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Same Sunshine
More Value



Jolywood Namic PV Module Product Introduction

From Cost Optimization to Strategic Choice: Silver Reduction Is Reshaping PV Module Metallization

Silver Is Becoming the "Hard-Constrained Resource" for the Next Phase of PV Manufacturing

Silver reduction is no longer just cost optimization but a strategic route for PV manufacturing

2025 Global New Installations
~700GW

Annual PV Silver Consumption
6,147 tons

PV Share of Global Industrial Silver Use
≥20%

Silver Cost as Share of Module Cost
15%+

Larger scale means stronger silver resource constraints

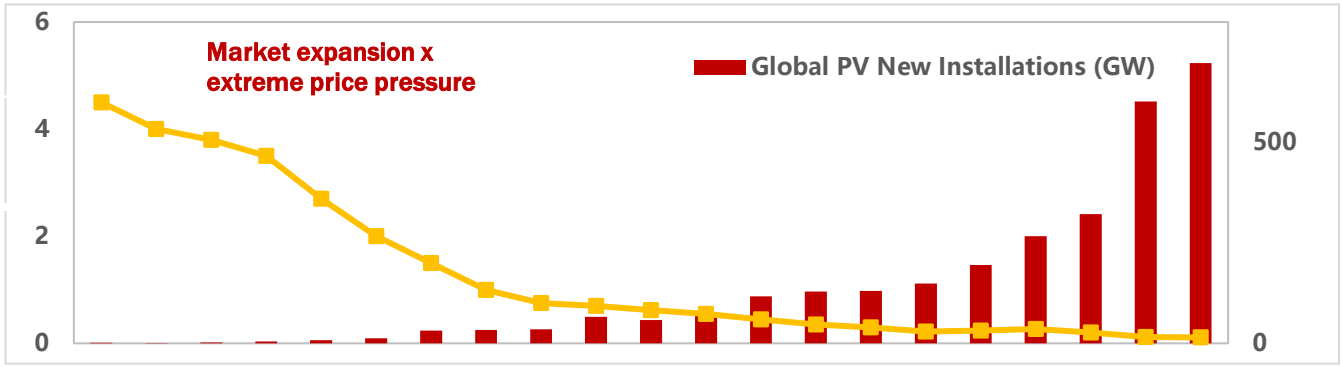
TW-scale new installations have made silver a key industry variable

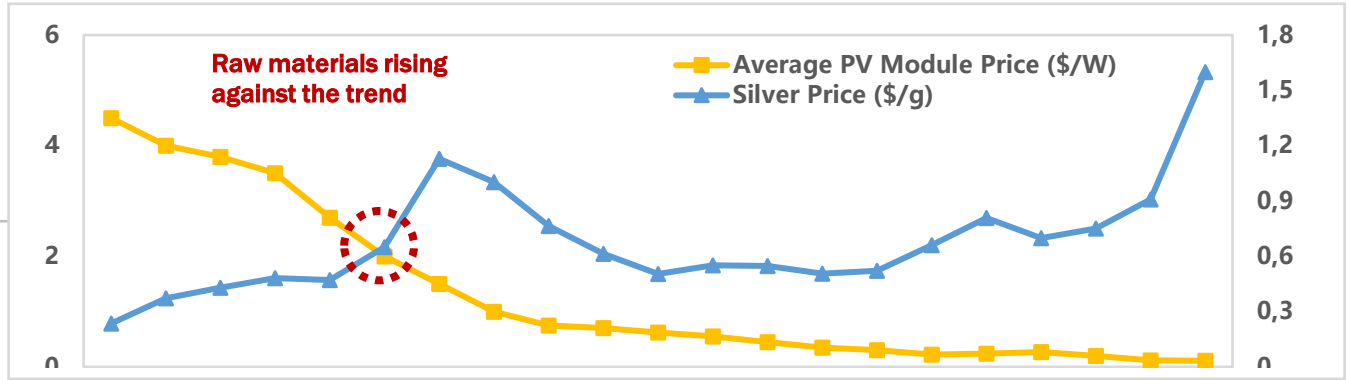
Lower prices make modules more sensitive to silver cost

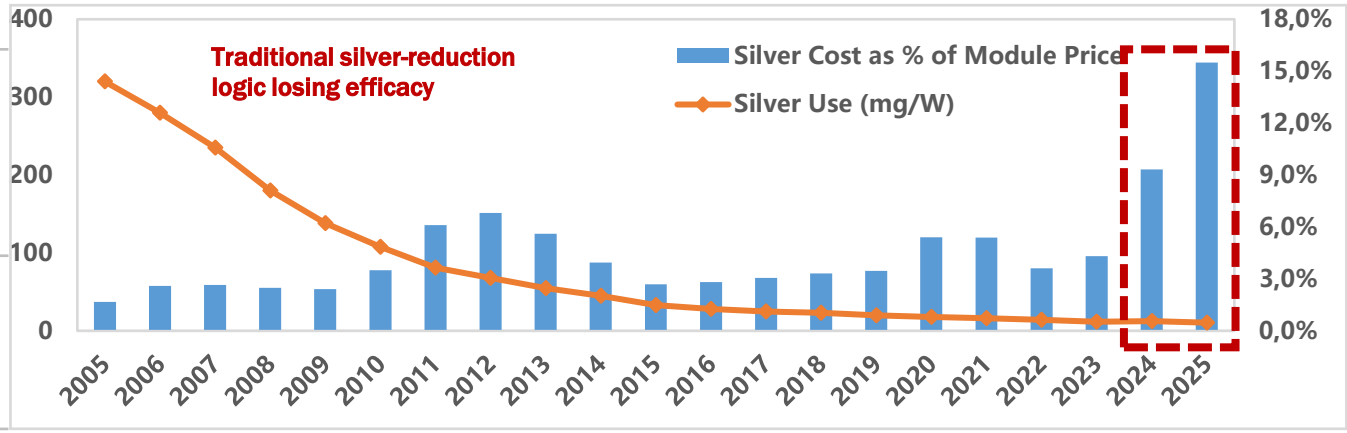
As module prices fall to low levels, silver's cost share rises passively

Technology routes must upgrade

Low silver use + high efficiency + high reliability







Technology Routes and Stage Trends for Silver Reduction in Mainstream Crystalline Silicon PV Cells

Route divergence is accelerating: different cell structures define different silver-reduction priorities, with staged industry evolution

Silver-Reduction Routes for Different Crystalline Silicon Cell Technologies

	PERC	TOPCon	HJT	IBC/BC
Current Main Route	Fine-line printing / SMBB / 0BB	Low-Ag paste + LECO + SMBB/OBB	Ag-coated Cu paste + OBB + ECA	Rear-side fine lines, pattern transfer, local silver reduction
Mid-Term Evolution	Low-Ag paste, busbar optimization (limited room)	Rear Ag/Al/Cu synergy; Ag-coated Cu paste	Lower-Ag paste; copper plating	Photosensitive dry film / LDI + Ni/Cu/Ag copper plating
Key Bottlenecks	Near the physical limit; limited room for silver reduction	High-temp firing window; contact stability; Cu diffusion; bifacial consistency	Low-temp interconnection; adhesion; long-term reliability	Pattern precision; wet processing; CAPEX/OPEX; yield and reliability
Industry View	**Continues in the short term, gradually phased out**	**Next 3-5 years main battlefield for silver reduction**	**Most closed-loop low-silver mass-production route in the near to mid term**	**High long-term potential, but high process threshold**
Current Ag Use Reference	~8-10mg/W	~8-12mg/W (advanced lines can reach 8-9 mg/W)	~6-10mg/W (significant gains from Ag-coated Cu)	~5-8mg/W (depending on structure)

Stage Trends for PV Cell Silver Reduction

Near-Term Mainstream

Mass-producible with low adoption cost

- Fine-line / narrow gridlines
- Low-Ag paste + LECO
- SMBB / 0BB / busbarless interconnection

Most widely used today; already scaled in TOPCon and HJT

Mid-Term Watch

Structural synergy balancing cost reduction and reliability

- Rear-side Ag -> Al substitution
- Rear-side Cu / Al synergistic metallization system
- Cell-interconnection-encapsulation co-optimization

Ag-coated Cu paste is already in HJT/TOPCon mass production or testing

Long-Term Potential

Lowest Ag use, but major process challenges

- Ni/Cu/Ag and Ni/Cu/Sn plating
- Pure Cu paste / seed layer + plating
- Pattern transfer, inkjet printing and other new processes

Fraunhofer ISE verified TOPCon Ag use down to 1.1 mg/W

Silver Optimization → Coordinated Silver Replacement → Silver-Free Reconstruction

Sources: public papers, PVinfolink, ITRPV, research institutions and manufacturers' public materials

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NANO-ARMOR METAL INTER-CONTACT

Nano-Armor Metal Inter-Contact Technology

Jolywood Namic Module - Multi-level, multi-technology synergy, not simple substitution

Jolywood Namic modules coordinate the cell, interconnection and module layers to balance silver reduction, reliability and system compatibility.

Engineering Direction and Logic

- Replace rear-side Ag with Al to reduce reliance on precious metals
- Use the interface layer to regulate contact formation and diffusion barriers
- Optimize interconnection and encapsulation together to avoid system risks from single-point changes

Engineering Verification Focus

- Can the interface layer deliver low contact impedance and long-term stability?
- Will the Al system introduce recombination, corrosion or process-window issues?
- Can mass production converge to acceptable yield, take time and consistency?

	Goals & Methods	Features	Reliability Tests
Cell Layer	Goal: lower Ag use while controlling contact, diffusion & leakage risks • Rear Electrode Aluminization • Nano-Interface Protective Layer	Lower rear Ag use; optimized light-receiving structure; interface protection potential	Contact resistance, recombination penalty, Al diffusion, long-term interface stability
Interconnection Layer	Goal: design an adapted encapsulation solution • Light-enhancing EPE film, transparent grid backsheet encapsulation	Stronger barrier properties; improved light utilization	PID resistance; aging resistance
Module Layer	Goal: improve mechanical/environmental redundancy and amplify cell-layer value • Fully tempered / steel frame / high-strength encapsulation • Passes extreme scenarios such as hail, load and wind tunnel	Higher hail/load/wind-tunnel redundancy; improved transport and installation tolerance	Long-term outdoor validation, cost trade-offs, failure-attribution boundaries

Three-layer optimization maps to different failure and reliability modes, so validation must assess the reliability closed loop alongside efficiency gains or Ag reduction.

Cell Layer - Introduction and Innovation of Jolywood Namic Cells

Namic Cell Technology (Nano Armor Metal Inter-contact)

Structural Re-optimization

Jolywood launched the Namic cell project in 2019. After six years of deep R&D by an international PhD team, it developed **Nano-Armor Metal Inter-Contact technology. With this technology, Namic cells can reduce, minimize or eliminate rear-side silver** without lowering efficiency, significantly cut metallization cost, and achieve key breakthroughs in stable efficiency, controllable cost and production-line compatibility.

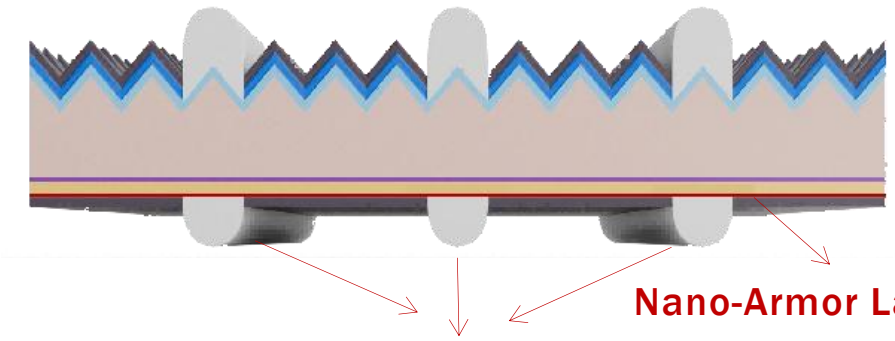
Full-Chain Independent Innovation

Three core innovations drive breakthroughs in nanoscale film technology

Patent Layout

On Sept. 28, 2014, Jolywood filed its first BC-related patent. To date, Jolywood has filed **224** BC cell/module patents, including **86** non-silver-technology patents.

Jolywood Namic Cell



Material Innovation

Original aerospace-grade film material integrating surface passivation, radiation resistance and non-silver metallization compatibility

Process Innovation

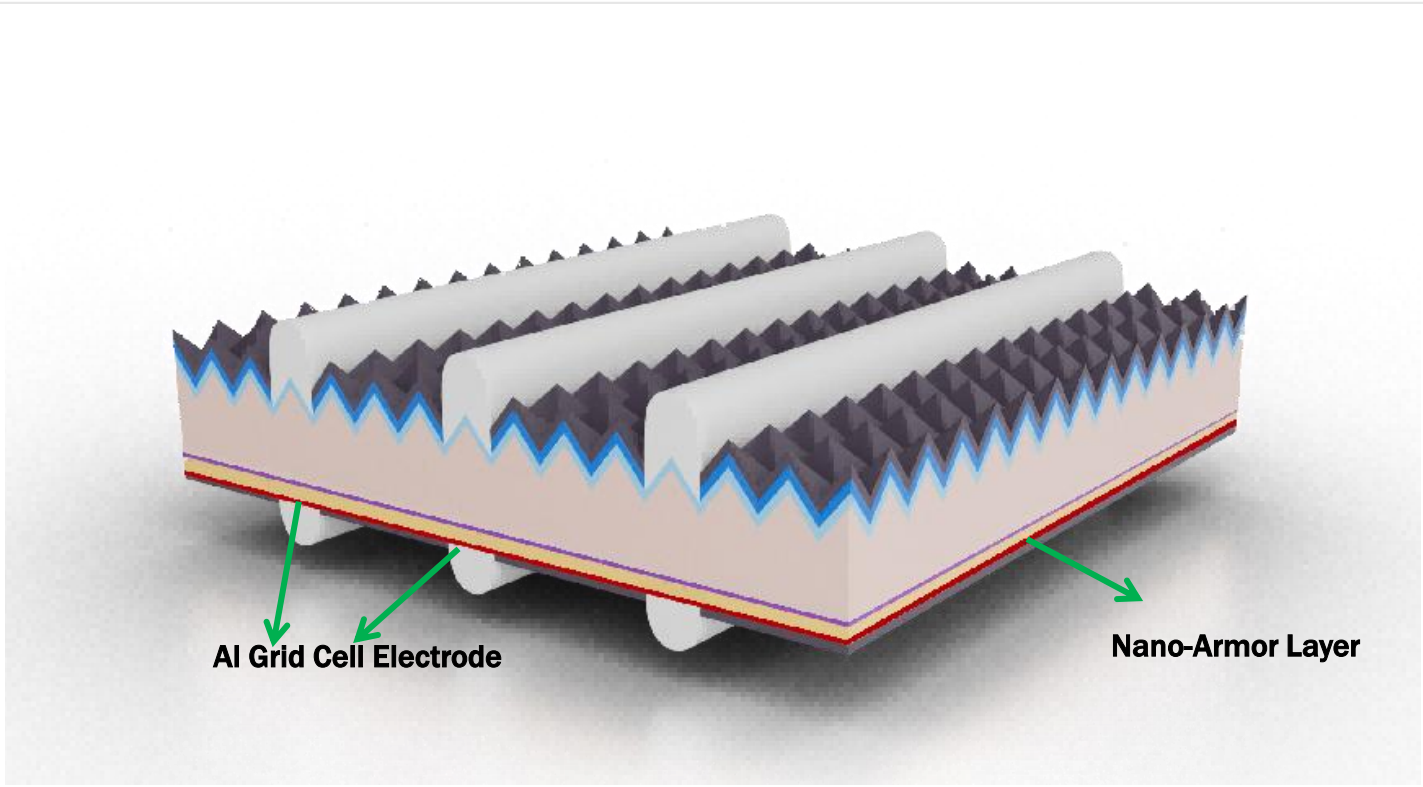
Original nanoscale film process enables high efficiency, high density, and high-durability film formation

Equipment Innovation

Self-designed special coating equipment enables efficient nanoscale film preparation

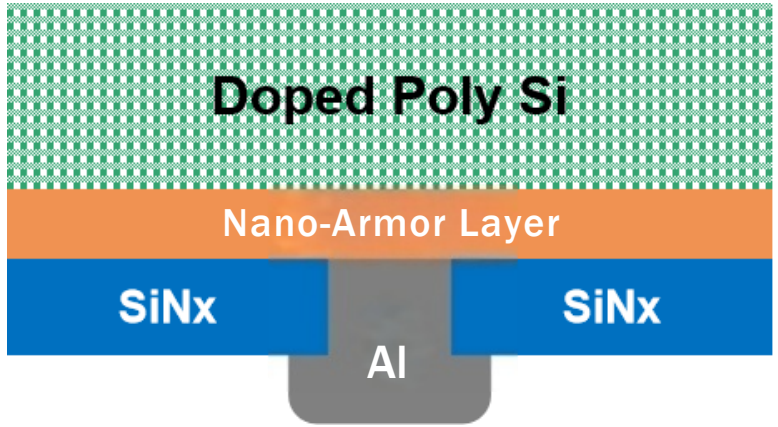
Cell Layer - Namic Cell Structure and Features

Floating grid-electrode contact: rear Al grid electrode + Nano-Armor protective layer interface design



Nano-Armor Layer - Floating Grid-Electrode Contact Structure

Excellent vertical conductivity	Supports grid current collection
Extremely low lateral conductivity	Reduces leakage and lateral crosstalk risk
Prevents Al diffusion into polysilicon	Controls aluminized interface reactions
High transmittance, low optical loss	Balances optical and electrical design
Compatible with traditional metallization schemes	Screen printing & high-temperature firing



Namic1.0

Rear Silver Solder Pads

Namic2.0

All-Aluminum Rear Side

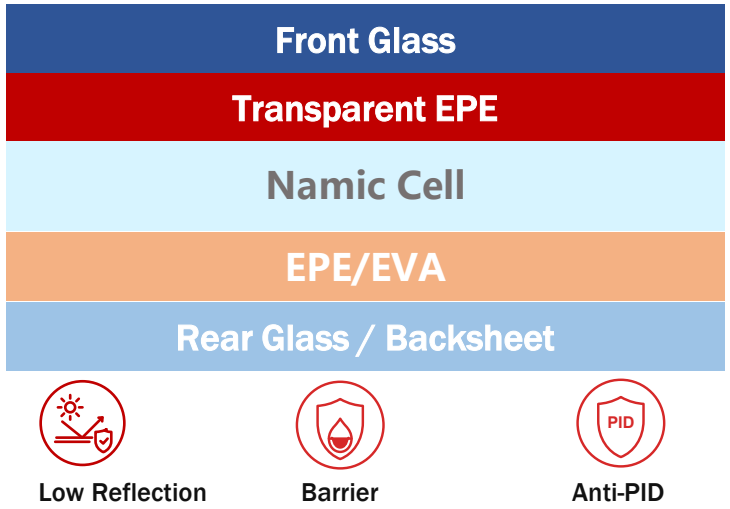
Namic3.0

All-Aluminum BC

Interconnection Layer - Encapsulation Material Matching

Film barrier and backsheet secondary reflection improve module adaptability

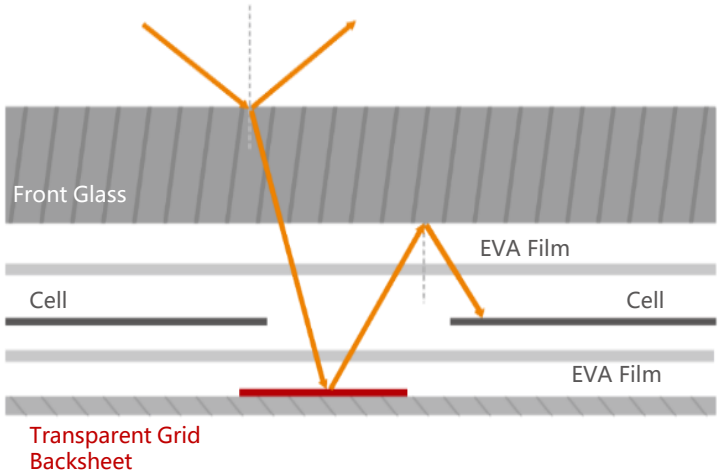
Transparent EPE Film: Balances Barrier and Optics



Transparent EPE balances light transmission, barrier properties and PID resistance

- Reduces interface refractive-index differences and visible-light reflection
- Improves moisture and ion barriers; strengthens anti-PID design

Transparent Grid Backsheet: Improves Rear-Side Light Utilization



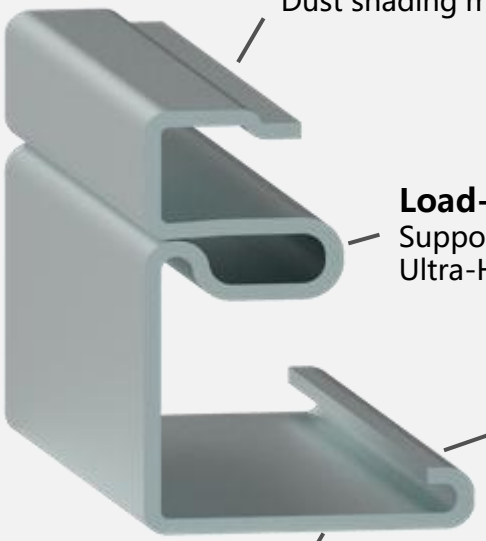
Backsheet grid creates secondary reflection to improve rear-side light utilization

- Grid structure improves light reuse in cell-gap areas
- Transmittance **>93%** for light incident from multiple angles
- Passed 500 kWh/m2 enhanced aging test, verifying weatherability

The interconnection layer adds value through encapsulation barrier performance and rear-side light utilization.

Module Layer - Dual-Beam Alloy Steel Frame

High Compatibility、High Strength、High Safety、Superior Corrosion Resistance、Ultra-Low Carbon



Lower Height of A Side
Silicon gel overflow prevention
Dust shading mitigation

Load-Bearing Beam
Supports PV Laminate with Ultra-High Load Performance

B Side
Combination of Rigidity and Flexibility

Reinforcing Beam
Enhances Structural Stability

C Side
High Tear Strength, high Bifaciality ratio by smaller shading area

1 Material — Zn-Mg-Al Alloy Coating + High Strength Steel Alloy

2 Structure — Double-Beam Structure: High Strength & Stability

3 Rebound — The elimination of 0T (180° bending) structures fully leverages alloy steel's spring-back characteristics, cushioning module stress to mitigate risks of cell microcracks and glass breakage.

4 High Compatibility

Dimensional Compatibility
Matches Module Aluminum Frame Profile Dimensions

Equipment Compatibility
No modifications required

Installation Compatibility
No changes needed

Steel Dual-tooth interlocking structure



Anti-detachment: Tensile > 800N

Anti-Galvanic Corrosion: Corner Brackets & Frame with Identical Material

Solution - Jolywood Namic Module

“4 Protections” for Extreme Reliability

Snowstorm | Hail | Hurricane | Burst Resistant



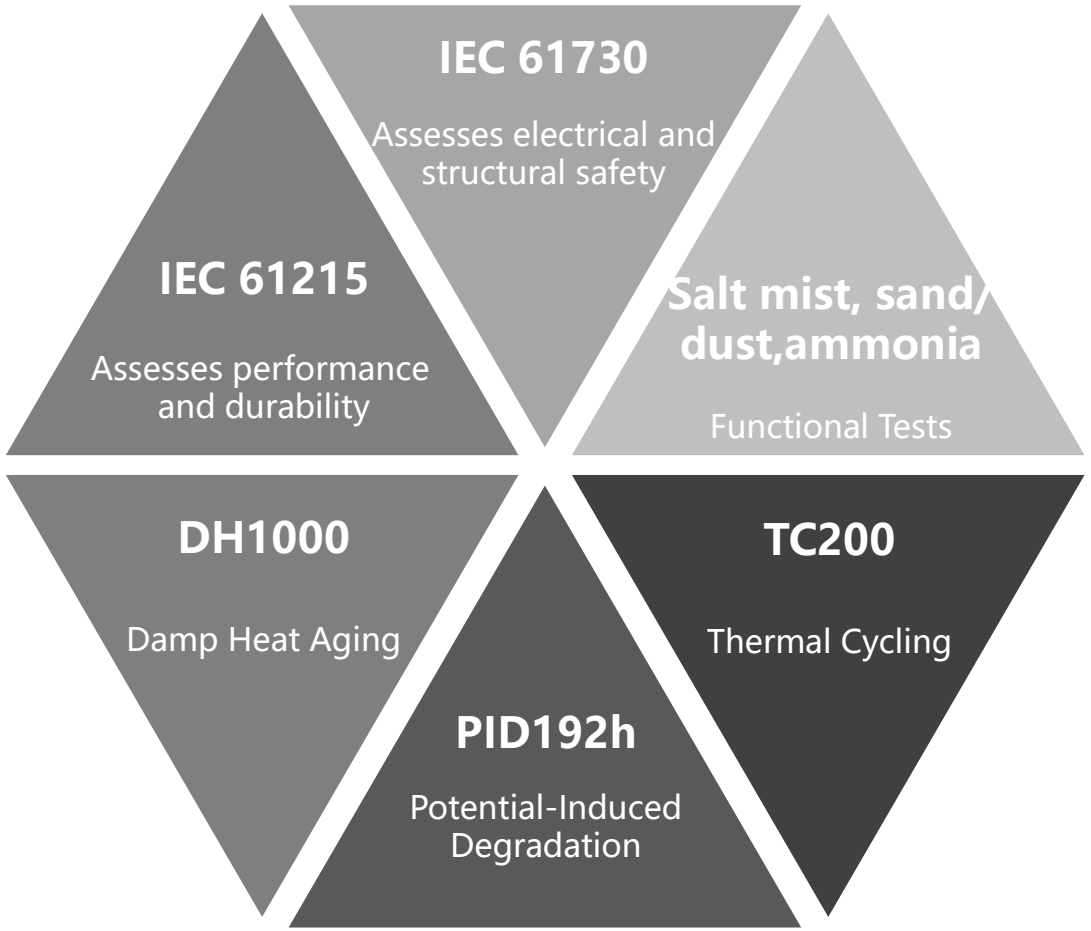
+8100 Pa/-3000 Pa
Static Mechanical Load Test

55mm
Hail Test

60m/s Wind
Tunnel Test
Withstands Level-17 Hurricane

±1000Pa 10000cycles
Dynamic Mechanical Load Test

Product Reliability Verification



Authoritative Certifications, International Standards

Basic and Functional Certifications


CERTIFICATE
No. Z2 098081 0020 Rev. 10

Holder of Certificate: Jolywood (Taizhou) Solar Technology Co., Ltd.

Certification Mark:

Product: Crystalline Silicon Terrestrial Photovoltaic (PV) Modules


TÜVNORD

Certificate

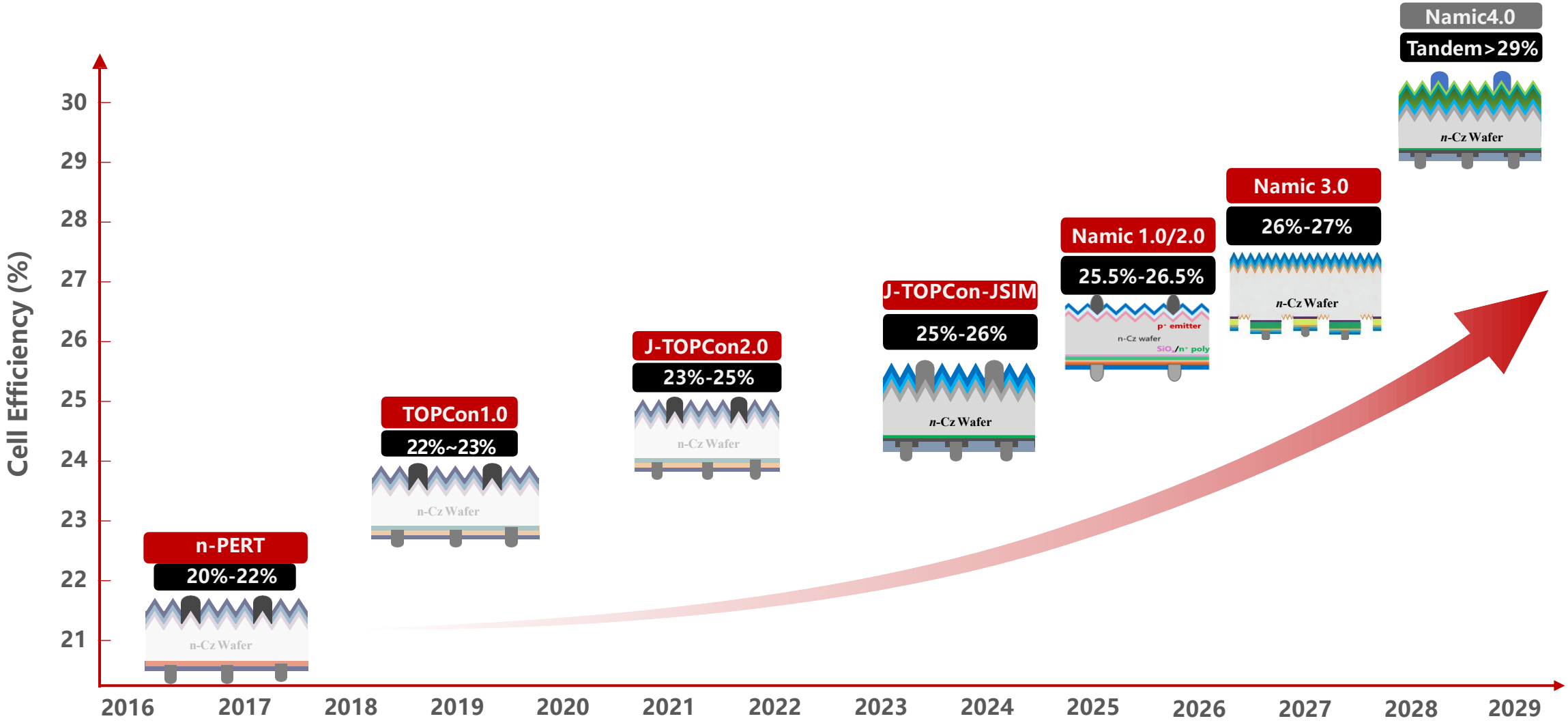
of Conformity

Jolywood (Taizhou) Solar Technology Co., Ltd.
Kaiyang Rd. Jiangyan Economic Development Zone
Taizhou City, Jiangsu Province, 225500
P.R. China


产品认证证书

地面用晶体硅光伏组件认证

Technology Advances, Never Stops



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