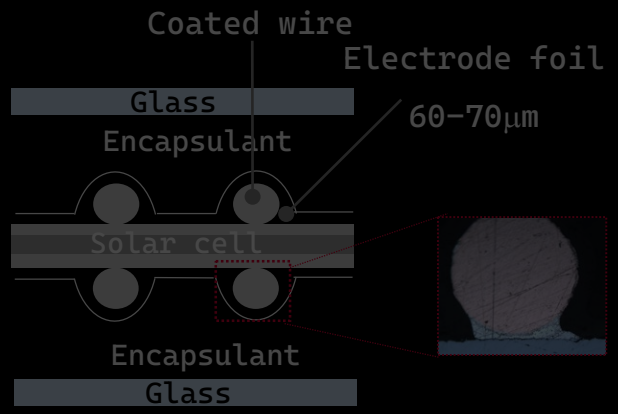

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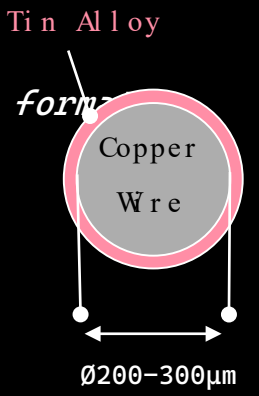

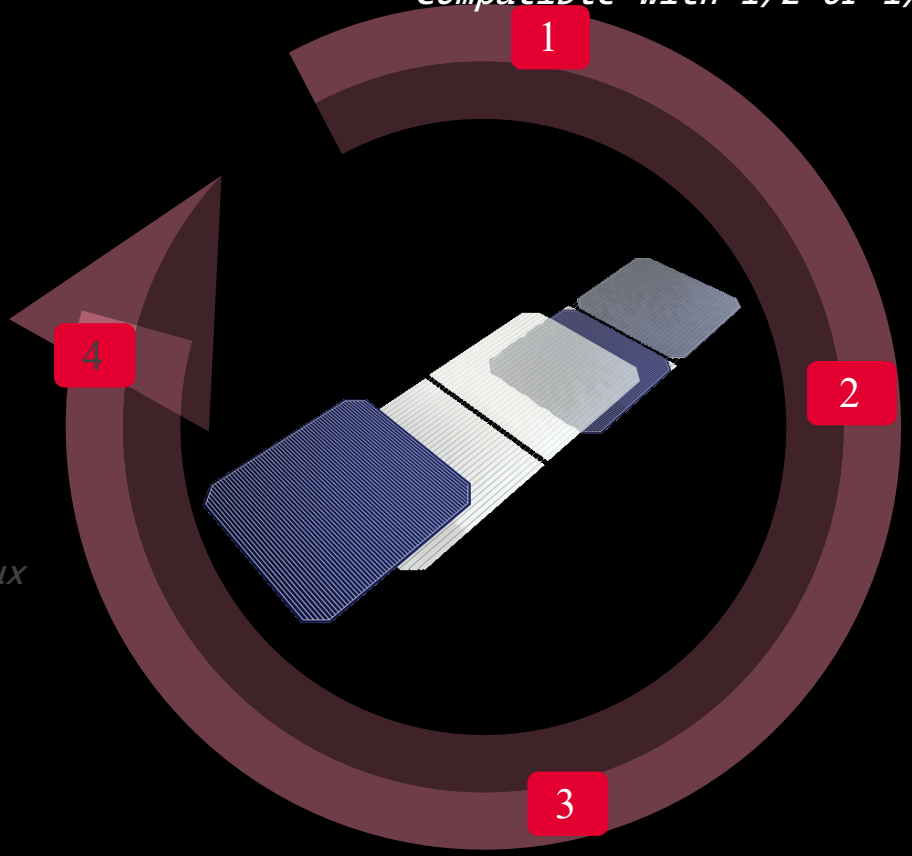

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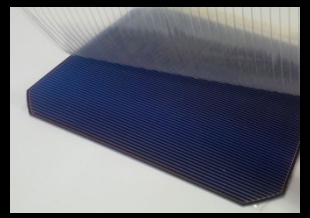

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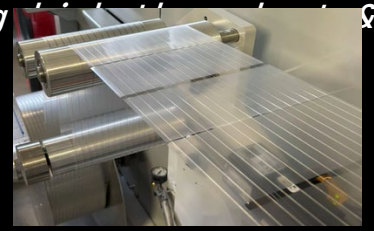

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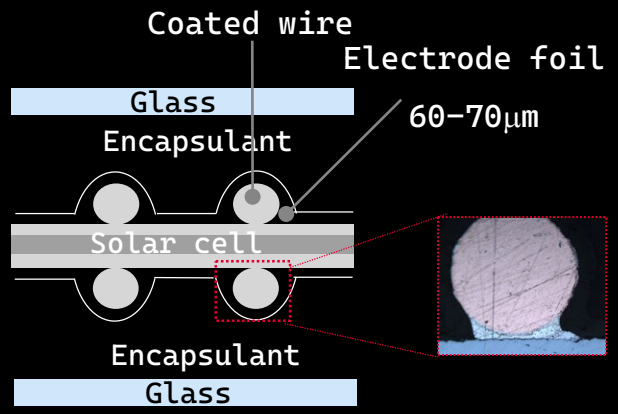

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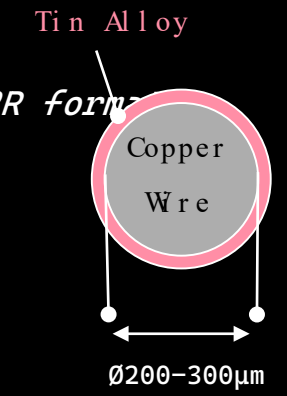

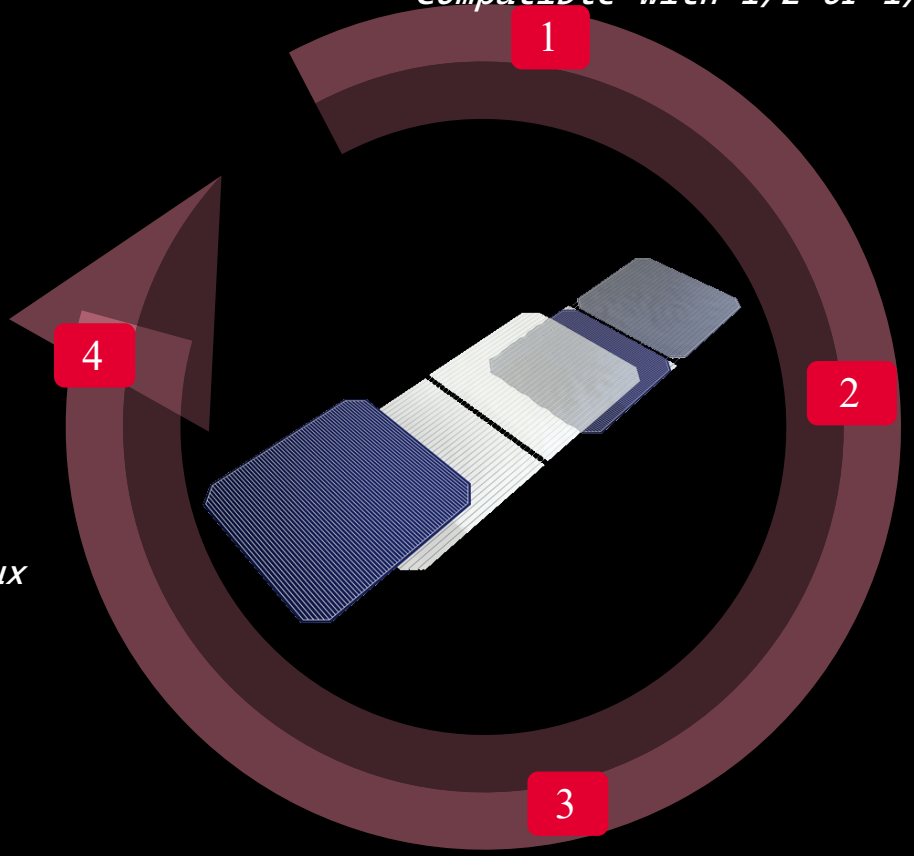

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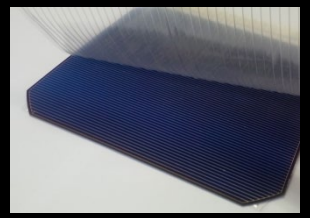

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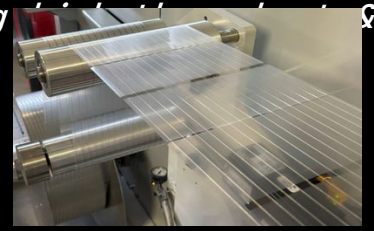

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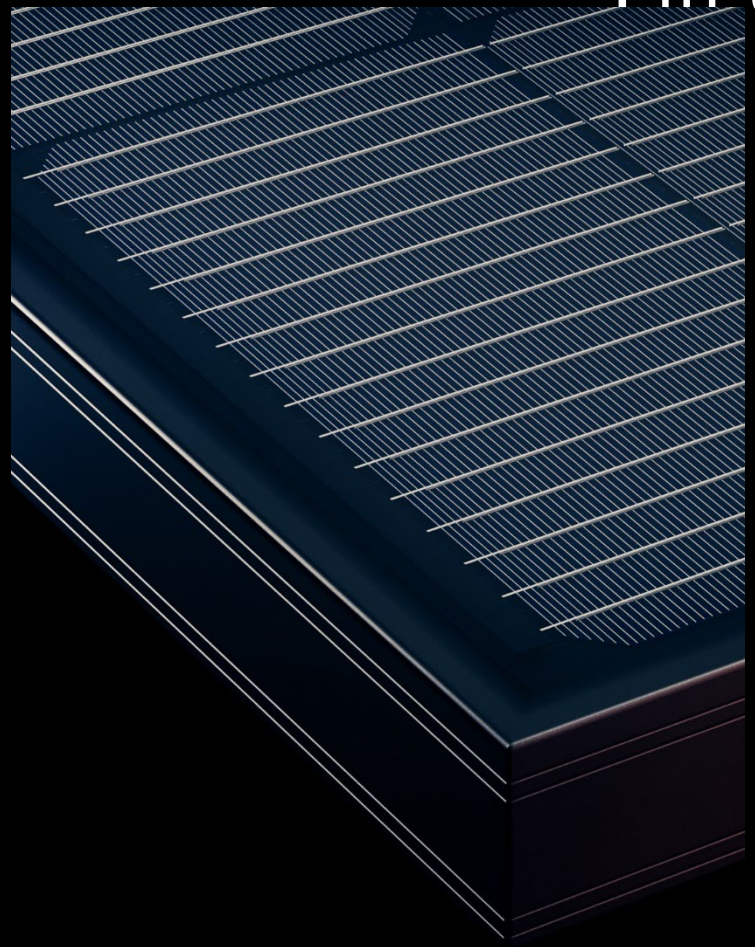
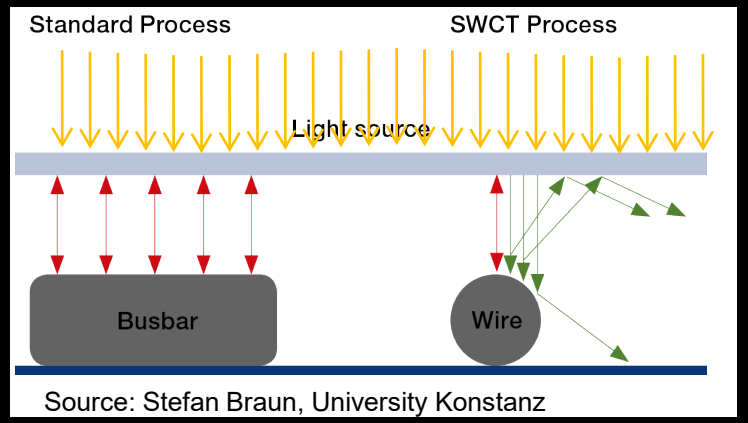
Advantages of Meyer Burger's SWTC Interconnection



Higher yield with minimized optical shading with round wires



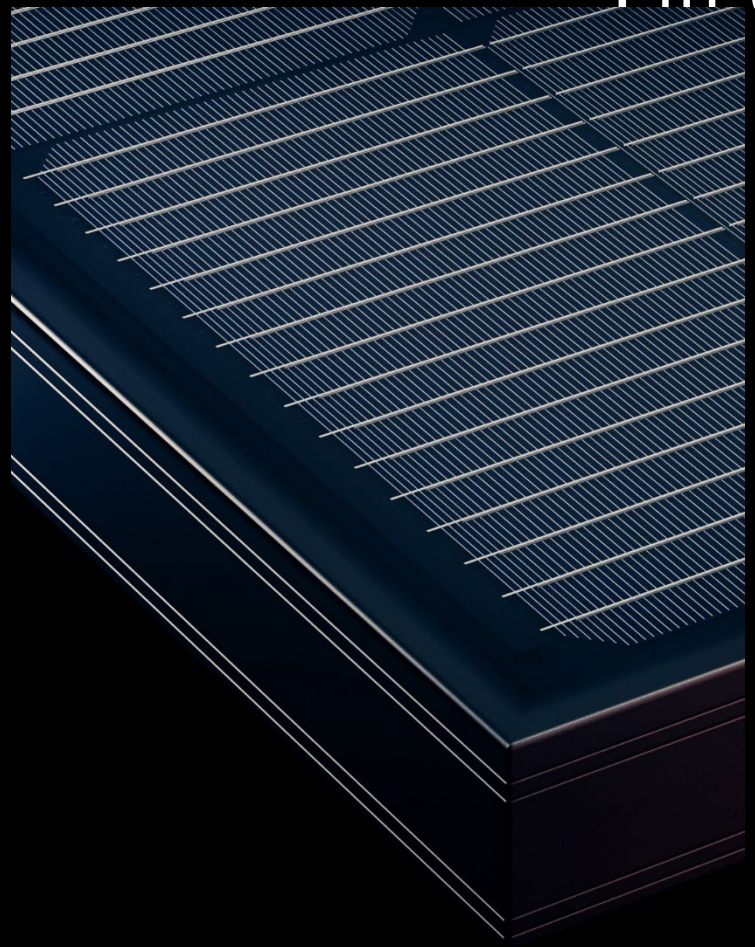
Optical losses in the module:

- light shading (Busbars)
- light absorption (Glass)
- light reflection (BB & Glass)

Round geometry → Better diffuse light reflection

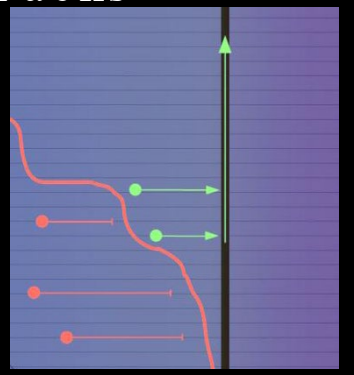
30 % less shading compared to BB technology

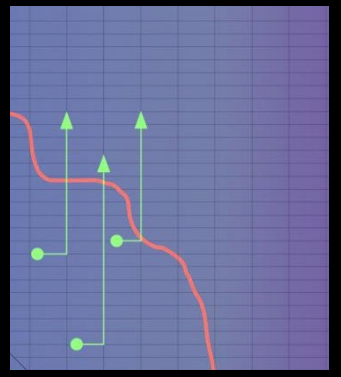
Advantages of Meyer Burger's SWTC Interconnection



Higher yield with minimized optical shading with round wires

Better resistance for micro-cracks





- Short wire to wire gap
  → low finger resistivity loss

- High density of contact points
  → less sensitive on finger interruptions/ cell cracks

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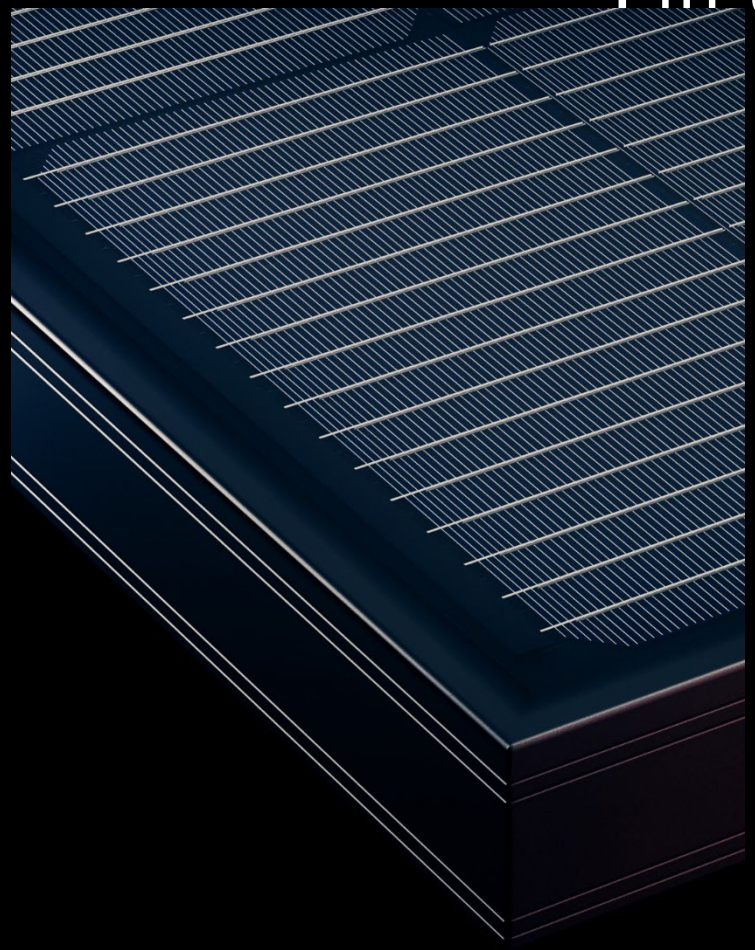
Advantages of Meyer Burger's SWTC Interconnection



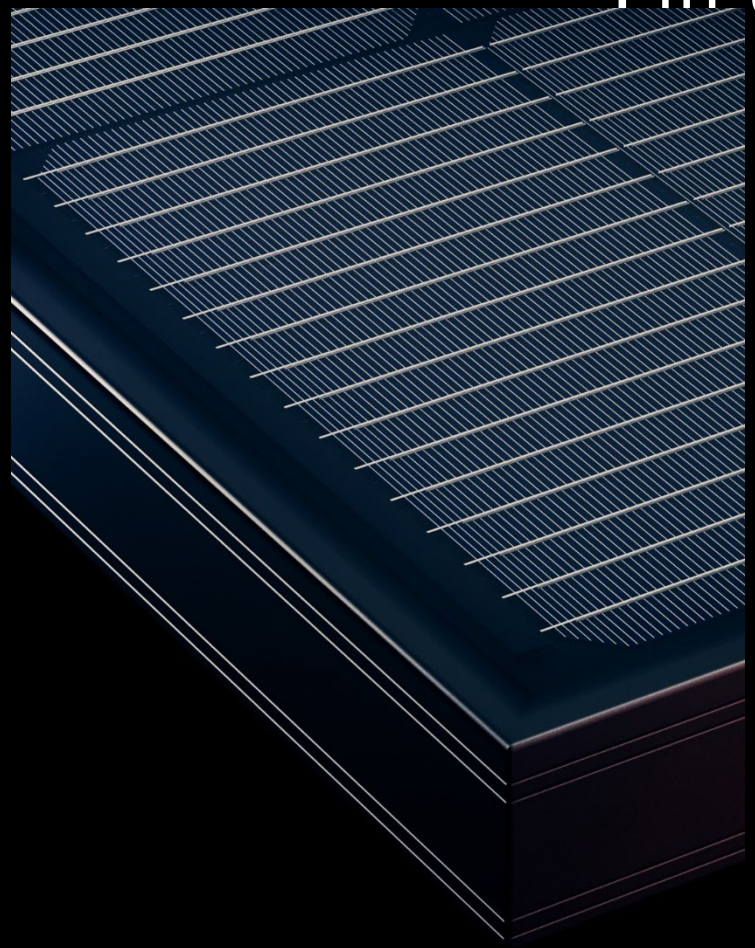
Higher yield with minimized optical shading with round wires

Better resistance for micro-cracks

Low temperature and easy process with design flexibility

- Low temperature process perfect fit for silicon HJT
- Compatible with M10, G12, G12R format & half, 1/3 with simple modification of wire number and foil size

Advantages of Meyer Burger's SWCT Interconnection



Higher yield with minimized optical shading with round wires

Better resistance for micro-cracks

Low temperature and easy process with design flexibility

Material- & energy-saving with electrical interconnection formed during lamination

- Reduced silver consumption
- No soldering within stringing process

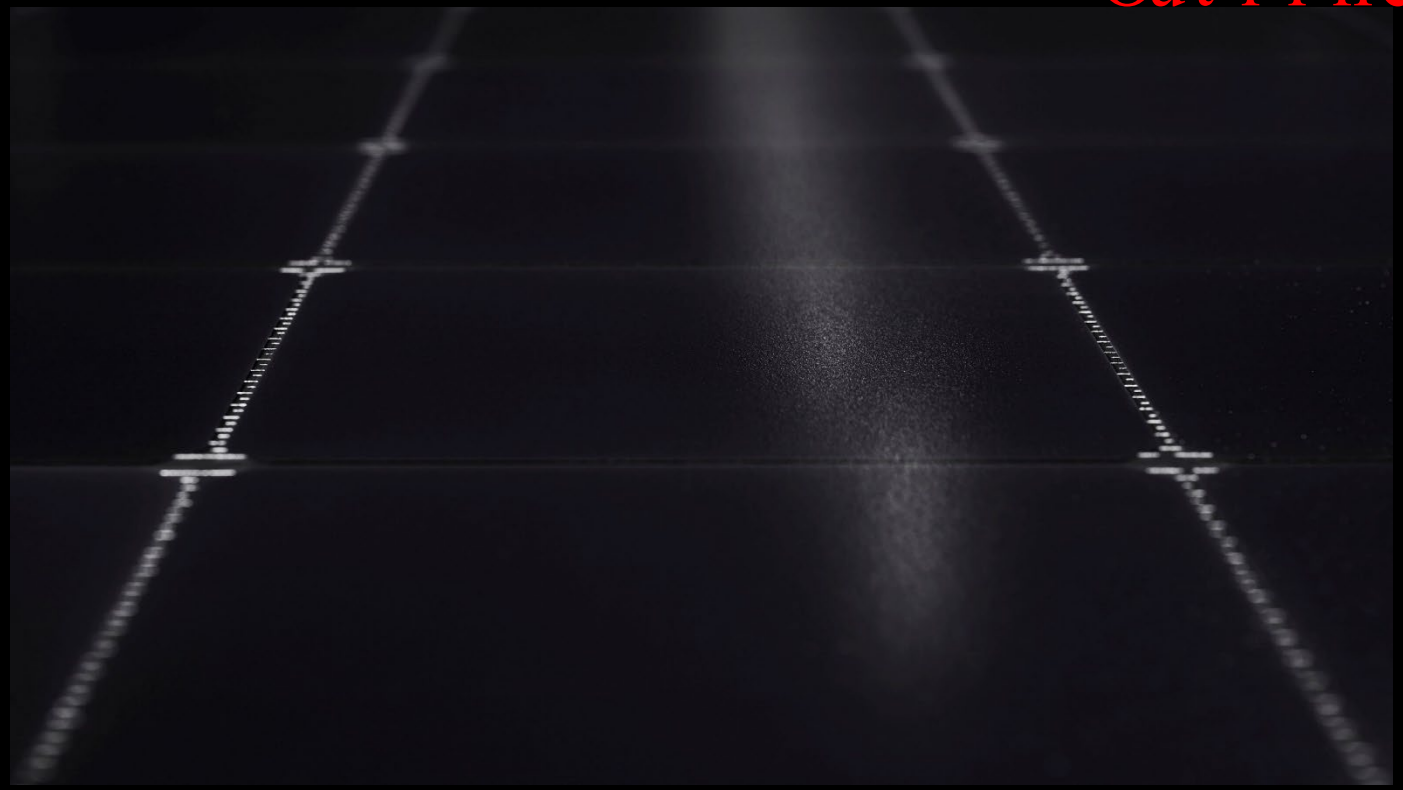
Tunnel IBC Module Developments

Tunnel IBC Advantages at Module Level compared to HJT apart from power gain

- 50% less SWCT foil (only on the back)
- -6.25 % less wires
- Thin encapsulant (up to 50% less encapsulant)

→ Leading to significant cost saving per module

Outline



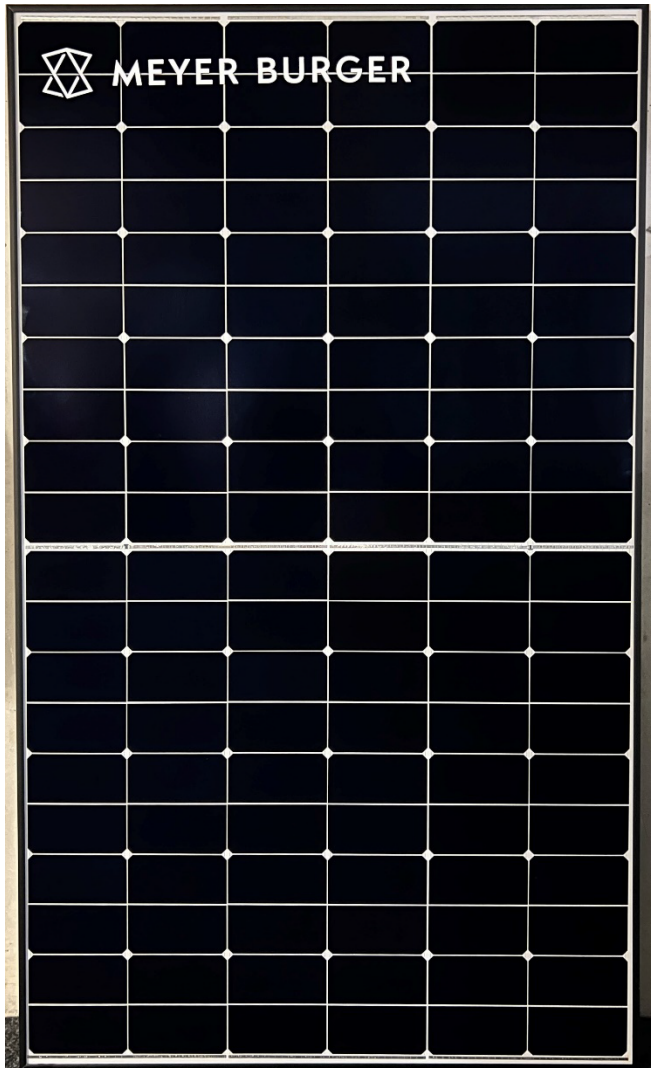
1 Introduction of Development Sites

2 Tunnel IBC Solar Cells

3 SWCT and Tunnel IBC Modules

4 Reliability Results

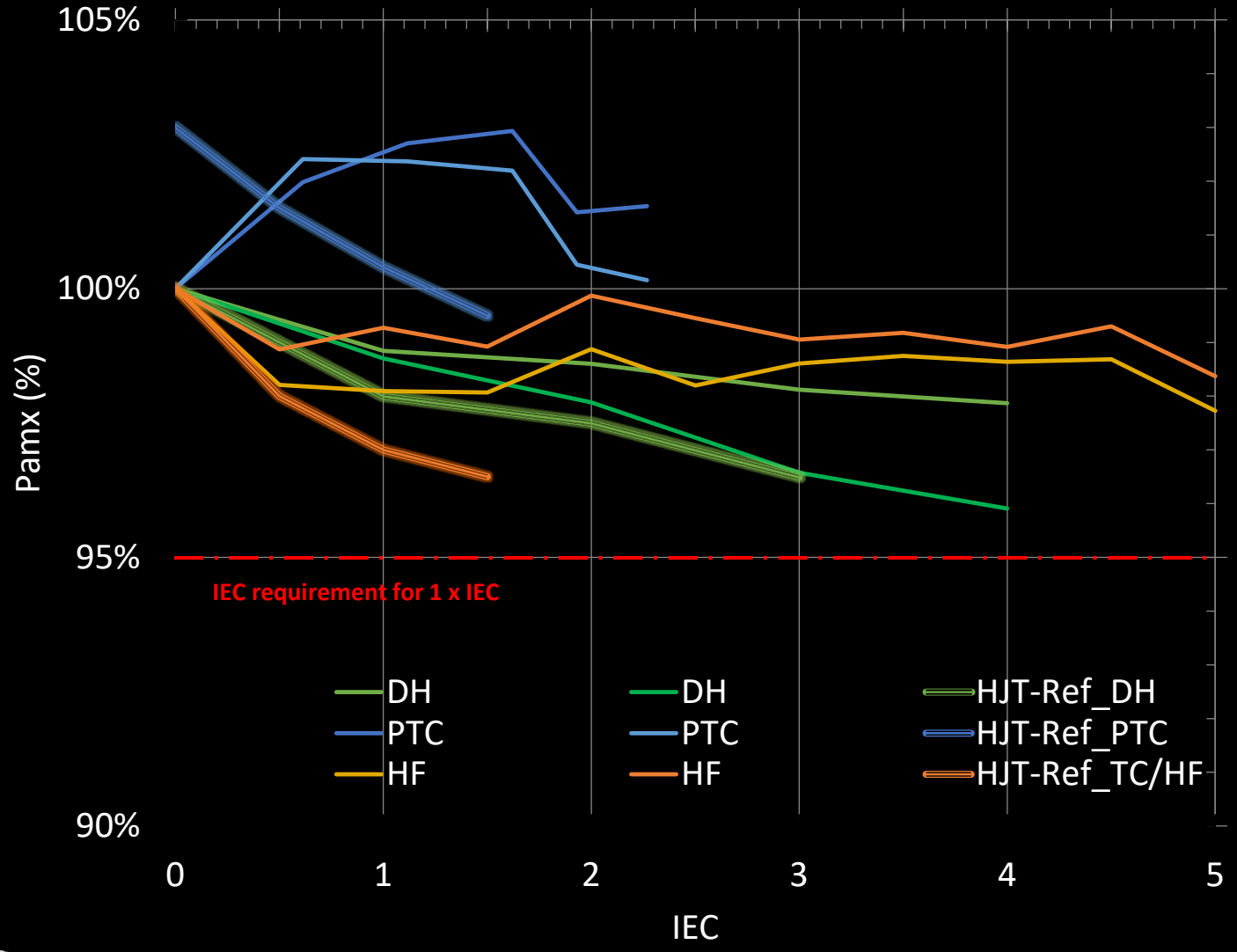
Tunnel IBC Module Developments



- Currently 120 HM6 modules built for EU Project Pilatus
  - Targets transition to 108 HM10 + BOM development for superior longevity
- The best power achieved 394 W with 24% efficient cells
  - Expected to increase with better CE and module design (potential >450W)
- 21 modules built for pre-certification

Test	IEC conditions	IEC duration	MB-Int.Q
TC	Temperature cycle between -40°C and +85°C powered with Imp during T ramp-up	200 cycles (1 cycle ~4-5 h)	960 cycles
DH	85°C, 85% relative humidity (r.H.)	1000 hours (42 days)	4000 hours
HF	85°C; 85% r.H., 1 freezing cycle for 1 h per day down to -40°C	10 cycles (10 days)	50 cycles
ML	minimum test load of 2,4 kPa, positive (downward) and negative (upward)	+/- 2.4 kPa 1 hour each	+ 5.4/-3.2 kPa 1 hour each

Module Reliability Results



- All modules passed ≥ 4 times IEC requirements
  - Power degradation <5%
  - Electrical safety ok (insulation & wet leakage)
  - Visual inspection no bubbles or delamination

- Initial power increase of TC modules due to current soaking effect
  (Rs reduced → FF increased → power gain

- HJT-Reference shows average degradation from production monitoring
  → Product warranty 25 years
  → IBC promises increased lifetime of 30 years

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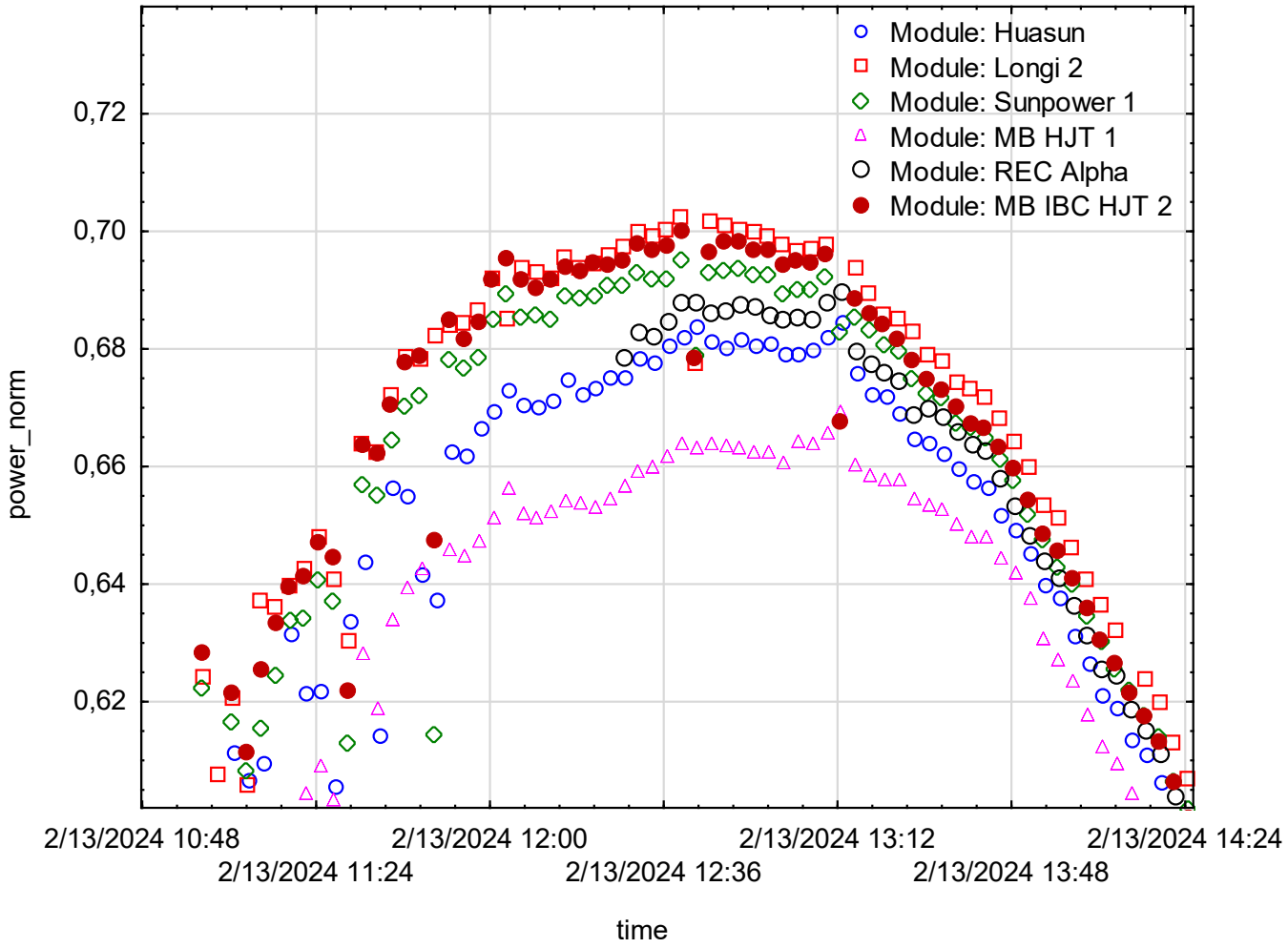
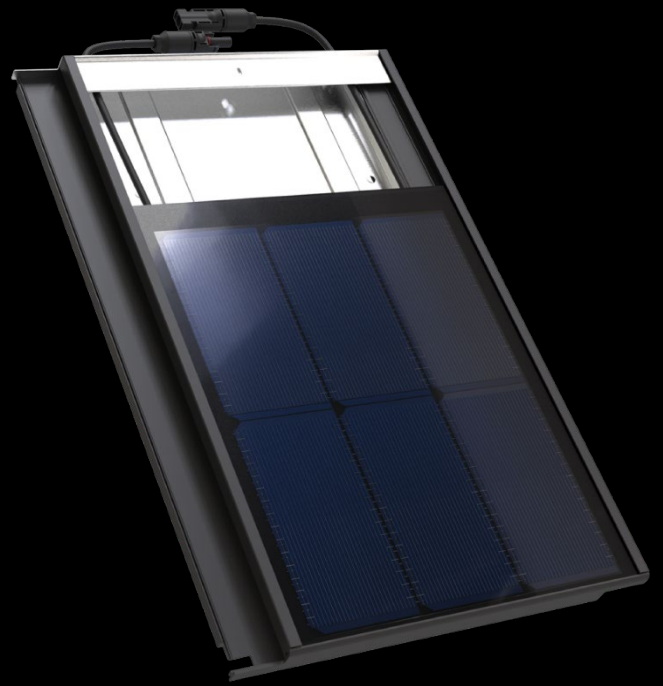
Tunnel IBC modules outdoor monitoring



- MB IBC HJT is very close to Longi HiMo6 and Sunpower Max3 modules and significantly better than REC, Huasun and MB HJT modules.

In Pilatus we also evaluate the alternative market for tunnel-IBC adoption and we assess the requirements

→ IBC roof-tile is going to be shown on a 1 kWp demonstration roof at the end of the project



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Tunnel - IBC technology

> 25% Efficiency

- HJT based technology
- Solid patent portfolio

10 Process Steps

- No Indium
- 3.3mg/Wp Ag

IEC Superior Reliability

- TC, DH, HF
- PID, UV

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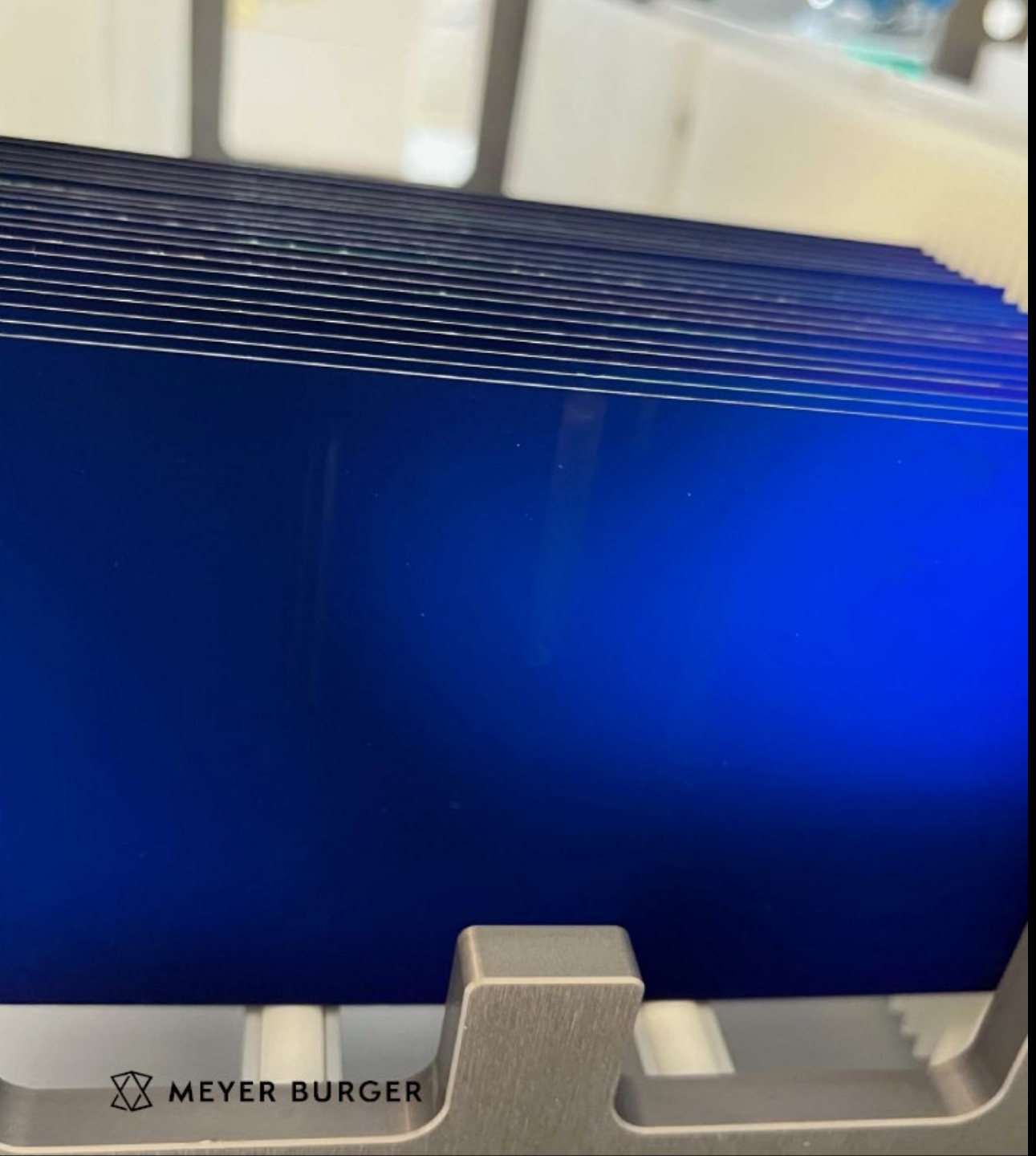

Contact & Acknowledgment

Do you have any questions?
Gizem Nogay@meyerburger.com

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