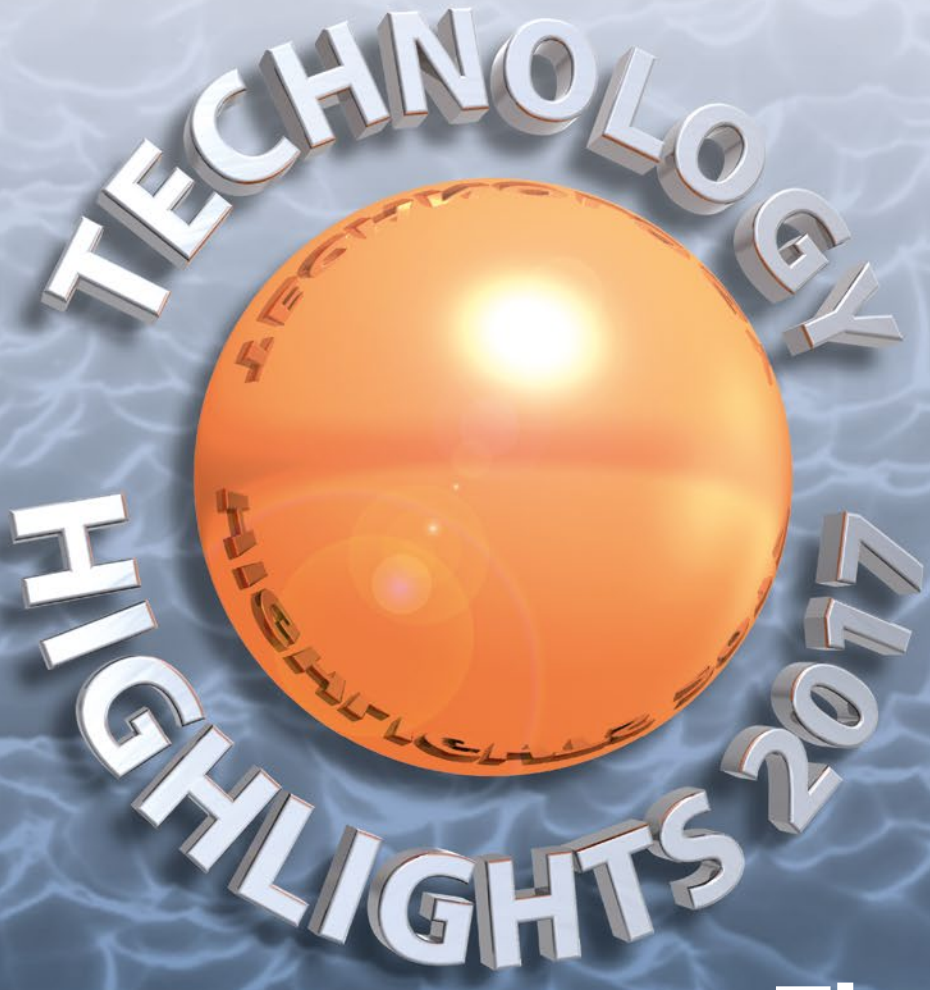
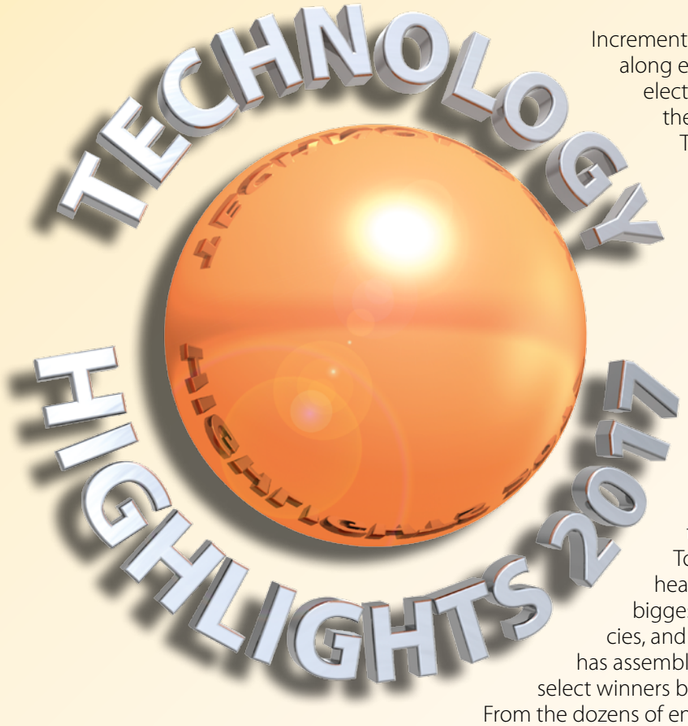
pv magazine

PHOTOVOLTAIC MARKETS & TECHNOLOGY



The shape of things to come



Incremental or step change: Technological improvement along every stage of PV production - from raw materials to electrical output - is the force that drives solar PV into the mainstream of energy supply all over the world.

The third edition of **pv magazine**'s Technology Highlights counts down 30 products and innovations for PV ingot, wafer, cell and module manufacturing, all of which have made a valuable contribution to solar's strength.

"Once again, the selection of technologies shortlisted in this feature encompass many of the key areas in which PV manufacturers, and their equipment and material partners, continue to push the industry further," states Professor Martin Green, of the University of New South Wales' renowned Solar Research Group. "This year's finalists represent some of the most promising technologies likely to make an impact in PV manufacturing either today or in the near future."

To gain further insight into where the industry is heading and to recognize the innovations with the biggest potential to bring prices down, increase efficiencies, and keep PV on an upward trajectory, **pv magazine** has assembled a jury of experts to produce a ranking and select winners based on entries gathered from around the world. From the dozens of entries received, six finalists were chosen to be further discussed in detail by the jury and to select the winners below as the technologies with the best potential to have a major impact on the manufacturing sector.

"Among the finalists this year we see technologies that could dramatically reduce costs and increase efficiencies," continues Martin Green. "A solution to facilitate diamond wire sawing in multi-Si wafer could bring a new growth phase. A process that replaces costly silver with copper, while also increasing efficiency, is very encouraging, and it's great to see testing platforms that produce masses of highly accurate data in a fashion that can be easily handled."

Technology Highlights 2017 Winners

Schmid
DW PreTex process for texturing diamond wire cut wafer

Macdermid Enthone
Helios PoSi copper metallization process

"Technology to watch"

Sinton Instruments FCT-750 cell tester

Finalists

1366 Technologies Direct Wafer process

3D Micromac TLS 5000 laser cutting tool

m10 Kubus stringer

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

Andrew Blakers, Australian National University

Andrew Blakers is a professor of Engineering at Australian National University. His research interests include photovoltaic and solar energy systems, concentrator solar cells, components and systems, and sustainable energy policy.

"One thing that comes out of being involved in awards like this is to see that there is no end in sight to the cost reductions in a silicon solar cell."

Corrine Lin, Independent Analyst

Corrine Lin is an independent industry analyst based in Taiwan, formerly a specialist in supply analysis at leading market researchers EnergyTrend. She now works on market conditions, spot market prices, capacity expansions, and mass production technology across all sectors of the supply chain. In April 2017, Corrine joined **pv magazine***'s Investigations and Insight team.*

Götz Fischbeck, Smart Solar Consulting

Götz brings his many years of PV industry experience to **pv magazine***'s Investigations and Insight team. With more than 16 years of experience in finance, 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 PV companies in their business strategy development and other financial topics.*

Matthias Hörteis, Heraeus

Matthias began his career at Fraunhofer ISE in Freiburg, Germany in 2005. After completing his PhD in 2009 at the University of Konstanz, he became head of the "metallization Group" at Fraunhofer ISE. Since 2011, he has been working in R&D for Heraeus, developing silver pastes for solar cells. Two years ago, Matthias relocated with his family to Conshohocken, USA and became responsible for paste R&D.

Pierre Verlinden, Trina Solar

Pierre is Vice President and Chief Scientist at Trina Solar. Verlinden holds a Ph.D. in Electrical Engineering from the Université Catholique de Louvain in Belgium. He has been working in the field of photovoltaics for 35 years and has published over 100 technical papers. Before joining Trina Solar, Verlinden founded AMROCK in Australia and served from 2005 to 2012 as Managing Director and Chief Scientist.

Xiaoting Wang, Bloomberg New Energy Finance

Xiaoting 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.

1 Texturing innovation for diamond wire cut wafer

SCHMID DW PRETEX

The application of diamond wire (DW) sawing has been a significant driver of cost reductions in wafer production. The cost benefit of diamond wire saws are clear – they operate more quickly and create less waste silicon. However, the smooth wafer surface left behind by DW sawing can create problems for cell production at later production stages.

This is particularly true of multicrystalline wafer production. Schmid's DW Pretex texturing solution for the production of multi wafers addresses this, potentially opening the way for diamond wire applications in multi production in a cost-effective way.

The DW Pretex process roughens the wafer surface, so that it can go on to be processed with the standard HF/HNO_3 treatment at the next stage of production.

Demand for a solution to the DW cutting issue is clear – having launched the tool in February, Schmid claims to have already received orders for 500 MW industrial production capacity, and expects to see 5 GW by mid-2017.

DW Pretex is a modular wet processing system that can be integrated into production lines through the addition of one machine, either as the final stage in wafer processing or the initial step in cell manufacture. Schmid has not yet disclosed the chemicals involved in the process, but states that they are already in common usage within the PV industry.

The majority of alternative solutions that have been attempted since the problems relating to diamond wire cut multi wafers came to light have proven to be either too complex or expensive to be viable. These include plasma and dry etching under vacuum.

Schmid's patent pending process has led to wafer surfaces with reflectivity as low as 21%, say Schmid, at an operating cost of less than €0.01 per wafer. The company also states that the process achieves better surface uniformity than is seen with slurry cut wafers, paving the way to even higher cell efficiencies.

–

Jury comments

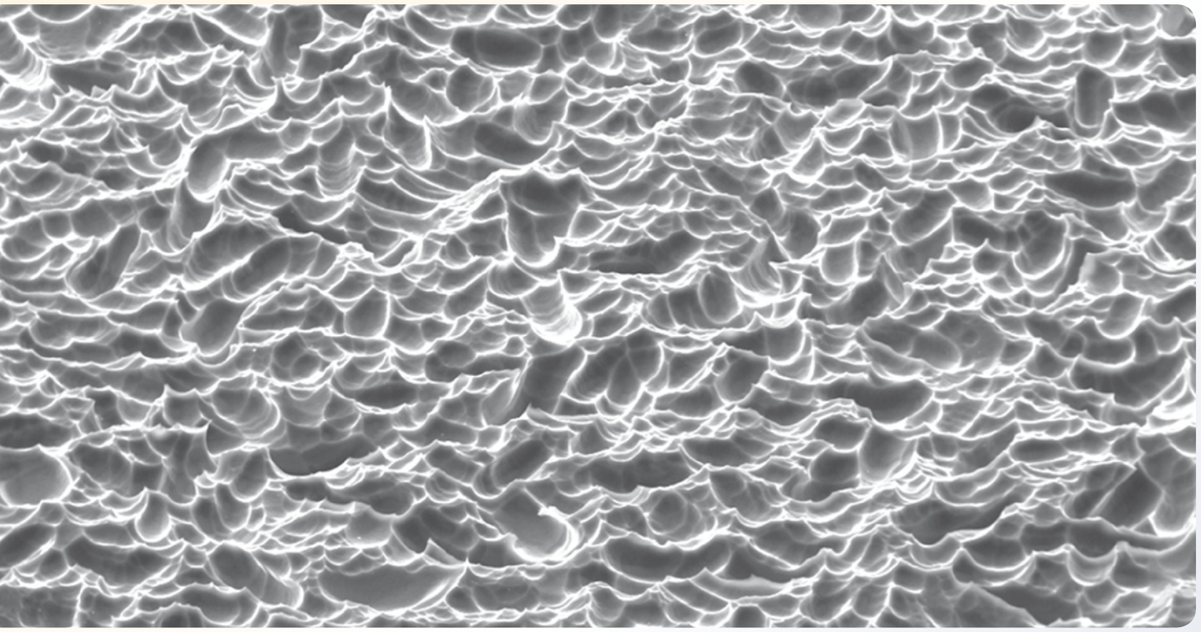
The compelling thing about the Schmid technology is that it doesn't introduce any new chemicals. It's a very smart process that really solves an issue. Virtually all monocrystalline silicon is cut using diamond wire saws, but with multi you still have the issue of texturing. If you look at how cost effective this solution is, it really could bring new life into the multi space."

–

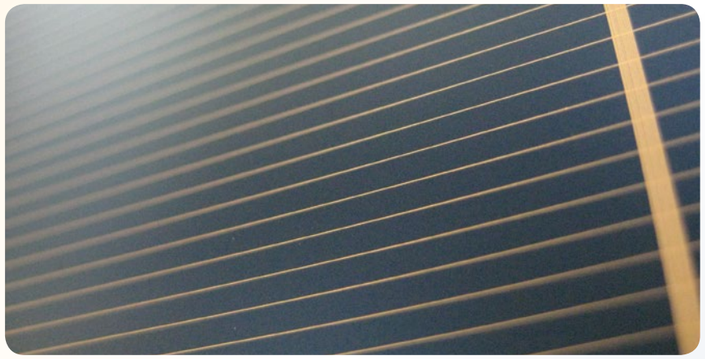
This is a game changer in the sense that the disadvantage of multi wafering , which we have been stuck with for two years now has a cost-efficient solution,
and cell manufacturers do not have to change anything at all.

–

Cost is the important thing for wafer and cell manufacturers, they don't want to add anything in terms of dry etching because the machines are too expensive. This process lets them adopt diamond wire without adding too many other things to their production line.



Photos: Schmid



2 Copper steps up to the plate

MACDERMID ENTHTONE HELIOS PoSi PLATING PROCESS

Manufacturers from previous decades would likely express surprise that screen-printing is still the dominant method for PV cell metallization today. While other, more high-tech methods may seem more in step with PV production in 2017, most have struggled to match the constant levels of innovation and improvement screen printing and silver pastes have achieved.

Macdermid Enthone now introduces its Helios PoSi, an inline laser > plate > anneal process, as a direct replacement for front side screen printing and firing methods.

Helios PoSi utilizes an innovative laser ablation process to expose silicon, then deposits copper, nickel, and thin silver into the opening. The plated material then undergoes a thermal annealing process in an inert environment at a low temperature.

The U.S.-based Macdermid claims a number of benefits of its process, not least of which is the price. "Typical overall cost of ownership for the PoSi metallization process is about $0.03/cell," states a Macdermid press release. This is far below what the company estimates as the cost of $0.07-$0.085/cell for production using silver paste.

The cost benefit arises from a dramatic reduction in the amount of silver used, something which the industry has sought to achieve for many years. Macdermid's process could reduce silver use by a factor of 40-80.

Cost is not the only benefit of this innovation in the process. There could also be significant efficiency gains as well. "By laser patterning the SiNx, finger widths are achievable that simply cannot be attained with screen printing. The typical laser opening is 15 µm and the finished finger width after plating is about 20 µm. This will be even further reduced as the process matures. This significantly reduces shading losses."

Copper plating processes for cell metallization are by no means a new idea in the industry, however, adhesion of the plated materials to the silicon cell has been a major hurdle for the technology.

Macdermid claim to have overcome this issue, and say that it is now producing plated layers with strengths that exceed industry requirements. "Depending on the cell type, we even see adhesion so strong the Si actually fractures and tears during peel test. This means the adhesive bond of the plating is stronger than the cohesive strength of the Si itself."

The claimed enhanced robustness has been achieved through two innovations. First, the use of picosecond lasers, supplied by Innolas, rather than nanosecond lasers that were previously relied upon. The company says that these make thermal degradation of the silicon surface far easier to control, and also that the lasers create a 'nano-texture' on the surface of the silicon, which enhances bonding of the plating material. Second, Macdermid experimented to optimize the plating formula to allow fast, ductile, low stress deposits using light induced plating (LIP).

Alongside Innolas, Macdermid collaborated with Rena for the copper plating process.

–

Jury comments

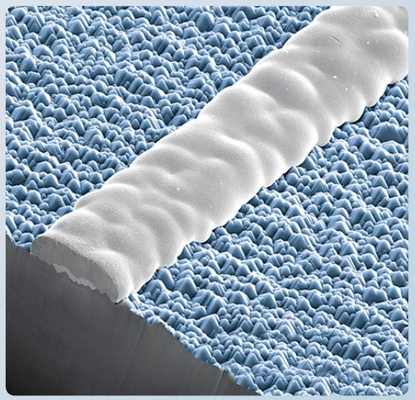
A shift to laser/Ni/Cu/Ag in place of screen printed silver facilitates a major gain for all types of cells. The ability to precisely ablate dielectrics means you can make a very nice PERC cell, removing dielectric from the rear of the cell. There is a lot of potential for moving away from screen printing – adhesion and contact resistance are the biggest questions.

–

Better electric contacts and substantial savings in silver consumption make this an innovation with substantial market potential. The issue is the higher initial capital expenditure, although this would be the case for any plating solution.

–

I think it's a question of when [copper will be adopted more widely]. Whether this is the solution that's finally cracked it, or whether it'll be in another three years, I don't know, but this has a good chance.



Photos: Macdermid Enthone

2017 "TECHNOLOGY TO WATCH"

3 Research-level analytics in mass production

SINTON INSTRUMENTS FCT-750 CELL TESTER

Already a technology leader in module testing, Sinton Instruments is now bringing R&D level analysis to cell production lines. The company is bringing to the market a cell tester capable of measuring up to 3,600 cells per hour, compatible with cell technologies including PERC, AI BSF and n-type.

The FCT-750 utilizes Sinton's patented voltage modulation technique to provide full characterization of the cells, including the conventional measurements of power, voltage, short circuit current, fill factor, and efficiency. While many cell testing instruments stop here, Sinton's FCT-750 goes further in enabling the advanced optimization of cells and modules, providing further measurements such as true series resistance and direct shunt.

Photo: Sinton Instruments

The FCT-750 also features a unique measurement of substrate doping, and can determine emitter saturation and wafer bulk lifetime through a full Suns-V_{OC} analysis. All of this is achieved in a test time of less than 200 ms, with a 5 ms flash time.

Sinton Instruments' products are already well known within PV R&D labs. Now, with a new tool for production that can factor in more parameters, Sinton is looking to bring R&D level analytics to production scale.

"Traditional solar cell test instruments use techniques that have not changed significantly over the last 40 years," say Sinton. "We took advantage of the opportunity to develop a cell tester that is faster, gives better results, and is more cost effective."

Development of this tool was partly funded under the U.S. Sunshot Initiative, a program led by the Department of Energy aimed at driving down the cost of solar. Sinton says it has already installed over 300 MW of production capacity of the tester on several lines.

"The real value of this instrument is the feedback of information allowing an acceleration of advances in the efficiency and cost trends of the solar cells," say Sinton Instruments. "This will enable a faster conversion to solar electricity worldwide."

–

Jury comments

A very innovative method to test the performance of high-efficiency cells and accurately extract important parameters, such as real series resistance, lifetime, and substrate doping. This is the best method to measure PERC, IBC, and HJT cells.

Photo: Sinton Instruments

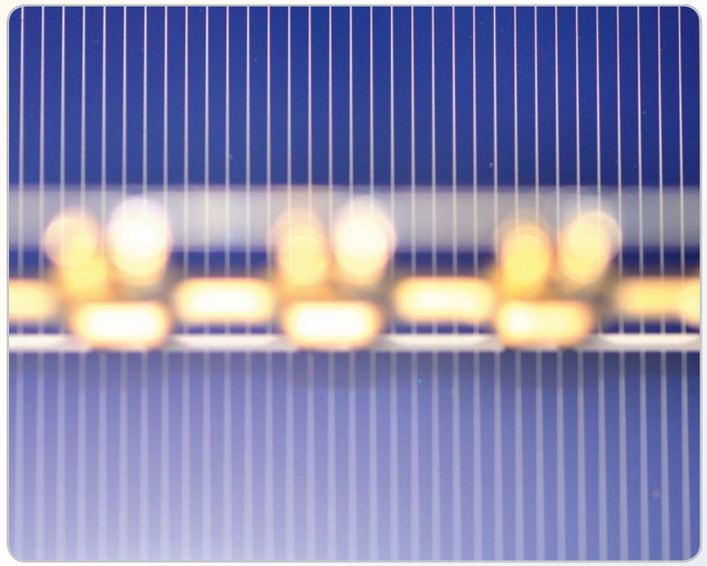


Photo: h.a.l.m GmbH

TECHNOLOGY HIGHLIGHTS 2017 FINALIST

4 Multi wafers with zero kerf and cutting

1366 DIRECT WAFER PROCESS

Since last year, when the Direct Wafer process developed by U.S.-based 1366 Technologies was a runner up in our Technology Highlights award, the team has taken the technology several steps further, heading towards large-scale commercialization with its partners at Hanwha Q Cells.

Notable highlights in 2016 include a 19.9% efficient 156 mm multi PERC cell, produced by Hanwha; a strategic partnership with polysilicon producer Wacker Chemie, including a $15 million equity investment; and the first commercial installation of modules using the 1366 wafers, at a 500 kW array in Japan deploying modules produced by an unnamed Chinese manufacturer.

On the technology front, 2016 saw 1366 roll out its 3D wafer concept, whereby thicker wafers can be produced and deployed (180-200 microns) for encapsulation at the edge of solar modules while thinner wafers (100-120 microns) can be used towards the center of the module – all of this on the standard 1366 process. By deploying thinner wafers at parts of the module that are not subject to high levels of stress during production, 1366 says that silicon consumption can be cut by around 1.5g/W.

The company says that its process can produce silicon wafers at less than one third of their traditional cost, reducing the energy required for manufacturing by 66%. Additional technological advantages include a high purity growth environment, limiting impurity build up; a superior microstructure avoiding the formation of dislocation clusters; and the ability to modify dopant concentration between the front and back of a wafer, that produces a doping gradient – a potentially "powerful tool" for manufacturers.

The kerfless wafer process involves the formation of wafers from molten silicon, and while this is not a completely new idea, 1366 appears to have overcome several challenges inherent to the process. The company can now claim that it is the only wafer made using kerfless technology with a standard format, meaning they can be used in cell and module production with no requirement for manufacturers to invest in new equipment.

–

Jury comments

With reduced silicon consumption and 20% efficiency demonstrated, there is an attractive potential for reduced-cost wafer production. This technology also offers plenty of potential for further innovation.

–

1366 seems to be tracking towards full-scale production. The approach will make a difference in several areas if 1366 can get online. It is now hitting 20% efficiency, and that's the magic number that says the technology has got a real chance.

–

1366 claims to have production time of 15 seconds/wafer. I would like to see the calculation comparing capex/opex against traditional saw wafering. The issue is: How are the economics when you want to go to thousands of wafers per hour? Direct Wafer is attractive by itself, data on cell efficiencies show that you can get high quality material. I'm still wondering to what extent this can actually compete at the commercial level.

–

1366 has a good idea. However, its improvement is still slow. Two years ago the technology was a good idea, but right now the market has access to really cheap wafers.

–

From an economic perspective, the technology didn't show much potential in its early stages, but now 1366 has achieved stable production.

Photo: 1366 Technologies

TECHNOLOGY HIGHLIGHTS 2017 FINALIST

5 Evolution of cell separation tech for half-cut production

3D-MICROMAC MICROCELL TLS 5000 WPH CELL CUTTING TOOL

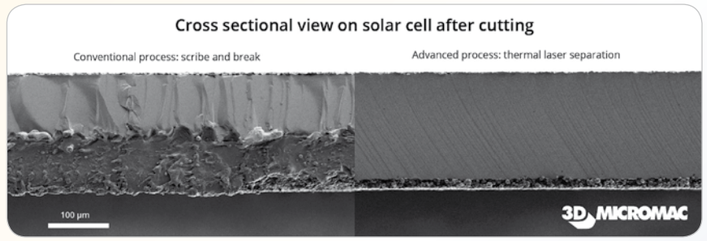
Half cut cells have the potential to deliver a power boost at the module level. However, there are challenges in how to efficiently cut standard cells in two, without resulting in a low quality cell edge. Low yield rates are also a potential pitfall. Typical scribe and break processes, 3D Micromac argues, are particularly prone to these problems.

To meet this challenge, the German technology supplier is continuing to build on its thermal laser separation (TLS) platform. 3D Micromac claims that TLS can deliver on both quality and yield requirements, while pushing throughput levels higher.

The company's TLS process promises higher power and mechanical strength. TLS deploys a laser to scribe the cell, then applies heat along the break point, followed by rapidly cooling using a DI water mist. The result is a complete cleaving of the cell into two undamaged halves.

The TLS process placed inside the top 10 of 2016's Technology Highlights, and this year 3D Micromac return with several improvements, including an increased throughput by 35% to 5,000 wafers per hour (full-sized cells), on the same footprint and single lane concept. The tool has also been adapted to cut heterojunction cells, where the company says gains can be seen thanks to the lower heat level compared with the current ablation process.

Photo: 3D Micromac



Jury comments

3D Micromac already had a similar product last year, and now they have good results in mass production. This year they have improved the technology, and output is good compared to mass production lines. The technology is already stable. This year, everybody led the p-type cell to higher efficiencies, but if you add on a half cut cell, the power output can increase by maybe 3 W/module.

–

This is probably the neatest way of dicing cells, a very good solution to an admittedly relatively minor problem.

It's a very innovative way of cutting cells.

–

The big question is yield, and any other additional costs such as in contacting [half cut cells]. If this was the bottleneck preventing others from adopting half cut cells, it could indeed be interesting.

TECHNOLOGY HIGHLIGHTS 2017 FINALIST

6 Non-stop, high-speed stringing

M10'S KUBUS 5500

M10's Kubus 5500 is a high-speed stringer, and the only one in the world that can operate without any interruption for ribbon replacement. Kubus 5500 represents a 10% performance increase on the previous Kubus 5000 platform, a result achieved over the last 12 months and presented for the first time at this year's SNEC.

This makes it the fastest stringer in the world, according to M10. The tool boasts 98% uptime. The addition of separately adjustable strings means that no ribbon cutting is required, which the company says leads to significant reductions in ribbon waste.

The tool operates with four independent ribbon supplies, and only requires three of these to operate at 100% capacity. This means that operators can change the spool without any interruption to its productivity. The German equipment supplier states that this can lead to an increased capacity of 30 MW/year at the same production cost.

The Kubus 5500 platform requires only one operator. It is compatible with module featuring from three to six busbars and sits on a footprint of only 35m².

–

Jury comments

A good representation of the optimization in current manufacturing technology.

–

This is an example of the type of innovation we see from year to year.

Photo: M10 Industries

7 Cell sorting data brought together

h.a.l.m CETISPV BIFACIAL FLASHER

Big data can lead to headaches if it is not well processed, sorted, and stored. On the flip side, when well managed it can be used as a fault prevention tool, allowing process parameters to be tweaked before they become a problem.

Testing equipment specialist halm, along with its new hardware for in-line EL testing, has developed a software package to analyze EL images, IV measurements and other test data. The PVControl-EL-eval software can carry out image analysis in-line during cell production and store data for cell sorting.

The software system can identify and report a range of defects including cracks, finger interruptions, contaminations, and firing defects. All factors relevant to a decision on cell quality are brought together by the PVControl-EL-eval package, and the information sorted into different defect categories. In this way, the platform can be used simultaneously for both process control and cell quality control.

PVControl-EL-eval allows for a throughput of up to 3,600 wafers per hour, and is compatible with all crystalline silicon module concepts, regardless of the number of busbars. It will run with most common production sorters and lines. Halm says that the structure of the program is ready to incorporate future changes in cell concepts and metallization layouts.

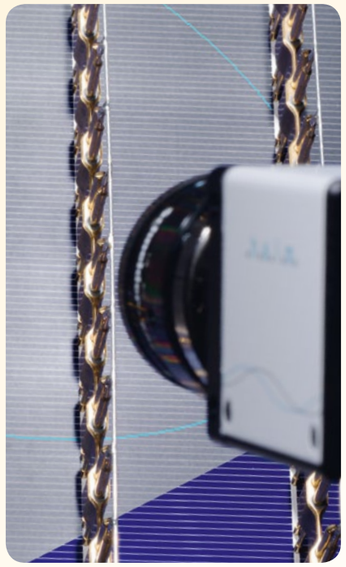


Photo: h.a.l.m GmbH

8 Versatile paste for PERC and ULDE

HERAEUS SOL9641B SILVER PASTE

At the PV Expo Japan in March, Heraeus unveiled its new silver paste product platform. The paste has been designed to bring improved performance in both PERC and ultra-low doped emitter (ULDE) applications. Heraeus cites performance increases of up to 0.2% in mono PERC cells through the application of its SOL9641B pastes.

The SOL9641B paste is compatible with both mono and multicrystalline wafers.

SOL9641B's unique paste chemistry and wide firing range make it ideal for use in PERC technologies, says Heraeus, and offers improved performance with light-induced degradation, as components likely to impact potential-induced degradation have been designed out. The paste also shows the potential for increasing efficiency in ULDE, a technology that appears on the road maps of several manufacturers for the next two years.

The paste was developed by the Heraeus innovation team, which worked with glass products, silver powders, and organic media. All of its own invention, the SOL9641B product is compatible with different printing technologies and offers room for new emitter designs.

Heraeus cites efficiency gains between 0.05% and 0.2% as proof of the product's efficacy.

Paste usage during mass production can also be reduced by up to 10%, thanks to ultra-fine screen printing, achievable with the new paste, and can be integrated into existing lines with little or no additional equipment investment.

–

Jury comments

This represents a step improvement of existing silver paste for higher-sheet resistivity (rho) emitters.

–

When compared with the other four leading silver paste providers, the result does seem all good. However, it is not an entirely surprising result.

Photos: Heraeus Photovoltaics

9 Analysis at the ingot stage

BT IMAGING LIS-B3

Australia's BT Imaging, working with the University of New South Wales, has developed a technique and a tool for the rapid bulk lifetime of silicon ingots using advanced photoluminescence imaging.

With the high efficiency cell concepts being brought to market in crystalline silicon PV, bulk minority carrier lifetime is a significant factor affecting performance, and one which is valuable for manufacturers to determine.

BT Imaging believes that the ingot is the ideal processing stage to measure bulk lifetime, and has developed a technique to do so, useful for quality control and efficient process improvements in silicon casting and pulling.

Each LIS-B3 unit can measure squared ingots or bricks up to 650 mm in length, and has an inspection capacity of up to 2 GW/year, dependent upon brick size. The tool can be used standalone, or integrated into factory production. There is an option to add capabilities for measuring wafers and cells. BT Imaging says that the tool provides far more accurate measurements than many common techniques employed at the ingot stage, which only look at the surface. Using photoluminescence imaging, the LIS-B3 can report impure zones and recombination defects. The tool can be configured to provide automatic cutting guides.

The Sydney-based company highlights the bulk lifetime of silicon as a key factor in the variability of solar cell efficiency, and says that the LIS-B3 tool could be useful both to cell manufacturers in setting wafer supply specifications, and to silicon manufacturers in improving their factory performance.

–

Jury comments

The ability to measure silicon bricks prior to wafering is important for quality control and optimization of ingot growth.

–

Photo: BT Imaging Pty Ltd

10 Another side to flash testing

h.a.l.m CETISPV BIFACIAL FLASHER

Germany-based testing specialist halm introduces its new flasher, aimed at the testing of bifacial solar cells. The cetisPV is available for both lab (cetisPV-Celltest3-BF) and production applications. The tool allows the simultaneous flashing of both sides of a cell in one flash sequence.

The widescale adoption of bifacial technology has been partially hamstrung due to a lack of standardized testing protocols for rear side output. For some years halm has been working to address this and its cetisPV provides a platform on which such rear side testing can be carried out.

In a typical use, the flasher will simultaneously illuminate both sides of a PV panel, at 1,000 W/m² on the front side, and 200 W/m² on the rear side. These values are not restrictive, says halm, and both light sources can be freely programmed to the desired intensity – between 200 W/m² and 1,100 W/m², with an illumination area of 180mm × 180mm.

halm also states that the system is the first to facilitate examination of a panel's front and rear side efficiency in one single contacting station and cycle, supporting the rollout of new bifacial concepts which can greatly increase energy output. The alternative is to flip the cell or module, testing each side separately. The cetisPV system utilizes xenon light source technology, with a lamp lifetime of up to three million flashes, dependent on the parameters.

–

Jury comments

This is a good implementation of a bifacial module tester.

Photo: h.a.l.m GmbH

11 Versatile PECVD system

CENTROTHERM C.PLASMA

As PERC technology becomes an industry standard, stack deposition of aluminum oxide/silicon nitride will be a vital step for cell manufacturing. With this in mind, centrotherm offers its C.PLASMA system for AlOx deposition.

C.PLASMA is the first horizontal batch-type PECVD system for AlOx deposition to run in high-volume production. The PECVD system can operate at just 10 mg of TMA consumption/wafer. Centrotherm says that the tool can operate in continuous wafer flow at 98% uptime, with no need for regular tube cleaning or maintenance intervals.

The tool features four tubes that work independently of each other, meaning that a high throughput can still be maintained if one tube is shut down.

Centrotherm says that its direct plasma deposition technology produces high quality anti-reflective coatings, high density masking layers, and optimized surface and bulk passivation, all of which contribute to higher efficiency.

The company has already installed more than 1,000 of the systems worldwide, and claims that due to a configurable design able to implement several processes and capacities, as well as opportunities for upgrades, the machine will be suitable for most future industry applications.

Photo: centrotherm photovoltaics AG

12 Functional dry texturing for mono and multi

NINES PV ATMOSPHERIC DRY ETCHING

Irish process and equipment developers Nines has developed a wafer texturing process using atmospheric dry etching (ADE). The company says that its new process removes any uncertainty regarding upcoming wafer technologies, and represents an ideal complement for PERC cell production.

The patented Nines process uses fluorine etching gas to create surfaces with controllable variation of reflectivity. Wafers are first processed by a wet saw damage removal stage, before undergoing the ADE process. Afterwards, a short cleaning stage is carried out to functionalize the texture.

The process is non-vacuum and does not require plasma, which keeps costs down and allows for a robust in-line design on a small footprint. Nines says a throughput of up to 6,000 wafers/hour can be achieved on the platform. The company stresses that its ADE process is a future-proof solution, compatible with both mono and multicrystalline technologies, diamond wire cut wafers, and also cast wafers thinner than 100 micrometers, without any need to change chemicals.

Nines PV says that the low reflectivity which achieved using ADE allows for efficiency levels beyond those seen with cells textured using wet chemical processes, citing a 0.3% increase certified by Fraunhofer ISE, and the potential for more than 1% in multicrystalline cells.

Jury comments

This is an effective and easy-to-implement solution for dry etching.

For dry texturing processes the efficiency gain is consistent, and it is easy to operate.

I am unsure as to whether manufacturers necessarily want to have a dry etching process in their production, because fluorine gas is very reactive.

Photo: Nines Photovoltaics

13 Heterojunction solution for industrial scale

INDEOTEC OCTOPUS III PECVD TOOL

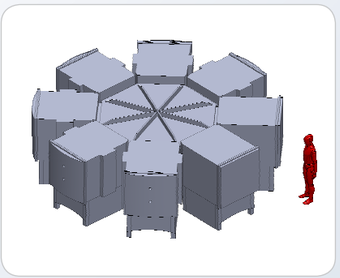
Swiss supplier Indeotec is continuing to make sales of its Octopus II PECVD platform to PV research bodies. The original Octopus II system was first released last year and is for the deposition of amorphous silicon onto a crystalline silicon substrate. Now the company is developing the next stage in its development, the Octopus III, set to be released later in 2017.

The Octopus III is a PECVD coating system targeting mass production of the next generation of PV modules, specifically heterojunction cell devices. The tool utilizes Indeotec's 'Mirror Reactor' concept, whereby the deposition is carried on both sides of the cell, with no need for cell flipping or for breaking the vacuum.

Photo: Indeotec SA

As well as simplifying the process and increasing throughput, the concept inherently reduces the risk of contamination during the deposition stage. Indeotec says that the patented concept, present in the previous Octopus II tool, has received strong positive feedback from the industry.

The tool will deposit an amorphous silicon layer between five and 10 nanometers thick, with 24 wafers processed at a time. Indeotec says that its PECVD process has the ability to do so without compromising the integrity of the crystalline silicon base cell.



Jury comments

This tool represents an upgraded plasma deposition tool for HJT applications.

14 Championing Industry 4.0 in PV

ASYS ALIGNUS 1.5S

German equipment maker Asys introduced its new metallization line in March, taking another step towards its aim of reducing cycle times at all stages in PV production. As part of the Industry 4.0 approach that Asys is keen to promote, the line exhibits a high level of automation and digital communications.

As its name suggests, the Alignus 1.5s boasts a cycle time of 1.5 seconds, scaling up to 4,800 wafers/hour. The line is built for the future, compatible with current trends such as PERC and concepts such as metal wrap through, and prepared for emerging concepts such as heterojunction and bifacial.

Alignus 1.5s includes a cell testing line with an IV tester developed by Asys subsidiary Botest, compatible with cells from two up to six busbars. The cell tester further reduces the process time by performing alignment alongside testing.

Alignus 1.5s is compatible with Asys' PULSE solution. This means that warnings and system information can be sent directly to an operator's smartwatch or tablet device, connecting them to the production tools in what is termed an 'Industry 4.0' approach.

PULSE has already been successfully installed in several PV production lines, with improved efficiency and reduction of line stops confirmed from the customer side, according to Asys.

Jury comments

Increased printing speed allows for higher throughput.

Photo: Asys GmbH

15 A boost for bifacial

COVEME SELECTIVE BACKSHEET

With its ability to achieve higher energy outputs from similar materials as a standard silicon module, bifacial technology has the potential to expand its share in today's market. This is particularly true within the high efficiency market segment, where LG, Panasonic, and other producers are pushing bifacial solutions. Italian backsheet specialist Coveme has developed a product designed specifically to address this demand. The Selective backsheet combines both transparency and high reflectivity.

The backsheet takes advantage of the spaces between cells, where it is printed with a white grid that bounces the light that hits it back into the adjacent cell.

According to Coveme, a study carried out by researchers at the University of Trieste showed that the output of modules utilizing the backsheet increased by 10% in terms of kWh/year.

Many of the bifacial cells currently on the market utilize a second layer of glass on the rear of the module, rather than a backsheet. Coveme presents its Selective backsheet as an alternative to glass-glass technology, making its solution both lighter and more efficient.

"Selective backsheet is a ground breaking innovation for the bifacial cell market," says a Coveme company spokesperson. "It combines high end innovation with feasibility, having zero impact on production processes."

–

Jury comments

A good product to help improve bifacial module performance.

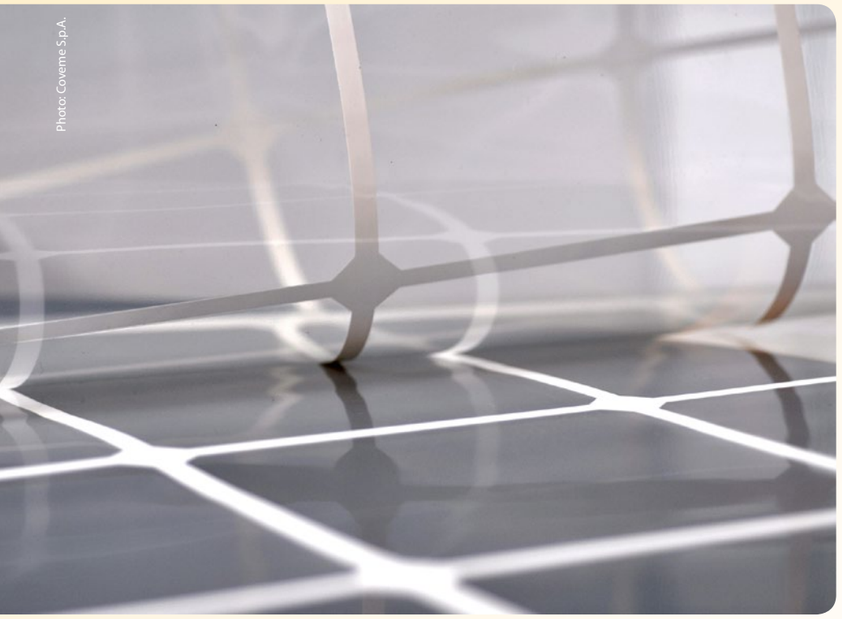


Photo: Coveme S.p.A.

16 Doubling up on light source

ALFARTEC BLUESKY MT40 SIMULATOR

Photo: Alfartec Sàrl

Testing equipment manufacturer Alfartec is a relative newcomer to the PV industry, founded in 2014 in the mountainous Swiss city of La Chaux-de-Fonds. Its Bluesky MT40 solar simulator takes an innovative approach to the testing of all types of solar cells.

The simulator utilizes both halogen lamps and LEDs at the same time for I-V measurement. This allows for accurate and broad coverage of the solar spectrum, from 350 to 1200 nm.

The system can be used to test any module or cell technology, and is capable of providing minimum pulse duration of 100 microseconds, right up to continuous light.

Alfartec say that the product is prepared for the future, with a lifetime of more than 15,000 operational hours. "LEDs and halogen lamps are extremely long lasting light sources, no service except calibration is needed for several years of operation," the company says. "Alfartec's products are designed to be used for actual and future module and cell technologies, so the customer will be able to use our system for at least the next 20 years."

The system features an integrated touchscreen with adjustable parameters, so it can be calibrated for testing different module technologies. "The idea behind this innovation is to provide the long light pulse and very good spectral matching needed by actual and future cell technologies," says Alfartec. "This is necessary to reach high quality measurement, allowing manufacturers to sell their production at the best price."

–

Jury comments

No extraordinary piece of innovation here, but it seems to be an excellent sun simulator for PV modules.

17 Wet bench processing for high efficiency

SINGULUS SILEX II

The latest iteration of Singulus' Silex II wet processing line features a flexible configuration and a range of different process options for the wet chemical treatment of silicon wafers in both standard and high efficiency cell concepts.

Silex II can achieve an output of up to 6,000 wafers/hour, with scrap rates as low as 0.01%. The German equipment manufacturer claims that the tool fulfills both current and future industry requirements for capacity, flexibility and stability for mass wafer production.

The machine's core application is the alkaline texturing of monocrystalline silicon wafers, which, according to Singulus, generates wafers with pyramidal-etched surfaces with optimal light trapping, passivation, and contacting properties.

Regarding future industry requirements, Singulus expects advanced cleaning steps to become indispensable in cell production, as a contributor to increased efficiency and reduced cost. The company suggests that Silex II'S Ozone-based cleaning process is an efficient way to combine organic and metal removal with appropriate surface conditioning, and a less costly alternative to multi-step RCA cleanings seen elsewhere.

Jury comments

A classic iteration of a wet chemical processing tool.

Photo: Singulus Technologies AG

18 Clearing the pathway to HJT at scale

MEYER BURGER HELIUS HJT

Swiss PV technology specialists and joint winners of 2016's Technology Highlights Award, Meyer Burger, return to this year's feature with its HELiUS equipment platform, which is designed to enable research and development into high efficiency heterojunction (HJT) cells, and create a pathway towards high volume manufacturing.

HJT is widely seen as step-change technology, allowing new entrants or established manufacturers to push efficiencies beyond those that can be achieved on single-junction crystalline silicon PV cells. The Meyer Burger HELiUS can deposit the amorphous silicon semiconductor layer, along with silver and indium tin oxide layers. Meyer Burger's development team have achieved cell efficiencies of up to 23.7% using the HELiUS tool in combination with tools at other process stages that have already demonstrated their suitability in mass production.

With this tool, Meyer Burger is aiming to reduce risk for manufacturers, by allowing them to develop and test reliable processes before investing in large-scale manufacturing. It also looks to bridge the gap between research institutes and mass production by providing highly flexible processes which customers can scale up using tools from the company's HELiA production line.

–

Jury comments

An upgrade on existing HJT tools, Meyer Burger can provide a turnkey solution for HJT production.

Photo: Meyer Burger AG

19 Crosslink polyolefin encapsulant for PID resistance

FIRST PV MATERIALS TF4/TF8 POLYOLEFIN ENCAPSULANT

China's First PV Materials has introduced its TF4 and TF8 polyolefin encapsulant that it claims provides excellent moisture barrier properties and good insulation. First PV claims that both TF4 and TF8 provide a lower water vapor transmission (WVTR) rate when compared to standard EVA material, along with long-acting PID resistance.

Alongside these properties, TF4 and TF8 have outstanding light transmittance and adhesion to glass, metal, and the polymer backsheet. The resultant encapsulate is durable against high temperatures, UV light, and high levels of humidity.

The encapsulants are suitable for glass-glass, as well as conventional crystalline PV modules. "It's unique optical property can increase the effective utilization of light," states First PV's press release, "ultimately enhancing the power output of PV modules."

–

Jury comments

Demonstrates continuous improvements.

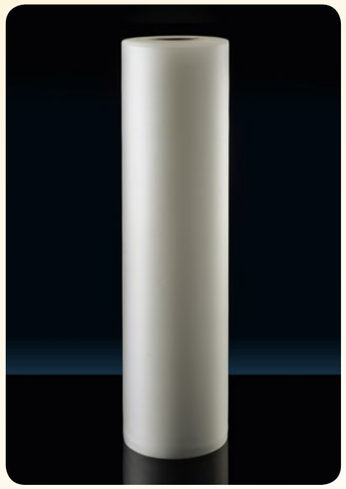


Photo: First PV Materials

20 Laser application for PERC and more

INNOLAS ILS-TTNx LASER PLATFORM

Innolas is launching its new laser machine platform, a flexible tool that can be applied to a number of the PV industry's emerging cell technologies.

With the PERC investment cycle continuing, laser tools have become an essential part of many cell production lines, as the most cost effective method for contact opening in PERC cells.

On top of PERC, Germany's Innolas suggests that possible applications for the ILS TTnx platform include laser doped selective emitters and front side contact opening for PoSi metallization technology. The tool can achieve throughput of up to 6,000 wafers/hour.

Based on the existing rotary platform deployed in previous iterations of the Innolas ILS TT line, the tool will be the first of its kind to allow a throughput higher than 4,000 wafers/hour at a footprint this size.

The tool brings the throughput for lasering processes in line with other stages of cell production, avoiding bottlenecks.

–

Jury comments

A great laser process platform: Perfect for PERC, laser doping or plating process.

Photo: InnoLas Solutions GmbH

21 High speed stringing solution

TEAMTECHNIK TT4200 GIGA STRINGER

The latest stringing tool from Germany's teamtechnik comes with a guaranteed 4,200 cycles per hour. The company claims that it is the fastest stringer, with the highest capacity/footprint ratio in the world.

The TT4200 GIGA requires only 15m² of floor space, and boasts up to 130 MW of production capacity. Teamtechnik guarantees an output of 4,200 cycles per hour, doubling the output of their previous machine. Infrared light soldering is utilized in the process, alongside a closed loop control system to ensure uniform results.

Other advantages include the ability to process full or half cells, with three up to six busbar configurations, without any impact on the stated production speed. Teamtechnik's patented hold down device separates the processes of soldering and cell handling, which ensures precise cell and ribbon positioning, as well as delivering minimal breakage.

Photo: teamtechnik Maschinen und Anlagen GmbH

Also 24/7 operation is possible on the TT4200 GIGA platform, teamtechnik claims. The tool can also process ribbons as thin as 0.6 mm.

When combined with a layup system, says teamtechnik, the first and last ribbon in each string can be produced to the precisely required length, with no additional cutting required in the layup system.

Teamtechnik stresses the tool's efficiency can lead to savings for the solar industry, both in terms of increased output on a limited footprint, and efficient production with reduced waste. The German toolmaker has also taken steps forward in reducing power and air consumption, stating that one TT4200 GIGA has the same capacity as two of their previous tool, the TT2100, but requires 25% less energy to operate.

–

Jury comments

There are a few innovations incorporated into the stringer, but it won't fundamentally change the way we solder cells.

22 Integrated module testing on limited footprint

ENDEAS QUICKSUN 550CE MODULE TESTER

The many different methods for producing highly efficient PV cells provide challenges to testing equipment makers, which must constantly innovate to keep up and provide accurate data in a way that is practical and affordable in the context of large-scale module production. The Quicksun 550CE module testing station, from Finnish supplier Endeas, performs a range of measurements on a tool that has a limited footprint.

The Quicksun 500CE tests the I-V curve, durability, insulation resistance, and frame continuity of a module, as well as testing bypass diodes and carrying out EL assesment with automatic defect detection, thus combining final module testing on an assembly line into a single, automated machine. The measurements can be carried out at a rate of 120 modules per hour, claims Endeas, on a footprint of only 7 m². As well as saving space, Endeas says that the machine can reduce energy consumption.

The tool is compatible with high efficiency cell concepts, including PERC and heterojunction. The xenon tube flasher carries out a 40 ms flash pulse, and has been certified A+A+A+ by TÜV Rheinland. Six 8.3-megapixel cameras detect microcracking and finger breakage, with exposure times between 5 and 20 seconds.

–

Jury comments

A good module tester with a wide variety of characterization tools.

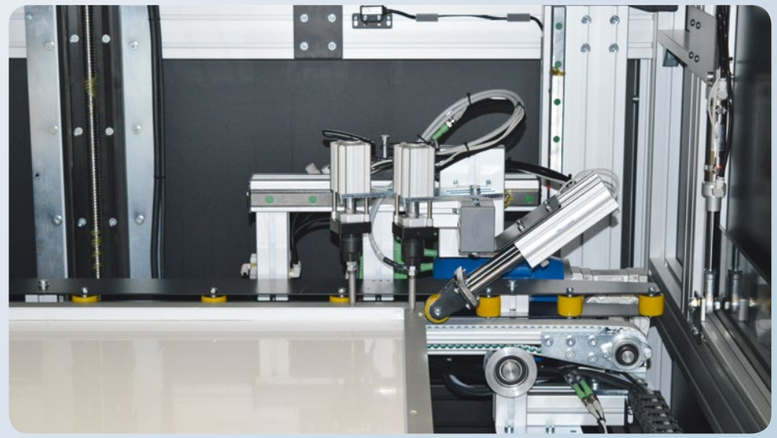


Photo: Endeas Oy

23 Up to six busbars, at high speed and quality

MONDRAGON 150 MW FRONT LINE

Spain's Mondragon Assembly has continued the development of its cell interconnection technology, with its latest Front Line solution capable of 150 MW of annual capacity, while ensuring high quality production. The company, which is a part of the world's largest industrial cooperative, is offering the unit standalone, the MTS2500, or as a part of its integrated module-assembly platform for new market entrants.

Mondragon describes its Front Line as being "the most modern in the market." It is comprised of two MTS 2500 tabber/stringers, a common layup, and one IC150 interconnection system.

The Mondragon Front Line can cater for modules with up to six busbars.

The company claims that as busbar configurations increase beyond three, to four, five, and even six, tabbing/stringing can become a bottleneck in manufacturing. Mondragon says its new Front Line prevents this.

Mondragon claims its MTS2500 tabber/stringer is the fastest of its kind on a single welding track, with a net production capacity of up to 2,400 cells/hour. As a standalone system, it can handle configurations of three to eight busbars, at various cell dimensions.

The layup system features a single robot, and the IC150 Machine Interconnection utilizes induction welding, where heat input at the welding point is optimized.

Mondragon's frontline is fully automated, and its automatic visual inspection system allows operators to monitor at the cell and string level. The line also incorporates 'Industry 4.0' principles, with data monitoring for efficiency and self-diagnosis.

–

Jury comments

An incremental but significant improvement in module assembly.

Photo: Mondragon Assembly

24 Simple solution for anti-soiling coating

IRIS HELLAS SOLARSKIN

As PV generation is increasingly adopted in deserts and other hot, dry, and dusty climates – areas boasting excellent solar irradiation but otherwise challenging conditions for deployment – maintaining power output by keeping modules free of dust and dirt becomes a major issue.

Athens-based Iris Hellas has developed a protective coating for solar glass, which it says can prevent abrasions, mineral deposits, pollution, and corrosion from damaging modules and reducing their output. SolarSkin is based on Iris Hellas' patented HyDrop technology, which the company says can protect the glass without blocking any incoming light. The coating relies on a covalent bond structure, strongly bonding with the glass to guarantee resistance to temperature changes, chemicals, dust and dirt, and other abrasions. The coating is also breathable, allowing water vapor – which can cause glass corrosion – to escape.

The coating is hydrophobic, with an initial contact angle of 105 degrees, and highly durable, according to Iris Hellas, which says that after 15,000 cleaning cycles the coating's efficiency is reduced by less than 20%.

Iris Hellas states that SolarSkin can be integrated into glass or module manufacturing processes easily and without the need for investment in new equipment. The coating can also be applied retroactively to an existing PV power plant. Curing time is 24 hours, which can be greatly accelerated through the application of heat.

–

Jury comments

An interesting solution but there are serious doubts as to whether a DIY kit to coat PV modules would be sufficiently reliable.

Photo: Iris Hellas

25 In-line EL module testing

GSOLA GEL-M11 EL TESTER

Photo: GSola

GSola's latest electroluminescence (EL) module tester can help manufacturers to improve production processes using high resolution imaging to reveal a range of module defects. The GEL-M11 boasts a Nikon camera, which produces EL images at better than a 42 mega-pixel resolution. Exposure times can be customized. This way, the tool can detect microcracks, contamination, sintering defects, material defects, broken fingers and low efficiency cells.

GSola reports that its GEL-M11 utilizes three high resolution cameras and tests modules under both high and low current. The tool can test modules both before and after lamination and framing, and can achieve a throughput of 130 modules per hour, which translates to 300 MW/year from one machine.

26 Immediate handling encouraged

SIKAMELT-9185

Modules can be rotated for flashing or immediately stacked after junction box (JB) bonding due to the high initial strength delivered by the latest addition to the SikaMelt range.

Switzerland's Sika Services is introducing SikaMelt -9185 IA to the PV sector, with the product delivering reduced material usage and improved mechanical performance when compared to silicones. Sika claims that only a thin layer of the SikaMelt -9185 IA is required to deliver an equivalent stress distribution to silicones.

SikaMelt -9185 IA is a single component, reactive hot melt with low density. It is applied at a temperature above 160°C. SikaMelt -9185 IA is a fast-cooling adhesive and once cured by atmospheric air moisture, it results in an elastomer, which cannot be re-melted.

Sika claims that this latest iteration of the SikaMelt range to be applied to PV production can achieve a reduction in material consumption of up to 50%. It achieves good adhesion to nonpolar substrates as polypropylene and polyethylene, along with glass – for dual-glass module production.

With no buffering of curing zone required and strong adhesive performance, Sika claims its new adhesive will assist PV manufacturers to achieve ongoing cost reductions and hit quality milestones in module production.

Photo: Sika Services AG

27 Roll-to-roll perovskite solar cells

SOLLIANCE R2R PEROVSKITE

In recent years, perovskites have been a popular area for research and development in PV, with researchers seeking methods to mitigate instability in the material and to take advantage of its potential to produce highly efficient solar cells at a low cost.

Though the technology is still in the development stages, the past year has seen some major progress towards the commercialization of perovskites. One such development has been the demonstration by European R&D partnership Solliance, working alongside industry partners, of a roll to roll (R2R) process for the production of perovskite solar cells.

The process has produced cells with a conversion efficiency of 12.6%, a record for full size, perovskite cells produced on industrial equipment. The dual R2R coating line developed by Solliance is for both perovskite and electron transport layers. Using a commercially available PET/ITO foil, coating, drying, and annealing processes were executed under ambient conditions at a rate of five meters/minute.

The foil floats through the line without any mechanical contact, which reduces the risk of scratching or abrasions to the coating. Solliance also stresses that the process does not utilize temperatures above 120 degrees, which will keep down production costs.

Solliance has not disclosed full details of the production line, but does say that the design incorporates deposition of sub-micron thick layers, with high accuracy and low particle concentrations, and that it has developed a deposition process with no release of CMR compounds.

–

Jury comments

It is still too early for perovskite commercialization. Cells are frequently tiny, with modest efficiencies, and often uncertain stability. It appears that much more materials science is required.

Photo: Solliance

28 Output boost from extra clear glass

BOROSIL SOLAR BURST GLASS

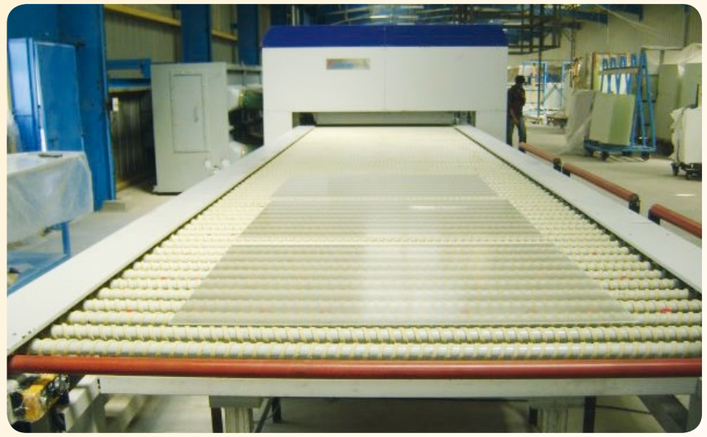


Photo: Borosil

India's Borosil reports that its claims that its Solar Burst Glass can deliver an output boost over conventional glass of 7.5% have been validated by field testing. Borosil claims that its Burst Glass exhibits low iron levels, delivering a superior optimal transmission at the normal response range of a solar cell.

In testing it carried out in 2015 and 2016, using its glass and competitor product in modules produced by Indian manufacturer Emmvee Photovoltaic Power, an average power boost of of 10% was observed.

The key to achieving this, says Borosil, was producing glass with the lowest possible levels of iron, which can give the glass a blue-green hue. Borosil produces glass with less than 90 ppm of iron and completely free of toxins, including antimony.

Further testing by the Photovoltaik Institute in Germany has demonstrated the product's long service life and that low sodium levels within its glass ensure PID minimization, says Borosil.

–

Jury comments

An incremental improvement of standard product.

29 Flexible CIGS in action

MIDSUMMER BIPV METAL ROOFING

Photo: Midsummer SE

Building-integrated solutions will play an important role in the future of PV, as authorities begin to announce energy efficiency requirements for new buildings and space becomes an issue in major cities. "The solar cell market is facing a paradigm shift," says Midsummer CEO Sven Lindström. "Focus is shifting to installations on large buildings in cities."

Using its DUO production tool for CIGS deposition onto flexible substrates, Sweden's Midsummer has now teamed up compatriot roofing company Clix Steel Profile to provide PV steel roof plates.

Midsummer reports that the outcome of the collaboration is steel roof plates featuring 14% efficient integrated lightweight flexible panels. The Clix Steel metal roof system features a unique fixing principle for steel sheets, and a highly competitive price for both small and large-scale use.

The roof plates are integrated with Midsummer's lightweight, flexible CIGS modules at the factory, thus reducing the time and cost required for installation. Panels are mounted to the roof plates using a high performance elastometric butyl adhesive tape, designed to provide tack and adhesion in field conditions.

Midsummer's DUO manufacturing tool deposits its CIGS semiconductor stacks onto flexible substrate using a roll-to-roll process. Up to 25 sputtering targets can be added to the DUO platform, allowing for the PV stack to be optimized without changing the tool's layout.

The Midsummer process is cadmium-free and involves the sputtering of all cell layers. "Our focus on lightweight flexible modules appeals to the market," says Midsummer's Lindström. "As well as our use of sputtering for all layers, and that the production process is an all dry, all vacuum process."

Midsummer says that it has achieved an 18% aperture area cell efficiency on its commercial DUO platform.

Photo: Iris Manz AG

30 Turnkey CIGS into mass production

MANZ CIGSFAB

German equipment supplier Manz has been attempting to commercialize its CIGSfab turnkey production line since 2010. In January this year, it was welcome news when it signed a 350 MW supply deal with Chinese coal giant Shenhua, alongside Shanghai Electric.

The deal will see Manz and its partner and shareholder Shanghai Electric install a 306 MW production line for Shenhua to operate in Chongqing and a second 44 MW R&D line in Beijing. Besides the production equipment supply deal, Manz has also entered into a series of JV partnerships with Shanghai Electric and Shenhua to develop CIGS technology further and produce its CIGS equipment in China – in an attempt to accelerate efficiency improvements and cost reductions. Manz has already achieved 16% module efficiencies on its CIGS platform, and its technology partner the ZSW has pushed small CIGS cells up to 22.6% efficiency.

"Based on many years of experience," says the company, "Manz is convinced that the dominant crystalline technology will no longer be able to compete with the rapid development of thin film technology."

With the scale that China undoubtedly delivers, two financially robust partners, and the JV vehicles through which it will attempt to drive down both capex and opex, it is now up to Manz and its engineers to see whether it is indeed CIGS technology can match its fighting words.

–

Jury comments

Since c-Si base product costs are much lower than last year, CIGS' cost and efficiency will still find it difficult to compete.