Updates of Metallization and Interconnection Development from Chinese Mass Production

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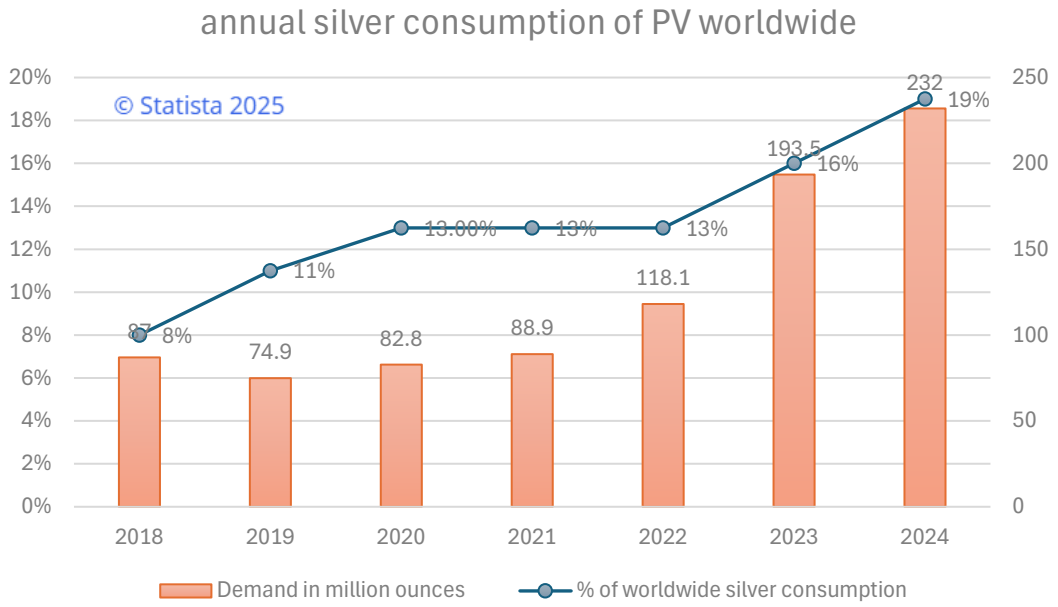
[1]CSEM / [2]InfoLink Consulting/ [3]Tongwei Solar/ [4]Nahum Eli/ [5]Yanyang New Energy/ [6]Maxwell/ [7]iSilver/ [8]HuaSun/ [9]WV Automation/ [10]SHXZZ/ [11]Risen/ [12]Astronergy/ [13]Copprint

13th MIW/ 20.10.2025/ Berlin Germany

OUTLOOK

- Overview, Mainstream Cell Technology and Cost
- Development of Metallization in Mass Production
  - Low Silver Content Paste Development
  - Screen Development
  - Cu-Plating Development in HJT
- Development of 0BB Solutions in Mass Production
- Summary

Overview- Silver Demand in PV Industry



PV industry could account for 40% of global silver demand by 2030

New research from Europe shows that the global PV industry may require up to 14,000 tonnes of silver per year in 2030, with global supply being only 34,000 tonnes. The scientists said more efforts should be made to reduce silver content in TOPCon and heterojunction solar cells.

SEPTEMBER 11, 2025 EMILIANO BELLINI

The analysis showed that total silver demand is projected to reach 48,000 to 52,000 t/y in 2030, with supply being enough to reach only 34,000 t/y. The PV industry, meanwhile, is projected to see its silver demand grow by a factor of 1.6 to 2.3 to 10,000–14,000 t/y in 2030, as a consequence of higher silver consumption in new cell designs such as TOPCon and HJT. "As a result, the silver demand of the PV industry could account for 29–41 % of the projected supply in 2030," the academics emphasized.

Source: pv maganize

- Annual silver consumption in the PV industry, as well as its share in % of global silver consumption, both increased significantly over the past three years.
- Silver price increased rapidly in last months and touching now the record in last 20 years.
- In a report from PV magazine in Sep 2025, the silver demand of the PV industry could account for 29-41% of global demand by 2030.

Reduction of silver consumption in PV industry is getting more urgent!!!

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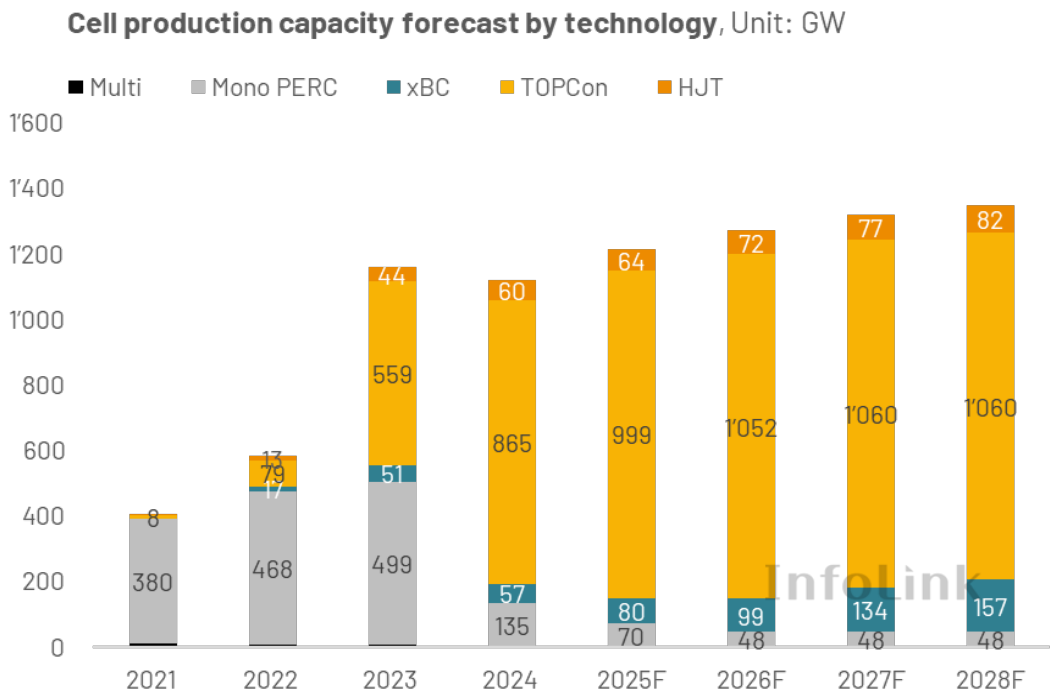
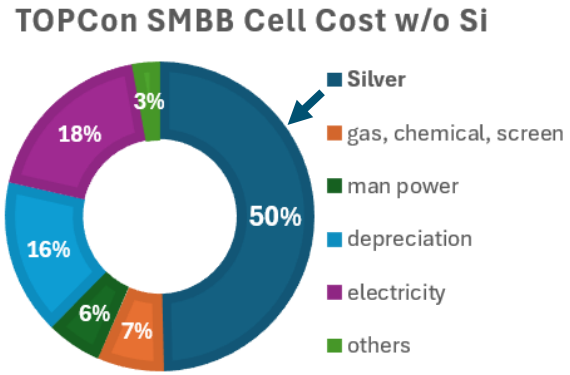
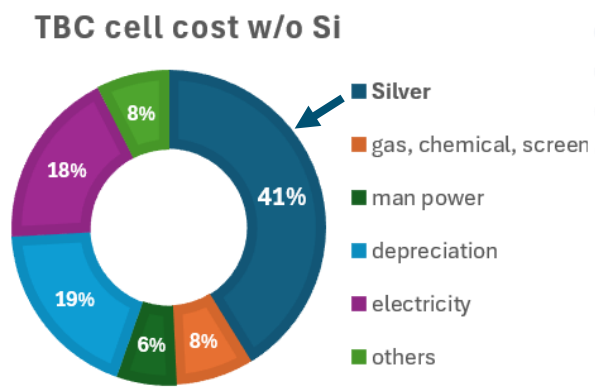
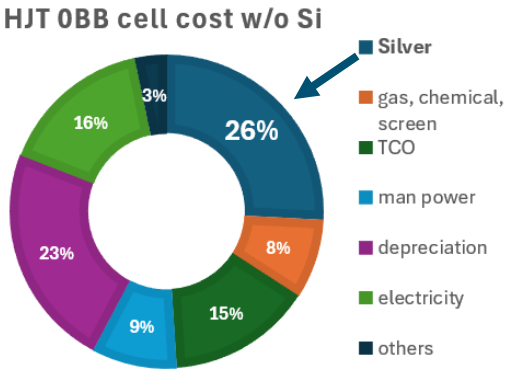
PV Market Report from InfoLink – Cell Tech and Cost



Source: New Technology Market Report_May-25, InfoLink







Source: New Technology Market Report_Aug-25, InfoLink

- TOPCon remains the mainstream cell technology in the future years, BC's capacity beyonds HJT and its market share keeps increasing.
- Silver still dominates the cell cost for TOPCon SMBB and TBC. By involving low silver Ag/Cu pastes and 0BB in HJT, the silver cost has much less ratio in total cell cost.

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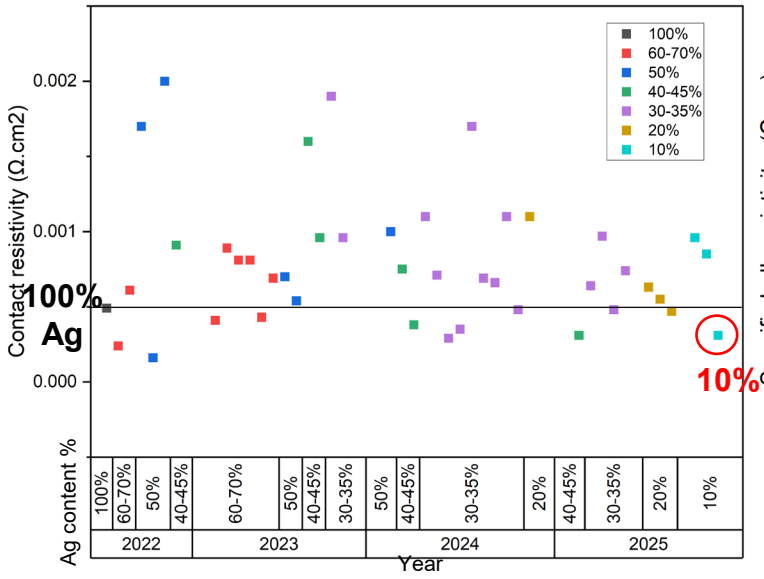
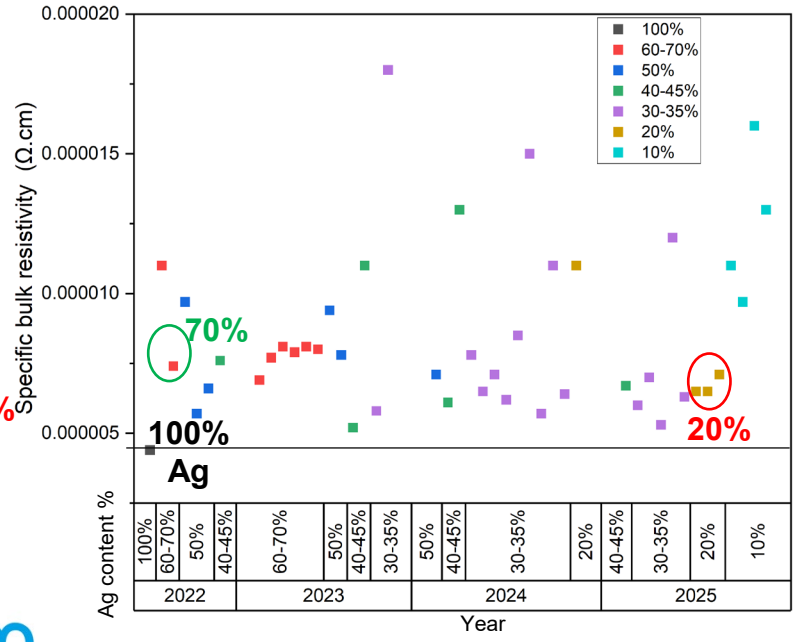
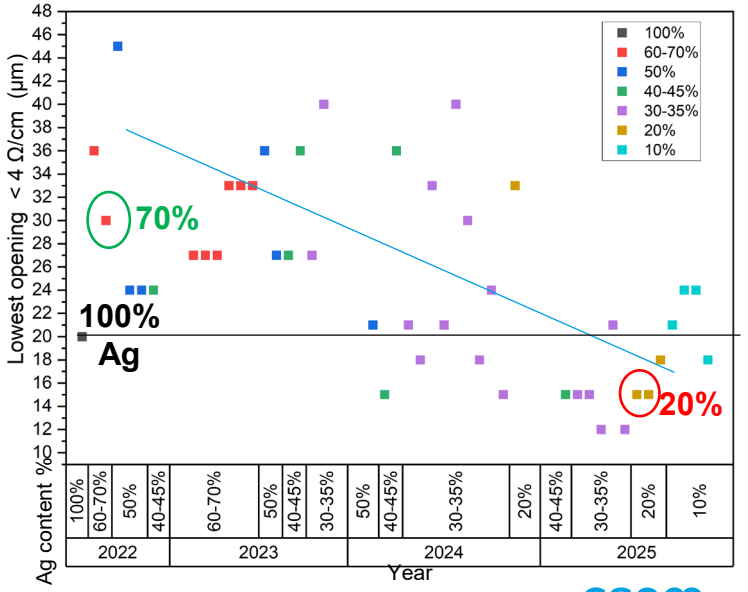
HJT Ag/Cu Paste Evaluation since 2022 @CSEM

- From 2022 to now, more than 130 pastes were evaluated at CSEM. From them 45 are Ag/Cu pastes and they are mainly provided by 10 different paste suppliers.
- 3 main parameters from paste evaluation are monitored for diff. silver content.
- In 2025, 10% Ag/Cu can meet even lower level in contact resistivity than pure Ag paste.
- Now, 20% Ag/Cu has even lower bulk resistivity than most 70% Ag/Cu in 2022.
- To get line resistance below 4 Ω/cm, in 2022 paste with 70% silver can be printed through 30 µm screen openning. Now, 20% Ag/Cu can be easily printed through 14 µm opening.

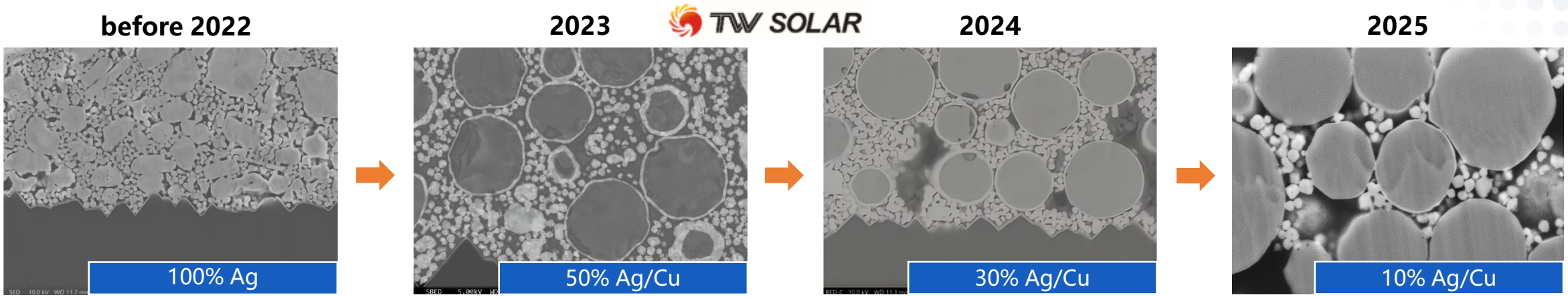




Significant improvement of HJT Ag/Cu paste development in last 3 years!



HJT Ag/Cu Paste Evaluation since 2022 in Mass Production

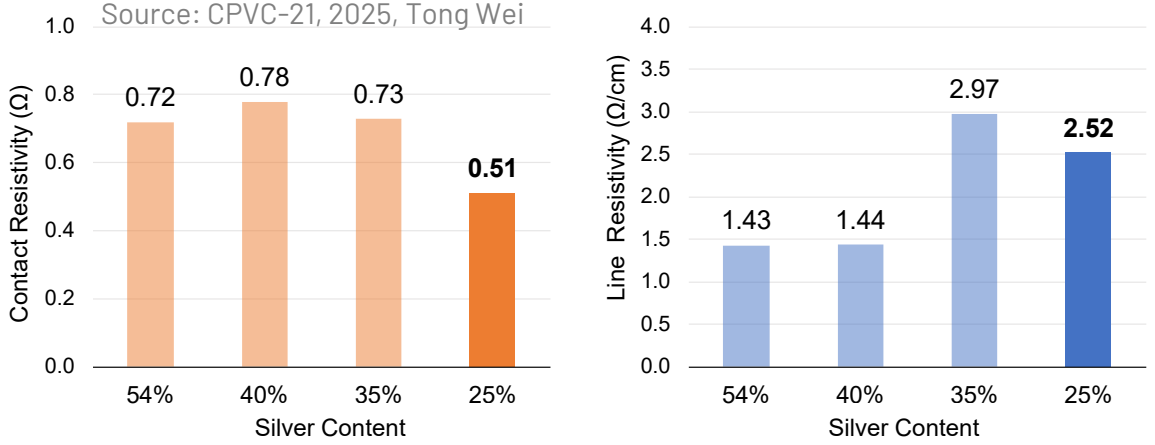


Source: CPVC-21, 2025, Tong Wei

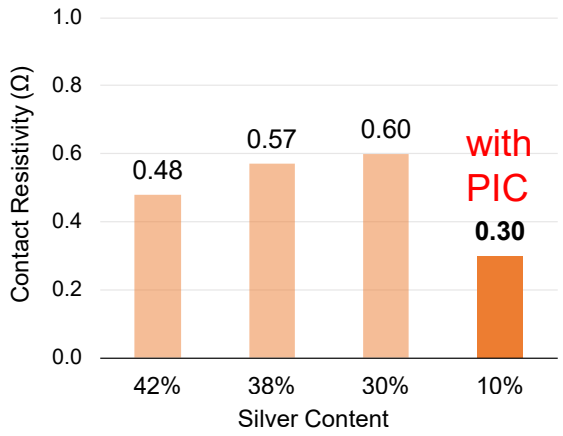
- The silver content of the paste is decreasing year by year.

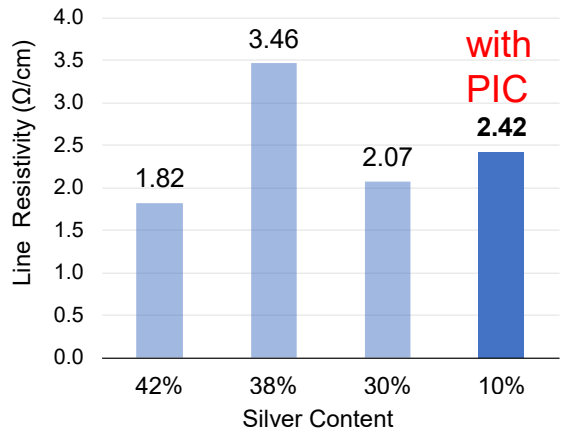
Front Paste Contact Resistivity, Line Resistivity

Source: CPVC-21, 2025, Tong Wei



Rear Paste Contact Resistivity, Line Resistivity





- Currently, at Tongwei the Ag/Cu with a silver content of 25% on the front and 10% on the back is ready for mass production. **10% Ag/Cu has to combine with Photot Induced Curing (PIC).**

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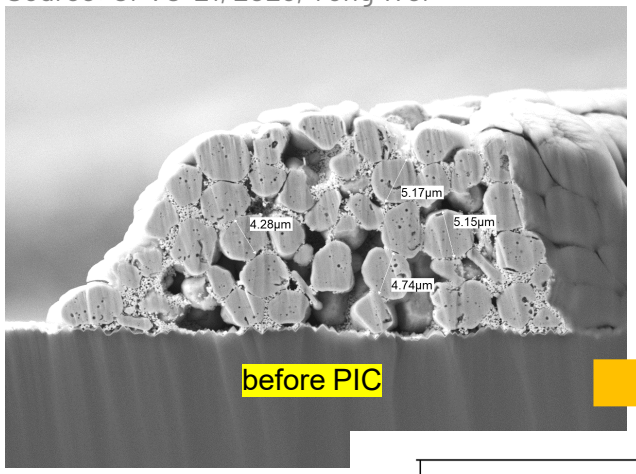
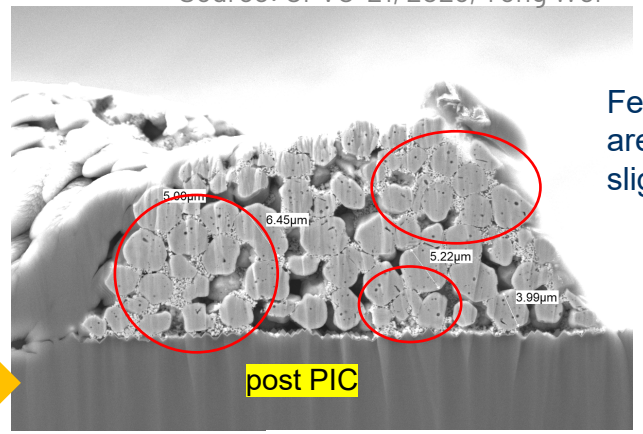
Conductivity Booster for 10% Ag/Cu - Photon Induced Curing (PIC)

Source: CPVC-21, 2025, Tong Wei

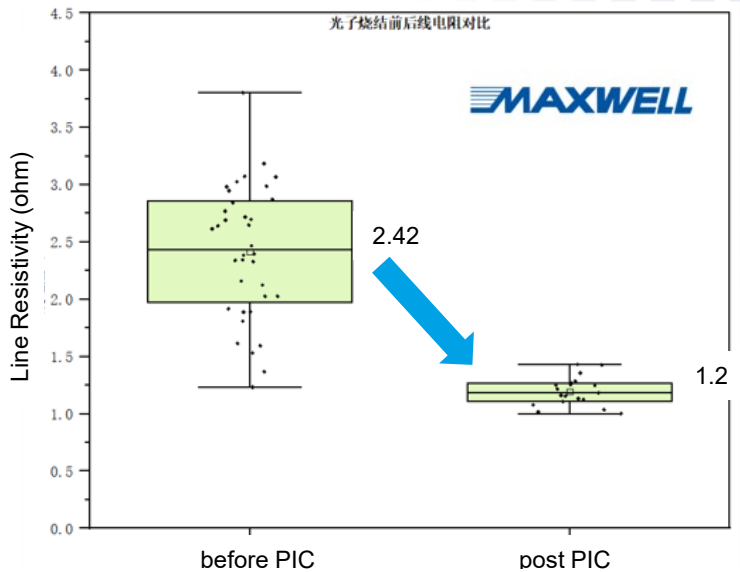


PIC

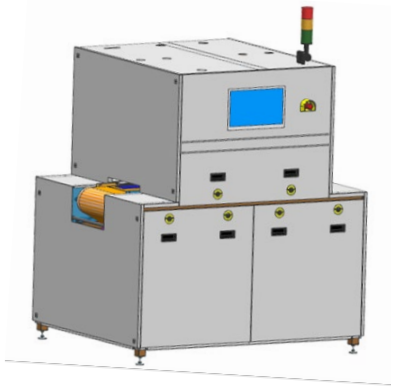
Source: CPVC-21, 2025, Tong Wei

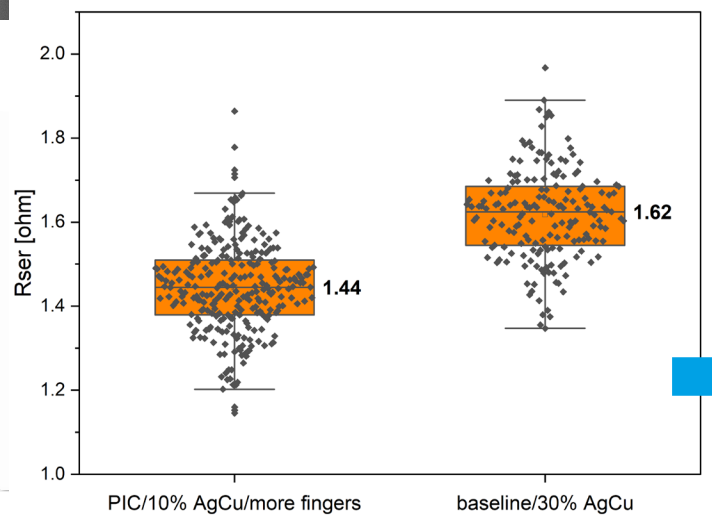


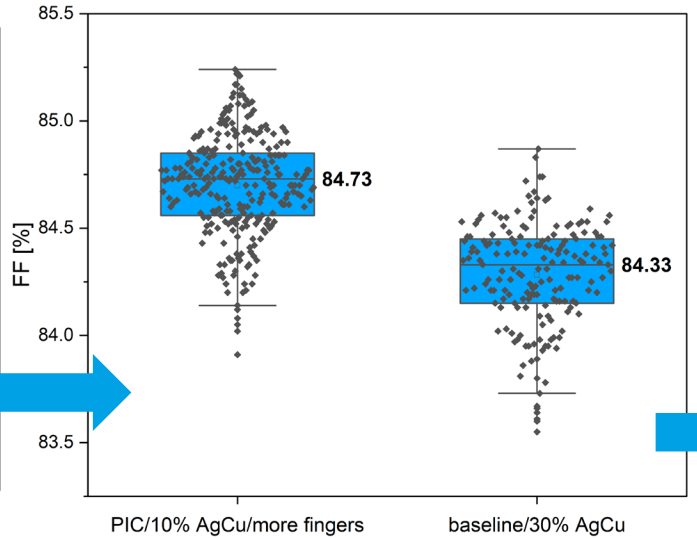
Few Ag/Cu powders are observed in a slight molten state.

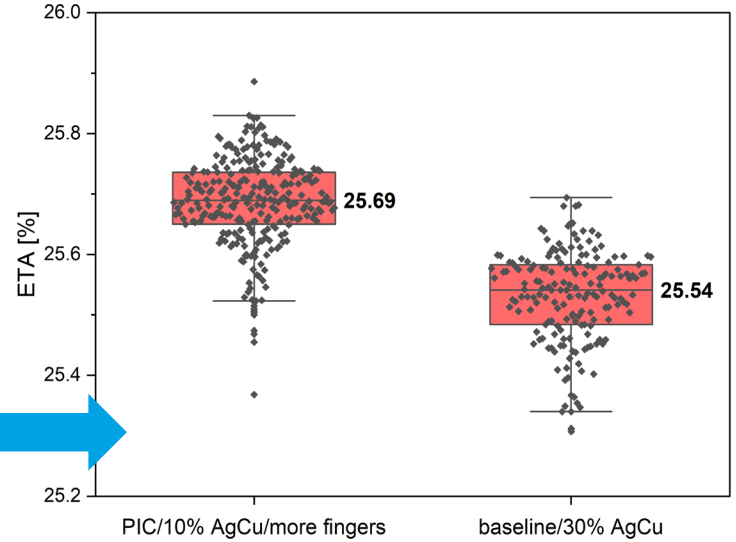


MAXWELL









Source: Experimental results from Maxwell in mass production

- **Reliability in module level is running at Tongwei with 10% Ag/Cu**

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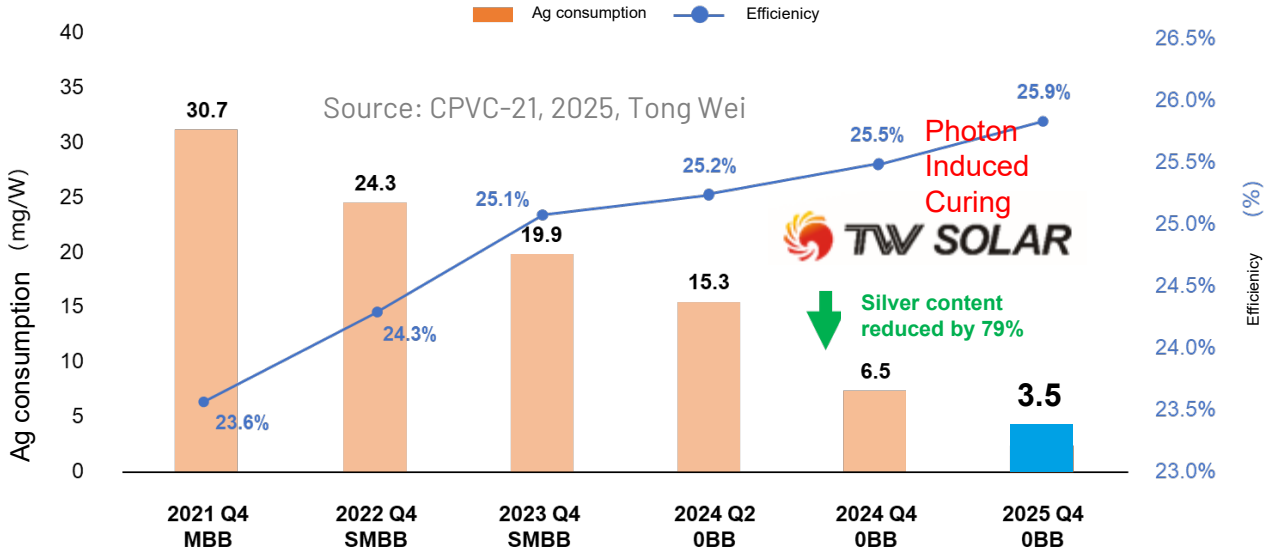
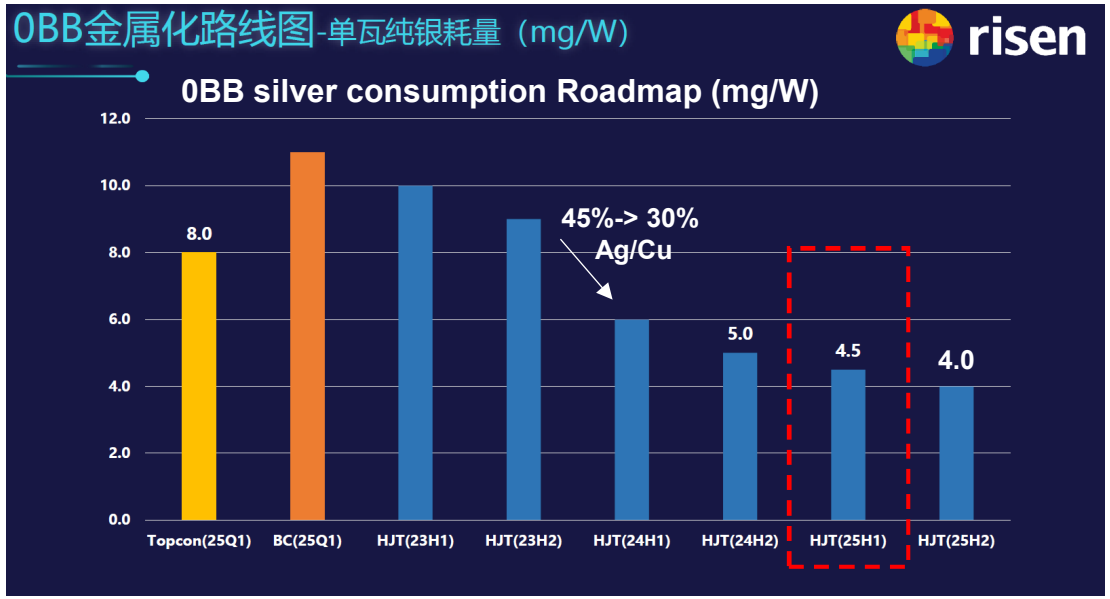
Development of Ag/Cu is Booster for HJT Ag Reduction

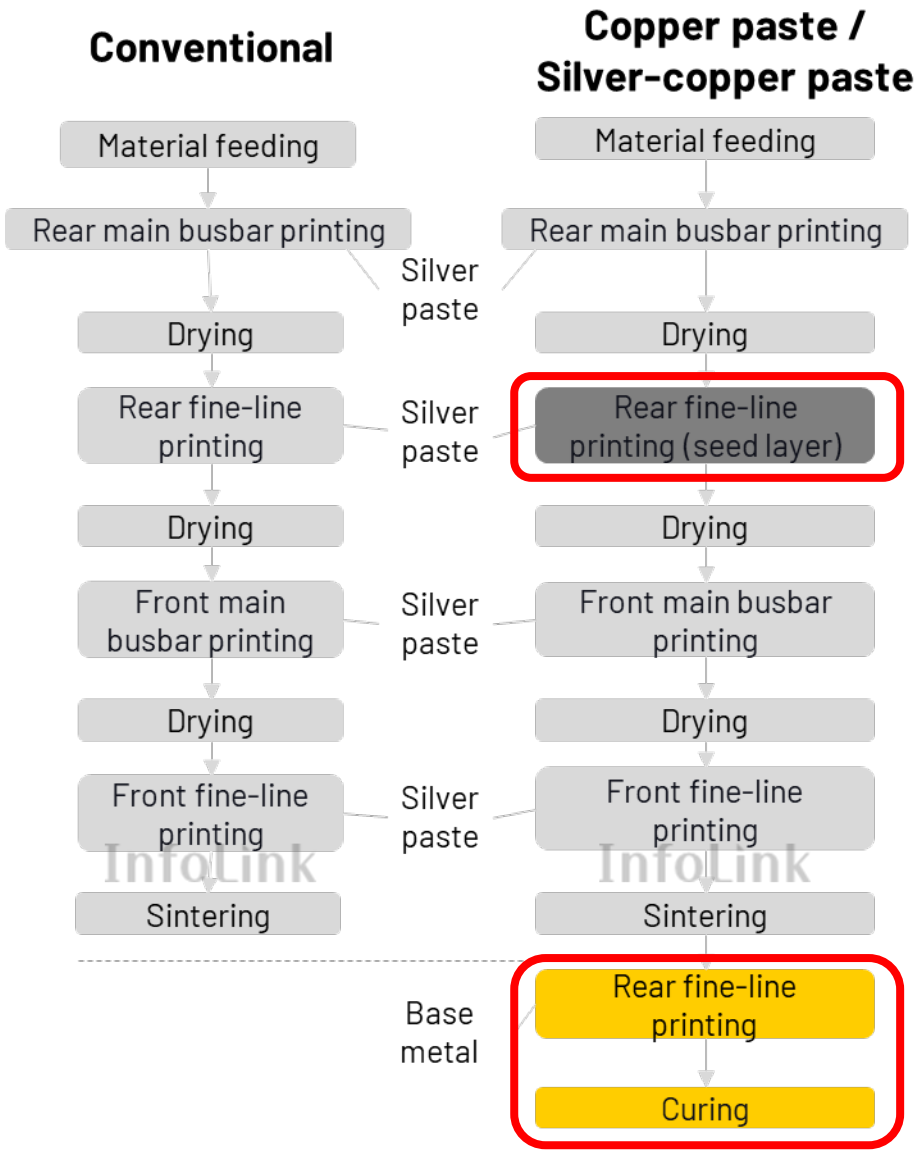


- By involving 10% Ag/Cu paste, the Ag consumption on HJT mass production could be reduced to 3.5 mg/W.

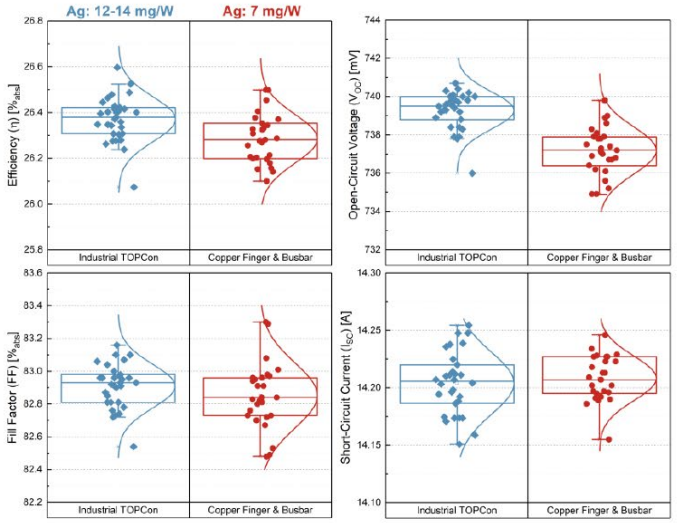
- Silver consumption in HJT mass production at Risen fulfilled 4.5 mg/W and it has still potential to meet 4 mg/W in 0BB until end of this year, which is **below half** of TOPCon's consumption.



Low Silver Content Paste on TOPCon Back Side

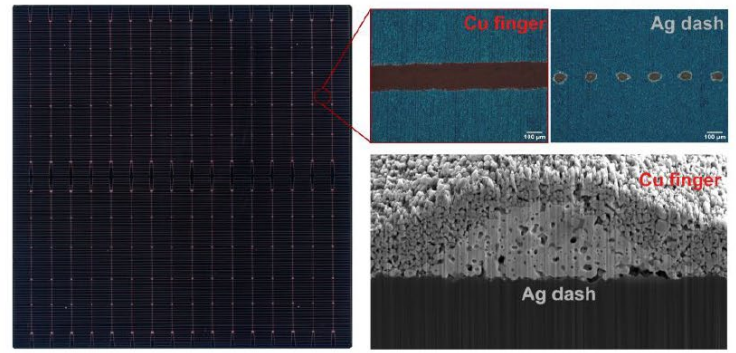


2024: TOPCon: New results from Yuchao Zhang



7mg Ag/W

Copprint



Source: Copprint, less Silver Metallization Forum, 2025/03

- Seed-Ag paste with **20%** low temperature Ag/Cu covering paste from **DKEM** are applied at one **TOPCon tier 1 company**; 15% less Ag completed; **DH2000 passed** and **DH3000 ongoing**; **25Q4** mass production planned. *
- Several TOPCon cell manufactures are trying **Ni-Ag** mixed paste to replace pure Ag paste. Currently, **85% Ag** content secured similar wet weight and ETA to BL, **80% Ag** paste is in evaluation. **

* ** *Source: New Technology Market Report_Aug-25, InfoLink*

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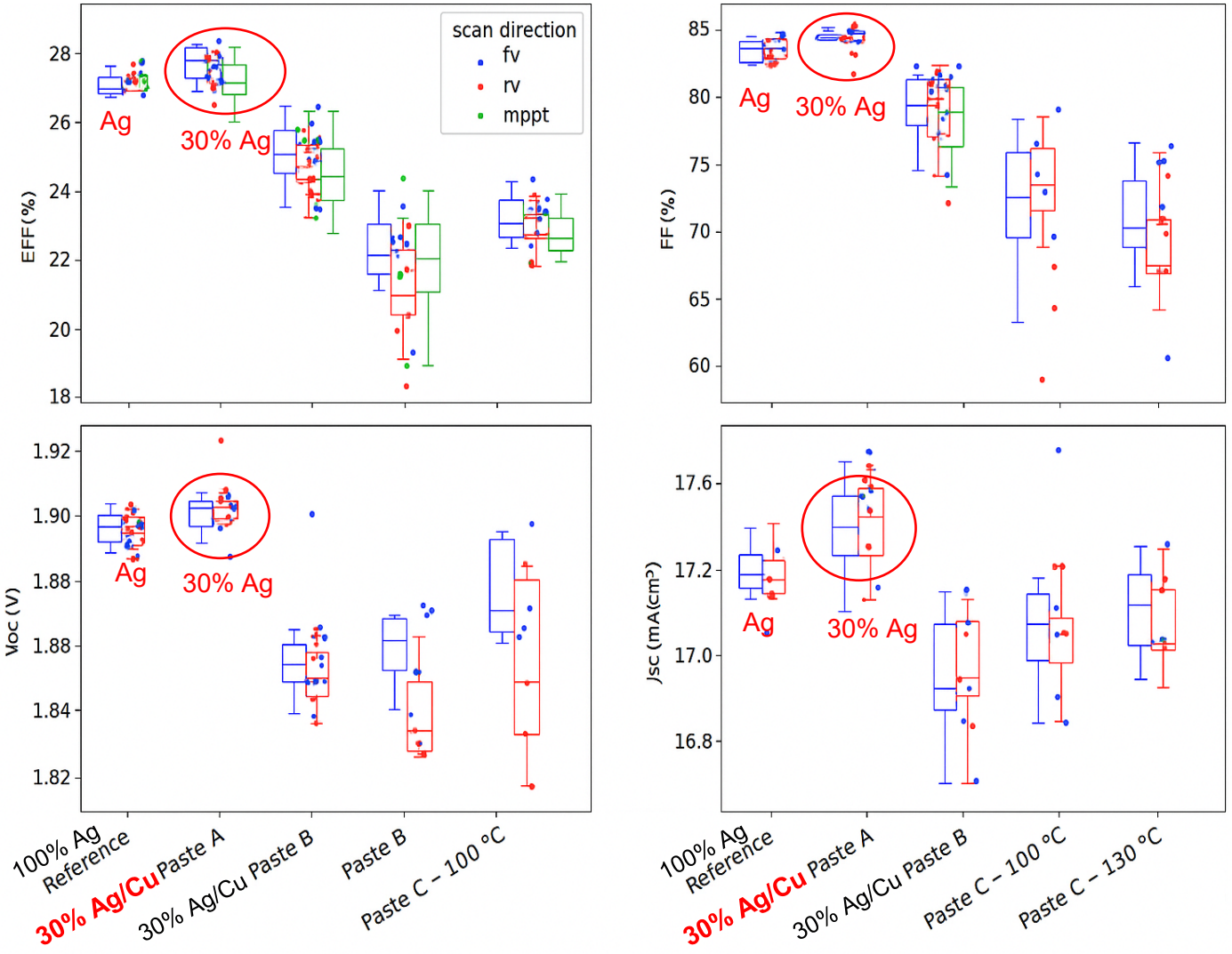
30% Ag/Cu Paste Evaluation in 2T SHJ/Pk Tandem Device



- Paste comparison test on 2T SHJ perovskite tandem device at CSEM.
- Ag/Cu Paste A with 30% silver has received higher level in all electrical parameters than reference pure silver paste.

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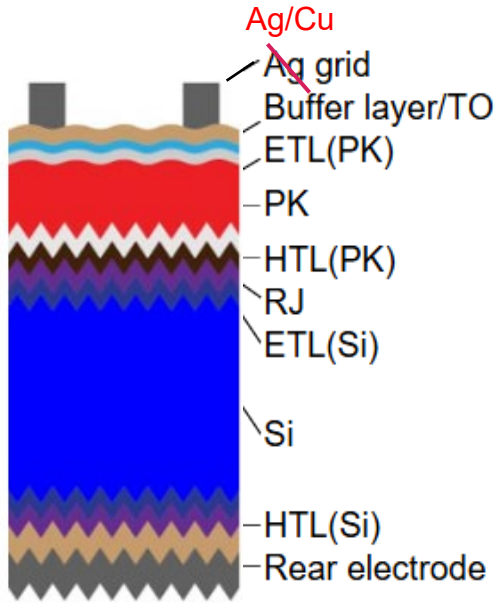

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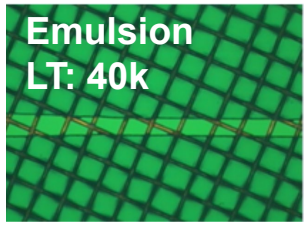
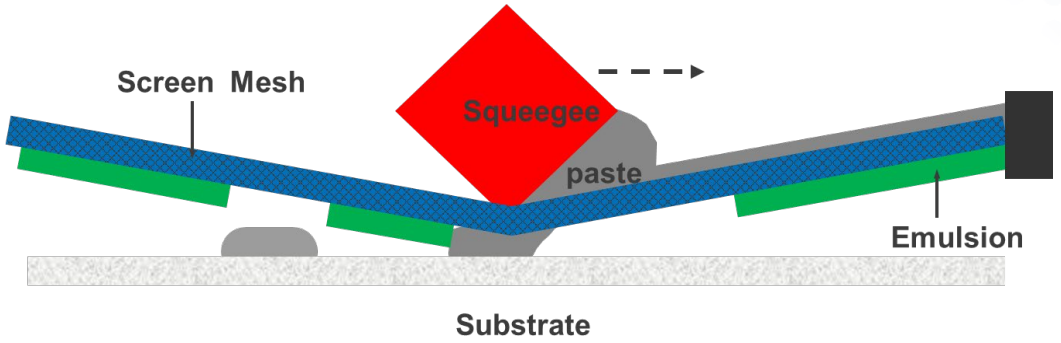
Screen Development in Chinese Mass Production





2009-2010 2010-2011 2013-2014 2017-2019

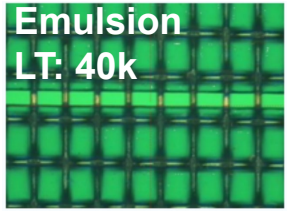
22.5°

50% opening

290/20

325/16
360/16
380/14

430/13



2014-2018 2019 2022 2023 2024 2025

0° Knotless
70% opening

480/11

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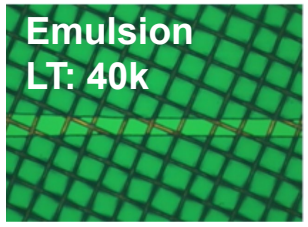
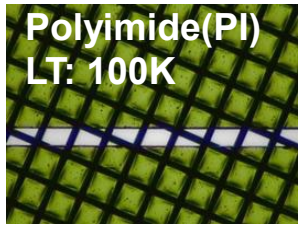
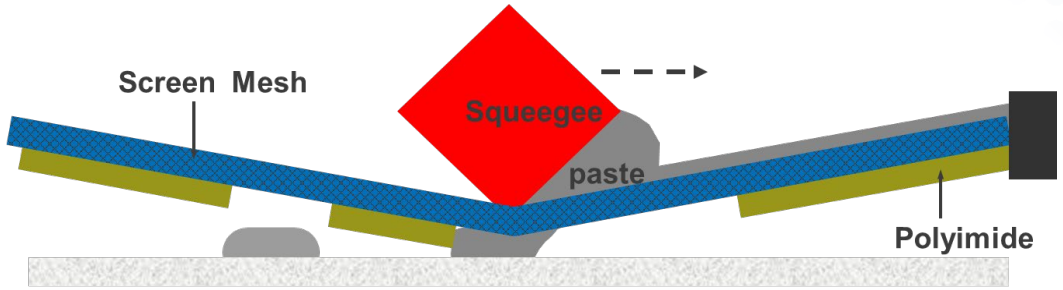
Screen Development in Chinese Mass Production





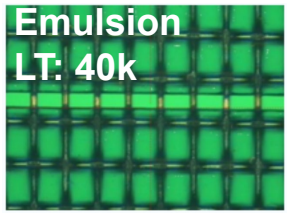


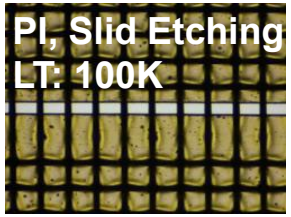
22.5°

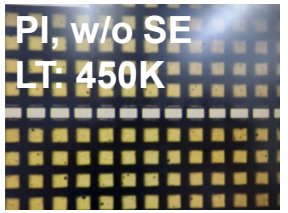
2009-2010	2010-2011	2013-2014	2017-2019
290/20	325/16 360/16 380/14	430/13	480/11

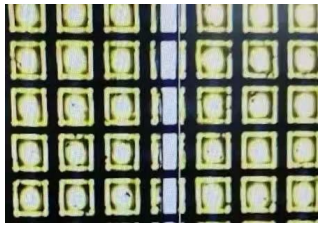
50% opening

Nickel Alloyed Mesh (Nahum-Eli) LT: 450K









0° Knotless 70% opening

2014-2018	2019	2022	2023	2024	2024-2025
480/11	520/11	520/11	640/9	700/8 640/9	700/6 760/5 (Nickel Alloyed)

Polyimide(PI) vs Emulsion:

- Higher resolution
- Better edge definition
- Longer screen life

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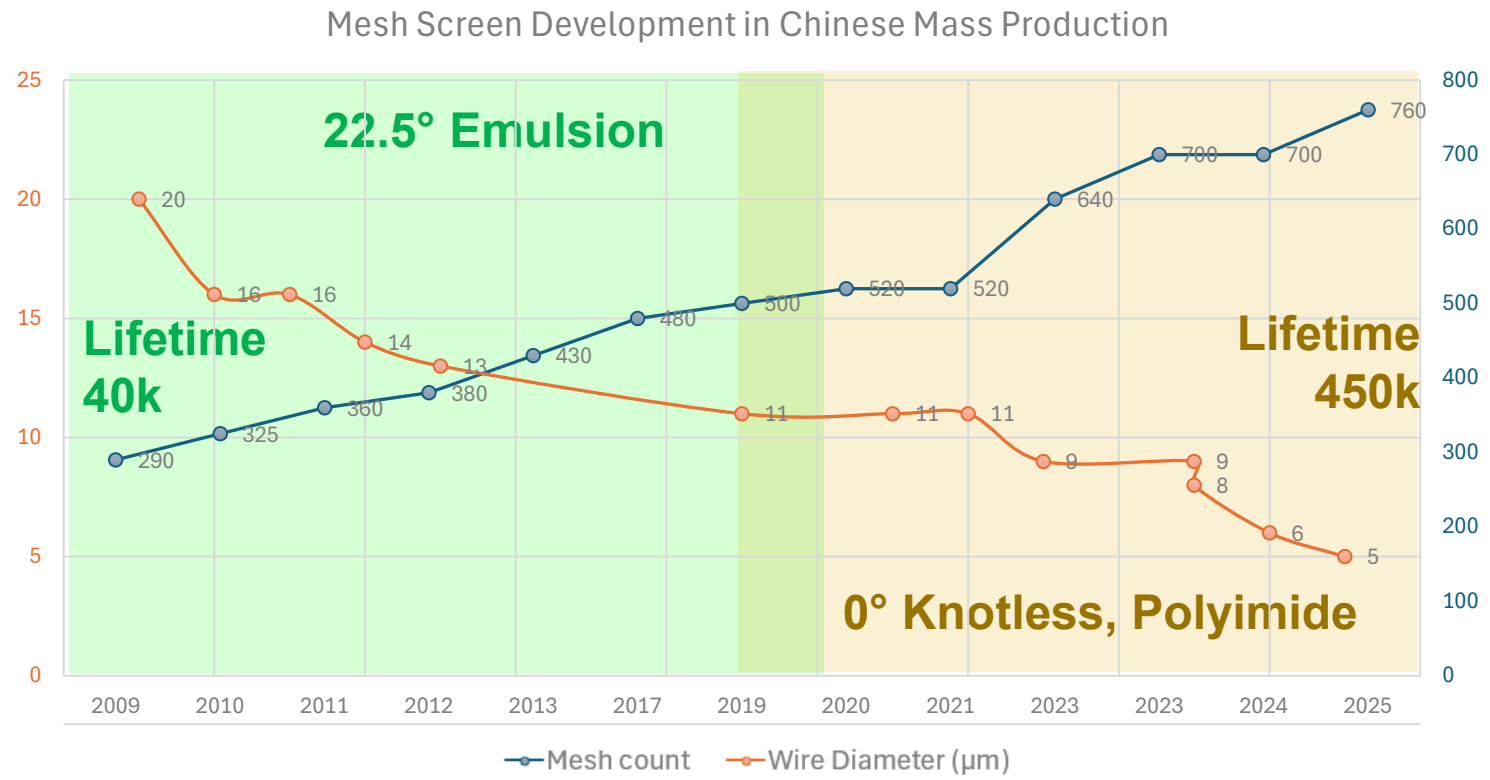
Screen Development in Chinese Mass Production



Source: screen supplier SHXZZ, Nahum Eli

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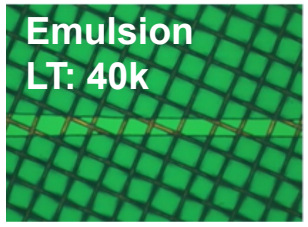
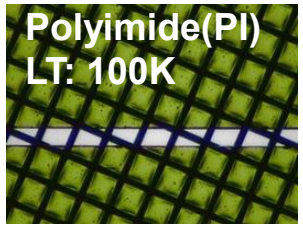
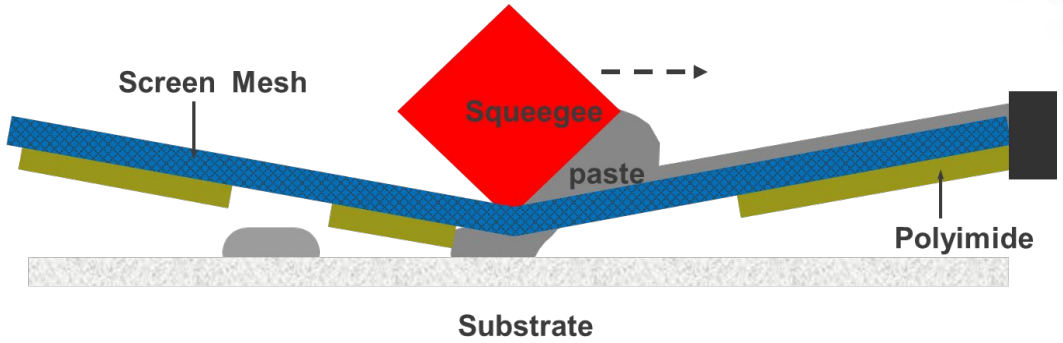
Screen Development in Chinese Mass Production







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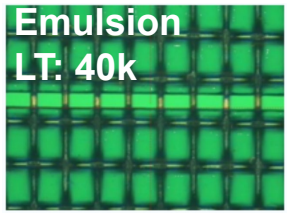
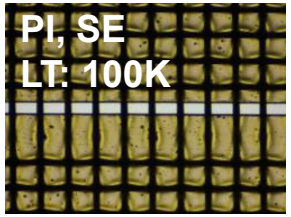
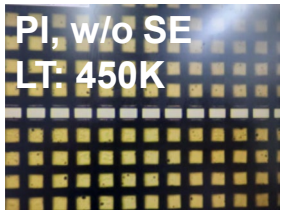
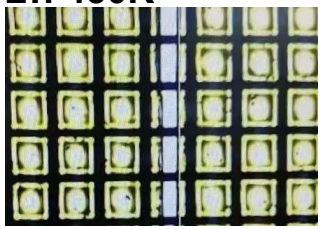
2009-2010	2010-2011	2013-2014	2017-2019
50% opening	290/20	325/16 360/16 380/14	430/13	480/11







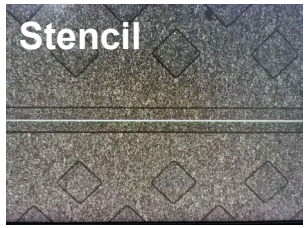
Nickel Alloyed Mesh(Nahum)
LT: 450K



0° Knotless
70% opening

2014-2018	2019	2022	2023	2024	2025
480/11	520/11	520/11	640/9	700/8 640/9	700/6 760/5

Two types
1) laser opened (Maxwell…)
2) Nanoimprinted (YanYang, Nahum Eli…)



Mainstream ?

BC, TOPCon production
LT> 500k

HJT mass production

100% Full opening

2022-2023	2024	2025

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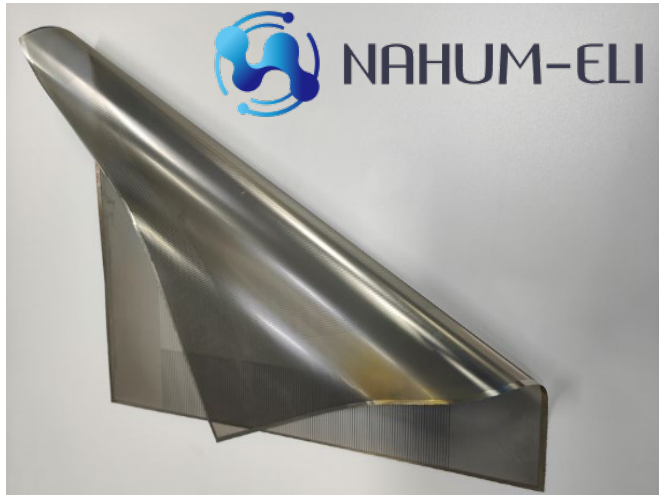
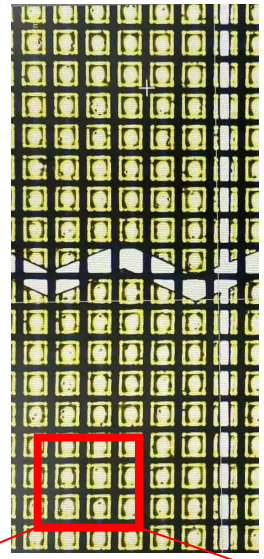
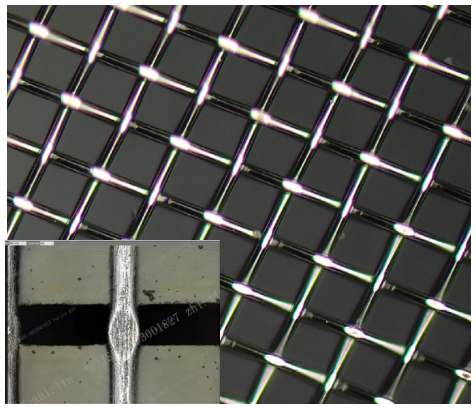
Advanced Screen Technology- Nickel Alloyed Mesh Screen

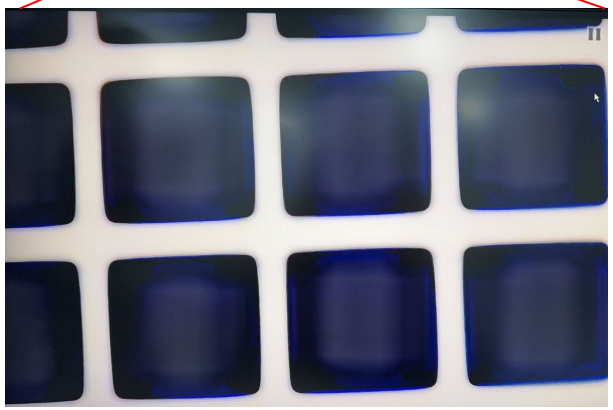


Nickel Alloyed Mesh





by roll press on convertional mesh obtains thick knot at wire conncetion



nickel alloyed mesh offers flat knot opening for better paste flowing

Convertional Mesh Screen

Filament → Weaving → Roll Press

VS

Design Modeling → Nanoimprint → Electroplating

Nahum Technology

Advantages to compare with convertional mesh screen

- -20% ~ -30% less expensive
- Customizable parameters such as mesh count, wire diameter, thickness; 600-6 and 760-5 as main products.
- Maintain a knotless design to ensure structural stability
- Higher mechanical strength for higher lifetime.

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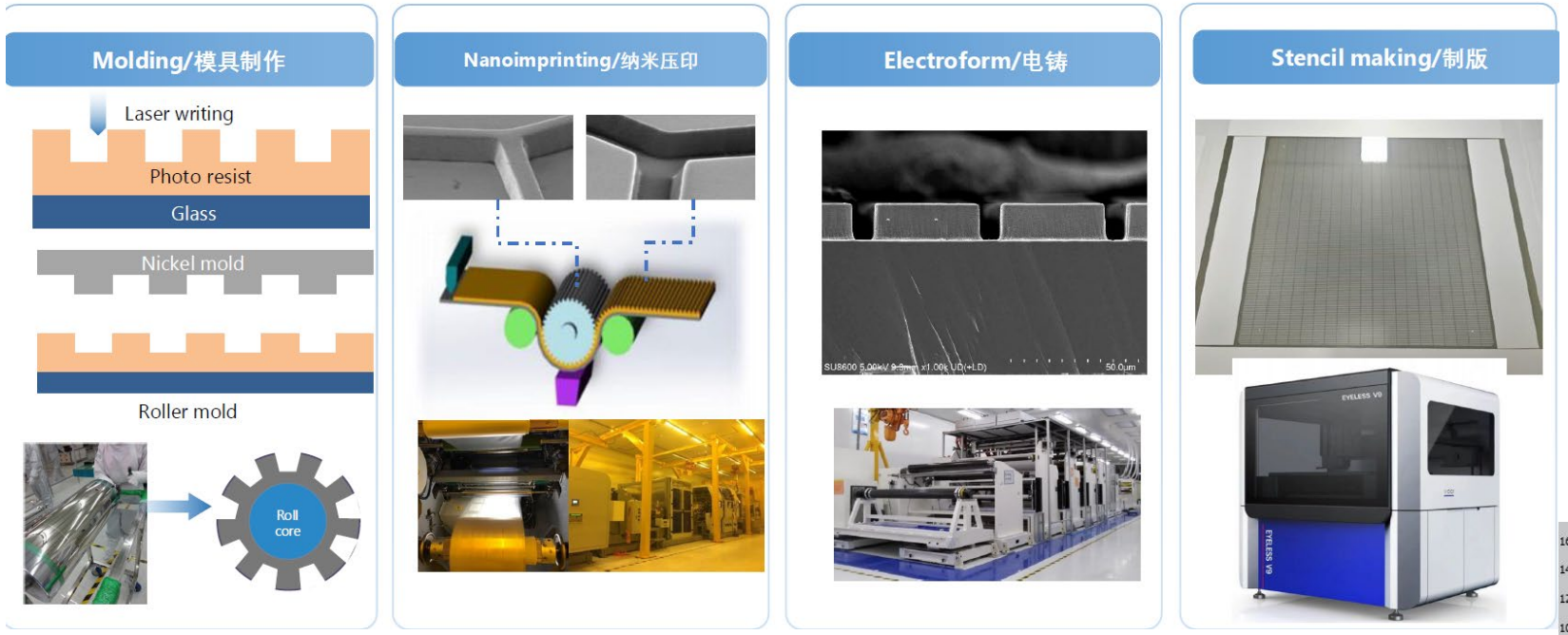
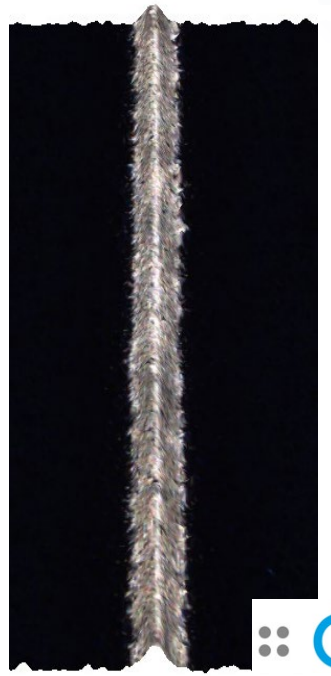
Advanced Screen Technology- Stencil Fabrication

Production Process





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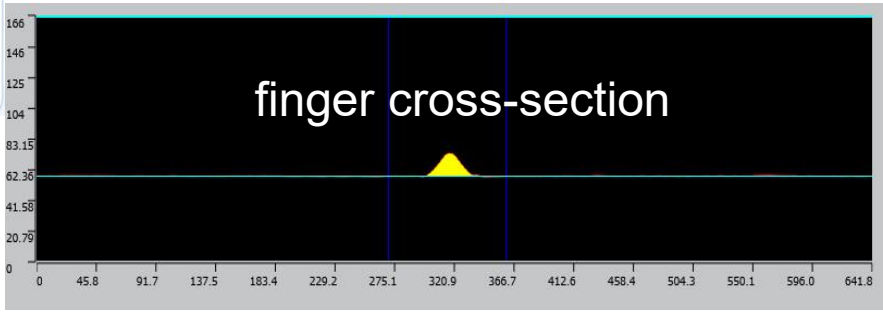
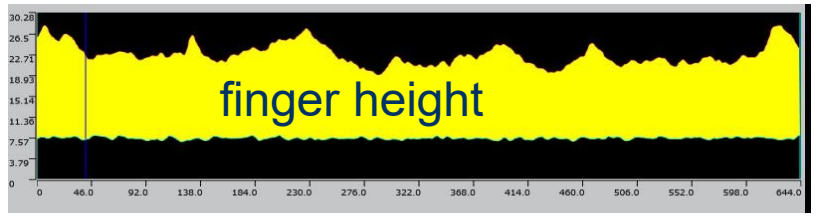


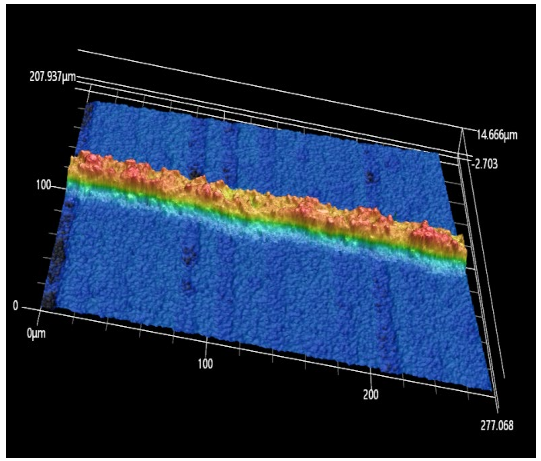
- With full opening screen, high performance of triangle shape finger cross-section and homogenous finger height on HJT Ag/Cu paste were demonstrated at CSEM with high-speed print



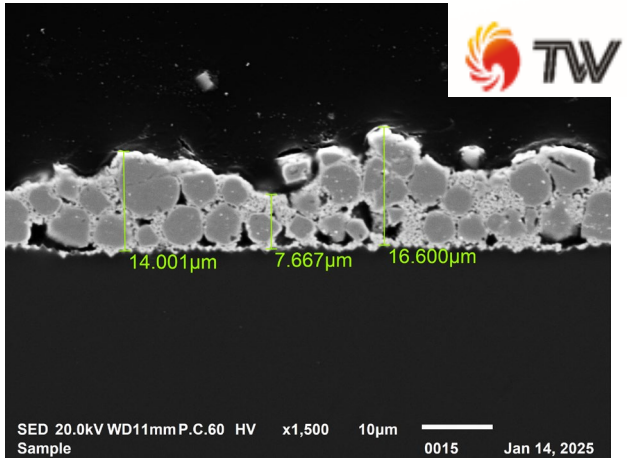
Stencil vs Mesh Screen in HJT Production

Source: CPVC-21, 2025, Tong Wei

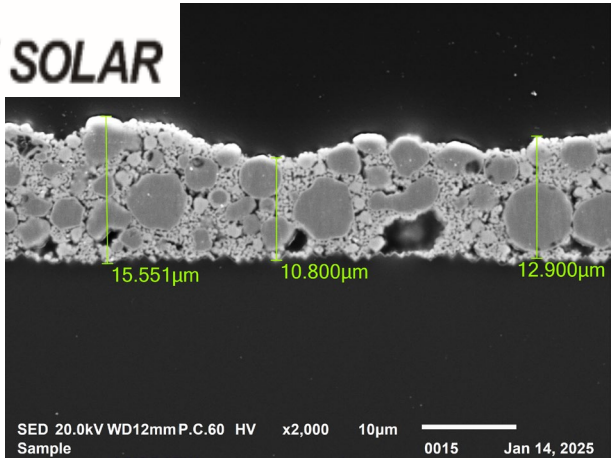
Stencil



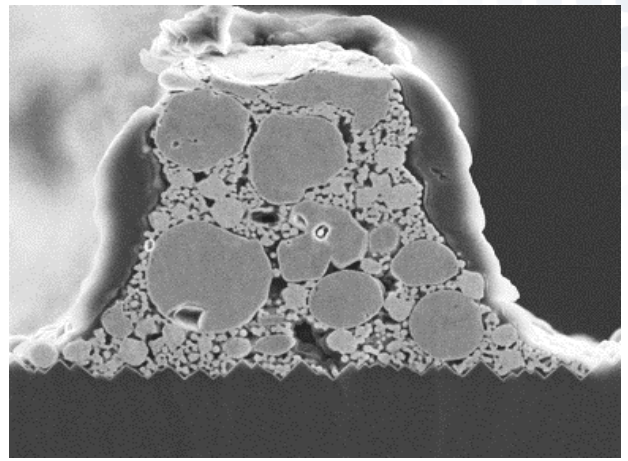
3D finger geometry



Rear Finger longitudinal section

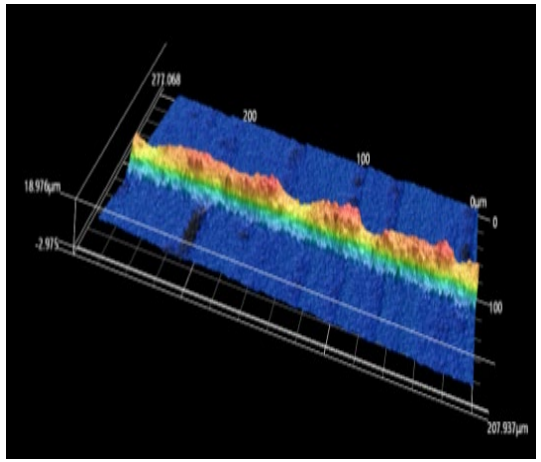


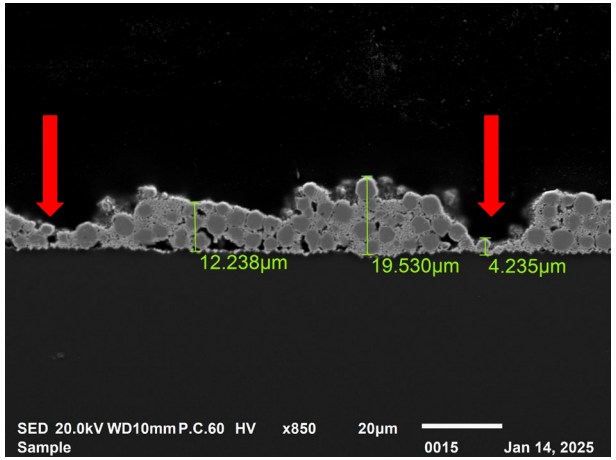
Front Finger longitudinal section

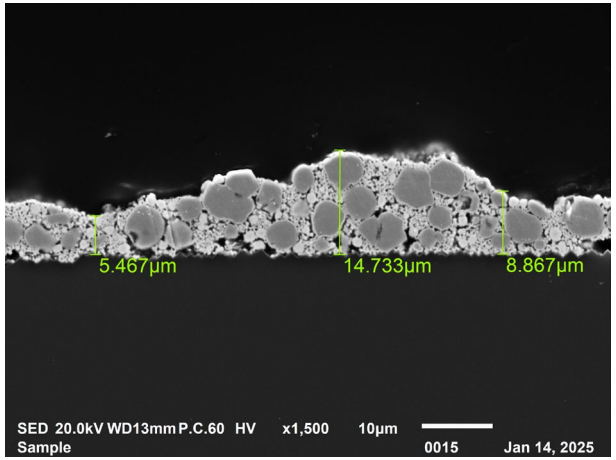


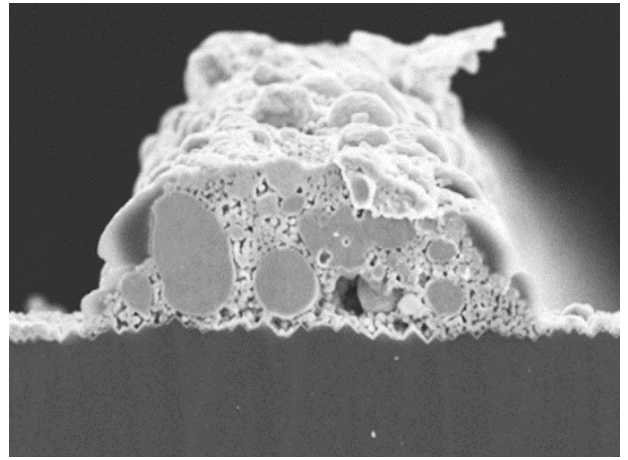
Front Finger cross section

Knotless mesh screen









- Stencil with full opening can form more homogenous finger height and higher aspect ratio. It leads **3W** higher module power than standard mesh screens.

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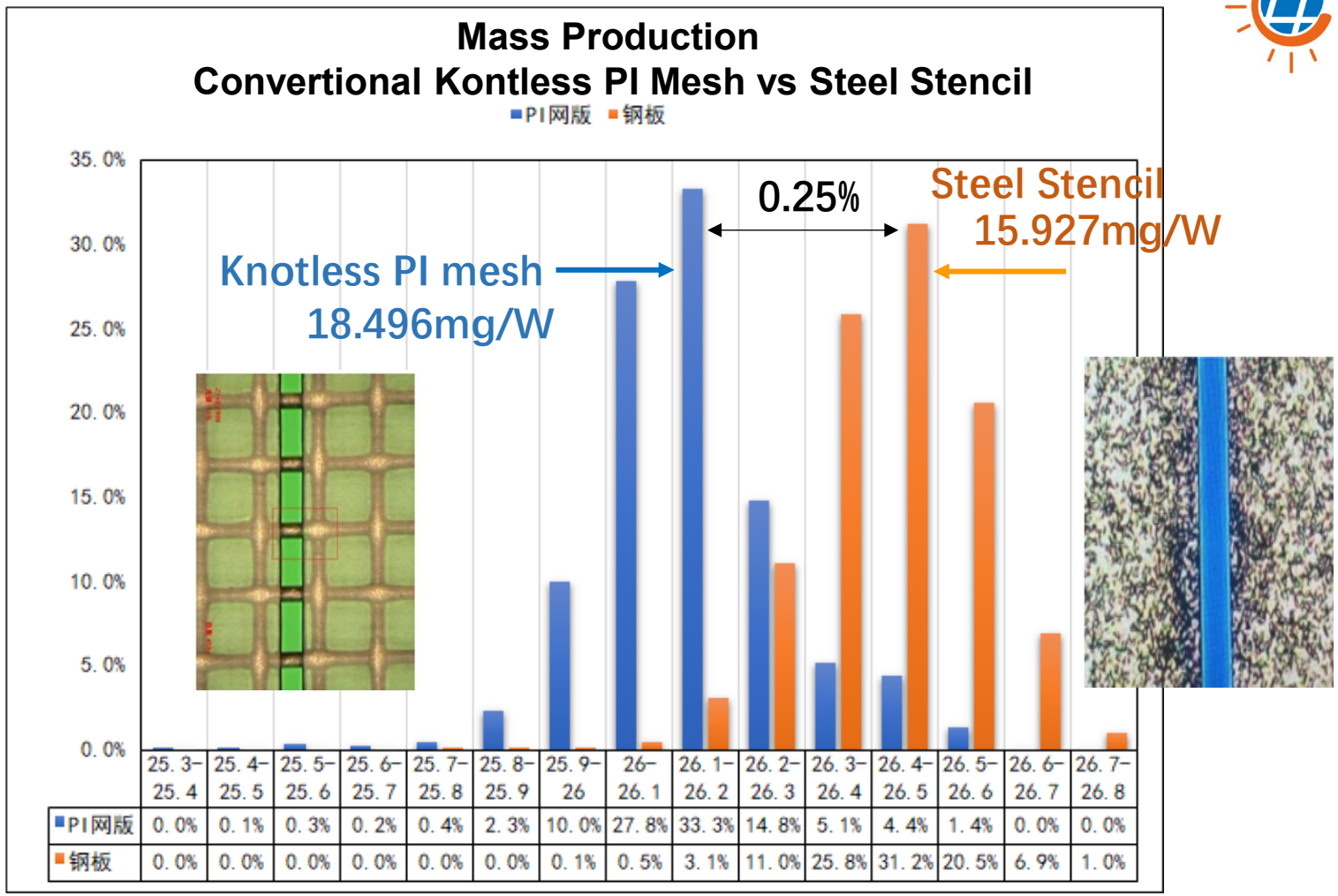
Steel Stencil- Less Laydown for Higher ETA in HJT



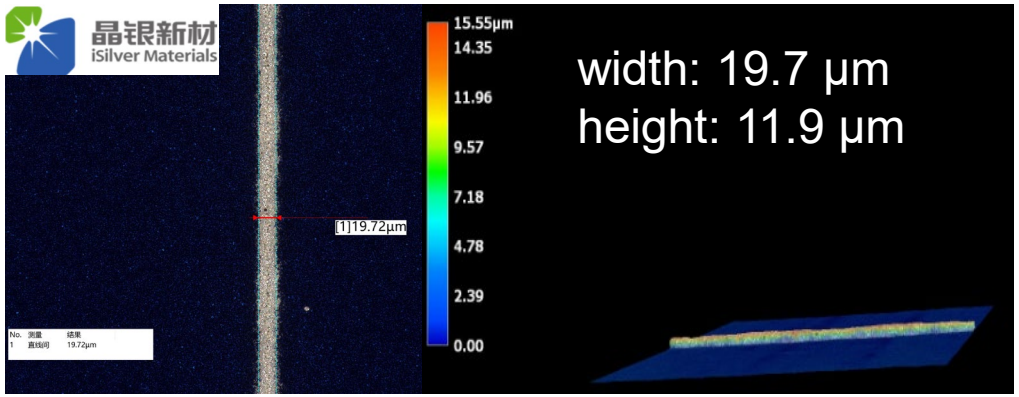
	25.3–25.4	25.4–25.5	25.5–25.6	25.6–25.7	25.7–25.8	25.8–25.9	25.9–26	26–26.1	26.1–26.2	26.2–26.3	26.3–26.4	26.4–26.5	26.5–26.6	26.6–26.7	26.7–26.8
PI网版	0.0%	0.1%	0.3%	0.2%	0.4%	2.3%	10.0%	27.8%	33.3%	14.8%	5.1%	4.4%	1.4%	0.0%	0.0%
钢板	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.5%	3.1%	11.0%	25.8%	31.2%	20.5%	6.9%	1.0%

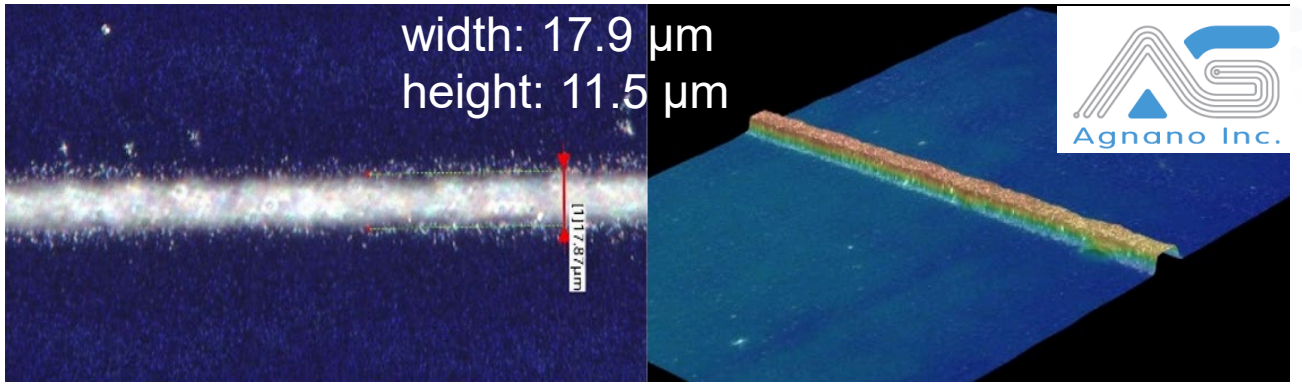
Source: HuaSun Presentation from Dr.Wenjing Wang

- By involving the stencil full-opening screen, relatively higher ETA distribution with lower paste laydown have been fulfilled at HuaSun's experiment on mass production

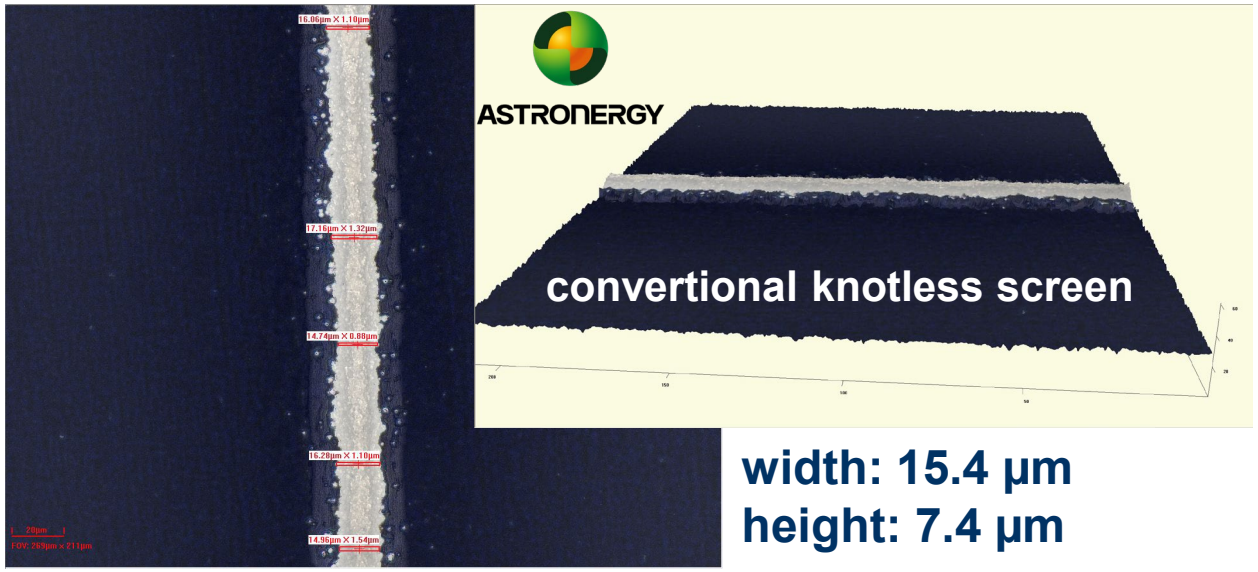
Front Fine Finger Grid in Mass Production

HJT production – 30% Ag/Cu

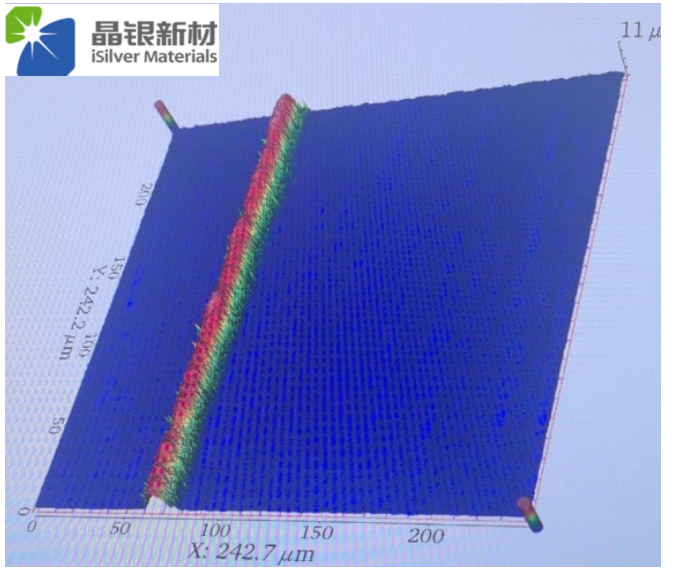




TOPCon production – 100% Ag



width: 15.4 µm
height: 7.4 µm



width: 11.3 µm
height: 7.8 µm

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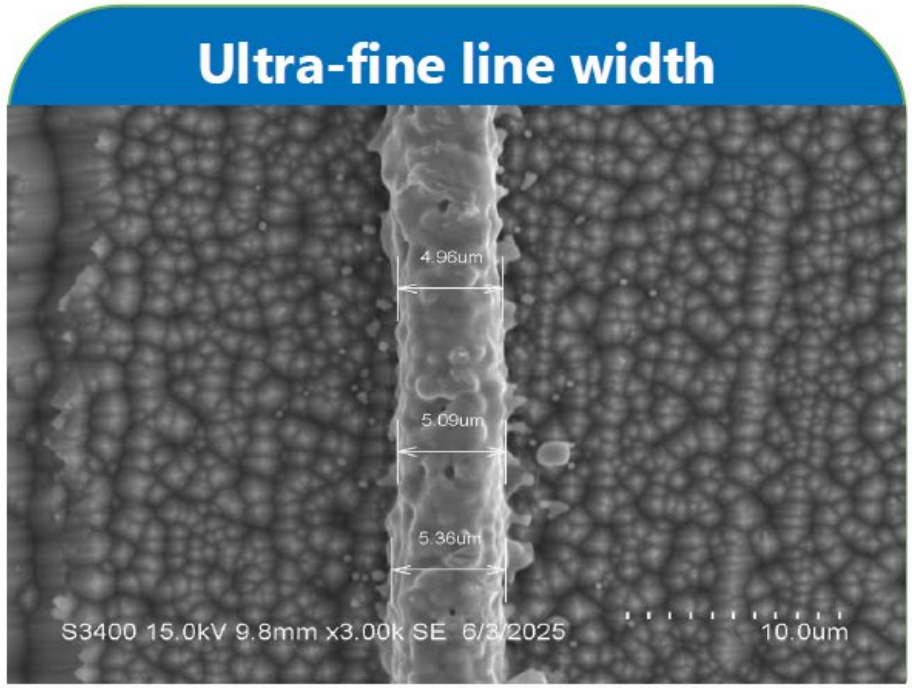
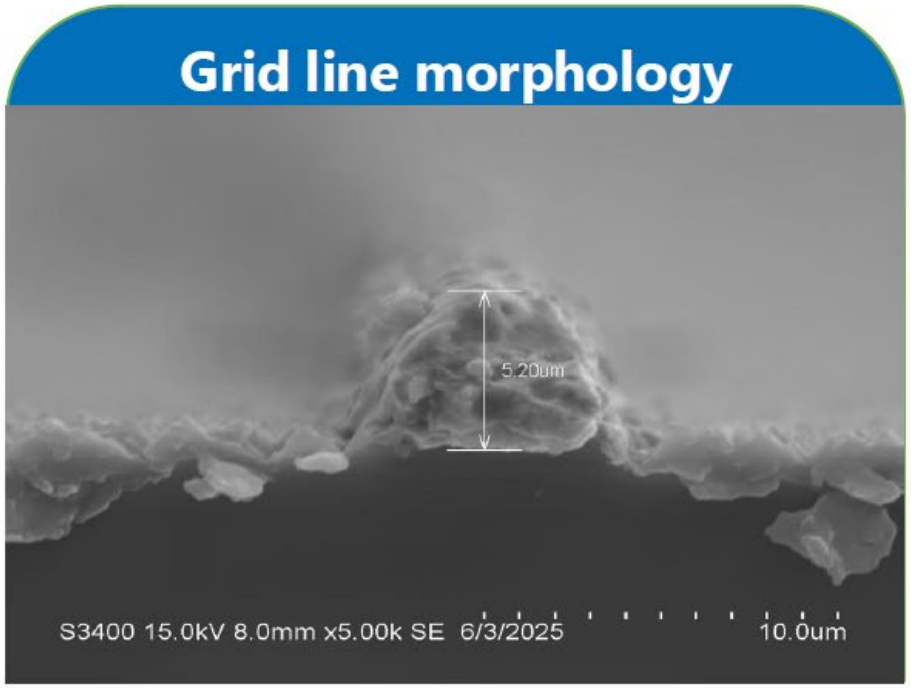
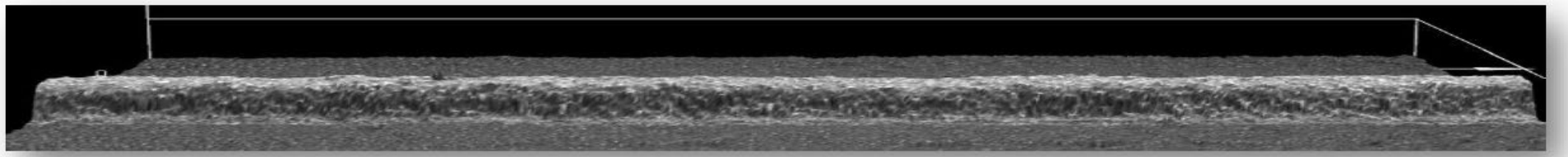
Cuting-Edge Stencil Print Performance in TOPCon R&D





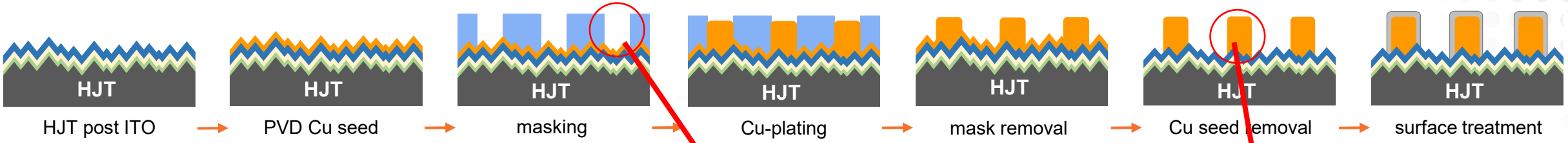


YanYang stencil screen combines with Fusion TOPCon paste, obtained 5µm x 5µm in cross-section at one Chinese tier 1 R&D line.

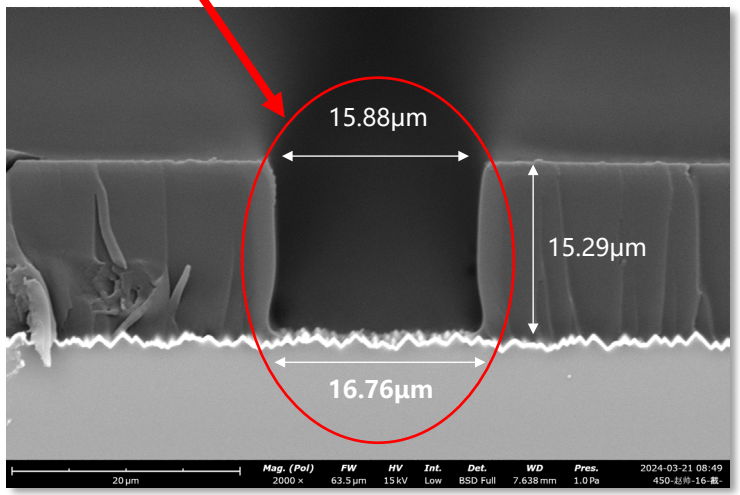
OUTLOOK

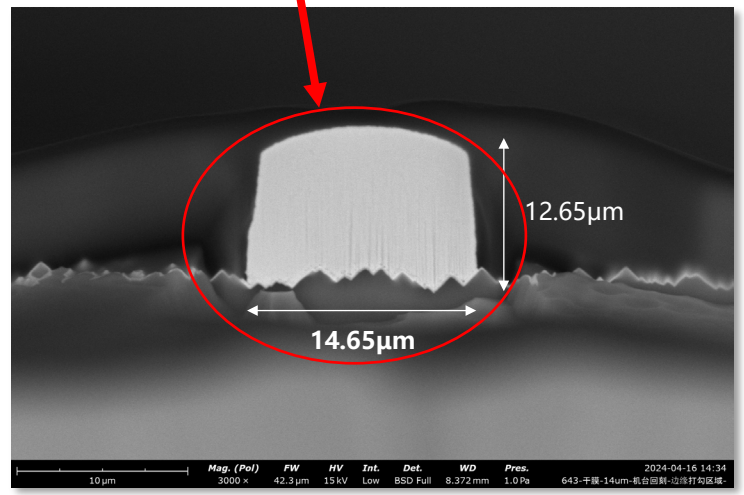
- Overview, Mainstream Cell Technology and Cost
- Development of Metallization in Mass Production
  - Low Silver Content Paste Development
  - Screen Development
  - **Cu-Plating Development in HJT**
- Development of 0BB Solutions in Mass Production
- Summary

Tongwei's Cu Plating Development



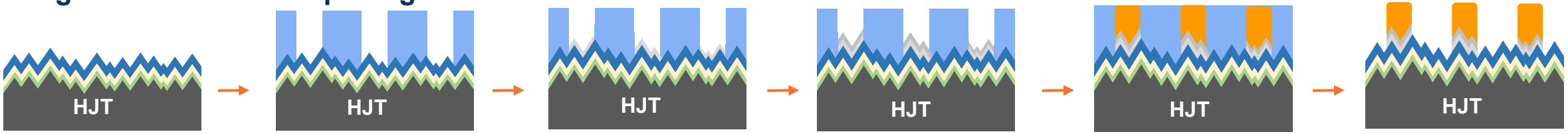
In 2021, in collaboration with plating supplier Sunwell, Tongwei took the lead in the pilot production of half G12 HJT copper plating interconnection. Good aspec ratio is achievable.





Source: CPVC-21, 2025, Tong Wei

Tongwei's seedless Cu-plating

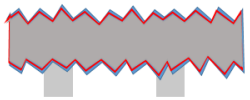


Maxwell- Single Side Seedless Cu-Plating on HJT

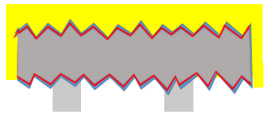
工艺流程

Suzhou Maxwell Technologies Co., Ltd.
苏州迈为科技股份有限公司

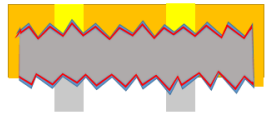
1、P面金属化/丝印
P Metalization / Printer



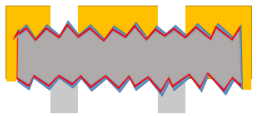
2、N面印刷感光材料
N Spraying photosensitive material



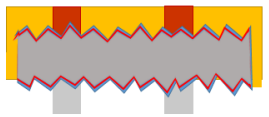
3、感光材料曝光
Photosensitive material exposure



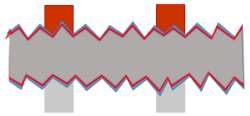
4、显影
Development



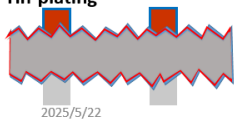
5、镀铜
ECP on N side



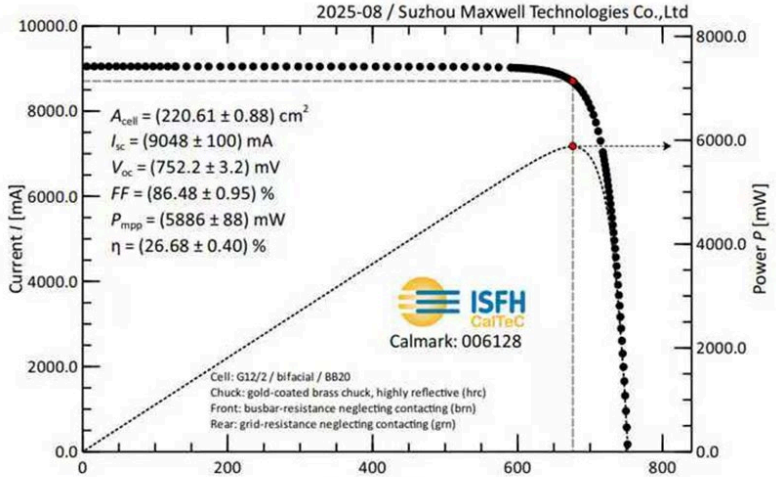
6、感光材料去除
PR-strip



7、镀锡
Tin-plating

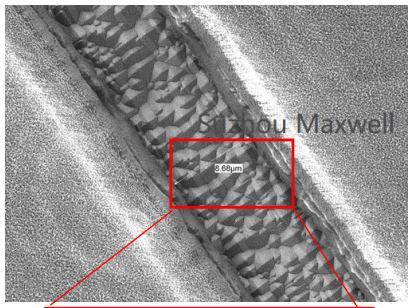


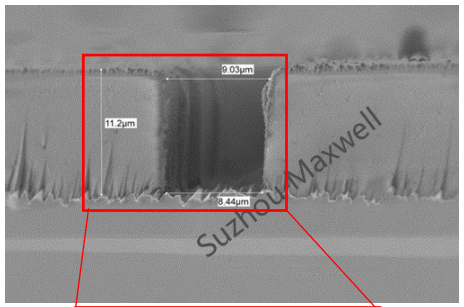
2025/5/22 12

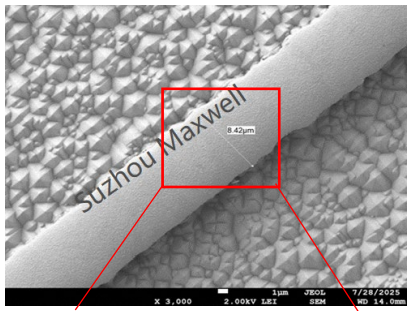


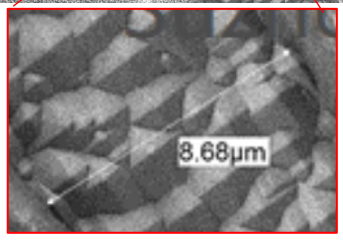
1st publication: New world record on half-G12 full area!!!

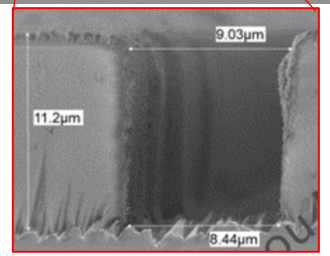
MAXWELL

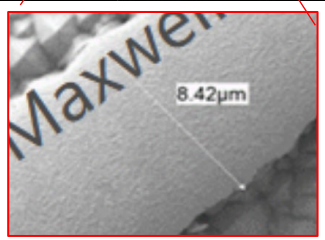




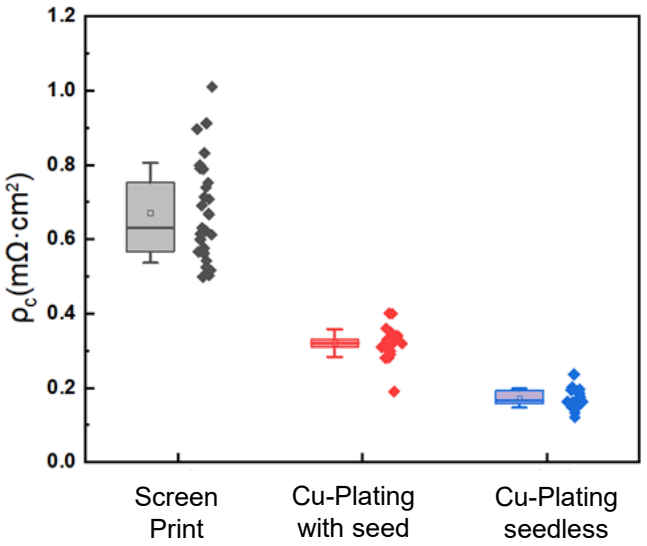








Source: Maxwell



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0BB Interconnection Technology- Motivation

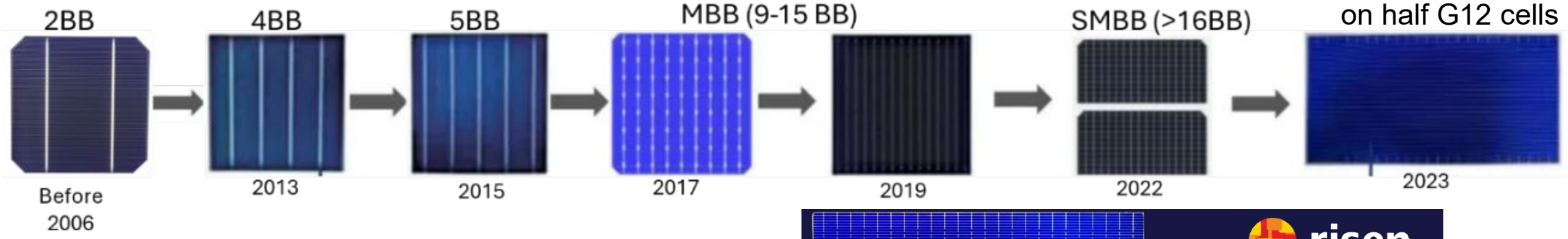
$$P_f \propto \frac{J^2 L}{12 n_f} \frac{R_f}{n_{BB}^2} \propto C \frac{R_f}{n_{BB}^2} \quad [1]$$

J is the current density, L, the width of the cell, n_f, the fingers number, R_f, the finger line resistance, n_{BB} the busbar number and C a constant.

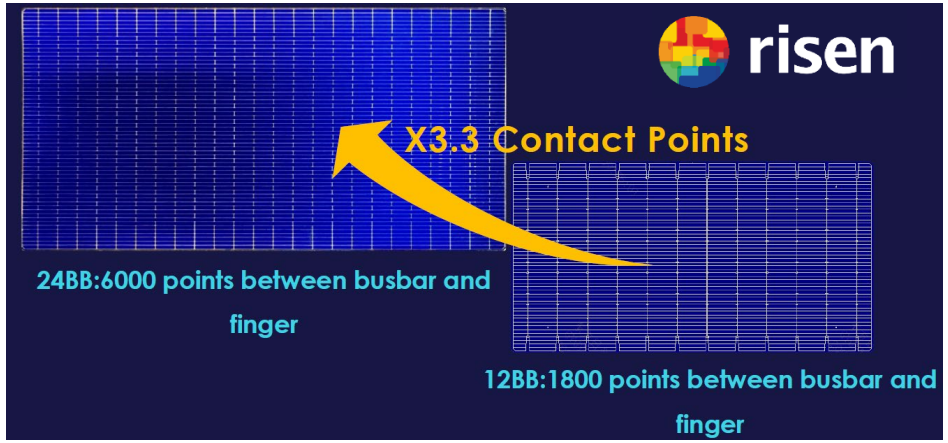
- The power loss (P_f) in the cell metallic fingers is inversely proportional to the square of the number of busbars.

[1] A. Faes *et al.*, *SmartWire solar cell interconnection technology*, in proc. 29th European Photovoltaic Solar Energy Conference and Exhibition (29th EU PVSEC), September 2014, Amsterdam, The Netherlands, p. 2555

Mainstream number of busbars in PV industry



- Increasing the number of busbars at cell or at module level, can efficiently lower the power losses.



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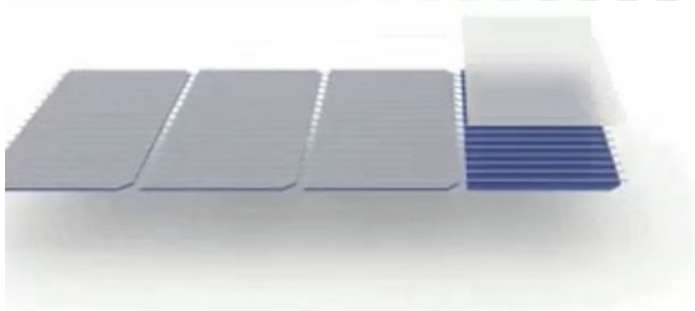
0BB Interconnection Technology – IFC (Integrated Film Connection)



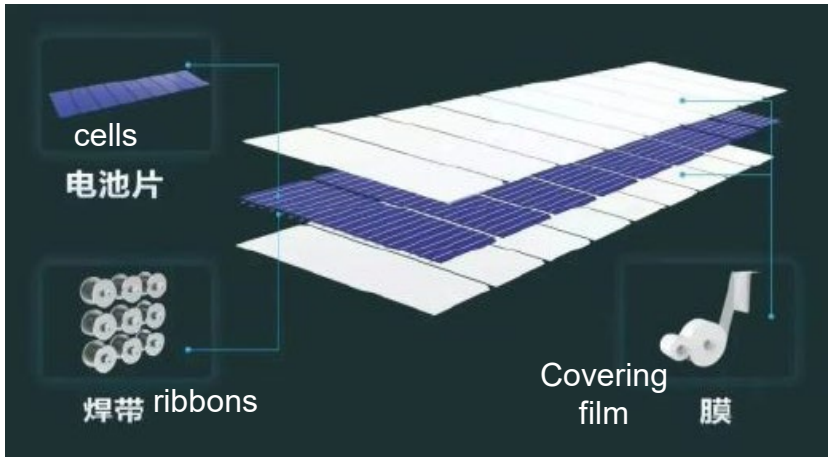
Description

- Soldering round ribbons with the integrative adhesive film in cell size are pressed onto the both sides of the cell during a low-temperature pre-soldering process
- then standard encapsulation adhesive foil is applied by conventional equipment.

Alloy Formation Process: in lamination

Adhesive foil Requirement

covering adhesive film + encapsulation foil



Advantages

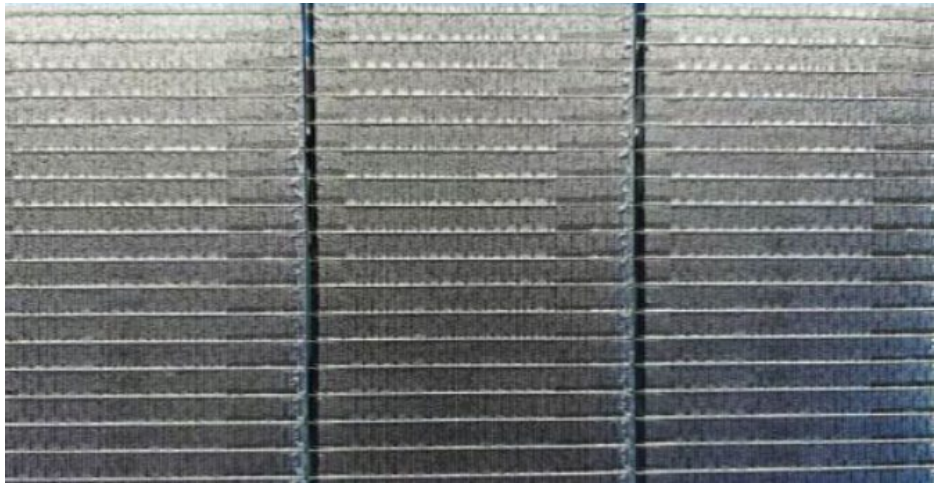
- good adhesion between wires and cells no flux residues.

Disadvantages

- additional adhesive film required;

Representative Supplier: XN

Remarks covering adhesive film weights ~100 g/m²



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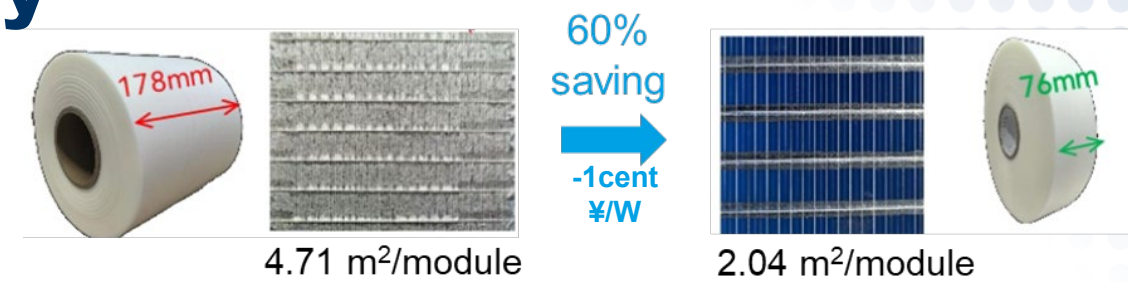
0BB Interconnection Technology
– Strip Film Interconnection



Description

- similar to the IFC solution, just using a narrow strip adhesive tape film to cover on the round ribbons, both parts are pressed onto the both sides of cells during pre soldering.
- then standard encapsulation adhesive foil is applied by conventional equipment.

Alloy Formation Process: in lamination

Adhesive foil Requirement

covering adhesive film + encapsulation foil

Advantages

- adhesive film saving ~ 60%; app 1cent ¥/W
- precise positioning of the narrow strip tapping for higher adhesion- adaptable with 1/3 or 1/4 cells in shingling
- EL after string possilbe
- no flux

Representative Supplier: WV Automation

Remarks: Strip adhesive foil weights ~100 g/m²

new launched

7200 pics/h half-cells
14400 pics/h ¼ cells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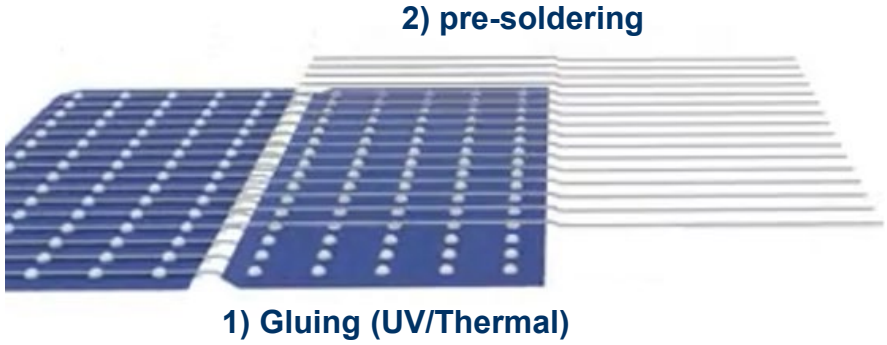
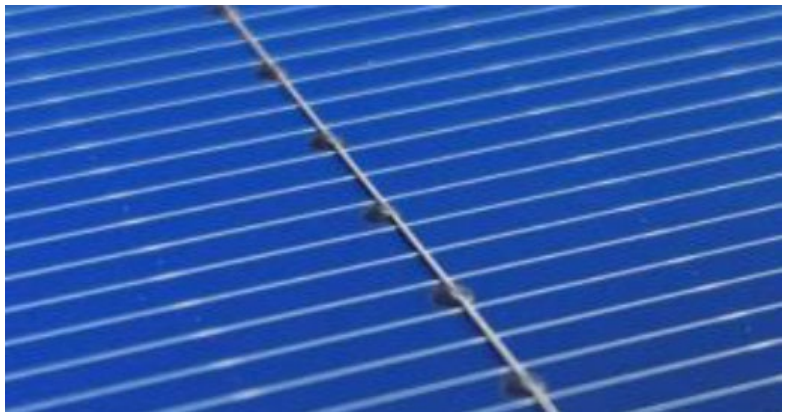
0BB Interconnection Technology
– Adhesive Gluing + pre-Soldering Interconnection





Description

- Apply glue between fine finger grids (dispensing/SP),
- ribbons are fixed onto the cell by gluing, real soldering happens during lamination process.

Alloy Formation Process: in lamination

Adhesive foil Requirement

PVB/integrated foil

Advantages

- simple process and equipment design

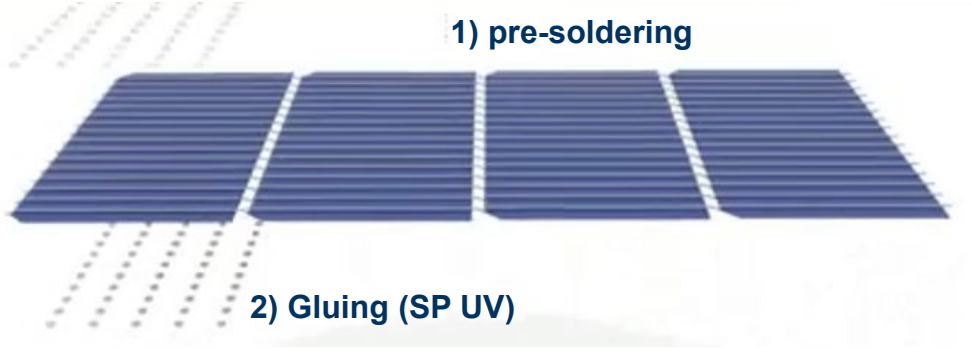
Disadvantages

- adhesion between ribbon and cell isn't so strong
- EL only after lamination possible
- risk of yellowing on the gluing dots after years

Representative Supplier: ATW, AUTO-ONE

Remarks: mostly applied in HJT mass production

0BB Interconnection Technology
– pre-Soldering + Adhesive Gluing Interconnection



Description

- First pre-solder the ribbons to the cell (similar to commericial soldering),
- then further fix soldering ribbons onto the cell by dispensing adhesive glue dots.

Alloy Formation Process: IR soldering

Advantages

- strong adhesion between cell and ribbons
- EL on strings is possible before lamination
- higher soldering temperature allows more tolerance for hot spots

Disadvantages

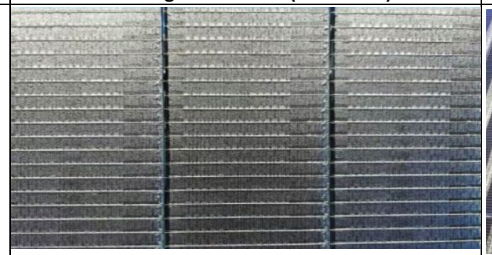
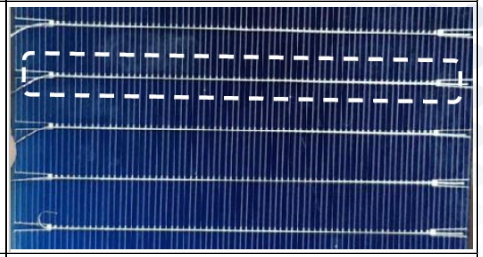
- 4 SP still needed for wider fingers under ribbons, less silver saving than other 0BB approaches
- Risk of yellowing on the glue

Representative Supplier: ATW, AUTO-ONE, Maxwell

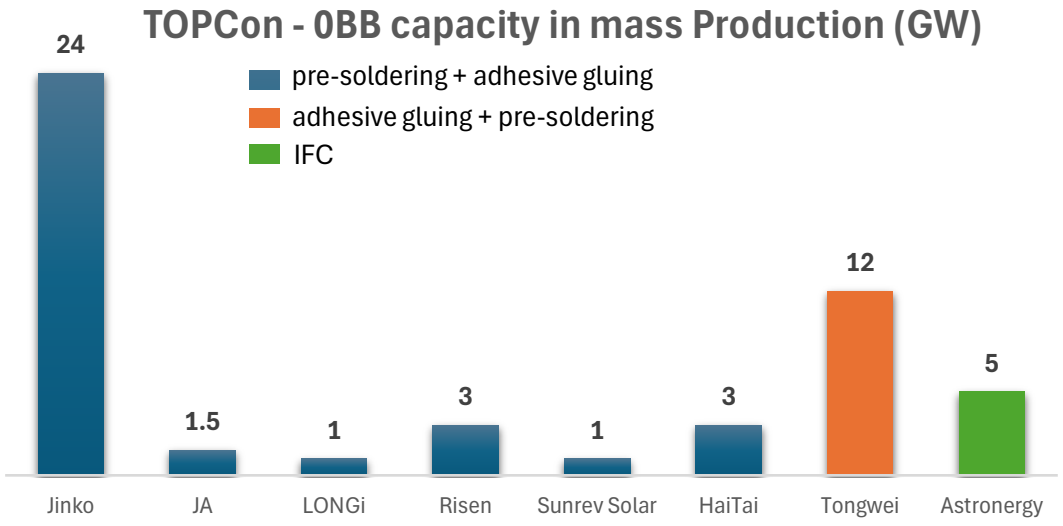
Remarks: some companies are trying to use only SP for fingers

0BB Interconnection Technology

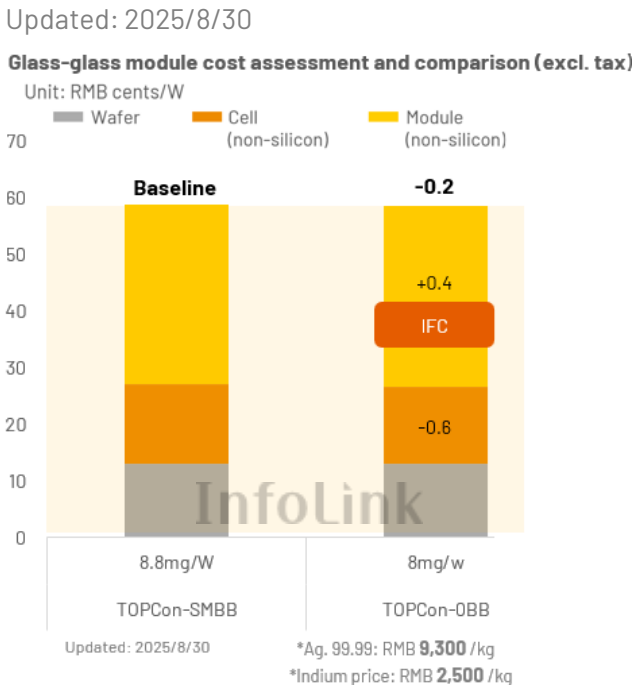
Source: New Technology Market Report_Aug-25, InfoLink

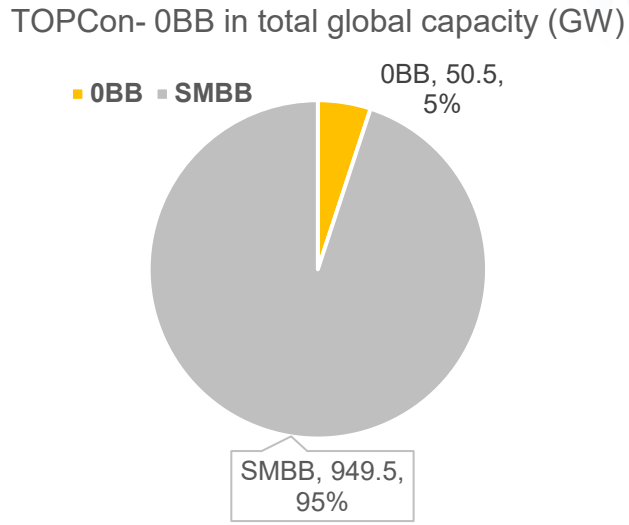
Solution	SWCT®	covering IFC Solution (SWCT like)	Strip Film Interconnection	Adhesive Gluing + pre-Soldering Interconnection	pre-Soldering + Adhesive Gluing Interconnection
Example Image					
Description	- The FWA is completely pressed with multiple coated copper wires and film in separate machine. - The stringer process is to fix the FWA with cells and handle the strings easily. - The soldering happens during the lamination process.	- Soldering round ribbons with the integrative adhesive film in cell size are pressed onto the both sides of the cell during a low-temperature pre-soldering process - then standard encapsulation adhesive foil is applied by conventional equipment.	- similar to the IFC solution, just using a narrow strip adhesive film to cover on the round ribbons, both parts are pressed onto the both sides of cells during pre soldering. - then standard encapsulation adhesive foil is applied by conventional equipment.	Apply glue between fine finger grids (dispensing/SP), ribbons are fixed onto the cell by gluing, real soldering happens during lamination process.	First pre-solder the ribbons to the cell (similar to commericial soldering), then further fix soldering ribbons onto the cell by dispensing adhesive glue dots.
Equipment Changes	- no BB SP - FWA R2R preparation tool - SWCT stringer	- no BB SP - IFC stringer: cell size adhesive film, ribbons and cells are pressed and pre-soldered together in one stringer	- no BB SP - one integrative stringer, include strip tape/ribbon positioning, press and pre-soldering on cells	- no BB SP - additional SP for UV glue - 0BB stringer	- 4 SP still needed for wider fingers under ribbons - additional SP for UV glue - 0BB stringer
Soldering Ribbon	ϕ0.25mm SnBiAg	ϕ0.2mm SnPbBi/SnBiAg	ϕ0.2mm SnPbBi/SnBiAg	ϕ0.2mm SnPbBi	ϕ0.2mm/0.22mm SnPbBi
Soldering Melting Temperature	135-145°C	140–150°C	140–150°C	140–150°C	160–170°C (Bi content lower)
Ribbon Fixation Method	Fixed by covering adhesive film in FWA	Fixed by covering adhesive film	Fixed by covering adhesive strip tape	UV/thermal glue (dispensing/SP)	IR soldering step first, then adhesive glue dots fixation
Flux	None	None	None	None	Yes
UV Glue	None	None	None	around 15-20g/module@210 cell format	Yes
Alloy Formation Process	in lamination	in lamination	in lamination	in lamination	IR soldering
Adhesive foil Requirement	covering adhesive film + encapsulation foil	covering adhesive film + encapsulation foil	Strip-type covering adhesive film + encapsulation foil	PVB/integrated foil	Conventional encapsulation adhesive foil
Advantages	- good adhesion between wires and cells - the covering film of FWA improves the module reliability	- good adhesion between wires and cells no flux residues. - no flux	- similar to IFC, adhesive film saving >60%; - precise positioning of the narrow strip film for higher adhesion - adaptable with 1/3 or 1/4 cells in shingling - no flux	simple process and equipment design	- no covering film or carrier film - strong adhesion between cell and ribbons - EL on strings is possible before lamination - higher soldering temperature allows more tolerance for hot spots
Disadvantages	- additional separate tool only for FWA preparation - EL only after lamination possilbe	- additional adhesive film required; - additional PL for string quality control	Additional strip adhesive tape required.	- integrated foil/PVB foil needed - adhesion between ribbon and cell isn't so strong - EL quality control only after lamination possible	- less silver saving than other 0BB approaches - difficult to form stable direct soldering between fingers and the ribbon
Representative Companies	Meyer Burger	XN	WV Automation	ATW, Guangyuan	Maxwell, ATW, Guanyuan
Remarks	1st 0BB interconnection solution from Day4	covering adhesive film weights ~100 g/m^2	Strip adhesive foil weights ~100 g/m^2	Currently mostly applied in HJT technology solutions	some companies are trying to use only SP for fingers

TOPCon 0BB in Global Capacity



Source: New Technology Market Report_Aug-25, InfoLink

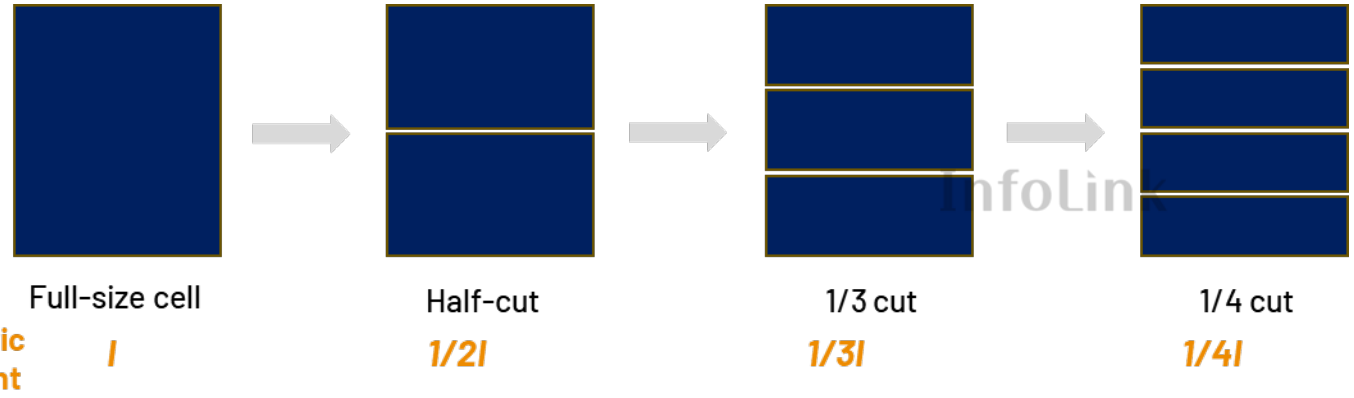


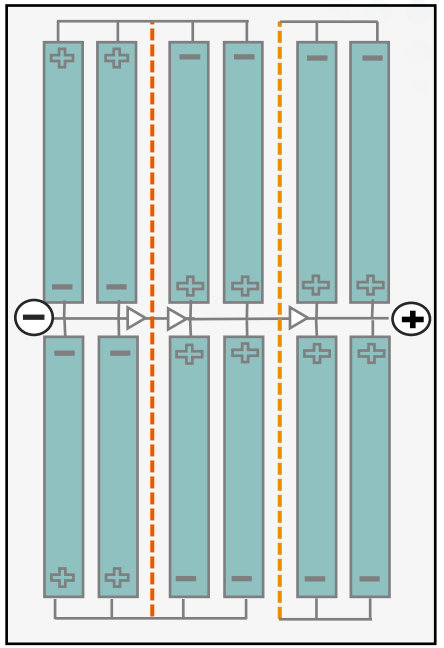


- In all installed TOPCon 0BB capacity, Astronergy with IFC was the 1st 0BB in TOPCon mass production. Jinko with pre-soldering+adhesive gluing has the most capacity. Tongwei with adhesive thermal gluing+pre-soldering meets relatively lower cost.
- Recently, TOPCon 0BB with more CAPAX in module didn't show significant advantage in cost saving to SMBB. Thus, 0BB expansion was developed slowly under the overcapacity situation.
- Until Q3 2025, TOPCon 0BB has secured 50.5GW, 5% of the global TOPCon capacity.

Multi-Cut Technology

Source: New Technology Market Report_Aug-25, InfoLink





1/4 cut, parallel-connected by four

Jinko's 500 MW pilot line for 1/4-cut cells (650 W) is ramping up mass production, with plans to expand to 39 GW of multi-cut cells. Other leading manufacturers remain in the R&D stage.

Advantages for ¼ cell cut

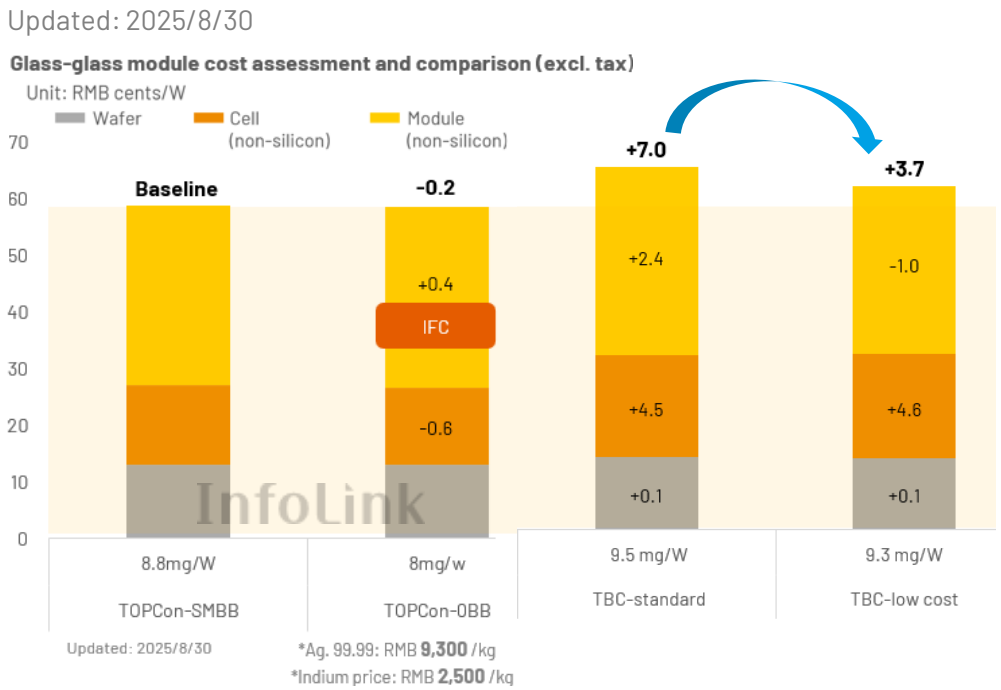
- Reduces resistive losses (Power loss due to resistance = **Current² × Resistance**)
- Lowers the risk of hot spots
- Minimizes optical losses
- Can be further combined with thin ribbons, shingling, and ultra-thin wafer technologies
- Package more cut cells in shingling on module to enhance its power density

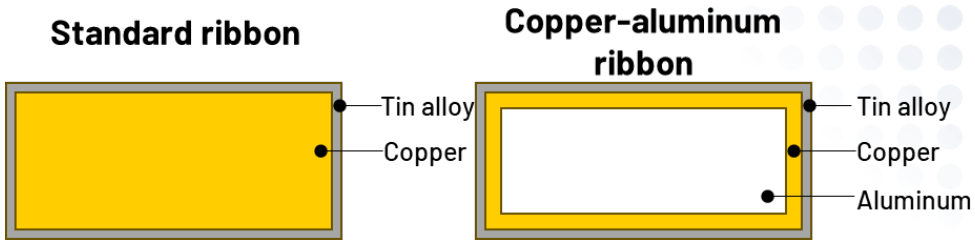
Challenges for ¼ cell cut

- Requires optimization of the cutting process to reduce slicing losses or **edge passivation**
- More complex design for module manufacturing

Copper-Aluminum Ribbon in xBC - cost down Booster

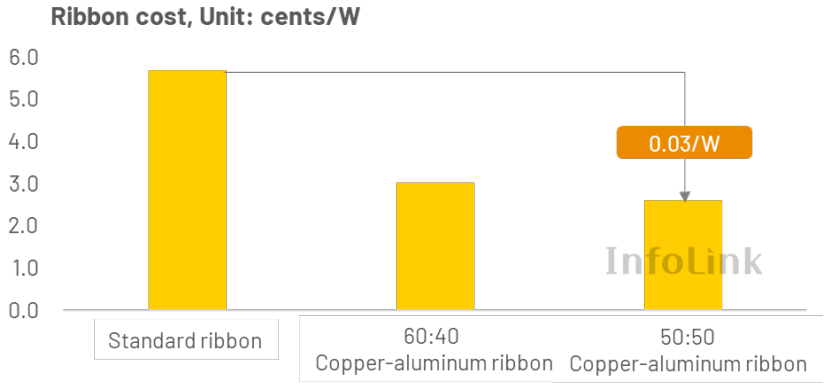
- With copper-aluminum composite ribbons proven reliable in xBC, leading BC manufacturers are now adopting them at scale to significantly reduce module costs with acceptable power loss.
- Cost gap to TOPCon SMBB is furthermore reduced from 7 cents ¥/W to 3.6 cents ¥/W.





Source: New Technology Market Report_May-25, InfoLink

	Copper ribbon	60:40 Copper-aluminum ribbon	50:50 Copper-aluminum ribbon
Density	8.91 g/cm^3	≈4.649 g/cm^3	≈4.149 g/cm^3
Price	★★★	★★	★
weight per meter	100%	**50-55%**	**45-50%**
Reliability	OK	• xBC flat ribbon has passed reliability test. • TOPCon round ribbon poses higher reliability risks.	
Power@ xBC	-	↓ **≈2 W** (1134*2382 mm)	↓ **≈3 W** (1134*2382 mm)



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OUTLOOK

- Overview, Mainstream Cell Technology and Cost
- Development of Metallization in Mass Production
  - Low Silver Content Paste Development
  - Screen Development
  - Cu-Plating Development in HJT
- Development of 0BB Solutions in Mass Production
- **Summary**

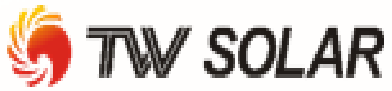
SUMMARY

- **Reducing silver content w/o losing cell performance is the key for sustainability.**
- **Paste Development**
  - **HJT**: Significant improvement in recent years! 10% Ag/Cu paste with PIC is getting standard for mass production. **HJT already met half silver consumption of TOPCon in mass production.**
  - **TOPCon**: dash form silver seed layer + Ag/Cu or Cu pastes and Ni-Ag paste are in evaluation on mass production
- **Screen Development:**
  - **HJT**: Full opening screen is getting standard for better finger geometry, higher ETA and less laydown.
  - **TOPCon SMBB**: high performance knotless mesh screens dominates the market; full opening screens are still in evaluation.
- **Cell-to-Module Interconnetion:**
  - **HJT:** 0BB is performing as standard in many mass production. Gluing+ Pre-soldering is more applied.
  - **TOPCon:** SMBB remains 95% of market share. 0BB hasn't strong advantage in cost and yield.

During periods of overcapacity, it is extremely difficult for tier-1 companies to adopt new technologies unless they offer significant advantages in ETA or cost.

THANK YOU VERY MUCH FOR YOUR ATTENTION!

We gratefully acknowledge the contributions of our industrial partners in this work!!!



Contact: jun.zhao@csem.ch

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FACING THE CHALLENGES OF OUR TIME