TAIYANGNEWS

ALL ABOUT SOLAR POWER

New Cell & Module Production Equipment and Materials 2025

Overview of New Cell & Module Production Equipment and Process Consumables Presented at Leading Solar Shows

Authors: Shravan K. Chunduri, Michael Schmela

COMPANY PROFILE

- LAPLACE Renewable Energy Technology Co., Ltd., established in May 2016, is a global leader in renewable energy innovation. Founded by a team of experts with extensive experience in solar cell research, development, and manufacturing, LAPLACE specializes in core components, advanced equipment, and solutions for the photovoltaic and semiconductor industries.

- The product portfolio of LAPLACE and its subsidiaries includes state-of-the-art thermal process technologies (diffusion, oxidation, annealing), LPCVD, PECVD, ALD, EPD and automation equipment. These solutions empower clients by setting world records for photovoltaic cell conversion efficiency—over 10 times to date. Harnessing expertise from both domestic and international markets, LAPLACE is dedicated to delivering cutting-edge process solutions that drive advancements across these critical technologies and equipment.

- With 6 R&D centers, 4 production facilities, and 3 customer service hubs, LAPLACE supports diverse technological pathways such as BC and TOPCon cell technologies. Its seamless delivery mechanisms, coupled with robust production experience and after-sales support, ensure outstanding customer satisfaction.

- Collaborating with leading research institutions and universities, LAPLACE fosters innovation to shape industry trends. The company has delivered projects with capacities exceeding 300 GW, including a single project of up to 30 GW. Guided by its mission to 'Enable renewable energy innovation for a sustainable future', LAPLACE is steadfast in advancing high-end equipment, core components, and composite materials. We are excited to utilize our top-tier innovative technologies to provide world-class renewable energy solutions to our partners worldwide.

LAPLACE Atomic Edge Passivation Deposition Complete solution

PATENT

1400+ PATENTS APPLICATION

800+ PATENTS GRANT

80+ INVENTION PATENT

600+ UTILITY MODEL PATENT

As of the first quarter of 2025

The company has obtained nearly **800+** patents

including approximately **80+** invention patents

over **600+** utility model patents

and more than **60+** design patents

LAPLACE RENEWABLE ENERGY TECHNOLOGY CO., LTD.

Executive Summary

With global solar markets facing intense pressure from overcapacity and falling prices, innovation has become a crucial strategy for companies seeking to remain competitive. This was clearly reflected at the industry's 2 biggest trade shows – The smarter E Europe in Munich and SNEC in Shanghai – where manufacturers introduced a broad range of advanced products spanning the entire solar value chain. Exhibits ranged from new cell architectures and refined module designs to state-of-the-art manufacturing tools, specialized materials, and digital-ready grid connection equipment. The overarching theme across both events was clear: higher performance, smarter integration, and technology-driven differentiation.

To capture these developments, TaiyangNews closely followed the showcases and announcements. Given the volume of innovations observed, we've structured our report into 3 distinct parts. The first edition, published in mid-September, focused on modules and mounting systems. This second edition shifts the spotlight to cell and module manufacturing equipment and materials, providing a snapshot of the tools and components enabling the next wave of solar production.

On the production equipment side, we have one company listed that represents the wafering area covering every stage from cropping full ingots, while the majority of the tools in our overview are for cell and module production. Production equipment is the key to deploying any cell technology. The solar expos represented products based on all mainstream and advanced cell technologies. While TOPCon is undoubtedly the clearly dominating status quo, several leading module makers have upgraded their TOPCon technology, called TOPCon+, which is discussed in the module part of the report. The key element of this upgraded TOPCon cell is establishing the poly fingers on the rear side. Laser tools for forming poly fingers on the cell's rear side are critical for these next-gen TOPCon designs.

The other advancements often included with this upgrade are edge passivation and stencil printing. An equipment maker included in this overview presented a range of processing tools, including lasers, LPCVD-based tunnel oxide and polysilicon deposition, boron diffusion, and edge passivation. The standard TOPCon technology, particularly based on PECVD, was also highlighted, with a focus on aspiring solar cell producers based outside China.

Today's production equipment segment is so robust that one can practically obtain every piece of production equipment for all known cell technologies – PERC, TOPCon, HJT, and perovskites from a single source. Not only that, but key equipment makers are also offering turnkey solutions. Wherever possible, the PV equipment supply wing is also keeping sustainability in view. Wet-bench suppliers have presented water and energy conservation, as well as reduced chemical usage. Measurement and inspection tools are also seeing refinement, helping manufacturers better control layer quality and optimize performance parameters. As the focus slowly shifts toward tandem architectures, new tools are emerging to support early-stage development – particularly around lab testing and characterization of perovskite-based tandem architectures.

On the module side, manufacturing is moving in step with these changes. Production lines are increasingly modular and automated, designed to accommodate a wide variety of interconnection formats. Tools that enable zero-busbar layouts, multi-busbar designs, or back-contact configurations are increasingly presented. In module testing, there is increased emphasis on LED-based IV characterization tools for tandem cell architectures, supporting lab-scale and full-size modules. Manufacturers are offering compact tool setups for on-site evaluation of PV modules. This part of the value chain also has a representation from a sustainability angle, with solutions now being introduced to handle end-of-life recycling of conventional crystalline modules.

Materials, too, are keeping pace with the changing demands of high-efficiency modules. While we have covered updates for pastes, the key material for solar cells in our recent market survey on cell production equipment and materials (see here), on the module side of things, the major emphasis was on the encapsulation materials fine-tuned to meet the specific needs of a wide variety of cell technologies, including TOPCon, BC, and HJT. The market is seeing more tailored film combinations for both glass-glass and glass-backsheet modules.

Enjoy reading our report on New Cell & Module Production Equipment and Materials 2025.

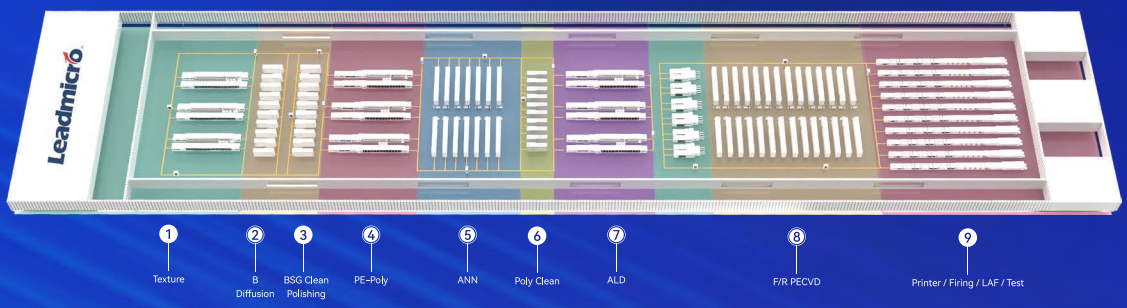
Shravan K. Chunduri
Head of Technology, TaiyangNews
shravan.chunduri@taiyangnews.info
+91 996 327 0005
Hyderabad, India

Michael Schmela
Managing Director, TaiyangNews
michael.schmela@taiyangnews.info
+49 173 15 70 999
Duesseldorf, Germany

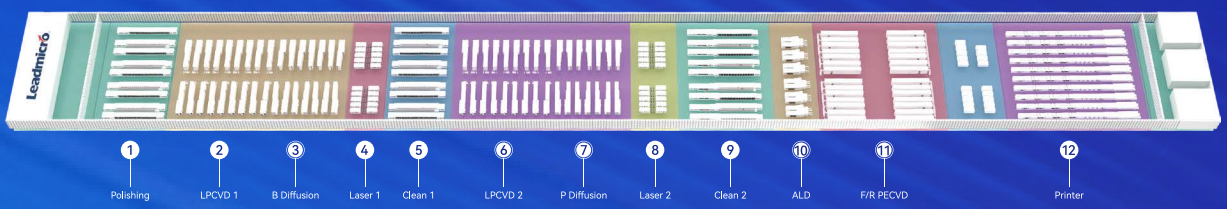
Global Leader in PV Cell Turnkey Solutions

Leadmicro™

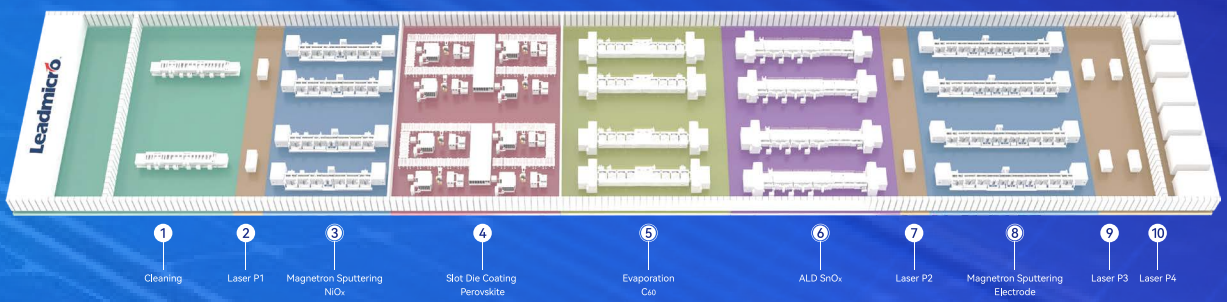
TOPCon 4.0
Turnkey Solutions



XBC
Turnkey Solutions



Perovskite
Turnkey Solutions



One Global Partner, All PV Solutions

State-of-the-Art Equipment & Technology

SMART AEP™ (ALD enabled Photovoltaics)

Tech Mastery | Efficient Delivery | Trusted Reliability | Global Support

Jiangsu Leadmicro Nano-Technology Co.,Ltd. www.leadmicro.com pvsale@leadmicro.com

Contents

01 Wafer & Cell Production Equipment

02 Module Production Equipment

Contents

03 Materials

TAIYANGNEWS
ALL ABOUT SOLAR POWER

New Cell & Module Production Equipment and Materials 2025

Overview of New Cell & Module Production Equipment and Process Consumables Presented at Leading Solar Shows

ISBN: 978-3-949046-34-6

Cover Photo Credit: Cover collage by TaiyangNews using images from sources (left to right followed by top to bottom: TaiyangNews; halm; Laplace; Maxwell; TaiyangNews; RENA; Shenzhen SC; Avalon; Confirmware; Ecoprogetti; Leadintelligent; TaiyangNews; TaiyangNews; TaiyangNews; TaiyangNews; SC-Solar; TaiyangNews; TaiyangNews; Cybrid; Betterial; TaiyangNews; Crown; TaiyangNews; TaiyangNews; TaiyangNews)

Authors:

Shravan K. Chunduri shravan.chunduri@taiyangnews.info

Michael Schmela michael.schmela@taiyangnews.info

For Media Contacts and Queries: info@taiyangnews.info

Publisher:

TaiyangNews UG (haftungsbeschraenkt)

An der Golzheimer Heide 23

40468 Duesseldorf, Germany

www.taiyangnews.info

Advertisers:

Disclaimer:

1. Wafer & Cell Production Equipment

Overview

The photovoltaic (PV) manufacturing landscape today is defined by the rapid commercialization of high-efficiency solar cell architectures – from TOPCon and heterojunction (HJT) to emerging tandem technologies. This progress would not have been possible without the vital contributions of **equipment manufacturers**. This chapter highlights the latest developments from key equipment vendors, as presented at major solar trade shows, and showcases how these tools are enabling both mainstream and next-generation cell technologies.

Gaoce Technology presented a complete suite of tools for processing crystalline silicon ingots into wafers – covering every stage from cropping full ingots, squaring, edge grinding, to final slicing using diamond wire. These machines support the upstream backbone of any high-efficiency solar cell production line.

LAPLACE presented a full equipment package designed to upgrade current TOPCon production lines. A highlight is the laser tool for forming poly fingers on the cell's rear side, which is critical for next-gen TOPCon designs. Complementing this are systems for LPCVD-based tunnel oxide and polysilicon deposition, boron diffusion, and edge passivation. **Shenzhen S.C**, besides promoting its comprehensive range of production equipment and turnkey solutions for all cell architectures, primarily emphasized PECVD-based TOPCon solutions. **RENA Technologies** showcased its wet chemical processing tools for solar cell manufacturing, highlighting water and energy conservation, as well as reduced chemical usage across its portfolio.

NXT promoted 3 characterization tools. One is designed to measure the total reflectance of the textured front side and the spatial angle reflectance of the wafer's rear side. Another is intended for characterizing a wide variety of dielectric and functional layers. The third is a TOPCon-specific tool to measure the thickness and optical constants of poly-Si layers.

As the industry increasingly evaluates tandem structures, equipment makers are enabling these evaluations by introducing characterization and processing tools. **HALM** unveiled an LED-based IV tester designed for laboratory characterization of perovskite-silicon tandem solar cells, supporting accurate efficiency measurement at the research scale. **Maxwell** is another player actively addressing tandem cell manufacturing, showcasing developments in perovskite-on-HJT tandem lines. In addition to presenting its equipment for HJT cell production, Maxwell also highlighted cost-reduction strategies for the technology through copper plating techniques.

Gaoce Details Ingot-to-Wafer Equipment at Intersolar Europe 2025

At Intersolar Europe 2025, Qingdao Gaoce Technology Co., Ltd., a China-based equipment supplier, discussed its latest developments in wafer slicing and ingot processing. Speaking to TaiyangNews, Gaoce's Jackson Liang outlined the company's core focus on equipment that bridges the gap between ingot and finished wafer, a part of the solar value chain that typically receives less attention.

Gaoce has developed a comprehensive set of tools for processing crystalline silicon ingots into wafers. These include machines for cropping full ingots, squaring ingot sections, edge grinding, and final wafer slicing using diamond wire. At its booth, the company also presented solutions for post-slicing processes such as wafer singulation, cleaning, and de-glueing. According to the company, its current wafer slicing platforms support a range of wafer sizes from M10 to G12 (182 mm to 210 mm), with thicknesses as low as 110 µm.

The company claims that its equipment is deployed in solutions worldwide, with 63 GW of installed wafer cutting capacity, and is expected to touch 104 GW soon. Gaoce's customer base spans multiple regions, with clients in India, Turkey, and the United States, including both dedicated wafer producers and vertically integrated PV manufacturers.

➡ Gaoce

LED-Based Lab IV Characterization Tools from halm

Perovskite-based tandem cell architecture is a hot topic in today's PV industry. While a few companies have managed to hit the piloting stage, the majority are still in the research phase. One segment of PV that is gaining attention is lab-scale IV characterization. In line with this trend, halm has also introduced an LED-based IV tester for lab applications.

For background, the trick with tandem cells is that they are designed to harness a specific part of the sunlight. For example, the perovskite tandem cell combines a wide-bandgap perovskite top cell with a narrower-bandgap silicon bottom cell. Since each sub-cell absorbs different parts of the spectrum,

Slicing Precision: Gaoce displayed its full suite of ingot-to-wafer processing tools at Intersolar Europe 2025, covering cropping, squaring, grinding, slicing, and post-cut cleaning solutions.

Tunable Light: LED light engines offer the flexibility to tune the light to a compatible wavelength to analyze the IV characteristics of a tandem PV device.

achieving accurate current matching is essential. This is where LEDs enjoy a monopoly. LED sun simulators utilize multiple independent LED channels, each emitting light at a specific wavelength. This enables unparalleled spectral tunability, offering flexibility to customize the light profile to simulate real-world conditions. This level of control also allows independent irradiance adjustment for each sub-cell. LEDs offer both balanced and deliberately mismatched conditions for in-depth analysis. Xenon-based systems can also be configured for such tasks, but not without employing complex filters.

As a result, a strong advocate and pioneer of xenon-based IV testers, HALM has also introduced an LED-based IV tester, called cetisPV-IUCT-LF3.1. As said above, it is a lab tester based on an LED light source with an A+A+A+ rating. The light source, which combines 28 wavelengths, supports an adjustable spectrum. It has a maximum illumination area of 240 x 240 mm. In addition to IV characterization, the tester is also designed to accomplish advanced hysteresis, SunsVoc, 2-diode analysis, doping concentration determination, MPP tracking, spectral response, and external quantum efficiency.

halm elektronik

Rear Poly-Finger & Edge Passivation Tools from LAPLACE

LAPLACE Renewable Energy Technology Co., Ltd. showcased its latest high-efficiency n-type cell production equipment and solutions. On top of its promotion list were the LPCVD, boron diffusion tool, laser equipment, and deposition systems for edge passivation.

Developed for TOPCon cells, LAPLACE Laser-Poly finger (Poly Thickness Reduction) equipment uses an ultrafast laser to open the back phosphorus silicate glass PSG, and then cooperates with a wet process to achieve the function of thinning polysilicon. This approach helps reduce the parasitic absorption of light by the back polysilicon and, in turn, improving efficiency . The company quantifies the benefit as a 0.15% absolute gain in module efficiency in mass production.

At the heart of this process is the laser tool. LAPLACE uses a large spot laser process solution, which superimposes high-speed and high-precision laser scanning systems, and high-precision CCD visual positioning systems. A single device solution supports the processing of 8,000 to 10,000 pieces

Source: Laplace

Process Advances: LAPLACE highlighted its laser-based poly-finger thinning and edge passivation tools developed for TOPCon solar cells at SNEC 2025.

per hour. LAPLACE says that the system has already been delivered to customers in batches and has been in stable mass production at multiple bases for nearly a year.

With its deep know-how in TOPCon equipment and technology, LAPLACE has also developed an edge passivation tool. The solution based on ALD technology applies aluminum oxide onto the edges cut with lasers when slicing fully processed cells into 2, but not limited to.

Laplace

Maxwell Presents HJT and Tandem Cell Manufacturing Technologies at SNEC 2025

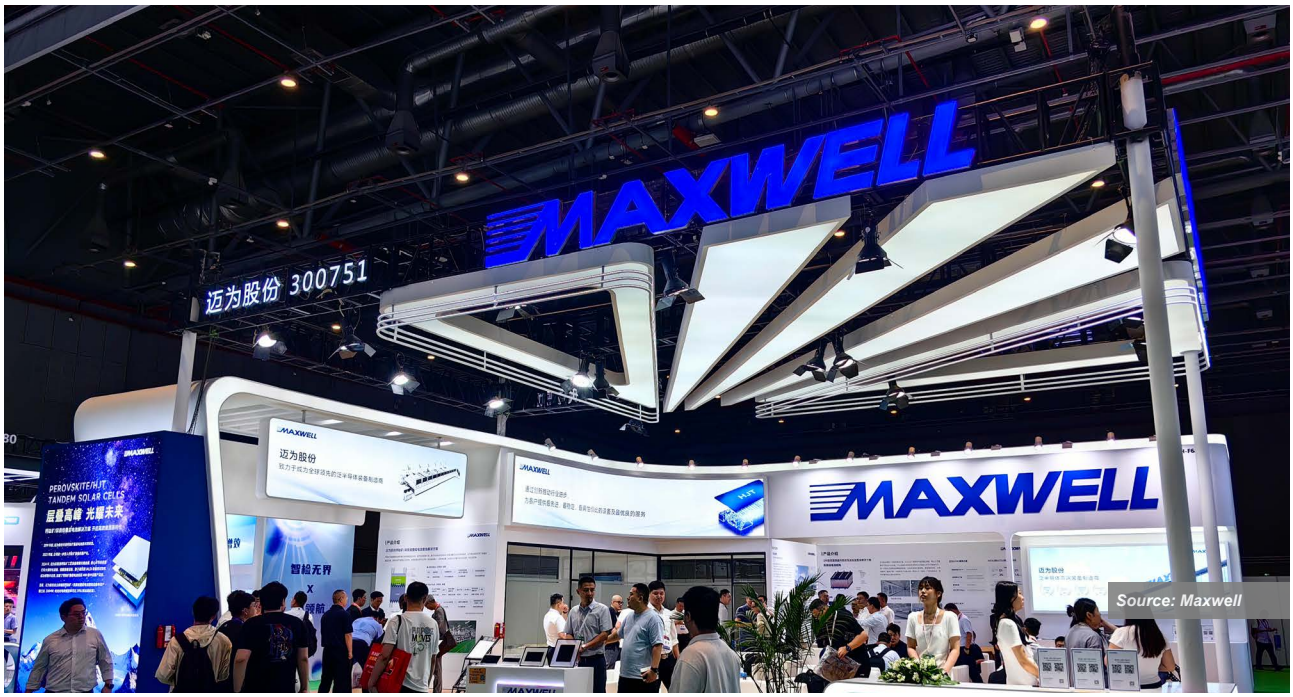
Maxwell, a manufacturer of solar cell production equipment, presented its ongoing work in HJT and tandem cell technologies during SNEC 2025. The company focused on its progress in perovskite-on-HJT tandem cell development, equipment for HJT cell production lines, and cost-reduction strategies through copper plating techniques.

According to Maxwell, it began research on perovskite-HJT tandem technology in 2019 and initiated equipment development for large-scale production in 2023. By 2024, the company claims to have developed lab-scale versions of inkjet printing systems, evaporation tools, and ALD machines for perovskite layers. These tools are now being scaled for pilot production lines with 100 MW capacity.

Maxwell reports that between 2024 and early 2025, its full-textured tandem cells achieved efficiencies between 31.50% as certified by Fraunhofer ISE in Germany and 34.02% as validated by the National Photovoltaic Industry Metrology and Testing Center (NPVM) in China.

In addition to tandem cells, Maxwell also showcased its development in metallization technology for HJT, particularly its direct copper plating process. The company states that this method eliminates the need for a seed layer, allowing direct deposition of copper onto the n-type side of the HJT cell. Maxwell claims this seedless process reduces metallization costs by more than 30% and improves efficiency by approximately 0.3%. The solution includes in-house tools for patterning and plating, which the company says deliver stable processes, high throughput, and good production yields, with readiness for scale-up. To support commercial adoption of both tandem and copper plating, the company says it has built a fully integrated production line for perovskite/HJT tandem cells with a reported annual capacity of 200 MW per line. Maxwell claims the system can achieve 29% efficiency and that all core tools and automation systems are developed in-house.

Maxwell



Tandem Progress: Maxwell presented its tandem solar cell and copper plating technologies at SNEC 2025, with pilot-scale equipment targeting 100 MW to 200 MW capacities.

NXT GmbH Displays Inline Quality Control Tools

NXT GmbH, a Germany-based characterization tool builder, specializes in high-precision spectrometric measurement systems for industrial and laboratory applications. The company has a 34-year history in optical metrology and offers both inline and offline measurement systems. These tools enable non-destructive analysis of thin film properties, such as layer thickness, refractive index, and reflectance/transmittance or both.

Specific to solar cell manufacturing, the company provides characterization solutions for critical process steps of production lines for all cell architectures – PERC, TOPCon, HJT, IBC, and tandem. Its Helios product family offers a wide range of systems for various stages of the cell production process. They are available in both inline and offline versions, where the offline systems are either manually operated for lab applications or can also be motorized for x-y mapping – a scan configuration. These tools are compatible with a range of materials, including dielectrics, semiconductors, and transparent conductive oxides (TCOs), on substrates such as glass, silicon wafers, and films.

The company has 3 major inline process control measurement tools – NXT Helios-rc, NXT Helios-tn, and NXT Helios-r8. The company promotes its NXT Helios-rc tool for measuring the total reflectance of the textured front side and the spatial angle reflectance of the rear side of the wafer. It supports a spectral acquisition speed of less than 100 ms. It can also measure the color and thickness of thin-film layers, such as anti-reflective coatings.

NXT Helios-tn is promoted for the characterization of functional layers, such as SiNx, AlOx, SiOx, SiOxNy, TCO, ITO, and AZO, used in different cell architectures. It is configured to measure layer thickness, optical constants (n&k), and the ellipsometric parameter (Psi) across single and multiple layers, such as the layers mentioned above. It also features the ability to measure 2-3 parameters simultaneously.

NXT has also developed a particular tool for TOPCon, called NXT Helios-r8. This tool is designed to measure the thickness and optical constants (n&k) of the Poly-Si layers deposited on top of a thin tunneling oxide layer in a TOPCon cell structure. Its 8-channel multi optics design enables it to remain stable and accurate even with fluctuations

CHINA S.C

Global Leading Solar Cell Turnkey Solutions Provider

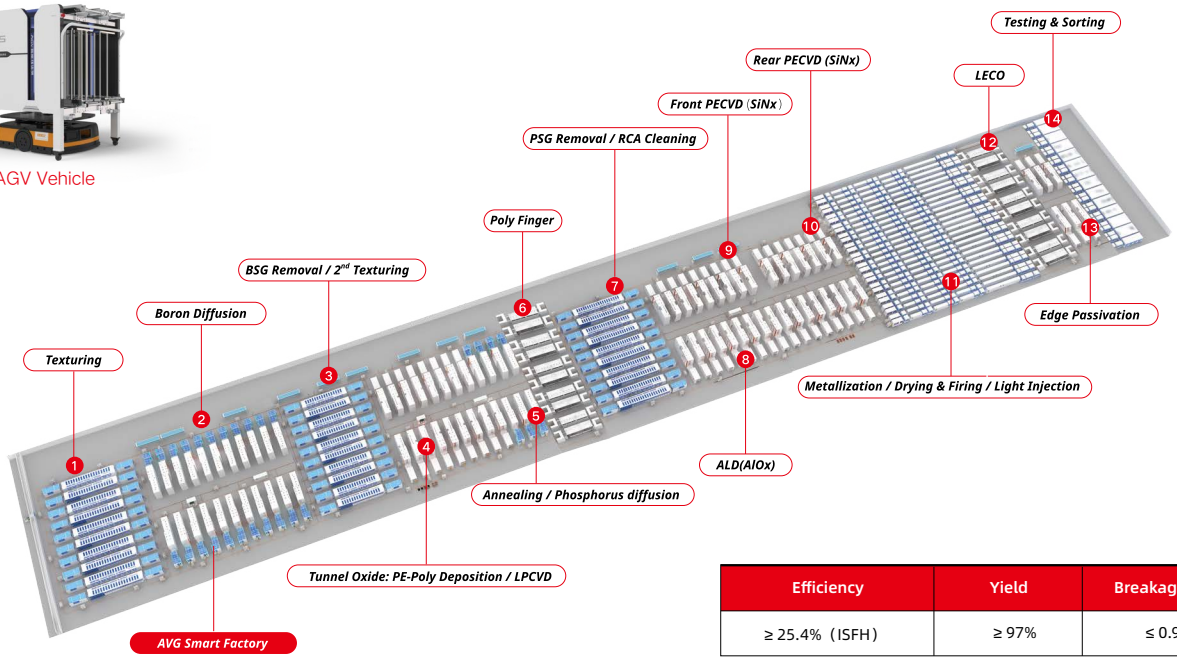
exact S·C 捷佳伟创

Solar Cell Turnkey Solutions

n-TOPCon Solar Cell Smart Production Line

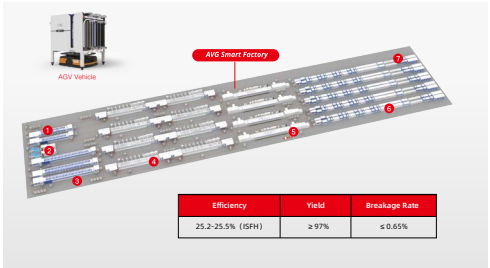
(PECVD/ LPCVD Technical Route)

AGV Vehicle



Efficiency	Yield	Breakage Rate
≥ 25.4%（ISFH）	≥ 97%	≤ 0.9%

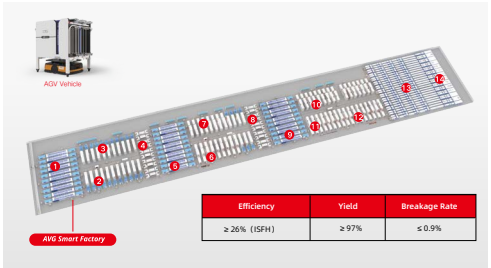
More Turnkey Solutions



Efficiency	Yield	Breakage Rate
25.2-25.5%（ISFH）	≥ 97%	≤ 0.65%

1. Pre-cleaning
2. Gettering
3. Texturing
4. Silicon -Based Film Deposition
5. TCO Film Deposition
6. Metallization
7. Testing & Sorting

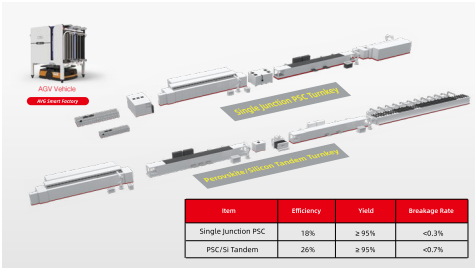
HJT Solar Cell Smart Production Line



Efficiency	Yield	Breakage Rate
≥ 26%（ISFH）	≥ 97%	≤ 0.9%

1. Polishing
2. LPCVD 1
3. Boron Diffusion
4. Laser 1
5. Polishing
6. LPCVD 2
7. Phosphorus Diffusion
8. Laser 2
9. Etching+Texturing
10. ALD
11. FS Passivation
12. BS Passivation
13. Metallization
14. Testing and Sorting

TBC Solar Cell Smart Production Line



Item	Efficiency	Yield	Breakage Rate
Single Junction PSC	18%	≥ 95%	<0.3%
PSC/Si Tandem	26%	≥ 95%	<0.7%

Single Junction PSC

1. FTO Cleaning
2. P1 Scribing
3. HTL Deposition
4. PVK Deposition
5. ETL Deposition
6. Buffer Layer Deposition
7. P2 Scribing
8. TCO Deposition
9. P3 Scribing
10. P4 Edge Deletion
11. Sealing & Test

PSC/Si Tandem

1. HJT/TOPcon
2. HTL Deposition
3. PVK Deposition
4. ETL Deposition
5. Buffer Layer Deposition
6. TCO Deposition
7. Ag Paste Screen-Printing
8. Sealing & Test

PSC Solar Cell Smart Production Line

Shenzhen S.C

Shenzhen S.C New Energy Technology Corporation
No.62 Jinniu East Road,Zhukeng Community,Longtian Street,
Pingshan District,Shenzhen,Guangdong Province,China
Tel:+86-(0)755-81449696 Fax:+86-(0)755-81449658
Http:// www.chinasc.com.cn E-mail:sales@chinasc.com.cn

Changzhou S.C

Changzhou S.C Exact Equipment Co .,Ltd.
No.790 Huanghe West Road, Xinbei District, Changzhou,
Jiangsu Province, China
Tel:+86-(0)519-81009988

Malaysia S.C

SC New Energy Malaysia Sdn.Bhd
10,Jalan N.i.p. 1/1,Taman Perindustrian
Nusajaya 1,79200 Iskandar Puteri,Johor,Malaysia.
Tel:+60 1130606990
E-mail:Admin_Mas@chinasc.com.cn

Tools for Key Film Characterization: NXT presented its latest Helios tool range for monitoring wafer texturing, thin-film coatings, and poly-Si layers in PV cell production at Intersolar Europe 2025.

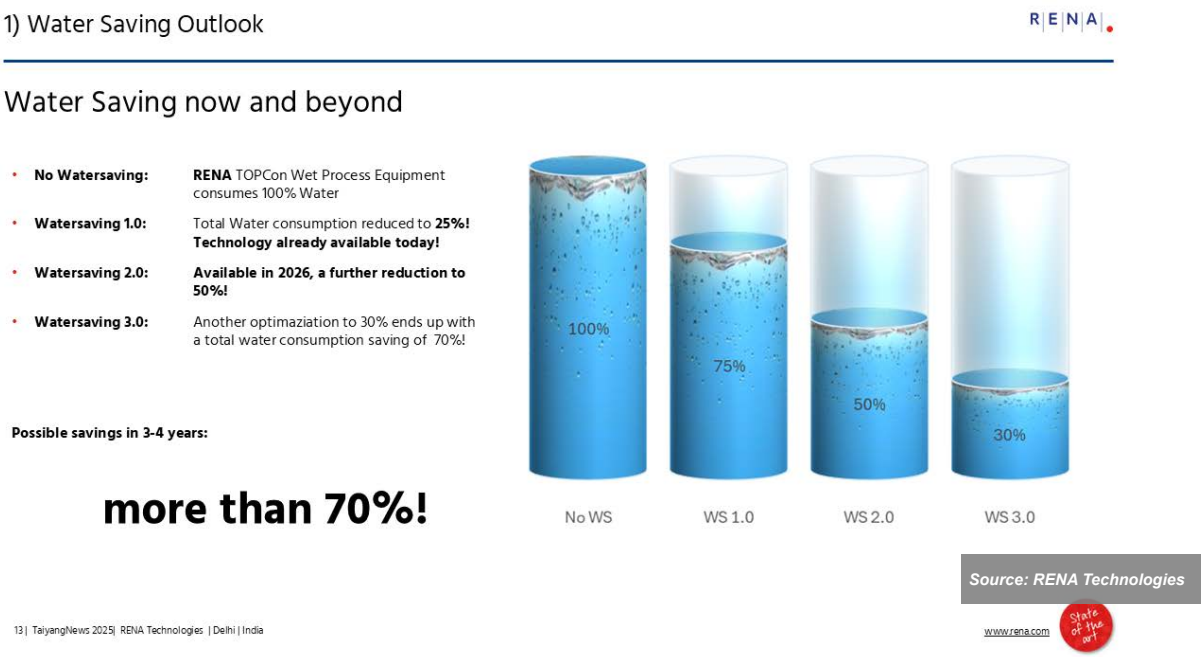
in wafer rotation, distance, or tilt. The company emphasizes that this is an important advantage over ellipsometers, adding that over 700 of these systems have already been installed worldwide.

NXT GmbH

RENA Highlights High-Throughput Wet Processing Tools at Intersolar Europe 2025

RENA Technologies showcased its wet chemical processing tools for solar cell manufacturing at Intersolar Europe 2025. The company highlighted water and energy conservation, as well as reduced chemical usage across its portfolio. The company supplies wet-chemical benches for all major crystalline silicon cell architectures, including PERC, TOPCon, HJT, and BC. The company offers batch solutions for wafer and cells, in addition to inline solutions for cell processing. Its solutions include tools for saw damage etching and texturing, dopant glass etching, edge isolation, polishing, and polysilicon wraparound removal.

For saw damage etching, RENA offers batch tools. The BatchTex 3 N600 platform supports a maximum throughput of 15,000 wafers per hour. In the context of TOPCon, the wet-chemical treatment in the post-diffusion stage can be realized in a cluster or inline fashion, with RENA offering both solutions. In the cluster configuration – each combining inline and batch tools – the company recommends 2 such clusters. These clusters are typically positioned before and after tunnel oxide and polysilicon deposition. Here, wafers first undergo single-side HF treatment to remove BSG at the edges and rear, a task handled by inline tools. Since BSG is typically thicker and harder to etch than PSG, RENA has adjusted both HF concentration and temperature to enable a compact tool design while maintaining high throughput. With the front-side BSG acting as a natural mask, the wafers can then move into a batch system using alkaline etching with additives to polish the rear or remove poly wraparound on the front. RENA's InEtchSide range is used as an inline component of the cluster solution, while its batch tool platform, used for SDE and texturing, can also be a part of the cluster. In addition, the company also offers purely inline solutions for glass and polysilicon etching through its InOxSide range.



Source: RENA Technologies

Less thirsty wet-processes: RENA has roadmap to reduce the water consumption by 70% in coming 3 to 4 years, as the company presented at TaiyangNews flagship event in December 2024.

The key point of optimization for the company these days is energy and water savings. The company estimates that over the next 3 to 4 years, total water consumption in wet chemical processing could be reduced by more than 70% through a phased implementation of water-saving measures. RENA presented the details of its water savings strategy at the TaiyangNews Solar Technology Conference. The first level, called Watersaving 1.0, reduces water usage to 25% of the baseline of current mainstream production. This technology is currently in use. Watersaving 2.0, the second stage, is planned for release in 2026, targeting a further reduction to 50%. A subsequent stage, Watersaving 3.0, aims to decrease usage to 30%, leading to an overall water saving of 70% compared to conventional systems.

RENA

Shenzhen S.C Highlights Complete Equipment Portfolio, Emphasizes PECVD In TOPCon

Shenzhen S.C is somewhat special in the equipment supply stream, offering cell production tools across virtually all solar cell architectures – from PERC to perovskites. In addition to supplying every major process tool required for these technologies, the company also provides turnkey solutions for PERC, TOPCon, HJT, and perovskites. At the recent solar exhibitions, Shenzhen S.C promoted its complete portfolio for the solar cell process chain alongside its turnkey offerings. While the company covers a wide range of cell technologies, its primary focus remains on TOPCon. This was also reflected in the presentation – Unlocking Optimization Potential in TOPCon – by Homer Chen, Associate Dean of the company's Research Institute at the TaiyangNews Cell and Module Production Equipment Conference.

Chen reported that Shenzhen S.C's cumulative shipments of TOPCon equipment have reached 575 GW, accounting for roughly 72% of the global market share. As is well known, TOPCon technology is divided into 2 streams – PECVD and LPCVD – depending on the core deposition process. While Shenzhen S.C offers tools for both approaches, the company recommends PECVD, citing shorter process times, higher throughput, and lower consumables costs as key advantages. The ability to support in-situ doping on the tool platform further simplifies processing, and the technology avoids damage to quartzware, reducing replacement costs and downtime. Overall, Chen noted that PECVD-

based processing cuts costs by 15-18% compared with LPCVD.

Beyond the TOPCon core processes, Shenzhen S.C also supplies equipment for texturing, PSG removal, boron diffusion, oxidation, annealing, ALD, SiNx/Al_2O_3 coating, metallization, LECO, and wraparound removal. Its smart production lines, ranging from 500 MW to 10 GW, are designed for mass production with high yields and low breakage rates.

Shenzhen S.C

Source: Shenzhen S.C

PECVD Preference: Shenzhen S.C showcased its end-to-end cell manufacturing solutions, highlighting PECVD as the preferred approach for TOPCon production.

2. Module Production Equipment

Overview

The pace of innovation has also increased in module manufacturing. Several technologies have been implemented that promise an improvement in the performance characteristics of a module, independent of the cell level. Module production equipment providers are developing integrated, high-throughput, and increasingly automated solutions. This chapter outlines notable equipment innovations showcased at recent solar trade fairs, reflecting the industry's continuing push toward more flexible, precise, and efficient module assembly and testing processes.

Mondragon Assembly presented a miniature model of its 1.5 GW turnkey PV module production line, illustrating the company's integrated manufacturing approach. The line includes up to 36 interconnected tools, covering key stages of module assembly with a focus on scalability and automation. **ConfirmWare** introduced its 3rd generation stringing platform, designed to support zero-busbar, xBC (back contact), and multi-busbar formats.

LEAD Intelligent Equipment showcased its complete suite of smart manufacturing solutions for PV module production. The company highlighted several platforms engineered for higher throughput, enhanced automation, and improved process reliability. **M10 Solar Equipment** presented updates to its interconnection platform based on the company's Shingle Matrix Technology. Module samples fabricated with this approach were also displayed.

SC Solar emphasized its expertise in module lamination by promoting its flagship multi-stack laminators. In addition to showcasing equipment, the company organized technical sessions at its booth, covering key topics such as perovskite integration, back-contact modules, lamination processes, and packaging innovations.

In the area of **module characterization**, Switzerland-based **Avalon ST** introduced 2 IV testing platforms based on LED light sources. One system supports one-shot IV characterization across a range of technologies, including PERC, HJT, TOPCon, perovskite, and tandem. The company also launched a portable module characterization tool for on-site testing.

WAVELABS, now part of **Eternal Sun**, exhibited 2 module testing platforms. One tool is designed for both wafer-based and thin-film PV technologies and includes multiple diagnostic features valuable for tandem module research. The second is a compact LED solar simulator tailored for full-size tandem module evaluation.

MBJ Solutions GmbH promoted a portable luminescence tester capable of conducting rapid, daylight-enabled fault diagnosis in operational PV installations. In parallel, the company also presented a lab-scale sun simulator that supports both continuous and flashlight operation.

On the sustainability front, **Ecoprogetti** unveiled its latest PV module recycling solution, specifically targeting crystalline silicon modules.

Avalon ST's LED-Based Advanced Module Characterization Tools

Switzerland-based Avalon ST, a leading supplier of LED-based module flashers, presented 2 of its latest IV testers – Nexun Pro Max and Nexun Mobile Lab – at Intersolar Europe 2025.

The Nexun Pro Max features an LED light source that spans a spectral range of ultraviolet (UV) to infrared (IR), allowing one-shot characterization of modules based on mainstream technologies such as PERC, HJT, TOPCon, as well as advanced architectures, including perovskite PV and tandem. The tool delivers long pulse durations ranging from 20 ms to 500 ms and supports irradiance levels from 100 W/m² to 1,300 W/m². According to the company, the system offers a repeatability of less than ±0.05% for maximum power (Pmax) measurements.

The Nexun Pro Max's LED source has a lifespan of over 30 million flashes. The company also offers a dual light-source configuration for bifacial module testing. Additional features include EQE and Dark IV measurements, with options for integrating electroluminescence (EL) imaging, a steady-

Source: Avalon ST

Any technology, no problem: The latest Nexun Pro Max module flasher is designed to evaluate the IV characteristics of modules of various cell architectures, such as HJT, TOPCon, perovskite, and more.

state light source for light soaking (relevant for perovskites), and a thermal chamber. Avalon has started taking orders for this tool.

Avalon also presented the Nexun Mobile Lab, a portable PV module characterization platform designed for on-site testing. The testing setup can be integrated into a van, container, or trailer, enabling module testing at installation sites, such as solar farms, or after events like hailstorms, offering laboratory-grade precision in field conditions. The system uses an LED-based light source with an irradiance range of 200 W/m² to 1,100 W/m², supporting pulse lengths of 50 ms to 200 ms, and P_{max} measurement repeatability of < ±0.05%. The LED array has a service life exceeding 30 million flashes.

Integrated functions include IV curve measurement, EL imaging with up to 150-megapixel resolution, bypass diode checks, HiPot testing, and grounding tests. It also features an automated uniformity measurement system that can map and adjust spatial light uniformity across the full illumination area in under 10 minutes, using 200 measurement points.

Avalon

A high throughput and modular stringer from Confirmware

ConfirmWare Technology, a leading supplier of module production equipment, has presented its third-generation stringing system platform for various cell technologies, including zero busbar, xBC and multi-busbar. The company has unveiled its high speed stringer called AZS120CA that supports multiple module designs and interconnection layouts. The tool supports a throughput of 12,000 pieces/hour, which the company characterizes as “world’s fastest Ultrahigh Speed MBB Cell Stringer.” This number not just represents the consistent pursuit of the company to improve the production capacity, but also represents several refinements of equipment details and a precise control over other key parameters of performance such as yield and reliability.

Confirmware also underscores several other important features of the tool, including modularity. The tool enables seamless switching between zero busbar and multi-busbar soldering. Equipped with the AI-powered Tunnel Lightbox Temperature Control V2.0 system, it achieves precise and uniform heating on the cell surface. It is also equipped with a high-precision ribbon handling system, floating steel plate

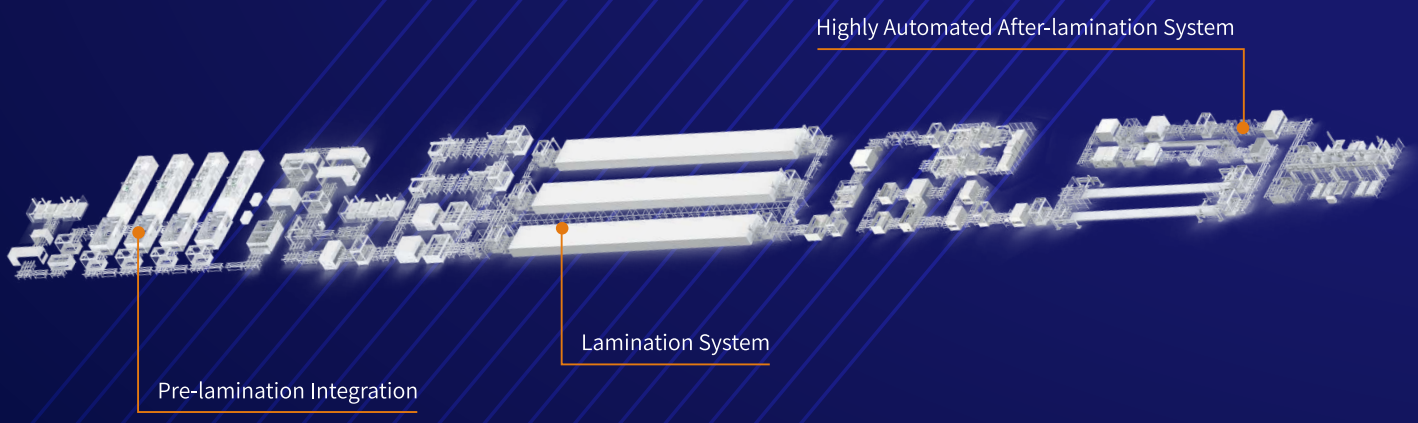
CONFIRMWARE

Leading PV Module Equipment Manufacturer

TOP Brand SMBB CELL STRINGER Launch !

1.2GW PV Module Automated Production Turnkey Solution

■Customized design ■High stability ■Highly automated ■Better ROI



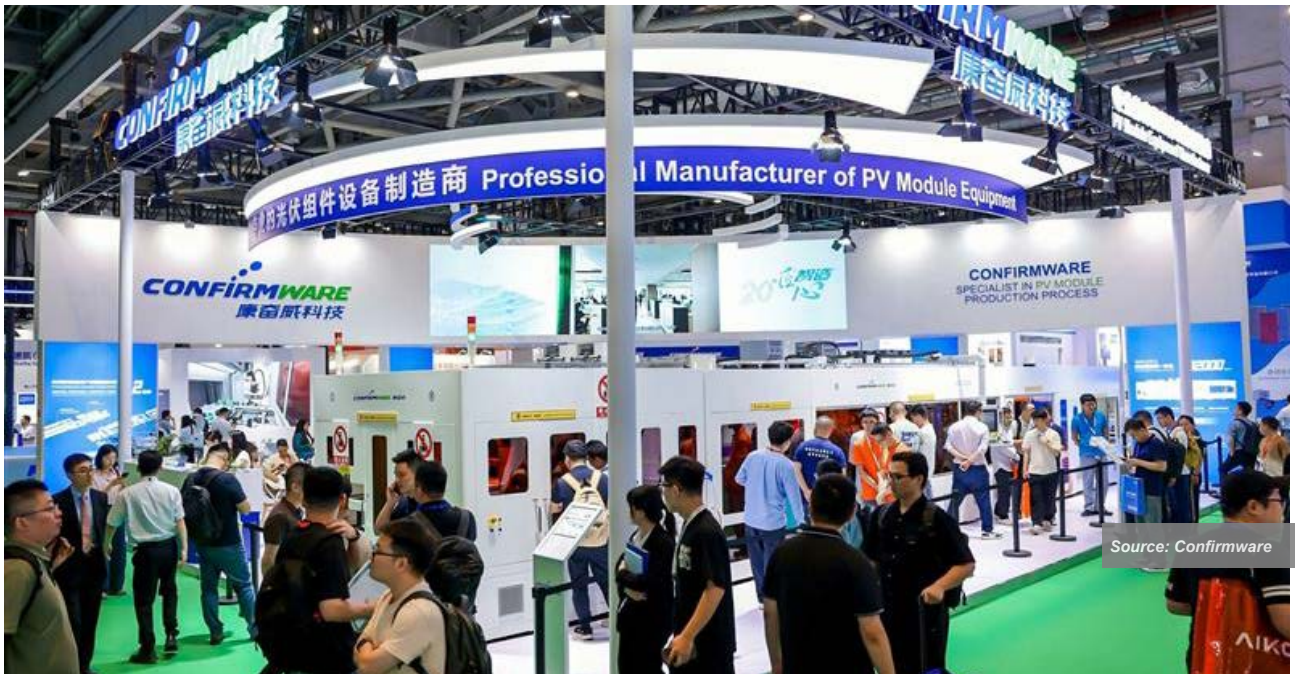
Compatible module size:
length 1630-2600(mm),
width 950-1450(mm)

Compatble cell types:
0BB、xBC、TOPCon、HJT、PERC，
156-230mm，5-24BB，1/2、1/3 cell

Compatible module:
Framed, Framed(no C side),Frameless
Regular, Double glass/Bifacial, BIPV etc.

Web: www.en.confirmware.com

Email: Marketing@confirmware.com



Modular Speed: ConfirmWare presents its latest ultra-fast and modular stringer for high-efficiency modules, featuring a 12,000 cph stringing platform at Intersolar Europe 2025.

dispensing platform and flexible transport system to realize stable equipment operation. The dual-track circulating buffer system, AI self-diagnostic data adjustment, and order-specific recipe system are all designed for user-friendly operation. The application of AI intelligence systems and machine vision significantly enhances process control, enabling real-time production data monitoring and automatic optimization of process parameters, emphasizes Confirmware. On top the solution is specifically designed to facilitate the rapid development of high-efficiency n-type cell technologies at the module level innovations like low-silver/no-silver soldering, back-contact soldering, and new backsheet/frame/junction box technologies. Through technological innovation, intelligent integration, and process upgrades, ConfirmWare promotes its latest intelligent total solution for high-efficiency module production.

ConfirmWare

Ecoprogetti Showcases PV Module Recycling Line

Ecoprogetti, a well-known Italian PV equipment maker, unveiled its HORIZON series PV module recycling line during Intersolar Europe 2025.

The company states that its new recycling line supports glass-backsheet or glass-glass configured monocrystalline or polycrystalline PV modules. However, it is not suitable for thin-film or concentrated PV technology.

Compatible with end-of-life PV module sizes (L × W) between 1,600 × 800 mm and 2,500 × 1,400 mm, this system starts with a junction box (JB) removal station. This tool is designed to remove both single and triple centralized split JBs. Subsequently, the glass-glass or glass-backsheet laminate goes through the frame removal stage to dismantle the frame. It combines an automated frame unloading station with a conveyor belt. Once the frame is removed, the module laminate is sent to the glass removal station. According to the company, this stage removes most of the front glass from the PV laminate. The laminate then continues through the treatment process, and the glass is redirected onto a discharge belt. During the treatment process, the laminate is crushed to segregate plastics from

Recycling: Ecoprogetti unveiled its HORIZON series PV module recycling line at Intersolar Europe 2025, designed to process up to 60 waste modules per hour.

embedded PV materials. The crushed materials are moved to a gravity screener via a spinning separation device that uses centrifugal force, called a cyclone. Once inside the screener, the materials get separated by their weight or density for subsequent discharge. The collection of different materials, such as silicon, dust, plastic, copper, and metals, is carried out by different pipes. According to Ecoprogetti, glass accounts for 73% of a standard glass-backsheet PV module's weight of 20 kg, plastic 12%, aluminum 10%, silicon 3%, and other metals 2%.

The HORIZON line, with a 500 m² footprint, can recycle up to 60 PV waste modules per hour, claims Ecoprogetti. In terms of recycled material volume, it reaches up to 1.5 tons per hour.

In addition to end-of-life, this line can recycle PV modules damaged due to certain conditions like hail, fire, glass breakage, delamination or metallization corrosion, and dirty, rusty, or worn-out modules.

Ecoprogetti

LEAD Presents Integrated PV Manufacturing Solutions

At SNEC 2025, LEAD Intelligent Equipment introduced its full range of smart manufacturing solutions for PV modules. The company showcased several equipment platforms with improved throughput, automation, and process reliability in the next-generation solar segment.

In the PV module segment, LEAD displayed its ZBB stringer solution, which achieves a throughput of up to 11,000 half-cells per hour using uniform glue printing with a precision of 0.02 mm. This system supports busbar-free module architectures and is designed for high-volume, low-maintenance operation. The XBC stringer system, built for back-contact cell technologies, includes a proprietary anti-warping welding mechanism to address deformation during single-sided welding. It operates at 6,800 half-cells per hour, maintains cell warpage below 2 mm, and reaches a mechanical yield of 99%.

LEAD also introduced a universal ultra-high-speed stringer featuring a linear motor-driven pick-and-place unit and non-stop feeding, capable of handling over 12,000 half-cells per hour.

For upstream solar cell manufacturing, LEAD

presented its perovskite production line. This system includes tools for plasma cleaning, annealing, vapor crystallization deposition (VCD), ALD, and magnetron sputtering. The company displayed lab-scale, pilot-scale, and production-scale coater systems, with the largest version supporting substrate sizes up to 1,200 × 2,400 mm. In addition, LEAD introduced its fully automated TOPCon 3.0 smart factory setup. This production line is designed for high-throughput TOPCon cell manufacturing, targeting cell efficiencies of up to 26.5%. The platform supports full automation of key process steps and material handling, enabling unmanned production lines.

LEAD

M10 Solar Showcases Shingled Matrix Interconnection Tool for Next-Gen PV Modules

M10 Solar Equipment GmbH, a European manufacturer of cell interconnection tools, presented its SURFACE interconnection platform and the corresponding module samples at Intersolar Europe 2025. During a booth visit, Philipp Zahn, Managing Director of M10 Solar, introduced a small-format PV module developed by Source Energy Company using SURFACE.

Shingled matrix technology offers an alternative to conventional PV module layouts. Instead of cell gaps, it arranges overlapping cell strips in a masonry-like pattern. These strips are bonded using an electrically conductive adhesive (ECA), which replaces traditional ribbon and flux materials. This layout shortens current paths and lowers resistive losses, helping to improve electrical performance.

These particular shingled modules also combine both series and parallel electrical connections. This structure limits the effect of partial shading to the shaded region, in contrast to conventional half-cut modules, where shading can reduce output across an entire substring. The ECA method is also lead-free, supporting environmentally responsible manufacturing. The technology supports custom-designed modules for advanced VIPV, BIPV, and aerospace applications.

M10 also displayed a space-grade module by Source Energy, based on the shingled matrix layout and assembled using the SURFACE tool. It delivers a power output of up to 15.6 W.

SURFACE Interconnection: M10 Solar displayed its SURFACE tool and a mini space-grade PV module at Intersolar Europe 2025, showcasing shingled matrix interconnection using ECA for advanced VIPV, BIPV, and aerospace applications.

The tool can process up to 12,000 cell strips per hour. It supports cell formats up to M12+ and is compatible with HJT, TOPCon, and tandem cell technologies. It supports interconnection for modules up to 2,300 × 1,300 mm in size.

M10 Solar

MBJ Presented Portable EL Inspection Tool for Daylight and Onsite Use

At Intersolar Europe 2025, German PV testing equipment manufacturer MBJ Solutions GmbH promoted its innovative portable luminescence tester – MBJ Quickcheck – designed for quick, daylight-enabled, on-site module diagnosis. Unlike conventional EL testers, Quickcheck can be used in fully operational PV plants during daylight hours for rapid fault diagnostics. This compact, portable, battery-powered EL inspection tool incorporates an imaging system with a 640 × 512-pixel camera. The camera is mounted on a telescopic rod adjustable between 106 cm and 300 cm. Live images can be viewed in real-time via smartphones or optional virtual reality (VR) glasses, allowing operators to capture sharp luminescence images even in bright daylight – hands-free, as the company explained. These images can be saved to the system's integrated computer and later downloaded via Wi-Fi.

The company highlighted that this tool does not require rewiring of the PV array or shutting down the inverter, another key differentiation over the typical EL characterization. It can be operated by a single person, with no need for a licensed electrician. Quickcheck is powered by a lithium-ion battery with an integrated charger. It can operate for 2 to 3 hours on a single charge, with the battery requiring up to 3 hours for full recharging. MBJ presented the details of the product at the TaiyangNews PV System Technology Trends Conference 2025.

In addition to its field tool, MBJ also gained recognition for its MBJ Sunlike Lab, which was named a finalist for The smarter E AWARD 2025 under the Photovoltaics category. This solar simulator with integrated EL functionality is engineered for lab testing of modules up to 1.4 × 2.5 m. Using 32 LEDs, it supports both continuous and flashlight operation. According to the company, this sun simulator

Daylight Diagnostics: The Quickcheck portable EL characterization tool from MBJ enables inspection in daylight and does not require any interference with operating modules.

achieves over 99.5% spectral coverage with less than 10% spectral deviation, allowing for highly accurate solar spectrum simulation – minimizing spectral mismatch in module testing.

MBJ Solutions

Mondragon Assembly's Turnkey PV Module Production Line

At Intersolar Europe 2025, Spain-based equipment supplier Mondragon Assembly showcased a miniature model of its 1.5 GW turnkey PV module production line, underlining the company's integrated approach to module manufacturing. While the company has mainly been promoting individual processing tools at tradeshows over the past couple of years, it turned its focus back to turnkey solutions at this year's Intersolar.

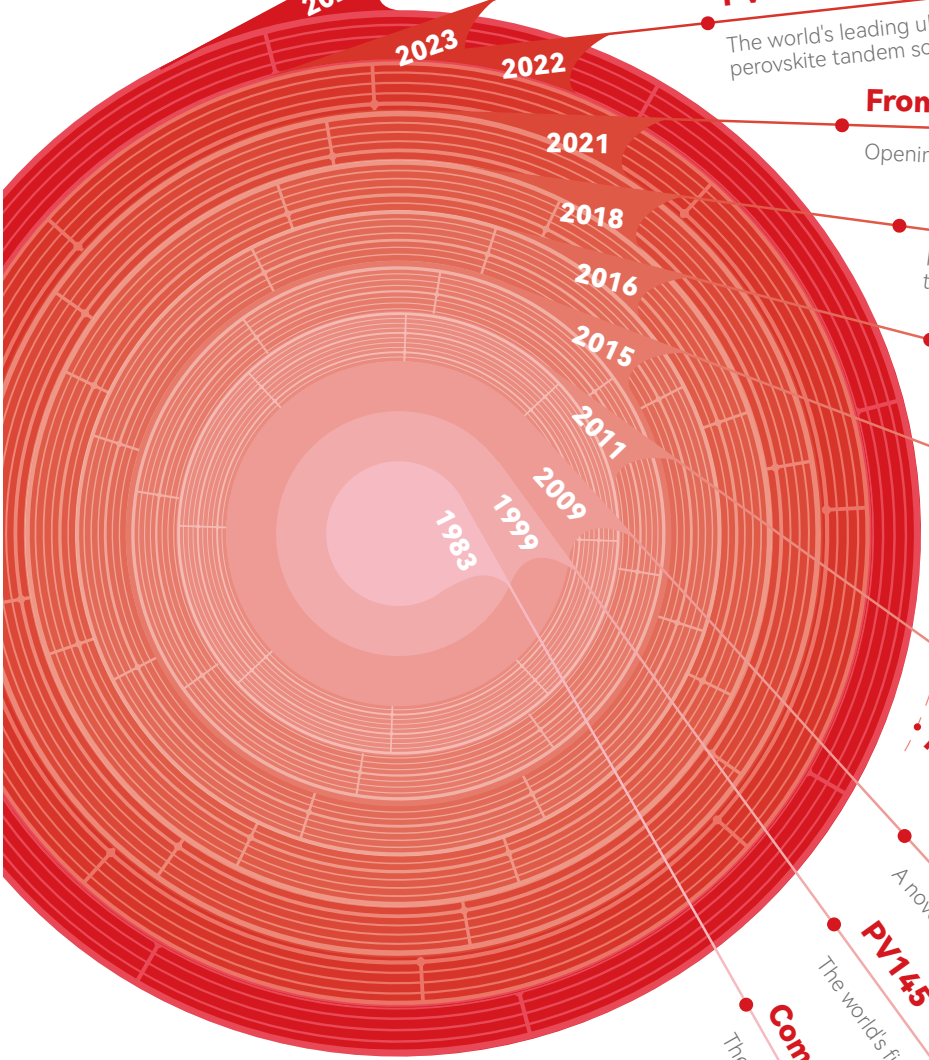
Speaking to TaiyangNews, Xabier Otaño, Head of Sales – Solar Business Unit at Mondragon Assembly, said that prioritizing which product to promote is simply a matter of strategy. While the company has continued to execute turnkey projects in the background, the promotional emphasis in the past few shows has been more on individual tools. Mondragon's turnkey line consists of up to 36 tools. It includes Cell Cutter, Glass Loading, Foil Cutting, Encapsulant Flattening and Ironing, MTS Stringer, String Lay-up, Auto-Bussing, String Taping, Barcode Placement, Punching, Second Glass Loading, Lead Bending, EL Testing, Glass–Glass Rework, Edge Taping, Tape Removal, Edge Trimming, Visual Inspection, Framing, Junction Box Station (bonding, placing, soldering, potting), Curing Line, Sun Simulator (EL + Hi-Pot), Labelling, and Module Sorting. The line also includes operator training and standard support services.

In addition to the turnkey setup, Mondragon Assembly is also working on new production solutions. Otaño noted several module types fabricated with in-house innovations, including flexible modules, organic PV modules, BIPV with varied cell gaps, and 3D-shaped modules on fiberglass using BC technology.

He also emphasized the company's focus on process optimization. This includes improvements in tabber and stringer operations, especially in interconnection technology. The goal is to improve maintainability

Turnkey Back in Focus: After emphasizing single tools at recent shows, Mondragon brought turnkey solutions back to the spotlight at Intersolar Europe 2025 with a miniature model of its 1.5 GW PV module production line.

SOLAMET® | 40+
METALLIZATION PASTES | YEARS



PV6NL TOPCon rear-side low solid content silver pastes continuously redefining the benchmark for cost and performance.

PV43A HJT low silver content silver-coated coppper pastes driving cost reduction and efficiency improvements.

PV3NL The world's first mass-production TOPCon laser carrier injection metallization paste.

PV43B The world's leading ultra-low-temperature paste specifically designed for perovskite tandem solar cells.

From DuPont Solamet® to Solamet® Opening a new chapter.

ACS Heroes of Chemistry Award Recognizing the contribution of the patented Pb-Te-O technology to the photovoltaic industry.

PV3Nx/PV6Nx/PVD2x The world's leading commercialized full package metallization solution of N-type.

PV76x/PV56x/PV36x The world's first commercialized full package metallization solution for PERC.

PV93x Novel one-paste metallization solution for IBC.

PV3N1 The world's first commercialized front side silver-aluminum paste for N-type solar cells.

PV36x/PV56x The world's first PV-specific aluminum paste/rear side silver paste.

PV17x Revolutionary silver paste based on the patented Pb-Te-O glass technology.

PV41x A novel low-temperature conductive silver paste.

PV145 The world's first commercialized fire-through conductive silver paste.

Come on stage The world's first photovoltaic conductive paste is introduced.

Bearing Innovation, Advancing Relentlessly

built from 200+ years of innovation DNA and 40+ years of metallization practice, today, Solamet® has the stronger innovation capability, the broadest IP and product portfolios, and professional global customer service capabilities in photovoltaic metallization area.

From n-type to perovskite tandem solar cells, we are making possibilities into realities.

and expand the process window across production stages, he added.

Mondragon Assembly also promoted the MEGAFab series, a dedicated product line aimed at customers requiring sub-GW production capacity. Already commercially available, MEGAFab is positioned as a solution for both new entrants and established players seeking compact but advanced lines.

This series is designed with a higher level of automation, full line monitoring, and data analysis. Otaño stated that it is also compatible with the latest cell technologies – TOPCon, HJT, and BC. Mondragon complements the equipment with a package of services, including technology and know-how transfer, business development assistance, technological advice, module design, raw material selection, and local service.

The company is focusing its commercialization efforts for MEGAFab on the Middle East, Africa, Europe, and the Americas. According to the company, each MEGAFab line is tailored to specific customer needs.

Mondragon Assembly

SC-Solar Showcases Advanced Process Solutions for Perovskites, BC, Lamination, and Module Packaging

At this year's SNEC, SC Solar, in addition to promoting its flagship multi-stack laminators, has also organized several technology sessions at its booth by highlighting the company's corresponding solutions. The company covered hot topics of the segment – perovskites, BC, module packaging and lamination technology.

SC Solar is indeed a leading supplier of automation equipment for solar module production and module laminators, especially in China. The company has been offering stacked laminators designed with multi chambers. When combined with intelligent control system, the solution effectively addresses traditional lamination challenges such as slow throughput, large footprint, high energy consumption, and higher maintenance, according to the company. Each chamber of the SC Solar's product can laminate 24 modules simultaneously, improving output efficiency per unit area—achieving higher capacity with less space and energy use, says the company. The product platform is equipped with

From Tandem and BC to Deep Down: SC-Solar, well- known for its stacked laminators, has presented its latest solutions for perovskite-s tandem and BC architectures, and packing and warehousing solutions for the final product.

precise temperature control, rapid vacuuming, liquid cooling, and intelligent material handling. It enables full-process data traceability and automatic recovery from anomalies.

Addressing the hottest topic of the industry, perovskites tandem technology, SC-Solar presented a comprehensive high-efficiency perovskite cell solution, covering core processes from vacuum coating, laser scribing, atomic layer deposition, to automatic encapsulation. A highlight was the self-developed evaporation + RPD solution for large-area functional layers. It supports multiple cell structures and enables continuous production of large-area modules

For module encapsulation, SC Solar showcased its automated perovskite module packaging technology. The modular front-end encapsulation system integrates multiple precise application steps—including conductive tape, butyl sealant, and busbars—and dual-glass lamination. It supports various structures such as single-junction, 2T, and 4T modules, offering fast cycle times and high precision. The system establishes a highly automated and standardized pre-encapsulation process for perovskite layers.

SC-Solar also presented its comprehensive wet cleaning solution for BC. The key focus areas include platform modularity, process automation, and intelligent data control. The company presented the applications of both inline and batch equipment platforms in BC manufacturing. The solution the company covers critical cleaning steps of BC processing such as wafer polishing, texturing, and PSG removal. On the technical side, the solution integrates spectrum monitoring, conductivity control, and scheduling systems to improve cleaning consistency and process stability.

In addition to packing the cell matrix to make module, SC-Solar also developed total solution for module packaging, smart warehousing, and automated loading. The solution accommodates various packaging processes, supports multiple module sizes and logistics needs, and is compatible with different production line layouts and shipping modes.

SC-Solar

WAVELABS Showcases Advanced Tandem Module Characterization Tools

WAVELABS Solar Metrology Systems GmbH, now part of Eternal Sun, exhibited 2 advanced PV module characterization systems – SINUS-1000 ADVANCED and SINUS-3000 ADVANCED – at Intersolar Europe 2025, with the former also displayed at SNEC weeks later. The tools are designed to meet the growing demand for precise metrology solutions in perovskite and perovskite-silicon tandem module R&D.

The SINUS-1000 ADVANCED mini-module tester is optimized for both wafer-based and thin-film PV technologies. It uses LED-based light sources with A+ class homogeneity, providing uniform irradiance over a 50 × 50 cm area. The tool integrates multiple diagnostic capabilities essential for tandem module research, including IV measurement, EQE (External Quantum Efficiency), electroluminescence (EL), and infrared (IR) imaging. It supports IEC 61853-1 standard testing and includes automated spectral calibration for individual sub-cells, enabling current mismatch tuning and MPP tracking for tandem configurations. A closed-loop system with an integrated spectrometer and an intensity sensor helps in attaining spectral stability. For sensitive devices, the system includes vacuum-based handling and thermal management.

The SINUS-3000 ADVANCED is a compact LED PV simulator specifically designed for full-size tandem modules. The device is developed to provide Class A+A+A+ spectral quality across a large test area of 2,500 × 1,500 mm. It adds that the system enables accurate IV characterization for multi-junction cells, with spectral non-uniformity under 1% and long-term light instability below 0.2% for sub-second flash durations. It also supports extended exposure durations that are useful for stabilizing slow-responding tandem sub-cells and integrates temperature-controlled measurement. In addition, it features dual-camera EL/PL imaging with replaceable filters and high parallelism LED architecture for minimal optical distortion. An R&D version with an expanded illumination area of 2,810 x 1,720 mm version is also available. The tool was labeled as “coming soon” at Intersolar, with no specific commercializationtimeline announced.

WAVELABS

An Eye on Tandem: At Intersolar Europe 2025, WAVELABS showcased several versions of its LED-based characterization tools, with special emphasis on the characterization of perovskite-based tandem PV substrates.

3. Materials

Overview

As solar modules adopt more advanced cell architectures and face increasingly diverse operating environments, materials used in their construction continue to evolve. Suppliers are introducing specialized encapsulants, backsheets, and packaging solutions tailored to meet the structural, electrical, and durability demands of high-efficiency modules. This chapter highlights material innovations showcased by key players across recent solar exhibitions.

HANGZHOU FIRST highlighted its latest encapsulation film combinations tailored for bifacial TOPCon solar modules. The company showcased 2 specialized film stacks – one for glass-glass modules and another for glass-backsheet configurations – both designed to enhance durability and PID resistance under high heat and humidity conditions.

Cybrid Technologies showcased its back contact (BC) module material portfolio at SNEC 2025. The display focused on encapsulant films, insulating tapes, and backsheet materials developed specifically for the structural and electrical requirements of BC modules. Betterial exhibited a range of encapsulation solutions aimed at addressing the reliability and performance needs of BC solar modules.

CROWN presented a variety of PV packaging materials, including films and backsheet solutions applicable to TOPCon, BC, and HJT module types. **CAPSSUN** showcased its encapsulation film range developed and manufactured in Türkiye. The portfolio includes EVA, POE, and EPE film types.

Jolywood exhibited a selection of PV encapsulation materials. The company's presentation featured backsheet variants, encapsulant films, and an integrated thin-glass encapsulation design compatible with advanced n-type modules.

HANGZHOU FIRST Debuts Encapsulant Stacks for LECO TOPCon Modules

At Intersolar Europe 2025, HANGZHOU FIRST highlighted its latest encapsulation film combinations tailored for bifacial TOPCon solar modules. The Chinese supplier showcased 2 specialized film stacks – one for glass-glass modules and another for glass-backsheet configurations – both aimed at improving durability and PID resistance, especially under high heat and humidity.

For the dual glass module format, HANGZHOU FIRST introduced S406(P), an EVA film designed for bifacial modules manufactured with LECO (laser-enhanced contact optimization) technology, especially those with low-aluminum or aluminum-free. S406(P) can be used as a dual-sided EVA or in combination with the company's EP304, an EPE (coextruded EVA/POE/EVA) based film for the rear layer. This stack has reportedly passed a stringent pressure cooker test at 121°C, 100% relative humidity(RH), and 0.2 MPa for 192 hours.

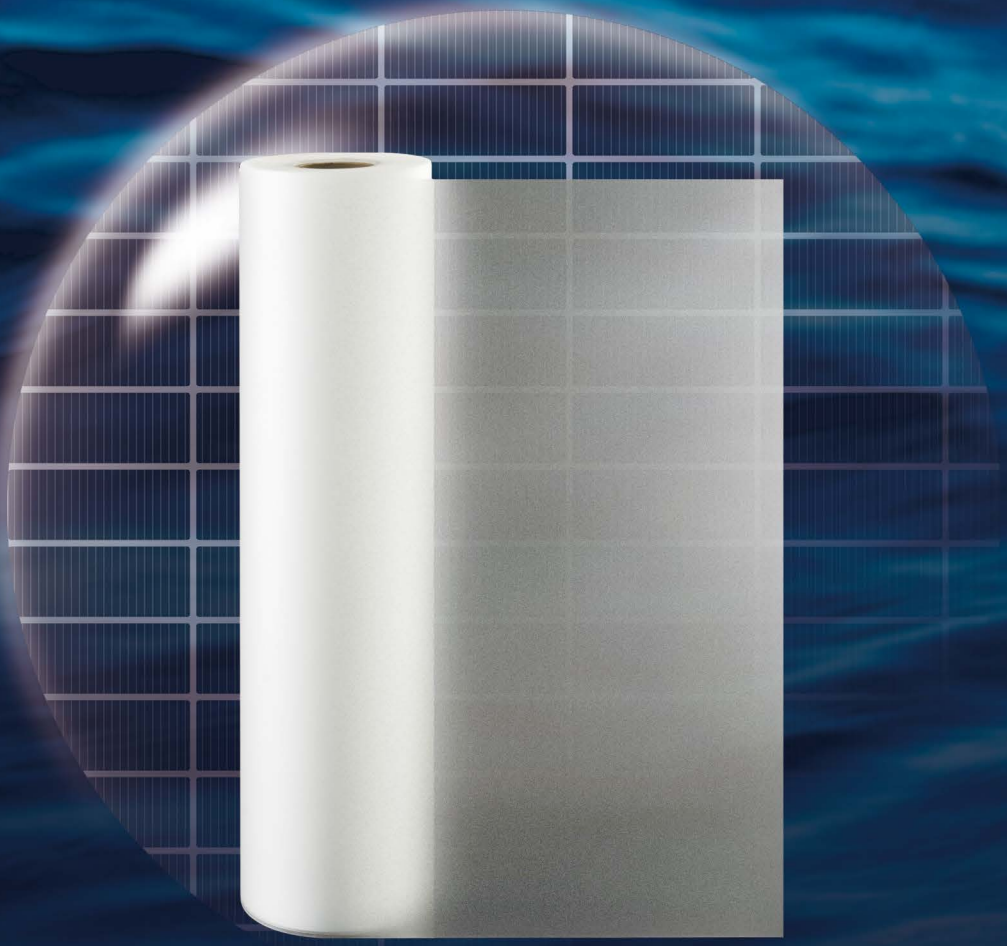
The EVA film incorporates EBISU, a patented acid-resistant EVA formulation from Kyocera now exclusively licensed to Hangzhou First. The company claims that this feature improves both cell protection and long-term module stability, particularly in humid climates.

The company also shared pote PID test results for a LECO-based TOPCon module using S406(P). After 3 cycles of 96 hours at 85°C, 85% RH, and –1,500 V DC, the module showed a power degradation of 0.6% compared to 9.09% observed in a comparable module using an unnamed competitor's EVA.

For glass-backsheet LECO modules, HANGZHOU FIRST exhibited a stack combining TF4(N) – a thermosetting polyolefin elastomer (POE) film – on the front side and F806W EVA film on the rear. In testing, this stack endured 92 hours of PCT and passed a 2,000-hour damp heat test at 85°C and 85% RH, with power degradation limited to 3.78%. A similar module with a competitor's POE + EVA stack showed 10.82% degradation under identical conditions.

FIRST

Encapsulant Solutions for High Efficient Cells & Modules



Anti Corrosion

EBISU Anti-Acid EVA, Special POE for Glass-Backsheet TOPCon Module

Anti UVID

UV Down Conversion Encapsulant, UVB Cut-off Encapsulant

High Efficiency

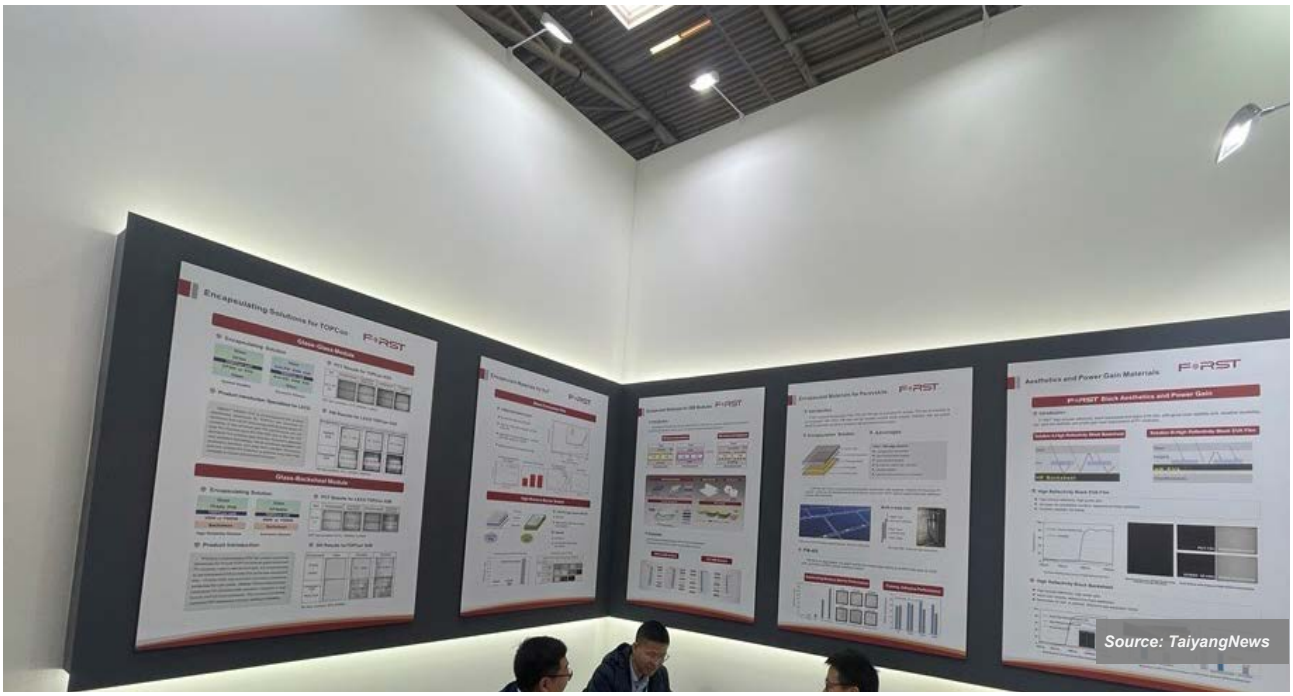
High Reflective Black EncapsuaInt, High Reflective White EncapsuaInt, Reflective Strip

High Barrier

PIB Tape and Glue, Al Backsheet, Al Tape

HANGZHOU FIRST APPLIED MATERIAL CO., LTD.

Tel:86-571-63812086 Email:sales@firstpvm.com



Material Innovation: HANGZHOU FIRST showcased its new encapsulant film stacks for bifacial LECO TOPCon modules, designed to improve PID resistance and durability.

The company positions these encapsulation stacks as optimized solutions for next-generation TOPCon modules, where LECO processing and bifacial design demand improved reliability, PID resistance, and compatibility with extreme climate conditions.

Hangzhou First

Cybrid's Polymer Solutions For BC Modules

Cybrid Technologies, a Chinese supplier of polymer-based PV materials, showcased its BC module material portfolio at SNEC 2025. The company's exhibit focused on encapsulant films, insulating tapes, and backsheet materials specifically developed for the structural and electrical demands of BC solar modules.

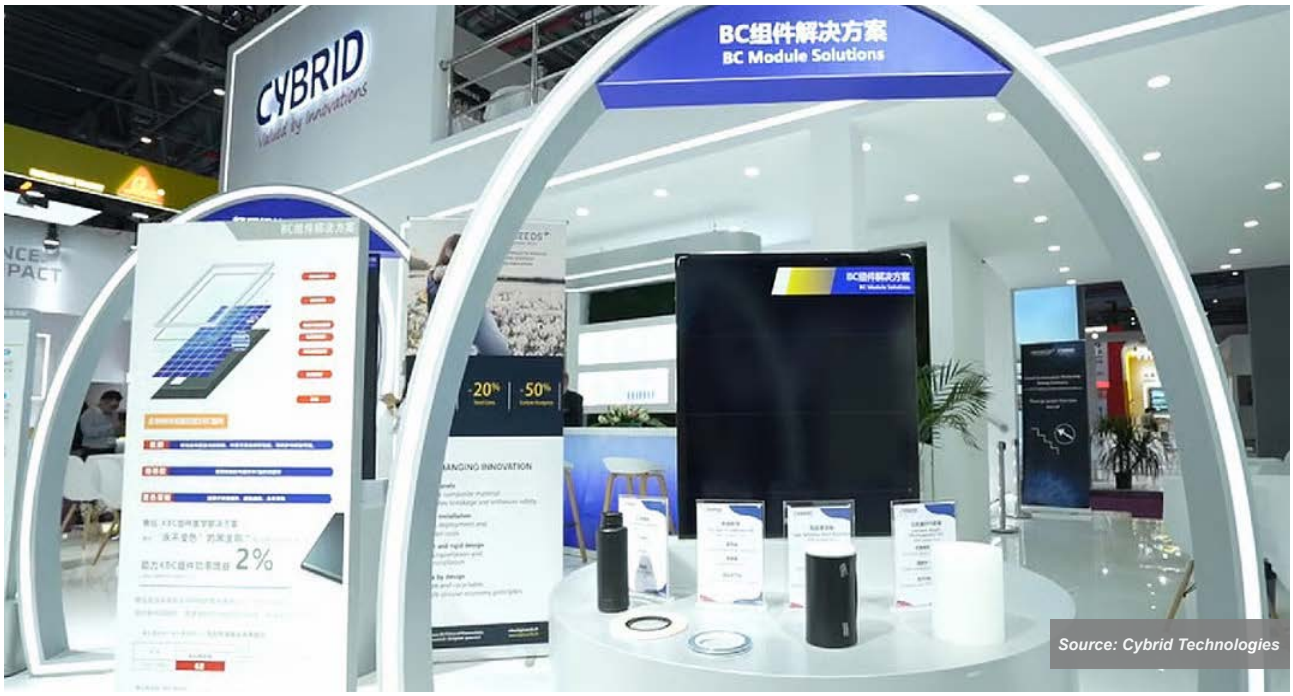
Cybrid's encapsulants are grouped into POE and EPE categories. For rear-side encapsulation, it offers the B11H black EVA film, which is black on the cell side and white on the outer side. Designed to enhance aesthetic appearance while offering reflectivity from the internal white layer, it is compatible with both single- and double-glass module formats.

The W11H encapsulant combines white EVA and POE in a coextruded structure. It is white on the outer side and transparent on the inner side, and is positioned for rear-side use in BC modules. The film is designed to reduce cell movement and bubble formation during lamination, a common issue in BC module processing, according to the company.

For front-side encapsulation, Cybrid promoted its T22H and T22 series POE films. These coextruded films are fully transparent and claimed to offer anti-PID properties due to their volume resistance characteristics. The T22 variant additionally incorporates UV filtering functionality.

Cybrid also exhibited its Cynagard 115G protective tapes, available in black and white variants. These tapes are designed to mitigate the risk of short-circuits arising from the close proximity of positive and negative ribbons in BC modules. The product structure includes layers of EVA, fluorinated film, and polyimide (PI) film. These tapes are compatible with both 1,000 V and 1,500 V system voltages.

Cybrid's PET-based backsheets for BC modules include the Cynagard 295D and Cynagard 275A series. The 295D is a dual-layer design with a fluorinated inner layer and an enhanced PET outer



Polymer Packs for BC: Cybrid Technologies presented its special polymer wraps, including encapsulants, tapes, and backsheets, specifically tailored for BC modules at SNEC 2025.

layer, designed for 1,500 V DC system voltage. It is available in black and white color schemes. The Cynagard 275A features a multilayer construction including fluorinated film, PET, barrier coatings, and adhesive layers. This design reportedly achieves a water vapor transmission rate (WVTR) of less than 0.5 g/m²/d. A fluorine-free version of this backsheet is also available.

Cybrid

Betterial Showcases Encapsulation Materials for BC Modules at SNEC 2025

At SNEC 2025, Jiangsu-based materials company Betterial showcased a range of encapsulation solutions designed to meet the reliability and performance needs of BC solar modules.

With both electrical contacts moved to the rear of the cell in BC designs, module reliability heavily depends on advanced rear-side protection and insulation. To address this, Betterial presented its BC Ultra-Barrier Film, developed to limit degradation effects such as hydrolysis and acid formation typically associated with EVA films in humid environments. The film features anti-hydrolysis technology and ion-trapping agents, designed to minimize risks such as PID and metallization corrosion. According to the company, the formulation is designed to reduce acid generation and extend module life in moisture-prone conditions.

For electrical insulation of the rear-side electrode layout, Betterial's subsidiary Westdon introduced 2 adhesives: a thermal-cure variant and a UV-cure variant. These are engineered to support the high-density electrode designs of BC cells by offering strong adhesion, resistance to damp heat, and color stability over time. The UV-cure version is designed to cure quickly under LED light, reducing reliance on photo-initiators and improving production speed.

To support front-side optical performance, Betterial also presented its Ultra-Transparent EVA/EPE encapsulation film. This film is designed to increase light transmittance across the standard solar spectrum and reduce reflection losses.

For applications requiring visual uniformity and higher energy recovery from internal reflection, the company introduced 2 types of highly reflective black encapsulation films. These films are designed with reflective fillers to redirect near-infrared light back toward the cell. The materials are targeted at

CYBRID

Valued by Innovations

RayBo film produced by Cybrid under license of Choushu Industry.

Patent No:JP2012211071

Cybrid Technologies' Innovative UV Light Conversion Raybo® Film

Enhancing Efficiency and Extending Lifespan for HJT/TOPCon Modules

High-Efficiency Protection with Superior Conversion Rates

Converts UV light into blue light to protect solar cells, achieving quantum conversion efficiency of over **95%**.

Long-Lasting Durability and Reliability

Encapsulation with the light conversion film ensures less than **1%** power attenuation under **180 kWh** of UV exposure over long-term outdoor use, meeting the **30-year** lifespan requirement.

Exceptional Performance, Boosting Power Output

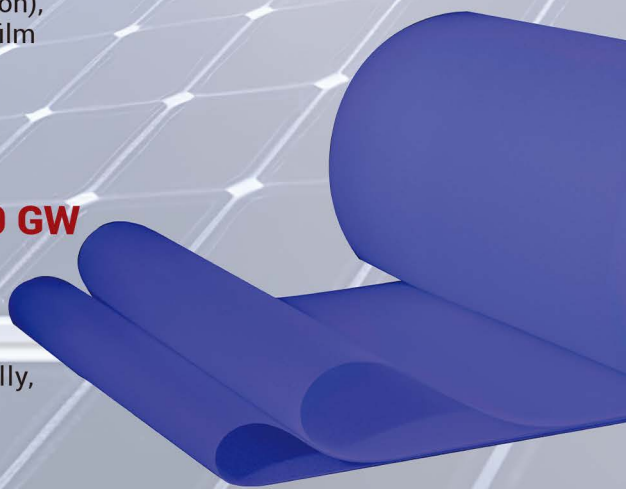
Power output of modules encapsulated with the light conversion film increases by 1% to 1.5% (compared to standard encapsulation), enhancing solar plant investment efficiency by 10%–17%. The film combines excellent adhesion and superior light transmittance.

International Certification and Market Recognition

Certified by TUV and UL, with a cumulative global shipment of **10 GW** to date.

Patented Technology

RayBo® Film has exclusive intellectual property rights globally, authorized by Supershield Industries.



Cybrid Technologies Inc.

Your Leading Provider of Comprehensive and Diverse High-Performance Polymer Material Solutions

Raybo®
UV Conversion Film

+86(0512)-82878808
www.cybrid.com.cn
info@cybrid.net.cn

aesthetic module designs and are offered in versions with 60% and 95% reflectivity.

Source: Betterial

Encapsulating Reliability: Betterial presented high-barrier films, adhesives, and reflective encapsulants designed to meet the reliability and performance demands of BC modules.

Betterial stated that these materials aim to support the increasing commercial demand for high-performance BC modules, particularly in environments where humidity, heat, and electrical stress could compromise long-term reliability.

Betterial

Encapsulation Films from CAPSSUN

At Intersolar Europe 2025, CAPSSUN Plastic Insulation and Chemical Industry Inc. showcased its range of encapsulation films developed and manufactured in Türkiye. The company's portfolio includes EVA, POE, and EPE types.

Speaking to TaiyangNews, CAPSSUN's Manufacturing Engineer, Kaan Talu, explained that EVA remains a widely used material due to its high light transmittance and strong adhesion between the glass and cell layers after crosslinking. To address the issue of acid formation, which can lead to long-term degradation, CAPSSUN has also developed an anti-acid EVA variant.

The company's POE film, based on a proprietary formulation, is designed to resist slippage during lamination and to minimize PID. Its low water vapor permeability helps reduce moisture ingress,

Intersolar EUROPE, Munich, Germany, May 2025

Source: TaiyangNews

Film Portfolio: CAPSSUN presented its EVA, POE, and EPE encapsulation film types, with features tailored to durability and PID resistance.

improving module durability, especially in humid climates, says Talu.

For a balanced approach between performance and cost, CAPSSUN also promoted its EPE film. This structure sandwiches a POE layer between 2 EVA layers. According to the company, this combination improves anti-PID performance while maintaining good adhesion to glass and cells.

CAPSSUN

CROWN Showcases Advanced PV Packaging Materials

At Intersolar Europe 2025, Mingguan New Material, also known internationally by its brand name, CROWN, exhibited a range of PV packaging materials. The company presented specialized films and backsheet solutions applicable to TOPCon, BC, and HJT module architectures.

For TOPCon modules, CROWN introduced a high-refractive-index encapsulation film aimed at improving light transmittance, resulting in a 2 to 3 W power gain per module. The company stated that the film was co-developed with overseas partners to meet the optical requirements of TOPCon structures.

A Matrix of Applications and Technologies: CROWN showcased packaging solutions for TOPCon, BC, HJT, and ZBB module technologies at Intersolar Europe 2025, including multiple variants of encapsulants, black backsheets, and foils.

In the BC segment, the company showcased a black high-reflectivity backsheet designed for residential rooftop installations. Additionally, a black high-adhesion encapsulant was introduced for double-glass BC modules to ensure consistent appearance and structural compatibility.

CROWN presented a trans-photo-luminal film – in other words, a down-conversion film – for HJT modules. It converts ultraviolet light (wavelengths below 380 nm) into visible blue light, aiming to reduce degradation of the transparent conductive oxide (TCO) layer and contribute to a 5 to 6 W increase in module output. The film is engineered to resist moisture and UV exposure.

The company also introduced packaging material for ZBB interconnection.

CROWN

Jolywood Presents Full-Stack Encapsulation Solutions

Jolywood, a PV manufacturer that has been a longtime proponent of n-type cell technologies, is also a leading backsheet supplier that has forayed into encapsulation materials. The polymer materials arm of the company exhibited a range of PV encapsulation materials at Intersolar Europe 2025. The company's display featured backsheet variants, encapsulant films, and an integrated thin-glass encapsulation design suitable for advanced n-type modules.

A key material showcased was the JW-EPE01 encapsulation film, an EPE with a thickness of 0.45 mm, light transmittance of ≥91%, a UV cutoff of ≤360 nm, and a gel content of ≥75%. The film is formulated for use in high-transparency applications such as bifacial and/or TOPCon modules.

In the backsheet category, the company presented a black PET backsheet designed for modules in rooftop and BIPV installations where visual uniformity is required. A composite backsheet was also introduced, consisting of fluoropolymer and PET layers to enhance barrier properties.

Additionally, Jolywood showcased a thin-glass encapsulation solution that integrates 1.8 mm tempered front glass, a transparent meshed backsheet, and a double-beam steel frame. This structure is designed for high mechanical stability under wind and snow loads. The breathable backsheet component helps expel internal acids that may form during module aging, thereby reducing the risk of busbar metallization corrosion. According to the company, this design is 17% to 20% lighter than standard double-glass modules, potentially lowering transportation costs and simplifying installation.

Jolywood

Backsheets to Polymers: Jolywood exhibited a range of PV packing polymer materials at Intersolar Europe 2025, including its encapsulation film, composite and black backsheets, and encapsulation solutions for thin-glass modules.

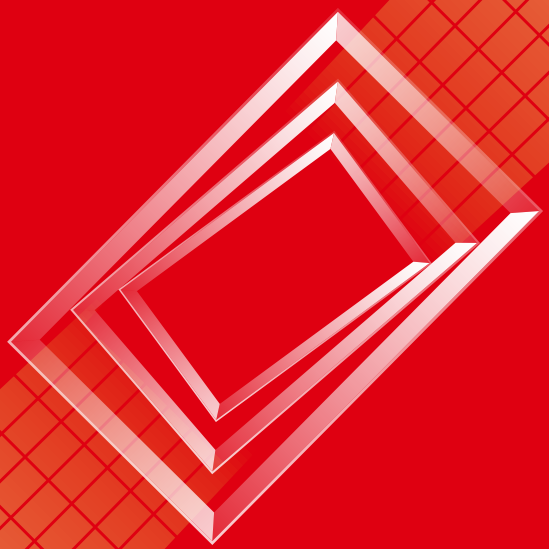
When Performance Matters

2010-2025

15 YEARS OF PASTE INNOVATION CHASING LIGHT INTO THE FUTURE

DKEM®
Innovative Photovoltaic Material Solutions

- TOPCon+ | HJT | xBC Metallization Paste Solutions
- Silver-Lean Metallization Paste Solutions
- Module Interconnection and Encapsulation Material Solutions



As a global leader in photovoltaic metallization pastes, over the past 15 years, DKEM® (300842.SZ) has pioneered the domestication wave of photovoltaic silver pastes in China and spearheaded the technology revolution from p-type to n-type solar cells. Consistently adhering to the collaborative innovation strategy of technology-driven and market-oriented, DKEM® is committed to advancing the development of photovoltaic technology through material science and technology innovation, empowering the industry to navigate cycles and reach for the boundless future.

EMPOWERING A BRIGHT NET-ZERO FUTURE

TAIYANGNEWS

ALL ABOUT SOLAR POWER

9 783949 046346