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viewpoint

Does Trina's exit signal the demise of MIP?

THE EXIT by Trina Solar from EU-China price controls was to be expected. It came just days after the European Commission (EC) decided in early December to continue minimum import price (MIP) levels while it investigated complaints—for another 15 months.

Although the EC seemed surprised by Trina's action, Industry insiders saw this coming.

A basic fallacy of MIP as it exists today is rooted in willful ignorance of global market forces. Solar module price erosion has occurred not solely because of Chinese competition. For years the cost of materials has declined while more manufacturers got into the game. PV prices are cheaper today for the same reasons that products from ASICs to Wi-Fi routers cost less over time. Yet the EC seemed to believe it could wave a wand and players would ignore economics, content with ever-shrinking margins and markets.

Trina plans to do what EU Commissioners should have expected. Having trouble selling made-in-China products in Europe? No problem. Find another place to make them. Trina and other manufacturers plan to do just that. Nevertheless it is understandable that EU regulators would want to do what they could to support home interests. Europe helped build the Solar Energy juggernaut; it is hard to watch manufacturers outside the EU capitalize on a market Europe nurtured.

While everyone appreciates that EU industries need to profit, the way to sustain solar growth is through innovation—creative solutions that benefit manufacturers and investors while giving consumers better, less expensive products.

Protectionist trade policies can work for a season, but the clock is ticking. If the EC wants continued solar industry growth, underwrite more research into higher solar efficiency and cut bureaucratic hurdles that constrain manufacturers from delivering improved products at sustainable prices.

The EC needs to let people who want to buy inexpensive PV modules make that choice, knowing that their systems may fail more quickly or underperform compared to better-made devices. This is how free markets work. Price controls might sound good and proper to home-grown interests lobbying the EC, but marketplace forces ultimately decide whether a product sells, or just sits.

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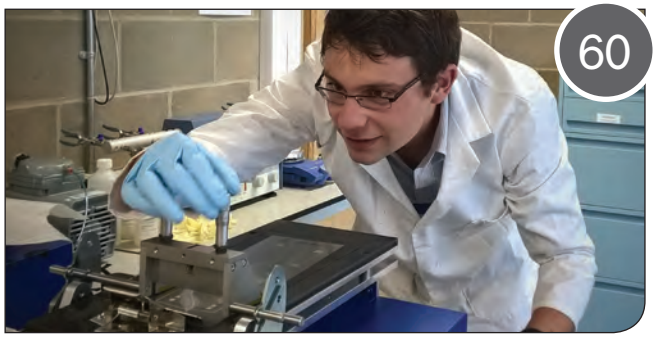

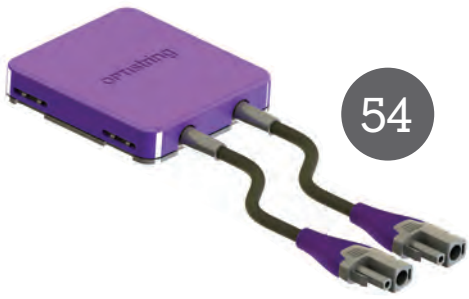

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Ecoppia to deploy robotic technology to 40 MW PV site

ECOPPIA has inked a deal to retrofit a 40 MW PV solar site jointly owned by EDF RE and Arava Power with its autonomous and waterless robotic cleaning solution.

The agreement is significant because it lends increasing commercial clout to a technology that is disrupting the solar energy business. Dirt and dust cover (soiling, in industry speak) on solar panels are a significant challenge and can decrease energy output by up to 40 percent. Existing solutions - oftentimes labourers with water and brushes - can damage panels, use huge amounts of water and be cost-inefficient.

Ecoppia provides a solution in the form of autonomous, waterless robots that are managed through the cloud and clean panels every night after production stops.

"It's the next step for the solar industry," says Eran Meller, CEO of Ecoppia. "We're seeing significant value creation in all the projects we're currently involved in, both here in the Middle East and in India. For many of the big industry players, a solution that can clean panels nightly, can respond instantly to weather and is waterless – we feel solutions like ours have the potential to become the industry standard."

The site is among the largest solar parks in the Middle East and is located in Southern Israel's Arava Valley – next to the Jordanian border and 20 and 60 miles from Egypt and Saudi Arabia, respectively. The cleaning technology is so promising that Meller has been asked by Israel to attend COP21 as part of a special delegation of green technology companies from Israel.

"It's very exciting to see the progress Ecoppia is making in terms of winning large clients – it's because of promising technology like theirs that we believe Israel has a bright future in the International Solar Industry and why Ecoppia was chosen to take part in a side event on "Israeli Innovation in response to climate change". This special event which the Government of Israel has organized together with Israel Green Energy Association, is part of the COP21," said Ron Adam, the permanent representative of Israel to IRENA (The International Renewable Energy Agency).

European Commission extends import tariff on Chinese solar panels

THE EUROPEAN COMMISSION extended its import tariffs and price controls on solar panels from China which were originally due to expire Monday 7 December. The move, called an Expiry Review, will mean that the import tariffs could remain in place for several more years and possibly until 2020.

The Commission announced on Saturday morning that it would undertake two Expiry Reviews into anti-dumping and countervailing measures, and an interim review as to whether cells should remain subject to the tariffs. The UK solar industry, represented by the Solar Trade Association, has expressed disappointment with the move which they say will continue to artificially inflate the price of solar unnecessarily.

However the EU can now, as part of its proceedings, officially consider whether the import duties are doing the European solar industry as a whole more harm than good, which the Solar Trade Association hopes will help bring the tariffs to an end.

Trina Solar board to consider buyout proposal

TRINA SOLAR has announced that its board of directors has received a preliminary non-binding proposal letter, from Mr. Jifan Gao, Chairman and Chief Executive Officer of the Company, and Shanghai Xingsheng Equity Investment & Management Co., Ltd. (together with Mr. Jifan Gao,), a subsidiary of Industrial Bank Co., Ltd, to acquire all of the outstanding shares of the Company not owned by the Buyer Group, including ordinary shares represented by American depositary shares.

The Board has formed a special committee consisting of two independent directors, Messrs. Sean Shao and Qian Zhao, to consider the proposal.

The Board, other than Mr. Jifan Gao, is reviewing and evaluating the proposal, and cautions its shareholders and others considering trading its securities that the Board has just received the proposal letter and has not had an opportunity to carefully review and evaluate the proposal yet, nor has the Board made any decision with respect to the Company's response to the proposal.

Silicor commits to carbon neutrality in Iceland

SILICOR MATERIALS, INC has announced an initiative to achieve a carbon-neutral status at its commercial manufacturing facility in Grundartangi, Iceland.
In cooperation with the Icelandic Forestry Association and the Icelandic Environment Association (KOLVIDUR), Silicor will fund the planting of more than 26,000 trees across the country to offset 2,800 tons of CO2 annually—enough to cover both Silicor's manufacturing process and the transportation logistics related to plant operations, shipping and receiving at the site.
Silicor produces solar silicon, a lower-cost alternative to the polysilicon that serves as the feedstock for the vast majority of solar photovoltaic (PV) technologies.

The company's manufacturing process is environmentally friendly by design, consuming as much as two-thirds less energy than traditional methods, and using no toxic chemicals. Silicor's manufacturing process produces only 48 tons of CO2 emissions per year. To further lessen its environmental impact, the company is locating its primary manufacturing plant in Iceland for shorter transportation routes to customers located in Europe and North America. Silicor plans to take advantage of local renewable energy resources (geothermal and hydroelectric) to further off-set environmental impacts and power its manufacturing plant once construction is completed. Silicor expects to actually have cash-in-hand in 2016 (not complete the building). Construction will take 2 years after cash is received; operation of the Iceland plant is expected to commence in 2019 –

The Silicor solar silicon process sends no waste to landfills; it instead produces two safe, by-products: an aluminum alloy and polyalumium chloride, both of which can be sold into a number of industries, including the automotive, aerospace and water treatment sectors.

"It's not enough for renewable energy companies to produce materials that support the growth of our industry. To leave a lasting positive impact, we must also adopt environmentally conscious business practices and reduce our own reliance on fossil fuels," said Terry Jester, Chairman and CEO of Silicor. "We chose to site our plant in Iceland in part because it allowed us to use 100-percent renewable energy to power our operations. By taking our commitment one step further and achieving carbon neutrality, we aim to serve as a barometer on environmental stewardship for organizations around the world."

Hanwha Q Cells Turkey grid connects 8.3 MW Plant

HANWHA Q CELLS Turkey, the Turkish branch of Hanwha Q CELLS Co., Ltd has finished construction and grid connection of an 8.3 MW solar power plant in Burdur, Turkey. The system is the first part of a project totalling 18.3 MW.

The construction of the second part, comprising 10 MW, is expected to start in 2016. Moreover, the company has closed a USD 20.15 Million project financing for the complete 18.3 MW together with Yapı Kredi Bank. In its largest solar project in Turkey so far, Hanwha Q CELLS Turkey has been responsible for module supply, engineering, procurement, construction (EPC), operations & maintenance (O&M) and also is a shareholder of 50 percent of the power plant with their partner Zen Enerji A.S. holding the other 50 percent.

Hanwha Q CELLS Turkey started construction of the park in Burdur, in south-west Turkey in August 2015 and reached grid connection two-and-a-half months later, in November 2015. The power plant is comprised of 31,878 polycrystalline solar modules of the type HSL60S and covers an area of around 128,600 m2. With 8.3 MW, the power plant is one of the largest in the country so far. It is expected to produce around 13.467 megawatt hours of clean energy per year, which is to be fed into the grid; enough to power around 2,700 average households in Turkey.

Solarpark Blautal potential new investor of centrotherm

SOL FUTURA VERWALTUNGSGESELLSCHAFT GmbH has concluded an agreement concerning the disposal of its entire 80 percent interest in centrotherm photovoltaics AG. Solarpark Blautal GmbH, Blaubeuren, is the acquirer of the interest. This company's shareholders comprise centrotherm co-founder Robert M. Hartung as well as an international strategic investor.

Following the execution of the purchase agreement, which still depends on conditions being met, Solarpark Blautal will hold 90 percent of the shares in centrotherm photovoltaics AG, including the shares of TCH. The purchase agreement is anticipated to be executed by the end of the first quarter of 2016 at the latest. The shares in Swabia-based technology and systems supplier centrotherm will then transfer from Sol Futura to the new owner. centrotherm co-founder Robert M. Hartung and an international strategic investor will then hold a qualified majority of the shares in centrotherm photovoltaics AG via Solarpark Blautal.

The employees have been informed about the transaction at an employee meeting held today. Robert M. Hartung comments as follows on the forthcoming transaction: "As co-founder of centrotherm photovoltaics AG, I have always felt committed to the company, and to finding a further investor for it. We have managed to acquire an international strategic investor as a co-shareholder, and I am convinced that together we can provide important impulses for the company's future."

The Management Board of centrotherm photovoltaic AG has negotiated a financing agreement to secure the company's financing after the disposal of the interest by Sol Futura. The due insolvency receivables of unsubordinated creditors of centrotherm photovoltaics AG as well as of one of its former subsidiaries will be serviced one month after the execution of the transaction.

Once the disposal of the interest comes into force and creditors are satisfied, the insolvency plan of centrotherm photovoltaics AG would be almost completely fulfilled, subsequent to approval of the plan by the Ulm District Court. The new investor and majority shareholder Solarpark Blautal will retain the Blaubeuren location.

Fitch releases report on Brazilian solar PPA structure

FITCH RATINGS has published a new special report: 'Brazilian Solar PPA Structure'. The report describes the key elements related to volume and price risks for solar PV projects in that country, and how that translates to revenue volatility.

The standard power purchase agreement (PPA) under energy reserve auctions for solar photovoltaic (PV) draft has been made public and is applicable to all regulated solar PV projects.

The report discusses the structural mechanisms present in the PPAs affecting revenue predictability and describes how annual settlement payments work when energy volumes are lower or higher than the volume sold in the PPA.

The degree of cash flow volatility for a Brazilian solar project is mostly driven by the volume of energy sold, either at P-50 or P-90 levels, as these projects are not exposed to spot prices,' said Victor Tamega, Associate Director in the Global Infrastructure and Project Finance Group, based in Brazil.

Fitch describes the main differences between PPAs for the nascent solar PV sector in the country in contrast to wind project PPAs.

Solar PV projects will not benefit from quadrennial measurement periods present in wind PPAs which smooth out revenues in the event of production shortfalls,' said Tamega.

Canadian Solar secures additional loan with Credit Suisse

CANADIAN SOLAR INC has announced that it has raised a final tranche of $80.0 million under its previously announced two-year senior secured term loan arranged by Credit Suisse AG, Singapore Branch ("Credit Suisse"), bringing the total facility amount to $180.0 million.

In connection with the term loan, Canadian Solar issued the lenders warrants to purchase up to 940,171 shares of common stock at an exercise price of $28.08 per share.

The warrants will expire two years from the date of the closing, on December 10, 2017. This term loan is being used for general corporate purposes.

"We are pleased with the positive outcome of this transaction and we appreciate the confidence of the lenders in our business," said Dr. Shawn Qu, Chairman and Chief Executive Officer of Canadian Solar.

Ifratech supplies Californian floating solar panel array

A LARGE SCALE floating solar panel array road tested in the South Australian Outback is set to soak up the Californian sunshine.

The City of Holtville has signed an agreement with Aussie company Infratech to manufacture the one megawatt floating solar system including 3576 panels, 276 rafts and 12 treatment pumps.

It will float on the surface and power a new water treatment plant to be used for the town's drinking water supply and irrigation. The system will also significantly reduce evaporation and decrease the reliance on chemicals such as chlorine to treat the water.

The photosynthesis process that creates blue-green algae will be limited by the shade provided by the panels, which will also keep the water cool and further raise its quality.The floating system can shift on the surface in the instance of tremors and is purpose-built to withstand waves.

"Our decision to use Infratech's floating solar system means we are not losing valuable farmland to massive solar farms; we can use three existing ponds and save our soil for increasing our capacity to produce crops," he said.

The floating system can shift on the surface in the instance of tremors and is purpose-built to withstand waves. The system is expected to be fully installed and operational by mid-2016.

Infratech this year opened its first floating solar system at Jamestown in the mid-North of South Australia.
The 300kg Jamestown floating solar array is putting renewable energy back into the local grid and powering the council's water treatment facility. It is the first of its kind in Australia.
The Infratech system claims to generate more than 50 per cent more energy than rooftop solar systems to deliver consumers a saving of up to 15 per cent on regular electricity prices.

Trina Solar withdraw from EU price undertaking

TRINA SOLAR has announced its withdrawal from the European Union ("EU") Price Undertaking ("UT") and will continue to service EU customers through its overseas manufacturing facilities.

On December 5, 2013, the European Council imposed anti-dumping ("AD") and anti-subsidy ("AS") duties on solar cells and solar panels imported from China. Subsequently, the European Commission accepted a UT whereby Chinese companies would sell solar cells and solar panels in the EU at a price above a fixed Minimum Import Price ("MIP"). Chinese manufacturers that did not accept the terms of the agreement faced high AD and AS duties, which for Trina Solar were 47.7 percent and 3.5 percent, respectively, to be applied for a period of two years beginning on December 6, 2013.

At the time, Trina Solar chose to join the UT as a participating company and has duly complied with its terms and conditions.

However, the current interpretations of the UT agreement by EU Commission unfairly limit the Company's growth potential in the European region, and are disruptive to the Company's ongoing global expansion strategy.

Furthermore, the EU Commission announced recently to initiate review investigation during which the AD&AS and the UT measures will remain in force. Trina Solar believes this is contrary to the principles of free and fair trade and it is in its best interest to exit the UT. Mr Jifan Gao, Chairman and Chief Executive Officer of Trina Solar, commented:

"We believe the current iteration of the UT agreement misinterprets the rules and scope of the original UT, and adversely affects the execution of our global expansion strategy. In particular, the prohibition of manufacturing modules in overseas facilities, regardless of whether the modules will be sold to the EU or to non-EU markets is an obvious misapplication to the UT agreement. Furthermore, we believe the current MIP does not reflect the ongoing market trends in the solar sector, particularly as average selling prices in major markets continue to decline at a faster than expected rate, with downward pressure anticipated to continue for the foreseeable future. Consequently, the Chinese companies that are party to the UT have lost their competitiveness to their non-Chinese peers in selling to EU markets.

With our recognised brand name, advanced technology and established customer base, we believe our withdrawal from the UT will allow us to better develop our business in the region through our tariff-free overseas facilities, and to regain market share under a more flexible pricing strategy.

However, I would like to emphasise our continued commitment to fair market competition and a balanced trading environment that would help to achieve our mission of benefiting mankind with clean energy."

Betely selects ASM to facilitate silver paste research

ASM ALTERNATIVE ENERGY (ASM AE) announced that its HouYi solar cell metallization platform has been selected by Suzhou Betely Polymer Materials Co., Ltd. (Betely) to enable the company's advanced silver paste development.

Betely, which holds numerous patents for its innovations, produces multiple materials for the electronics sector including inks and coatings, conductive and non-conductive adhesives, RFID inlays and biological and semiconductor electrodes. The company's latest research is focused on silver paste optimization for higher efficiency solar cells.

"Our knowledge of silver paste technology for various applications in the electronics and photovoltaics industries has informed this latest research initiative," explains Mr. Li Liang, Technical Director of Betely.

"Central to the solar cell paste project is the ability to analyze the performance of the material in the printing process and we needed a platform with exceptional accuracy, control and ease-of-use. ASM AE's HouYi met all of our requirements, as we aim to develop a paste that can help customers achieve exceptional solar cell quality and efficiency."

HouYi's small footprint, 1,450 wafer per hour (wph) capability and scalability make it the ideal platform for multiple applications – from R&D thorough to commercial solar cell production. Robust handling of wafers as thin as 120 μm and an intuitive control system unite to simplify complex processes and produce high-yield solar cells.

HouYi's reliable performance, low breakage rates of <0.3 percent and alignment capability of 2 CpK @ +/- 12.5μm lead the market among 1,450 wph platforms.

In addition to HouYi's proven performance, Betely's decision to partner with ASM AE also hinged on the company's world-class support and service capability. In fact, Betely's visit to ASM AE's state-of-the-art Suzhou Technology Center helped secure the business relationship, as Betely was impressed with the scope of resource and expertise available, as well as the collaborative spirit of the ASM AE team.

"ASM AE is the only manufacturer in the industry to have invested in a technology centre to better understand solar cell process characterization that goes well beyond function of the print system," comments Mr. Hong Xu, Deputy Managing Director of Betely. "This comprehensive approach aligns with our company culture very well and we fully trust that ASM AE will be instrumental in this and future development projects."

Heraeus expands Taiwanese paste production

HERAEUS PHOTOVOLTAICS announced at the PV Taiwan trade exposition in Taipei that it is expanding its presence in the Republic of China (RoC) by adding local manufacture of front-side metallization pastes to its existing product line.

Making the announcement in a ribbon cutting ceremony on the tradeshow floor was a delegation of senior executives including Andreas Liebheit, President of Heraeus Photovoltaics Global Business Unit; Dr. P. H. Chang, CEO of Motech Industries, Inc., Chairman of the SEMI Taiwan PV Committee and the TPVIA; and Dr. Sam Hong, CEO of Neo Solar Power Corp.

Heraeus expects manufacture of front-side pastes to begin in its expanded Taiwanese facility in November.

Installers in Germany offer energy storage systems

PV INSTALLERS in Germany offer energy storage solutions to their customers more often as compared to last year. This is one of the results from a current study by market researcher EuPD Research.

For the eight year running EuPD Research is compiling the annually published study „European PV InstallerMonitor". The study offers comprehensive insights into important photovoltaic markets. For this purpose, installers of PV systems are surveyed about several relevant topics.

The "European PV InstallerMonitor 2015/2016" shows that PV installers in Germany carry energy storage systems more often in their portfolio in comparison to last year. Around three quarters of all surveyed installers offer energy storage solutions to their customers, which corresponds to an increase of six percentage points to the previous year. When PV systems are equipped with energy storage solutions, in 83 percent this refers to new installs and not to retro-fitting existing PV systems with energy storage. Further topics of the study include the brand portfolio, recommendation levels of and the satisfaction with PV module, inverter and energy storage manufacturers. Furthermore, the procurement management of the surveyed installers is a subject. A part of this analysis focuses on whether installers prefer to purchase directly from the manufacturer or indirectly via wholesaler.

The focus countries of the study are the European core markets Germany, the UK, Italy, France, the Netherlands, Austria and Switzerland. Furthermore, for the first time, the photovoltaic market in Australia, a country with a high potential for solar energy, is included in the survey

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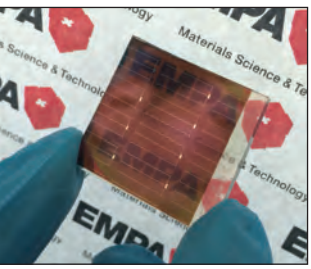
Tandem solar cells are simply **better**

Empa researchers have come up with a procedure that makes it possible to produce thin film tandem solar cells in which a thin perovskite layer is used.

STACKING TWO SOLAR CELLS one over the other has advantages: Because the energy is "harvested" in two stages, and overall the sunlight can be converted to electricity more efficiently. Empa researchers have come up with a procedure that makes it possible to produce thin film tandem solar cells in which a thin perovskite layer is used. The processing of perovskite takes place at just 50 degrees Celsius and such a process is potentially applicable for low cost roll-to-roll production in future.

What is true for double-blade razors is also true for solar cells: two work steps are more thorough than one. Stacking two solar cells one on top of the other, where top cell is semi-transparent, which efficiently converts large energy photons into electricity, while the bottom cell converts the remaining or transmitted low energy photons in an optimum manner.

This allows a larger portion of the light energy to be converted to electricity. Up to now, the sophisticated technology needed for the procedure was mainly confined to the realm of Space or Concentrated Photovoltaics (CPV). These "tandem cells" grown on very expensive single crystal wafers are considered not attractive for mass production and low cost solar electricity.



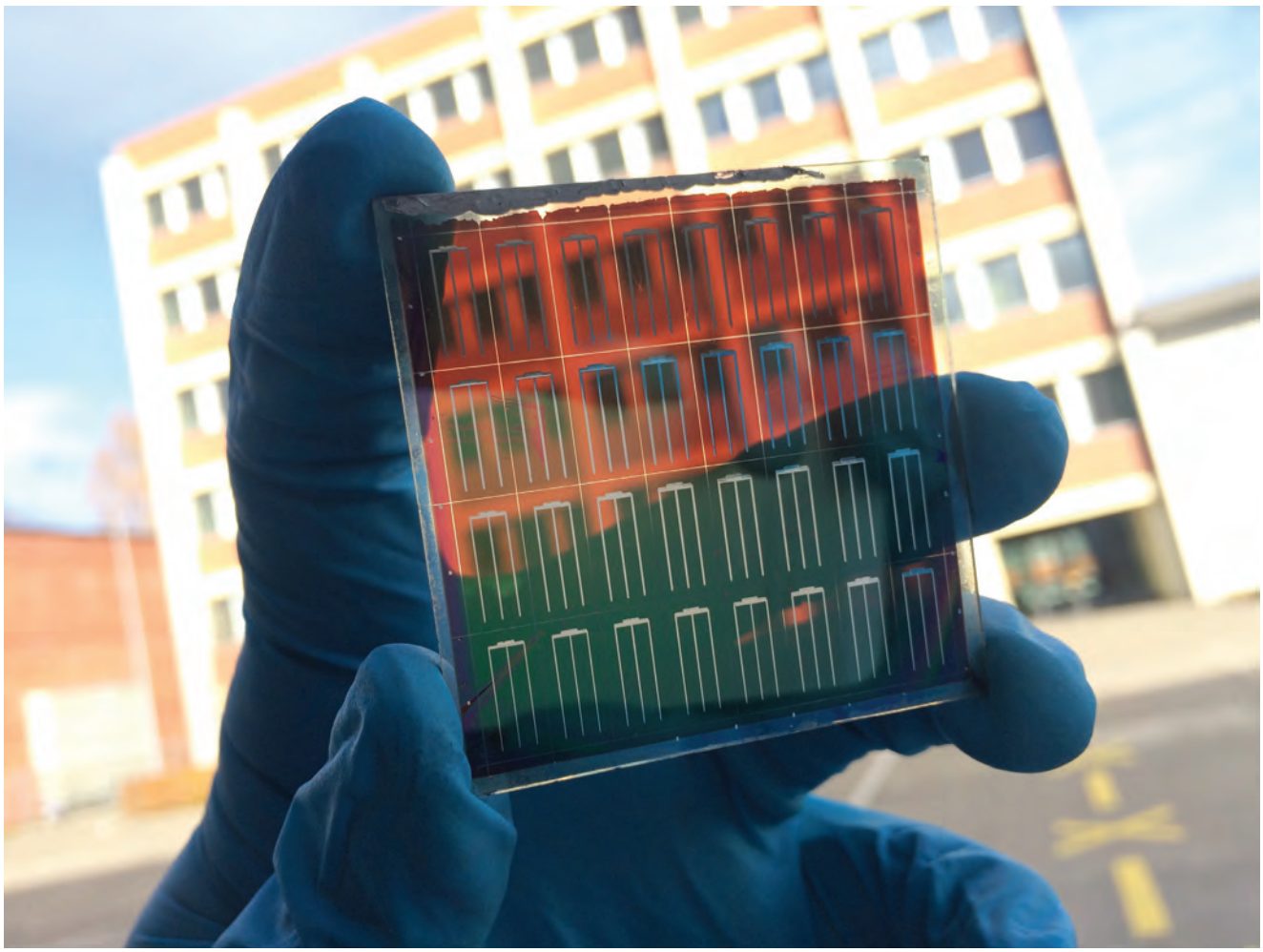
The research team working under Stephan Buecheler and Ayodhya N. Tiwari from the Laboratory for Thin Films and Photovoltaics at Empa-Swiss Federal Laboratories for Material Science and Technology has now succeeded in making tandem solar cells that are based on polycrystalline thin films, and the methods are suitable for large area low cost processing, Flexible plastic or metal foils could also be used as substrate in future. This marks a major milestone on the path to mass production of high-efficiency solar cells with low cost processes.
The secret behind the new process is that the researchers create the top solar cell perovskite film with a low-temperature procedure at just 50 degrees Celsius. This promises an energy-saving and cost-saving production stage for future manufacturing processes. The tandem solar cell yielded an efficiency rate of 20.5 percent when converting light to electricity. Already with this first attempt Empa researchers have emphasized that it has lots more potential to offer for better conversion of solar spectrum into electricity.

Molecular soccer balls as a substrate for the magic crystal

The key to this double success was the development of a 14.2 percent efficient semi-transparent solar cell, with 72 percent average transparency, made from methylammonium lead iodide deposited in the form of tiny perovskite crystals. The perovskite is grown on a thin interlayer made of the substance abbreviated as PCBM (phenyl-C61-butyric acid methyl ester) is used . Each PCBM molecule contains 61 carbon atoms interconnected in the shape of a soccer ball. The perovskite film is prepared by a combination of vapour deposition and spin coating onto this layer, which has tiny football like structure, followed by an annealing at a "lukewarm" temperature. This magic perovskite crystal absorbs blue and yellow spectrum of visible light and converts these into electricity. By contrast, red light and infrared radiation simply pass through the crystal. As a result, the researchers can attach a further solar cell underneath the semi-transparent perovskite cell in order to convert the remaining light into electricity.

Advantage of the double-layer cell: better use of the spectrum of sunlight

For the lower layer of the tandem solar cell, the Empa researchers use a CIGS cell (copper indium gallium diselenide), a technique that the team has been researching for years. Based on the CIGS cells, small-scale production is already under way for flexible solar cells.



A scientist shows, how much light can pass through the new perovskite cell developed at Empa. (Image: Empa). The advantage of tandem solar cells is that they exploit sunlight better. A solar cell can only convert radiation with an energy level higher than the bandgap of the semiconductor used. If the radiation is weaker, no electricity is generated. If the radiation is higher in energy, the excess radiated energy is converted to heat and is lost. A double-layer solar cell like Empa's perovskite CIGS cell can combine substances with differing bandgaps and thus convert a larger share of the irradiated solar energy to electricity.

More than 30 percent efficiency is possible
While very good single-layer polycrystalline solar cell may practically convert a maximum of 25 percent of the solar energy to electricity, tandem solar cells could increase this figure to beyond 30 percent. That's according to Ayodhya Tiwari, head of the Thin Film and Photovoltaics laboratory. He does say, however, that a lot of research work is needed before that will be possible. "What we have achieved now is just the beginning. We will have to overcome many obstacles before reaching this ambitious goal. To do this, we will need lots of interdisciplinary experience and a large number of combinatorial experiments until we have found a semi-transparent high-performance cell together with the right base cell, and technologies for electrical interconnections of these solar cells."

Stephan Bücheler, who coordinates the lab research in Tiwari's team, reminds us that the race for efficiency in solar cell research is certainly not just an academic show. "When producing solar-powered electricity, only half of the costs are down to the solar module itself. The other half are incurred for the infrastructure: inverters, cables, carriers for the cells, engineering costs and installation. These ancillary costs are reduced when the solar cells become more efficient and can be built in smaller sizes as a result. This means that efficient solar cells are the key to low-cost renewable electricity."

Green storage for Green energy

Rechargeable battery to power a home from rooftop solar panels.

THIS IMPROVED FLOW BATTERY could make storage of electricity from intermittent energy sources like solar and wind safe and cost-effective for both residential and commercial use. Unlike solid-electrode batteries, flow batteries store energy in liquids contained in external tanks (seen here in red and green), similar to fuel cells.

Harvard researchers wanted to improve on their 2014 flow battery. Their goal was to replace the conventional bromine-bearing electrolyte with something nontoxic. The team's findings "deliver the first high-performance, nonflammable, nontoxic, noncorrosive, and low-cost chemicals for flow batteries."

A team of Harvard scientists and engineers has demonstrated a rechargeable battery that could make storage of electricity from intermittent energy sources like solar and wind safe and cost-effective for both residential and commercial use. The new research builds on earlier work by members of the same team that could enable cheaper and more reliable electricity storage at the grid level.

The mismatch between the availability of intermittent wind or sunshine and the variability of demand is a great obstacle to getting a large fraction of our electricity from renewable sources. This problem could be solved by a cost-effective means of storing large amounts of electrical energy for delivery over the long periods when the wind isn't blowing and the sun isn't shining.

In the operation of the battery, electrons are picked up and released by compounds composed of inexpensive, earth-abundant elements (carbon, oxygen, nitrogen, hydrogen, iron and potassium) dissolved in water. The compounds are non-toxic, non-flammable, and widely available, making them safer and cheaper than other battery systems.

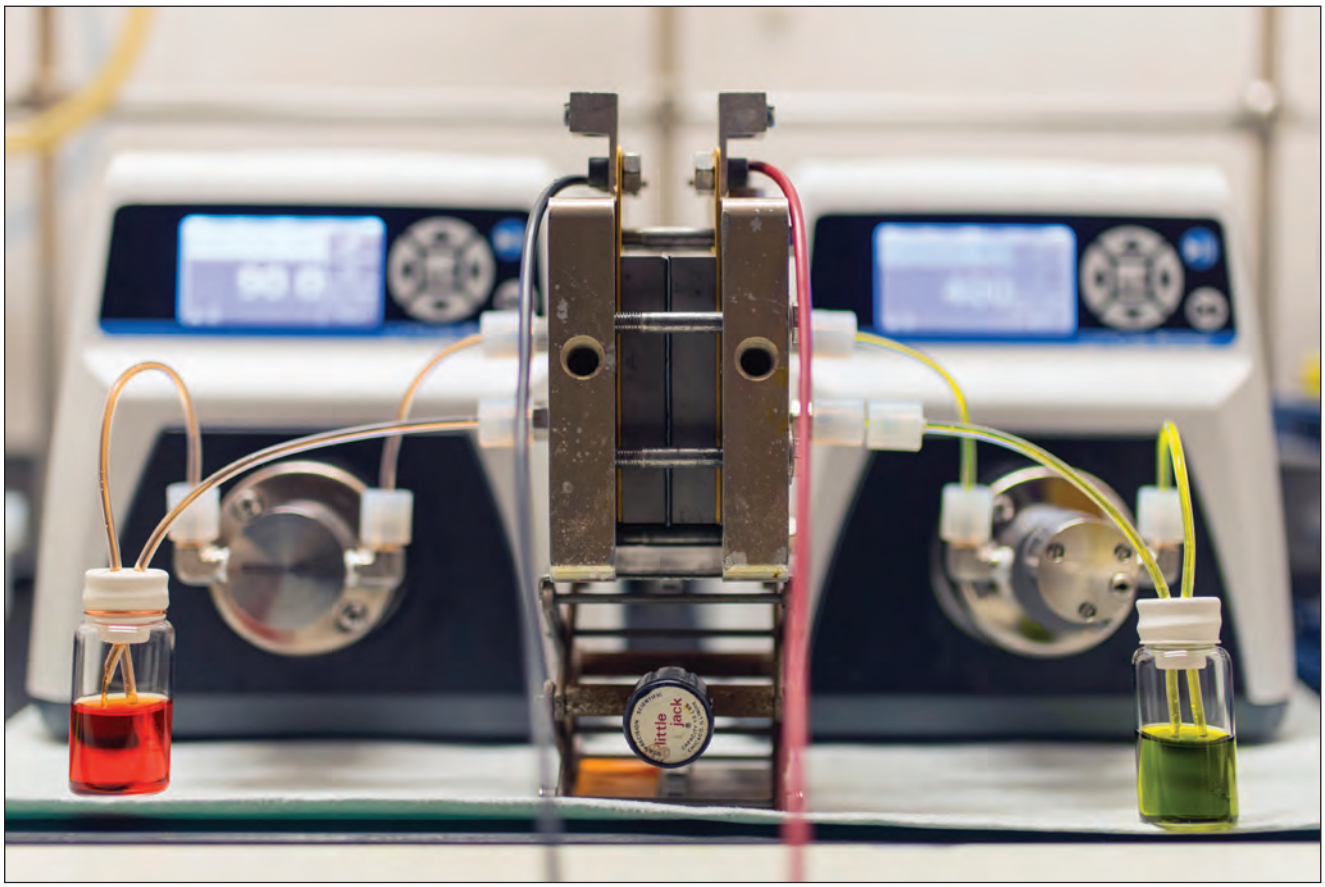
"This is chemistry I'd be happy to put in my basement," says Michael J. Aziz, Gene and Tracy Sykes Professor of Materials and Energy Technologies at Harvard Paulson School of Engineering and Applied Sciences (SEAS), and project Principal Investigator. "The non-toxicity and cheap, abundant materials placed in water solution mean that it's safe -- it can't catch on fire -- and that's huge when you're storing large amounts of electrical energy anywhere near people."

The research appears in a paper published in the journal Science. This new battery chemistry was discovered by post-doctoral fellow Michael Marshak and graduate student Kaixiang Lin working together with co-lead author Roy Gordon, Thomas Dudley Cabot Professor of Chemistry and Professor of Materials Science at Harvard.

"We combined a common organic dye with an inexpensive food additive to increase our battery voltage by about 50 percent over our previous materials," says Gordon. The findings "deliver the first high-performance, non-flammable, non-toxic, non-corrosive, and low-cost chemicals for flow batteries."

Unlike solid-electrode batteries, flow batteries store energy in liquids contained in external tanks, similar to fuel cells. The tanks (which set the energy capacity), as well as the electrochemical conversion hardware through which the fluids are pumped (which sets peak power capacity), can be sized independently. Since the amount of energy that can be stored can be arbitrarily increased by scaling up only the size of the tanks, larger amounts of energy can be stored at lower cost than traditional battery systems.

The active components of electrolytes in most flow battery designs have been metal ions such as vanadium dissolved in acid. The metals can be expensive, corrosive, tricky to handle, and kinetically sluggish, leading to inefficiencies. Last year, Aziz and his Harvard colleagues demonstrated a flow battery that replaced metals with organic (carbon-based) molecules called quinones, which are abundant, naturally occurring chemicals that are integral to biological processes like photosynthesis and cellular respiration.



(Photo courtesy of Kaixiang Lin)

Unlike solid-electrode batteries, flow batteries store energy in liquids contained in external tanks (seen here in red and green), similar to fuel cells. Electrons are picked up and released by compounds composed of inexpensive, earth-abundant elements dissolved in water. The compounds are non-toxic, non-flammable, and widely available, making them safer and cheaper than other battery systems.

While quinones in aqueous solution formed the negative electrolyte side of the battery, the positive side relied on a conventional bromine-bearing electrolyte that is used in several other batteries. The high performance and low cost of the technology, which Harvard has licensed to a company in Europe, hold the potential to provide scalable grid-level storage solutions to utilities.

But bromine's toxicity and volatility make it most suitable for settings where trained professionals can deal with it safely behind secure fences.
So the team began searching for a new recipe that would provide comparable storage advantages -- inexpensive, long lasting, efficient -- using chemicals that could be safely deployed in homes and businesses. Their new battery, described in a paper published today in the journal Science, replaces bromine with a non-toxic and non-corrosive ion called ferrocyanide.

"It sounds bad because it has the word 'cyanide' in it," explains co-lead author Marshak, who is now assistant professor of chemistry at the University of Colorado Boulder. "Cyanide kills you because it binds very tightly to iron in your body. In ferrocyanide, it's already bound to iron, so it's safe. In fact, ferrocyanide is commonly used as a food additive, and also as a fertilizer."

Because ferrocyanide is highly soluble and stable in alkaline rather than acidic solutions, the Harvard team paired it with a quinone compound that is soluble and stable under alkaline conditions, in contrast to the acidic environment of their original battery developed last year. Marshak compares exposure to the concentrated alkaline solution to coming into contact with a damaged disposable AA battery. "It's not something you want to eat or splash around in, but outside of that it's really not a problem."
There are other advantages to using alkaline solution. Because it is non-corrosive, the flow battery system components can be constructed of simpler and much less expensive materials such as plastics.

"First generation flow batteries were single-element couples -- transition metals like vanadium or iron or chrome," says Michael Perry, Project Leader for Electrochemical Systems at United Technologies Research Centre, who was not involved in the work. "Now we're seeing the possibility of engineered molecules giving us the properties and attributes that we want in one complete system. More work is required and justified but the Harvard team is really

> "A cloud comes over your solar installation and BAM – the production goes crashing down. Then the cloud goes away and the production goes shooting up. The best way of dealing with that is with batteries"

demonstrating the promise of next-generation chemistries."

Robert F. Savinell, Distinguished University Professor and George S. Dively Professor of Engineering at Case Western Reserve University, another battery expert who was not part of the Harvard research, agrees that the new technology offers significant advantages over other flow batteries concepts, including "potential very low costs with sustainable materials, high efficiencies at practical power densities, and safe and simple operation."

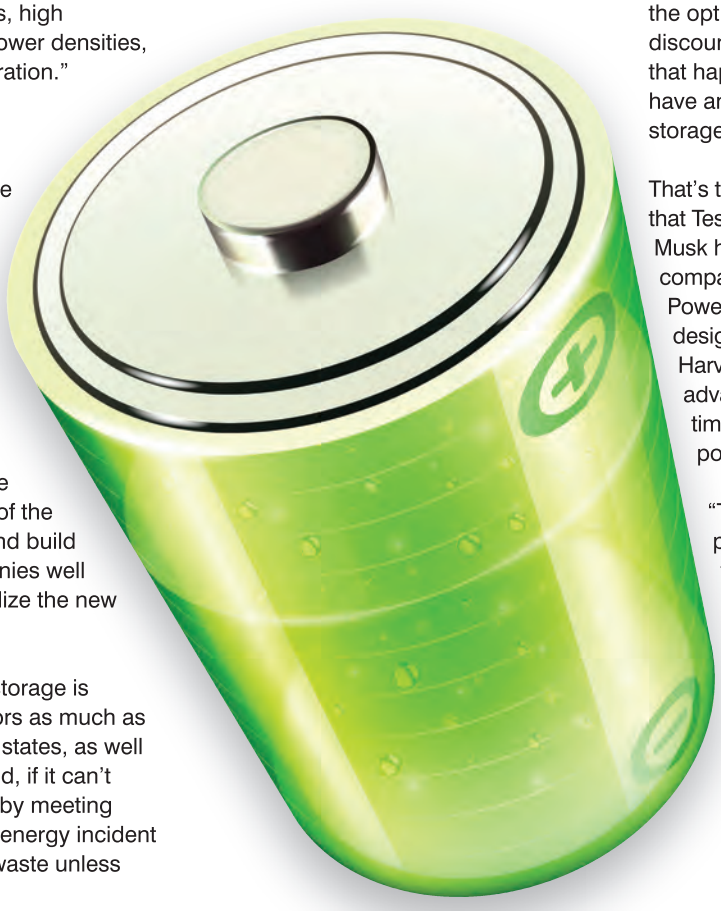
He adds: "It should be expected that this flow battery approach will have a short development and scale-up path for fast commercial introduction."

Harvard's Office of Technology Development has been working closely with the research team to navigate the shifting complexities of the energy storage market and build relationships with companies well positioned to commercialize the new chemistries.

The demand for battery storage is driven by regulatory factors as much as economic ones. In some states, as well as many parts of the world, if it can't be instantaneously used by meeting electricity demand, solar energy incident on solar panels goes to waste unless the electricity is stored.

However, in many states, customers have the right to sell electricity produced by rooftop solar panels at high consumer rates under a regulatory scheme called net metering.

Under those circumstances, consumers have little incentive to install batteries. But market experts like William W. Hogan, Raymond Plank Professor of Global Energy Policy at Harvard Kennedy School, believe that such policies are ultimately "uneconomic and unsustainable." And as more and more homeowners install solar panels, utilities are opposing requirements to buy electricity from their customers.



Hogan says net metering is one of a series of "regulatory gimmicks designed to make solar more attractive" and predicts that eventually consumers with rooftop photovoltaic panels will lose the option of exchanging electricity for discounts on their utility bills. When that happens, these homeowners have an incentive to invest in battery storage.

That's the emerging market opportunity that Tesla Motors entrepreneur Elon Musk hopes to leverage with his company's recently-announced Powerwall system. But the flow battery design engineered by Aziz and his Harvard colleagues offers potential advantages in cost and the length of time it can maintain peak discharge power compared to lithium batteries.

"This has potential because photovoltaics are growing so fast," Aziz says. "A cloud comes over your solar installation and BAM – the production goes crashing down. Then the cloud goes away and the production goes shooting up. The best way of dealing with that is with batteries."

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Stanford researcher suggests storing solar energy underground for a cloudy day

A common criticism of a total transition to wind, water and solar power is that the U.S. electrical grid can't affordably store enough standby electricity to keep the system stable. Stanford researcher Mark Z. Jacobson proposes an underground solution to that problem.

A NEW STUDY shows that wind, water and solar generators can theoretically result in a reliable, affordable national grid when the generators are combined with inexpensive storage.

Over the last few years, Mark Jacobson, a Stanford professor of civil and environmental engineering, and his colleague, Mark Delucchi of the University of California, Berkeley, have produced a series of plans, based on huge amounts of data churned through computer models, showing how each state in America could shift from fossil fuel to entirely renewable energy.

In a new study published today in Proceedings of the National Academy of Sciences, they use the data from those single-state calculations of the number of wind, water and solar generators potentially needed in each state to show that these installations can theoretically result in a reliable, affordable national grid when the generators are combined with inexpensive storage and "demand response" – a program in which utilities give customers incentives to control times of peak demand.

An underground effort

The proposed system relies on the ability to store and retrieve heat, cold and electricity in order to meet demand at all times.
Summer heat gathered in rooftop solar collectors could be stored in soil or rocks and used for heating homes in winter. Excess or low-cost electricity could be used to make ice, which would be used for later cooling when the price of electricity is high.
Excess electricity could also be used to make more electricity, by supplementing the energy-producing mechanisms that drive concentrated solar power plants and pumped hydroelectric facilities. Utilities would also provide incentives to reduce energy use during times of peak demand.

In Jacobson's plan, hydrogen would also be used as a storage medium; during low-demand hours, excess electricity would be used to create hydrogen, which could be stored in fuel cells and used to power some vehicles.

Jacobson's new model foresees, and is dependent upon, an all-electric country, with virtually everything running 100 percent on electricity: cars, trains, buses, industry, heating and cooling, and with the electricity originating from wind, water and sunlight.
There would be no need for coal, natural gas, biofuels, nuclear power or enormous battery farms for storing electricity. Such a world, which would be 100 percent clean by 2050, can result in a stable grid, he said.

Jacobson's previous studies have drawn wide attention, but critics have argued that a national electric grid without power plants powered by coal for background power and natural gas to fill in gaps of supply would not be reliable. The wind doesn't always blow and the sun doesn't always shine, and batteries for the grid are not yet affordable enough for storing and managing the nation's electricity.
"The utilities and others who are against renewables have always argued that the lights are going to go out, the grid is going to be unstable, and it will cost too much to keep a clean, renewable-energy grid stable and reliable," Jacobson said. "Skeptics have never studied a system of 100 percent clean, renewable energy for all purposes, and particularly one that combines low-cost storage with demand response and some hydrogen, as in this new paradigm."

Jacobson, who is also a senior fellow at the Stanford Woods Institute for the Environment and the Precourt Institute for Energy, briefed a congressional panel on his research on Nov. 19.

Restructuring the grid

In his new study, Jacobson and his co-authors, including Bethany Frew, now at the National Renewable Energy Laboratory, and graduate student Mary Cameron, suggest that combining existing low-cost ways of storing green energy and using that stored energy

to smooth out the uneven demand for electricity, heat and cold simultaneously over the course of a minute, day, week or year could solve that problem.

All raw energy for this system would come from wind, water and sunshine – no natural gas, biofuels, coal or nuclear power. The resulting drop in air pollution would save tens of thousands of lives each year, the researchers say. Sixty thousand to 65,000 people die prematurely in America annually as a result of air pollution.

As a demonstration of some of these technologies, Jacobson points to the Drake Landing Solar Community in Canada, near Calgary. The 52 homes there are heated in winter with solar energy captured and stored underground during the summer. Water warmed to 175 degrees Fahrenheit by the sun is kept in insulated tubing buried under 120 feet of rocks, earth and insulation. The stored warmth is enough to heat the homes in the community through winter, Jacobson said.

An all-electric nation could reap a number of benefits. While the cost of electricity per kilowatt hour in Jacobson's system might be about the same as electricity generated from fossil fuels, users would actually spend about 30 percent less due to the fact that fewer kilowatt hours are needed in the new system because the efficiencies of electric engines exceed those of combustion engines, Jacobson said.

And underground storage of energy is cheaper than batteries, he added. Some wind turbines now shut down when there is no immediate demand for their electricity, because the cost of storing it is too high. Using excess electricity to produce heat simultaneously with using solar collectors to produce heat increases the availability of stored energy.

Widespread use of underground energy storage and the other types of storage he proposes would cost much less than batteries, Jacobson says. Storing electricity in batteries currently costs $350/kilowatt hour, compared with a cost two orders of magnitude lower for storing heat in soil, he said. Similarly, storage in concentrated solar power, pumped hydroelectric power and existing hydroelectric reservoirs costs one-tenth of storage in batteries.

"You eliminate air pollution and global warming emissions, stabilize fuel costs, create over two million more jobs than are lost in the U.S., you reduce reliance on international trade of fuels, and you reduce the risk of power disruption, such as from terrorism or massive failure, because more energy is distributed over larger areas," Jacobson said. "Most energy would be local. You can eliminate a lot of fuel emissions, just because you won't have to transport oil in tankers across the ocean, you won't have to use trains of coal cars to ship the coal."

This methodology for keeping the grid stable, he said, should work in many places worldwide.
Mark A. Delucchi, Mary A. Cameron and Bethany A. Frew are co-authors of the research paper.

"underground storage of energy is cheaper than batteries, he added. Some wind turbines now shut down when there is no immediate demand for their electricity, because the cost of storing it is too high"

New approaches for hybrid solar cells

Using a new procedure researchers at the Technical University of Munich (TUM) and the Ludwig Maximillians University of Munich (LMU) can now produce extremely thin and robust, yet highly porous semiconductor layers. A very promising material – for small, light-weight, flexible solar cells, for example, or electrodes improving the performance of rechargeable batteries.

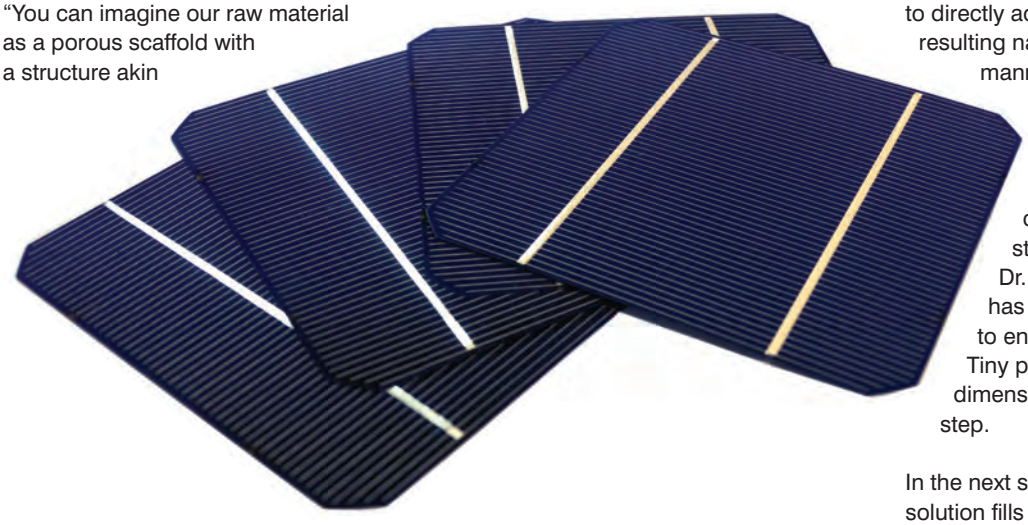
THE COATING on the wafer that Professor Thomas Fässler, chair of Inorganic Chemistry with a Focus on Novel Materials at TU Munich, holds in his hands glitters like an opal. And it has amazing properties: It is hard as a crystal, exceptionally thin and – since it is highly porous – light as a feather.

By integrating suitable organic polymers into the pores of the material, the scientists can custom tailor the electrical properties of the ensuing hybrid material. The design not only saves space, it also creates large interface surfaces that improve overall effectiveness.

"You can imagine our raw material as a porous scaffold with a structure akin to a honeycomb. The walls comprise inorganic, semiconducting germanium, which can produce and store electric charges. Since the honeycomb walls are extremely thin, charges can flow along short paths," explains Fässler.

The new design: bottom-up instead of top-down

But, to transform brittle, hard germanium into a flexible and porous layer the researchers had to apply a few tricks. Traditionally, etching processes are used to structure the surface of germanium. However, this top-down approach is difficult to control on an atomic level. The new procedure solves this problem.



Together with his team, Fässler established a synthesis methodology to fabricate the desired structures very precisely and reproducibly. The raw material is germanium with atoms arranged in clusters of nine. Since these clusters are electrically charged, they repel each other as long as they are dissolved. Netting only takes place when the solvent is evaporated.

This can be easily achieved by applying heat of 500°C or it can be chemically induced, by adding germanium chloride, for example. By using other chlorides like phosphorous chloride the germanium structures can be easily doped. This allows the researchers to directly adjust the properties of the resulting nanomaterials in a targeted manner.

Tiny synthetic beads as nanotemplates

To give the germanium clusters the desired porous structure, the LMU researcher Dr. Dina Fattakhova-Rohlfing has developed a methodology to enable nanostructuring: Tiny polymer beads form three-dimensional templates in an initial step.

In the next step, the germanium-cluster solution fills the gaps between the

beads. As soon as stable germanium networks have formed on the surface of the tiny beads, the templates are removed by applying heat. What remains is the highly porous nanofilm. The deployed polymer beads have a diameter of 50 to 200 nanometers and form an opal structure. The germanium scaffold that emerges on the surface acts as a negative mold – an inverse opal structure is formed. Thus, the nanolayers glitter like an opal.

"The porous germanium alone has unique optical and electrical properties that many energy relevant applications can profit from," says LMU researcher Dr. Dina Fattakhova-Rohlfing, who, in collaboration with Fässler, developed the material. "Beyond that, we can fill the pores with a wide variety of functional materials, thereby creating a broad range of novel hybrid materials."

Nanolayers pave the road to portable photovoltaic solutions

"When combined with polymers, porous germanium structures are suitable for the development of a new generation of stable, extremely light-weight and flexible solar cells that can charge mobile phones, cameras and laptops while on the road," explains the physicist Peter Müller-Buschbaum, professor of functional materials at TU Munich.

Manufacturers around the world are on the lookout for light-weight and robust materials to use in portable solar cells. To date they have used primarily organic compounds, which are sensitive and have relatively short lifetimes. Heat and light decompose the polymers and cause the performance to degrade. Here, the thin but robust germanium hybrid layers provide a real alternative.

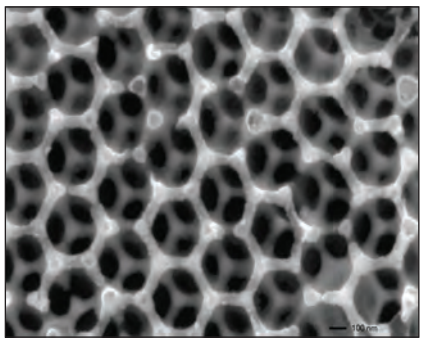


Image: Katia Rodewald / TUM

Electronmicroscopical image of the germanium-structure after removal of the polymer templates

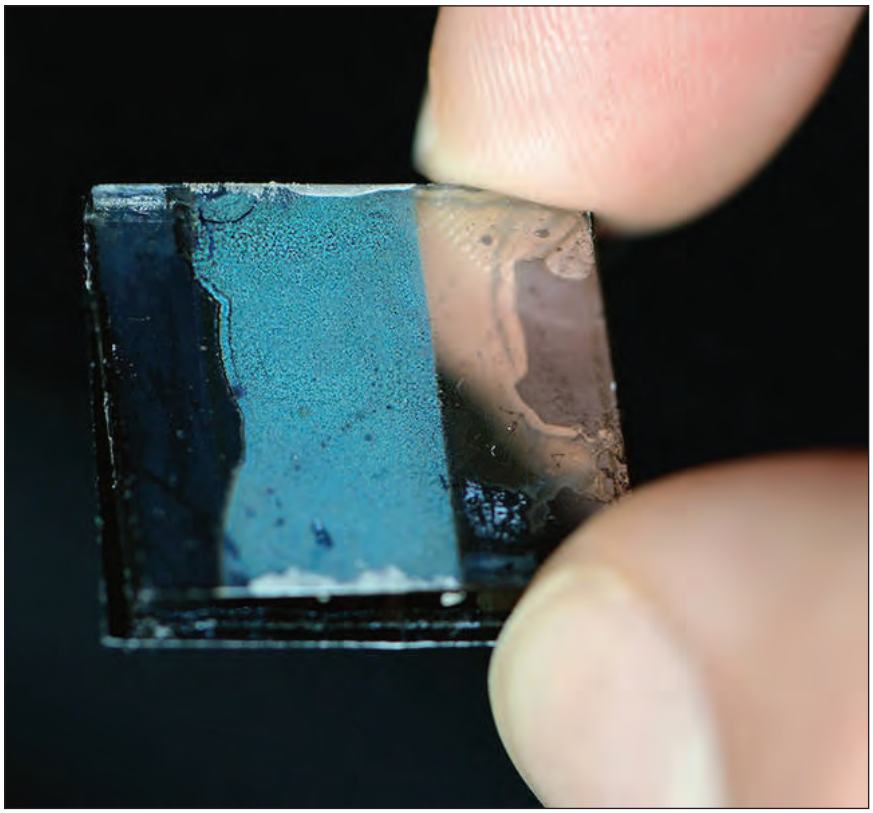


Photo: Andreas Battenberg

FILLED WITH suitable organic polymers the highly porous germanium nanofilm becomes a hybrid solar cell.

Nanolayers for new battery systems

Next, the researchers want to use the new technology to manufacture highly porous silicon layers. The layers are currently being tested as anodes for rechargeable batteries. They could conceivably replace the graphite layers currently used in batteries to improve their capacity.

The research was funded by the "Solar Technologies Go Hybrid" program of the Bavarian State Ministry of Science, in the context of the excellence cluster "Nanosystems Initiative Munich (NIM), the German Research Foundation (DFG) and the Center for Nanosciences (CeNS).

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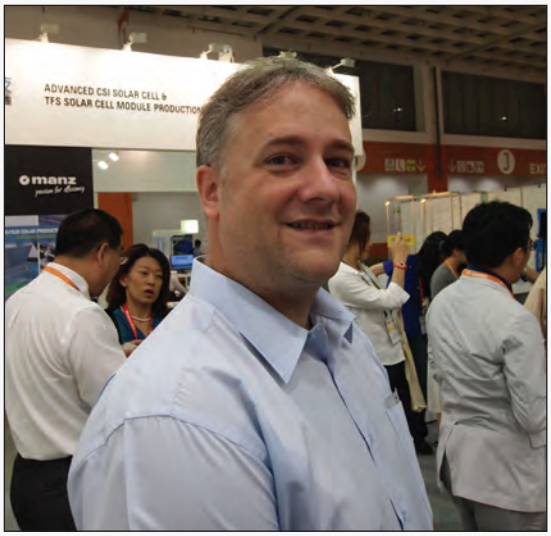
PV Taiwan
shines with solar innovations

The PV Taiwan 2015 exhibition in Taipei spotlighted the industry's latest work to boost cell efficiency, make storage more affordable and instill confidence in the long-term future of solar power. Mark Andrews brings the latest technology highlights.

PV TAIWAN brought together the industry's leading solar cell designers and manufacturers in Taipei, celebrating the industry's continuing growth while addressing the need for improvement in product quality and long-term durability.

The exhibition and conference (14-16 October) is in its 9th year. More than 120 exhibiting companies in 365 booth at the Nangang Exhibition Centre saw more than 9,300 visitors. Most attendees came from Taiwan and neighboring China, Singapore, Hong Kong, the United States, Germany and other countries across Europe and Asia.

Taiwan's Bureau of Energy and Ministry of Economic Affairs take the needs of its industrial base very seriously. To that end they have established product assessment criteria and certification for PV products, with awards for cells and modules that not only meet standards of the IEC, but also 13 separate safety requirements and 18 performance tests and do so while maintaining high efficiency: 20 percent or more for monocrystalline cells and at least 18.5 percent for multicrystalline devices. Companies winning 2015 'Taiwan Excellent PV Awards' included AU Optronics, Neo Solar Power Corporation, TSEC Corporation and WINAICO.



Taiwan's photovoltaic industry is expected to report NT$184.8 billion in 2015 sales revenue (about $6.1 billion USD) according to the Taiwan External Trade Development Council (TAITRA) and SEMI. Even though the market has slowed in some parts of the world where subsidies have been cut, the overall solar market continues to grow at double-digit rates. This expansion is envied by the wider semiconductor industry where growth is expected to remain flat or increase about 1 percent in 2015.

A survey conducted by Solar Power Europe (formerly EPIA) shows that in 2014, solar installations increased significantly in Japan, China and the U.S. Global PV installations exceeded 40GW last year, and are expected to reach 58 GW in 2015 (about 30 percent growth), followed by further expansion to 85 GW generating capacity per year by 2020.

Solar's growth spurt is what brought many suppliers and manufacturers to the PV Taiwan marketplace including Heraeus Photovoltaics that announced it was expanding its presence in the Republic of China

(ROC) by adding local manufacture of front-side metallization pastes to its existing product line.

Making the announcement in a ribbon cutting ceremony on the tradeshow floor was a delegation of senior executives including Andreas Liebheit, President of Heraeus Photovoltaics Global Business Unit; Dr. P. H. Chang, CEO of Motech Industries, Inc., Chairman of the SEMI Taiwan PV Committee and the TPVIA; and Dr. Sam Hong, CEO of Neo Solar Power Corp. Heraeus expects manufacture of front-side pastes to begin in its expanded Taiwanese facility by the end of 2015.

Liebheit met with Solar + Power Management magazine prior to the official ceremony to discuss the company's history in Taiwan and operations across Asia. Liebheit said the manufacture of high quality solar cells and modules as well as new research and development work was driving his company's expansion in Taiwan.

"In order for us to offer customization and shorten lead times for customers, it is vital to have a strong operational presence where our customers are, and Taiwan has grown to become an important market for us," Liebheit said.

Quality, shorter lead times, increased ruggedness and longer in-service lifetimes were recurring themes expressed by companies at the event. Major Taiwanese manufacturers acknowledged that long-term market success meant delivering quality, not just low costs.

More manufacturers are working towards end-to-end supply chain management strategies as well as relationships with installers and trade groups to encourage feedback and continual product improvement. PV Taiwan exhibitors included a wide range manufacturers and suppliers. While many had new product announcements, most device details pointed toward continuing advances towards greater efficiency and serviceable lifetimes.

GinTung Energy Corporation, founded as Apollo Solar Energy Co. in 2005, offers a wide range of mono- and multicrystalline cells. Module efficiency is on par with industry averages between 15 and 18 percent. Its existing product line is popular across local and international markets. But what caught many visitors' attention were plans to release its new 'Lightwave' panel line early in 2016, with full production expected in third quarter.

> "GinTung Sales and Marketing Division Manager Cyrus Wong said that the new Lightwave panels will be 50 percent lighter than current models (glass sealed cells in aluminum frames) that average about 19 KG per module. Lightwave modules will tip the scale at only 9 KG"

GinTung Sales and Marketing Division Manager Cyrus Wong said that the new Lightwave panels will be 50 percent lighter than current models (glass sealed cells in aluminum frames) that average about 19 KG per module. Lightwave modules will tip the scale at only 9 KG. Wong said the company believes that this revolutionary leap in weight reduction will impact future residential installation the most since residences tend to have more weight-related concerns than commercial structures. But no matter the location, cutting weight in half while maintaining performance will give both end-use customers and retailers a new product worthy of consideration.

Like many larger manufacturers at PV Taiwan, Neo Solar Power Corp. has been in the PV cell and module business since 2005. Starting with PV cells, they grew capabilities to embrace all aspects of manufacturing end-use products; they now also partner with installers so they have contact with the product from start to finish. They also support community, grid-scale projects around the world including the largest airport installation to date (32 MW), that was completed recently in Indianapolis, Indiana (USA). They also supported a 42 MW plant in Manchester, England—their largest project so far. The Manchester plant will produce enough electricity for about 17,000 homes.

Neo Solar Power Corp. has been in the PV cell and module business since 2005. Starting with PV cells, they grew capabilities to embrace all aspects of manufacturing end-use products

Vendors supplying manufacturers with wide selections of process tools included Symtek Automation Asia (SAA), a European automation expert that has extended its product line to include machinery for handling PV wafers and cells. Tobias Rapp, PV Division Vice President, said the company sees great opportunity for the future growth across Asia.

Rapp indicated that one of the interesting transitions he is seeing across the industry is the move from manually handling PV cells throughout various processing steps to fully-automated systems. When the PV industry was just gaining traction in Taiwan and China, transferring cells from one machine to another was often done by hand. The workers were highly skilled and rarely broke cells. The problem his company noticed was that this highly skilled and careful work force saw opportunity as the industry grew, and a sizeable percentage of the workforce might move from plant to plant seeking higher wages. Rapp said his sales pitch is to empower plant operators with a process tool solution that won't move up the street, doesn't take time off and is ready whenever the plant operator needs to change production parameters.

Sino Green Energy (SGE) was one exhibitor that had more of a challenge displaying its product than most because unlike others, SGE doesn't manufacture PV products, it builds solar-based distributed electric cooperatives in Taiwan. Although currently operating 230 sites across the island nation, it doesn't plan to export its management technology outside the ROC—at least for now. What is does bring to the market is a savvy efficiency enhancement approach that delivers results it claims are better than any other generating company.

SGE President Eric Wang explained that his company found that programs to monitor and affect solar generating efficiency was lacking. SGE hired

the engineering expertise to create its own software that now maximizes efficiency. During the summer of 2015, Wang said SGE's capacity was 3.91 kWp while other solar plants in the same area were averaging 3.19 kWp. While Wang did not speculate about his company's plans to export their management software, achieving an 18 percent increase in usable generating capacity is no small feat in an industry that gets excited about even single point efficiency gains.

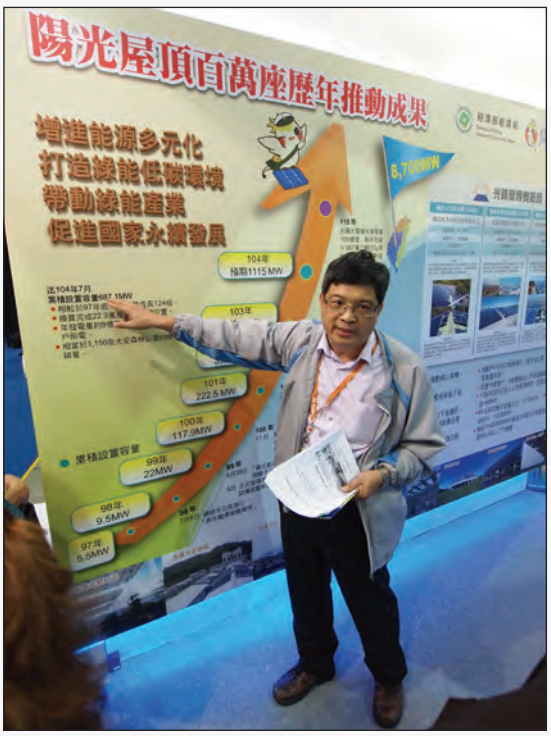
AU Optronics (BenQ Group subsidiary) was another stand-out company that combined PV cell and module manufacturing with a line of storage solutions that scale from residential needs up to commercial and micro-grid applications. AUO was also one of the few companies also involved in smelting polysilicon ingots. They offer a wide range of module choices, from 16 to 20 percent efficiency, and a company history dating to 1996. AUO is also listed on the Dow Jones Sustainability World Index and was the first Taiwanese manufacturer to receive a LEED Platinum Certification.

Taking solar in another direction entirely was Aplus Energy Company that manufactures crystalline solar modules laminated to coated steel roofing panels to eliminate the need for rack systems. Their panels can be installed with no penetration of existing roof structures. Roof panels can also be constructed of polycarbonate, further reducing weight loads. The panels have obvious weight advantages, require little to no racking, and provide unusually high wind and precipitation resistance due to their flush-mount characteristics. PV cell efficiency is currently rated at 17.6 percent, and panels are guaranteed to perform at 90 percent capacity for 10 years and 20 years at 80 percent capacity.

Industry analysts, financers and investors anticipate further worldwide growth of solar generating capacity. By mid-century, renewable energy will dominate electric power generation. Innovation continues to push photovoltaic cells to greater levels of reliability and long-term quality.

Taiwanese PV companies are bringing products to every major solar market, and continue to grow either through direct connections with retailers or wholesalers. While the competitiveness of Taiwanese and Chinese solar manufacturers has led to 'anti-dumping' regulations, manufacturers have responded by creating local assembly and testing facilities in large markets, which also brought them into closer connection with end users and retailers.

Solar energy is truly an international industry. Design and manufacturing can be found in Taiwan, China, Japan, Singapore, the Americas and Europe; expansion further into Africa, India, the Middle East and Oceania is expected as well. Although fossil-fueled electricity generation still provides most of the world's power, more than 70 percent of new generating capacity added in the last year came through renewable energy. Taiwanese manufacturers continue to play a leadership role in this rapidly evolving industry and will offer exciting new products in 2016 and beyond.



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Perovskites: the new GOLD

Imec and Solliance – a consortium of companies and research institutes focused on thin-film photovoltaics (PVs) – discuss their latest perovskite PV module and say that it is already a step towards commercialisation.

PEROVSKITE SOLAR CELLS could become the solar cell of the future. They are thin, light, inexpensive, and easy to make and allow people to play with color and transparency. What's more, their efficiency has taken a giant leap forward in recent years. However, there are still obstacles on the road to industrialisation. And the industry is eagerly looking forward to a more stable, scalable and less toxic version.

What are perovskite solar cells?

Perovskite solar cells are a type of thin-film solar cell. They exist in various architectures, all of which have one thing in common: they use a perovskite as the light-absorbing material. Named after the Russian mineralogist Lev Perovski, perovskites are a class of compounds with the crystal structure ABX3. Solar cell applications typically use an organometal-halide perovskite. In these, material A is typically an organic cation, material B is a metal ion such as lead and X is a halide anion such as iodide, bromide or chloride.
The first perovskite solar cell (2009) was a dye-sensitized solar cell (DSSC) where the perovskite was used as the light absorber. In this type of solar cell, the perovskite material covers a layer of mesoporous titanium dioxide, which is in turn immersed in a liquid electrolyte.

However, as the perovskite dissolves in the liquid electrolyte, this was quickly switched to a solid electrolyte. Today, perovskite solar cells are not limited to DSSCs. We also have perovskite solar cells using the planar heterojunction structure, the same structure used in conventional organic solar cells (or OPVs). Here, the perovskite is not just the light absorber, it is also used for charge transport. This configuration is often called a hybrid-OPV solar cell.

Why is industry so interested in perovskite solar cells?

Perovskite solar cells have many properties that make them interesting for a wide range of applications. The first is their cost effectiveness. The perovskite material has a high absorption efficiency for sunlight. Hence not much is required: a layer of at most a few hundred nanometers. Moreover, they can be made with simple fabrication technologies such as coating and printing in which an ink-like material is spread over a substrate.

Second, a wide range of substrates can be used, both flexible (plastic and metal foils) and rigid (glass). Third, the composition of the material (the components A, B and X) can be varied to deliver different optical and electronic properties. This also allows the color and transparency of the cell to be adjusted.

However, the biggest plus is their efficiency and its enormously fast evolution: from a lowly 3.8 percent conversion efficiency in 2009 to 20.1 percent (at cell level) in November 2014. It is this evolution – and the expectation that it can get even better – that is causing so much excitement in the industry. Thus, the OPV market is increasingly moving towards this hybrid variant. Many applications lie within reach. The trick is to find the best perovskite cell (in terms of efficiency, substrate, transparency, color, etc.) for each specific application.

One such application is building-integrated photovoltaics (BIPV): construction materials that have solar cells integrated into them. But there are also possibilities in the automotive industry, greenhouses, sensor networks, etc. These solar cells can work in both daylight and in reduced sunlight. So they could be integrated into, for example, furniture for recharging

wearable devices. Perovskite solar cells are a type of thin-film solar cell. But the conventional silicon solar cell world is also showing interest in them. A perovskite-based solar cell can be stacked on top of a conventional silicon solar cell. This tandem configuration could achieve efficiencies above 30 percent – well above the 25 percent limit predicted for traditional silicon modules.

Are these cells already on the market?

Currently, there are still three main challenges to commercialization: the stability and scalability of the technology, and its use of lead. While current silicon solar cells can easily last twenty years, a 'naked' perovskite cell will last just a few hours or, at best, days. The main reason for this is the cells' sensitivity to moisture. The absorption of moisture changes the chemical structure of the material, degrading the solar cell. This greatly limits the outdoor use of this type of cell. One way to overcome this is to seal the cell in a water-tight package, for example by sandwiching it between two glass plates. Researchers are also looking for other materials and manufacturing processes to improve stability.

The second challenge is the scalability of the technology. The highest reported efficiencies are achieved at cell level. But if the technology is to become implemented widely, these efficiencies must be replicated at module level. That means material and device quality must be maintained over larger areas – up to square meters in size.

The third issue is the toxicity of the material. The most commonly used perovskites today are methylammonium lead halides. The amount of lead in the final PV-module may well be low, but there are a number of laws that prohibit its use. For example, the WEEE and RoHS laws limit the use of harmful elements in electrical and electrical products within Europe. These laws don't present a problem for using lead in PV modules. But if the solar cells were used in consumer products, these products would be banned. Hence it is vital to find a lead-free material with good stability.

What is imec's focus? And is imec working with industry?

In 2014, imec began working on perovskite solar cells. The emphasis is on developing a scalable, stable and lead-free technology. This research is carried out within the framework of Solliance, a partnership between companies and research institutes from mainly Belgium, the Netherlands and Germany working together to shape the new generation of solar cells. The Solliance perovskite solar cell program covers both flexible substrates (at ECN and Holst Centre in Eindhoven, the Netherlands) and rigid substrates (at imec, Belgium).

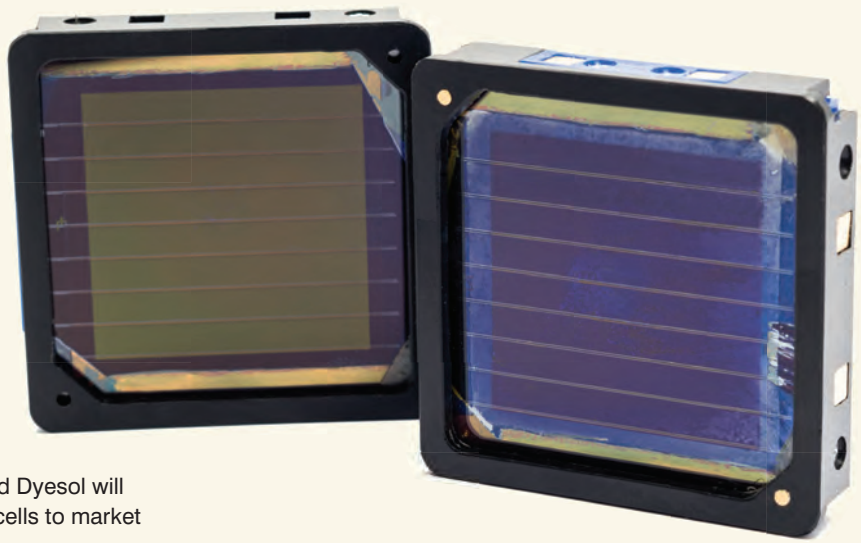
Australian company Dyesol recently joined Solliance as an industrial partner. Solliance and Dyesol will share their expertise to bring perovskite solar cells to market faster. Dysol brings a great deal of experience in processing, design and materials, while Solliance principally brings its roll-to-roll lines for production on flexible substrates.

What recent developments are bringing perovskite solar cells closer to market?

Researchers at imec have created a perovskite PV module that delivers 11.3 percent efficiency over an aperture area (the total surface area of the module minus the area covered by the rim) of 16cm2. The geometric fill factor for this module is 95 percent, which means the surface area of the module is used very efficiently. According to the literature, this is the highest aperture efficiency and geometric fill factor recorded to date for a perovskite PV module. Moreover, the technology is scalable: the perovskite layer and one of the contact layers were deposited using blade coating. This is a linear process that can be applied at fab level.

Imec and Holst Centre are also making progress on stability, based on their experience in encapsulating thin-film organic solar cells. The first indications are that a perovskite PV module with a waterproof encapsulation can withstand the damp-heat-test for 1000 hours. This test is carried out at 85°C and 85 percent humidity. In the silicon PV world, modules that achieve these results are typically guaranteed for 20 or 25 years. However, the same conclusion cannot yet be drawn for perovskite modules: this is a new technology and the assumption valid for silicon cells cannot be applied here.

Perovskite solar cells can also be used to give silicon solar cells an extra efficiency boost. The idea is to stack the two types of cell. Researchers from imec are working on two ways of doing this: the 2-terminal tandem cell and the 4-terminal stacked cell. The first results are very promising. You can read more about this approach in the April edition of imec magazine*.



How digital light microscopy is enhancing solar cell fabrication

Working to drive the global spread of solar cell technology, French company S'Tile has employed the latest in digital light microscopy to optimise each step of its manufacturing process. By Markus Fabich, Olympus Europa.

MINIMISING the cost of solar cells is key to promoting their widespread application, and this is the goal of S'Tile, a spin-off company from the University of Poitiers (France) founded in 2007. To further improve the cost-performance ratio of S'Tile's innovative i-Cell design, the company teamed up with Olympus, employing high-resolution digital light microscopy and confocal laser scanning microscopy for a new investigative approach. This latest generation of light microscopy merges sophisticated imaging techniques with a user-friendly interface, enabling S'Tile engineers to quickly and efficiently inspect a range of features, from porosity to surface texture – all in unprecedented detail.

How to improve the cost/efficiency ratio

While conventional solar cell designs use a thick layer of expensive MonoSi with thick metallic contacts, the S'Tile i-Cell minimizes the cost versus efficiency ratio through several approaches:

- Photon-harvesting layer is composed of only a very thin layer of p-type monocrystalline silicon (MonoSi)
- Low-cost silicon supporting solar-grade layer protects against breakages, reducing cost compared to conventional solar cells with thick solar-grade silicon layers
- Reduced size of metallic contacts decreases silver use by half and copper by 90 percent
- Four sub-cells connected in series lowers current and increases voltage through electrodes, improving energy efficiency thanks to reduction of resistive losses during module integration.

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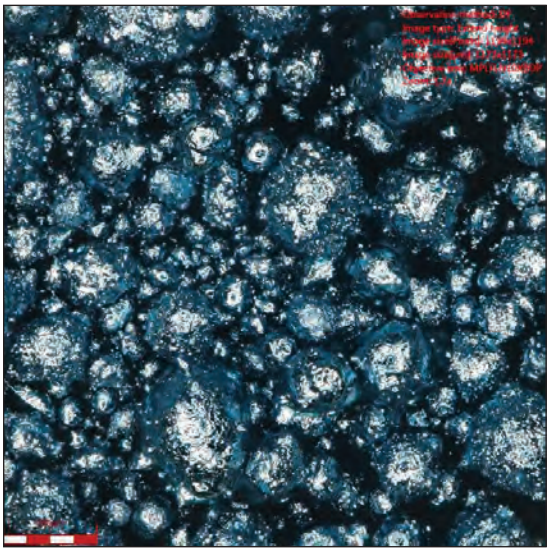

Figure 1: Silicon powder inspection guides sintering conditions. Size and shape of grains can be inspected with the automatic software of digital light microscopy systems. (Olympus DSX500 digital light microscope).

Commercially viable efficiencies of over 18 percent have now been achieved with the i-Cell, and this number is continually improving.

Optimizing each step of the fabrication process
The manufacturing process of the i-Cell dictates the cost-performance ratio, and this involves several steps, as explained below:

1. Substrate fabrication
The substrate is produced through sintering of low-grade silicon powder. On applying heat and pressure, sintering produces a dense layer from a powder, and this process is highly dependent on grain size and morphology of the silicon powder.

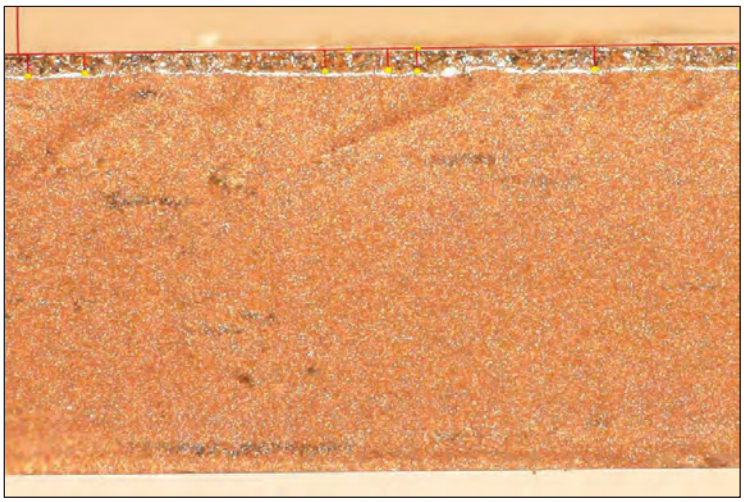

Figure 2: Measuring thickness of conductive wells. Layer thickness measurement software with polarized imaging was employed to measure conductive wells. (Olympus DSX500 digital light microscope).

S'Tile previously relied upon laser granulometry to determine the size and distribution of grains. This is fast, but does not provide information on grain morphology – only the average size and distribution. Microscopy presents a complementary approach, and instead allows the visualization of grain geometry to facilitate inspection (Figure 1).

2. Inspecting the conductive wells in the substrate
Conductive wells are formed in the silicon substrate to connect the substrate and the overlying thin MonoSi layer. Well shape and depth affect current transport within the sintered substrate, and if the process is modified, it is vital to know how this alters the wells, for example in terms of depth consistency.

This is enabled through digital light microscopy, using the layer thickness measurement tool (Figure 2).

While the primary property of these wells is electrical connectivity, measured through electrical resistance, it is also important to know how these interact with the substrate, and whether they damage the surface. These properties can be observed with digital light microscopy, once more complementing the primary measurement tool.

3. Layering
The very thin MonoSi layer and the low-cost silicon substrate are bonded using a proprietary process. It is crucial to have a perfect surface on the MonoSi, as any breaks compromise the electrical capability of the layer. Samples are cut as cross-sections and inspected for any voids or breaks using digital light microscopy (Figure 3). A key advantage of this inspection approach is the need for less sample preparation, due to the High Dynamic Range digital tool featured with many platforms, which creates a fully-focused image from different z-layers.

Avoiding sample polishing employed with standard 2D microscopy is highly beneficial, since this is both time consuming and can also damage the silicon wafer. If this happens, it is then impossible to know if the breaks were due to the fabrication process, or sample preparation.

4. Reducing reflection through surface texturization
When light hits a flat silicon surface, approximately 30 percent is reflected instead of absorbed. Minimizing reflectivity is vital for solar cells and is achieved through two means: surface texturization, and an additional anti-reflective layer. With its high resolution imaging capabilities, confocal laser scanning microscopy (CLSM) lends itself to measuring surface features such as these, and

> The pyramid morphology of the surface reduces reflection, capturing and continually re-reflecting light between each pyramid. Height, shape and distribution are all important, and can be optimized through fabrication

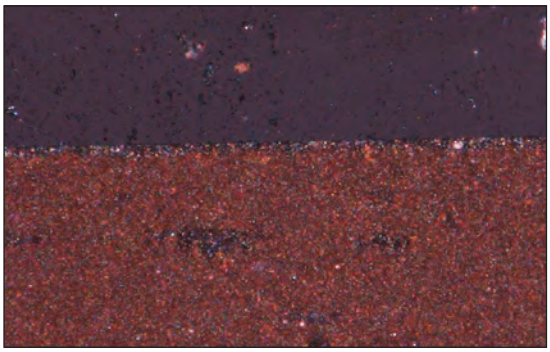

Figure 3: Inspecting the bonding between silicon layers. Bonding quality was analyzed with polarized. At 4,000x magnification, it can be verified that the MonoSi remains undamaged, with perfect contact and no voids at the interface. (Olympus DSX500 digital light microscope).

S'Tile employed the Olympus LEXT OLS4100 3D measuring microscope for this purpose.

The pyramid morphology of the surface (Figure 4) reduces reflection, capturing and continually re-reflecting light between each pyramid. Height, shape and distribution are all important, and can be optimized through fabrication. Different protocols are tested and the success of each compared, based on surface texture using standard widefield light microscopy.

However, with the height differences being in some cases just one micron, the limited resolution meant this was not possible, and CLSM was subsequently employed for this task.

Combining an optimized surface texture with an anti-reflection layer, it is possible to reduce reflection to 5 or 10 percent, maximizing energy efficiency.

5. Engraving

To form the i-Cell structure, in which several small area sub-cells are electrically connected in series, laser scribing separates the MonoSi and creates channels in the silicon to be partially filled with silver. Inspecting this process, it is important to collect information on a variety of aspects.

Well shape and depth dictate electrode morphology, and therefore resistance. In order to change the width and depth, a variety of different parameters can be controlled with laser scribing, such as wavelengths and intensity. S'Tile previously employed 2D microscopy, and although the depth of the wells could be inspected, this could not be performed along the wells to produce a complete picture, which is now possible with the 3D imaging capabilities of the Olympus DSX500 digital light microscope (Figure 5).

It is also important to inspect surface integrity, as a smooth surface is required for fabricating the interconnections between subcells. Since the laser parameters can also be modulated for the smoothest surface, it is vital to know if the laser is damaging the silicon, and it can be seen quickly and directly with

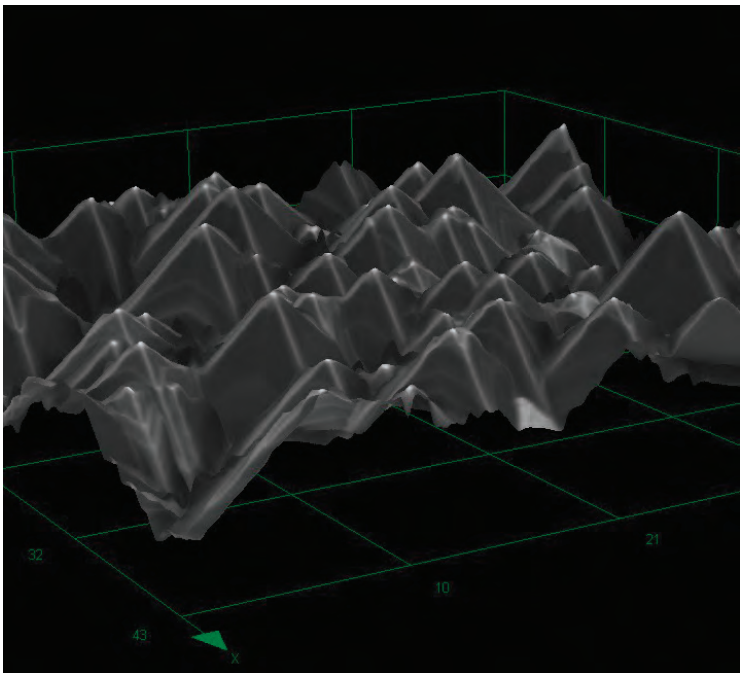

Figure 4: Measuring surface texture for reducing reflection. High-resolution characterization is achieved even through the anti-reflective coating with 3D confocal laser scanning microscopy, assessing the texturisation process and reducing light reflection. (Olympus LEXT OLS4100 3D measuring microscope).

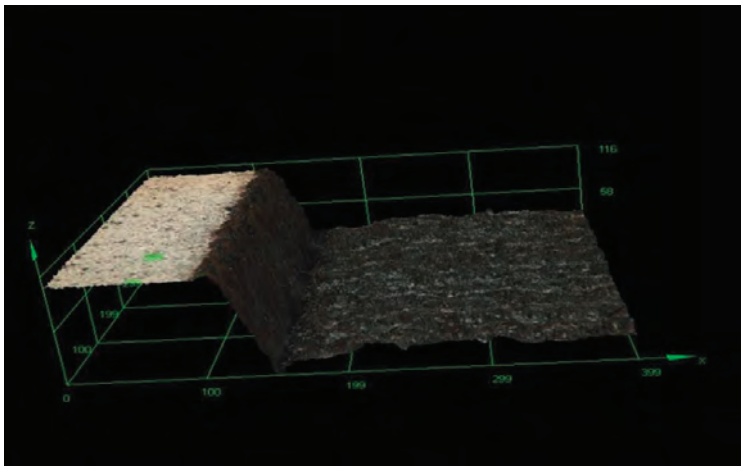

Figure 5: Well shape and surface integrity inspected after laser engraving. High-resolution 3D imaging enables inspection of well morphology and surface integrity, optimizing laser engraving parameters and avoiding surface damage. (Olympus DSX500 digital light microscope).

digital light microscope if the surface is damaged.

6. Metallization & firing

The metallization of silver on the MoniSi surface and in the engraved channels is performed using screen printing and firing, and the form of the electrodes has a significant impact on solar cell efficiency.

A larger surface area minimizes resistive losses, where a really thin strip maximizes the surface area of the photon-harvesting silicon. Screen printing has many parameters to control, and to guide the process optimization, 3D images of the silver electrodes were captured and analyzed with digital light microscopy (Figure 6). The height mapping function provides a comprehensive view instead of individual points. Volume, average surface area and minimum surface area can be measured, enabling the quality of a metallization protocol to be judged.

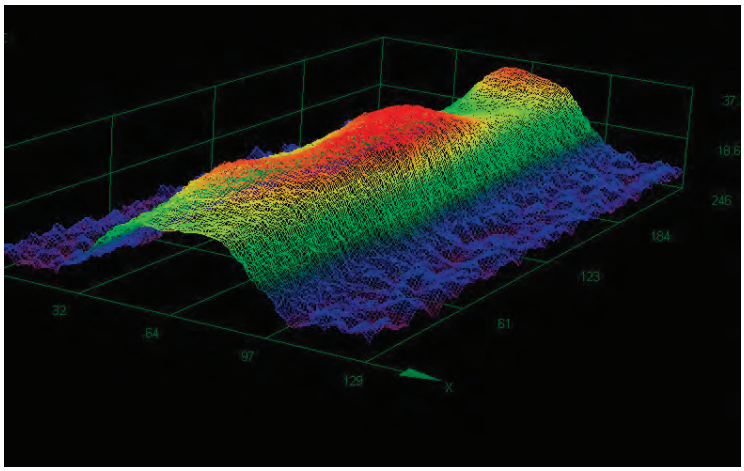

Figure 6: Inspecting electrode grid morphology. Height and width of the finger grid can be modulated from screen printing optimization to minimize resistive and optical losses. Inspecting the metallization helps guide this process, using 3D analysis software at 100x magnification. (Olympus DSX500 digital light microscope).

Digital light microscopy has advanced the metallization process. Cross sections were previously analyzed, restricting testing to final samples to only find the best printing and firing combination. With 3D analysis of printed samples, the steps can be separated for each to be easily and individually optimized.

Summary

Sustainable energy sources such as solar power are set to contribute increasingly towards our ever growing global demands. Decreasing manufacturing costs alongside increasing efficiency is therefore a primary goal of the solar industry, and a variety of approaches are in development in order to make this renewable energy source more accessible.

The work of S'Tile on its i-Cell design is proving instrumental in this trend, and the company is fast approaching a market-ready design. Alongside efficiencies of 20 percent, the second goal is to attain manufacturing costs 30 percent lower than conventional designs, and the company is now exploring industrial collaborations to help reach these targets.

The new generation of digital light microscopy systems enable fast and efficient inspection after every process, alongside more specialized methods. It is now possible to understand with more clarity why one protocol leads to better results, as different measurement tools fit together to guide the complete process optimization.

Author information:
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Solar Securitisation

A Rising Solar Financing Strategy

WonJu Sul, Associate Cadwalader, Wickersham & Taft LLP tell us how securitisation represents a rapidly emerging financing strategy.

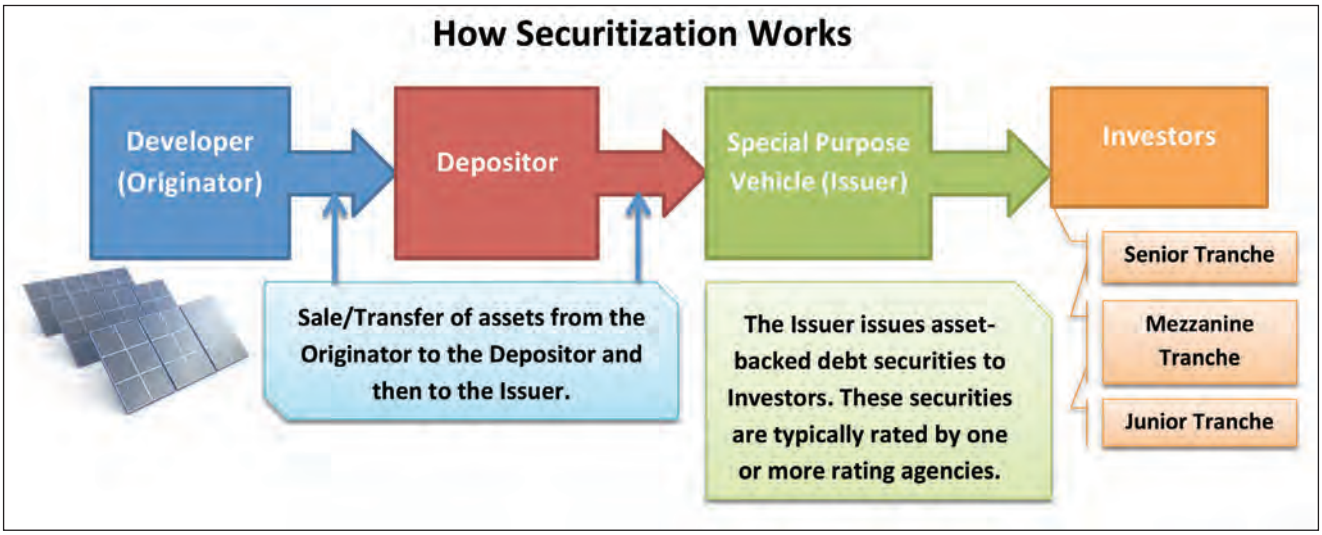
THE GLOBAL INTEREST in climate change is greater than ever and so is the importance of renewable energy technologies as a means to achieve climate targets both nationally and internationally.

With its abundance, relative reliability and adaptability to urban settings, solar energy is widely considered as the most promising alternative to fossil fuels and coal, and is one of the most popular renewable energy sources in both the US and the UK. However, despite the critical need to decarbonize the energy system, fewer financing options remain available from traditional players such as government, banks and tax equity investors. In the UK, the government has repeatedly scaled back its green subsidy schemes and seemingly plans to retreat completely by mid-2020s. In the US, the federal investment tax credit, which allows investors to realize tax benefits from financing solar projects, is set to reduce from 30 to 10 percent at the end of 2016, thereby significantly reducing the tax equity investors' incentive to continue funding at the current level. On both sides of the Atlantic, a host of post-crisis regulations constrain banks' lending ability and, with interest rate expected to increase soon, the borrowing costs via traditional routes will rise quite significantly.

Solar securitisation represents a rapidly emerging financing strategy. The solar receivables are particularly well suited to securitisation technology as solar technology lends itself to long-dated contracts, which is very attractive to investors. This article explores how securitisation can open up the access to the capital markets for solar developers and installers to obtain favourable financing opportunities and expand their businesses and allow solar industry to gain greater liquidity and scalability faster.

What is securitisation?

Securitisation is a form of asset-backed financing that transforms a pool of assets, through financial engineering, into debt securities to be offered either in public markets or to large institutional investors through private placements. The beauty of securitisation is the ability to turn illiquid assets into liquid, standardized and tradable instruments. The process begins by delinking credit risk of the assets from



other business risks of the originator by selling the assets to a special purpose vehicle (SPV) that is structured to be bankruptcy-remote.

The SPV then sells the rights to the underlying assets by issuing the debt securities, typically in multiple tranches to match different risk appetites of the investors. The proceeds of the issuance are used to finance the business operations and pay the purchase price of the assets acquired from the originator. The SPV uses the revenues generated from the underlying assets to make interest and principal payments to the investors on the securitized bonds over a set period of time.

Why securitize?

Securitisation offers many potential benefits to solar developers including:

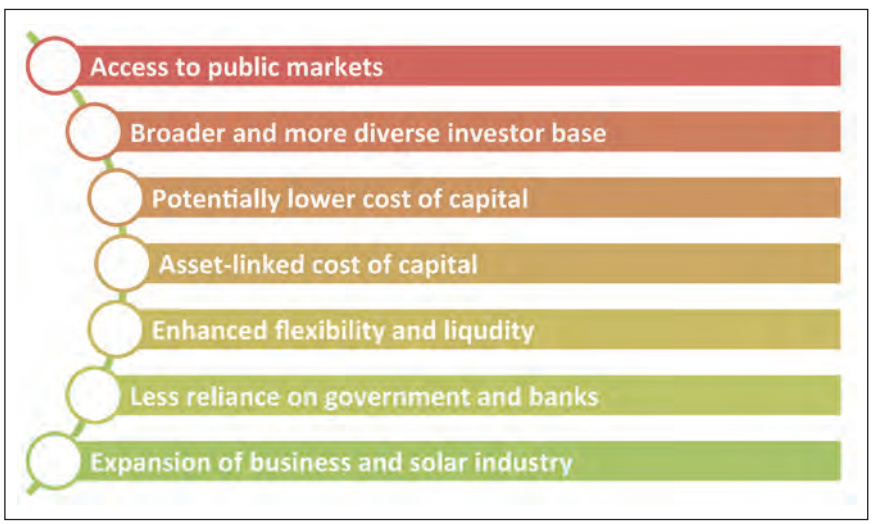
Access to capital markets
The ability to access broader and more diverse investors provides the developers much-needed flexibility and liquidity while also reducing the reliance on government subsidies and other equity financings. Most investors are much more comfortable dealing with debt securities than solar assets directly; and the relative ease of securitized bonds to be marketed, sold or listed abroad can broaden available financing options for many solar businesses.

Upfront lump sum payment
The developers will receive a lump sum payment of money reflecting the value of the underlying assets upon closing securitisation offerings instead of having to wait for years for the payment streams to pay back the principal over time. This lump sum payment from investors can be reinvested to expand the business and grow market share faster than it would have been without the securitisation.

Leverage
Different securitisation techniques such as subordination, over-collateralization or use of up-front cash reserves may allow the developers to lower the overall costs of capital. Using these techniques, together with offloading of the assets to a SPV that frees up the balance sheet capacity and the monetization of the assets that were previously illiquid, the solar businesses may benefit from the increased leverage, originate more assets and securitize those assets to fund expanded operations.

Longer tenor
Securitized bonds tend to have much longer maturities than other bonds, making them much more attractive to solar developers given the relatively longer time necessary for the developers to fully recoup the costs of typical solar projects. In solar securitisations, the maturities to date have ranged from 8 to 30 years.

Delinking of credit risks
Because the assets are transferred to a bankruptcy-remote special purpose entity, investors primarily account for the riskiness of cash flows from the investment itself and not the credit risk of the originating company. This is a significant advantage over secured or unsecured bank facilities and corporate bonds, under which credit ratings, hence the price, are directly tied to both the company's performance and the quality of the assets.



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Who can securitize?

The full benefits of securitisation can only be achieved if certain commercial conditions are met. First and foremost, the developer must have operational assets of certain scale and quality to take to market. Broadly, there are two types of collateral typically used in solar securitisations: government-mandated subsidies and customer payments under leases and consumer contracts. If the developer owns a robust portfolio of intellectual property rights, it may be able to securitize the future payment streams generated by such rights as well. The assets must be able to generate a relatively stable stream of cash flows over the life of the securitisation.

Additionally, unless the size of the asset pool to be securitized is sufficiently large, the costs associated with setting up securitisation facilities may outweigh the benefits of savings from lower margins on the financing. Although future-flow securitisation technique is available to raise financings against assets that have not yet come into existence, enabling the originators to raise capital multiple times larger than the current annual cash flows, only those solar developers who can demonstrate the reliability and consistency of their operations may be able to benefit from such technique. It should be noted that, because solar systems require ongoing monitoring and periodic maintenance in order to ensure optimal energy production, in most solar securitisations, the originating developer will typically act as the operations and maintenance services provider for the term of the securitisation.

> "there are two types of collateral typically used in solar securitisations: government-mandated subsidies and customer payments under leases and consumer contracts"

Thus, the rating process thus far has been quite developer-centric and demanded the developers to have a fairly robust credit quality and sufficiently broad presence or network of subcontractors to effectively manage the securitized portfolio.

Market status: it is still nascent but growing fast

In the UK, the solar securitisations have centred on its feed-in tariff (FIT) and renewable obligation certificates (ROC) schemes. Under the FIT scheme, there is certainty of subsidy generation and of minimum sale price for selling solar power back to the grid.

The ROC scheme is slightly different and its prices fluctuate, unless an agreed power purchase agreement is in place. In any event, under both schemes, there is a long-dated cash flow that is government mandated, providing certainty that investors look for. Among the first securitisation deals were

SOLAR PV SECURITIZATION (as of October 2015)

Closing Date	Deal	Notes	Amount	Coupon	Ratings	Rating Agency
November 2013	SolarCity 2013-1	Class A	$54,425,000	4.80%	BBB+	S&P
April 2014	SolarCity 2014-1	Class A	$70,200,000	4.59%	BBB+	S&P
July 2014	SolarCity 2014-2	Class A	$160,000,000	4.02%	BBB+	S&P
		Class B	$41,500,000	5.44%	BB	S&P
		Total	$201,500,000			
July 2015	Sunrun 2015-1	Class A	$100,000,00	4.40%	A	KBRA
		Class B	$11,000,000	5.38%	BBB	KBRA
		Total	$111,000,000			
August 2015	SolarCity 2015-1	Class A	$103,500,000	4.18%	A	KBRA
		Class B	$20,000,000	5.58%	BBB	KBRA
		Total	$123,500,000			
Nov/Dec 2015	Aurora Master Funding 2015-1	Class A	$92,500,000	N/A	BBB	KBRA
		Class B	$7,500,000	N/A	B	KBRA
		Total	$100,000,000			

the two FIT securitisations closed in 2012, each with the size of £66 million and £40 million issuances, securitizing the FIT revenues for two 20 megawatt (MW) and two 5 MW solar projects respectively.

Both deals were unrated and indexed to the retail price index (RPI), with 24-year and 25-year maturity respectively. In 2013, the UK saw its first solar conduit bond issuance that pooled small projects. This £60 million senior secured RPI-linked deal priced at a 2.59 percent coupon, was listed on the London Stock Exchange, and the proceeds were used to refinance four solar parks developed in the UK with an aggregate output of 15MW. The underlying revenue stream for this deal consists of renewable obligation certificates.

On the other hand, the US solar securitisations in the private sector developed around customer agreements in connection with commercial and residential rooftop solar photovoltaic (PV) systems. These customer agreements are structured as either leases or power purchase agreements (PPAs). The lease customers pay a fixed monthly fee with an electricity production guarantee whereas the PPA customers pay a rate based on how much electricity the solar energy system actually produces. These long-term lease and PPAs create recurring customer payments, investment tax credits, accelerated tax depreciation, and other incentives.

To date, there have been five solar PV securitisations completed in the US. All of them have been privately placed and their collateral pools consisted predominantly or exclusively of residential solar PV systems. The size of the pool ranges from 5,033 to 16,400 PV systems with the weighted average of remaining terms of the related contracts ranging from 217 to 233 months. The customers weighted average FICO scores ranged from 742 to 767. All of these securitisations required originators to put aside at least 6 months of interest payments as well as expected inverter replacement expenses in cash reserve accounts at the outset. The table below shows the specifics of each US solar PV securitisations to date:

Solar PV securitisations to date have been limited to a single developer deal that is sponsored by a large-scale, experienced developer. Also, there has not yet been a pooled solar securitisation or a purely commercial solar PV securitisation in the US. But some developers are now targeting standalone commercial and industrial portfolios and many other developers are adding securitisation to their financing repertoires. As market becomes more comfortable with the asset class, multi-borrower deals are likely to emerge allowing smaller developers to take part.

Because the solar securitisation industry is still embryonic, there are still many hurdles to be overcome for the asset class to burgeon. So far, the lack of historical data for solar systems and the lack of standardization of underlying contractual arrangements have made it difficult for rating agencies and investors to accurately evaluate the risks involved with solar-backed securities.

If rating agencies can build models and methodologies based on historical data, it would help to make solar a scalable market, allowing traditional investors to join the buy-side. As more deals are issued and historical data accumulates, ratings are expected to improve, thereby further lowering the costs of capital for the originators.

Another issue to keep an eye on is, as technology evolves and costs continue to come down, securitized contracts may be terminated or renegotiated.

Although originators may agree to make up for any potential shortfalls, investors may feel nervous about those uncertainties and be discouraged from actively investing in solar-backed securities. Additionally, as is applicable to all fledgling industries, new regulations can impose unexpected constraints on how solar businesses operate, which in turn may adversely affect the value of the assets.

Conclusion

For the renewable energy sector to play a key role in tackling the risks posed by climate change, enormous upfront investments are necessary. However, with constraints on traditional funding sources and reduced governmental subsidies, solar developers are facing increasing challenges securing near-term financings and finding an alternative financing venue.

Securitisation can help developers to monetize future cash flows, gain access to larger and diverse pools of investment and expand their businesses, which in turn may potentially lower the costs of capital and make solar more affordable for consumers to further ramp up demand.

That said, securitisation of solar assets could be instrumental in meeting the increasing demand for solar financing, particularly in an environment where traditional sources of financing are diminishing.

Take precision to a higher level

3D-Micromac has built a global reputation around precision laser micromachining. Its new approaches to half-cell cleaving push speed and performance to new levels.

SINCE 2002, 3D-Micromac AG has grown to become a leading supplier of laser micromachining systems for photovoltaic (PV) and ophthalmic applications in Asia, Europe and North America. The company also offers optimized coating and printing technologies as well as systems for precise handling of PV and semiconductor waf ers. Their annealing, pre-treatment and finished product encapsulation techniques round-out the company's wide-ranging portfolio.

Leadership comes through innovation, and 3D-Micromac offers new solutions for PERC cell and half-cell cutting that improves efficiency and wafer throughput. Solar + Power Management asked 3D-Micromac to explore what distinguishes their latest advances in PV technology.

Q Half-cell modules offer a significant gain in efficiency compared to full-cell panels. How does the new microDICE OTF system differ from other ways manufacturers can produce half cells?

A The standard procedure for cutting full cells into half cells is a two-step process: laser scribing and subsequent mechanical cleaving. First, the laser scribes a 30-100 μm deep groove on the rear side of a solar cell. In order for the cell to break into two halves, an additional mechanical force needs to be applied, which adds to the handling costs of manufacturing. The disadvantage of separating cells with this method is twofold: it creates chips (that have to be cleaned

from the production line) and it generates micro-cracks at the cutting edge. As a result, we see a significant mechanical strength reduction (minus 30-40%) of the separated half cell in comparison to a full cell. This can have a negative impact on the final module lifetime and efficiency in case cracks caused by laser scribing and mechanical cleaving propagate any further on the separated cell.

The 3D-Micromac Thermal Laser Separation (TLS) process does not require any mechanical breaking by externally applied forces. It enables ablation free cleaving to separate solar cells with a high edge quality. The process is based on thermal induced mechanical stress, generated by a well-adjusted combination of a laser (heating) and cooling with an application of sprayed deionized water.

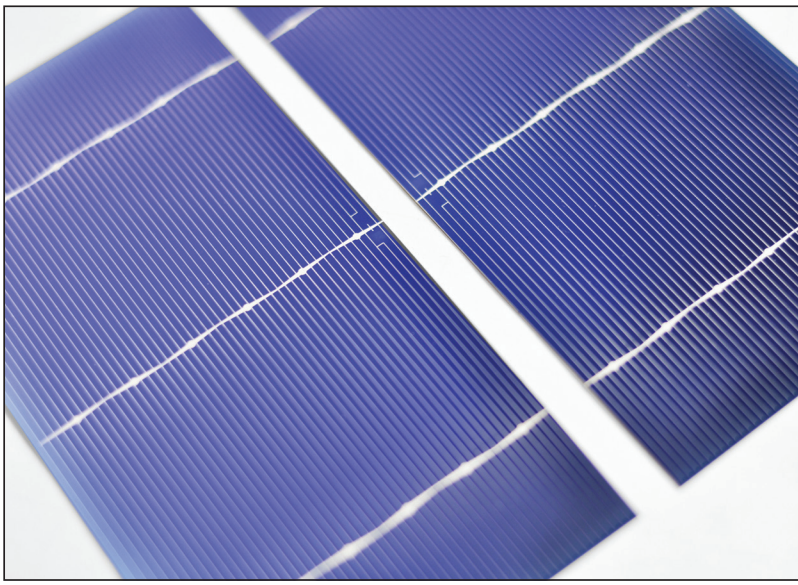
The separation by cleaving is a one pass-process. To give the separation line a well-defined stating point a second laser is used. This laser initiates the cleaving by a small local scribe at the starting edge (only a few micrometers long and deep – not at the whole surface). The microDICE OTF system is equipped with two industrial fiber lasers for initial scribing and TLS cleaving. Thanks to the on-the-fly processing, laser utilization is nearly 100%.

Q PV cells move continuously through an automated production line for Thermal Laser Separation (TLS). Is the process the same for PV cells cut into half cells as it is for semiconductor wafer applications?

A TLS is a well-investigated process (utilized) in semiconductor packaging. The design and internal workflow in our microDICE machine for segmentation of SiC or Si wafers for semiconductor packaging slightly differs compared to the process used in PV half cell separation. Instead of a continuously running transport belt, wafers are positioned on a vacuum chuck via a cassette handling system. The semiconductor wafer is mounted on tape and frame to handle the hundreds or thousands of separated die after wafer dicing. The chuck is mounted on a high speed stage, which is used for accelerating the wafers underneath the laser processing heads. Again it is an on-the-fly process, but using a different method of positioning and transporting the wafers.

Q Is the new approach for cell separation exclusively for PERC cells or can other cell types also benefit?

A For half cell separation of PERC cells, the TLS process certainly has the biggest advantage. The main reason lies in the fragility of the high-efficiency PERC cells in comparison to so-called “standard cells.” Due to this increased fragility, a reduction in mechanical strength could cause the half cells to break at a certain lifetime inside the module. Only the TLS process can guarantee that the mechanical strength of separated cells is retained. Standard solar cells also benefit from the TLS separation process. Higher mechanical strength, high edge quality, no particle generation and no need for mechanical cleaving makes the TLS process an interesting alternative to standard cutting technologies.



Q Are there other benefits to 3D-Micromac’s microDICE OTF system beyond continual processing speed?

A The microDICE OTF system is based on the successful microSTRUCT OTF system, which is used for the Laser Contact Opening for PERC solar cells. Our customers can benefit from a proven platform, which guarantees highest uptime, lowest breakage rates and an unbeatable cost-benefit ratio. In addition, TLS is ‘kerf-less’ – no area is wasted.

Q You mentioned that the new microDICE system can be utilized in stand-alone operation or incorporated into existing production environments. Does this mean the new system is compatible with most PV cell manufacturing infrastructure?

A Yes, the new microDICE OTF system is compatible with the common SEMI/PV standards and meets the customer demands for infrastructure requirements. The machine platform itself is in operation already 24/7, e.g. for the LCO application – the system has seem many years in the solar industry. Most customers ask for the stand-alone version of the TLS system.

Q Are there any misconceptions about the cost or efficiencies of other separation technologies compared to TLS?

A As mentioned before, TLS output is a completely cleaved cell. This method in one tool replaces two process steps, scribing and breaking, that other approaches utilize. Our throughput will be extremely high and the process itself uses a minimum of consumables. However, the real cost benefit is more than just the cost of ownership savings. The real benefit is a higher product quality by lower yield loss due to no micro-cracks and lower efficiency loss due to our very smooth cutting edge.

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SOLAR PANELS

Faster acoustic inspection

By maximizing the scan area and developing innovative software, it is possible to significantly increased both the speed and the efficiency of the inspection process. Tom Adams, consultant, at Sonoscan, Inc explains.

THE STRUCTURAL DEFECTS that solar panels are inspected for include cracks in the silicon, delaminations between the silicon and the silicone adhesive, delaminations, broken traces, and others. Any of these structural defects can diminish the performance and lifespan of a solar panel.

Some of the most critical and most frequent structural defects involve the solder that joins the bus bar to the silicon cells. These defects include non-bonds or partial bonds (which may be caused by surface contamination on the silicon) between the solder and the cell, as well as voids (air bubbles) in the solder. The defects may have all sorts of configurations, but are undesirable because they shrink the area of contact between the cell and the bus bar, and because physical and thermal stresses during service are likely to shrink the area of contact even more. Eventually the contact is broken. In the best case, only the single cell is lost; in the worst case, the entire panel goes dead. These structural defects are not visible optically but are easily seen by acoustic micro imaging tools. They are typically too thin to be imaged by x-ray.

Ideally a solar panel will go into service and operate with high efficiency for its expected lifetime. Structural defects involving the solder joints can seriously compromise this performance. A cold joint, where the solder is in place but not bonded at all to the solar cell, may be intermittent and may or may not be detected by electrical testing. But when a solder joint is only partly bonded or harbors voids, the bus bar can lose contact with the solar cell gradually until it abruptly fails. In order to eliminate problem solder bonds, a manufacturer can perform acoustic imaging of the panel during assembly. Rework can often be performed to ensure normal operation in service.

Countless devices, modules and assemblies aside from solar panels run the risk of sudden field failure caused by loss of electrical contact between two elements. Most of these items are smaller than a solar panel in their x-y dimensions, and fit nicely onto the scanning stage of most acoustic micro imaging (AMI) tools. The defects in solar panels, and particularly in bus bar solder joints, are similar to the defects in smaller devices, but the solar panel itself is far larger. Using a standard AMI system it is possible, but unwieldy and time-consuming, to examine all of the bus bar connections in a solar panel. Typically the operator will position the panel and the ultrasonic

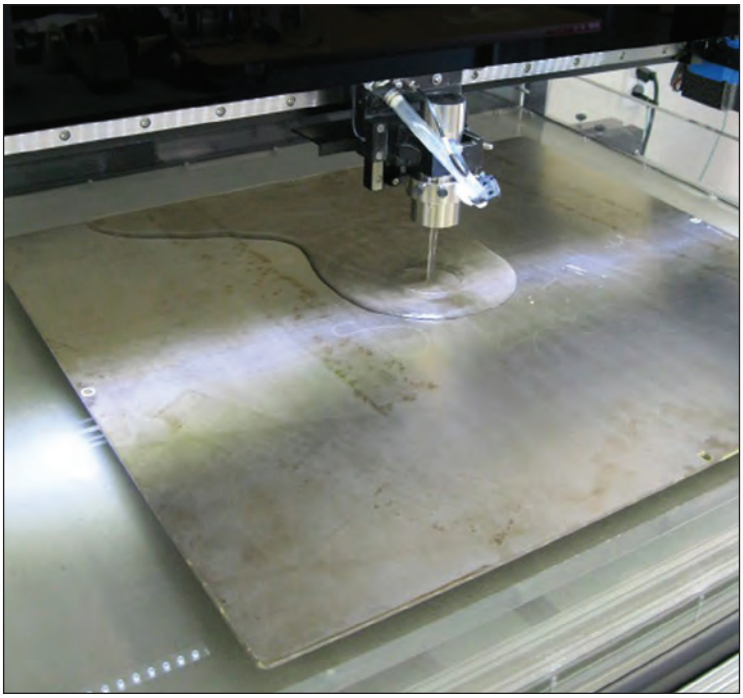


Figure 1: Sonoscan's oversized scan area, here at work on a very large unpopulated PC board, speeds the inspection of solar panels.

transducer will scan one small area to produce an acoustic image. The operator will then reposition the panel to scan the next small area, and so on until the entire area of the panel has been scanned. This method is effective but tedious.

Sonoscan also developed a C-SAM AMI tool that has a much larger scan area (0.6096 m x 0.6096 m) than other laboratory, semi-automated or automated AMI tools. It is shown scanning the bottom side of a large pc board (solar panels being proprietary) in Figure 1. Some solar panels can be imaged in their entirety in one scan, without repositioning the panel. Even panels measuring up to 1m x 3m require relatively few scans. Because there are many fewer interruptions of the scanning process to reposition the solar panel, inspection is much faster. To further speed the inspection process, Sonoscan has developed software that can accommodate scanning to the geometry of the panel. The layered structure of the panel may have defects such as cracks or delaminations in the silicon and other materials, but such defects are both less common than and less lethal than bus bar defects. The new software therefore scans only the bus bars, looking for anomalies and defects in the bonds between the bus bar and cells. This selectivity greatly reduces scan time and the area that must be scanned, and means that even very large solar panels can be inspected for the most dangerous features in the shortest possible time.

The concept of scanning only the most relevant regions of a sample is used by Sonoscan in non-solar applications as well. An AMI system having a smaller scan area, for example, may be scanning a JEDEC-style tray that contains only a few large parts. Time may be saved if each of the few parts is scanned individually, without scanning the regions of the tray that contain no parts. The two major types of solar cells are both imaged acoustically in panel form, but not at the same stage of production. Thin film solar cell panels have no backside material that will block the transmission of ultrasound, and the common anomalies and defects occur on the backside. Thin film panels are typically imaged just after busing.

Traditional glass solar cell panels differ in that a strengthening material is placed on the backside of the panel. The material covers the whole area of the backside and prevents ultrasound from reaching and imaging the solar cells. A reflective coating makes imaging from the frontside impractical. For these reasons, traditional panels are imaged from the back side just before the strengthening material is applied.

During the acoustic imaging process, the AMI tool's transducer is coupled to the panel's surface by a column of water that rides with the transducer. The transducer scans across the width of the bus bar at a given point, moves fractionally, and scans back across the bus bar. The transducer moves back and forth across the bus bar at relatively high speed. Thousands of times a second, it sends a pulse

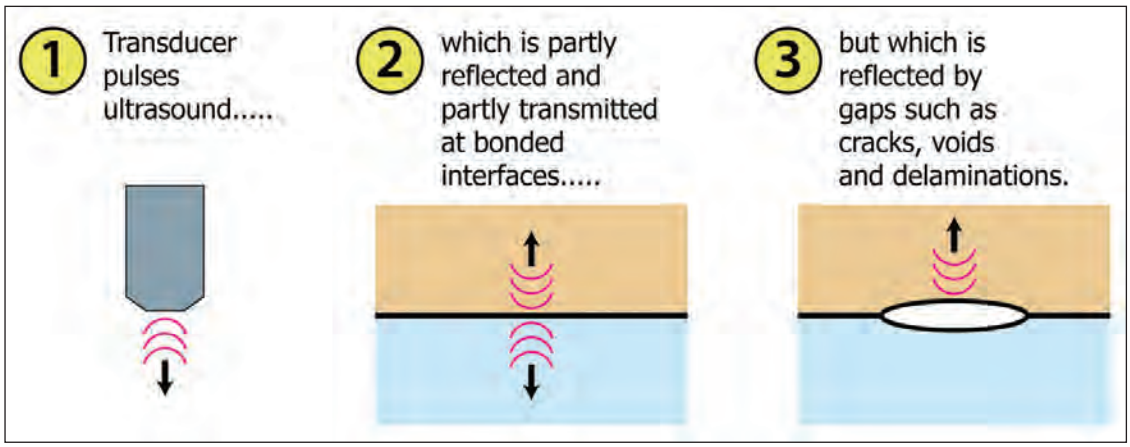


Figure 2: Well bonded interfaces both reflect and transmit an ultrasonic pulse, while a gap - even one as thin as 100Å - reflects essentially all of the ultrasound.

of ultrasound into the panel and receives return echoes having various amplitudes. The transducer typically has a long focal length and pulses 230 MHz ultrasound to achieve the highest spatial resolution in the acoustic images.

Well bonded material interfaces in the bus bar attachment reflect a portion of the ultrasound; another portion crosses the interface and travels deeper into the sample. A well bonded bus bar will therefore send back moderate-amplitude echoes that will appear gray in a monochromatic acoustic image. But any material gap, even if it is as thin as 100Å, will send back a maximum-amplitude echo that will be displayed as bright white in the acoustic image (Figure 2). The near-total reflection of the pulsed ultrasound is caused by the interface between a solid material and the air or another gas in the gap. Bright white features in acoustic image of the bus bars are non-bonds, voids, delaminations or other types of gaps. Their location and size are evaluated to determine how great a threat they pose to long-term performance.

Figure 3 is the acoustic image of one junction box, where the bus bar is soldered to the solar cell. The depth imaged was the glass-to-silicon interface. Imaging revealed two areas of concern:

- The bond between the bus bar and the silicon. Only the right and left regions of the bus bar display the medium gray tone that is indicative of successful bonding. There are significant regions (blue arrows) whose white color indicates that they are delaminated or non-bonded. In the center of the bus bar weld only small regions are well bonded (the medium gray seen at the left and right extremities) and there are numerous small delaminations. These anomalies may be the result of thermal interaction between the bus bar and the bond pad during assembly.
- The bond pad. Most of the area of the oval bond pad seems to be well bonded (evenly gray), but the outer edges of the bond pad are white - delaminated or non-bonded. Although these regions are relatively small, they are likely to expand in area until the bond itself is compromised. The bond pad is also surrounded by small more or less circular features that are likely to be voids.

Figure 3 is representative of the sorts of defects that need to be found during acoustic inspection of solar panels. By maximizing the scan area and developing innovative software, Sonoscan has significantly increased both the speed and the efficiency of the inspection process.

> “Traditional glass solar cell panels differ in that a strengthening material is placed on the backside of the panel. The material covers the whole area of the backside and prevents ultrasound from reaching and imaging the solar cells. A reflective coating makes imaging from the frontside impractical”

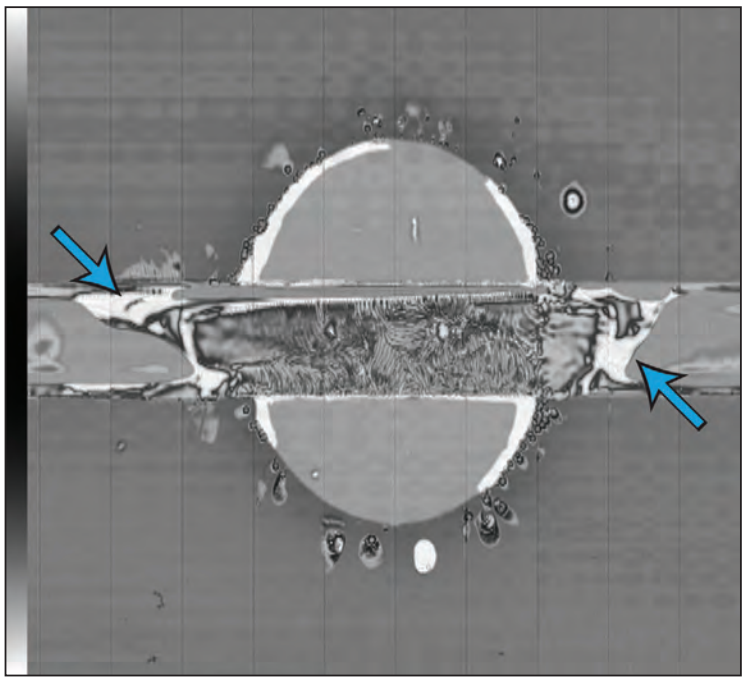
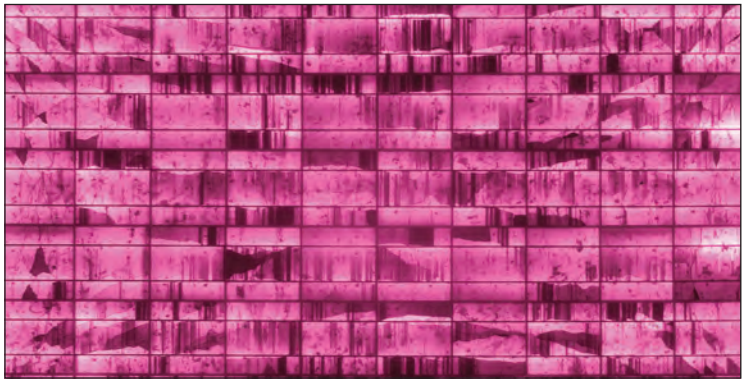


Figure 3: White areas in the acoustic image of a junction box are delaminated. Evenly gray areas are bonded.

Systematic evaluation of PV projects on the secondary market

With the number of transactions related to operating PV plants in the UK looking to increase over the next couple of years, a systematic evaluation of PV projects would ease the transaction process. PI Berlin with the BBA have developed the PQ Rating to assist decision-makers verify the performance and quality of PV assets. Steven Xuereb, Head of Business Unit PV Systems at PI Berlin explains.

ACCORDING to the market analysts from IHS, the amount of PV plants beings transacted on the secondary market in Europe over the past five years has been between 1.4-2GW. In particular, the most active of these markets is the United Kingdom, where in 2014 close to 1.5GW of PV assets were transacted and as of October this year, another 1GW was acquired or re-financed. This year at the Solar Energy UK conference in Birmingham, a panel of respected financiers and investors unanimously agreed that we have yet to reach the peak of the secondary market in the UK, and it is to be expected that more and more PV projects will be changing hands over the next two to three years.



Electroluminescence imaging is a key tool to evaluate the quality of the modules.

There are clear reasons for this level of activity on both the supply and demand side of the transaction equation. A wider range of investors has turned to PV plants over the last few years as a safe haven for their investments, where they can achieve stable returns over a long period of time. These investors, such as pension funds and insurance companies, are typically not interested in taking risks associated with the development and construction phases of projects, so they enter the market through acquisitions of operating assets. Meanwhile, many of the parties that developed and built the gigawatts of projects in the UK from 2010 to 2015 to take advantage of the lucrative ROC and FIT schemes, did so by using their own equity in order to speed up the completion rate to beat subsidy deadlines. These project developers and EPC construction companies didn't have the goal to hold on to the assets long term, and were eager to recoup their capital by selling the projects once in operation so that they could re-invest in new projects – either in the UK or elsewhere.

Stoking the fire of the secondary market were the sudden and significant changes to the solar incentive schemes in the UK by the government. Initially it looked as if only larger scale projects larger than 5MW were to be affected but now development of commercial and residential scale projects will certainly be throttled. With significantly less new

projects likely to come onto the market, those projects that are already grid connected with lucrative revenue streams will become more and more valuable.

Investors will certainly be placing premiums on these operational projects that will quickly turn most developers into willing sellers. With a bullish secondary market expected over the next 1 to 2 years, there will be a lot of competition for assets – not only on the seller's side, but particularly on the buyer's. Equity investors will be scrambling to find assets to fill their portfolios and funds. Debt financiers will also be competing to re-finance operating projects, as there will be less and less opportunity to project finance new plants. This competition is likely to lead to investors and lenders willing to be more aggressive in their financial models in terms of their return expectations and financing conditions. At the same time, competition will also create the need to act quickly, as any kind of delay may leave the door open for another party to swoop in and make the deal.

Technical due diligence

What we end up with is an environment where everyone involved in a transaction is eager to get things done as quickly and as uncomplicated as possible. Add this to the more aggressive financial appetite, there is certainly less room for error and potentially an increase in risk exposure associated with the asset targets. Typically technical due diligence (TDD) is the tool used by investors or lenders to mitigate the technical risks of a project. Based on experience, the TDD is also the last risk assessment conducted and as a result needs to be concluded as quickly and cost-effectively as possible. The deal has usually been mostly negotiated and agreed on both sides and the TDD is left as a tick-the-box exercise. The financial community has become very comfortable with PV technology – almost to the point where technical risks are an after-thought.

PV is certainly a reliable technology and the large majority of projects are built well using quality projects. That said, particularly in markets like the UK that saw very rapid growth in a short period of time with tight deadlines, there are certain to be some projects that may have an increased level of technical risk associated with them. The PV industry is still relatively young and has a minimum of standards that are applied. The modules themselves have IEC standards guaranteed by certificates, of which everyone is aware. There are however limitations to these standards as they do not cover all aspects of quality that can affect the long term reliability of the modules. As for the whole PV system in a power plant, there are no industry-wide accepted standards. The Institute of Engineering and Technology, IET, has recently published its Code of Practice for Solar Photovoltaic Systems. This code is certainly helpful to ensure that safety, functionality and code compliance is fulfilled in PV plants. There is also a working group within the IEC trying to establish a minimum level of quality for PV plants, as opposed to only the individual components – but this is still a work in progress.

During my discussions with lenders and investors over the past twelve months in the UK and elsewhere in Europe, common themes were mentioned time and again when discussing TDDs and the role of their technical advisors. Firstly they want to ensure that the asset is compliant – in terms of permits, H&S, grid, and industry standards. Secondly, they are concerned about the commercially relevant risks associated with the plant – e.g. does the plant produce and will it continue to produce what the seller says it produces. Thirdly, they want the results in a form that they can quickly digest and that their credit committees can easily comprehend. Finally, they don't want to unnecessarily create concerns that may affect the deals they are considering – again, while everyone is eager to make the deal happen.

PQ rating

PI Berlin and our partner in the UK, British Board of Agrément (BBA), took these comments as a


PI Photovoltaik Institut Berlin

BBA

PQ Rating

B-15-1045

Photovoltaic Plant – Performance and Quality Inspection

for

Hangleside and Tront Ltd

Blue River Solar Farm
Plaidstone Lane
Upper Mendip
Somerset
BA92 5QL

RATING: 8.1

Project Stage: Q3 – Inspection during operation

4 5 6 7 8 9 10
Class 3 Class 2 Class 1

Achieved: Class 1

Date of inspection:

Having been scored against the criteria described herein, the BBA has awarded this PQ Rating to the photovoltaic plant above. This rating applies to the plant on the date of inspection.

On behalf of the British Board of Agrément

[Name] [Position]

[Name] [Position]

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The PQ Rating gives the project an overall score based on performance and quality.

Checklists with over 1400 pass/fail criteria are used to evaluate PV plants systematically.

challenge to create a TDD product that addresses the needs and concerns of the players in the secondary market. The PQ Rating is a summarized report evaluating the performance (P) and quality (Q) of a PV plant, beyond the standard compliance evaluation of a TDD. The two-page report gives decision-makers a quick overview of the plant's performance and quality based on an overall score out of 10 points. Partial scores for each key aspect of the plant and their subset of topics are presented in bar charts with a summary explanation of the scoring results (see example in graphic). The reader has the ability to get an understanding of the key strong and weak points of the plant, before reviewing the complete TDD document, and can then focus only on the aspects that are of particular interest and concern.

The PQ Rating methodology is based on dividing the operating project into seven key aspects: contracts and permits; technical design; module quality; system performance; commissioning; electro-mechanical installation; and operations and maintenance. For each aspect there are detailed checklists with pass/fail criteria (in total over 1400) that result in partial scores.

Each of the aspects are weighted in a manner that gives particular emphasis on performance and quality issues that are of most interest to investors and lenders of operating assets. Contracts, permits, commissioning protocols and design issues would have more weight in the development and construction phase, but have less significance once a plant is in operation. That said, there may be a point that could be a red-flag deal-killer, such as missing land agreements or an invalid generating licence.

System performance, installation and module quality are aspects that have greater weight as they directly impact the long term revenue line and reliability of the investment. If a serial defect is found in the modules that leads to excessive annual degradation, this can completely change the business case for the buyer. If deficiencies in the plant are determined, the investor or lender is provided with quantitative impacts and concrete measures to address the aspect which can be used in the negotiation with the current owner.

For the module serial defect mentioned above, the annual production can be re-simulated and estimated which can directly affect the purchase price. In addition perhaps there will be the need to develop a maintenance reserve account to address potential large scale substitution of modules in the future. More and more asset managers are noticing the need for a more robust budget for the operations phase of the project to address ongoing issues in the plant – the PQ Rating results can assist to determine this budget.

The systematic approach and evaluation of PV plants with the PQ Rating allows for a relative comparison of a number of assets that an investor may be targeting for a fund. While the projects may be in the same market, they may have had different developers, different installers and different main components. By taking the final PQ Rating for each of the assets, the investor can quickly compare the projects and determine a value for the assets based on the results for negotiation with the seller.

Rating provides comfort

Rating systems are common place in the financial world to evaluate stocks, companies and assets. In the PV industry, investors and lenders have typically used TDDs to verify the technical risks associated with an operating asset. These TDDs have primarily focused on red-flags and compliance rather than performance and quality that have a significant effect on investment and financing decisions. The amount of activity on the secondary market for PV assets is highest in the UK and will likely continue for the next couple of years. With the backdrop of the regulatory uncertainty for new development, competition for attractive operating assets is strong. A rating system such as the PQ Rating can help decision-makers evaluate technical risk quickly, with a focus on commercially impactful aspects. With return expectations diminishing and lending conditions being more aggressive, an efficient rating tool can provide the comfort that investors and lenders need when evaluating and valuing assets.

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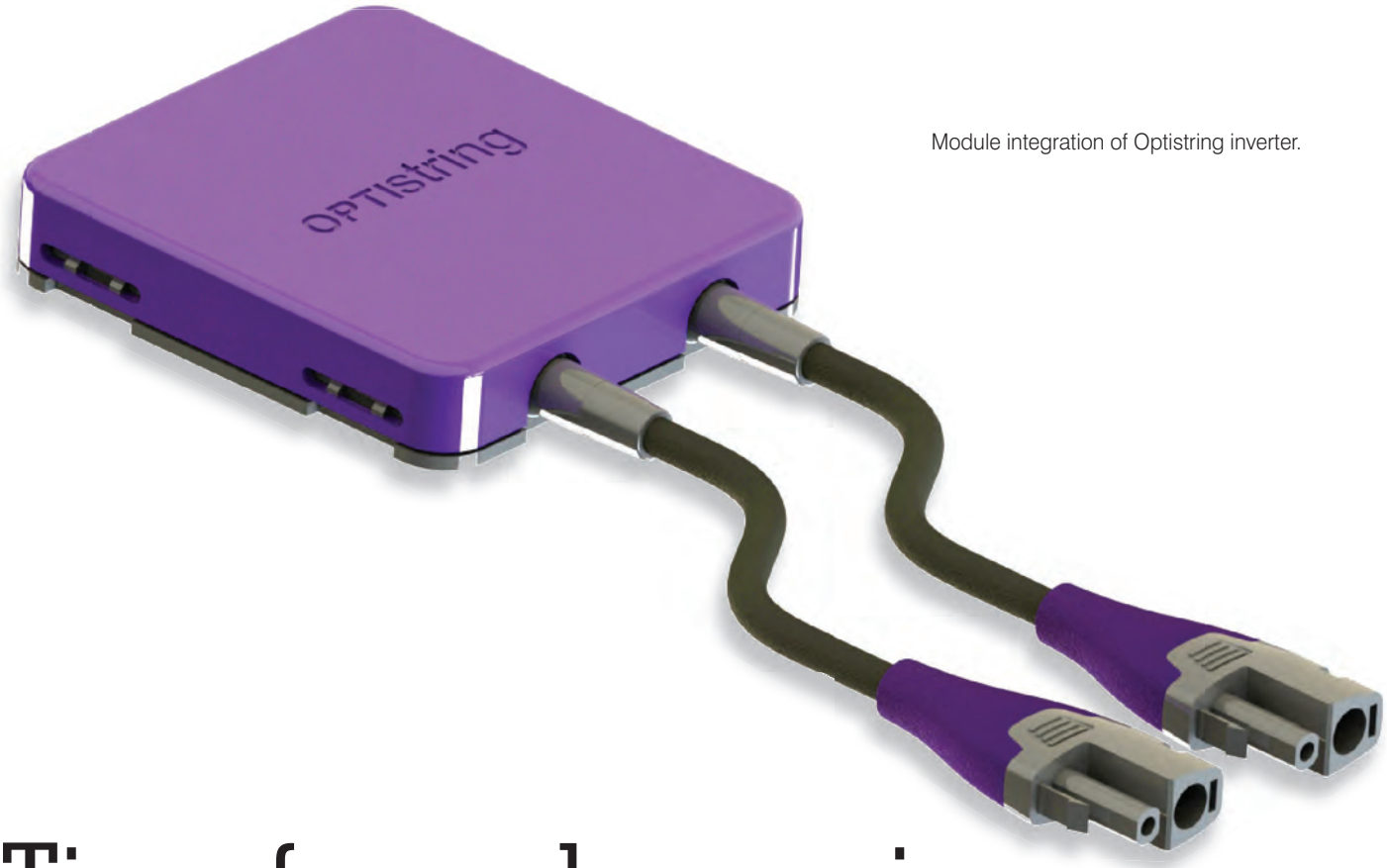

Module integration of Optistring inverter.

Time for a change in the inverter business

Optistring discusses a new smart way of feeding solar panel power into the power grid.

AS MUCH AS WE LIKE to think that the there is a technical revolution and that we are leaders in our fields we are usually working on a technical evolution and optimization of the track we already are on. Believe me I'm and engineer, I know. That established track can lead very far like internal combustion engines in cars or a new track opens and the whole business changes, like Jet engines in aircraft. The drivers of change are the same, based on better return of investment and lower risk for the system owner. To gain acceptance the new solution must be less complex, better integrated and open more and new business opportunities. The change will only come if the business is under competitive pressure with low and sinking margins. The next step is often presented by an outsider, like in the automotive case Tesla. The solar inverter business is a very competitive place today with low and falling margins, here Optistring is the new thinking outsider. Optistring has developed high end inverters for photovoltaic (PV) energy systems based on well-known technology from high power distribution, stacked inverters. By enhancing and optimizing this technology for PV systems the new distributed inverters increase the energy harvest in case of shading or mismatch with up to 25% compared to conventional string inverters, and reach 99% cycle weighted conversion efficiency. With only one step of power conversion the system is far less complex than conventional inverter architectures and is, through its modular design, very well set up for high level of mass production. Module level monitoring, MPPT and rapid shutdown are inherent features of the system without adding complexity.

The system consists of module units, one for each PV module, and a central unit common for up to 20 modules in single phase and up to 140 units in three phase application. The module units handle the power conversion, in one single step for high efficiency and low cost. The grid connection as well as the internet connection for monitoring is made

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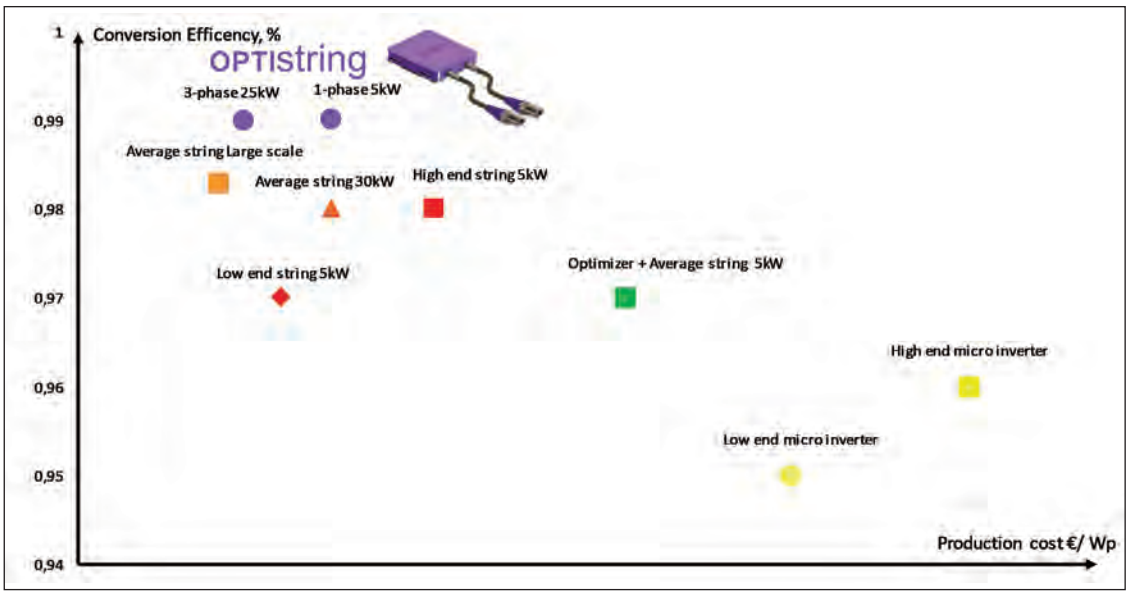
Figure 1: Cost and Efficiency vs. Competition



through the central unit. Optistring is achieving all the module level benefits through their innovative distributed inverter technology with fewer steps of power conversion. Fewer steps of conversion means savings in hardware and lower conversion losses in the system.
Total cost of the Optistring system is below a single good string inverter while delivering features of a string plus optimizer combination at a much higher efficiency. Optistring delivers half the losses at half the cost compared to prevailing optimizer installations making Optistring a good alternative for Utility, Commercial and Residential application worldwide.

For years the industry has increased conversion efficiency and used those numbers as a marker of quality. Today's string inverters are at levels slightly below 98% and every further increase has become associated with higher and higher cost. As the levels have improved and systems costs have come down it has become more and more an academic interest rather than a business consideration. An easy example is to value a 1% conversion efficiency improvement projected to the total system cost (1-2€/ Wp), which gives 1-2€ct / Wp. What has gained increasing interest over the last couple of years is improved harvest efficiency. With efficiency gain over a string inverter of 3% in a well-balanced ideal location to over 10% in a shaded small installation, the harvest efficiency will be the dominant factor in selection of inverter technology for best ROI. The module level monitoring is further increasing the ROI by enabling surveillance of dirt and faulty modules This will hold true not only in residential but in all installations going forward. Module level electronics is the fastest growing part of the solar industry today.

The high conversion efficiency of the Optistring inverters has some other indirect benefits. The power losses in the module units are at ~1 W at full power so there is no need for cooling and heat sinks. The low weight combined with low self-heating make the technology ideal for integration onto the backside of the modules at manufacturing. This reduces the total system cost as the inverters replace the normally used junction boxes and the installation will be even further simplified.

With harvest efficiency gain of 3% in a well-balanced ideal location to over 10% in a shaded small installation, the harvest efficiency will be the dominant factor in selection of inverter technology for best ROI

When integrated onto modules the Optistring product is a crucial component in a PV system and hence the life span must correlate with rest of the system. The system builders request components of high and consistent quality for their PV systems. The reliable Optistring system delivers that with a life span of more than 25 years, this is another benefit of having low losses and low self-heating as temperature are the major life limiting factor for electronics.

Another trend of the maturing PV industry is the increased awareness of safety. This can especially be seen on the US market with the rapid shutdown requirement in the NEC 2014 standard. The high DC voltage of traditional string inverter installations is a potential hazard. It is dangerous not only for us in the industry installing and maintaining the systems, it can also cause fires in case of arcing. The Optistring technology is using AC for power distribution in the array, eliminating the risk of DC arcing. Cabling errors and breakage is also intrinsically detected in the system and will automatically cause all module units to turn off, leaving the system in a safe and voltage-free state in less than 1 second.

End customers benefits

Increased energy harvest - increases power output
The module level MPPT optimally extracts energy from every PV module in the system, independent of external site conditions such as mounting angles, partial shading or panel performance variation. It provides the possibility to use PV modules with different output power characteristics in the same

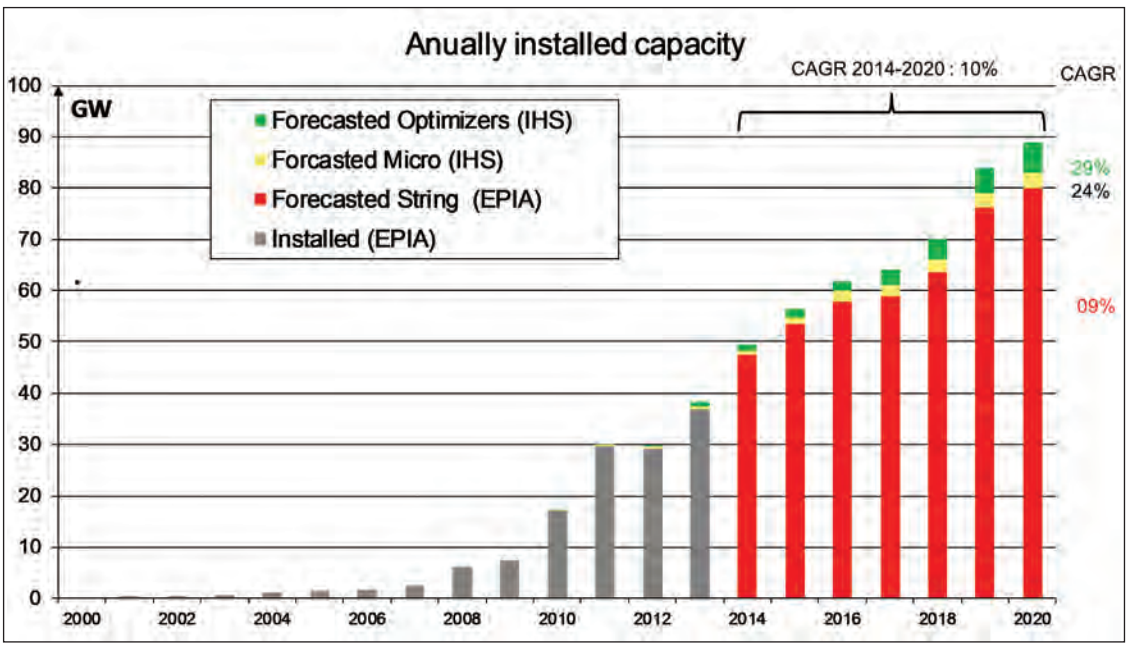


Figure 2: Global demand and power optimizes market share forecast [source IHS 2014, EPIA 2014]

Optistring combines performance, safety and cost

	String inverter	Power optimizer	Micro inverter	Optistring
Efficiency (Euro)	≈ 98%	≈ 97%	≈ 96%	**99%**
Cost	1x	2x	3x	**1x**
Module level - Safety Optimization Monitoring	NO	YES	YES	**YES**
Module integration	NO	YES	NO	**YES**
Simplified planning / install	NO	YES	YES	**YES**

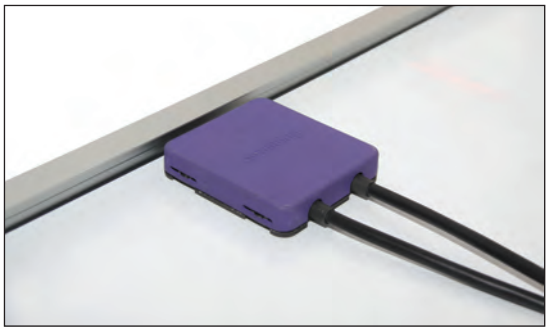
Table 1: Inverter systems comparison

installation. Matching and sorting of panels becomes unnecessary. Up to 25% more energy can be harvested compared to a traditional string inverter system under challenging conditions.

Improved conversion efficiency – increases power output
The 99% efficiency of the Optistring system further improves efficient housekeeping of the precious power output from PV panels. Only one percent is lost from the conversion of the power on its way from the panel to the grid.

Individual module monitoring – improves availability and ROI
The system offers individual remote monitoring of the panels in the installation. This provides the ability to continuously monitor performance on each of the installed module. Preventive maintenance where performance degradation, dirt covering or failures of the panels can be immediately detected and resolved on a panel to panel basis, to maximizes overall return on investment of the system.

Increased reliability – improves ROI
The Optistring system can operate with as much as 94% of the modules shaded or faulty while maintaining a high efficiency. The low impact of a faulty panel allows for scheduled maintenance and lower servicing cost. The system availability is high with very few single points of failure. Panels can be switched out and replaced in the system without consideration of module mismatch from aging or sorting.



Simplified installation – accelerates deployment time, reduces cost
The module level MPPT of the Optistring inverter provides the installer more freedom in the planning of a PV system. Partial shading and different mounting angles do not have an impact on neighboring modules in an array. This makes it possible and more profitable to fully utilize the climate shells of buildings in areas where shading might occur, for example in building integrated PV and urban environments. In commercial and utility scale applications there is no need to do narrow band sorting of the modules for optimal energy harvest. Every module in the system will perform at its best through the life of the installation.

The interconnection between panels is simplified and based on AC wiring which renders additional components such as DC breakers or remote disconnect devices obsolete, further reducing overall system cost. Modules can be connected in any direction or order as the connectors are bi directional, enabling large flexibility in installation. In time of need for a new solution for Solar power conversion Optistring offers a robust, flexible and highly effective solution for future inverter performance. Low losses and compact modular design enable full integration to module. Module level MPPT, Monitor, Arc-protection and Rapid shutdown are inherent features of the system at a cost comparable to a string inverter. Optistring is taking inverter technology to the next level.

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New materials to drive panel price down

Harry Cronin is one of only ten exceptional graduates in the UK to be honoured with an Industrial Fellowship from the Royal Commission 1851. In this article he explains how the long-awaited dream of high performing printed solar cells may soon become a reality.

A PRESTIGIOUS INDUSTRIAL FELLOWSHIP has been awarded by the Royal Commission for the Exhibition of 1851 for doctoral work on printable Perovskite solar cells. These fellowships are awarded to around ten doctoral researchers annually with the aim of fostering UK science and engineering to aid productive industry, and involve a collaboration between academic and industrial partners.

This project, which forms part of an Engineering Doctorate (EngD) at the University of Surrey, England is led by doctoral researcher Harry Cronin in collaboration between the University's Advanced Technology Institute and DZP Technologies Ltd., a technology development business based in Cambridge, UK. The aim is to fabricate Perovskite active layer materials in a printed solar cell structure to produce flexible, low cost solar cells.

The research in this project builds on two decades of progress in the solution processing of electronic materials, a field known as large-area or printed electronics. This is an emerging industry, forecast to be worth $70bn by 2024 (IDTechEx 2014). As well as allowing low-cost devices to be manufactured on a range of substrates including flexible plastics, as an additive manufacturing technology printed electronics also offers environmental benefits arising from the reduced use of materials and elimination of energy-intensive processes such as vacuum deposition and high temperature treatments. While this is a nascent industry, some successes have been achieved in printed logic and memory circuits, and Radio Frequency Identification (RFID) sensors.

However, despite intense research interest, printable solar cells have yet to become a large-scale commercial reality. One reason is that until now, active layer materials which combine solution processing with high solar power conversion efficiency have not been available; this is where Perovskites comes in.

Perovskite solar cells have become a hot topic in PV research in recent years, driven largely by the rapidly improving power conversion efficiencies (PCEs) achieved. These solar cells, based on organic-inorganic hybrid semiconductors, offer the potential to combine high performance with low cost, a goal which has proved elusive in solution-processable PV research to date. The high PV performance of these materials arises from their excellent opto-electronic properties, including strong light absorption, a near-optimal bandgap of around 1.55 eV and high electron and hole mobilities.

Furthermore, Perovskites consist of earth-abundant materials and can be processed entirely at temperatures below 150oC, meaning that the energy payback time of such cells could potentially be very short. These advantages are combined with the fact that Perovskites can be dissolved in an appropriate solvent and cast from solution, opening the way for the use of high-throughput, low cost techniques such as printing and coating. It is this last property which this project aims to exploit, by combining an improved understanding of the Perovskite active layer materials with the printed electronics and formulation chemistry know-how of DZP Technologies, an SME with world-leading expertise in

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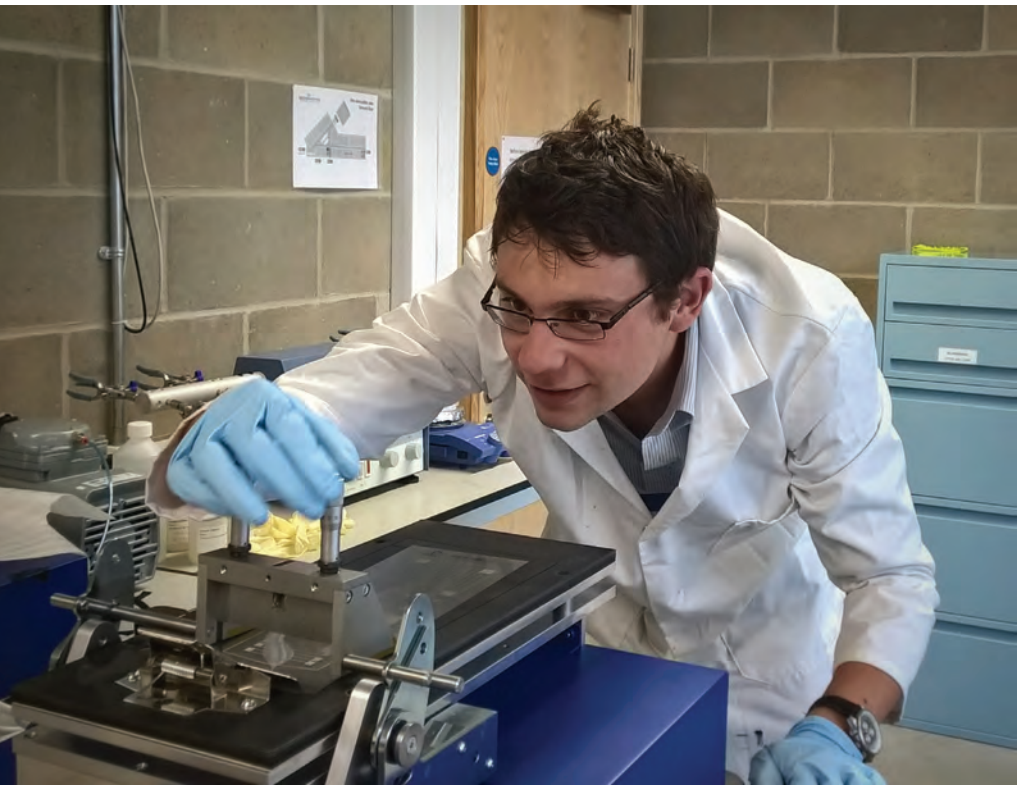

the development of functional inks and novel printing processes. By using large-area techniques such as printing to produce solar cells, their financial cost and energy payback time can be greatly reduced.

It is hoped that if a printed solar cell with high performance can be produced at large scale, then the cost per watt of the power produced would be drastically reduced. Such cells could furthermore be deposited on plastic substrates, which would open up new applications where properties such as mechanical flexibility and low weight are important. One such area is use for off-grid power generation in remote or disaster areas, where low weight and the ability to rapidly deploy would be critical; or as an ultra low-cost distributed power supply to enable the sensor networks which are widely expected to emerge as part of the so-called Internet of Things. By using solution processing, conformal coating of existing structures with PV materials may also become a reality, opening up applications in building-integrated PV; an area for which Perovskites may prove uniquely suited because their band gap, and therefore colour, can be tailored chemically.

In the most general sense, the name Perovskites is given to the class of compounds with general formula ABX3, which adopt the crystal structure seen in the calcium titanate mineral of the same name, which is named after the 19th century Russian mineralogist Lev Perovski (Rose 1839). Both oxide and halide Perovskite materials have been known for many years, and many of them have interesting properties beyond photovoltaics, including antiferromagnetism and superconductivity. However the Perovskites of interest for PV applications are metal-organic halide materials, in which the “A” cation is a small organic molecule, the “B” metal cation is typically lead or tin, and the “X” anion is a halogen. The archetypal compound is methylammonium lead triiodide (CH3NH3PbI3).

The first use of such halide Perovskites in Light-Emitting Diode (LED) and Thin-Film Transistor (TFT) applications was reported by a team at IBM Research in the 1990s (Mitzi et al. 1995), but at the time no report was given of their use in solar cells. The first such report came in 2006, when a team of researchers from Korea used Methylammonium Lead Tribromide (CH3NH3PbBr3) and later in 2009 used Methylammonium Lead Triiodide as a drop-in replacement for the commonly-used organic dyes in a dye-sensitised solar cell (DSSC) structure, with a liquid electrolyte (Kojima et al. 2009). This structure uses a mesoporous TiO2 scaffold infiltrated with the sensitising material – in this case the Perovskite – which absorbs incoming light to generate an electron-hole pair. The photo-excited electrons are then transferred to the external circuit through the TiO2, a good n-type conductor, while the holes are transported through a p-type liquid electrolytic hole conductor. However, the use of a liquid as the hole conductor severely limits such devices as these materials are corrosive to the Perovskite active layer. Due to the very limited lifetime of such cells, this research was not widely followed up on by the community for several years.

However, two breakthroughs occurred in 2012 which split the field wide open. Researchers working in Switzerland (Kim et al. 2012) overcame the problem of corrosion by the electrolyte, using a solid state hole conductor (consisting of an organic molecule known as Spiro-MEoTAD) in a mesoporous device structure containing TiO2. Almost simultaneously, a team working at Oxford University (Lee et al. 2012), also using solid-state devices, showed that the electron-conducting TiO2 scaffold was not necessary for charge transport by replacing this with Al2O3 – which provides a similar morphology but is insulating. This breakthrough realisation that the Perovskite can provide all three necessary processes for solar energy conversion (light absorption, charge separation and charge transport) has driven a frenzied research interest in these materials in the last three years.

A number of further refinements have been reported, including the introduction of simpler planar heterojunction device structures, which resemble the well-known p-i-n structures used in some inorganic PV cells, with the Perovskite absorber layer sandwiched between solution-processed p-type and n-type materials. The A cation can be changed, with options including formamidinium (HC(NH2)2) and caesium – in the former case the bandgap can be slightly reduced and power conversion efficiencies greater than 20% have been reported. For a solution processable material to reach such levels of performance in a few short years of R & D is unprecedented.

As with any new technology, there are several drawbacks of Perovskites. The keen-eyed reader will have noticed that

the Perovskite compounds referred to so far contain lead, and the environmental and toxicological issues of this will need to be addressed prior to commercial scale-up of this technology. One solution may involve re-engineering the structure to contain more benign materials, and work on tin-based perovskites is ongoing. As another possible avenue, some recent studies have suggested that the lead content in a future commercial Perovskite solar cell may be low enough to be tolerated, providing that the device is very well encapsulated; however this would likely require some regulatory support.

A further issue is that the Perovskite materials are sensitive to moisture and severely degrade if exposed to the atmosphere. However, recently published work has shown great progress in this area, pushing device stability up to and beyond the 1000 hour mark. Another open question is whether the excellent performance achieved so far can be retained when the devices are scaled up. Lab-scale cells currently used in many research studies are tiny – often less than 0.1 cm2 – which will have to be enlarged by several orders of magnitude to be commercially useful (This project works with a minimum device size of approximately 1 cm2 – which is still small, but at least larger than many lab scale devices).

A further unknown factor in Perovskite technology is the detailed influence of processing conditions on the structure and performance of the active layer, and the current project has started off by gaining a deeper understanding of the influence of environmental factors by producing Perovskite cells under a range of controlled conditions and measuring their structure and performance, making use of the advanced materials characterisation facilities at the University of Surrey.

As with any new technology, there are several drawbacks of Perovskites. The keen-eyed reader will have noticed that the Perovskite compounds referred to so far contain lead, and the environmental and toxicological issues of this will need to be addressed prior to commercial scale-up of this technology

The next steps in this project will be to build upon work already undertaken at DZP Technologies in the field of printable solar cells in order to integrate the Perovskite active layers with the necessary charge transport and encapsulant layers in a cost-effective manner to form prototype printable solar cells.

One aspect of this work is extending the use of high intensity visible light photo-curing, a high-throughput and low-cost post-processing method for printed electronics, to improve the conductivity of the printed metallic structures needed to collect electrical charges from the active region, This work has already shown large improvements in performance on lab-scale test structures. It is hoped that by integrating the recent advances in academic research into Perovskite materials, the materials expertise of the University of Surrey, and the commercial and technological knowhow of an innovative SME, the long-awaited dream of high performing printed solar cells may soon become a reality.

In addition to the Industrial Fellowship, Harry's EngD research is supported by EPSRC and DZP Technologies through the University of Surrey's Centre for Doctoral Training in Micro- and Nano Materials and Technologies (CDT in MiNMaT), in collaboration with the Advanced Technology Institute. DZP Technologies are able to provide contract research, collaborative R & D and market-leading functional electronic inks, and can be contacted through www.dzptechnologies.com

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Two-in-one innovation for water storage and energy supply in semi-arid region

Benecke- Kaliko solar floating cover offers relief and a climate friendly solution to water conversvation.

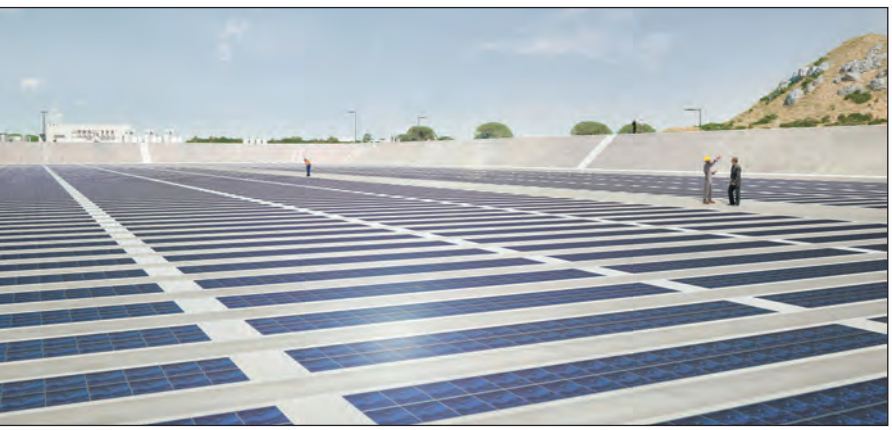
Tobias Haarburger, Program Manager Industry, Benecke-Kaliko

WATER SCARCITY is a hotly debated issue. The problem is especially serious in areas that are not connected to municipal grids and suffer lengthy periods of drought. Here water and electricity are often in short supply. It's a problem that affects not only large countries, such as the USA, Australia and China, but also the Near East and Africa.

Tobias Haarburger, Program Manager Industry at the ContiTech subsidiary Benecke-Kaliko, came up with an ingenious solution: A solar floating cover which combines simple, cost-saving water conservation with climate-friendly power generation.

Known as "Dynactiv Power – with integrated solar technology", the special laminated foil consists of opaque sheeting with a number of different functional qualities. The innovation seals water reservoirs completely, preventing water from evaporation and improving its quality. At the same time, integrated photovoltaic modules produce renewable energy. The solar floating cover thus offers several benefits: storage of potable or reclaimed water, serving as a self-sustainable hydraulic buffer. At the same time the systems produces electricity for local pumping stations, water treatment or electrical grid feed in. "Dynactiv Power keeps as much as 40 percent more service water available for use, opening up far more land for agriculture and, in turn, delivering considerably larger yields," Tobias Haarburger explains. But it also has another advantage: depending on how much energy the local area and its people need, suitable numbers of solar cells can be chosen and laminated straight into the surface of the foil. This enables the energy needed to be generated directly from the sun. In a reservoir with an area of 100,000 square meters, the innovative foil harnesses enough power to run a small power station generating 5.0 megawatt peak (MWp). "For many communities in remote areas, this represents an important part of a secure energy supply," Haarburger says, clarifying the situation." In line with the guiding principle of 'Engineering Next Level', ContiTech is setting a benchmark in a new industry thanks to this latest innovation.

Dynactiv Power Installation is a very simple installation:
1. Excavate a reservoir and line it with protective foil
2. Fill the reservoir with water
3. Cover the reservoir with protective
4. Fit the reservoir with Dynactiv Power



As the first system to combine water conversation with climate-friendly energy generation Dynactiv™ Power is the ideal solution for utility provider and water companies.

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PV Materials Award

DuPont: Solamet photovoltaic metallization pastes

DUPONT SOLAMET PV19A photovoltaic metallization paste, the first product in the PV19x series, is a front side silver paste based on proprietary Tellurium technology and tailored to optimize the efficiency with which solar cells convert sunlight into electricity.

]It enhances the power output of solar cells by enabling fine line printing down to 30 microns and demonstrating excellent paste transfer for improved line aspect ratios that minimizes the shading effect on the surface of the solar cells, while maintaining superior electrical conductivity.
Solamet PV19x pastes offer wider processing latitude during manufacturing, which means cost savings result from higher yields, and tighter cell distribution is shifted toward higher efficiency.

Improved frit technology enables extreme Lightly Doped Emitters (LDEs) because it improves contact resistance by 10 fold to further boost efficiency on monocrystalline and multicrystalline solar cells.

Receiving the award: Peter Brenner, Global Business Development Manager

Project Development Award

Zero Emissions Initiative

POWER CLOUDS INC. started a project founding plants driven by sustainable power around the world thanks to the contribution of corporates and public institutions. “Zero Emissions Initiative” is the name of the new challenge thrown by the company together with the “Power Clouds Project” that last year got the Solar Industry Award – in the category Project Development. Zero Emission is a voluntary initiative that invites the biggest responsible for CO2 emissions on the Planet – such as public and private companies- to compensate the impact generated by their products and services by recognizing them as 100 percent replaced by renewables.

The company involved buys the certificate to be applied on each product or service. The certification is issued after calculations made by Power Clouds Inc. according to a protocol that meets the highest international standards concerning this field. It will prove that the impact in terms of CO2 has been compensated by a number of plants powered by renewable sources built by Power Clouds. The complete solution is really innovative to finance the promotion of renewables and fight climate changes by directly involving public and private companies.

Zero Emissions Initiative is the alternative to the conventional funding aiming to involve private businesses and public organizations against climate change. That will be possible through awareness-raising and compensation process in concerning those emissions that are the main causes of Global Warming. The innovation is in funding plants construction indirectly by getting the participants into a network of benefits and best practices easy to spread on a global scale.

The contribution in this fight is given by building renewable energy facilities thanks to the profit of the certifications sale to those companies that compensate this emissions. The plants produce clean energy replacing the one coming from fossil fuels sources and that goes into the national electricity grid. Each participant will know exactly the role he has played in the plant development by being associated the necessary amount of Watts to compensate each product/process/service emission.

Power Clouds thinks that the only way to face climate changes is involving the direct responsible of gas emissions: people corporates public and private organizations. Obviously there already are companies promoting project following the same steps but Power Clouds Inc. is different. It’s the company that combines all those steps together in a single project that leads emissions producers to become renewable technology promoters. Also all the participants are going to take part into a network of virtues partnership business opportunities.

Receiving the award: Attilio Palumbo, Executive Vice-President Strategy and Communication

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Turnkey Project Award

Onyx Solar: BIPV turnkey projects

ONYX SOLAR develop building integrated photovoltaic solutions which are used for the replacement of conventional construction materials from different parts of the building's exterior such as skylights, façades, windows, curtain walls or roofs. Onyx Solar has developed the first Low-e Photovoltaic Glass. It improves the properties of conventional glass.

Alongside the VCS 1200 system, Manz's LAS 2400 laser ablation system provides a simple, precise and high-throughput solution for local contact opening of rear side passivation layers. Being a one-stop process, laser ablation offers the lowest cost of ownership for this step in cell production and offers safe wafer handling with the industry's lowest breakage rates. This Low-e Photovoltaic Glass improves the thermal and sound insulation of the building and filters the ultraviolet and infrared radiation, avoiding adverse impact on people, furniture and buildings' interior.

At the same time, it allows to control the indoor temperature, achieving big savings on air conditioning systems and avoiding greenhouse effect so common in glass buildings.

Onxy Solar is a business committed to the development of intelligent solutions for the sustainable integration of solar energy photovoltaic in buildings.

These solutions contemplate the integration of façades and ventilated roof façade as one of the principle constructive solutions designed with the objective to optimize not only the production of energy but also to make important energy savings for the building.

Receiving the award: Reiner Mack, official distributor for Onyx in Germany

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Turnkey Equipment Award

Singulus Stangl Solar GmbH:

Equipment for wet chemical processes for wafer fabrication

TODAY'S dominating solar cell concept is based on cells made from crystalline silicon. SINGULUS STANGL SOLAR provides complete automated dry-in/dry-out solutions for wet treatment of Si-wafers in standard and high-efficiency cell lines.

Current and future market requirements of machines, processes and materials for solar cell manufacturing sets new standards for cost reduction, productivity, and process capability of wet-chemical production.

The ongoing evolution of proven concepts in process management and the integration of innovative approaches are the basis for the development of a new generation of horizontal etching systems. LINEA II is a horizontally working inline wet process platform for cleaning and etching of crystalline solar wafers. The SINGULUS LINEA II combines an advanced transportation system, sustainable and innovative processing modules with proven and efficient chemical etching and cleaning processes.

In addition to proven processes like texture etching, PSG etching or RCA cleaning, the focus is on newer applications with one or two side processes, such as polish etching, emitter etching and ozone-based or ultrasonic cleaning respectively.

The highly integrated design, high throughput, high availability and low breakage rate make LINEA II attractive for solar cell manufacturers.

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PV Tool Award

microDICE OTF

3D MICROMAC

The microDICE OTF system uses Thermal-Laser-Separation for cutting of cells into half cells. The separated cells show a significantly higher mechanical strength better edge quality as well as a lower power reduction compared to laser scribing and cleaving approaches. The highly-productive system microDICE OTF achieves a throughput of more than 7200 wafers per hour (single lane. The optical set-up relies on the industry-proven on-the-fly technology successfully used at 3D-Micromac's laser structuring tools for processing of PERC cells.

The laser processing is realized during the continuous transport of the cells under the laser source whereby the relative motion of the cells is automatically compensated for. Stops for the positioning of the individual cells are completely eliminated. The continual movement of the conveyor belt results in an almost 100-percent capacity utilization of the laser source. The microDICE OTF is a fully automatic 24/7 production solution and can be offered as stand-alone or inline system. As all 3D-Micromac production solutions the microDICE OTF is applied to meet cell manufacturers' demands for achieving maximum throughput rates and yield while cutting cell manufacturing costs. The system guarantees very high availability through the use of a sophisticated efficient concept and high quality components.

Receiving the award: Thomas Kiessling, Area Sales Manager China

The standard procedure for cutting of full cells into half cells is a two-step process: laser scribing and subsequent mechanical cleaving. First the laser is scribing a 30-100 μm deep groove on the rear side of a solar cell. In order for the cell to break into two halves an additional mechanical force needs to be applied which adds up to the handling cost of the machine. The disadvantage of separating cells with this method is the resulting chippings and generation of micro cracks at the cutting edge. As a result we see a significant mechanical strength reduction (minus 30-40 percent of the separated half-cell in comparison to the full cell. This can have a negative impact on the final module lifetime and efficiency in case initiated cracks caused by the laser scribing and mechanical cleaving process propagate any further on the separated cell.

The TLS process does not require any additional mechanical breaking by external applied forces. It allows the ablation free cleaving to separate solar cells with a high edge quality. The process is based on thermal induced mechanical stress generated by a well-adjusted combination of a laser (heating and cooling (e.g. by sprayed Di-water. The separation by cleaving is a one pass-process. For giving the separation line a well-defined stating point a second laser is used. This laser initiates the cleaving by a small local scribe at the starting edge (only a few micrometer long and deep – not at the whole surface! The microDICE OTF system is equipped with two industrial fibre lasers for initial scribing and TLS cleaving. Due to the on-the-fly processing laser utilization is nearly 100 percent.

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PV Process Award

Luvata: SunWire

SUNWIRE is a copper-based flat wire used to connect silicon cells electrically and to carry out current in crystalline silicon and thin-film photovoltaic modules.

Extra soft Sunwire reduces cell breakages and reduces electrical resistance in modules. Combined with excellent spooling and straightness, Sunwire improves customers' manufacturing process and final product.

Sunwire is rolled from round wire to high precision, annealed to extra soft, plated all-over in hot-dip-tinning process and precision level-wound on returnable spools. All standard dimensions, plating alloys and spool sizes are available.

The latest annealing and plating technology in Sunwire products is completely chemical-free and compatible with new lead-free soldering alloys and saves energy. It was developed to help our customers to improve their production yield and product performance. Sunwire benefits include:

- **Smaller width**
  - To avoid sacrificing cell yield
  - To enable 3-wire solutions for larger cells
- **Softer material**
  - To avoid causing stress in the soldering process
  - To enable usage of thinner wafers
  - To reduce electrical resistance
- **Straighter material**
  - To get out the full power of the module
  - Usable also in large thin-film applications
- **Tin coating on every surface**
  - Applications

Receiving the award: Tero Horttana, Director Global PV Accounts and Product Group Manager - PV

Crystalline silicon panels: Ongoing development of both multicrystalline and monocrystalline silicon cells requires continuous improvements in the wire. We are developing new products to meet the most stringent technological and market demands for all these applications.

Thin-film panels: With the growth of thin-film solar panel markets, there are new requirements for both the wire and the connections between the wire and the thin-film module. Whether it is amourphous or 'micromorph' (microcrystalline / amourphous) silicon. CdTe or CIGS thin-films, we can provide the right solution for the module manufacturers.

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Industry Development Award

PCB^{TOUCH}

MEYER BURGER

THE PCB^{TOUCH} is a patent pending cell contacting solution from Meyer Burger's product and technology center for measurement technologies, Pasan SA. It addresses the market's need to contact back-contacting cells (such as MWT or IBC) or any complex backside printing layouts such as bifacial busbarless cells for IV/EL performance measurements.

Existing solutions for back-contacting cells are all based on vacuum systems that are costly and only compatible with one specific cell layout. Even slight changes to a cell design can require the purchase of expensive additional jigs in existing solutions. The novelty of the PCB^{TOUCH} is its full compatibility with diverse designs and technologies simply by replacing the backside printed circuit board (PCB). Its flexibility allows the easy creation of designs that match the layout of any cell backside.

No vacuum needed for cell measurements

The innovative PCB^{TOUCH} system is a contacting jig consisting of an upper frame and a bottom plate. The upper frame is composed of a wire grid while the bottom plate is slightly convex topped with a printed circuit board. Once the cell has been placed in the right position on the PCB, it is pushed onto the upper wire grid which ensures good contact of the backside's pads, fingers or busbars and also holds the cell in place during the measurement process. This renders the vacuum system redundant.

Existing solutions for contacting bifacial busbarless cells are limited when it comes down to front and back finger configurations. In contrast, the PCB^{TOUCH} is compatible with all parallel, perpendicular, 45° and interrupted fingers configurations.

Furthermore, the cell contacting solution distributes the pressure uniformly over the cell enabling contacting of much thinner cells. With existing solutions, the likelihood of damaging thin cells is much higher. The use of standard contact pins selectively engenders a high level of pressure.

The PCB^{TOUCH} is based on the proven Grid^{TOUCH} technology which has already been successfully installed and used in laboratories and industrial environments and will be initially available as manual unit. It is sold in combination with the A+A+A+ Spot^{LIGHT} HighCap cell tester to ensure the reliability of the measurement with a best-in-class light source and contacting solution.

The contacting unit is being developed further as an automated, industrially integrated unit which will be complemented by two vertical grooves. This will allow use with any automated conveyor belt system which will convey the cells between the contacting frames. It will be possible to integrate this solution into automated cell sorters in order to fulfil the market's need of increased throughputs and highly reliable measurement results.

Ernst Gockel (right), Head of Account Management Meyer Burger and Uwe Habermann (left) Sales and Strategic Business Development, PV Systems & Solutions, Meyer Burger