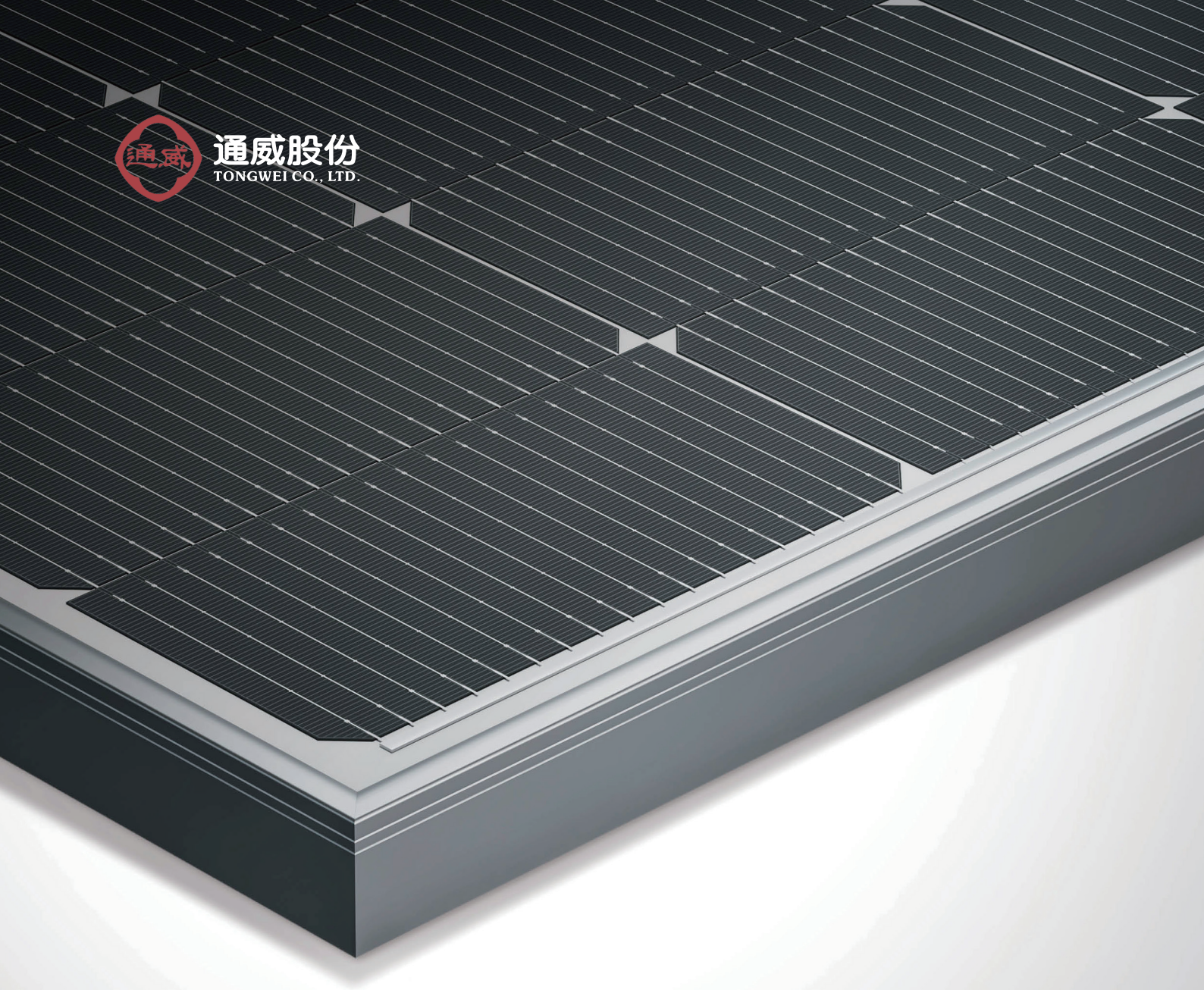


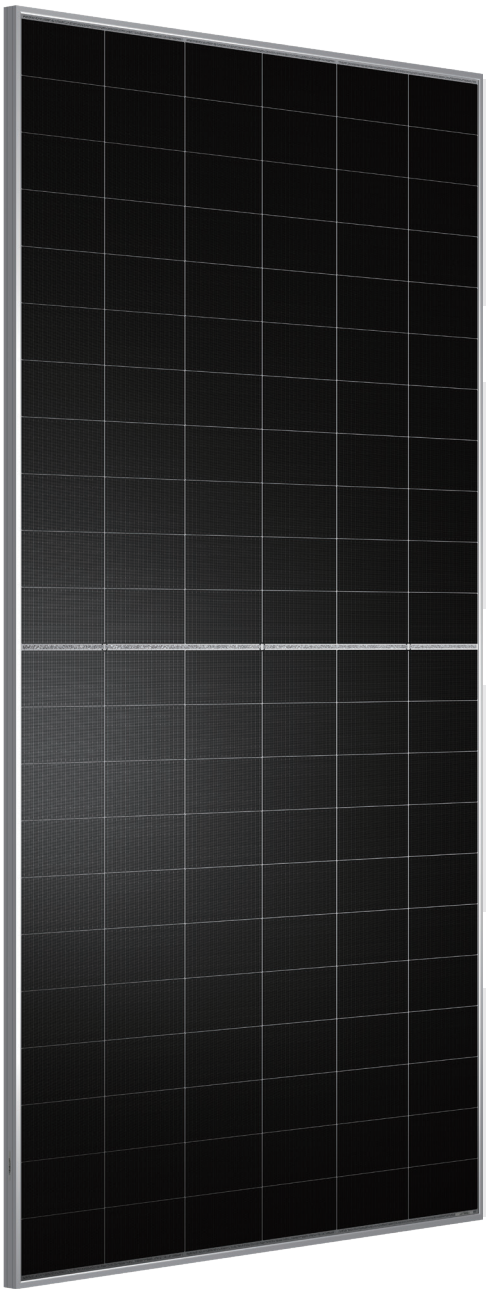
TECHNICAL WHITE PAPER
OF TONGWEI TNC MODULES

Contents

Tongwei TNC Modules: Technology Overview

Tongwei TNC modules are equipped with the new high-efficiency "Tongwei Gene" TNC solar cells. Tongwei TNC 1.0 cells & TNC 2.0 cells are all feature self-developed, industry-leading PECVD technology, combined with advanced MCR cell technology (This manufacturing process enables the creation of high-quality metal contacts without compromising the passivation layer in non-contact region). The mass production efficiency of TNC 1.0 cells reaches an industry-leading level of approximately 25.4%+.

Tongwei TNC 1.0 modules & TNC 2.0 modules all deployed the latest module technologies, including SLTT (Superior Light Trapping Technology) and Double-Layer AR Coating Glass, further optimizing module efficiency while ensuring exceptional module reliability. The maximum mass production efciency of TNC 1.0 modules can reach 23.3%+, the maximum mass production efficiency of TNC 2.0 modules has improved by approximately 1.0% compared to TNC 1.0 modules. Tongwei products have successfully passed extended reliability testing and cerifcations from IEC, PVEL, and other organizations.



Tongwei Gene

High-efficiency Solar Cell

- TNC 1.0 cell efficiency reach 25.4%+
- PECVD Technology: Stable Cell Supply
- Advanced MCR Cell: New Generation TNC Cells

Tongwei Technology

SLTT (Superior Light Trapping Technology)

- Higher Maximum Power & Higher Reliability

Double-layer AR Coating Glass

- Higher Light Transmittance Glass Design & Beauty Module

Tongwei Intelligence

Extended Reliability Testing

- The products boast excellent quality which have successfully passed extended reliability testing and certifications from IEC, PVEL, and other organizations.

Tongwei Innovation

TNC 2.0 Products

- TNC 2.0 Cell + TNC 2.0 Modules Platform
- Breaking through the maximum power limit of TOPCon modules, the TNC 2.0 modules has maximum power level over 670W++ (G12R-66), showcasing Tongwei's advanced manufacturing capabilities.

01

Chapter One

Tongwei Gene: High-efficiency Solar Cell

- PECVD Technology: Stable Cell Supply
- Advanced MCR Cell: New Generation TNC cells with higher efficiency.

Tongwei Gene: High-efficiency Solar Cell

Tongwei aims to build the entire photovoltaic industry chain and become the next-generation leader in the photovoltaics industry, Tongwei has industry-leading Technical strength in the TOPCon cell technology. TOPCon cell technology, due to differences in the manufacturing processes of the tunneling oxide layer and the doping of polycrystalline silicon, is currently being industrialized through two main routes: PECVD and LPCVD. In early 2021, Tongwei successfully developed the industry's first large-size cell (G12/G12R) production line, which utilizes PECVD Poly technology routes during manufacting. Tongwei achieved mass production of PECVD TOPCon cells routes in 2022.

Industry 4.0 Smart & Digitalized Production Line

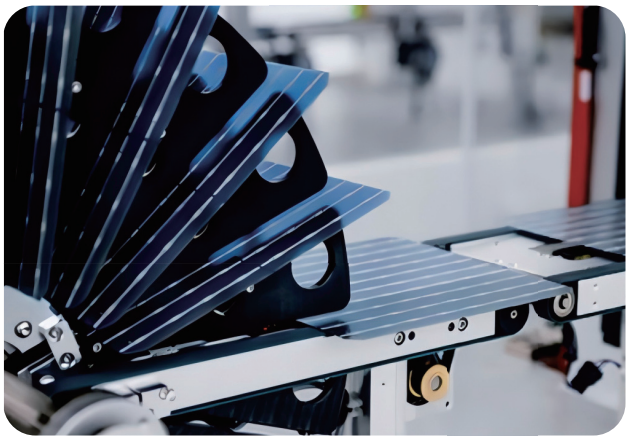
200+
Smart Manufacturing Line

300+
Intelligent Transport Robot

Industry 4.0
Automatic High-efficiency Cell Production

Global Leading
5G-enabled PV Industry Base

5G Dedicated Internet Access
Stability of internet band up to 99.999%



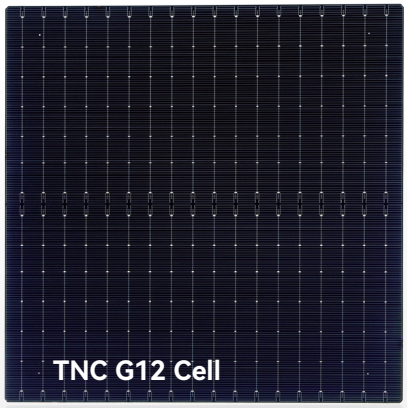
Solar cell shipments have ranked **'No.1 Globally'** for eight consecutive years*.

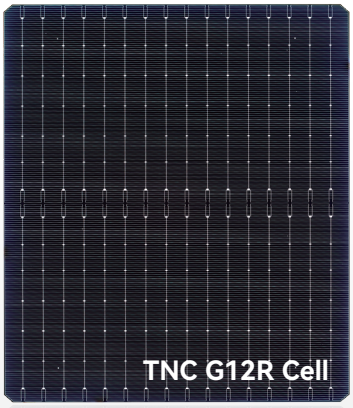
Current annual solar cell production capacity **'150GW'**

Over **'1200'** R&D Senior Researchers

* Solar cell shipment ranking data is sourced from PV Infolink.

By the end of 2025 H1, Tongwei's TNC 1.0 cells which deployed with the latest photovoltaic technology, have achieved a mass production efciency exceeding 25.4%+. In the future, Tongwei's TNC cells will continue to innovate, focusing on optimizing cell quality and improving cell efficiency. With TNC 2.0 solar cell technology deployed on the production line, the efficiency of TNC 2.0 cells is expected to reach approximately 26.5%. Tongwei TNC technology has also been successfully selected in the '2023 Photovoltaic Industr Innovation Achievement Director' due to its industry & technologically leading characteristics, and also become the frst TOPCon cell technology selected in the director.





TNC 1.0 Cell Efficiency:

25.4%+

- Better Temperature coefficient
- Higher Bifaciality
- Lower reverse Leakage current
- Lower LCOE
- Uniformative
- Better Low light performance

TNC Solar Cell Efficiency Roadmap

TNC 2.0 908 High-efficiency Cell

Compared with TNC1.0 cells, **the mass production efficiency of TNC2.0 cells has increased to 26.5%**, while the mass production efficiency of TOPCon cells will continue improving.

TNC 1.0 SMBB High-efficiency Cell

The mass production cell efficiency has reached **25.4%**.

Cell Efficiency Keeping Upgrading!

TIPS:The cell efficiency is estimated basedon a CTM ratio of approximately 97%.

Tongwei Gene: High-efficiency Solar Cell > PECVD Poly:

TNC PECVD Cells

Traditional TOPCon cell manufacturing utilizes LPCVD manufacturing process. Tongwei began researching TNC-TOPCon cells in 2020 and developed industry's first large-size cell (G12/G12R) production line, which utilizes PECVD Poly technology routes during manufacturing. Tongwei is the first photovoltaic manufacturer in China to deploy tube PECVD-Poly technology, achieved an innovative breakthrough and leadership in the TOPCon cell manufacturing process.

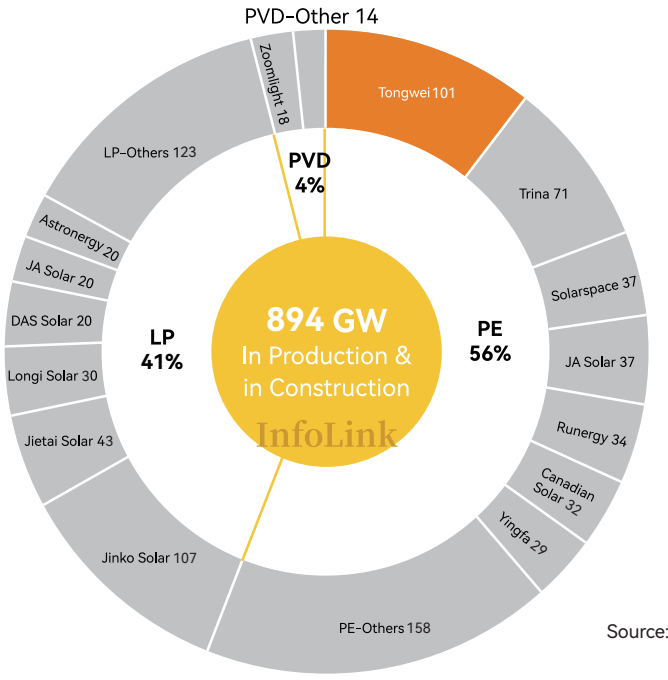
PECVD	LPCVD Intrinsic Poly	LPCVD In-situ Doped Poly
Texturing	Texturing	Texturing
Boron Diffusion	Boron Diffusion	Boron Diffusion
BSG Remove and Etching	BSG Remove and Etching	BSG Remove and Etching
PECVD In-situ Doped Poly	**LPCVD Intrinsic Poly**	**LPCVD In-situ Doped Poly**
Annealing	Phosphorus Diffusion	Annealing
PSG Remove and RCA Clean	PSG Remove and RCA Clean	RCA Clean
ALD、PECVD Front SiNx	ALD、PECVD Front SiNx	ALD、PECVD Front SiNx
PECVD Back SiNx	PECVD Back SiNx	PECVD Back SiNx
Screen Printing+Firing	Screen Printing+Firing	Screen Printing+Firing

通威股份 TONGWEI CO., LTD.

Traditional TOPCon cell manufacturing process

Tongwei leads the development of the PECVD technology route in PV Industry. According to PVinfolink's statistics, 56% of TOPCon cell manufacturers adopt PE-poly technology route. PECVD is mainstream technology for TOPCon cells mass production.

The Share of Back Surface Poly Deposition Capacity

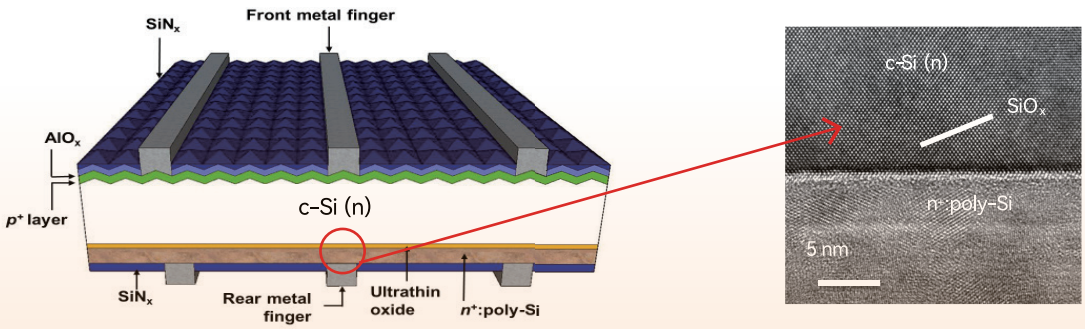


Source: InfoLink PV Technology Trend Research Report _FEB-25

Technical Principle

PECVD uses low-temperature plasma as an energy source. The silicon wafer is placed on electrodes under low pressure for glow discharge. The glow discharge (or additional heating equipments) raises the temperature of the silicon wafer to the desired level. Then, a controlled amount of SiH4 and PH3 are introduced, undergoing a series of chemical and plasma reactions to form n-type polycrystalline silicon on the surface of the sample.

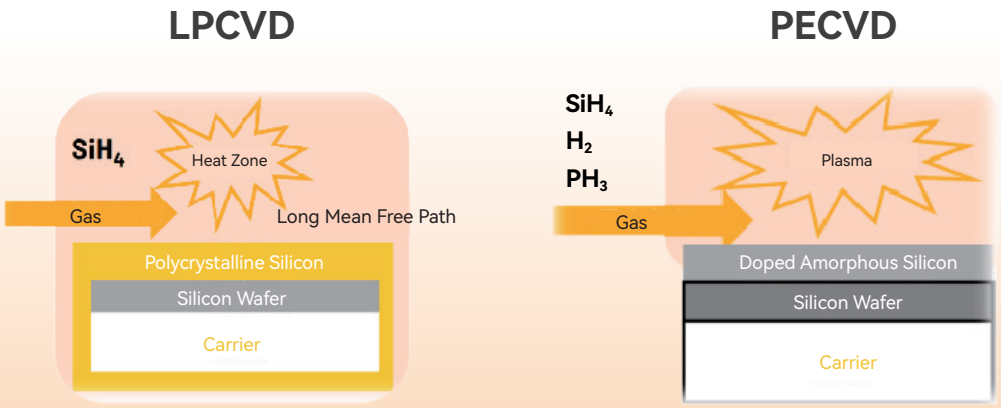
Schematic of Tunneling Oxide Layer + Poly Layer



PE-Poly: Tunneling Oxide + Polycrystalline Silicon.
The PECVD deposition equipment is used to deposit a tunneling layer and a polycrystalline silicon film on the surface of the silicon wafer.
Tunneling Oxide: $N_2O+Si \rightarrow SiO_2$
Poly: $SiH_4+H_2+PH_3 \rightarrow$ n-poly
N-Poly Function:

- The carrier has selectivity, allowing electrons to tunnel into the doped polycrystalline silicon layer while blocking holes, thereby reducing recombination current.
- The poly layer serves as a buffer between the metal contact and the silicon substrate, preventing direct contact between meta & silicon, thereby reducing contact resistance and recombination.

Comparison of PECVD and LPCVD.



Technical Comparison： PECVD & LPCVD

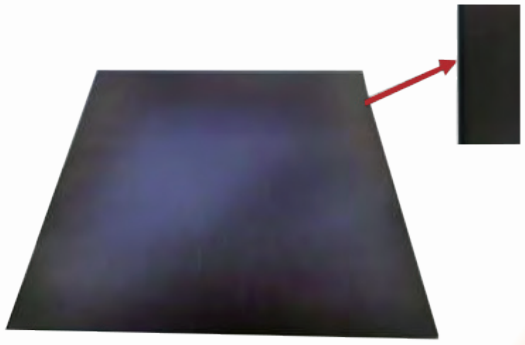
The PECVD route has become the mainstream technological choice in the TOPCon cell production industry. PECVD deposition of poly-Si has high potential for cell efficiency, high deposition rates, low coating-wraparound rate, long lifespan of quartz equipments, and high production capacity.

Technological Roate	LPCVD	PECVD
Mass Production	100GW+	**100GW+**
Cell Efficiency	≈ 25.4%	**25.4%+**
Production Capacity	Standard Level	**Higher than LPCVD**
Poly Si Coating-wraparound	Severe	**Low Rate**
Poly Si Deposition Rate	5-8nm/min	**10-13nm/min**
Product Yield	95%-98%	**98%+**
Lifespan of Quartz Equipments	Short lifespan of quartz tubes and quartz boats	**Long lifespan of graphite boat**

Coating-wraparound

In LPCVD manufacturing process, amorphous silicon undergoes significant and uneven wraparound deposition on non-coated surfaces, making cleaning and etching steps difficult to control, thereby reducing equipment's yield. The wraparound amorphous silicon layer produced by PECVD manufacturing process, is thinner and more uniform, making it easier to remove and not significantly impacting equipment's yield.

LPCVD



PECVD (Nano-level Coating-wraparound)

Tongwei Gene: High-efficiency Solar Cell > Advanced MCR Cell

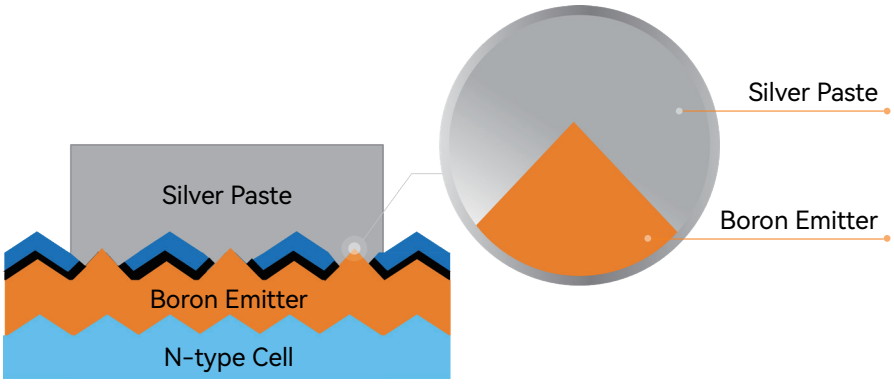
Tongwei MCR Cell Technology

MCR cells utilize Tongwei's self-developed firing process equipment, which features high energy concentration and controllability, to separate two key steps in the high-temperature firing process: passivation layer erosion (burn-through) and contact formation. This enables more precise control and regulation of the firing process. Tongwei MCR cell's new contact formation technology is designed to improve the metal-semiconductor contact, enhances the average performance of solar cells, optimizes the solar cell manufacturing process sequence, makes the contact resistivity more uniform, and ensures a more balanced fill factor distribution.

The Principle of Tongwei Advanced MCR Technology Improving the Cell Contact Mechanism

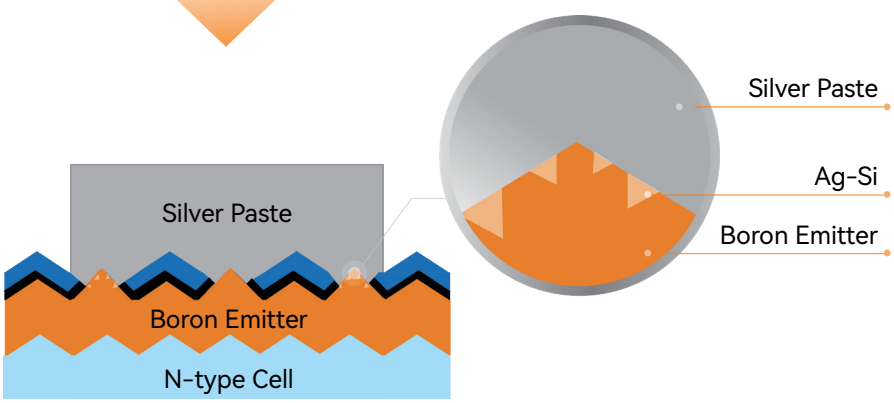
Before MCR:

Efficient electrical contact not formed between silver cantact and boron emitter.



After MCR:

The emitter and the contact form a silver-silicon alloy, enhancing the electrical contact performance.

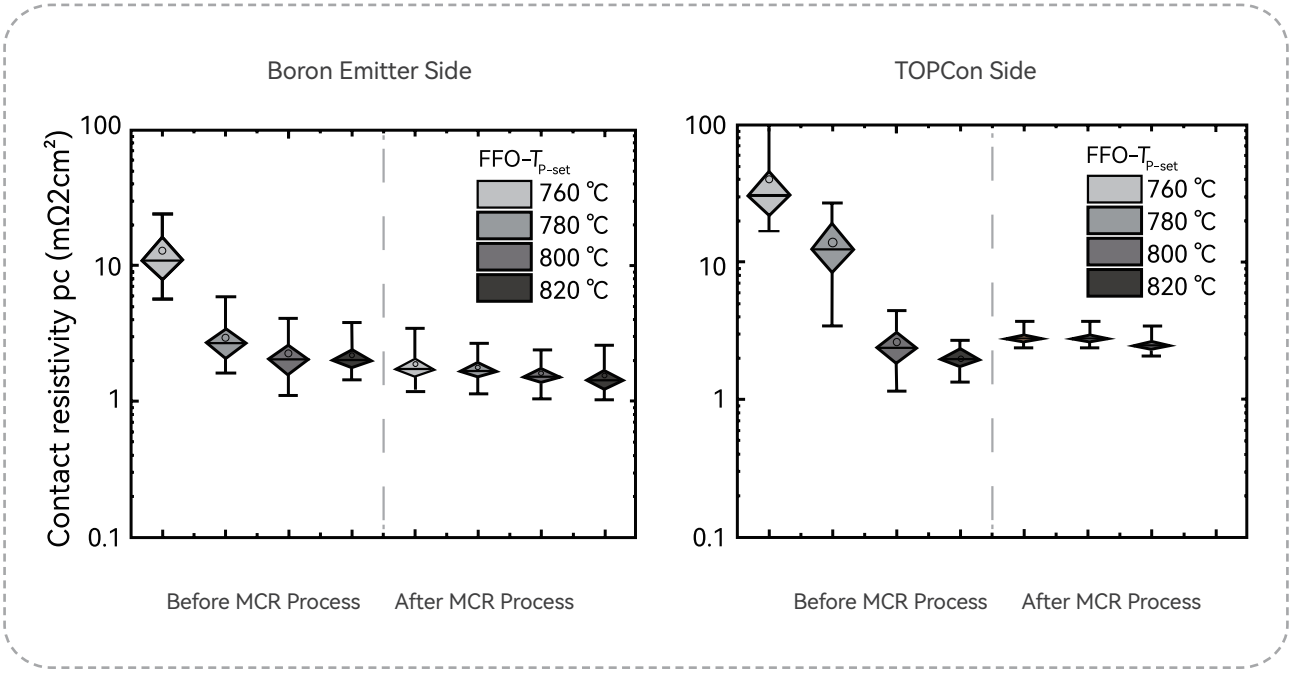


Advantages of Tongwei MCR Cell

- **Cell Efficiency Improved:** MCR process can optimize metal contacts, reduce contact resistance and minimizing the damage to the passivation layer while ensuring contact is not failure. There is a potential for an absolute efficiency improvement of 0.3%-0.4% of solar cells.
- **Precise Control:** Tongwei specialized firing equipment allows for highly accurate control of the thermal influence area, enabling the passivation layer to be disrupted (burned) and metal contacts to be formed without damaging the active area of the cell.
- **Contact Optimization:** Tongwei MCR cells deployed with Tongwei's specialized MCR-paste, has looser requirements for the depth of boron diffusion, and eliminate the necessity for a laser-selective emitter region. Thereby reducing the production steps and improving the product yield.
- **High Reliability:** Tongwei MCR technology deployed with optimized and specialized MCR paste (aluminum-free silver paste), which meets higher reliability requirements. As a result, during the encapsulation process, ethylene-vinyl acetate (EVA) copolymer film (a more cost-effective and easier-to-process option) can be used to replace polyolefin elastomer (POE) films, thereby protecting the solar cells from moisture and oxygen intrusion.

Optimize Contact Resistance

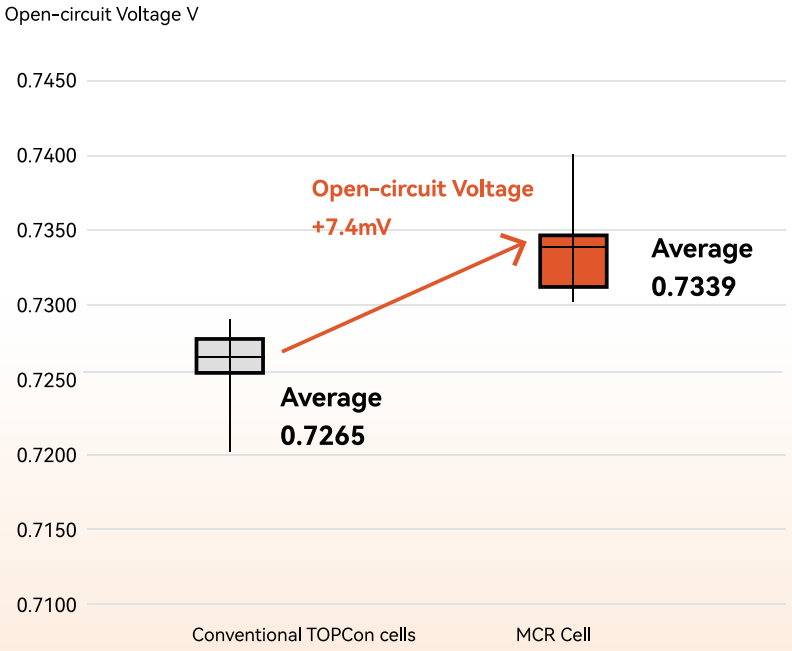
- Before MCR process, the lower firing temperature on the TOPCon side, the greater the increase in ρc. The MCR significantly reduces the contact resistivity on both sides.
- For T = 780° C, the contact resistance ρc measured at the boron emitter side decreased from 2.9 to 1.8 mΩ·cm^2, and for the TOPCon side, it decreased from 14.1 to 2.9 mΩ·cm^2, thereby achieving a high fill factor (FF) at a lower firing temperature and improving cell efficiency.



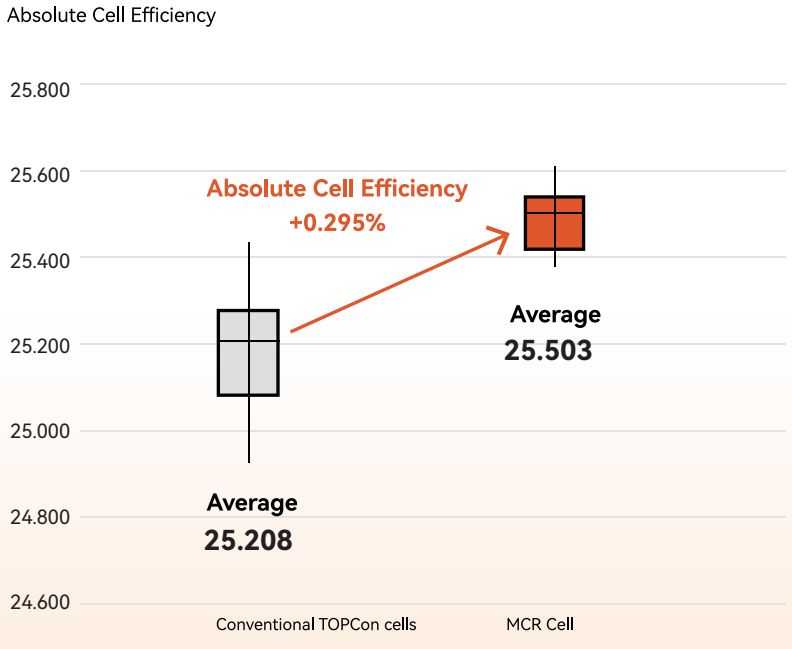
Tongwei MCR Cell : Cell Efficiency Improvement

Tongwei MCR Cell : Tongwei MCR cells deployed with Tongwei's specialized MCR-paste (aluminum-free silver paste), ensures that the optimized metal-semiconductor contact does not damage the passivation layer. MCR solar cells achieve an average open-circuit voltage increase of +7.4mV and an average absolute efficiency improvement of +0.295% compared to conventional TOPCon cells. The maximum absolute cell efficiency improvement of MCR cells can exceed 0.4%+.

Open-circuit Voltage Increased



Cell Efficiency Increased

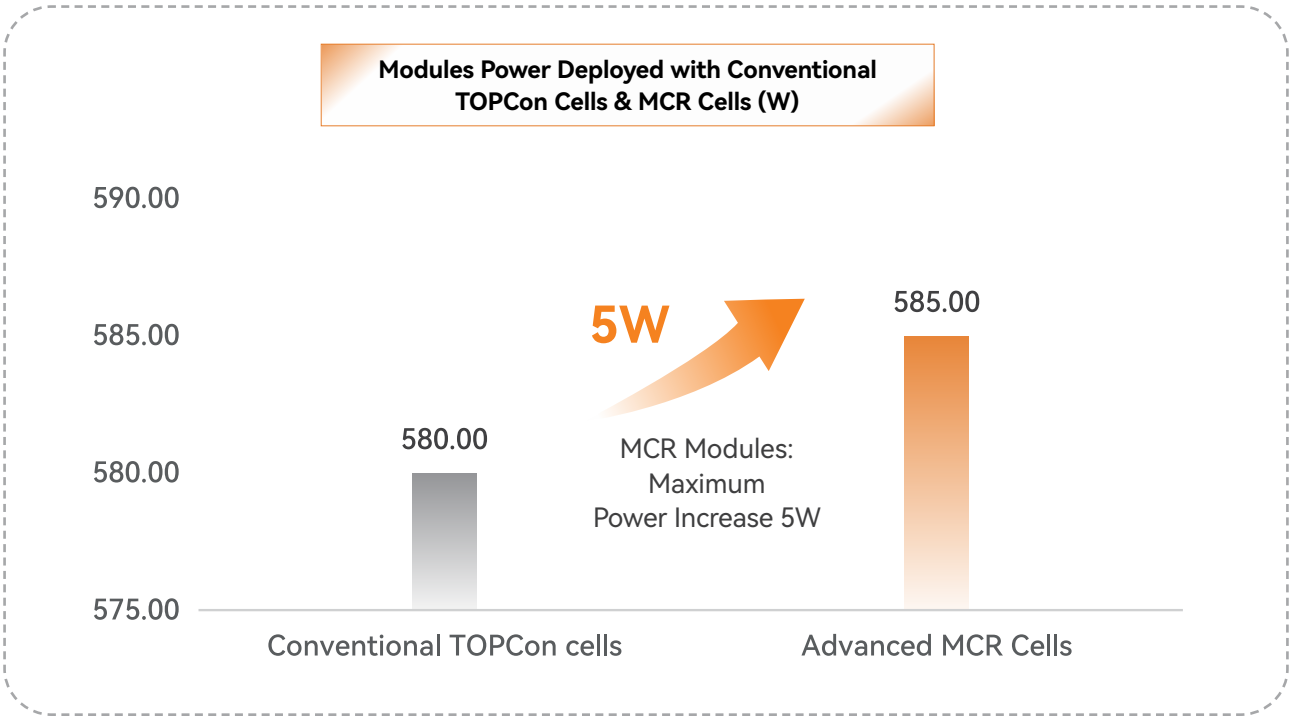


TIPS: Cell testing data is sourced from Tongwei's internal laboratory.

Modules Efficiency Improvement

According to research by Tongwei's R&D team, compared to conventional TOPCon cells, Tongwei's advanced MCR cells can significantly improve module efficiency and maximum power. For modules in different sizes, the increase in modules power is approximately 5W, reflected with optimization in open-circuit voltage (Voc) and fill factor (FF).

Research Projects	Cells	Absolute Cell Efficiency	Numbers of Modules	Average Maximum Power of Modules	Distribution of Module Power			
					575	580	585	590
BSL	Conventional TOPCon cells	25.3	834	582.23	4%	96%	0%	0%
Experimental Group A	Advanced MCR Cells	25.4	231	585.15	0%	45%	55%	0%
Experimental Group B	Advanced MCR Cells	25.5	292	586.59	0%	11%	89%	0%
Experimental Group C	Advanced MCR Cells	25.6	212	588.03	0%	1%	93%	7%



TIPS:

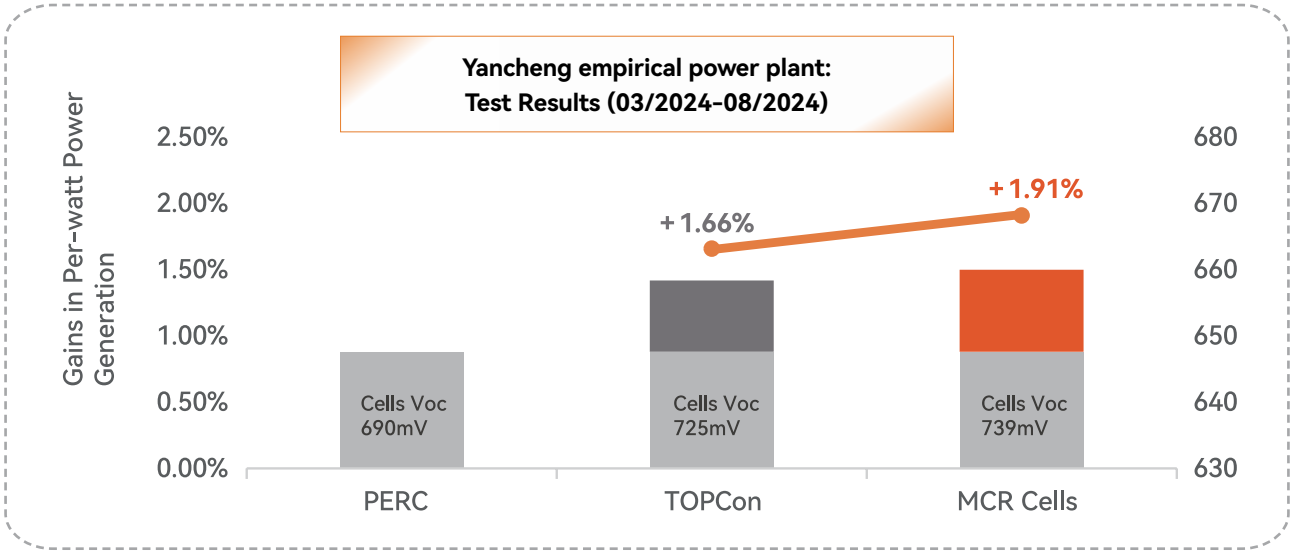
- Sample testing data is sourced from Tongwei's internal laboratory.
- The treatment group modules and the control group modules are both M10-72 half-cell models (standard cell spacing), The module BOM is exactly the same, except for the cells deployed in the different groups of modules.
- The testing was conducted in Q2 2024.

TNC Advanced MCR Cells: Higher Empirical Power Generation

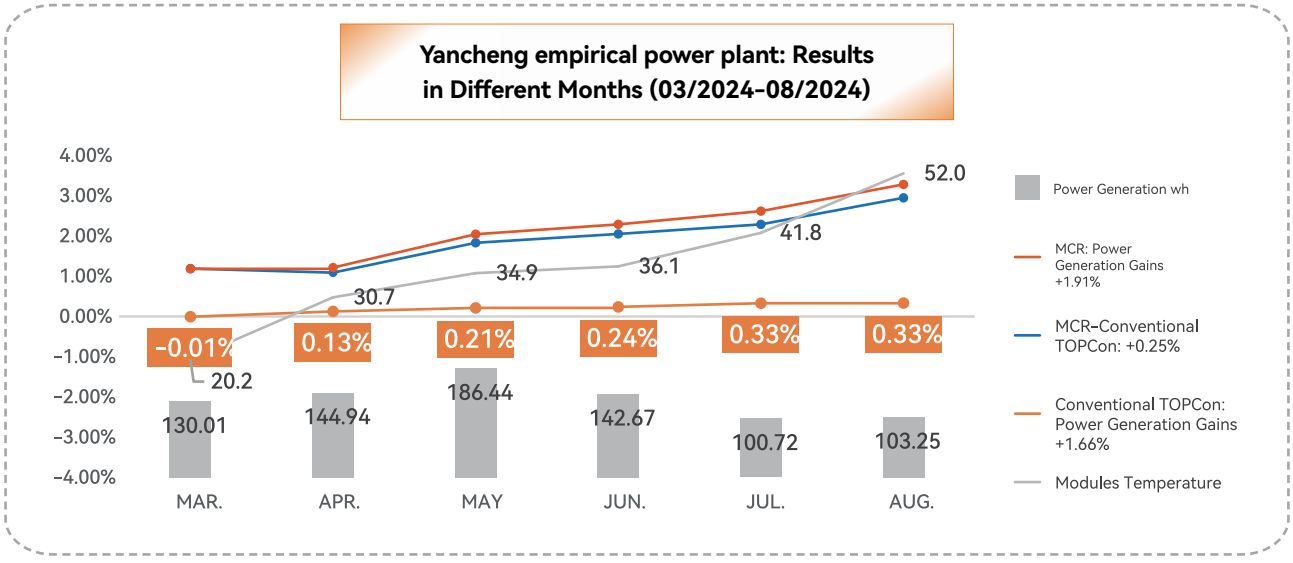
Compared to conventional TOPCon cells, TNC MCR cells have a higher open-circuit voltage, allowing MCR modules to achieve better per-watt power generation performance in high-temperature environments. In low-latitude regions with abundant sunlight resources, MCR modules exhibit significantly better power generation performance than conventional TOPCon modules.

In Tongwei's Yancheng empirical power plant, 12 units each of conventional TOPCon-TNC modules, MCR-TNC modules, and PERC modules were deployed for a cumulative seven-month power generation performance test (all using the M10-72 model with the same BOM, except for the cells deployed in the different groups of modules). The open-circuit voltage of the conventional TOPCon-TNC cells is 725mV, resulting in a 1.66% power generation improvement compared to PERC. The open-circuit voltage of the MCR cells leading to a 1.91% power generation improvement compared to PERC. The MCR modules generated 0.25% more power than the conventional TOPCon modules over the cumulative test period.

- **Figure 1:** Compared to conventional TOPCon modules, the MCR modules shows higher cumulative power generation



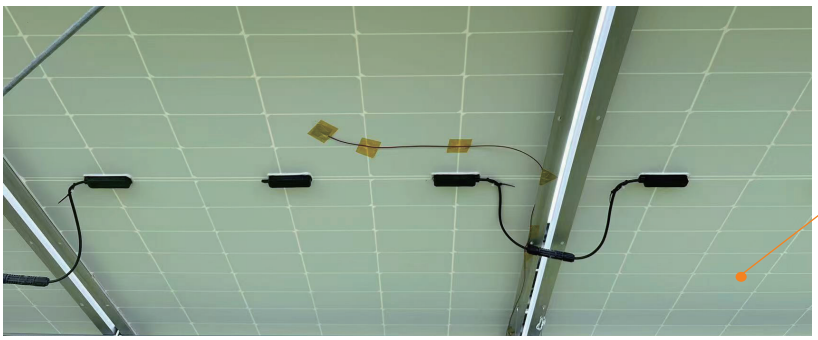
- **Figure 2:** As the temperature increases, the high open-circuit voltage of the MCR modules gradually takes effect, and the per-watt power generation performance improves when temperatures rising.



- **Figure 3:** Yancheng Empirical Power Plant (commissioned in December 2023)

Yancheng Empirical Power Plant

Power Generation Testing



Temperature Testing

Irradiation Testing

02

Chapter Two:

Tongwei Technology: High-Efficiency Module Platform

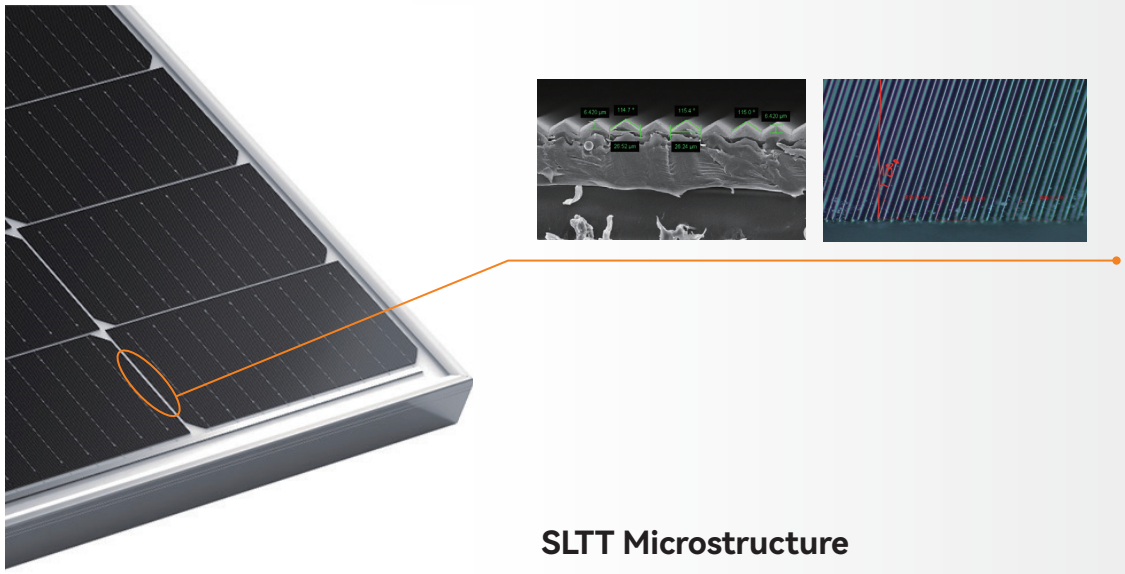
- SLTT (Superior Light Trapping Technology): Higher Maximum Power & Higher Reliability
- Double-layer AR Coating Glass: Higher Light Transmittance Glass Design & Beauty Module

Tongwei Technology: High-Efficiency Module Platform

SLTT (Superior Light Trapping Technology)

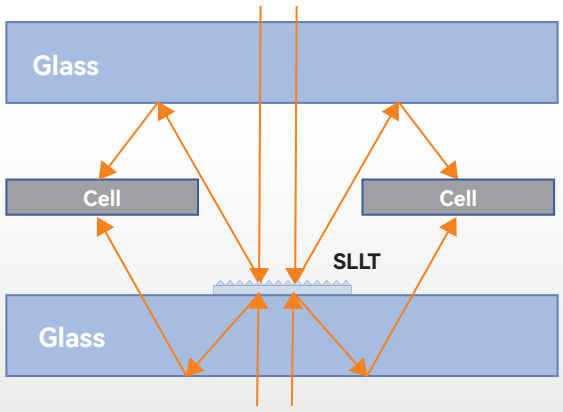
Technical Introduction

Tongwei TNC modules deployed with SLTT technology. SLLT is a high-adhesion, weather-resistant reflective tape which applied between the cellstrings to form a "reflective band". SLTT utilizes optical principles to reflect the incident lightin the gaps back onto the cells, enhancing the module's power output.



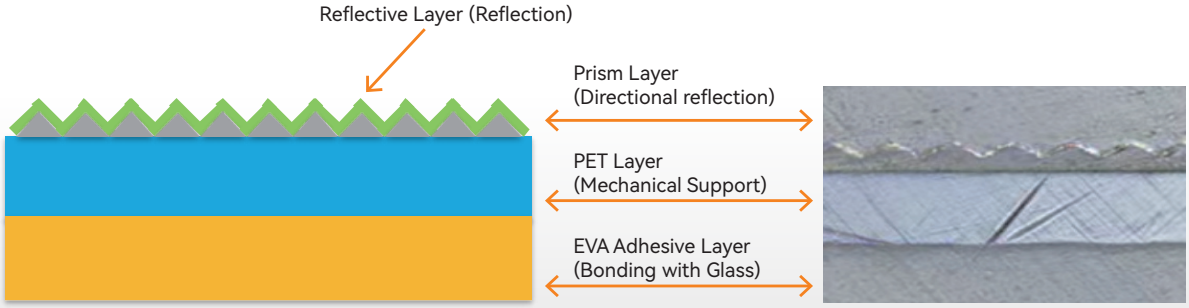
SLTT Microstructure

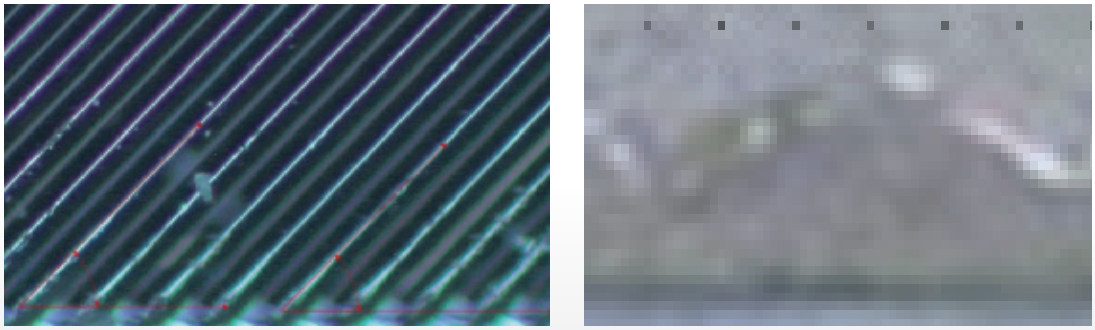
SLTT Schematic Diagram



Design and Structure

The TNC module SLTT deploys a 'non-metal' design with a four-layer structure, including a reflective layer, prism layer, PET layer, and EVA layer. Tongwei SLTT deployed large angle prism layer , maximizing the utilization of incident light from the gaps between the cell strings and enhancing the module's power level.

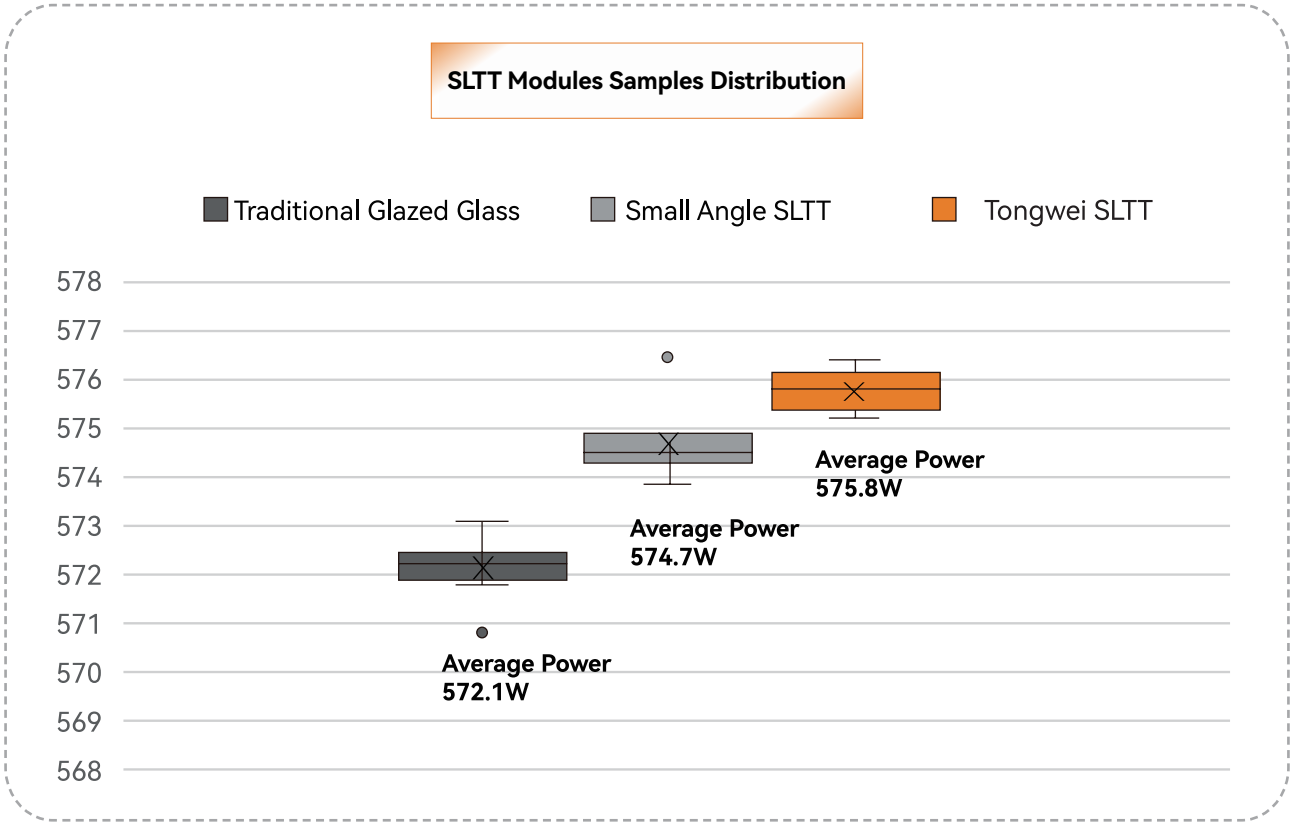




Tongwei Large Angle Prism Layer

Higher Maximum Power

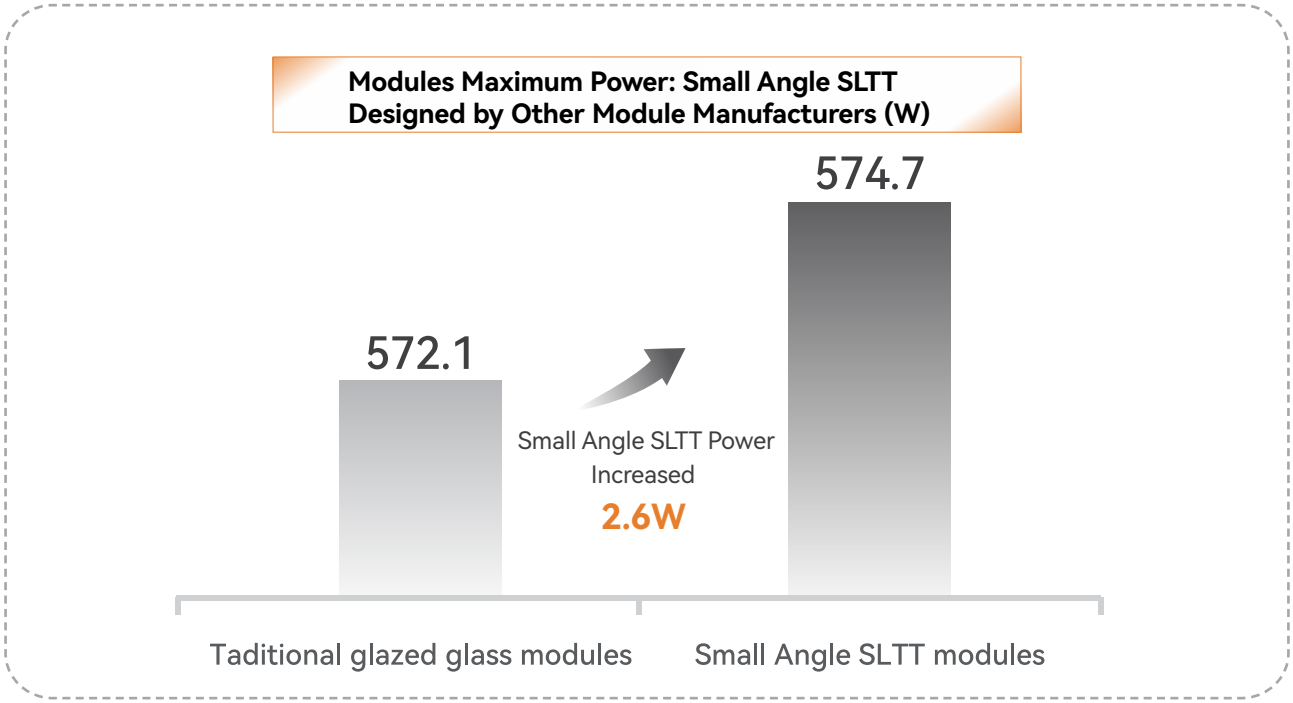
Compared to traditional glazed back glass, TNC modules deployed with SLTT technology offer higher maximum power. For modules of different sizes, the modules power can increase by approximately 3.0W to 5.0W, reflecting as current gain. The prism tilt angle in Tongwei's SLTT design is around 45°, compared with the small angle SLTT (around 20°) designed by other module manufacturers, Tongwei's SLTT techology results in a better enhancement in the module's maximum power gain.

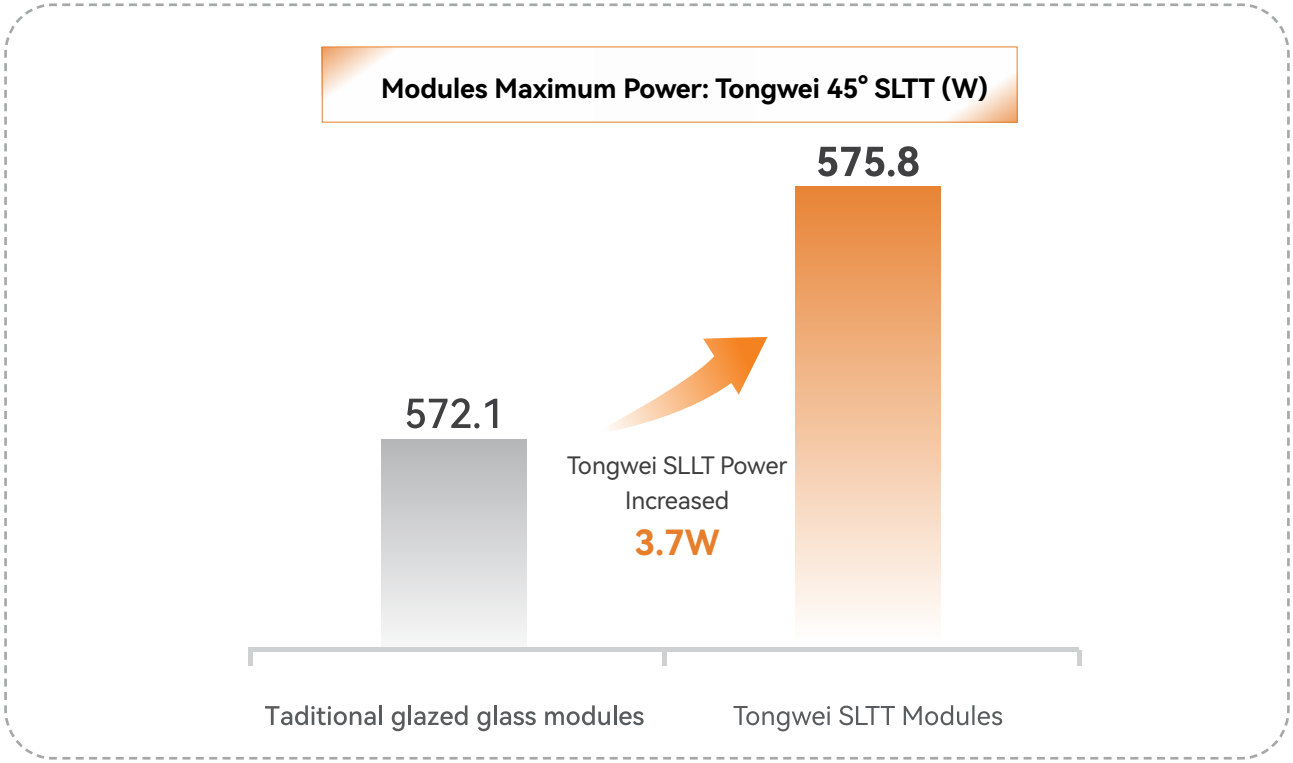


TIPS:

- Sample testing data is sourced from Tongwei's internal laboratory.
- The treatment group modules and the control group modules use TOPCon cells from the same batch, both groups modules are M10-72 half-cells (standard cell spacing) design, with identical module BOMs.
- Two sets of 10 modules with different SLTT designs (Tongwei 45° SLTT and small angle SLTT), along with one set of 10 traditional glazed glass modules, were produced on the sample line. The comparison was made to analyze the modules' maximum power.

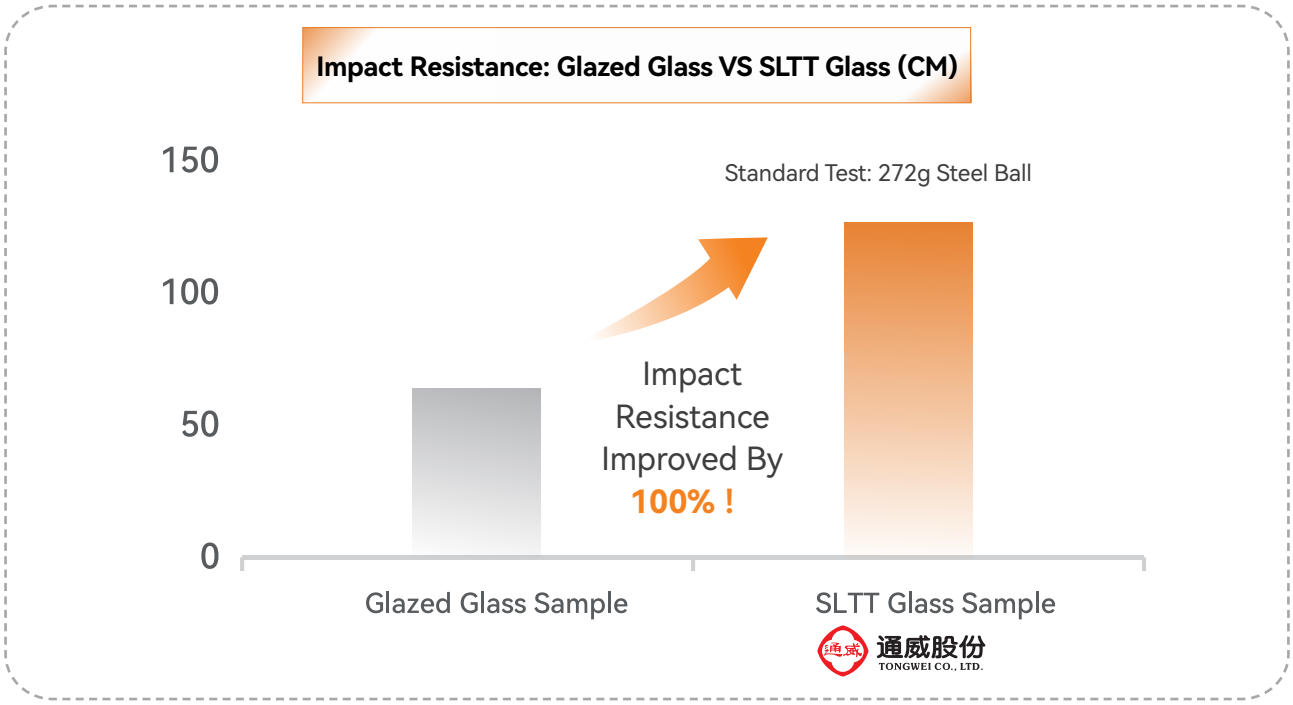
Results of Samples

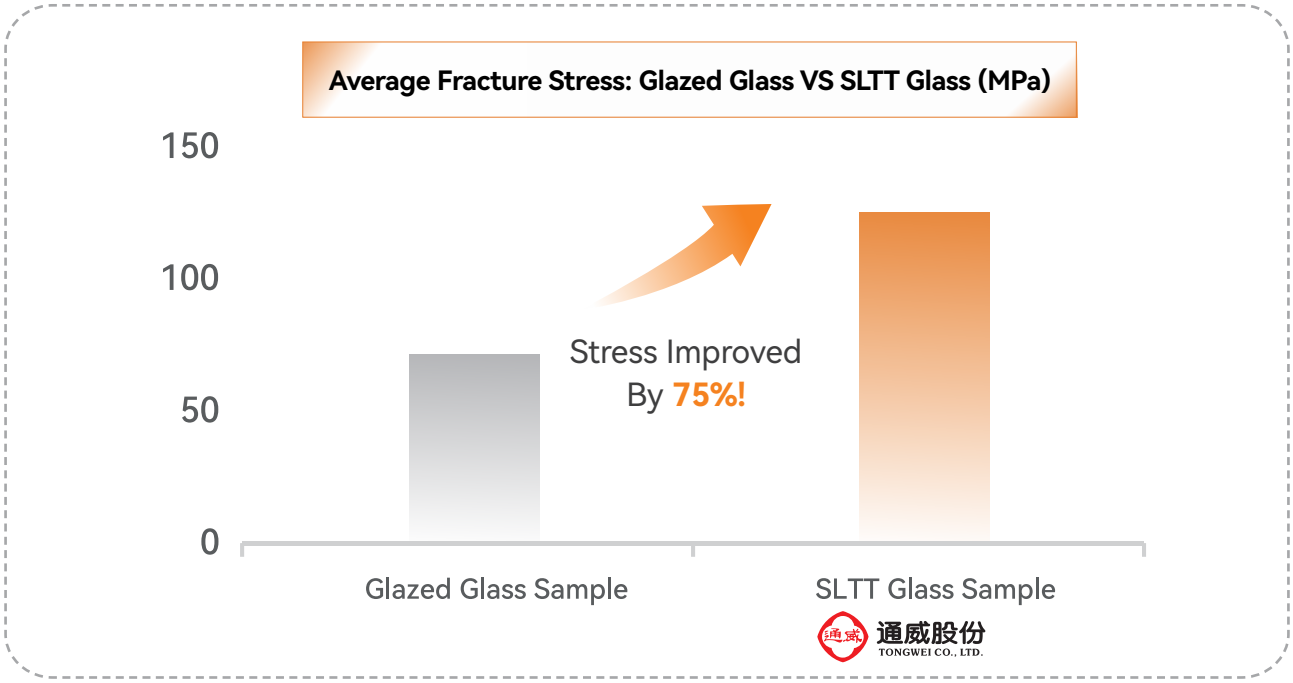




High Reliability

• Traditional Bifacial Module modules use glazed glass (glazing process before glass tempering) on the rear side. Studies have shown that high-reflection glazes increase defects on the glass surface. According to internal test results from Tongwei's laboratory, unglazed SLTT glass performs better in both drop ball tests and stress tests compared to glazed glass.

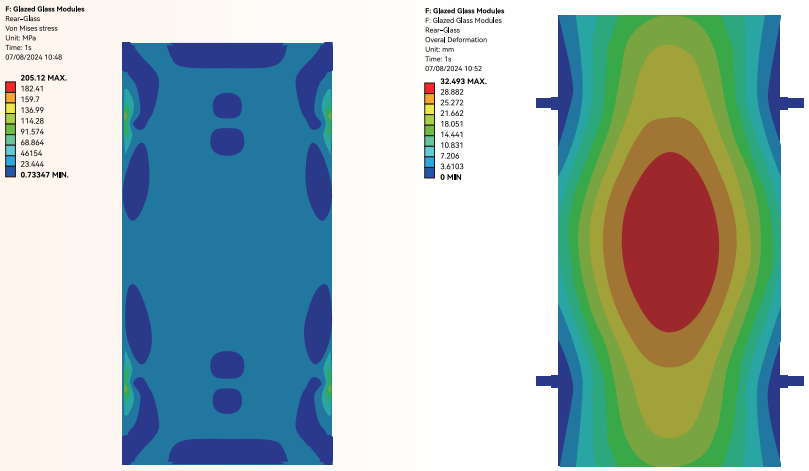




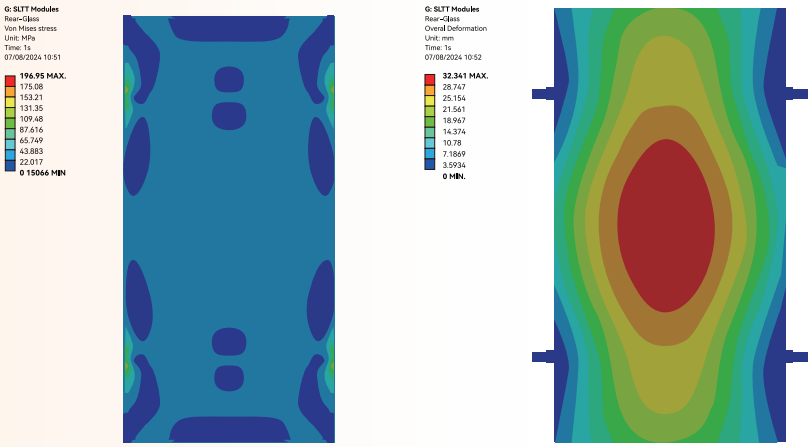
TIPS: Reliability testing data is sourced from Tongwei's internal laboratory.

• Under the same conditions, FEM (Finite Element Method) simulation results for the module static load of 5400 Pa shown: Compared with glazed glass, SLTT modules exhibit lower stress on both the front and rear glass; Overall module deformation also smaller than that of glazed glass. This indicates a stronger load-bearing capacity for modules deployed with SLTT glass.

Glazed Glass Modules

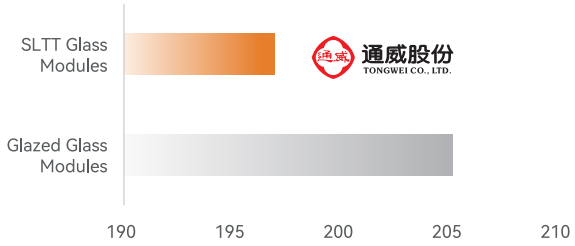


SLTT Glass Modules



Minimum Internal Stress: Glazed Glass VS SLTT Glass (MPa)

Maximum Internal Stress: Glazed Glass VS SLTT Glass (MPa)

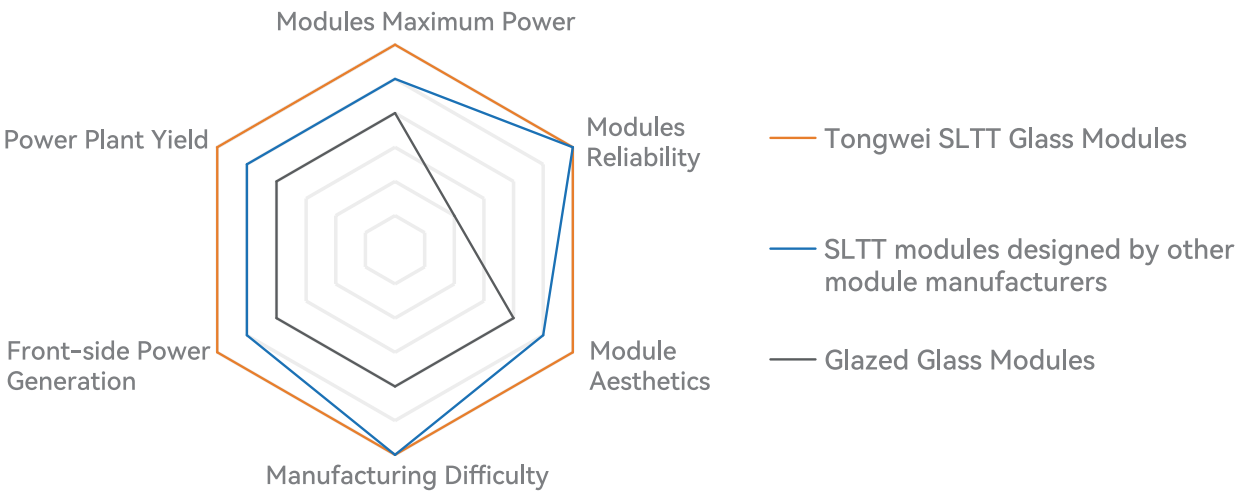


TIPS: Reliability testing data is sourced from Tongwei's internal laboratory.

SLTT Technology: High Cost-effectiveness

Compared to glazed glass modules, the system solution using Tongwei SLTT glass modules can reduce the cost per watt by 0.003-0.005 CNY, while ensuring over 30 years of reliability. Which meets the market demand for "high reliability" and "high power station yield" in module products.

Tongwei SLTT Technology Features



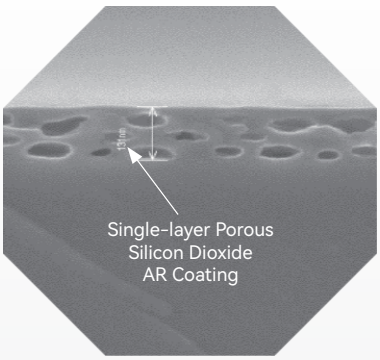
- Higher Module Reliability
- Higher Modules Maximum Power
- Higher Front-side Power Generation
- Easy to Manufacture
- Beauty Modules
- Higher Power Plant Yield.

Tongwei Technology: High-Efficiency Module Platform > Double-layer AR Coating Glass

Tongwei Double-layer AR Coating Glass

Tongwei TNC modules use ultra-white rolled glass with double-layer AR coating. Compared with normal single-layer AR coating solution, the double-layer coating solutions adds an extra dense silicon dioxide AR coating layer under basic single-layer porous silicon dioxide AR coating. New Double-layer AR coating solution could enhance the light transmittance and reliability of the photovoltaic glass.

Single-layer AR Coating Glass: Structure & SEM

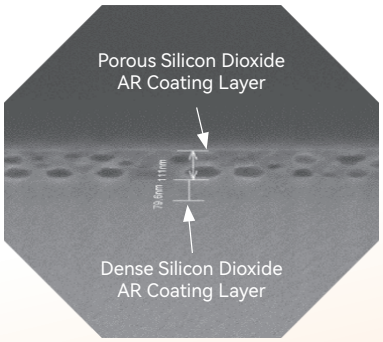


Porous Silicon Dioxide AR Coating ≈ 130nm

PV Ultra-white Glass

Commonly used single-layer coating photovoltaic glass in the PV industry utilizes single-layer porous silicon dioxide AR coating design. Under conventional natural light sources, its light transmittance can reach approximately 94.0%, and the coating layer exhibits excellent hardness performance.

Tongwei Double-layer AR Coating Glass: Structure & SEM



Porous Silicon Dioxide AR Coating ≈ 110nm

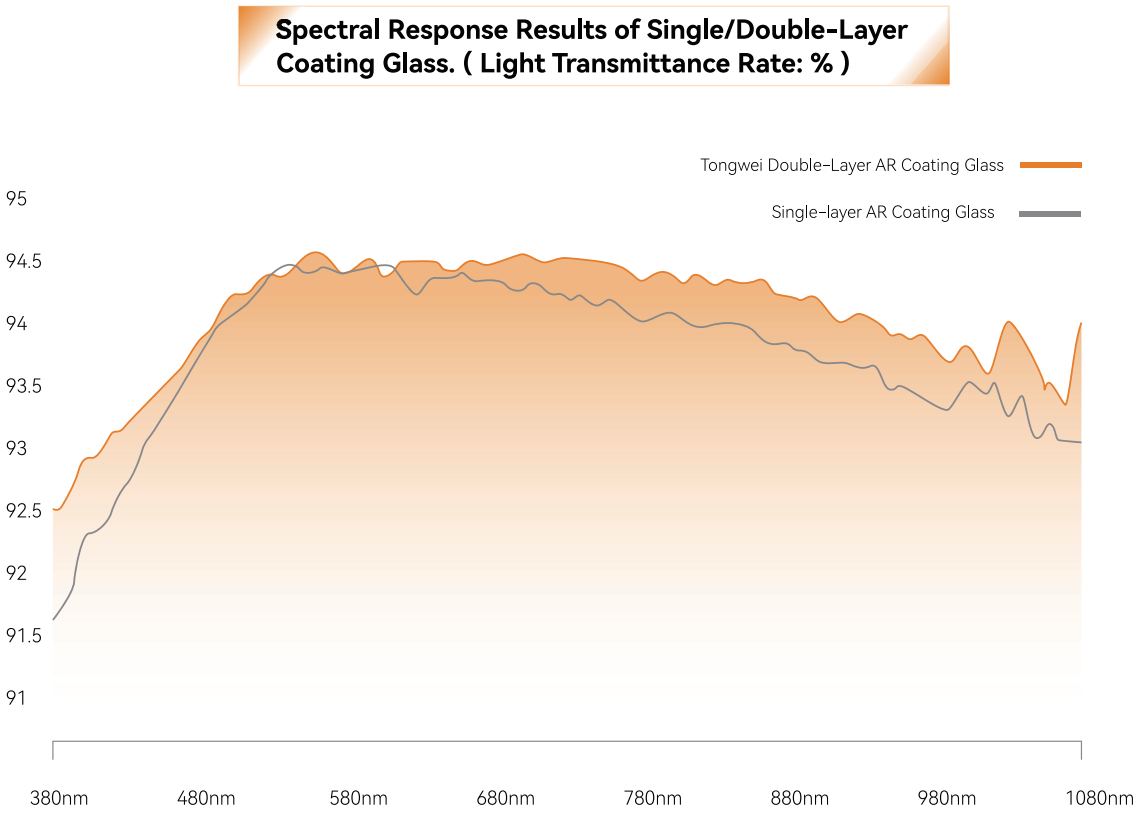
Dense Silicon Dioxide AR Coating Layer ≈ 80nm

PV Ultra-white Glass

Tongwei modules deploy double-layer AR coating glass, which sets a dense silicon dioxide AR coating layer between the porous silicon dioxide AR coating layer and the glass substrate. Under conventional natural light sources, the light transmittance of Tongwei PV glass can **exceed 94.5%**. The dense silicon dioxide AR coating in the bottom layer further blocks the intrusion of moisture and contaminants from the atmosphere, enhancing the reliability of modules in harsh environments.

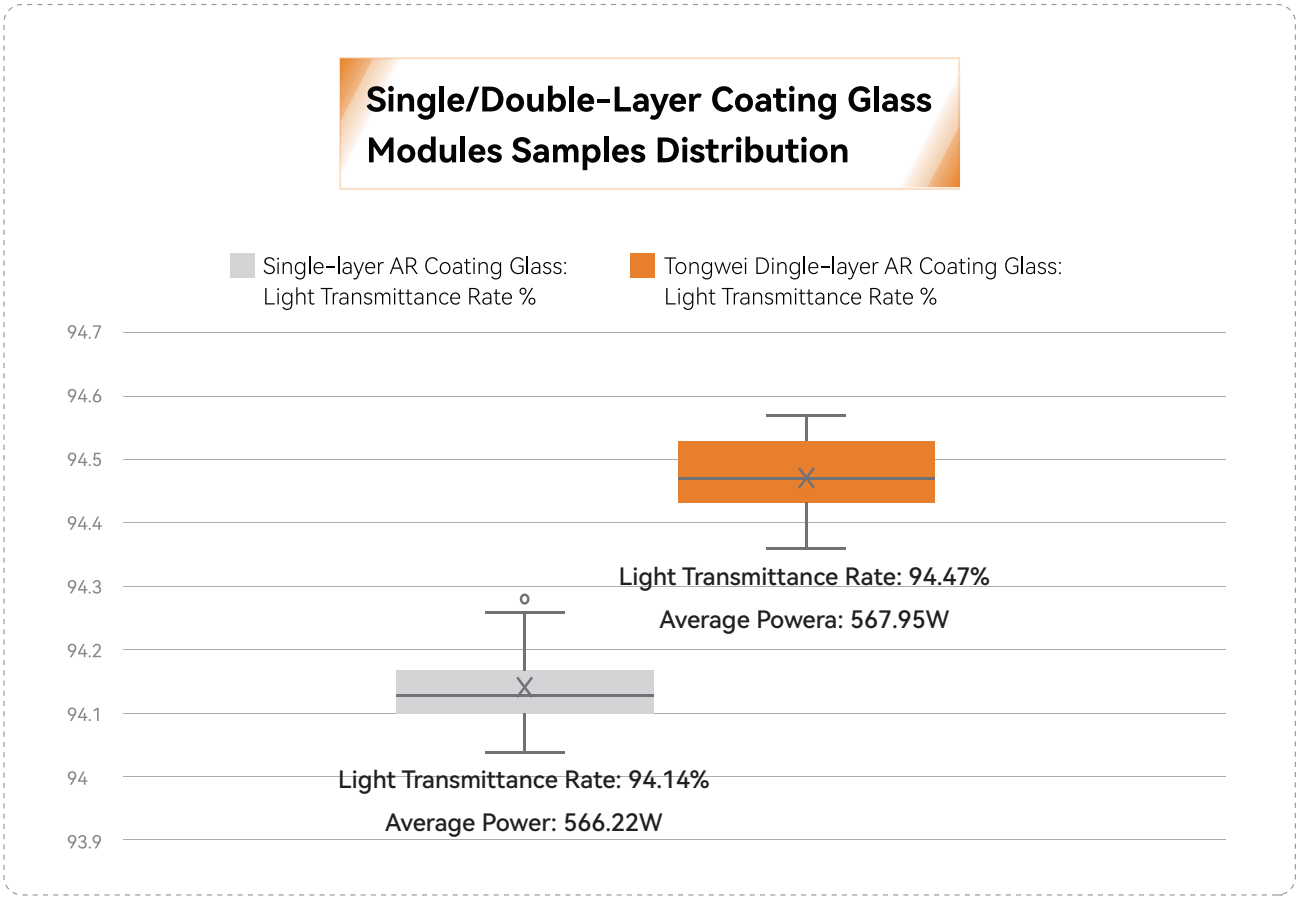
Introduction of Double-Layer Coating Glass

Interference reduction can be achieved by adjusting the refractive index and thickness of the adjacent coating layers, resulting in a coating solution with lower light reflection. Glasses with different coating schemes exhibit different light transmittance under the same wavelength of incident light. According to the spectral response test results of transmittance in the R&D laboratory, Tongwei's Double-layer AR coating glass solution exhibits better light transmittance performance compared to the conventional single-coating glass solution, under direct incident light across the full wavelength range (380nm-1100nm).



Better Light Transmittance Performance & Higher Module Maximum Power

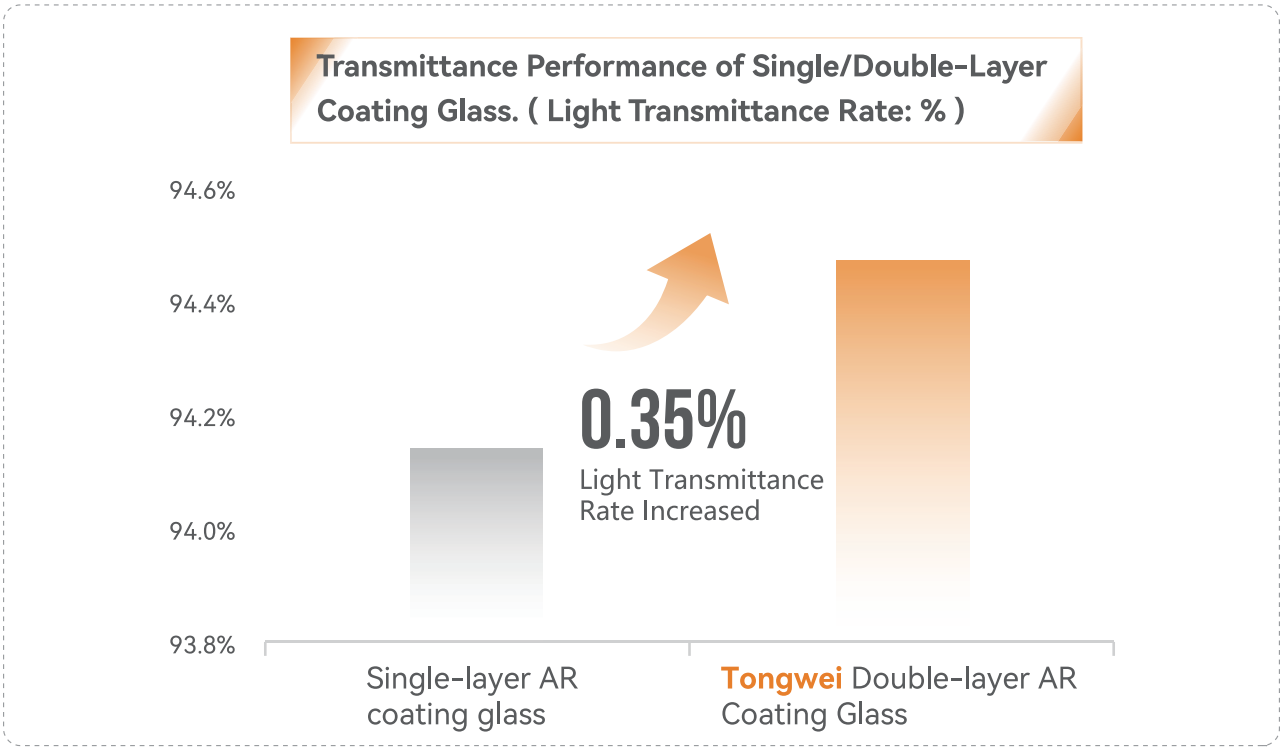
Under the conditions of a laboratory light transmittance tester with a long-life light source (fixed wavelength: between 760nm and 1000nm), the light transmittance of the double-layer AR coating glass used in Tongwei modules is approximately 0.35% higher than conventional single-layer AR coating glass. For modules of different sizes, the sample modules with double-layer AR coating glass show higher modules power (around 1.7W to 2.2W) compared to conventional single-layer AR coating glass modules, reflecting as a current gain.

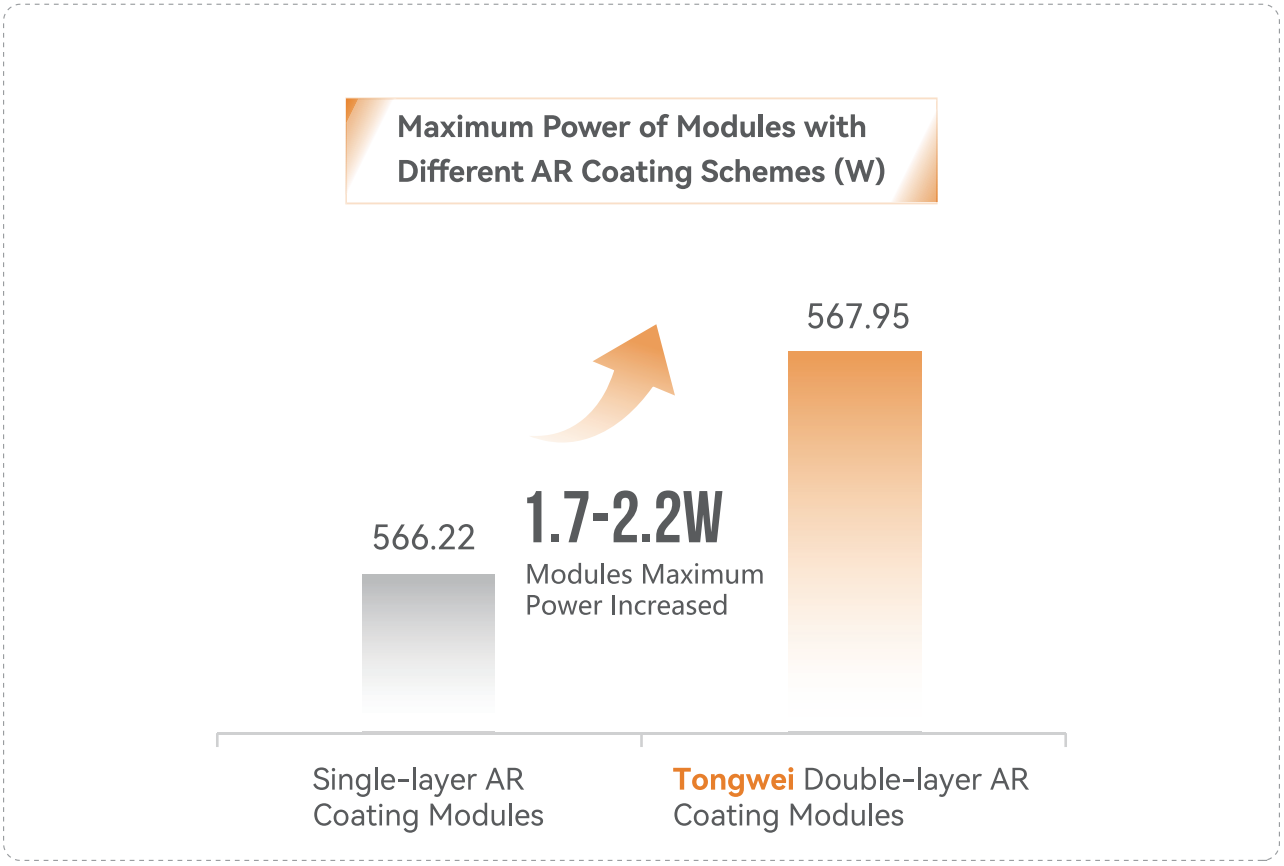


TIPS:

- Sample testing data is sourced from Tongwei's internal laboratory.
- The treatment group modules and the control group modules use TOPCon cells from the same batch, both groups modules are M10-72 half-cells (standard cell spacing) design, with identical module BOMs.
- Two sets of 50 modules in two test groups, were supplied with materials from the same suppliers but with different AR coating schemes. The light transmittance of the two groups of sample glass materials was compared and analyzed by using a long-life light source. Along with maximum power measurement of sample modules.

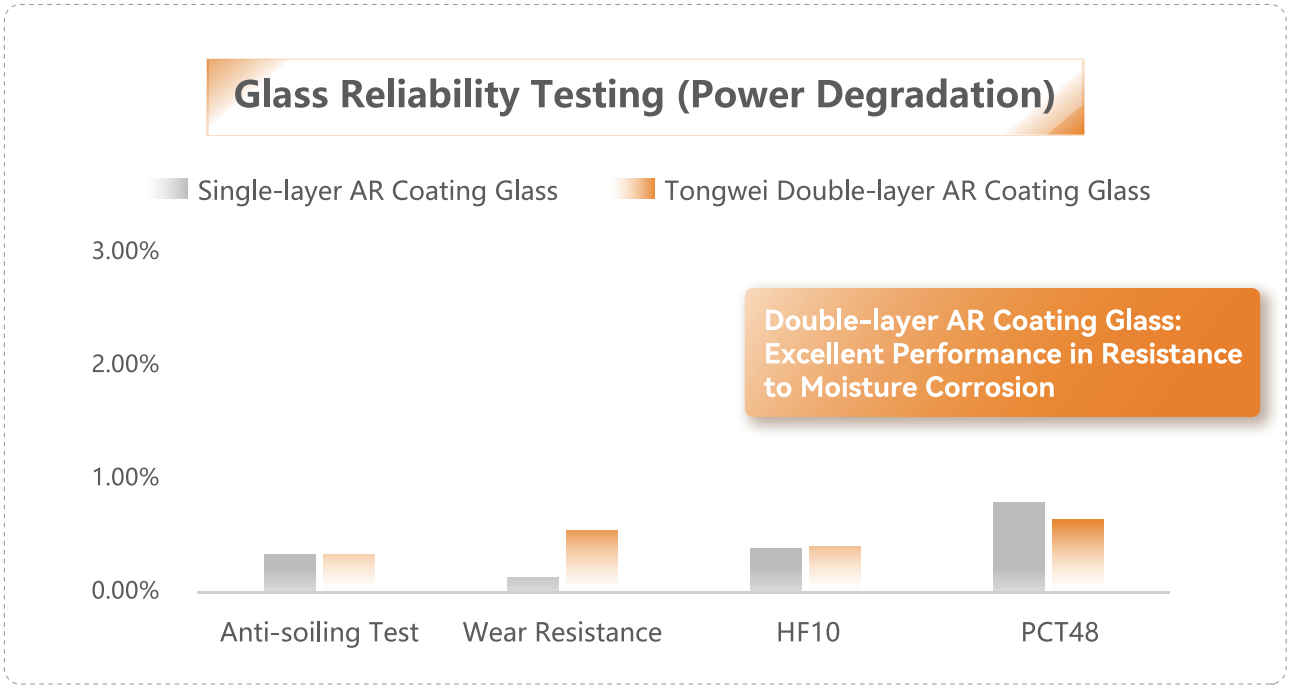
Results of Samples

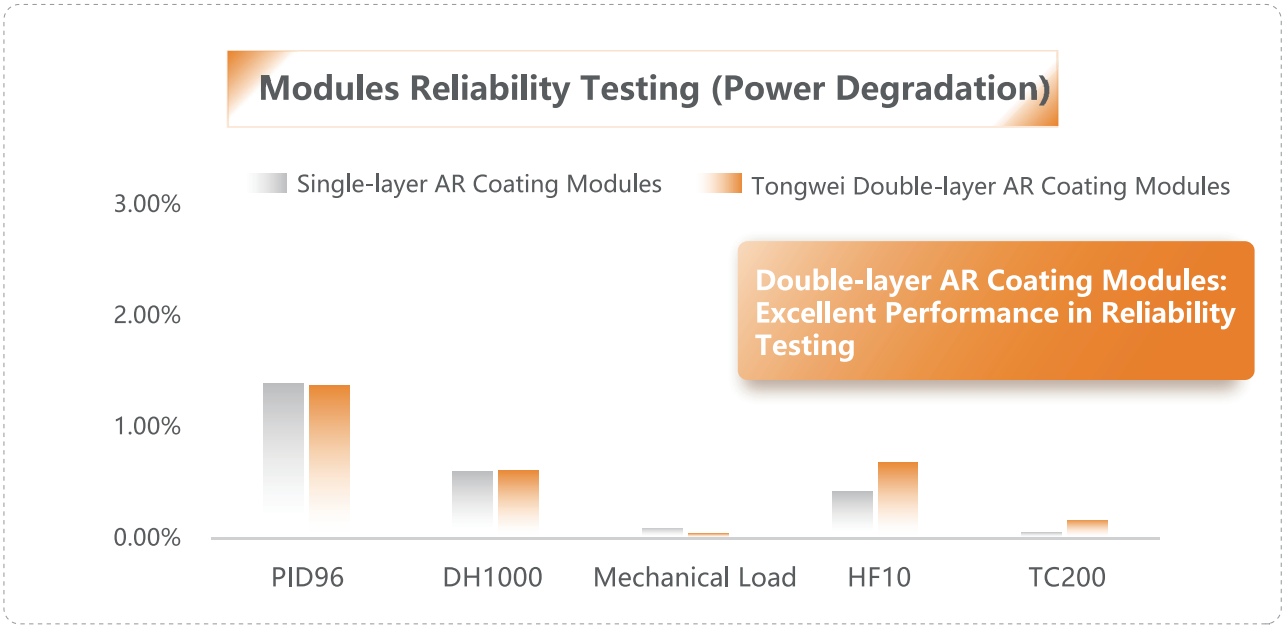




Reliability of Tongwei Double-layer AR Coating Schemes

- Tongwei double-layer AR coating glass features a dense two-layer structure, offering stronger resistance to moisture erosion compare with single-layer AR coating glass. Double-layer AR coating glass performs better in the PCT test, showing higher resistance to atmospheric erosion. Tongwei double-layer AR coating modules also has excellent performance in standard module reliability testing.

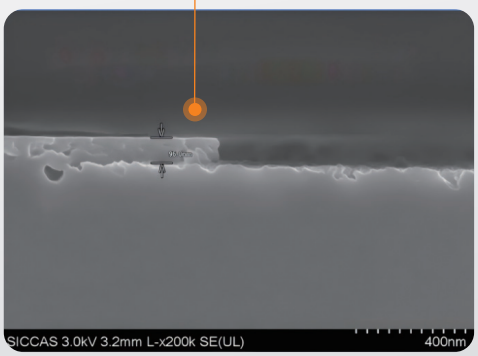




TIPS: Reliability testing data is sourced from Tongwei's internal laboratory.

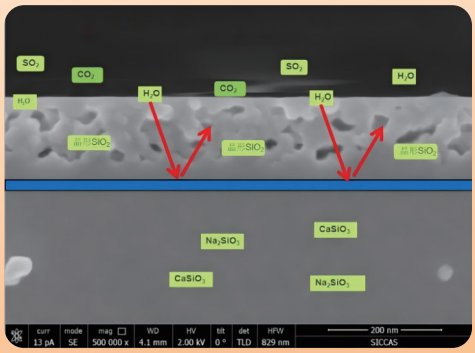
- When single-layer AR coating glass is exposed to moisture erosion, the silicate in the ultra-white base glass (beneath the coating layer) is prone to hydrolysis, generating NaOH (which is corrosive to glass) and H_4SiO_4 white substances (which affect light transmittance). Under atmospheric erosion, the single-layer AR coating is easily detached. However, the dense silicon dioxide layer in the double-layer AR coating effectively prevents the ultra-white base glass from moisture erosion, and inhibits the formation of crystal spots and deposits on the glass, making AR coating layer less prone to detachment under atmospheric erosion.

The coating layer is eroded and detached by the atmosphere



Single-layer AR coating:
Severe Erosion

The coating layer is hard to erode by the atmosphere



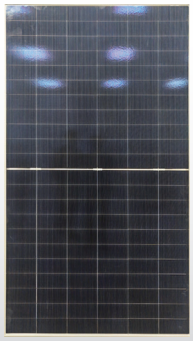
Tongwei Double-layer AR coating:
Mild erosion

Appearance

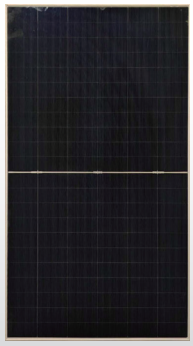
Through laboratory instrument testing, the color difference ΔE parameter of Tongwei double-layer AR coating glass: ≤ 2.0; The chroma B parameter: -4.0 to -2.5. For single layer AR coating glass, the color difference ΔE parameter: ≤ 2.5; The chroma B parameter: -6.5 to -4.0. **Tongwei double-layer AR coating glass has a smaller color difference, with a more uniform and consistent appearance, making the modules more aesthetically appealing.**

Single-layer AR Coating Glass

Tongwei Double-layer AR Coating Glass



Single-layer AR Coating Modules



Tongwei Double-layer AR Coating Modules

- Double-layer AR coating glass features a smaller color difference and a uniform, consistent appearance. It especially suitable for rooftop modules, all-black modules, and other aesthetically designed modules
- Porous SiO_2 glass coating layer exhibits good thermal and hydrothermal stability, making the modules suitable for offshore or marine environments.

03

Chapter Three

Tongwei Intelligence: Extended Reliability Testing

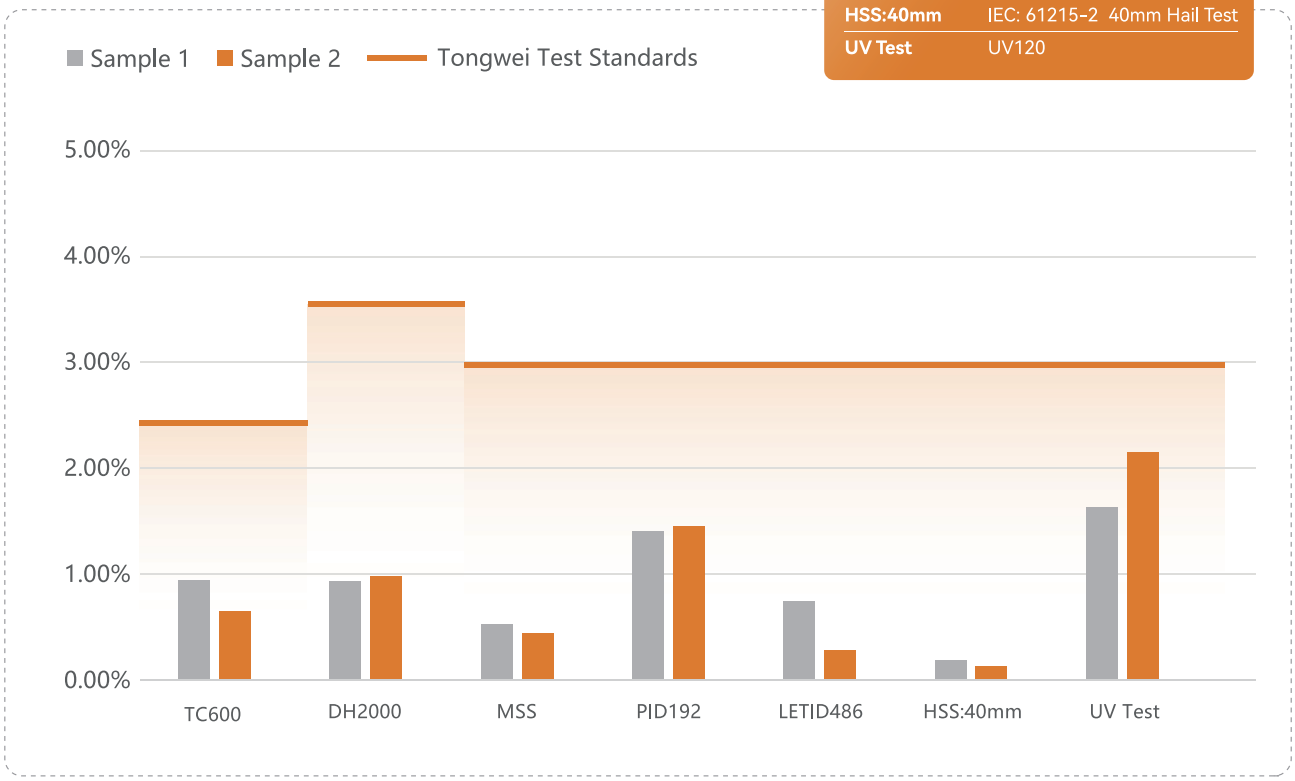
- The products boast excellent quality which have successfully passed extended reliability testing and certifications from IEC, PVEL, and other organizations.

Tongwei Intelligence > Extended Reliability Testing

Tongwei TNC series products, which deployed self developed TOPCon technology, have excellent reliability. Taking the TNC-G12R-66 modules as an example, the product has passed extensive tests by the globally recognized laboratory PVEL and has also obtained extended test certificates, including IEC 63209 and IEC 63126. Which includes Thermal Cycling(TC), Damp Heat(DH), Potential Induced Degradation Test (PID), Light and Elevated Temperature-induced Degradation (LeTID486), UV-induced Degradation (UV), Mechanical Stress Simulation (MSS), 40mm Hail Test and a series of other rigorous extended reliability tests.

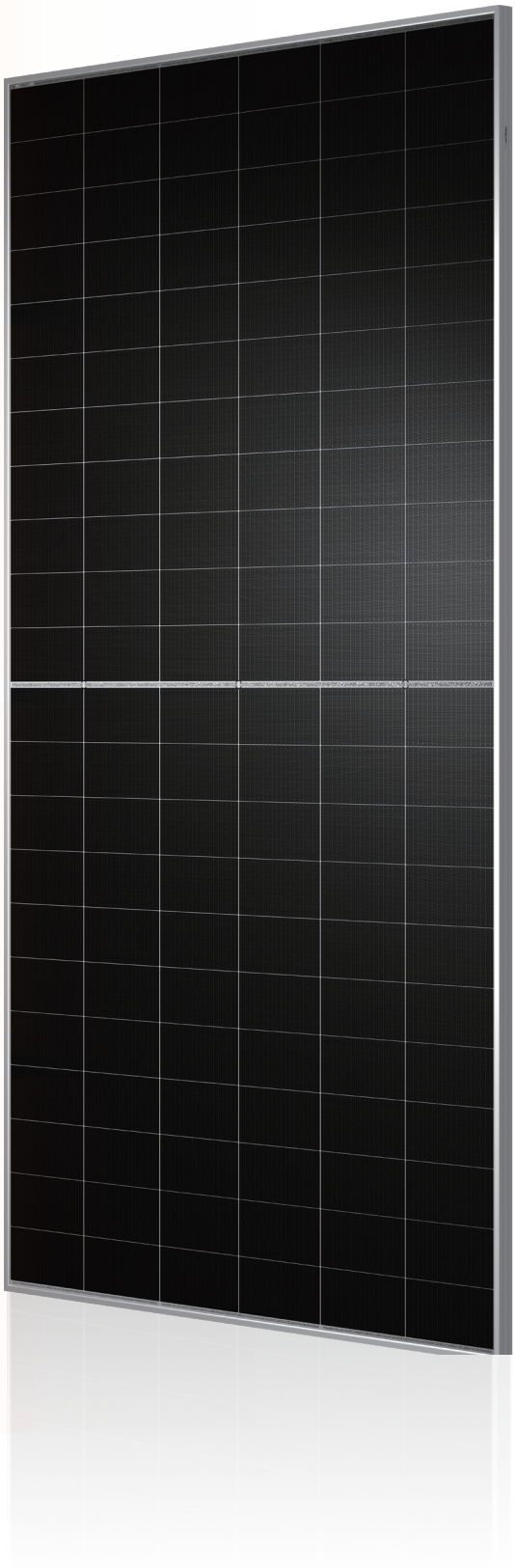
Performance in Extended Reliability Test (Power Degradation)

MSS	SML+DML+TC50+HF10
HSS:40mm	IEC: 61215-2 40mm Hail Test
UV Test	UV120



Tongwei Test Standards

- Tongwei Standard: Strict internal quality management system with double IEC tests standards.
- Tongwei Products: Higher product standards lead to enhanced reliability and superior quality performance.



High UV-resistant design

- UV-Resistant Design: Advanced passivation layer of TNC cells. enhancing UV-resistant.
- UVID Test: Power degradation less than 3% in UV120 & UV 300, top-leading performance in PV industry.

Hail-resistant design

- Hail Test: No cell micro-cracks during 40mm Hail Test, the module appearance is intact.
- Products Application: Extreme low risk of cell micro-cracks that may be caused by hail impact; Outstanding performance in harsh storm and hail weather.

Weatherability Design

- Extended Test: Excellent performance in TC600 & DH2000 extended reliability. Power degradation less than 2.5% Tongwei Test Standards.
- Products Application: Modules avaliable in hot & high humidity environment such as desert, rainforest & offshore.

IEC TS 63126 :PV Modules Operation at High Temperatures

- The testing sequence aims to verify the performance and reliability of photovoltaic modules operating under high-temperature conditions.
- The testing sequence is based on the existing IEC 61730 and IEC 61215 test sequences, with enhanced temperature conditions in the sequence according to different testing levels.
- This testing sequence includes high-temperature hot spot durability testing (60±10℃), high-temperature UV-induced testing (70±5℃), high-temperature thermal cycling testing (95±2℃), and high-temperature bypass diode thermal performance testing (90±2℃), among other high-temperature extended reliability tests.


Compliance Document

IEC 61326 Extended Reliability Test Certificate (TUV SUD)

IEC TS 63209 : Extended Reliability Testing Sequence

- This testing sequence is based on the IEC 61215 and IEC 61730 test sequences, extended tests specifically designed for photovoltaic modules operating in high-temperature, high-UV irradiance environments.
- This testing sequence includes extended damp heat test (DH2000), extended thermal cycling test (TC600), extended UV durability sequence test (DH200+UV60+HF10+TC50), extended potential-induced degradation test (PID192), and extended composite dynamic and static load test (SML+DML+TC50+HF10).


CERTIFICATE

IEC 63209 Extended Reliability Test Certificate (Dekra)

PVEL Lab : Extended Reliability Testing Sequence

- PVEL is a globally leading photovoltaic module reliability and performance testing laboratory. Each year, it conducts extended tests beyond IEC certification standards to simulate the reliability performance of modules under various extreme environmental conditions. PVEL's tests serve as a key benchmark for evaluating the reliability and performance of photovoltaic modules in the industry.
- PVEL's extended testing sequence builds upon the IEC extended testing series (including DH2000, TC600, PID192, and MSS), with additional extended tests such as the enhanced 40mm hail test and the extended Light-Enhanced Degradation (LeTID486) test.

Kiwa PVEL Extended Reliability Test Trophy

04

Chapter Four

Tongwei Innovation: Introduction of TNC 2.0 Products

- TNC 2.0 Cell + TNC 2.0 Modules Platform
- G12R-66 Modules can reach 670W+, showcasing Tongwei's advanced manufacturing capabilities

Introduction of TNC 2.0 Products

Introduction

Tongwei will launch the TNC 2.0 modules in Q1 2025, which will deploy new-generation TNC 2.0 solar cells. The efficiency of the TNC 2.0 cell has significantly increased compared to the TNC TNC 1.0 cells. TNC 2.0 products deploy several latest technology in the PV industry, including TPE (Tongwei Edge Passivation), stencil printing technology, Type-908 cell & interconnection technology and Poly Tech. The maximum power of TNC 2.0 modules (TNC 2.0 cells + TNC 2.0 module platform) will exceed 670W (G12R-66) and 765W(G12-66) , maintaining a leading position in the PV industry.

TNC 1.0 Products:

Deployed with Tongwei's TNC 1.0 high-efficiency TNC cells and advanced module platform. By the end of 2024, the maximum powerof the standard G12R-66 module will reach 630W.

TNC 2.0 Products:

Deployed with Tongwei's latest TNC 2.0 cells and TNC 2.0 module platform.
The maximum power of the standard TNC 2.0-G12R-66 module will reach 670W.

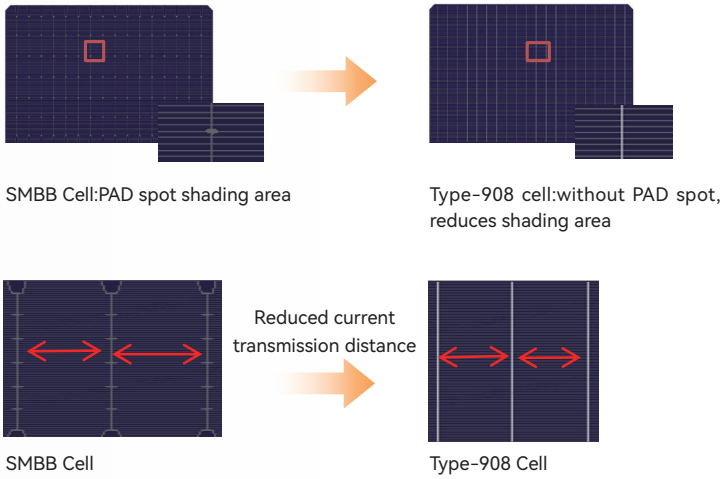
Introduction of TNC 2.0 Products > Technical Summary

The integration of four key solar cell and module technologies drives the iterative upgrade of Tongwei's TNC 2.0 products, resulting in a power increase of 20W+ and bifaciality increased by 5-10 PCT for the TNC 2.0 modules (ex. G12R-66 dual glass).

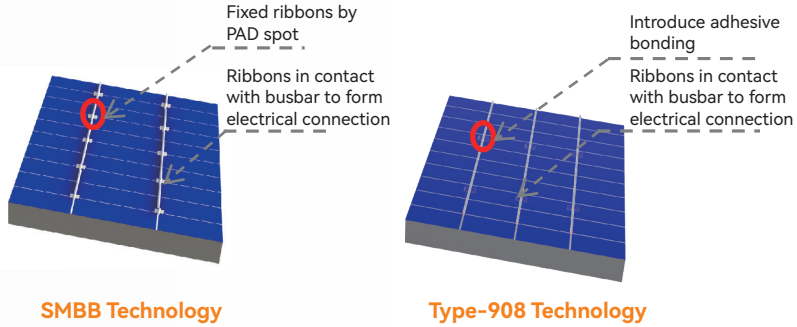
Type 908 Cell

"0BB Technology with Tongwei own patent"Adopts a multi-fingers (Ultra-narrow busbars)interconnection design to achieve higher module power. The cells feature a flexible interconnection design, which significantly reduces internal stress and lowers the risk of cell microcracks by 30%.

Compared to SMBB, Tongwei Type-908 technology selects specialized cells, eliminates cell Pad sopt, reduces shading area, and uses more welding ribbons solutions. Current transmission distance between fingers and each ribbon are reduced by about 30%, **as result the electrical loss from cell to module is reduced and product power is increased.**



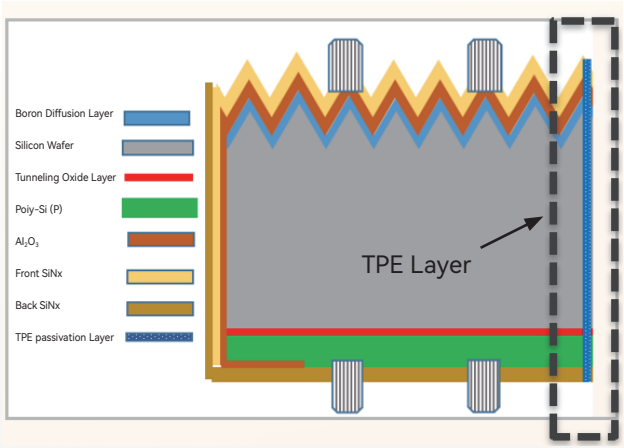
The main difference between Type-908 technology and other 0BB technologies is the use of heat-set adhesive and medium-temperature soldering process, instead of the ultralow temperature soldering ribbon and laminated alloy processes in other 0BB technologies. The soldering process creates a excellent ohmic contact, while the heat-set adhesive tightly bonds the ribbon to the cells, enhancing the module's ability to resist thermal shock, loading, and hot spot risks during practical operation. **Thus, Type-908 module has excellent reliability performance.**

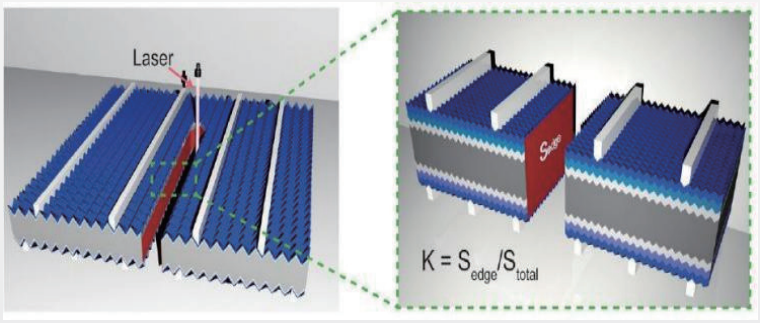


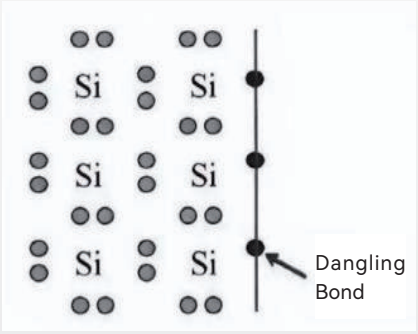
TPE Technology

"TPE Technology with enhanced quality and efficiency" The application of passivation technology significantly improves the electrical performance of the cells

Photovoltaic modules with a half-cell design, where the laser divides a single cell into two half-cells. The cutting process causes damage to P-type Si, N-type Si, and poly-Silicon, resulting in significant cell efficiency loss. In TPE Process. preferred passivation materials are applied to the laser-cut edges of the cells, to repair damage to the passivation layer and lattice defects caused during cell repair. Through TPE passivation technology, the cutting edge damage can be effectively repaired, **improving the efficiency of half-cut cells and module power.**



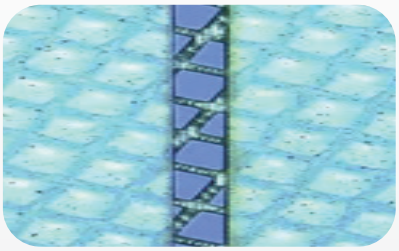




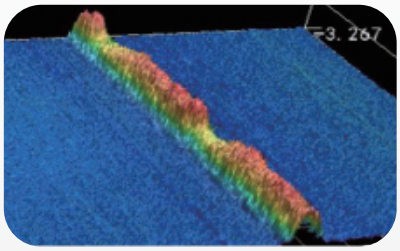
Stencil Printing

"Precision Screen Printing Technology" Improved current collection capability results in superior cells electrical performance.

Conventional screen printing use use a knotless design, where ink deposition is uneven under the wire blocking positions, leading to fluctuations in the fine grid line shape. Due to the limitations of the steel wire diameter, there is limited space for reducing the fingers width. By using a specially designed stencil printing, a 100% open-area ratio is achieved, meaning there is no mesh obstruction in the open areas of the mesh, resulting in higher ink transmission rates. Compared to conventional printing methods, stencil printing reduces the cell's fingers line width by approximately 25%, resulting in a 3.3% decrease in shading area. **This enhances current collection capability and significantly improves cell electrical performance.**

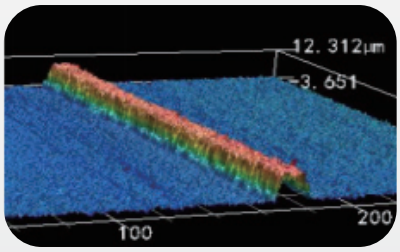


Conventional Screen Printing



Uneven printing at the wire blocking positions leads to fluctuations in the tinny fingers, affecting current transmission performance

Stencil Printing

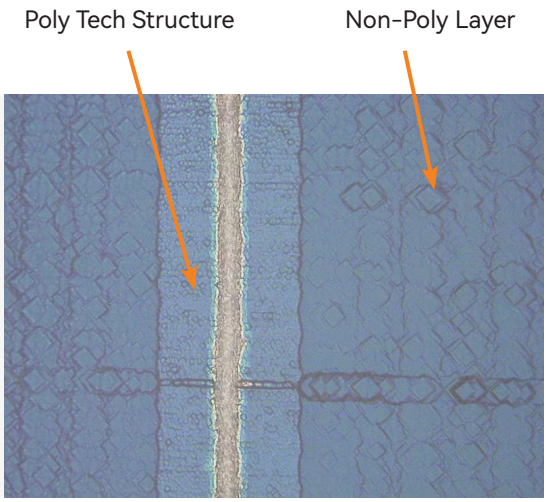


The Stencil Printing has a fully open area with no obstructions, resulting in a smooth appearance and improved current transmission performance

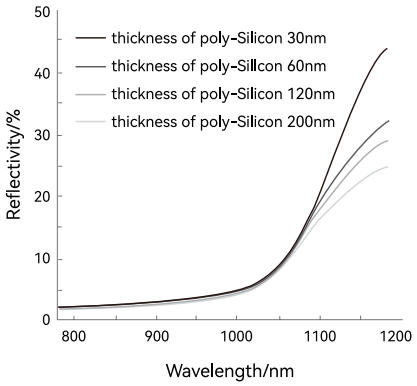
Poly Tech

"Higher bifaciality, Higer Power Generation"Cell efficiency is significantly improved, with bifaciality increased by approximately 5-10 PCT

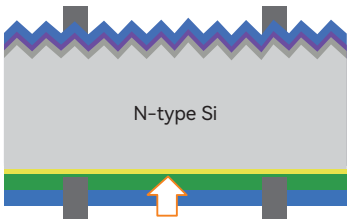
The doping of polycrystalline silicon on the back of TNC cells causes the absorption of free carriers when photons close to the silicon bandgap energy (Eg) are absorbed, leading to a decrease in infrared light response. Tongwei reduces efficiency loss by removing poly-Silicon in the non-contact areas. As a result, **the cell electrical performance optimized, and the module bifaciality improves by approximately 5-10 pct.**



88% Bifaciality Certification by TUV Rheinland

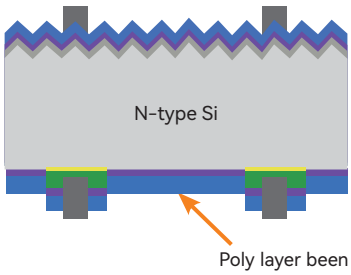


The relationship between the poly thickness and reflectivity



Poly doping & absorption of free carriers

TNC Cell Structure



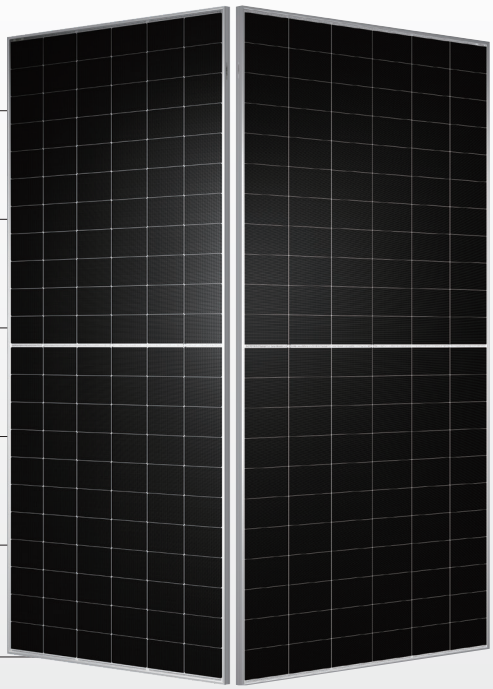
TNC Poly Tech Cell Structure

TNC 2.0 Product Platform

"TNC 2.0 Cell + Module Design Optimization"

New Product Platform Advantages

- Advanced Cell Electrical Performance
- Lower CTM Power Loss
- Higher Modules Power
- More Excellent Module Reliability
- Greater Power Station Yield
- Aesthetic Module Appearance



Covering Different Modules Type

- Residential Modules **TNC 2.0**-G12R-48
- Utility Modules **TNC 2.0**-G12R-66
- Utility Modules **TNC 2.0**-G12-66

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