

30 TECHNOLOGY HIGHLIGHTS

3 AWARD WINNERS • 5 FINALISTS

pv magazine

PHOTOVOLTAIC MARKETS & TECHNOLOGY





TECHNOLOGY HIGHLIGHTS

Change is the only constant: An ancient adage, but particularly true of the evolutionary nature of our PV's revolutionary technology. The second edition of **pv magazine's** Technology Highlights feature includes 38 entries from PV production equipment, technology and materials companies spanning the wafer, cell and module supply chain and production processes. And high praise has be leveled at the leading entrants. "One key strength of the (solar) industry lies in the diversity of

engineering skills and creativity being brought to bear worldwide on improving each and every step both in cell and module manufacturing and in subsequent field deployment," said Professor Martin Green, from the renowned solar research group at the University of New South Wales. Green reviewed the leading entries, commenting that these innovations "are key to the improved performance and ongoing cost reductions expected from the PV industry over the coming decade." "These products provide a superb cross-section of recent progress," concluded Green. For the first time this year,

pv magazine assembled an international jury of PV experts to produce a ranking of the entries and select winners of the 2016 Technology Highlights awards. Eight finalists for the inaugural **pv magazine** Technology Highlights Award were selected from the entrants by the jury and their comments on each of the highly-ranked technologies have been included throughout the 20 page feature. Cell and module testing equipment and wafering tools and processes have emerged as outstanding entrants to Technology Highlights 2016. After review, deliberation and debate, the jury has selected the following awardees:



TECHNOLOGY HIGHLIGHTS 2016 AWARD WINNERS

Meyer Burger
DW288 Series 3 diamond wire solution
Eternal Sun
Climate Chamber Solar Simulator
"Technology to watch"
DSM Anti Soiling Coating
Runners up
1366 Technologies' Direct Wafer
BT Imaging LIS R3 inspection tool

The **pv magazine** editorial team would like to thank all participating companies for submitting entries, and the jury for sharing their time and expertise. Technology is our business, innovation abounds.

AWARD JURY



Xiaoting Wang,
Bloomberg New Energy Finance
Xiaoting Wang has been conducting research on the PV industry for Bloomberg New Energy Finance since 2012 and has published more than 100 insight notes. Her research scope covers global supply chain, including supply-demand relationship, cost and price variation, technology progress and the impacts of international trade disputes.



Finlay Colville,
Solar Media Ltd
Finlay Colville is head of market intelligence at Solar Media Ltd, where he leads the in-house research team. Until October 2014, he was Head of Solar at NPD Solarbuzz, in charge of the global analyst team. Dr. Colville is currently recognized as a leading market analyst covering the solar PV sector, with particular focus on PV manufacturing and technology.



Andrea Viaro,
Jinko Solar Europe
Andrea Viaro is responsible for the Technical Service activities at Jinko Solar Europe and has been working in the PV sector for the last seven years. He has a wide knowledge of PV technology, in particular regarding PV modules' quality and reliability, as well as PV site assessment and troubleshooting.



Arno Stassen,
Heraeus Group
Arno Stassen joined Heraeus as technologist in the Business Unit Photovoltaics in Singapore in 2011. After moving to the U.S. in 2014, he became the head of business development. He is currently located in Hanau, Germany where he is responsible for identification and development of new products and processes.



Andrew Blakers,
Australian National University
Professor Andrew Blakers is a Professor of Engineering at the Australian National University (ANU). His research interests are in the areas of photovoltaic and solar energy systems, silicon solar cell technology, concentrator solar cells, components and systems and sustainable energy policy.



Goetz Fischbeck,
Smart Solar Consulting
Goetz Fischbeck holds a degree in physics and in economics and has 16 years of experience in the financial industry. For many years he actively accompanied firms from the solar industry in his role as a PV market and technology specialist working for investment banks. In 2012 he founded the advisory firm "Smart Solar Consulting" which supports companies from the PV industry in their business strategy development and in topics related to financial markets such as M&A.



MEYER BURGER'S DW288 SERIES 3 DIAMOND WIRE SAW OPTIMIZING WIRE AS THIN AS A HUMAN HAIR

Meyer Burger's DW288 Series 3 diamond wire saw has been specifically designed for use with extremely thin wires to dramatically reduce wafering kerf. Diamond wire wafering for mono is rapidly becoming the default technology and multi is beginning to follow suit.

Meyer Burger's latest innovation with its diamond wire solution can see thinner wires used, for fast-paced wafering and with extended wire life up to 50%, due to preventing wire-to-wire contact.

A BNEF survey from 2015 revealed that all large monocrystalline ingot

manufacturers have begun adopting diamond wire in wafering processes. The lowest penetration of diamond wire of the companies surveyed used diamond wires for 20% of its wafering, although this will increase to 60% in 2016.

One multi wafer producer BNEF surveyed deployed diamond wire for 20% of its production in 2015, with that set to increase to 70% this year.

BNEF forecasts predict 25% of all wafering, in both mono and multi, will deploy diamond wire within the next three years.

Meyer Burger reports that it is currently testing wires with a 50 μm diameter, which could represent a huge step forward, considering that 120 μm wires are the standard today.

The special wire tensioning system deployed in the DW288 Series 3 rapidly

regulates any fluctuations in wire tension, even at the highest speeds and accelerations, deploying ultra light pulleys. The Swiss PV technology company says its new technology has almost doubled throughput, compared to conventional solutions. Additional output is made possible by a loading length that has been enlarged to 650 mm. The tool is also said to enable the unmatched wire speed of 30 m/s.

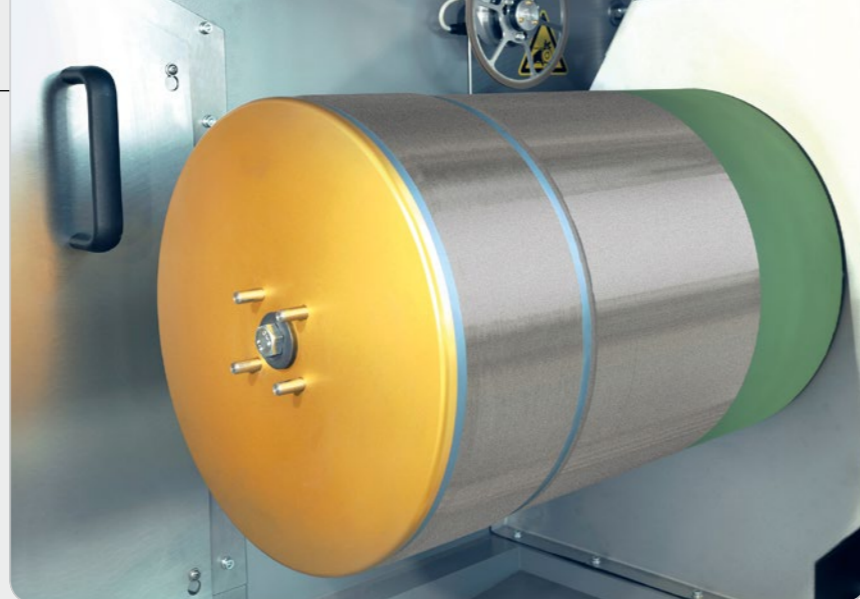
Optimized axis distance and a special high-speed cutting process ensure that the wire is less prone to bowing. This allows further speeding up of the cutting process. The Diamond Wire Management System (DWMS) installed in the tool eliminates any wire-to-wire contact and boosts the performance of the wire by more than 50%.

Jury comment

Improved handling of diamond wire allows for less wear and tear. Importantly, very thin wires coupled with highly uniform wafer thickness open the way to much reduced thickness, and hence lower silicon consumption per watt. There are also positive implications for cell performance. **Andrew Blakers**

This might not be a new concept, but the tool implements some new promising solutions, particularly, the way the wire is installed. This technology is likely to have a big impact on the market in the next five years. **Arno Stassen**

Manufacturers are always seeking to improve their efficiency; even 0.1% is a big achievement for us. Even if the technology itself has been on the market for a long time, a small improvement in it can be a breakthrough, if it helps to increase the efficiency. **Andrea Viaro**



ETERNAL SUN CLIMATE CHAMBER AND SOLAR SIMULATOR BRINGING TOGETHER TESTING STAGES FOR POWER PERFORMANCE DATA

Combining a climate chamber with a solar simulator, Holland's Eternal Sun allows for simultaneous environmental degradation testing with its stable solar simulator light source. Smart Solar Consulting's Götz Fischbeck says the combination represents a "very new and interesting technological concept."

The climate chamber can carry out I-V curve measurements of PV modules and cells under various heat, humidity and irradiance settings. The simulator enables extreme combinations of conditions such as 85%rH, 85°C and 1000 W/m² sunlight.

Eternal Sun's solar simulator enables light soaking, pre-conditioning and endurance tests in addition to I-V measurement. According to the developer, with the new climate chamber, performance testing and weathering can be carried out simultaneously, and electric parameters can be monitored in situ.

The technology is said to be able to run for 1,800 hours non-stop and perform 1,000-hour cycles of weathering with class AAA illumination.

Eternal Sun presents a new climate chamber solar stimulator, which it claims is perfectly suited for testing current and next generation solar cells and modules, including high efficiency crystalline, heterojunction cells, perovskites and other thin films. "With the equipment you will be able to get a better understanding of your PV technology's behavior in local and extreme conditions

with a wide range of relative humidity, temperatures and sunlight," the company says in a statement.

Jury comment

Previously, it has always been something separate: first, you test your modules with a flasher and get all your electronic data; afterwards you put them into a climate chamber for days or even weeks, then you take them out and flash them again. And now, with the innovation from Eternal Sun,

you can run the test and climate simulation simultaneously. **Götz Fischbeck**

This is definitely a very impressive solution, with a very high degree of innovation. However, it is always difficult to measure the impact of such laboratory tools on the actual manufacturing process. **Andrea Viaro**

It seems like a very promising technological solution that combines several technologies in one tool. **Arno Stassen**

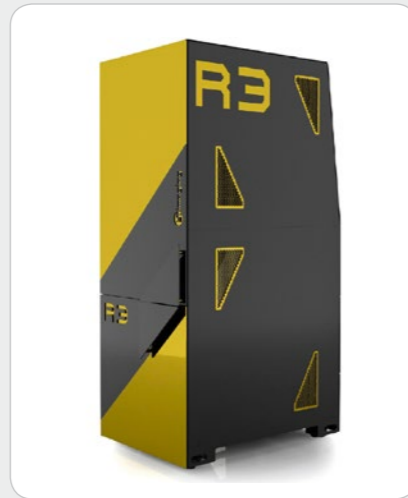


TECHNOLOGY HIGHLIGHTS RUNNER UP

1 BT IMAGING LIS-R3 – ‘SWISS ARMY KNIFE’ FOR PV LABS

At SNEC 2016, Australia's BT Imaging will be releasing its new LIS-R3, a third generation laboratory inspection tool for PV manufacturing and research. “Swiss Army Knife” for a PV lab – this is how the company describes its new product. It claims that most of its customers don't need other lab devices, once they start using LIS-R3.

BT Imaging's new technology can inspect all types of materials from silicon ingots, bricks, wafers, cells and even mini-modules. It offers a large number of inspection techniques. For example, the tool includes photo-



luminescence imaging, electroluminescence imaging, electrically-biased photoluminescence imaging, quasi-steady-state-photoconductance, injection dependent lifetime, calibrated lifetime imaging, series resistance imaging, IV testing, Suns- V_{OC} curves, Imaging for J_0 , R_s , V_{OC} , J_{mp} , and efficiency, front surface

and bulk photoluminescence defect analysis for cells, multicrystalline wafer defect algorithms and monocrystalline wafer defect algorithms.

BT Imaging reports that LIS-R3 has 34 granted patents, many of which protect specific functions of the tool as well as the basic concept of PL Imaging.

Jury comment

One of the most impressive and innovative technology concepts from the 2016 entrants. It can significantly speed up the testing process.

Andrea Viaro

BT Imaging is famous for its expertise on PL, and the new generation of tools can realize high-resolution spatial distribution of various parameters of solar cells and wafers. The innovation is impressive and is expected to better identify problems and improvement opportunities of PV products and manufacturing process.

Xiaoting Wang

2 1366 TECHNOLOGIES' DIRECT WAFER CUTTING SILICON WAFER COSTS IN HALF

U.S.-based 1366 Technologies is rolling out its Direct Wafer solution, where wafers are formed from molten silicon. The developer claims its process is the first and only kerfless wafer technology to make 156 mm standard thickness wafers.

1366 Technology says that its Direct Wafer solution needs only half of the silicon, one third of the energy, and half

of the capital to create a standard PV wafer. The innovation grows wafers one at a time, every 20 seconds, formed as a sheet on the surface of a melt “like ice on a lake.” When a wafer is removed and cut to size with a laser, any trimmings are recycled into the melt.

While making epitaxial wafers, either from gas or from molten silicon, is not a new concept, it appears that 1366 has overcome some key efficiency and throughput challenges, producing a wafer that can be used in standardized cell production.

1366 has been collaborating with Hanwha Q Cells, which is an investor

in 1366, on applying its Q.antum technology to 1366 Technologies' wafers. In November 2015, the two companies announced the achievement of 19.1% 1366/Q.antum cell efficiency. Taking a further step, Hanwha Q Cells has signed a deal to source 700 MW of wafers from 1366, in a five year deal.

The possibility to produce wafers directly from the silicon melt reduces the number of production steps from four to one, eliminating ingot cropping, squaring and blocking, as well as sawing – the most wasteful, highest-cost step in wafer production.

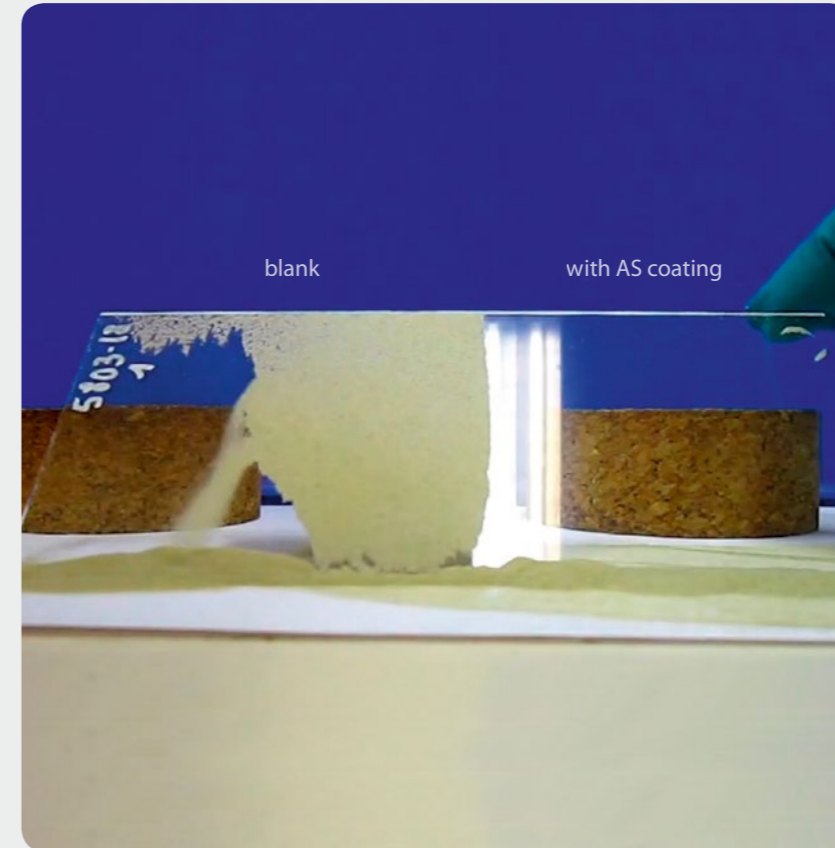
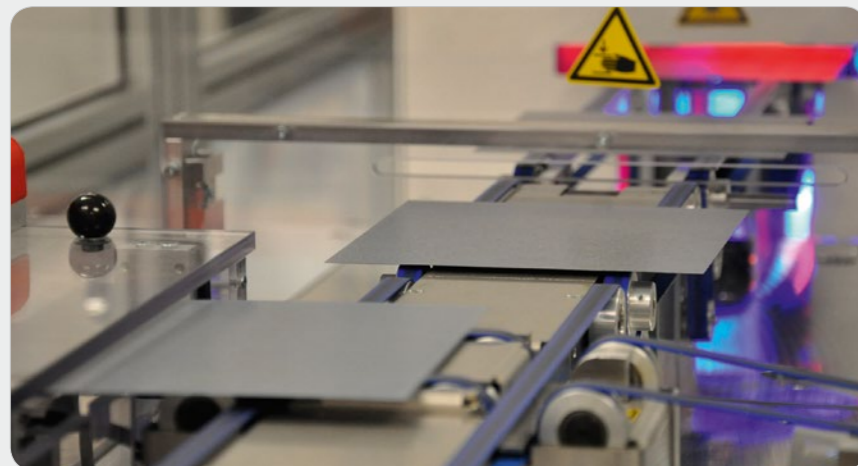
Jury comment

One of the most impressive and innovative technology concepts from the 2016 entrants. It can significantly speed up the testing process.

Andrea Viaro

Among many research groups, 1366 Technologies is probably the most successful one regarding commercializing this approach. The innovation level is high, but the argument on economics is a little weak. My concern is the relative cost reduction in terms of percentage was not based on an updated understanding of the industry achievement.

Xiaoting Wang



“TECHNOLOGY TO WATCH”

DSM ANTI-SOILING COATING KEEPING GLASS CLEAR

Netherlands-based DSM is well established as a provider of anti-reflection coating (ARC) – which is an increasingly mainstream solution on modules today. It has recently moved into backsheet supply and is on the verge of introducing an anti-soiling (AS) coating for solar cover glass.

Solar deployment is moving increasingly into dry and dusty environments, where irradiation is good but module cleaning more frequently required. DSM says its AS coating offers excellent anti-reflective properties: relative gain in average transmittance is ~6.6% for two-sided coated glass, so ~3.3% average per side. The technology also exhibits very good properties in the abrasion test and various durability tests. DSM reports that AS coating demonstrated excellent results during the soiling test. After dust deposition, when the glass samples were heavily soiled, gentle wind was enough to return the glass to its almost original clarity. The recorded transmission loss

of 3.8% was more than two times lower than the results demonstrated by the glass with DSM's anti-reflective coating (10.6%), and more than three times lower than that of the glass sample with no coating (12.9%). The coating's durability will no doubt play a major role in whether it can play a major role in today's PV production, and DSM has reported good results from its internal testing. Arno Stassen, from Heraeus, was pleased the innovation was recognized in a special award category as it, “offers a new solution for an old problem.”

Jury comment

AS coating is especially relevant now, as PV becomes more popular in countries with very sunny but also dry climates.

Arno Strassen

DSM offers a new solution in the area that so far hasn't been fully investigated and has a big potential for further improvement. This technology is also likely to have a significant impact on the market. Anti-soiling coating has a potential to make maintenance of the modules easier and more cost effective.

Götz Fischbeck

“As far as we are aware, the SINUS-2100 Outdoor is the only outdoor flasher which is portable, battery operated and transportable by hand,” says Wavelabs' Torsten Brammer.

Jury comment

It is a very interesting solution that can significantly speed up the testing process.

Andrea Viaro

The tester is obviously well suited for rugged outdoor applications. Due to its portable design this technology has clear advantages compared to one central flasher that has to be located far away.

Andrew Blakers

1 WAVELABS TAKES LED FLASHING OUTSIDE

Germany-based Wavelabs is introducing an outdoor solar simulator, deploying an LED light source for battery-powered operation. Wavelabs says the SINUS-2100 enables cost-efficient testing of modules with no need to disassemble the power plant.

Due to its lightweight design, SINUS-2100 is fully portable and can be handled by two operators. The design of the tool, however, doesn't affect the quality of the flasher, which showcases a superb spectrum for accurate characterization (A+AA+), the company says.

According to Wavelabs' estimations, utilization of its SINUS-2100 Outdoor can bring the cost of module testing for deployed modules down by about 90%. The device can be used for testing modules with up to 72 solar cells (1,050 mm × 2,050 mm).





2 M10 INDUSTRIES
HIGH THROUGHPUT
ALWAYS-RUNNING
STRINGER

Germany's M10 Industries has introduced its Kubus MTS 5000 stringer, which can enable savings of approximately 500 km or 1,000 ribbon rolls per year. Kubus MTS 5000 ensures no additional ribbon cutting, and, as a result, 2% less ribbon waste. Built in redundancy can

deliver extremely high utilization for manufacturers. The Kubus stringer can reach a head turning maximum throughput of 5,000 cells per hour, with a cycle time of 45 seconds per module, and achieves a yield of 98.4%. In addition, the machine is said to demonstrate a close to zero cell breakage rate even during long-term tests. Only one operator is required to control the whole process. M10 can demonstrate the performance

of the tool and provide operator training in a purpose built competency center, in Freiburg, and believes the built-in redundancy will be attractive to producers, as the tool does not need to be stopped for coil changing or refilling.

Solar Media's Finlay Colville noted, in the jury discussion that many module assembly lines are currently being supplied by Asian equipment producers. However, other jurors were impressed with the level of the innovation in the M10 tool and the industry reaction, thus far, to the Kubus design.

According to M10 Industries, all components of the new system have self-cleaning options, meaning there is no need to stop the machine for cleaning.

Jury comment
The Kubus MTS 5000 is definitively an interesting tool. With Emmvee Photovoltaic Power Pvt. Ltd. ordering two Kubus stringers at the end of last year M10 can finally also refer to a commercial installation of their tool, which is expected to be ramped up in 2016.

Götz Fischbeck



3 3D MICROMAC'S
THERMAL
LASER CELL
SEPARATION

Half-cut cells can reduce cell-to-module losses by 2% and have begun to be deployed by some module manufacturers. 3D-Micromac's solution for thermal

laser separation (TLS) aims at avoiding material damage at the laser cleaved edge as well as mechanical breakage in the cell separation process. The company's microCELL TLS technology is said to offer a damage free and residue free laser cleaving technique for brittle materials. The 3D-Micromac process deploys a laser to precisely scribe the cell, then

heats the cell and immediately cools it with a DI water mist. The thermally induced mechanical stress leads to a complete cleaving of the entire cell and two half-cells result, while the solar cell material is left undamaged. The company says that its TLS solution has no limitation for the crystal orientation of the substrate or wafer thickness.

MicroCELL TLS has a process speed of up to 300 mm/s. The tool is qualified for production of half cells. ANU's Andrew Blakers notes that the challenge in cutting cells cleanly has been a major barrier to a number of avenues of inquiry for PV researchers, with the TLS process appearing very promising.

Jury comment
More and more companies start using half or even quarter cells. This tool represents a new concept for upcoming technology. High speed of laser and hopefully low recombination surfaces make third, quarter cell or shingle modules also possible.

Arno Stassen

HIGHLY COMMENDED

1 HERAEUS SOL326
ENABLES
PERC
DEPLOYMENT

In September 2015 Heraeus Photo-voltaics Global Business Unit reported that its front side metallization paste had been successfully put to use to achieve a record PERC efficiency of 21.7%. Now, the company is aiming to build on this with its novel PERC back side silver tabbing paste for mono and multicrystalline silicon solar cell wafers.

According to Heraeus, its new SOL326 series paste shows higher open-circuit voltage (V_{oc}) and improved cell efficiencies, in addition to excellent solderability and adhesion.

Thanks to the good protection of the passivation layer, SOL326 series paste helps to achieve improved V_{oc} and thus increase cell efficiencies up to 20% and beyond. Especially for the SOL326 series pastes, Heraeus has developed in-house a new glass composition, as well as a



new concept for paste additives, which also help to minimize defects on the emitter during the metallization process.

The company reports that its innovation team is currently working on an even lower silver content version of the SOL326 series to support clients in lowering their material bill.

Jury comment
Heraeus is considered one of the most reliable silver paste providers. This new product is a type of back side silver paste or PERC cells, and it can synergize the advantage of improved cell structure. The higher efficiency can promote the market share rise of PERC technology.

Xiaoting Wang

2 CENTROTHERM'S
LP BORON
DIFFUSION
FURNACE

German equipment supplier cenrotherm rolls out its low-pressure BBr3 diffusion furnace for advanced n-type solar cells. The tool employs a time and cost saving "3-in-1" process for p-type emitter formation and surface passivation. This "3-in-1" process, developed by ISC Constance, deploys boron silicate glass as both emitter and passivation layer. Among the advantages of its new technology, centrotherm highlights its exceptional emitter uniformity with high sheet resistance of 150 Ω /square, and rapid change of gas atmosphere, which allows the design and deployment of new diffusion recipes and to fine-tune emitter profiles.

Moreover, according to the company, the new technology has a cost of ownership per wafer reduction of up to 60% compared to the company's own atmospheric



pressure (AP) solution. It also offers space savings, due to its minimized factory footprint, and up to 75% BBr3 savings, due to its lower media and utility consumption. The machine can reach a gross throughput of 2,940 wafers per hour.

Centrotherm also offers its customers an opportunity to upgrade their existing atmospheric systems with the LP process.

Jury comment
Centrotherm has been famous for providing low-pressure diffusion solutions for p-type cells, which has made a real impact on manufacturing: It helped double yield in a single batch without sacrificing diffusion uniformity. The new BBr3 diffusion tool transfers the concept to high efficiency cells on n-type cells, and it will effectively lower the costs in the p-type cell industry.

Xiaoting Wang



3 ON-THE-FLY REAR CONTACT OPENING FROM 3D MICROMAC

With PERC upgrades underway at many cell production facilities, Germany's 3D-Micromac introduces the second generation of its micro-CELL OTF, ablation system for back side laser contact opening (LCO), for both mono and multi PERC cells.

The company says that the new technology is able to tackle several challenges common to the LCO process, such as

microcracks and scratches caused by the gripper or the turntable's vacuum chuck, low on-duty usage of approximately 60% in conventional systems, high maintenance requirements due to moving parts, and less reliable and more expensive laser sources.

Using ultrasonic agitation, micro-CELL OTF enables damage-free, contactless wafer transport and on-the-fly processing without dead times resultant from the handling cycle. The machine uses 532 nm laser sources with 1,064 nm wavelength, offering a throughput of more than 3,600 cells per hour.

3D-Micromac has already installed over 40 tools worldwide. The company reports that the laser system, characterized by a compact structural form and minimal infrastructure requirements, is suitable both for new production lines and for equipping existing lines.

– **Jury comment**
PERC cell technology is on track to dominate PV. A contactless US levitation and transport system coupled with standard IR laser for rear contact openings offers an attractive solution to this non-standard part of the cell process chain.

Andrew Blakers

5 HIGH YIELD DSS INGOTING FROM GTAT

In a move welcomed by many, GT Advanced Technologies has emerged from bankruptcy. Its latest directional solidification system (DSS) for ingoting consists of GT's sixth generation furnace DSSTM 20M. GTAT says the 20M delivers substantial improvements in terms of cost, quality, throughput, and safety.

The company says that the new technology is capable of producing enough material annually to yield more than 20 MW worth of wafers. Due to its increased throughput, the new furnace reduces the conversion cost of polysilicon to high quality ingot material by more than 20% over its predecessor, the DSS850.

Due to its innovative design, the new furnace produces more material of a higher quality. One of the innovations is the independent control of hot zone heaters. It allows heat to be preferentially directed to the hot zone to ensure the solid-liquid interface; as a result, crystal growth is shaped appropriately for each process step.

DSS 20M also incorporates new safety features, such as GT's patent pending technology on the bottom head of the



furnace that prohibits interaction of molten silicon with the base metal in the event of a spill. The supplier claims its new technology to be "the most inherently safe furnace produced."

– **Jury comment**
The proposed tool represents the sixth generation of GT Advanced DSS technology.

As such the degree of innovation is not outstanding as it represents the typical evolutionary improvements you can expect from a next generation production tool. Its economic impact depends largely on how the COO of this tool compares to the COO of the alternative DSS furnaces available in the market.

Götz Fischbeck



4 LUVATA'S ONLINE RIBBON CALCULATOR

In June 2015 global technology developer Luvata launched its "Sunwire Calculator" – an online tool that can help PV module manufacturers to calculate their solar ribbon needs.

The calculator can determine the ribbon weight, the ribbon length per spool and the ribbon weight per solar panel and immediately send the results to the provided email address.

Sunwire is Luvata's PV ribbon brand. The company says that the product is already available in different spool sizes in order to meet the individual needs of module manufacturers. In addition, the Sunwire Calculator provides further opportunity to refine the usage of module materials and Sunwire ribbon for higher

module efficiency and lower overall material costs. The Sunwire Calculator requires a few simple details to determine the solar ribbon weight based on the copper width, copper thickness or coating thickness, or the length of Sunwire depending on the number of cells and busbars per cell. The tool is available 24/7 on Luvata's official website.

– **Jury comment**
The innovation submitted by Luvata has really great appeal in my opinion. It is not a new product but a new way of making their product customizable. The web tool is simple to use and has the sole focus to make sure that the customer gets a product that is tailored to their specific needs. I am impressed by the fact that indeed a company is not only proclaiming to put customer needs at the center of its operations but actually implement solutions that prove it.

Götz Fischbeck

6 MEYER BURGER EMBRACES LED IN NEW MIS TESTER

With its new MIS module tester Swiss technology provider Meyer Burger has shortened measurement cycles, to less than 15 seconds, and allowed manufacturers to achieve throughput of up to 240 modules per hour.

The company says that its new MIS technology has three main advancements. Firstly, the tester consists of a high quality A+A+A+ LED light source in terms of the spectrum and the light, and spectrum uniformity is high across the entire illuminated area. Second, the design of the tool has been downsized and adapted to an LED light source.

Finally, thanks to the advantages of LEDs, pulse length has been increased



to 100 ms. Meyer Burger reveals that it soon will be able to reach a pulse length of 200 ms.

– **Jury comment**
Meyer Burger's high throughput module

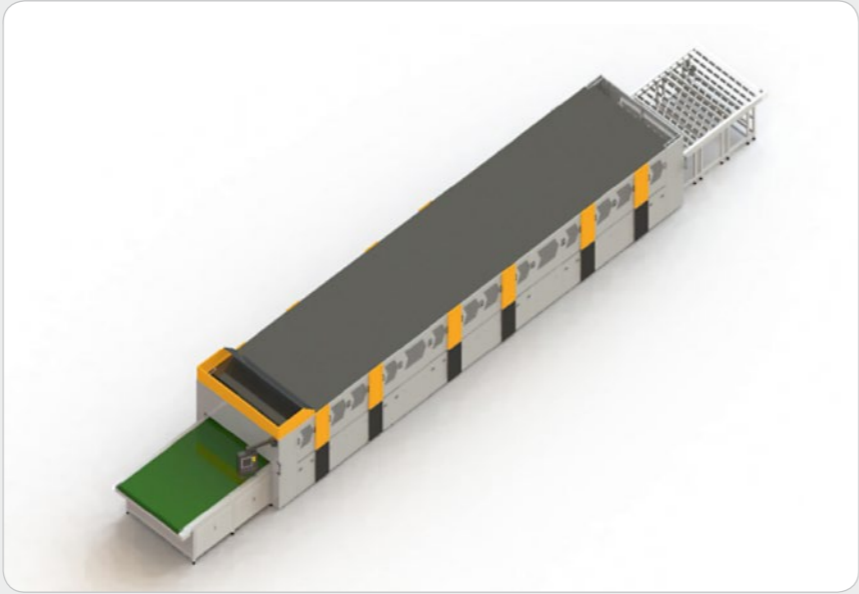
tester doesn't offer anything radically new in terms of technological development. However, the tool offers very precise measurements along with the improvement from previous designs.

Arno Stassen

7 JINCHEN'S GLASS-GLASS LAMINATOR

The new CCY2345-T-CP laminator introduced by Jincheng Machinery makes a breakthrough based on the previous generation with the addition of a cooling chamber and a pin-lifting system, especially suitable for glass-glass modules. The cooling chamber enables homogeneous and quick cooling process with an increased EVA transmittance, and the avoidance of module warping. It also facilitates the follow-up process such as trimming and IV testing by keeping module at an appropriate temperature and flatness. The pin-lifting system lifts the module during lamination, avoiding warping of the glass and reducing cell cracks and displacement rate.

The laminator has a maximum annual capacity of 65 MW and the cycle time of 6–8 minute per stage. It is equipped



with a chain tensioning device installed on both upper and lower drive systems to avoiding failures caused by chain loosening. The machine also incorporates a high-efficiency cleaning system.

Jury comment
Jincheng Machinery presents a good concept dedicated to glass-glass modules. The laminator enables quick cooling, which allows for improved EVA performance.
Arno Stassen



8 CELL REGENERATION FROM CENTROTHERM

After having implemented the stand-alone solar cell regeneration furnace c.REG in mass production, Germany-

based centrotherm has recently introduced its c.FIRE REG technology, which integrates a regeneration process in the c.FIRE fast firing furnace.

With its regeneration process and equipment centrotherm aims to passivate boron-oxygen-defects in mono c-Si solar cells and potentially reduce LID by

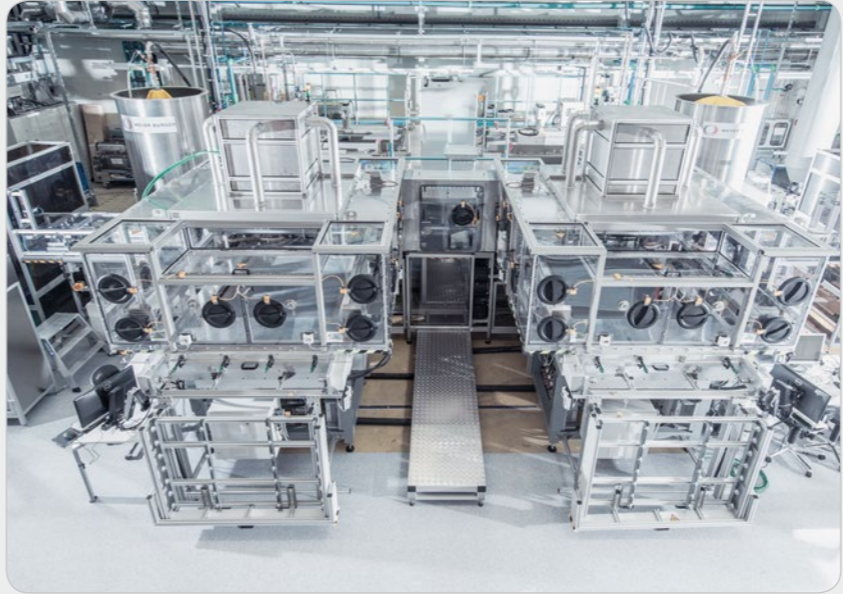
up to 80%. In the c.FIRE REG furnace the regeneration can be applied directly after fast firing, after sorting or even before module manufacturing. Average regeneration time is 22 seconds in mass production.

Key benefits of the technology include exact temperature profile repeatability, small footprint, and three different furnace lengths and regeneration durations that can be optimally tailored to production requirements.

Centrotherm's integrated firing and regeneration furnace can reach a throughput of 3,600 wafers per hour. The company says that its new technology has already been successfully tested by more than 25 customers.

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Jury comment
It is an advantage of the technology that the tool can be exchanged for existing one, causing minimum impact on production.
Arno Stassen



9 HJT FROM MEYER BURGER

Swiss technology supplier Meyer Burger says its new heterojunction (HJT) cell design and process results in a HJT cell types enables an unparalleled efficiency performance of well over 22%.

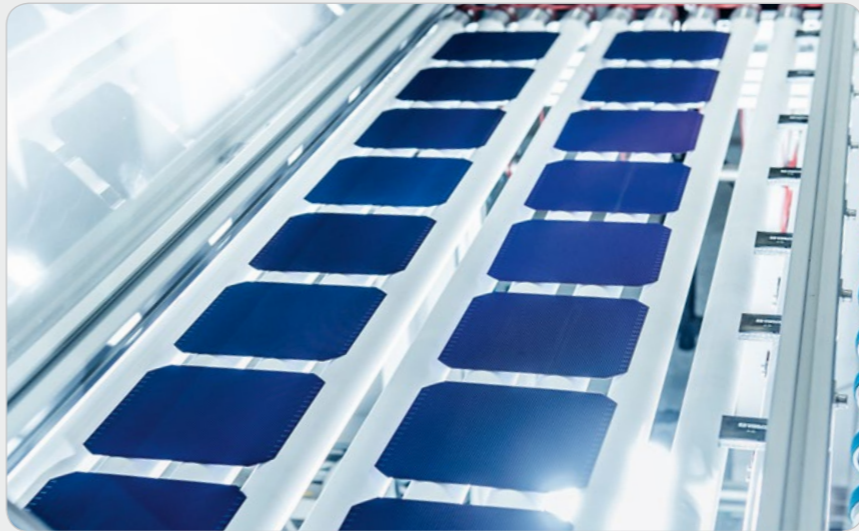
Meyer Burger's modular HELiA PECVD (plasma-enhanced chemical vapour deposition) and PVD (physical vapour deposition) tools offer gross throughput of 2,400 wafers per hour. According to Meyer Burger, its HJT technology delivers the highest energy yield due to its bifacial cell design, with no potential induced degradation (PID) or light induced degradation (LID). While standard cell manufacturing processes use a doping process at high tem-

peratures of around 900°C and a firing process of around 700°C, Meyer Burger's HJT process is below 250°C. It therefore does not require the heating and cooling of the wafer and all the equipment. As a result, the production process consumes less energy. Additionally, the new HJT tolls have a reduced number of production steps n therefore offers the greatest potential for cost reduction.

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Jury comment
The HJ-Technology has been pioneered by Sanyo (now Panasonic) more than 25 years ago. Meyer Burger took advantage of the patents expiring and has developed a commercial toolset so that HJT is now a "turnkey" option. The potential for this technology in the future might be higher than it currently appears.

Götz Fischbeck



10 SINGLE-LANE TESTING AND SORTING

Germany-based JRT Photovoltaics, a member of Jonas&Redmann Group, will be presenting its single-lane CTS 3600 SL testing and sorting system at SNEC this year. The system is designed for the fully automatic inspection and classification of completely processed c-Si cells according to their effectiveness and optical criteria.

JRT says that its new tool, which is suitable for very thin cells as well as full or half cut cells, has best-in-class performance for a single-lane testing and sorting system. Depending on the speci-



fication, the stand-alone system version can achieve an average throughput of up to 3,800 cells per hour with the lowest failure rates.

The high throughput of the tool is achieved by fast measuring instruments and camera systems, as well as by very fast rotary indexing tables. In addition, the technology has optimized material handovers and a compact design.

Due to its modular configuration, CTS 3600 SL can be perfectly adapted to different production environments. It offers a variety of options regarding material input and the number of sorting bins, providing customers with maximum flexibility.

–

Jury comment
JRT is an established supplier of cell testers. According to the provided information this "next generation" tool has lower COO than previous generation tools. The degree of improvement achieved at this level will ultimately decide on the economic impact of this innovation in the market. Götz Fischbeck

11 GSOLA'S LED CELL TESTER

Using multiple LED sources with colors chosen to match the spectrum and intensity of visible sunlight, Gsola's A+A+A+ cell tester can simulate irradiance distribution in different regions. The tester is said to be suitable for all kinds of cells, such as crystalline silicon solar cells, thin film, HJT solar cells. The tool has adjustable pulse width, ranging from 10ms to 200ms. The flash curve contains Suns- V_{oc} evaluation, IV testing, reverse current testing from -16V to 0V and spectrum response testing. The tester is A+A+A+ class and has a spectrum match up to 0.99-1, which greatly exceeds IEC 60904-9 2007 class A. The company says that, due to its simple design and 24-month long light generator lifetime, the machine has low



maintenance costs and, therefore, can reduce the general production costs.

Jury comment

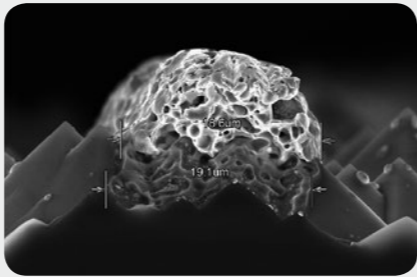
A number of cell testers/ module flashers with LED light sources have been recently introduced to the market. The obvious advantage is the longer lifetime of the light source and the lower energy consumption.

Götz Fischbeck

12 PTP TOOL FOR ULTRA-FINE FINGER LINES

Israel-based startup Utilight says it has reached a new achievement in its Pattern Transfer Printing (PTP) technology. Its patented non-contact laser 3D printing technology is now capable of printing ultra-fine finger lines of 15-20µm width and of uniform 12-15µm heights.

According to the company, these line widths enable the optimal use of multiple busbar technologies, which is currently one of the most promising trends in further improvement of the standard c-Si PV cells. Finger lines of 15-20µm width with an aspect ratio >>0.5 enable up to 0.4% increase of efficiency, and significant paste savings of up to 80% for all current cell designs.



Utilight reports that its newly improved PTP 1800i technology, which has a throughput of about 1,800 cells per hour, is ready to be integrated into existing metallization lines.

Jury comment

Screen printing is remaining the technology of choice for cell manufacturers, despite multiple attempts by alternative technologies to establish themselves as commercially viable options.

Götz Fischbeck



13 PVD INNOVATIONS FROM VON ARDENNE

Von Ardenne, a German manufacturing equipment supplier, rolls out two new coating systems for physical vapor deposition (PVD). The R&D SCALA and full-production XEA|nova are both designed for coating silicon wafers simultaneously on both sides and, therefore, ensuring short cycle times, a small footprint and lowest cost of ownership, the company says.

Production of high-efficiency crystalline HJT solar cells requires a reliable method for

depositing TCO layers. Von Ardenne claims to offer the "best-in-class" most efficient and cost effective solution.

The new coating tools are said to reach the same layer properties and comparable efficiencies with an ITO coating (indium tin oxide) that can be reached with an IWO coating (indium tungsten oxide) using the RPD method. Moreover, the technology has evidently eliminated the damaging effect on the substrate surface that is caused by the sputtering process. This damage had been considered a disadvantage of PVD for time.

Because of their modular design, the tools can be configured according to the needs of the customer and upgraded at any time.

14 DOUBLE SIDED PECVD FROM INDEOTEC

With its new PECVD platform Swiss technology developer INDEOtec claims to significantly reduce the contamination risks during the deposition process of c-Si wafers.

Conventional PECVD tools perform deposition at one side of a n-type c-Si wafer. For the deposition of the other side the wafer must leave the reactor for flipping, which inevitably leads to vacuum breakage and contamination risks. According to INDEOtec, its OCTOPUS II deposition platform solves the problem by using a carrier plate with holes and a secondary electrode underneath the plate. RF plasma now can be ignited above and below the wafer carrier plate.



The tool is said to offer uniformity levels of $\pm 3\%$ and minority carrier lifetimes >16 ms for a-Si:H films. The company says that in combination with a PVD

and several PECVD mirror modules, OCTOPUS II enables a complete heterojunction cell thin film deposition with no need for a cell to leave the system.

15 HIGH THROUGHPUT FLASHER FROM H.A.L.M.

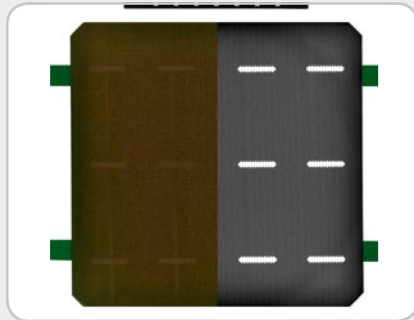
The cetisPV-IUCT-Q flatbed flasher system is now available. Developed by German's h.a.l.m. elektronik, the flasher features a high throughput rate with long flash pulses. The tool represents a floor-space saving system for PV-module production lines.

Together with the h.a.l.m. advanced hysteresis measurement this system allows for measurements of highest efficiency modules using one single xenon light source.

H.a.l.m. claims an extremely long light source lifetime together with the highest measurement stability. A further innovation brought to the market is the h.a.l.m. module EL-system cetisPV-EL-package-M, is that it can be integrated in all tunnel- and tower-type flasher systems. With an image resolution of 20 Megapixel and its integration into the IV-measurement equipment this new system allows 100% inline-EL inspection with low add-on costs and without additional floorspace. All standard crystalline silicon modules are measured in <10 sec measurement time with high signal-to-noise ratio at full image resolution.



16 MULTI-CHANNEL AND MULTI-IMAGE INSPECTION



German technology supplier Isra Vision/GP Solar presents its multi-channel and multi-image cell inspection technology CHROME+. Having inspected a reported 2.5 GW of PERC cells, ISRA Vision claims its CHROME+ system can effectively inspect rear-side PERC cell openings and contacts, avoiding pseudo effects and therefore “unsatisfactory classification.” ISRA deploys multiple illuminations of the cell, using different light wavelengths, providing sufficient contrast and meaning only sharply defined contours of a contact or defect show up.

The PERC inspection system is supported by a flexible CAD-style editor to define any arbitrary contact shape for the rear side, similar to the print pattern editor for the front side. This allows for individualized inspection and the fastest implementation on site, the company says. The editor also allows saving of the specified patterns and transferring them between different production lines and manufacturing sites.

The technology can be deployed as an upgrade to existing equipment, Isra reports.

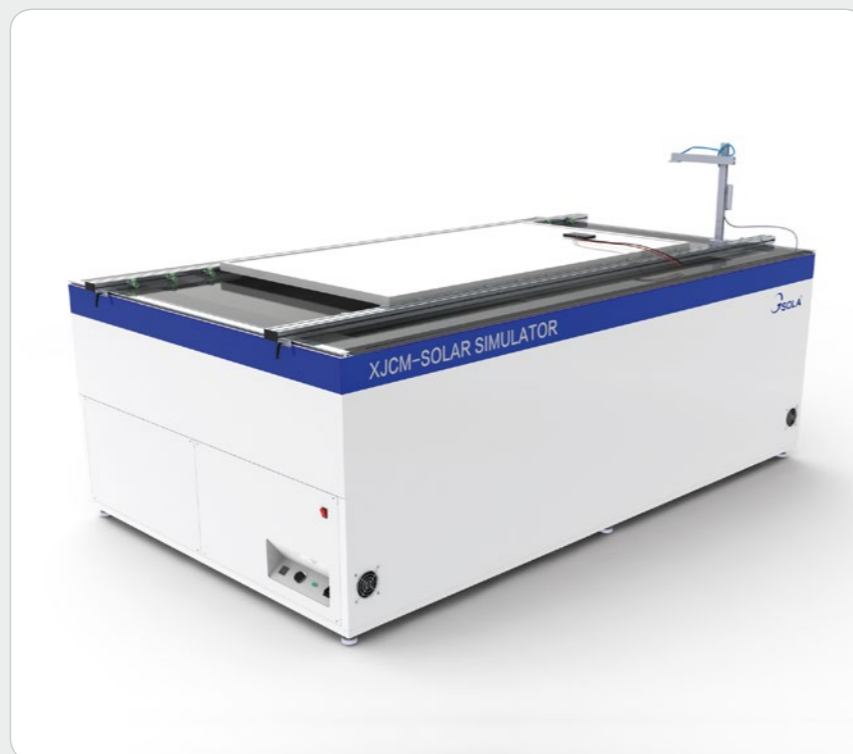
17 FULL SPECTRUM SOLAR SIMULATOR

At the end of last year, Chinese technology provider Gsola launched its new full spectrum solar simulator. The XJCM-10A+ technology can be used for measuring a crystalline module with the size up to 2,000mm x 1,100mm in face down position.

The company claims that the three core performance indexes of the tool fit the A+A+A+ standard, and are all twice as good as the highest international

standard (IEC 60904-9 2007): spectral mismatch below 12.5%, temporal stability and non-uniformity of irradiance below <1%.

Due to the improved design of the machine, the full spectrum range has been extended to 300nm–1100nm; it could also be expanded to 1700nm or even wider, Gsola says. The company notes that its tool is easy to use and fast, with its testing time of less than 1 second, with less than 10 seconds intervals. Gsola reports that 30 sets have been sold over the last two months. The JCM-10A+ simulator is now used by Trina Solar, Risen Energy, Renesola, Talesun.



19 LID SCOPE SOLUTION FROM LAYTEC

Germany's LayTec is introducing a new tool for the analysis of the Light Induced Degradation (LID) in solar cells. With the challenges of LID in PERC cells becoming better understood, the ability to test cells for LID, tweak processes, and provide customers with accurate LID measurements, are becoming increasingly important in today's production. LayTec's LID Scope allows prediction of the LID stability of PV modules already at cell level. The developer says the table-top, easy to handle LID Scope is able to analyze

all kinds of PV cells and perform all kinds of test scenarios. Using controlled heating and electrical current instead of light for carrier injection LID Scope can achieve an automated and repeatable degradation of the cell and predict the efficiency loss in the field.

LayTec's LID Scope can perform a quick 15-minute test at high temperatures with model-based extrapolation to real life behavior. The system can also perform testing that simulates real life conditions.

Analysis of the LID effect at single cell level enables tight quality control and makes it possible for operators to degrade a poor quality cell before assembling into a module.

20 COVEME'S NEW 1500VDC BACKSHEETS

Italy-based Coveme introduces its third generation of backsheets for high voltage insulation. New variations of Coveme's backsheets for 1,500V high system voltage modules, dyMat H2DPYE and dyMat MHPYE L, are in compliance with PDT 1500 VDC in AIR.

A new product range, for 1000VDC and 1500VDC, is compliant with the new regulations under discussion by IEC: both products are available with different customized reflectivity and in a low shrinkage version.

The company reports that it is currently developing a number of innovative products, such as superblack backsheets, which help to reduce the energy loss in the module by more than 50%, compared to the standard black backsheet. Another expected innovation is a transparent backsheet technology for BIPV and for PV bifacial cells, including a special hybrid solution for bifacial modules that is said to increase the output of the panel. This product can be also applied to glass-glass modules, the company says.



18 SOLDERING INNOVATIONS FROM JINCHEN MACHINERY

Chinese technology supplier Jinchen Machinery claims to innovate soldering of PV cells with its AUSTR-3600 stringer. The technology features newly designed pressing pins, which enable flexible pressure to be applied during ribbon placement, reducing nonuniform pressure caused by rigidity pressing.

A newly designed soft press device, implemented in the stringer, holds rib-

bon during soldering, ensuring a very low micro-crack and crack rate. Additionally, the machine uses smooth temperature increase in the soldering process, which causes less heat stress and results in lower cell breakage rate.

Jinchen Machinery's new stringer technology offers maximum capacity of 3,200 cell per hour, with a cycle time of 1.1 second per cell. Using closed-loop control, which enables precise adjustment of infrared lamps according to the soldering temperature, the technology can avoid accumulation of extra soldering heat under the lampshade. As a



result, the quality of the soldering process is ensured, the company says.

21 RENA'S COMPLETE TEXTURING SOLUTION

German-based RENA says that the combination of its BatchTex N cell cleaning technology with texture additive monoTEX and InOxSide+ wet chemical tool allows customers to create well-adapted wafer front-and back side topologies, according to the cell concept requirements.

RENA's BatchTex tools are said to interconnect ultra-compact tool design

with high throughput of up to 6,000 wafers per hour. The machine has short process time, with standard alkaline texturing time below 12 minutes. The tool uses monoTEX, RENA's next generation texturing additive. The cleaning process includes pre-cleaning, monoTEX process and metal cleaning.

The company says that with its BatchTex cleaning technology customers can run texture processes with well-defined pyramid sizes (1 to 3 µm or 2 to 5 µm) and highest uniformities. And by combining this tool with the InOxSide+ wet chemical tool, manufac-



turers can achieve very homogeneous backside smoothening.

InOxSide+ offers a single side etching process, hardware adaptations and improved process control, and can even moderate etch depths of ≤ 4 µm.

22 NON TOXIC
AND
EXTRA
CLEAR GLASS

Solar glass efficiency is not only limited to the high output, it is also determined by durability of the glass and its environmental effects, according to Borosil, the Indian solar glass manufacturer. The company says that its new solar glass solutions have all it takes to offer the highest efficiency: no antimony, low iron and the highest durability.

Borosil has developed an antimony-free solar glass, which is said to have excellent aqueous durability and transmission characteristics, reaching about



92% light transmission when measured with a spectrophotometer. The company reports that at the test installation, the antimony-free glass demonstrated a slightly higher power output than the glass containing antimony.

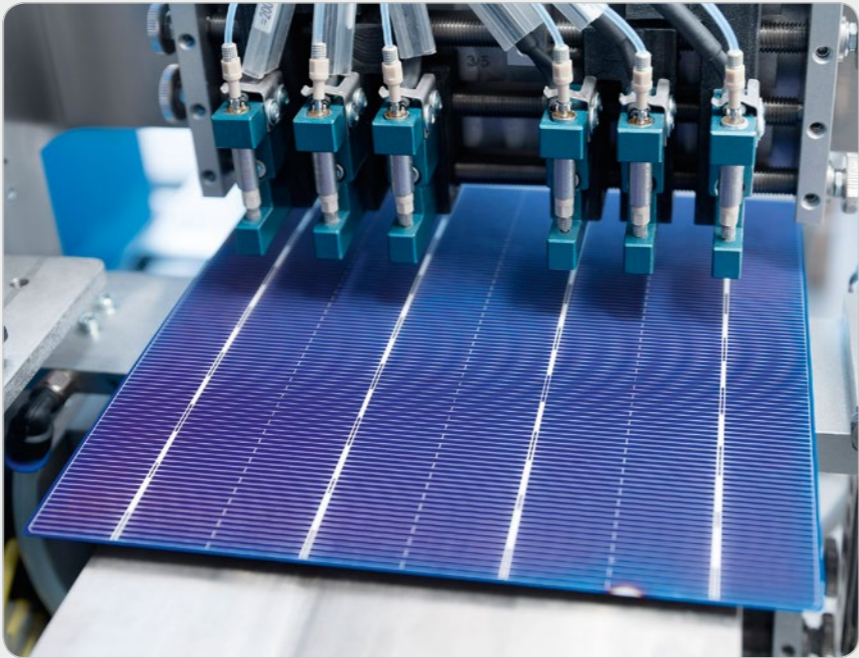
Low iron is another factor that enables higher efficiency of solar glass. High amount of Fe+3 ions in the glass causes a yellow-green hue, and Fe+2 ions give rise to a greenish blue color. Borosil claims that its 76 ppm iron glass contains the lowest amount of ferrous. As a result, its Extra Clear glass solution shows more clarity and higher transmittance, enabling a transmission of 92% maximum.



23 TEAMTECHNIK
DELIVERS
SPEED IN
SINGLE TRACK

Germany-based teamtechnik claims its Stringer TT2100 to be the fastest single track system in the world. The technology can run 2,100 cycles per hour, or every 1.7 seconds for a single cycle, and reach an annual throughput of 65 MW. The company says that its new tool has reduced electricity and compressed air consumption by 10%. It also requires less production floorspace, due to footprint reduction of 40%, compared to the previous model.

Among other advantages of its new stringer, teamtechnik lists the ability to process full cells and half cells with the same machine. Moreover, the technology can process solar cells with up to six busbars. With the patented teamtechnik's hold-down system, cells and ribbons are carefully held in place during transport, and even ribbons with very narrow widths of less than 0.6 mm are perfectly placed, the company says. The full teamtechnik's layup system with two TT2100 stringers and a 6-axis robot achieves a total output of 130 MW per year.



24 GSOLA'S
INTEGRATED
IV+EL
TESTER

China's Gsola introduces a machine that integrates an electroluminescence detector into the solar simulator. The company says that, due to its "simple but also unique" mechanical design, the new IV+EL testing technology helps to save space and labor, and, therefore, helps to reduce the module production costs.

The solar simulator is A+A+A+ class, which ensures twice higher performance results than the IEC highest standard AAA. The technology has spectral mismatch below 12.5%, temporal stability and non-uniformity of irradiance below 1%.



The EL detector uses a 16.2 megapixel camera and software that has 11 image-processing options, including brightness adjustment, local zoom, cropping, false color, and rotation.

25 SINGULUS
TEXTURING BENCH
FOR HIGH
EFFICIENCY CELLS

German equipment supplier Singulus Technologies has begun delivering its SILEX II modular wet chemical tool to high efficiency cell manufacturers. Both heterojunction cells and extremely thin wafers can be produced and accommodated on the SILEX II platform.

The latest generation of SILEX II batch system offers a clear modular design

and compact footprint, as well as a wide range of process options.

Singulus claims that its new machine fulfills current and future requirements of capacity, flexibility, and stability for mass production. Basic SILEX II system achieves an output of up to 3,000 wafers per hour, with possible upscaling of batch size, which can double the capacity of the tool. Moreover, the technology demonstrates very low scrap rates down to 0.01 %, and high process yield. Processing wafers with thickness down to 120 µm, the system follows the

specifications of the latest SEMI road-map guidelines. During the alkaline texturing process of mono-crystalline silicon cells, SILEX II generates pyramidal-etched surfaces with optimal light trapping, passivation and contacting properties.

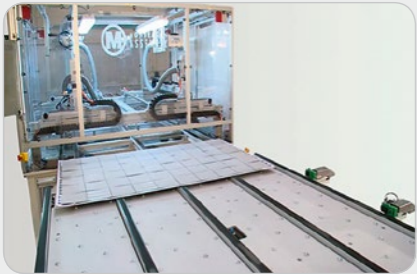
Singulus has delivered over 30 of its SILEX II systems for installation in heterojunction solar cell production in Europe and the U.S.



26 MONDRAGON ASSEMBLY LAUNCHES NEW IC TOOL

Spain-based Mondragon Assembly is introducing a new automatic interconnection (bussing) IC machine. As a number of busbars in a standard PV cell increases, the bussing or interconnection soldering process is becoming a bottleneck in many production lines, and requires more and more attention from technology providers. And considering the increasing capacity of new stringers and laminators, it is necessary to ensure that bussing technologies will be able to keep up.

Mondragon Assembly says its newly developed machine can satisfy the demand for higher interconnection capacity. The tool is said to process cells with up to six busbars and reach up to 150 MW of production capacity in a single machine.



27 ADVANCED HYSTERESIS EVALUATION WITHIN ONE FLASH

H.a.l.m. elektronik introduces two new systems for high-throughput production lines. The cetisPV-IUCT-3600 and the cetisPV-IUCT-2400 are able to adequately measure solar cells' IV-curves with an A+A+A+ rating. Special features of these systems are the long flash times of 40 ms (cetisPV-IUCT-2400) and 60 ms (cetisPV-IUCT-3600) at the nominal rated throughput.

Together with the advanced hysteresis evaluation of h.a.l.m., this makes the sys-

tems suitable for measurements of cells with the highest capacitive effects. In the advanced hysteresis, two IV-curves of the cell are measured in one single flash, one times swept from $I_{sc} \rightarrow V_{oc}$, one times from $V_{oc} \rightarrow I_{sc}$. The two measured curves are combined with an algorithm based on device physics to evaluate the steady-state IV-curve with highest accuracy.

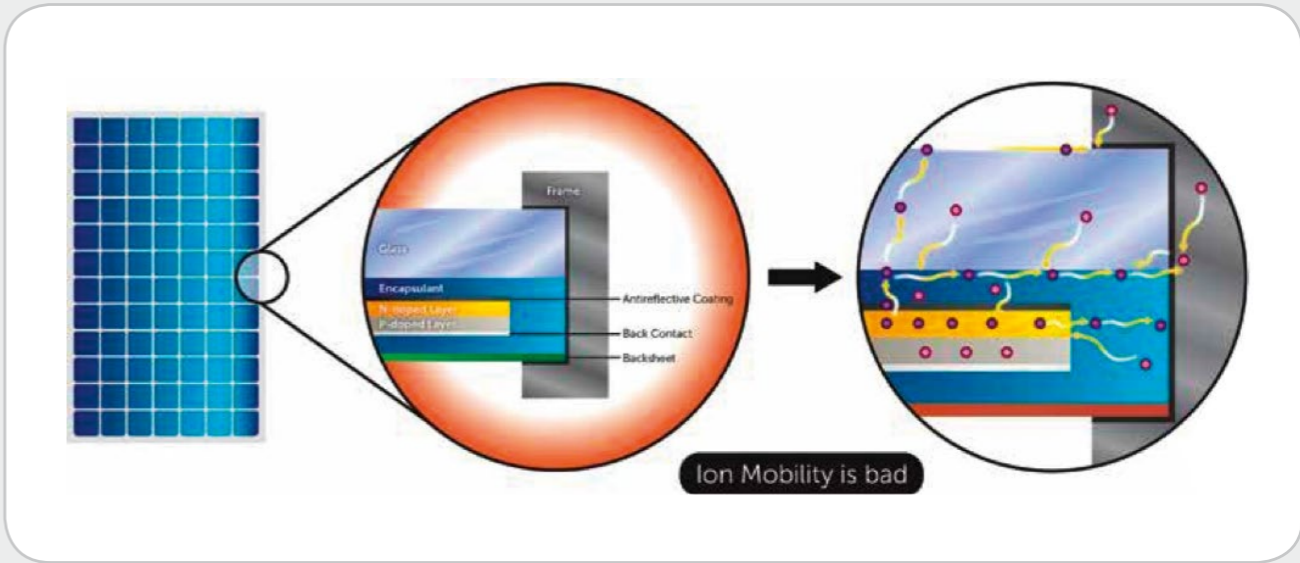
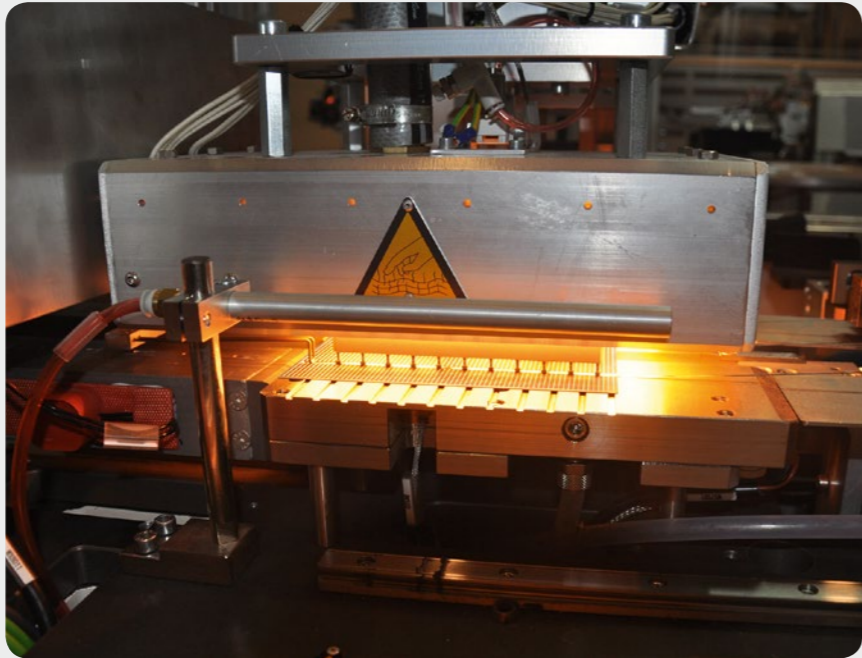
Both systems feature ultra-long flash lamp lifetimes and are combinable with additional measurement options, such as electroluminescence, infrared imaging detection of hot spots, and spectral response measurement.

28 MONDRAGON'S TABBER AND STRINGER

Spanish equipment manufacturer Mondragon Assembly is launching its new tabber and stringer solution. TS 2400 tabber and stringer will be able to perform 2,400 cycles per hour, the company says. In addition, it will be equipped with a 6 axis robot lay up with string control.

TS 2400 will be able to solder cells with up to eight busbars. The company says that with the new technology it will be able to deliver over 75 MW of production capacity in a single machine.

Simplicity of operation and maintenance, as well as the low breakage rate, are also among the main advantages of the new technology.



29 ZERO PID GLASS FROM BOROSIL

India-based Borosil says its new solar glass shows almost zero potential induced degradation (PID). PID occurs when the module's voltage potential and leakage current drive ion mobility within the module between the semiconductor

material and other elements of the module, thus causing the module's power output capacity to degrade.

According to Borosil, cover glass used in the module should be strong enough so that no sodium ion is allowed to leach out to create the PID effect. Leaching of sodium can be reduced if glass contains less sodium oxide (Na₂O). The company says that its new solar glass, which has the lowest Na₂O con-

tent i.e. 11.89%, shows zero PID. Zero PID glass needs special arrangement in the chemical composition to reduce the Na₂O content. Reduced quantity of Na₂O is replaced by other elements to maintain melting chemistry. The glass with zero PID has found hydrolytic resistance reading 5.5 to 5.7 ml. Borosil reports that the new product has already passed several PID tests.

30 MIDSUMMER'S FLEXIBLE CIGS

Sweden's Midsummer is pivoting in terms of the targeting of its DUO CIGS deposition tool, now taking a firm aim at the flexible module space. Midsummer's DUO can produce Cadmium-free CIGS in an unbroken vacuum deposition process.

Midsummer says the DUO can produce lightweight and flexible modules. Deposition can be carried out on to individual stainless steel substrates on an unbroken vacuum chain.

Midsummer's flexible modules, which weight less than 3.5 kg per square meter, don't require any racking or penetration of the mounting surface and can be used for membrane roofing or vehicle applications. These markets are not fully explored today due to the lack of suitable and cost competitive products, Midsummer says.

