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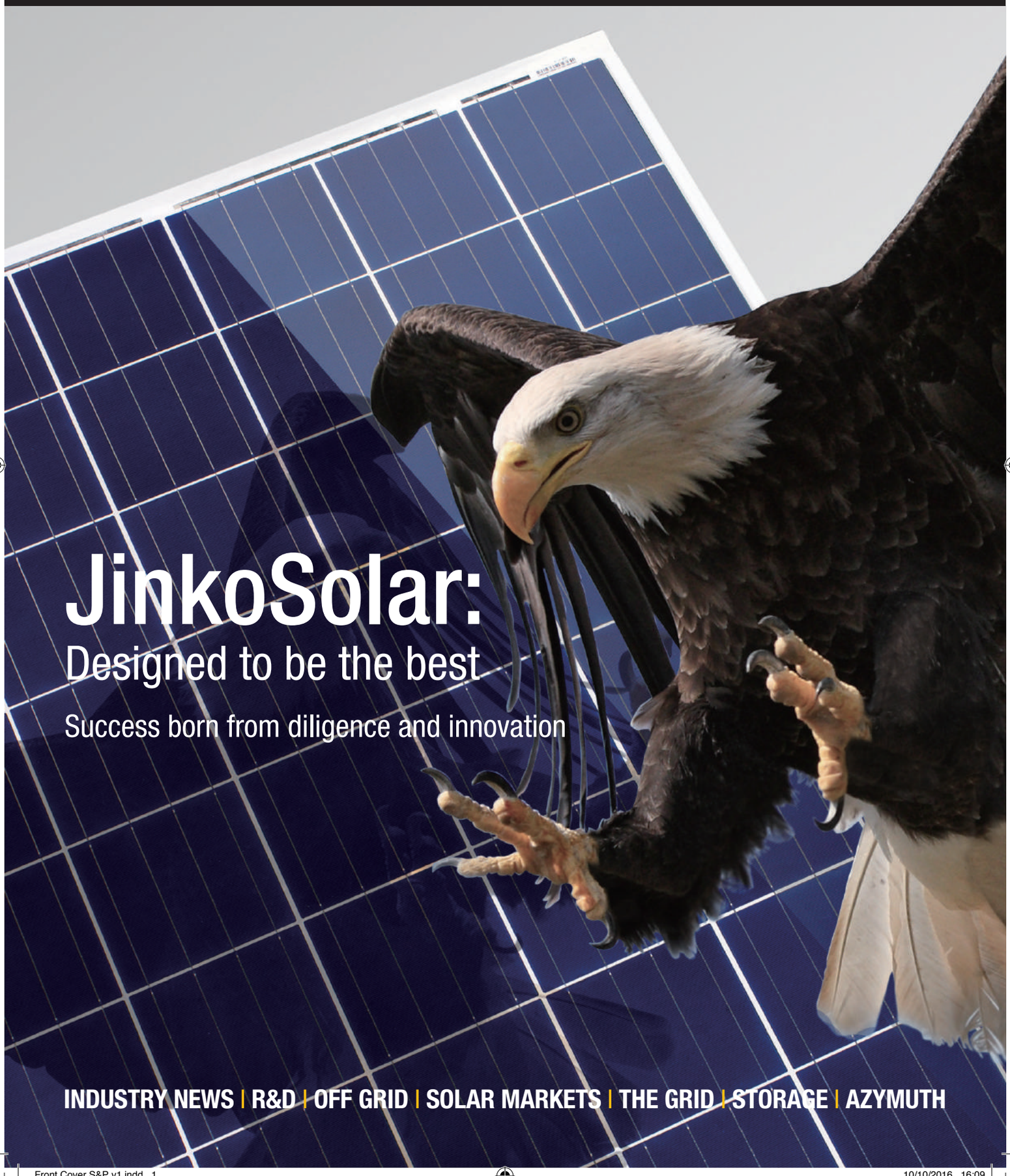

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viewpoint

Time to tighten the reins?

WATCHING the global PV market is a bit like viewing aircraft test pilots who make certain a plane can perform when pushed to the limit. What seems impossible one day is tried the next. Riding with a test pilot is not for the fainthearted; it is a lot like the jagged trajectory of global PV markets.

2016 has already set records. Last year's sizeable market growth fostered a 'build it and they will buy' mentality. The result? Overcapacity in 2016. At the recent Solar Power International (SPI) event, ASP declines had delegates talking.

Roth Capital analyst, Philip Shen, gave voice to concerns over ASP erosion, saying that module prices across China, India and North America could fall to (USD) 32-38 cents per Watt in Q4. This was echoed by other analysts including Deutsche Bank's Vishal Shah, who saw Chinese manufacturers collecting about 40 cents per Watt, down from an average of 60 cents per Watt in Q1. Deutsche Bank's assessment was better than Roth's, but no banquet.

The dive for bottom rung pricing is attributable to a decline in manufacturing costs as well as more manufacturers entering the fray.

The fact many Chinese and Taiwanese companies have shifted manufacturing off-shore effectively negates import tariffs, also easing prices. The consensus is that oversupply will continue until obvious market forces (greater demand/fewer module makers) take hold in key markets.

Pressing the brakes is not easy for a global industry. Researchers at EnergyTrend (Taiwan) said they expect overcapacity to persist through 2017. While China is expected to cut back PV expansion in Q4, growth will continue across India, the US and elsewhere. Government mandates and investors stymied by low yields in other markets remain a constant but inconsistent PV market driver.

Despite wide fluctuations, the fact we have PV module oversupply underscores manufacturers' belief in the long-term viability of renewable energy. Stay tuned for 2017 highlights. Expect manufacturers to pull-back on the reins. Improvements on the plant floor and new technologies that boost yield and efficiency will also impact PV markets. The upside is that with so many utilities and residential consumers adopting solar, the global market has years of growth yet to realize. But expect a bumpy ride. Like a test pilot pushing a new aircraft to greater heights, the climb of renewable energy onto the world stage will continue to challenge the nerves of even the most optimistic free marketer.

Editor / Publisher Jackie Cannon
T: +44 (0)1923 690205
E: jackie.cannon@angelbc.com

Technical Contributor: Mark Andrews
E: mark.andrews@amcsolutions.info

Sales & Marketing Manager Shehzad Munshi
T: +44 (0)1923 690215
E: shehzad.munshi@angelbc.com

USA Representatives:
Tom Brun, Tom Brun Media,
T: 724 539-2404, E: tbrun@brunmedia.com

Janice Jenkins, Tom Brun Media.
T: 724 929-3550, E: jjenkins@brunmedia.com

Design & Production Manager Mitch Gaynor
T: +44 (0)1923 690214
E: mitch.gaynor@angelbc.com

Director of Logistics Sharon Cowley
T: +44 (0)1923 690200
E: sharon.cowley@angelbc.com

Directors:
Bill Dunlop Uprichard – CEO
Stephen Whitehurst – COO
Jan Smoothy – CFO
Jackie Cannon, Scott Adams, Sharon Cowley, Sukhi Bhadal, Jason Holloway

Circulation and Subscriptions
T: +44 (0)1923 690200 E: circ@angelbc.com

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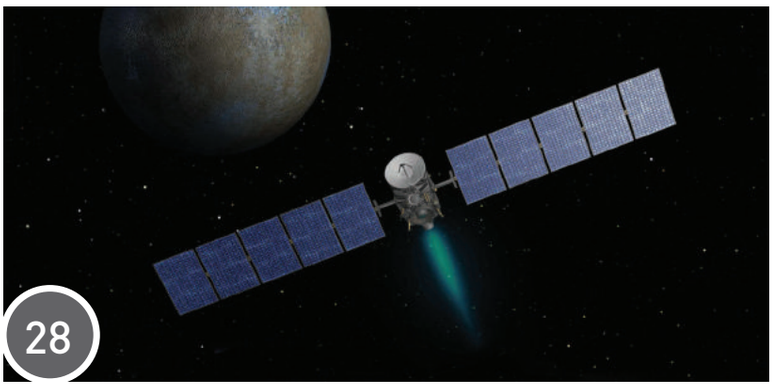


Huawei Solar announces new inverter production facility

HUAWEI SOLAR, manufacturer of string inverters by shipments, has announced an expansion of its European Supply Centre with a new inverter production facility in Eindhoven, Netherlands. The centre will greatly increase the flexibility of the company's customised inverter production and shorten delivery lead times. Leading logistics provider DHL will cooperate with Huawei to provide this production and delivery service.

All of Huawei's European string inverters are supplied through this Supply Centre situated in Eindhoven. The warehouse facility is 10,000m^2 and it has a production capacity of over 100,000 units per month, 7,000 of which are inverters. In addition to pick and pack services, Huawei and DHL handle software uploads and cable cutting activities that enable a more tailored and responsive service to Huawei's customers across Europe.

Guoguang Chen, General Manager for Huawei Solar Europe, said, "Today marks a significant milestone in the development of Huawei Solar's European business with enhancements to our supply chain operation and, most notably, the integration of our new inverter production facility. We pride ourselves in being a trusted and reliable partner to our customers and this upgrade of our capabilities means we can serve our European partners better."

Huawei has integrated new manufacturing capabilities into the Eindhoven hub, which enables the company to tailor services for local customer needs. Huawei can now amend and tailor the software and licensing for the inverters, enabling the company to increase its supply potential and provide more flexibility for customer orders.

Guoguang continues, "We are taking an end-to-end approach and reviewing operations from storage through to delivery. We have shortened production lead-time greatly and honed our ability to finish production within several hours for urgent orders. With DHL's professional operation, the result is an entirely customised logistics operation that meets the different requirements of our customers and fine-tunes our own operations so that we are now in a position to deliver products to European customers faster than ever."

Guoguang Chen was joined by senior Huawei colleagues Alison Finch, Chief Marketing Officer, Bruce Chen Xinzhi, Director of Huawei Europe Supply Center, and John Scherders, VP Operations Technology Europe, DHL, for the announcement at the facility. Twenty customers, including representatives from Profinrgy, Vamat, Solarcentury and Sungevity, also joined Huawei and DHL for an on-site visit where they received a tour of the new inverter production line, as well as a behind the scenes tour of the inverter delivery operation.

John Scherders, VP Operations Technology Europe at DHL, said, "We are very proud to add another service to our cooperation with the start of the inverter project today. The expansion of our partnership will improve our ability to support Huawei serve its customers. DHL will remain focused on quality, flexibility and innovation to keep supporting Huawei and give their customers the best service."

KACO to supply 50 MW of inverter capacity to the Aldo Group

KACO new energy has signed a deal with the Turkish Aldo Grup to supply inverters having a total capacity of 50 megawatts. The blueplanet 50.0 TL3 INT units from the Germany-based manufacturer are to be used in a range of projects to be financed and planned by the Aldo Grup between now and the end of 2017.

The agreement between KACO new energy and the Aldo Grup encompasses a total of 1000 inverters, to be delivered in two stages. The initial batch of 25 megawatts is to be delivered by March of next year, with the remaining 25 megawatts leaving KACO new energy's production site in Neckarsulm before the end of 2017. The order is for the XL version of the blueplanet 50.0 TL3 INT. In this version, the inverters are factory - fitted with ten string fuses and the DC combined conductor type 1 and 2. An AC combined conductor can be retrofitted easily. This reduces the complexity of installing the inverters in terms of safety and cabling. This is the second contract to supply the Aldo Grup: "We had a very good experience previously working with KACO new energy on a four-megawatt project. The team was very customer-focused and always available – especially for the all-important after-sales service. Given this previous reliable partnership and the good performance of the inverters, it was an easy decision to continue working with KACO new energy on further projects," said Haluk Veli Dogan, CEO of Aldo Grup. "The Aldo Grup is a family-run business that has been operating successfully for more than 35 years. We are delighted that a company with such a long history is turning to the workmanship of a medium-sized German business which is also run as a family business," said Nedret Ünlü, Country Manager for Turkey at KACO new energy.

ADB to provide India $500 million for rooftop systems

THE ASIAN DEVELOPMENT BANK (ADB) is set to provide $500 million in financing for rooftop solar systems that will help the Indian government expand energy access using renewable energy. ADB will provide the financing to Punjab National Bank - one of India's largest commercial banks - which will use the ADB funds to make loans to various developers and end users throughout India to install rooftop solar systems.

"There is huge potential for India to expand its use of solar rooftop technologies because of the sharp drop in the price of solar panels, meaning the cost of producing solar energy is at or close to that from fossil fuels," said Anqian Huang, finance specialist in ADB's South Asia Department. "Sourcing more solar energy will also help India meet the carbon emissions reduction target that it has committed to as part of the recent global climate change agreement."

The financing comprises $330 million from ADB and $170 million from the multi-donor Clean Technology Fund administered by ADB. This funding should mean that 11 million fewer tons of greenhouse gases are emitted over the typical 25-year lifetime of solar rooftop systems.

Combined with an additional $300 million in subproject equity investment and $200 million in loans from commercial banks and other financiers, the entire cost of the Solar Rooftop Investment Program is $1 billion. The Government of India aims to increase the amount of energy sourced from solar rooftop systems to 40 gigawatts by 2022. This is part of a wider goal under the Jawaharlal Nehru National Solar Mission to increase its overall solar energy generation to 100 gigawatts by the same date.

India's Intended Nationally Determined Contribution, or the carbon emission reduction target under the 2015 Paris climate agreement, is to lower the emissions intensity of the Indian economy by 33 percent from 2005 levels and to increase the share of non-fossil-fuel-based power generation capacity to 40 percent of installed power capacity by 2030. India formally ratified the Paris climate agreement yesterday. To support efforts by India and other Asian developing member countries to meet their targets, ADB has also committed to doubling its annual financing for climate mitigation and adaptation to $6 billion by 2020.

The solar rooftop market is still at an early stage of development in India and awareness of the latest technologies and the financial benefits is low. Banks see lending to such projects as risky, in part because they have limited past experiences. In this context, an additional $5 million technical assistance from the multi-donor Clean Technology Fund, administered by ADB, will be used to provide training, promote market development, and raise market awareness.

Ontario suspends renewable energy procurement

ONTARIO has announced it will immediately suspend the second round of its Large Renewable Procurement (LRP II) process and the Energy-from-Waste Standard Offer Program, halting procurement of over 1,000 megawatts (MW) of solar, wind, hydroelectric, bioenergy and energy from waste projects.

This decision is expected to save up to $3.8 billion in electricity system costs relative to Ontario's 2013 Long-Term Energy Plan (LTEP) forecast. This would save the typical residential electricity consumer an average of approximately $2.45 per month on their electricity bill, relative to previous forecasts. No additional greenhouse gas emissions are being added to the electricity grid. On September 1, 2016, the Independent Electricity System Operator (IESO) provided the Minister of Energy with the Ontario Planning Outlook, an independent report analyzing a variety of planning scenarios for the future of Ontario's energy system.

The IESO has advised that Ontario will benefit from a robust supply of electricity over the coming decade to meet projected demand.

Informed by the Ontario Planning Outlook, consultations and engagements will begin this fall with consumers, businesses, energy stakeholders and Indigenous partners regarding the development of a new Long-Term Energy Plan, which is scheduled to be released in 2017. As part of this plan, Ontario remains committed to an affordable, clean and reliable electricity system, including renewables. Glenn Thibeault, Minister of Energy commented " Over the course of the last decade, Ontario has rebuilt our electricity system and secured a strong supply of clean power. Our decision to suspend these procurements is not one we take lightly. This decision will both maintain system reliability and save up to $3.8 billion in electricity system costs relative to the 2013 LTEP forecast. The typical residential electricity consumer would save an average of approximately $2.45 per month on their electricity bill, relative to previous forecasts. As we prepare for a renewed LTEP, we will continue to plan for our future and ensure Ontario benefits from clean, reliable and affordable power for decades to come."

First operational IPP solar power plant for Senegal

A $20 MILLION loan to help finance the construction of Senergy 2, a 20 megawatt (MW) photovoltaic solar power plant in Bokhol, Dagana department, northern Senegal, has been agreed. Construction has already started on site and the plant is expected to be fully operational this year.

Senergy 2 will create an estimated 150 jobs during construction and 25 local jobs once the plant is operational, as well as reduce the country's CO_2 emissions by 22,320 tonnes per year.

Lender Green Africa Power (GAP) is a member of the Private Infrastructure Development Group and funded by the UK Department for International Development, the UK Department for Business, Energy & Industrial Strategy and the Norway Ministry of Foreign Affairs. GAP's mission is to promote the development of private sector owned renewable power generation in sub-Saharan Africa. GAP is supported by investment adviser EISER Infrastructure Partners LLP (EISER) alongside Camco Clean Energy.

Senergy 2's lead developer and sponsor GreenWish Partners is an investment company which specialises in renewable energy generation projects in sub-Saharan Africa.

GAP's loan to Senergy 2 will enable construction to be completed and the plant to become fully operational. As the sole debt provider at this stage, GAP will reduce financial risk by allowing time for long term senior debt to be put in place. The project will contribute 20MW towards the Government of Senegal's commitment to substantially increase the installed power generation capacity of the country.

Welcoming the deal, GAP Chair Jim Cohen said: "45 percent of people in Senegal have no access to power and this is holding back economic development. Once operational, Senergy 2 will make an important contribution to Senegal's capacity for growth. GAP is actively looking for similar projects, which will bring more power to Senegal and other sub-Saharan countries in need of renewable energy. Senergy 2 shows the market what can be done."

GreenWish President Charlotte Aubin Kalaidjian said: "GAP's focus supports GreenWish's own goal to encourage affordable renewable energy projects throughout sub-Saharan Africa. The electricity generated by Senergy 2 will be both environmentally friendly and competitive, with a cost per kilowatt-hour 50 percent below the current cost of the energy mix. GAP's loan will mean construction can continue through to operation.

EISER Partner Vivian Nicoli said: "The Senergy 2 project is an important demonstration of GAP's ability to enable viable investments in renewable energy projects in areas where the market would not otherwise support them.

Capacity improvements are needed urgently in Senegal, but high up-front costs can make financing renewable projects difficult due to a lack of willing long-term capital. By providing a construction finance loan, GAP can act to alleviate this impasse. Once construction has completed and the sponsor has been able to secure senior debt financing, GAP's funds can be released and re-invested in other much-needed infrastructure projects across sub-Saharan Africa."

Midsummer receives repeat order from Asia for thin film manufacturing system

MIDSUMMER, a Swedish technology provider of equipment for manufacturing of flexible CIGS thin film solar cells, has received a repeat order for its compact DUO solar cell manufacturing system from an undisclosed Asian customer. This new order was received in connection with Midsummer's first system at the customer going into production with an efficiency of the solar cells of over 15 percent, which was 2 percentage points higher than the promised specification. Midsummer has received a repeat order for its compact DUO thin film solar cell manufacturing system from an undisclosed Asian customer, this after the first machine surpassed the acceptance criteria for cell efficiency by over two percentage points at the customer's production site. Due to a strong demand for lightweight, flexible modules, the customer decided to buy yet another DUO manufacturing system, which will be delivered mid-2017.

"This fantastic success by our engineers is another proof that Midsummer AB and Swedish technology is at the forefront of the race towards a fossil free planet. The DUO system is now the most widely spread manufacturing tool for flexible CIGS solar cells. We have yet again shown that we are the leading provider of turnkey production lines of flexible thin film CIGS", said Sven Lindström, CEO, Midsummer AB. The system will be used for manufacturing of lightweight flexible panels to cater the growing needs for portable panels and roof top installations. The Midsummer DUO is a compact, fully automatic deposition system for CIGS solar cell manufacturing.

It is designed for operational stability and superior material utilization. Midsummer is a leading global provider of turnkey production lines for cost-effective manufacturing of flexible thin film CIGS (copper, indium, gallium and selenium) solar cells. Midsummer has developed a rapid process for the production of these solar cells using sputtering of all layers of the solar cell. This allows for scalable and cost-effective manufacturing of thin film solar cells. Midsummer's customers are manufacturers of thin-film solar cells worldwide.

$1.1 million SunShot award for WSU team

WASHINGTON STATE UNIVERSITY (WSU) researchers have received a $1.1 million US Department of Energy SunShot Initiative cooperative award to improve the performance and lower the cost of solar materials.

Working in collaboration with researchers at the National Renewable Energy Laboratory (NREL) and industry partner Nious Technologies, WSU researchers will improve the performance of CdTe solar material. They will improve its feedstock, or the raw crystal needed to make solar cells, with the goal of reducing costs and making it more competitive with popular silicon-based technology.

“A robust CdTe feedstock manufacturing technology and high quality CdTe materials will be available to the solar industry that could disrupt the current thin-film solar energy supply chain,” said Kelvin Lynn, Regents professor in WSU’s School of Mechanical and Materials Engineering and Department of Physics. “The overall outcome will positively impact American solar energy manufacturing sector by boosting technology competiveness.”

The solar market is growing rapidly with installed capacity expected to grow by about tenfold in the next decade. About two-thirds of solar cells are made of silicon, almost all of which are manufactured in China. In the 1990s, the U.S. was the primary manufacturer of solar materials but its market share has waned.

The SunShot Initiative seeks to strengthen US competitiveness in the solar industry and make solar energy cost-competitive with other forms of electricity by the end of the decade. “CdTe is most likely the first photovoltaic technology that will reach the SunShot goals,” said Lynn. “It is exciting that there is an opportunity to further increase performance and reduce manufacturing costs.”

CdTe cells have the lowest carbon footprint in solar technology and perform well in real world conditions, including in hot, humid weather and under low light. In the past few years, CdTe has caught up to silicon in terms of efficiency and manufacturing costs.

Earlier this year, the WSU researchers were part of a team that reached a critical milestone in solar cell fabrication by placing a small number of phosphorus atoms on tellurium lattice sites on a CdTe solar cell. The breakthrough overcame a one-volt barrier that researchers had been working on for decades.

The researchers hope that the improved material and manufacturing technique will reduce solar energy production costs and simplify the manufacturing process. The research is in keeping with WSU’s Grand Challenges initiative stimulating research to address some of society’s most complex issues. It is particularly relevant to the challenge of “sustainable resources for society” and its theme of meeting energy needs while protecting the environment.

Heraeus announces new collaboration with Jinko Solar

HERAEUS PHOTOVOLTAICS has announced a new collaboration with Jinko Solar to support the latter’s launch of efficient polycrystalline cells.

The Heraeus SOL9631J Series of new generation front-side silver pastes raises the conversion efficiency of solar cells. This collaboration marks another milestone in the long-term strategic cooperation between Heraeus and Jinko Solar.

Jinko Solar adopts Heraeus SOL9631J Series silver paste to enhance the power output of its solar module design. Compared with the previous generation of products, SOL9631J Series increases the conversion efficiency for Jinko Solar’s cells by more than 0.1 percent.

The improvement is made possible by superior electrical conductivity and excellent fine-line printing technology, which enables a higher aspect ratio and better printability. In addition, the paste is suitable for high-speed printing, which helps Jinko Solar boost its production line productivity and total production

capacity, enhancing its competitive power.

“Through our highly successful partnership, Jinko Solar and Heraeus have been able to jointly develop this new-generation of Heraeus silver metallization paste and successfully integrate it into Jinko Solar’s mass production process, thereby greatly improving the conversion efficiency of their solar cells. We are looking forward to creating further achievements with our strategic partners Heraeus in the future,” said Jinko Solar CEO Chen Kangping, ‘Jinko’s vision and mission is to change the energy structure, and to assume responsibility for the future by providing integrated clean energy solutions. We aim to become a benchmark in our industry to help build a more sustainable future. We want to achieve this important goal together with Heraeus.”

“We are very pleased to see our new-generation silver metallization paste to the level of mass production by collaborating development with Jinko. This testifies to the substantive progress of our strategic cooperation with Jinko Solar, “said Andreas Liebheit, President Heraeus Photovoltaics.

Andreas Liebheit further pointed out, “Heraeus constantly innovates our products and technologies, including customized photovoltaic products and services for Jinko Solar, to enable its next generation of products to advance further. We are convinced that this collaboration with our strategic partner Jinko Solar opens up new prospects for Heraeus‘ customized products in the photovoltaic industry.”

Munich team makes double helix inorganic semiconductor

Flexible semiconductor made of tin, iodine and phosphorus has similar properties to GaAs.

A TEAM from the Technical University of Munich (TUM) has made an inorganic semiconductor with a double helix structure. The highly flexible material, called SnIP, is a compound of tin, iodine and phosphorus that has both optical and electronic properties.

The centimetre-long fibres can be arbitrarily bent without breaking, a property attributable to the double helix, says Daniela Pfister (above), who discovered the material and works as a researcher in the work group of Tom Nilges, professor for synthesis and characterisation of Innovative Materials at TU Munich.

“SnIP can be easily produced on a gram scale and is, unlike GaAs, which has similar electronic characteristics, far less toxic,” she says.

Application possibilities

The semiconducting properties of SnIP promise a wide range of application opportunities, from energy conversion in solar cells and thermoelectric elements to photocatalysts, sensors and optoelectronic elements. By doping with other elements, the electronic characteristics of the new material can be adapted to a wide range of applications.

Due to the arrangement of atoms in the form of a double helix, the fibres, which are up to a centimetre in length can be easily split into thinner strands. The thinnest fibres to date comprise only five double helix strands and are only a few nanometers thick. That opens the door also to nanoelectronic applications. “Especially the combination of interesting semiconductor properties and mechanical flexibility gives us great optimism regarding possible applications,” says Nilges. “Compared to organic solar cells, we hope to achieve significantly higher stability from the inorganic materials. For example, SnIP remains stable up to around 500degC.”

“Similar to carbon, where we have the 3D diamond, the 2D graphene and the 1D nanotubes,” explains Nilges, “we here have, alongside the 3D semiconducting material silicon and the 2D material phosphorene, for the first time a one dimensional material - with perspectives that are every bit as exciting as carbon nanotubes.”

Just as with carbon nanotubes and polymer-based printing inks, SnIP double helices can be suspended in solvents like toluene. In this way, thin layers can be produced easily and cost-effectively. “But we are only at the very beginning of the materials development stage,” says Pfister. “Every single process step still needs to be worked out.” Since the double helix strands of SnIP come in left and right-handed variants, materials that comprise only one of the two

Daniela Pfister, who discovered the material – Photo: A. Heddergott / TUM

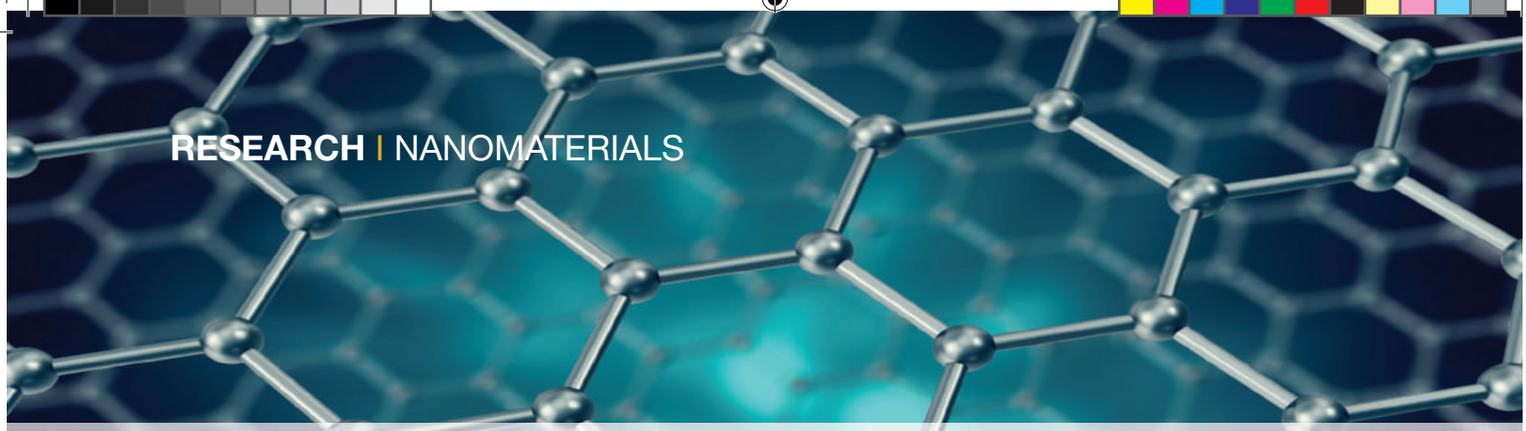
should display special optical characteristics. This makes them highly interesting for optoelectronics applications. But, so far there is no technology available for separating the two variants. Theoretical calculations by the researchers have shown that a whole range of further elements should form these kinds of inorganic double helices. Extensive patent protection is pending. The researchers are now working intensively on finding suitable production processes for further materials.

Interdisciplinary cooperation

An extensive interdisciplinary alliance is working on the characterisation of the new material: Photoluminescence and conductivity measurements have been carried out at the Walter Schottky Institute of the TU Munich. Theoretical chemists from the University of Augsburg collaborated on the theoretical calculations. Researchers from the University of Kiel and the Max Planck Institute of Solid State Research in Stuttgart performed transmission electron microscope investigations. Mössbauer spectra and magnetic properties were measured at the University of Augsburg, while researchers of TU Cottbus contributed thermodynamics measurements.

The research was funded by the DFB (SPP 1415), the international graduate school ATUMS (TU Munich and the University of Alberta, Canada) and the TUM Graduate School.

Further reading
'Inorganic Double Helices in Semiconducting SnIP' by Daniela Pfister et al: Advanced Materials, Sept. 12, 2016



New nanomaterial could pave the way for more efficient batteries

Masdar Institute researchers add value to Lockheed Martin's carbon nanostructures by developing advanced materials with higher thermal-electrical conductivity

Researchers at the Masdar Institute of Science and Technology have developed a novel type of "buckypaper" – a thin film composed of carbon nanotubes – that has better thermal and electrical properties than most types of buckypaper previously developed. Researchers believe the innovative buckypaper could be used to create ultra-lightweight composite materials for numerous aerospace and energy applications, including advanced lightning strike protection on airplanes and more powerful lithium-ion batteries.

Masdar Institute's Associate Professors of Mechanical and Materials Engineering Dr. Rashid Abu Al-Rub and Dr. Amal Al Ghaferi, along with Post-Doctoral Researcher Dr. Hammad Younes, developed the buckypaper with carbon nanostructures provided by global security, aerospace, and information technology company Lockheed Martin. A paper on their research was published earlier this year in the journal Diamond and Related Materials. The paper was co-authored by Masdar Institute PhD student Mahfuzur Rahman and Mechanical Engineering MSc alumni Ahmed Dalaq.

The black, powdery flakes provided by Lockheed Martin's Applied NanoStructured Solutions (ANS) contain hundreds of carbon nanotubes, which are one-atom thick sheets of graphene rolled into a tube that have extraordinary mechanical, electrical and thermal properties. Lockheed Martin's carbon nanostructures are unique because the carbon nanotubes within each flake are all properly aligned, making them good conductors of heat and electricity.

"Lockheed Martin's carbon nanostructures have many potential applications, but in its powdery form, it cannot be used. It has to be fabricated in a way that keeps the unique properties of the carbon nanotube," explained Dr. Al Ghaferi. "The challenge we faced was to create something useful with the carbon nanotubes without losing any of their unique properties or disturbing the alignment."

Dr. Younes said: "Each flake is a carbon nanostructure containing many aligned carbon nanotubes. The alignment of the tubes creates a path for conductivity, much like a wire, making the nanostructure an exceptionally good conductor of electricity."

The Masdar Institute team mixed the carbon nanotubes with a polymer and their resulting buckypaper, which successfully maintained the alignment of the carbon nanotubes, demonstrated high thermal-electrical conductivity and superior mechanical properties.

"We have a secret recipe for self-aligning the carbon nanotubes within the buckypaper. This self-aligning is key in significantly enhancing the electrical, thermal and mechanical properties of our fabricated buckypapers," explained Dr. Abu Al-Rub. Despite their microscopic size – a carbon nanotube's diameter is about 10,000 times smaller than a human hair – carbon nanotubes' impact on technology has been huge. At the individual tube level, carbon nanotubes are 200 times stronger, five times more elastic, and five times more electrically conductive than steel.

Because of their extraordinary strength, thermal and electrical properties, and miniscule size, carbon nanotubes can be used in a number of applications, including ultra-thin energy storage devices, smaller and more efficient computer chips, photovoltaic solar cells, flexible electronics, cancer detection, and lightning-resistant coatings on airplanes.

According to a report by Global Industry Analysts, the current global market for nanotubes is pegged at roughly US$5 billion and its market share is growing sharply, reflecting the rising sentiment worldwide in carbon nanotubes' potential as a wonder technology.

Masdar Institute's efforts to capitalize on this emerging technology have resulted in several cutting-edge carbon nanotube research projects, including an attempt to create carbon nanotube-strengthened concrete, super capacitors that can hold 50 times more charge, and a membrane that can bind organic micro-pollutants.

As the UAE moves towards a clean energy future, innovations in renewable energy storage systems and other sustainable technologies are crucial for the country's successful transition, and researchers at Masdar Institute believe that carbon nanotubes will play a huge role in achieving energy sustainability.

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Storage systems for renewable energies under scrutiny

Research focuses on safety of lithium-ion batteries

In 2016 more than 35 percent of our electricity will come from renewable energy sources. Increasing the flexibility of the energy system through storage systems is therefore being addressed by science and industry at all levels. One focus is the development of storage solutions based on lithium-ion batteries for private households. These batteries are especially efficient and durable. To date, however, adequate standards and testing procedures do not exist for this technology. The Fraunhofer Institute for Solar Energy Systems ISE is now working on two research projects which address the aspects related to the acceptance and dissemination of the technology. The German Federal Ministry for Economic Affairs and Energy (BMWi) provides funding for both projects.

For the home electricity supply of the future, most experts currently assume that new types of storage will come into wide use. Particular focus is on lithium-ion batteries, which have a longer lifetime, better efficiency, higher provision of services and require less space compared to conventional lead-acid batteries. Besides their use in electric mobility applications, lithium-ion batteries are gaining popularity for use in stationary applications (grid-coupled and grid independent). Synergy effects can be realized here that quickly lead to economies-of-scale effects although the storage requirements for the two applications differ.

Safety, a central issue for lithium-ion batteries, depends on different factors weighted according to the application. Heat localized over a small area at defects will dissipate slowly and can lead to material failure or fire in the worst case. There are many different approaches to ensure safety. The basic prerequisites are the selection of cells with high quality, a reliable battery management system and an efficient thermal management. Fraunhofer ISE has been working on lithium ion battery research for many years. “Whereas lead-acid batteries have been tested in the practice for many years, lithium-ion batteries must first prove themselves in stationary applications in order to win the trust of consumers. Longterm experience is not yet been available and therefore cannot be applied,” says Dr. Matthias Vetter, department head of “PV Off-Grid Solutions and Battery System Technology” at Fraunhofer ISE.

Project “SafetyFirst”: Safe grid-supportive storage for households

In the joint research project, Fraunhofer ISE partners with the Karlsruhe Institute for Technology (KIT) and the Center for Solar Energy and Hydrogen Research (ZSW) to investigate the current safety, quality and grid suitability of commercial electricity storage systems for households. In the “SafetyFirst” project, the scientists will develop recommendations for manufacturers, standardization bodies and authorities based on their investigations on commercially available home storage systems for self-produced electricity. “Grid-supportive home storage systems based on lithium-ion batteries are

FRAUNHOFER ISE’s test rig for home storage systems for self-produced PV electricity. Before beginning the battery tests, the set-up as well as all necessary process steps are checked once again. ©Fraunhofer ISE

becoming increasingly inexpensive and thus more attractive for the end user. Up to now, however, standardized, verifiable criteria for assessing the efficiency and safety of these systems has been lacking," explains Stephan Lux, team leader at Fraunhofer ISE. "In the project 'SafetyFirst', our goal is to couple the safety guidelines for lithium-ion home storage with commercially available PV home storage systems in order to prepare future standards."

In the project, twenty grid-supportive home storage systems undergo long-term tests, carried out on test rigs that imitate the actual operation in private households. Using special load profiles, it is not only possible to analyze the safety of new batteries direct from the factory but also at later aging stages. Data is collected on the safety properties, changing efficiencies and the expected lifetime of the storage systems. Complementary to the analyses on the home storage systems, singular lithium-ion battery cells are selected and analyzed at Fraunhofer ISE and at ZSW. Fraunhofer ISE analyzes and evaluates the aging properties of various cell types and the entire system in parallel.

With this acquired knowledge, information about aging and safety can be collected in the future by merely performing short investigative tests. Based on the results in the laboratory, the research team compiles recommendations so that the properties of modern lithium-ion batteries are factored into the standards, test specifications and funding.

Project "SpeiSi": Safety of stationary storage systems for solar electricity

Fraunhofer ISE is additionally working on a research project, headed by TÜV Rheinland, on the topic of safety and reliability of PV systems with storage. The project "SpeiSi" investigates the safety of such systems, which are installed mainly with the aim of increasing self-consumption. In cooperation with TÜV-Rheinland, the German Section of the International Solar Energy Society and the Centre for Solar Energy and Hydrogen Research (ZSW), weak points in the handling, installation and operation are analyzed within the project. "Existing regulations for stationary battery systems consider separate battery rooms for systems with emergency or back-up power or for systems with an uninterruptable power supply," says Hermann Laukamp of Fraunhofer ISE.

"The regulations must be adapted to accommodate a broader use of stationary energy storage with higher energy content like lithium-ion batteries in private homes," supplements Georg Bopp, team leader at Fraunhofer ISE. Beyond, criteria for determining the performance of PV storage systems, among other things, shall be developed, allowing further information about the quality of the energy management to be gained.

JINKOSOLAR
DESIGNED TO BE THE BEST

Photovoltaic manufacturers often cite capacity to establish global solar market position. Now celebrating 10 years of service, JinkoSolar stresses quality, reliability, innovation and size as key to their global PV leadership. By Mark Andrews, Technical Editor, Solar & Power Management.

2016 has been a volatile year across the photovoltaic industry as renewable energy system makers vie for market share and profitability. While many companies compete largely on price, quality and innovation have emerged as key differentiations, factors that have long driven JinkoSolar's bid to lead development within global solar markets.

JinkoSolar has grown rapidly since the company began its solar odyssey as a silicon ingot manufacturer in 2006. Today, Jinko serves commercial, utility-scale and residential customer bases in China, the US, Japan and key European markets as well as across Latin and South America, the Middle East, countries across Africa and many other locations. Its 15,000 employees in five production facilities have an integrated annual capacity of 4.5 GW of silicon wafers, 3.7 GW in solar cells and 6.5 GW in solar modules. It is also a utility-scale electricity provider, selling power in China through solar plants with more than 1 GW capacity.

Jinko recently reported a second consecutive quarter of solar module shipments that were higher than competing companies. Since the first quarter of 2016 JinkoSolar has become the largest solar module supplier in the world. The company has built module shipment momentum since 2014, reporting second quarter 2016 shipments of 1,716 MW, beating its top-end guidance by 16 MW. This established a new quarterly shipment record, beating a previous high of 1,709.9 MW in the fourth quarter of 2015.

JinkoSolar's general manager of European operations, Frank Niendorf, spoke recently with Solar + Power Management's Mark Andrews in discussing his company's drive to reshape renewable energy markets through stressing innovative, cost-conscious products with long-term reliability. The JinkoSolar portfolio includes its award-winning Eagle Dual modules that offer superior performance and sustained generating capacity.

"This year within Jinko we are celebrating our 10th anniversary. A major milestone was Jinko's successful IPO in 2010, which gave a major boost to our impressive company growth story. Remember we started as a small silicon ingot maker in 2006, yet today we are growing even faster than the fast-moving global PV market with a CAGR of over 60 percent. Jinko has in the meanwhile become one of the leading top 3 global PV module suppliers. I believe we have achieved these things because of our dual focus on cost consciousness and quality," he said.

From its early days Jinko saw opportunity to integrate and offer the renewable energy marketplace greater economy paired with innovation that led to its continuing quality focus. As Niendorf remarked, Jinko has never lost sight of the fact that making a solar investment is one of the largest purchases a residential customer might make besides the home itself, so every component of a solar module needs to offer the best value and long-term reliability.

"PV modules are the key component of a solar system, making up roughly 50 percent of the total investment. Such solar systems have to work in the field in very harsh weather conditions over 25

JinkoSolar technicians carefully assemble and test solar modules. This panel is undergoing inspection before a cascade.

years or more … modules need to perform reliably without major unplanned performance loses, and the purchaser needs to have confidence that the module supplier will still be there and financially capable to meet its product warranties. These ideals drive Jinko's business and are key reasons that we strive for continual quality improvements," said Niendorf.

Niendorf pointed to the company's corporate leadership vision as a key motivator for Jinko's continued growth. While any manufacturer might grow large by competing mainly on price, its reputation could fail if consumers buy low cost products only to discover those products have questionable reliability.

"Innovation is at least as important as cost consciousness. PV module technology has developed for many years along two axis: cost reduction and efficiency improvement. Both factors will make PV more competitive and economically viable. Product innovation can have an impact on both axis, but in particular on the cell and module efficiency side, innovation has a very important and positive impact," Niendorf said.

JinkoSolar's product line has grown to include a number of ground-breaking products that continue to win customers across global markets. Niendorf pointed to several stand-out benefits and innovations that set the company's modules apart from their peers.

- JinkoSolar was the first and only company to offer three different smart module technologies for optimized performance.
- The JinkoMX modules eliminate hotspots, a unique feature for extended operational lifetimes at high performance.
- JinkoSolar recently introduced its new Dual Glass modules with record efficiency and remarkable durability.
- Jinko introduced 1500 Volt Eagle modules (April, 2016) designed to improve the performance of utility scale projects. They are Underwriters Laboratories (UL) certified and protected with DuPont Tedlar PVF film-based backsheets for durability and long module lifetimes.
- JinkoSolar was the first company to offer PID-free modules across global markets.
- JinkoSolar introduced a new black poly silicon technology with higher performance and the streamlined all-black appearance that is highly appreciated in the residential rooftop market.

Among its many noteworthy products, JinkoSolar takes special pride in its Eagle Dual module that was recognized in 2016 with a Solar Award for Module Manufacturing Innovation. Niendorf stated that the Eagle Dual module is perhaps Jinko's best and most

Technicians in a JinkoSolar factory load panels into a thermal cycling test chamber.

Automation plays an important role across all JinkoSolar plants. Here we see industrial robots handling power binning tasks.

recent example of innovating superior products. Eagle Dual modules combine the benefits of eliminating potential induced degradation (PID) with dual glass encapsulation, which creates a truly dynamic value proposition. In awarding Jinko's innovation and quality, the Solar Award judges remarked that the Eagle Dual, "…incorporates a strong frame with a heat-strengthened back sheet glass layer that increases its resistance to micro-cracking, thus lowering the risk of 'snail-track' generation PID, light induced degradation (LID), and corrosion."

"The module has a record maximum efficiency of 16.54 percent and is incredibly durable. With less than a half-percent annual degradation rate, the Eagle Dual delivers about 20 percent more power over its lifetime than a conventional module. It can also perform better under difficult environmental conditions since the module resists salt, alkali, sand and acidic conditions. The module is certified to withstand huge snow and wind loads—it delivers such exceptional quality that we offer an extended 30-year linear warranty," he said.

Product quality at JinkoSolar is also demonstrated in the company's quest for continual safety performance. Niendorf remarked that Jinko products such as the Eagle Dual have received a Fire Class A certificate from the TUV, and that researchers along with product development engineers and the manufacturing group strive to meet the highest possible standards. Jinko has achieved continual improvement thanks to the many dedicated professionals that design and manufacture its solar products.

"We are proud to have a lot of very talented professionals working at JinkoSolar. Our chief scientist, Dr. Jin Hao, has recently been elected to lead a working group dedicated to PV cell research at the International Electrotechnical Commission (IEC), which is a big honour. His accomplishments, the support of upper management and the entire organization work together to deliver quality products that are second-to-none."

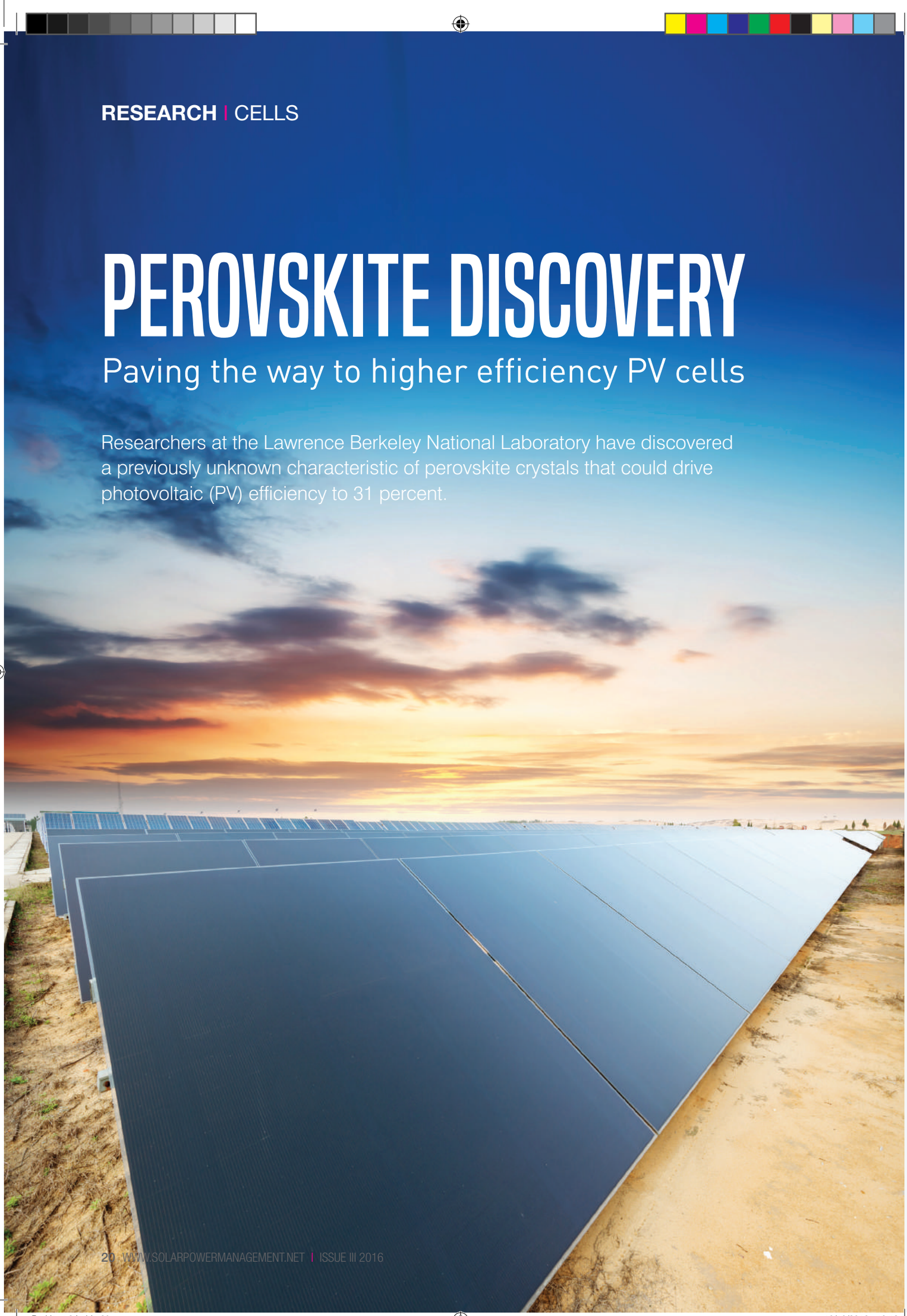
As JinkoSolar celebrates its 10th anniversary, the global photovoltaic market continues to evolve rapidly. Renewable energy, especially photovoltaic power, has become the world's fastest growing source of electrical energy and is on track to dominate electrical power generation by mid-century. JinkoSolar has distinguished itself through its dedication to quality and award-winning product innovation, setting a standard that investors, residential and utility-scale customers have come to rely upon for cost-effective and reliable solar solutions.

Frank Niendorf, General Manager, JinkoSolar Europe

PEROVSKITE DISCOVERY

Paving the way to higher efficiency PV cells

Researchers at the Lawrence Berkeley National Laboratory have discovered a previously unknown characteristic of perovskite crystals that could drive photovoltaic (PV) efficiency to 31 percent.



SCIENTISTS at the Lawrence Berkeley National Laboratory have discovered that all perovskite crystals are not equal, which dramatically affects how well a crystal converts photons into electrons. Some facets are like Olympic athletes while others would never make it onto a practice squad.

Berkeley Lab researchers described their discovery as foundational to greater in-depth knowledge of how perovskite materials generate electricity. They also credited support from Santa Clara-based Park Systems scientists and Park's unique atomic force microscope (AFM) with aiding their research.

Congratulating the Berkeley Lab researchers, Park Systems founder Sang-il Park (PhD) said, "Results using our AFM microscopes at Lawrence Berkeley Lab witnessed what scientists have never before been able to visualize and this phenomenon is happening across many industries world-wide." Park was a student of Calvin Quate, PhD, who has been honored along with other atomic force microscopy inventors with a 2016 Kavli Prize in Nanoscience. Park went on to found industry's first commercial AFM company. AFM was described by the prestigious Kavli Foundation (Oslo, Norway) as, "a breakthrough in measurement technology and nanosculpting that continues to have a transformative impact on nanoscience and technology."

The Berkeley Lab discovery points to the possibility of creating perovskites that could push efficiency to their theoretical limit – 31 percent. High performing solar cells incorporating the material have been sought-after because perovskite component elements and manufacturing processes are far simpler and less costly than c-Si PV manufacturing.

Primary challenges in bringing perovskite technology from lab to practical production have revolved around boosting efficiency and standardizing manufacturing techniques while eliminating toxic components. Perovskite efficiency has been steadily increasing (now as high as 22 percent in laboratories,) since Henry Snaith's (University of Oxford) groundbreaking work in 2009 pointed to the material's long-term possibilities. Perovskites that Snaith's team explored had efficiencies around 3 percent. Research work since 2009 has driven efficiency to a point comparable with today's commercial c-Si PV cells.

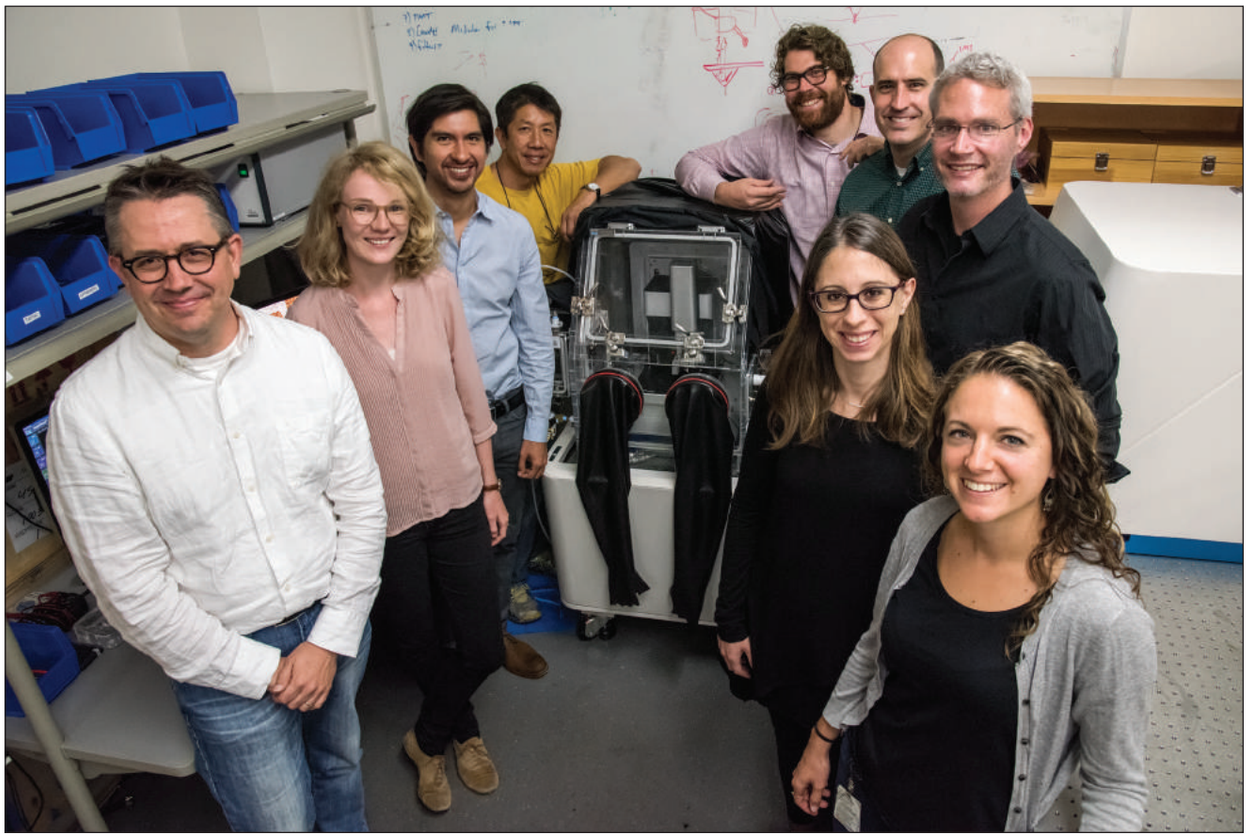
Peaks and Valleys

Berkeley Lab postdoctoral researcher Sibel Leblebici had been fascinated with perovskites for some while before undertaking what would become her ground-breaking work. In an interview with Solar+Power Management's Mark Andrews, Leblebici and lab supervisor Alexander Weber-Bargioni explained that work began when she was looking for a different way to explore perovskites. While other researchers had boosted efficiency through optimizing film growth conditions and energy level alignments within solar cell layers, she wanted to learn more about the material at the nanoscale. Like many crystalline forms, perovskites only appear smooth from a distance. At extreme magnification, individual crystals seem like rugged 'mountains' that are only 200 nanometers long. What she and the team found examining those peaks and valleys was unexpected. Leblebici and the team discovered that across the surface of each perovskite there were striking differences between one crystal facet and another. Some facets – like gemstone faces – exhibit much greater generating capacity than others. These peak performers sit alongside areas that were less productive while still other areas between facets seemed completely nonproductive.

Sibel Leblebici and Alexander Weber-Bargioni working at a computer monitor, looking at perovskite facets

It takes a different type of microscope to go where Leblebici's research would take her. Atomic force microscopes (AFM) are known for their ability to provide extreme detail in three dimensions, a feat not possible with scanning electron microscopes (SEM) or similar research tools. Berkeley Lab relied on a state-of-the-art AFM manufactured by Park Systems (Santa Clara, California and Suwon, Korea). The Park Systems approach to AFM differs from others in part because of its non-contact techniques. The company also supported Berkeley Lab by adjusting performance and scanning processes to perfectly fit research goals.

"Traditional AFMs use a tip that makes contact with the material being studied. In the case of perovskites,



A team of scientists from the Molecular Foundry and the Joint Centre for Artificial Photosynthesis, both at Berkeley Lab, found a surprising characteristic of perovskite solar cells that could boost their efficiency. Left side front to back: Jeffrey Neaton, Linn Leppert, Sebastian Reyes-Lillo, Ed Wong Right side front to back: Sibel Leblebici, Francesca Toma, Ian Sharp, Paul Ashby, Alexander Weber-Bargioni

this would have damaged the extremely delicate samples," Leblebici explained. "We used conductive atomic force microscopy to locally measure the photocurrent and open circuit voltage, two critical parameters for solar cell efficiency.

"To achieve reproducible results on the very rough perovskite surface, we employed the Park PinPoint scan mode, in which the conductive AFM tip approaches the surface, reaches a specific force between the tip and the sample, records the current, and then retracts the tip at each pixel. Using PinPoint mode allowed us to eliminate all artifacts in the current measurement that result from (examining) a rough surface." Leblebici and her fellow researchers found the Park Systems AFM needed technique refinement to handle its unique assignment, specifically to measure current. The Berkley Lab team worked with Park to improve the PinPoint mode capabilities, optimizing conductive AFM results. "We visited the Park Systems office in Santa Clara to explain what we wanted to measure and to better understand the capabilities of their system, and engineers from Park often visited our lab to suggest improvement," she remarked.

"We observed up to an order of magnitude difference in photocurrent and differences of open circuit voltage up to 0.6 V between facets of the same grain. These results suggest that the efficiency of perovskite

To achieve reproducible results on the very rough perovskite surface, we employed the PinPoint scan mode, in which the conductive AFM tip approaches the surface, reaches a specific force between the tip and the sample, records the current, and then retracts the tip at each pixel

solar cells could approach the theoretical efficiency (limit) by growing the film such that only the high performing facets interface with the electrodes," she said.

Both Leblebici and Weber-Bargioni noted the surprise they and everyone felt upon realizing the significance of their results. "This was a big surprise. It shows, for the first time, that perovskite solar cells exhibit facet-dependent photovoltaic efficiency," commented Weber-Bargioni.

Leblebici explained that while further research is still needed, evidence so far supports the idea that if the highest efficiency perovskite crystal facets can be isolated in a way that more electricity can be channeled to electrodes, the efficiency could be maximized. It will take time to determine how to best grow and practically produce 'super perovskite' materials, but understanding that the properties exist is a crucial step towards reproducing them in greater quantity than appears to occur naturally.

"The facet material we studied is all the same in a sense, but if you cut a crystal, different elements are revealed at the atomic scale—perhaps more iodine or more lead on a surface. We don't know (exactly) yet what the makeup of the higher performing crystals is, but now that we know that in a given sample there are significant differences between the facets, it gives us an important start to learning the rest of the critical mechanisms that could lead to higher performing perovskites," she remarked.

"Now that we have an insight on the mechanisms, this allows a much more systematic approach in taking the next steps, (such as) controlling crystal formation and how to organize the facets that are exposed...if we know what makes a facet good or bad, then it turns into an engineering problem in regards to how to produce just the good. We have discovered a key enabling factor."

Looking ahead

Leblebici and Weber-Bargioni remarked that while they are proud of their perovskite discovery, there is work ahead both within their group and scientific communities at large to optimize solar power efficiency utilizing perovskites. While efficiency gains help tip the balance in favor of solar power, the overall cost of solar includes producing materials, manufacturing, delivery and installing complete solar power plants; the collective picture drives or holds-back solar power adoption.

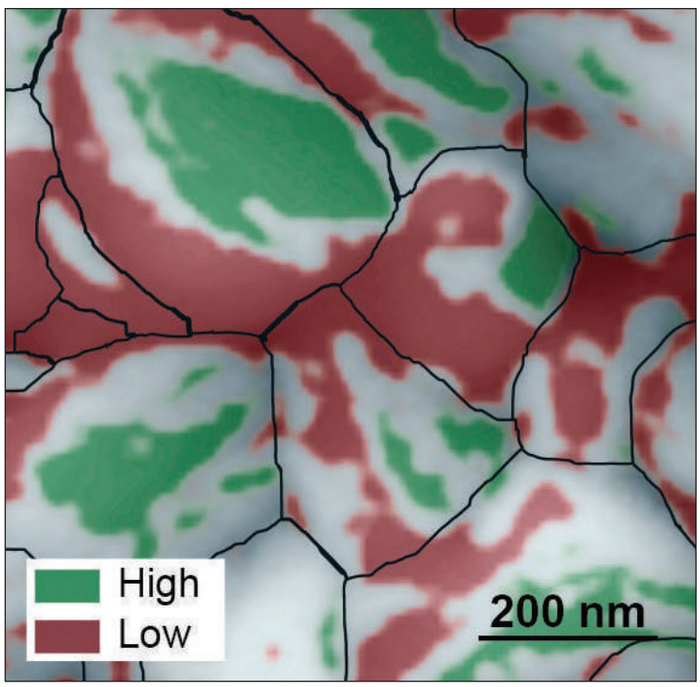
"We get the credit for this discovery, but the best research approach – and one that we have here (at Berkley Lab,) is sharing information…So our discovery is distributed to all who want to measure a solar cell or improve it. Through a systemic approach organic solar cells will get better and better. This is a team approach, but I have to give credit to Sibel (Leblebici). She was really critical because every project needs a person who pursues it without letting up – that was her."

Reflecting on the growth potential of solar energy, and the challenges that face the overall industry, Weber-Bargioni said he sees great potential, yet there is still a distance to go.

"Why isn't solar already more popular? Why isn't it already the world's largest energy source? Greed of the politicians and vested corporate interests that don't support it, I believe," he said. "To put it another way, the future of solar power depends on using the resources we have at our fingertips."

"We have more processing power in an iPhone that sits in our back pockets than the Apollo (moon mission) computers had available. But they used what they had and went to the moon … If we don't use all the free solar energy that comes to our planet every day, it will be our faults if we don't have a planet for our grandchildren."

Photos of perovskite researchers courtesy of Lawrence Berkeley National Laboratory and the DOE



Berkeley Lab researchers studying perovskite crystals at the nanoscale found a surprising facet-dependent characteristic that could boost energy conversion efficiency in solar cells.

OVERCOMING CHALLENGES FOR LARGE-SCALE PV WITH STRING INVERTERS

Analysts predict that whilst annual global single-phase and central inverter market revenues will decline, string inverter revenues will grow by 75 percent from 2014 to 2020. Alison Finch, Chief Marketing Officer at Huawei Solar, Europe explains the reasons why.

THE UTILITY-SCALE PV MARKET has had an eventful few years. Installed capacity at the start of 2016 was an impressive 91 GW globally, that's up from just 5 GW installed at the end of 2010.[1] Solar is now mainstream.

It is an established technology in markets such as Europe and North America and deployment worldwide in emerging markets, such as South America, India and China, continues to grow year-on-year. This success comes in spite of relentless cost pressures and the inevitable rolling back of subsidy support mechanisms in most markets.

The driver of this growth has been an industry-wide focus on innovation and cost-reduction that has seen the levelised cost of solar reduce. These technology enhancements have not come in the form of a silver bullet. Instead, it has been a process of incremental fine-tuning and improving best practices. It has been as much about learning as it has about innovating.

The sum of these small changes is the incredible growth we have witnessed in recent years. But the process continues. We continue to innovate, learn, adapt and ultimately improve. So what are some of the challenges facing utility-scale PV today and how do we overcome them?

Maximising yields

Maximising yields arguably remains the number one challenge. The application of string inverters for more consistent reliability, reduced O&M costs and improved monitoring represent changes to distinct aspects of the PV plant, which all help to increase yield. But yield benefits also come from the very structure and formation of string inverters within a PV plant compared to central inverters. Put simply, this comes down to the number of MPPTs in operation.

In a 2.0MW (AC) array, a Huawei smart PV solution has up to 200 MPPTs. These can optimize power generation by minimizing string mismatch. This is a result of the module cell output fluctuating between +/- 5W per module, then gradually these changes increase by the cells deteriorating with age. However, in a central inverter solution, if one string has a mismatch - like shading - all other strings will be affected. Based on our experience, multiple MPPTs can increase power yields by 1-2 percent. Over the lifetime of a plant, this can add up to a considerable difference in overall yield and return on investment.

Another way to improve yield is through I-V (Current-Voltage) Curve Testing, which EPC's are contractually required to do annually for 5-10 percent of the site at random. With Huawei's latest generation of inverters, EPC's are able to test 100 percent of the site with a click of a button from the convenience of their offices and see the results along with recommendations in less than 15 minutes. This saves time and labour costs whilst also improving safety of utility-scale solar sites.

Reliability

The significance of reliability cannot be understated. System failures can be costly and for this reason EPCs and investors must look to the best-in-class technologies to ensure consistency. The key factors at play with reliability are consistency and containment.

At Huawei, reliability has been a strong focus for our R&D team and the results are bearing dividends. By the end of 2015, Huawei SUN2000 String Inverters accumulated sales of around 15GWs, of which 10GWs (300,000 units) have been connected to grid for at least one month and the total accumulated failure rate is only 0.35 percent globally and 0.25 percent in the UK.

When things do go wrong however, the last line of defence is containment. In a string system, if one inverter fails, the impact on the overall system's yield is minimal. However, with a central system, if the one inverter fails, a large section of your PV plant will be down with zero power yield. This key design handicap in the central arrangement means reliability

Large scale solar shifts to small inverters - IHS Markit

issues are built into the system structure making it a case of 'when' a significant section of your plant will be generating zero electricity, not 'if'.

O&M

Related to reliability is the ongoing challenge of the O&M of a plant. If we continue with the previous example of system failure, the other consideration is how quickly repairs can be made so the plant can return to full yield capacity. String inverters are designed to be smaller and therefore easier to install. When one fails, two engineers can replace it with ease in just hours. With the central set-up, in addition to the whole plant being affected by the failure, the repair turnaround is much longer and requires highly skilled engineers, which are certified by the inverter supplier.

A recent IHS survey of customer opinions of string inverters found that the top reason for opting for string over central was this very issue. According to IHS Òsimplified diagnosis of faults and easy replacement of faulty components were the top reasons for using string inverters."

Beyond repairs, there are of course costs associated with the daily operation of the two types of inverters. The Huawei SUN2000 Smart PV inverters consume less than 20W power, while in a central inverter solution, power consumption is over 1500W for a 2MW inverter. The Huawei inverter can save 90 percent self-consumption when compared to central, mainly because of our patented natural cooling technology, which does not require a fan.

During the lifecycle of the project, with the central inverter solution, regular fuse replacements are required which incur costs or component labour. With the Huawei inverter solution, we use two strings per tracker that do not require fusing and this helps to bring down O&M costs too.

Monitoring

The rapid advance of data and monitoring systems has been one of the most exciting developments in our industry. Granularity in real-time monitoring has been an ambition of Huawei since its entry into the solar market. With our background in telecommunications, we felt this was a very natural challenge for us to take on.

When we approach monitoring capabilities our three considerations are optimising yield, reliability and improving monitoring accuracy. Our innovation here is the use of power line communication (PLC) technology which replaces the traditional RS485 cable solution. Think of this as fibre-optic replacing dated and complex wiring systems. The PLC cabling ensures higher speeds and reliable communications whilst also saving on cabling and labour costs.

THE RAPID ADVANCE OF DATA AND MONITORING SYSTEMS HAS BEEN ONE OF THE MOST EXCITING DEVELOPMENTS IN OUR INDUSTRY. GRANULARITY IN REAL-TIME MONITORING HAS BEEN AN AMBITION OF HUAWEI SINCE ITS ENTRY INTO THE SOLAR MARKET. WITH OUR BACKGROUND IN TELECOMMUNICATIONS, WE FELT THIS WAS A VERY NATURAL CHALLENGE FOR US TO TAKE ON

The physical element is just one part of monitoring. Using our Smart Logger, we collect the data and report back from string level monitoring to total the site output. The Smart Logger can also connect to weather stations which allows you to compare the site output with the irradiation on the site.

The combination of smart hardware, from the inverter through to the cabling, with intelligent monitoring and reporting is what Huawei call FusionSolar. The solution lets you monitor and manage multiple PV plants from one control centre, or more simply from your phone or tablet, so you're always able to see how they are performing and, if required, can make adjustments to maximise your yields.

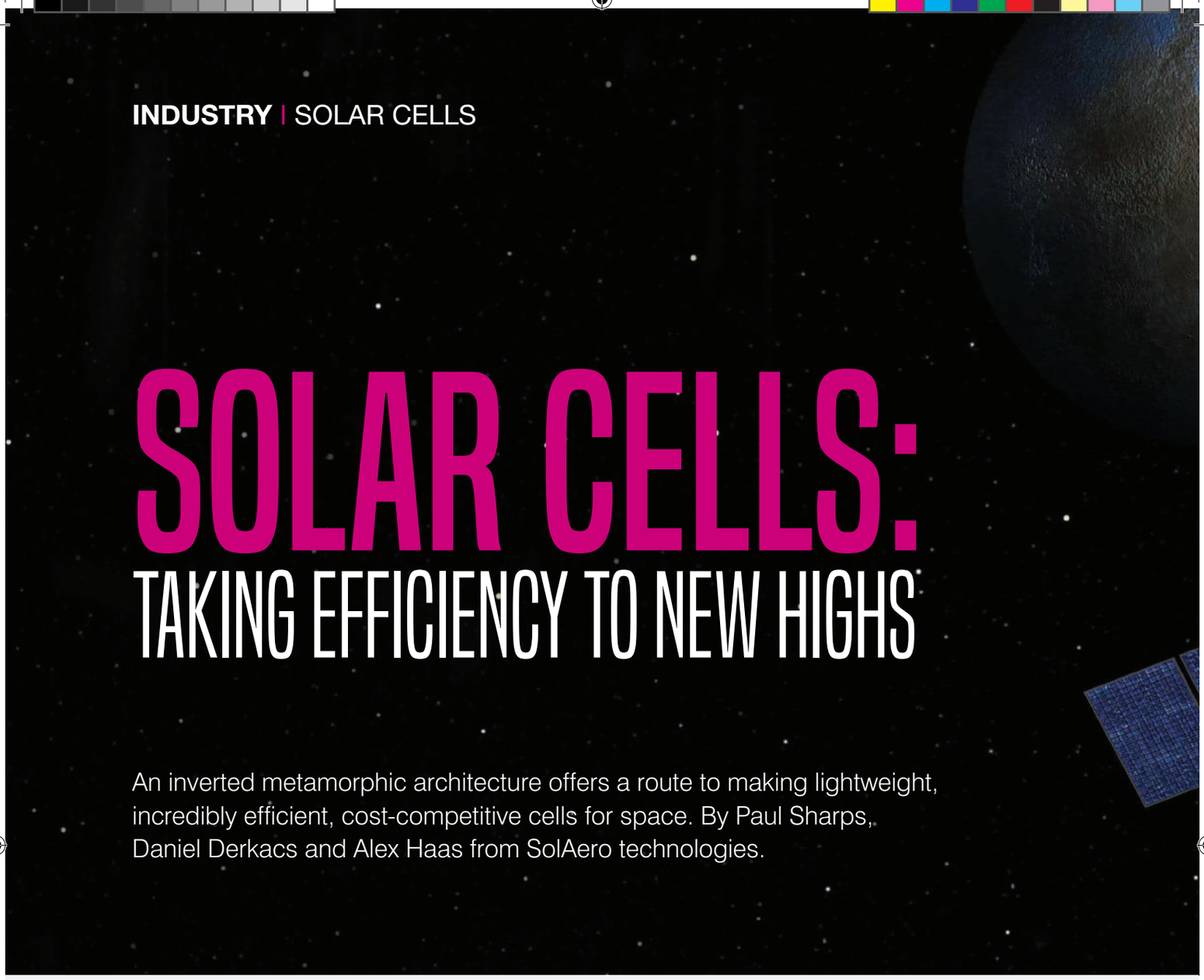
Competitiveness and the future of smart PV

Companies in the solar industry are often focused on competing with other players in the sector. Yet, the fact remains that we are ultimately in competition with any source of electricity generation that is viable in a target market. Our competitiveness against other sources of electricity therefore, remains a vital challenge in securing investment for projects.

We are all responsible as industry players to present a compelling case to investors that outline the benefits of solar. The way to do this is to demonstrate how we are delivering higher yields and greater returns on investment than ever before. Upfront costs and cost pressures generally remain a big issue for the industry. But we must hold a longer perspective and adopt the solutions that deliver over the lifetime of a plant and not give in to short-termism.

There is undoubtedly momentum in the market as more and more EPCs and investors opt for string solutions. As the recent IHS Markit report points out, ÒIHS predicts that whilst annual global single-phase and central inverter market revenues will decline, string inverter revenues will grow by 75 percent from 2014 to 2020." The evidence of the benefits is mounting and out-dated perceptions are giving way.

As the leading company by shipments of string inverters, Huawei has been at the forefront of this transformation. We are excited about what the future holds, particularly with the integration of smart technologies. We are convinced that the industry is reaching a new milestone when it comes to utility scale PV through the application of smart technologies. This is a development in which the industry as a whole can find comfort as they continue to invest in this clean energy source.



SOLAR CELLS:
TAKING EFFICIENCY TO NEW HIGHS

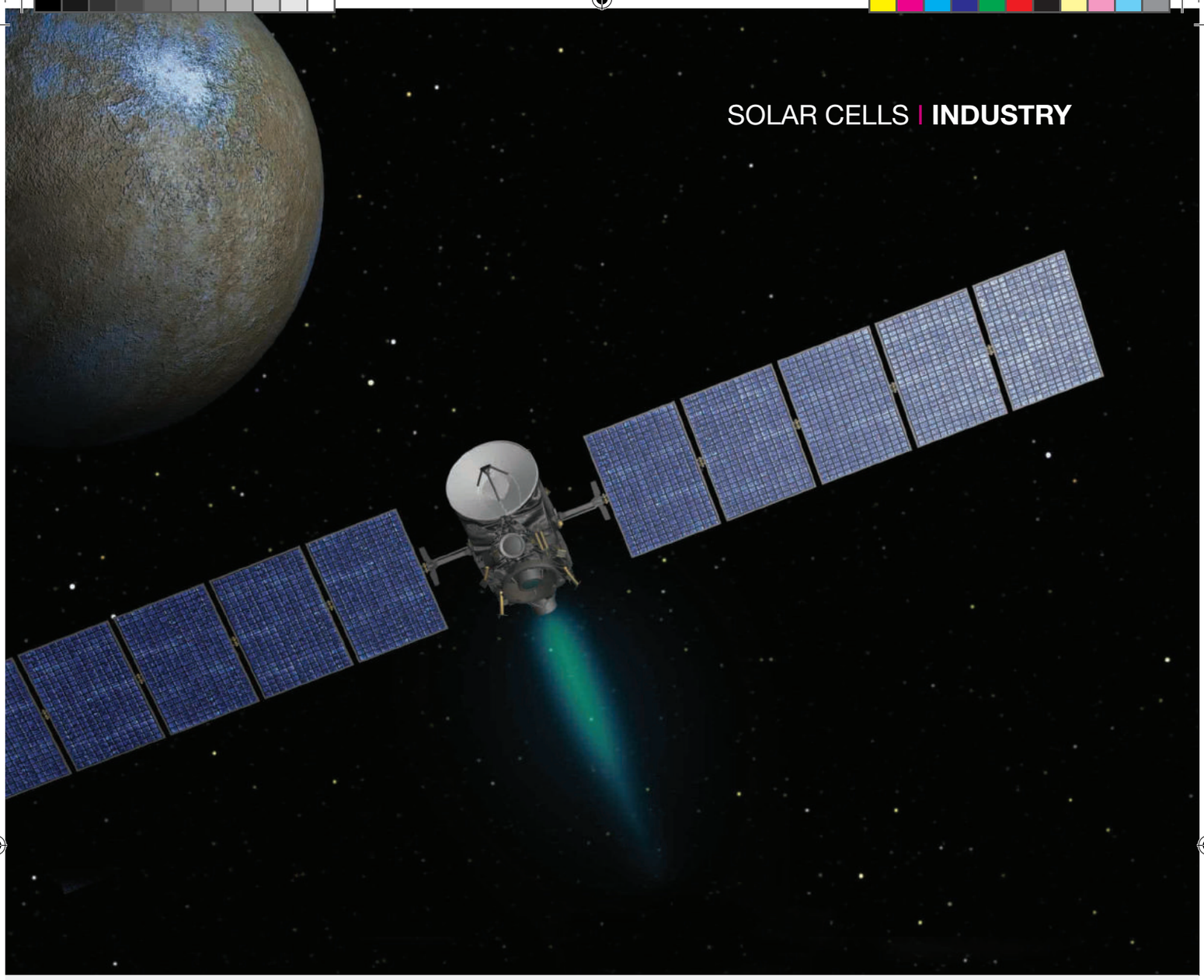
An inverted metamorphic architecture offers a route to making lightweight, incredibly efficient, cost-competitive cells for space. By Paul Sharps, Daniel Derkacs and Alex Haas from SolAero technologies.

ALTHOUGH III-V multi-junction cells have been deployed on earth to generate electricity, they are delivering their greatest commercial success in space. Out there they are highly valued for their high efficiency and robustness, particularly to particle radiation. What's more, they offer tremendous economic value at the system level by reducing satellite launch and operating costs. Together, these attributes make III-V cells ideal for supporting satellite missions requiring either a high specific power (W/kg) or a high power density (W/m2).

At SolAero Technologies of Albuquerque, NM – which took over Emcore's solar business in late 2014, while retaining all its expertise and capability – we have a great track record in improving the efficiency of our III-V multi-junction cells. Between 1998 and 2008 the measured efficiency of multi-junction cells under conditions replicating those in space increased from 23 percent to 29.5 percent (for these measurements, radiation was incident under no concentration (1 sun) with a spectrum mimicking that of the sun's before it passes through the earth's atmosphere (AM0)). These efficiency figures might suggest that our focus is on the production of a handful of cells with incredibly high efficiencies. But that is certainly not the case: we pride ourselves on the production of vast numbers of highly efficient cells. Over the past 18 years we have manufactured more than 3 million large-area space cells, defined as having an area of at least 26 cm^2. The knowledge gained from this has helped us to produce cells that have an initial efficiency of 29.5 percent and deliver 85 percent of this value at the end of a 15-year geosynchronous mission. Even now, we are not resting on our laurels, but pursuing a roadmap that involves the development of far more efficient devices that incorporate metamorphic structures and more absorbing layers.

Solar designs

Manufacture of our solar cells is based on multi-junction designs, rather than single-junction variants, because this leads to better spectral utilization and reduced thermalization losses. Multi-terminal and mechanically stacked architectures are options for the fabrication of these multi-junction devices, but we prefer two terminal devices, because this trims costs associated with cell fabrication and system integration.



In a two-terminal device, the cells are connected by lattice-matched Zener tunnel diodes, which reverse the polarity between each of the subcells. This allows multiple *n*-on-*p* subcells to be monolithically stacked on top of each other. The voltage produced by the multi-junction device is equal to the sum of those produced by each subcell, and optimisation requires the design of each n-on-p junction to produce the highest voltage possible without reducing the photo-generated current.

During the last two decades, the primary source of satellite power has been the triple-junction device formed from lattice-matched layers of GaInP, InGaAs and germanium (see Figure 1). The foundation for this is a *p*-type germanium substrate, on which GaInP and InGaAs layers are grown by MOCVD. During growth, the group V element from the nucleation layer diffuses into *p*-type germanium, converting a thin layer on the surface to *n*-type. This creates a diffused *n*-on-*p* junction. To provide precise lattice matching to the germanium substrate, a small amount of indium is added to the middle InGaAs junction. With this device, the internal quantum efficiency of all sub-cells approaches 100 percent (see Figure 2). Consequently, there is little room left for improvement in the current collection in this device.

Where gains can be made is in photocurrent. In these monolithic, two-terminal multi-junction cells the subcells are connected in series, so the same current must flow through all of them. This means that it is possible for one or more subcell to fail to operate at its maximum power point. For example, in a device with a GaInP/InGaAs/germanium architecture and bandgaps of 1.88 eV/1.40eV/0.67 eV, the germanium subcell is capable of generating twice as much current as it does in this triple-junction stack (see Figure 3). Due to this, the multi-junction cell will deliver an inferior performance to that of a cell with all junctions operating at individual maximum power points.

Improvements could result from increasing the bandgap of the bottom junction so that it adds to the operating voltage while still generating enough current to avoid limiting the overall device. Alternatively, gains could be made by lowering the bandgap of the top two subcells to increase

cell efficiency through superior spectral utilization and improved current matching at each subcell's maximum power point. With either of these approaches, or by adding to the number of junctions, it is possible to improve upon the AM0 efficiency limit of approximately 30 percent for the GaInP/InGaAs/germanium device. It is worth noting, however, that the obvious approach of adding more junctions suffers from a law of diminishing returns. So, assuming that the cost of every added subcell is the same, there is a point at which the increased efficiency comes at a price that the market will not bear.

Attempts to increase solar efficiency tend to involve either employing mechanical stacks, turning to novel materials, or creating metamorphic structures. Here we will we briefly describe the first two, before discussing in more detail the third option, which is the one that we pursue. Note that there are many III-V semiconductor materials that can be combined into multi-junction devices (see Figure 4), and we limit ourselves to monolithic devices, because, as previously stated, this trims cell fabrication and integration costs.

Pros and cons of stacking…

Mechanical stacking of cells to improve performance has made the headlines, because this class of device holds the efficiency record for devices operating under concentrated illumination (sunlight is focused by a factor of several hundred on to the cell). The great attraction of mechanical stacking is that it removes the bandgap/lattice constant constraint, opening the door to designs that combine a wide range of bandgaps with different lattice constants. One example of a mechanically stacked cell is the pairing of a GaInP/GaAs dual junction grown on a GaAs substrate with a GaInAsP/GaInAs dual junction grown on InP. The resulting device, with bandgaps of 1.89 eV, 1.41 eV, 1.00 eV, and 0.73 eV, is close to ideal for the maximum conversion efficiency for the space spectrum.

This device is created by wafer bonding, a process that forms a mechanically robust, optically transparent, electrically conductive interface between the component multi-junction cells. The challenge is cost. This approach requires a separate growth for each of the component multi-junctions, one of which involves a very expensive InP substrate. Costs could fall by turning to epitaxial lift-off, but this technology is still to be demonstrated to the degree required to significantly lower the substrate growth costs. Another drawback is that to ensure that the surfaces are adequately flat for wafer bonding, they must be polished with a chemical-mechanical process. If particles or growth imperfections are present, they prevent wafer bonding in local areas. Due to all these issues, despite its high efficiencies, mechanical stacking is simply too expensive to be considered for

Right: SolAero's Satellite Flight Heritage

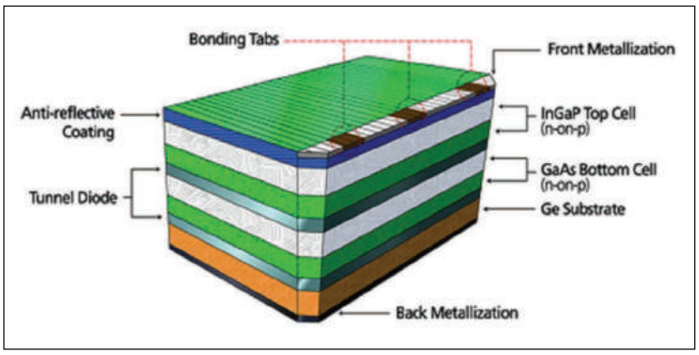


Figure 1. The GaInP/InGaAs/germanium lattice-matched, triple-junction cell is monolithic device that is grown on a germanium substrate.

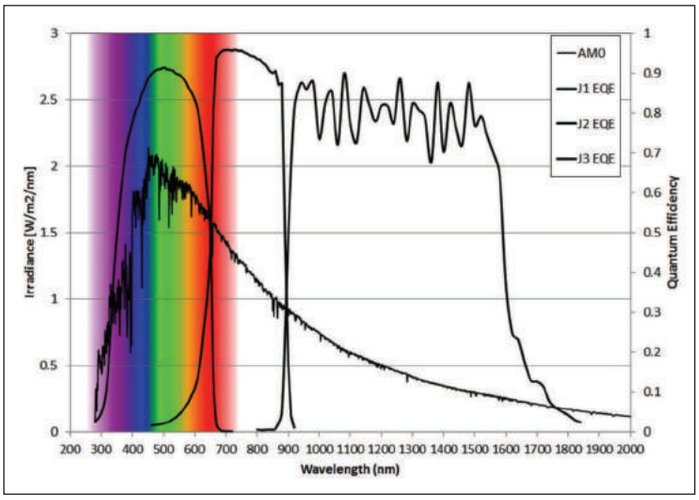


Figure 2. The internal quantum efficiency (IQE) of the Zener tunnel-junction cell overlaid on the space AM0 spectrum.

space applications.

… and novel materials

Novel materials are attractive, because they provide the opportunity to replace the germanium subcell with one of a higher bandgap, or to insert a 1.00 eV subcell between the germanium and InGaAs subcells to create a four-junction device. With the latter approach, a 1.0 eV subcell is grown directly on the germanium substrate prior to the growth of GaInP and InGaAs subcells.

The two most popular candidates for a 1 eV cell are the dilute nitride InGaAsN(Sb) and the ternary SiGeSn. Both materials have the virtues of an independent lattice constant and bandgap (within ranges). This allows a tuning of bandgap while retaining lattice matching to GaAs or germanium. A four-junction cell based on InGaP, GaAs, InGaAsN and germanium was first proposed in 1997 by a group at Sandia National Labs in Albuquerque, NM. However, due to the poor material quality of the MOCVD-grown InGaAsN junction, this cell never realised its expected performance. In addition, the device was expensive to grow. Progress has been made since then, by growing the InGaAsNSb layers by MBE, and incorporating them into triple-junction GaInP/GaAs/InGaAsNSb cells. These devices have produced an efficiency in excess of 30 percent under 1 sun, AM0 conditions, but the MBE growth process is expensive, partly because of the low throughput. Development of the alternative, SiGeSn, is still in its infancy. Junctions made from this ternary are yet to produce voltages consistent with their bandgap. Another concern is that this material is meta-stable, and requires a growth temperature of less than 400°C. Further fundamental studies are needed before this ternary can be incorporated in a multi-junction device.

Mighty metamorphics

We advocate a metamorphic approach, which includes upright and inverted structures. If upright metamorphic multi-junction structures are produced, the lowest bandgap subcell should be grown first, followed by higher bandgap subcells (see Figure 5(a)). With this architecture, the bottom junction is typically made from germanium, and above this are the metamorphic grading layers and finally the metamorphic subcells.

For this class of metamorphic cell, which tends to feature GaInAs-based metamorphic subcells, compositions of the III-Vs follow the GaAs-InAs tie line. The indium content is gradually added to the step grades to reach the appropriate lattice constant. A major downside of this approach is that all of the epitaxial layers are lattice mismatched with respect to the substrate, and consequently contain threading dislocations. This is a major drawback, because the threading dislocations act as carrier recombination sites that degrade solar cell performance through increased dark current and reduced photo-generated carrier collection. Since all of the epitaxial layers are metamorphic in these upright multi-junction structures, all tend to suffer from non-optimal performance for the particular bandgap. Defects are minimised, and cell performance optimized,

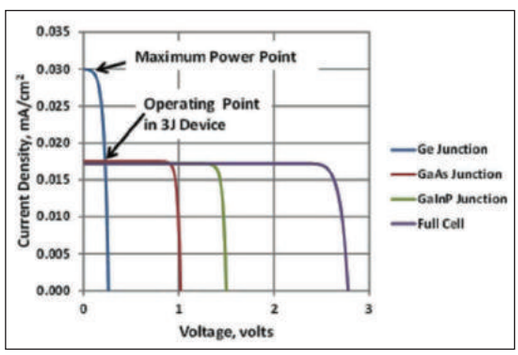


Figure 3. Individual and aggregate current-voltage curves for the GaInP/InGaAs/germanium solar cell. The germanium junction operates at the current-matched point in the complete triple-junction device, rather than at its maximum power point.

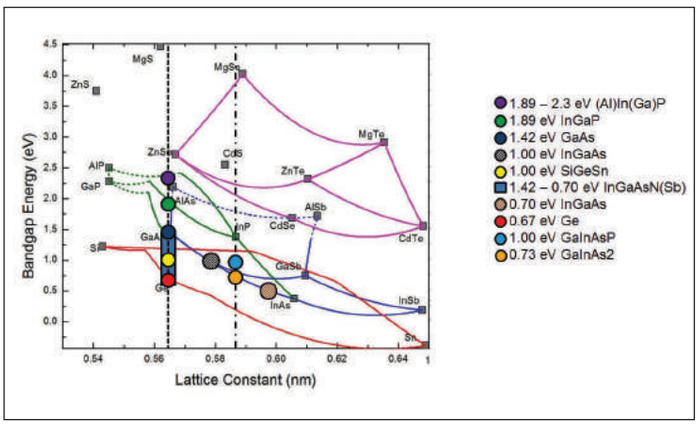


Figure 4: Bandgap and lattice constant for a number of semiconductor materials, with the III-V materials of particular interest for multi-junction cells noted.

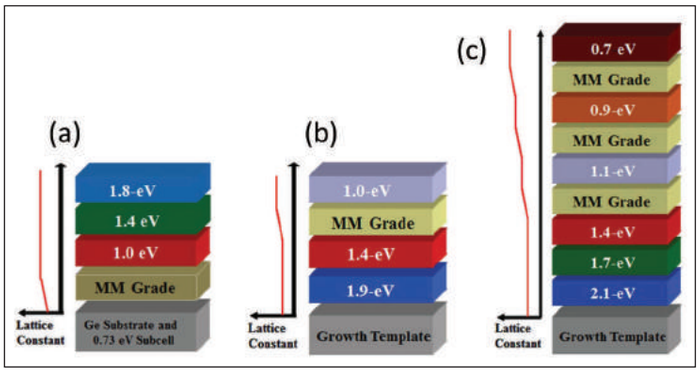


Figure 5: (a) The upright metamorphic four-junction cell has a performance that is compromised by threading dislocations through the entire structure. With inverted metamorphic cells with three (b) or six (c) junctions, only part of the structure suffers from threading dislocations.

by using the other class of metamorphic – the inverted metamorphic multi-junction. In this case, devices are grown 'upside down'. This means that the high bandgap junctions are grown first, lattice matched to the substrate, followed by lower bandgap metamorphic 'boost' junctions.

An example of this – a triple-junction inverted metamorphic – is shown in Figure 5(b). It features two lattice-matched subcells and one metamorphic subcell. The initial high bandgap subcells, such as GaInP, GaAs, InGaAlP and AlInGaAs, are grown lattice matched to the germanium growth substrate, and they generate the majority of the power from the cell. The metamorphic subcells, meanwhile, produce a smaller proportion of the generated power than they would in an upright metamorphic multi-junction structure. To produce this class of cell we attach the structure to a 'processing handle', such as silicon or kapton, before removing the growth substrate. Epitaxial layers are between 10 μm and 15 μm thick, depending on the number of subcells in the device, and the processing handle can be temporary, necessary only for processing; or it can

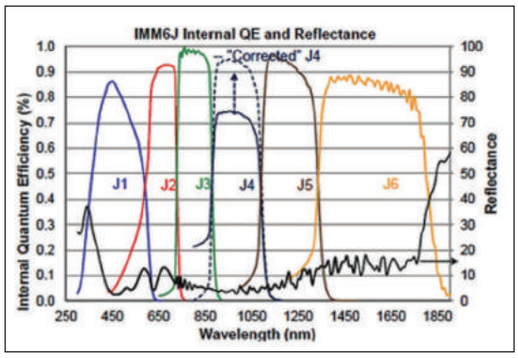


Figure 6: Internal quantum efficiency and reflectance for the inverted metamorphic, six-junction cell.

be permanent, providing an integral part of the final device. There is great freedom with this approach as devices can be flexible or rigid, and structures can be packaged for the end application. Selection of an appropriate permanent handle enables a very light cell, and ultimately a very high specific power (W/kg). This approach is ideal for epitaxial lift-off, where the epitaxial layers are removed from the substrate along a laterally etched release layer.

We have demonstrated inverted metamorphic cells with three, four and even six junctions (see Figure 5(c) for a representation of a six-junction cell, and Figure 6 for internal quantum efficiency and reflectance measurements from an actual six-junction cell). Using such a high number of junctions is cost competitive with current, commercially available space multi-junction cells, because production employs existing MOCVD growth technology and known fabrication practices. We have also undertaken a comparison between modelled and verified efficiencies (see Table 1, where the numbers in red are the NASA verified measurements, and the black numbers are the results of our model). Note that the performance modelling is based on a 'practical' approach that considers the likes of optical reflectance and series resistance. Based on these findings, we have a path for increasing efficiency beyond 30 percent to nearly 38 percent. Given this promise, the inverted metamorphic cell is expected to be the core technology in the next generation of commercially available cells for space applications.

Device structure	Number of Metamorphic Junctions	Efficiency	Voc, volts	Jsc, mA/cm²	FF
Three Junction	1	32.8	3.00	17.0	86.8
		32.4	3.02	16.9	85.6
Four Junction	2	34.8	3.28	16.6	86.5
		33.9	3.26	16.9	83.3
Six Junction	3	37.8	5.20	11.3	87.2

Table 1. Comparison between modelled space inverted metamorphic cell (black) performance and NASA verified (red) performance, for the 1 sun, AM0 spectrum.

Working the advantage of THIN FILM

Thin film photovoltaics using perovskites as a light absorbing material are a very recent development and they could propel the third generation of photovoltaics by a colossal step. The scientists at the Belgian research institute imec in Leuven have been vigorously focusing on this subject for some time. Philip Pieters, the director in charge of business development at imec explains the advantages of this thin film photovoltaic technology and points out potential applications.

IN THE REALM of thin-film technologies imec is currently focusing on the development of solar cells with perovskites as the light absorbing material. Why of all things have you adopted this specific technology?

In the past we had done many developments in the realm of organic photovoltaics. At the same time several firms emerged, first Konarka, and later Heliatek, Beletric OPV, Armor and Eight 19. In organic photovoltaics we managed to reach efficiencies of 12 to 12.5 percent. That was quite good. But then we noticed the ongoing developments based on perovskites.

At first we were somewhat hesitant to enter this field, because it looked pretty much like hype. But then we investigated this technology closer because we recognized that it is a technology with great potential.

Q How far have you gotten up to now?

A When we started developing solar cells based on perovskites we quickly achieved efficiencies of 15 percent. This was possible because we could draw on our rich experience in organic photovoltaics. In the mean time, we are getting as much as 18.5 percent efficiency with small cells having a size of 20 square centimeters. This is of course not the world record, which today stands at 21 percent and higher. But our focus is less on creating cells with ever higher record numbers, which exhibit their record marks only on small surface areas. Instead, we feel obliged to prove that we can reach this efficiency in large areas as well. Therefore, we concentrate on increasing the cell and module sizes and on transferring the technology to the realm of industrial manufacturing.

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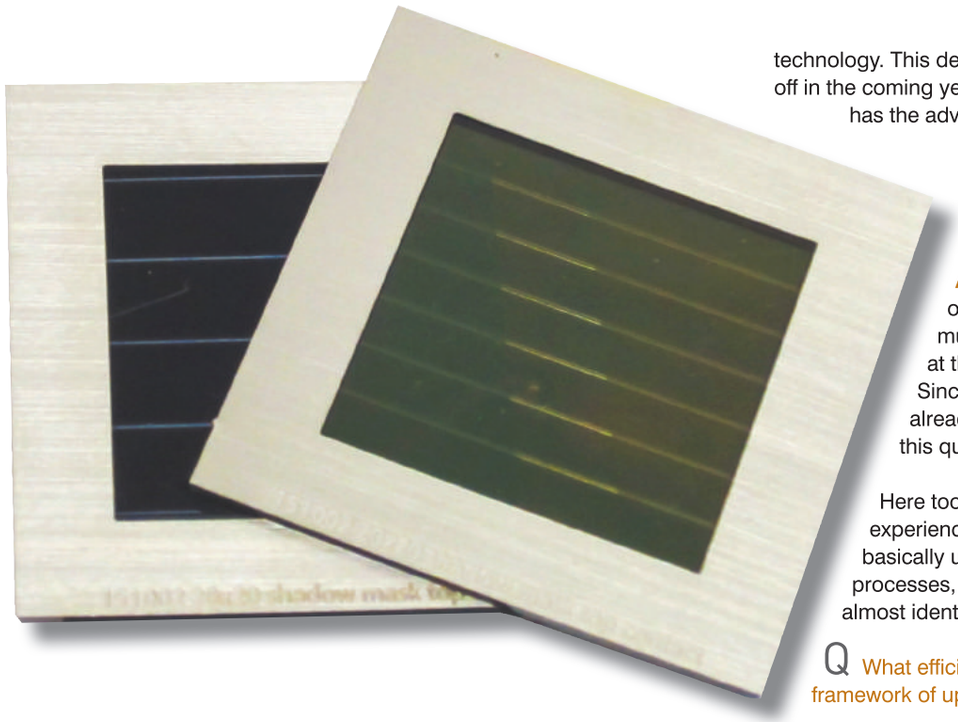

Q How are you tackling this task?

A On the basis on our perovskite cells, which have an efficiency of 18 percent, we are enlarging the surface area in which the light absorbing material is deposited. At a module size of 150 to 160 square centimeters we can still achieve an efficiency of 11 to 12 percent. Yet at larger sizes the efficiency goes down. The task here is to maintain the current efficiency value even across large surfaces. In the end we want to realize complete cells measuring 156 by 156 centimeters with this material and achieve up to 20 percent efficiency.

Q What printing processes are you using for this?

A Initially the objective is to realize the cells on a rigid carrier material. As a substrate glass is best suited, but metal sheets could also be used. We are doing this on our production line in Leuven. There we deposit the different materials in single quantities on glass substrates using the slot-die coating process. But from the end of the year on we also want to adopt the roll to roll process and thus print the materials on flexible substrates.

This will be done in the facilities of our R&D partners at Solliance in Eindhoven. At Solliance there is a lot of experience in roll to roll printing technology. This development, which we be kicked-off in the coming year, because the roll to roll process has the advantage of higher throughput.

Q Now, what are the challenges of printing perovskites?

A They are similar to those in organic photovoltaics: The layers must be printed and deposited at the highest possible uniformity. Since we have developed the process already for OPVs we can now control this quite well.

Here too we can benefit from our experience with OPVs, since these basically use very similar manufacturing processes, and the production machinery is almost identical as well.

Q What efficiencies are you striving for in the framework of upscaling the process?

A Evidently the efficiency should be as high as possible. So far, we have achieved 12 percent on 150 to 160 square centimeters. I think we must now drive this up to 20 percent and higher for this cell size, and then transfer this value to large surfaces. We see yet another application of perovskites – by combining them with crystalline silicon cells and this way achieve efficiencies of 28 to 30 percent for the entire tandem pack.

Q What would such a combination look like?

A We will put the perovskite semiconductor on top of the silicon cell. Then the crucial factor determining the efficiency will be the interconnect type. There are two options to do this. You can interconnect the tandem cell as one complete stack, with one contact on top of the perovskite layer and another contact beneath the silicon cell. This will be simpler to manufacture. But the problem here is that you must ensure current matching across the entire stack.

With this variant, the effective efficiency is limited, since the two cells are affecting each other. Therefore, the second option, a fourfold contacting scheme, is better suited in regard to the total efficiency of the tandem cell. This way, each part of the stack is contacted separately, and each part of the tandem cell

operates under its own optimum condition, without being impacted by the others.

However, this is certainly more demanding when implemented in a mass production environment, but is justified by its higher energy yield. In this scheme you can interconnect the silicon cell entirely in the back by utilizing, for instance, the IBC technology, which is readily available.

Q How will this impact the energy generation?

A We have simulated this with various light spectra. Separately interconnecting the individual parts of a stack achieves a significant increase in yield. After all, the light spectrum is not constant over the course of the day. It is different in the morning, midday and evening. If the individual cells are affecting each other they cannot realize their respective advantages for a certain light spectrum.

Q Do you have the same possibilities with perovskites cells as organic photovoltaics offers it, in regard to design variations?

A At the moment we are looking primarily at opaque perovskite cells. But we have already demonstrated that semi-transparent cells and modules based on perovskites are feasible as well. This is of particular interest for building integration, where the task is to integrate semi-transparent perovskite films in windows.

This will be necessary in the future to fulfill the higher energetic demands on buildings. Semi-transparent perovskite films will be of special importance in high-rise buildings since their roof surfaces will not be large enough. Different colors are possible as well. These we will achieve by band gap variations.

Q When will we see the first perovskite modules coming to market?

A Dyesol is in the process of establishing the appropriate manufacturing facilities. I think the company will bring out their first products in the not so far future. To reach properly up scaled production lines will take some time still. But it will be faster than in the realm of OPV since the fundamentals are already in place.

Stacked perovskite/CIGS solar module achieves unprecedented efficiency

IN SEPTEMBER scientists from imec (partner in Solliance and EnergyVille), Karlsruhe Institute of Technology (KIT), and Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (Centre for Solar Energy and Hydrogen Research, ZSW), announced that they had fabricated a thin-film solar module stack made up of perovskite and Copper Indium Gallium Selenide (CIGS) with a conversion efficiency of 17.8 percent. For the first time, this tandem module surpasses the highest efficiencies of separate perovskite and CIGS modules.

The stacked module (3.76cm2) implements a fully scalable device concept: both the perovskite top module and the CIGS bottom module feature a monolithic interconnection scheme, using seven and four module cell stripes respectively. The result is a reduction of area loss of less than eight percent for both technologies.

The consortium's process for creating this efficient perovskite/CIGS multi-junction solar module relies upon efficient exploitation of the solar spectrum. The higher energy part of the spectrum is harvested in the semi-transparent perovskite module on top, while the light with lower energy passes and is harvested in the bottom CIGS cell. As a result, the prototype shows an unprecedented power conversion of 17.8 percent, which outperforms the world-record up scaled perovskite module of 15.3 percent efficiency presented by imec, and also the highly-efficient stand-alone up scaled CIGS module of ZSW with efficiencies nearing 15.7 percent.

"This result was achieved through close and intricate collaboration leveraging the expertise of the three partners. Imec's expertise in perovskite technology was underscored by the use of a perovskite top module in these stacked solar modules," stated Dr. Tom Aernouts, head of thin-film PV research at imec.

According to Dr. Ulrich Paetzold, head of the research group at KIT, this result is just a starting point, with more exciting results to come in the next years such as perovskite/CIGS multi-junction solar modules surpassing efficiencies of 25 percent. The Helmholtz Young Investigator group of Dr. Paetzold is focusing on the optics in multi-junction perovskite solar modules and will develop further specialized nanophotonic materials for these devices.

Finally, ZSW contributed with its world class expertise in CIGS solar modules. ZSW holds the current world record for CIGS solar cells at 22.6 percent. Prof. Dr. Michael Powalla, member of the board and head of the Photovoltaics Division at ZSW, points out: "This success is an elegant way of combining the advantages of two highly advanced thin-film technologies. It will contribute greatly to ever more cost-efficient solar power for the customer."

Solar+Power awards2016

Solar Asset Management Award

First Solar

The PVGuard supervision software platform

THE FIRST SOLAR Operations Center in Berlin provides industry-leading remote monitoring, supervisory and plant controls capabilities for photovoltaic (PV) energy assets located across the Europe, Middle East and Africa (EMEA) region, seven days a week. Apart of performance management and on-site activities the facility is also capable of energy forecasting and ensuring that power plants under management conform to grid requirements.

The PVGuard® supervision platform is the heart of the Operations Centre. The SCADA software, specially designed for utility-scale PV plants, offers investors and operators who self-perform O&M or need a single platform to manage a diverse portfolio of PV assets an efficient tool for the monitoring and maintenance of PV plants from any location. Logged field data is compiled on a central platform so that yields, yield prognoses and faults can be analysed in real time. With its graphic depiction of detailed status information - down to string level - and comprehensive alarm management including automatic messaging, PVGuard® delivers information and incident control mechanism which are needed to optimize and effectively supervise PV power plants.

PVGuard® uses a self-adaptive algorithm to predict the plant output, based on high-quality, current weather data, the plant's characteristics and its output over recent weeks. Updated several times a day, projections are available worldwide at hourly intervals and for a period of up to seven days in advance. This allows you to maximize revenues for your photovoltaic systems in direct marketing situations or, where necessary, to meet the grid network requirements. The forecast data may be integrated seamlessly into your own views, analyses or reports, allowing you to visualize and evaluate it as you wish.

PVGuard® saves all historic data covering the entire lifespan centrally and incorporates an integrated service log for easier documentation and simplifies compliance with record keeping needs. The ultimate goal of Asset Owners and Managers is to maximize their return on investment and to optimize the performance of their power plant portfolio. Many PV systems, however, do not deliver the yield they are capable of. A number of factors such as environmental influences, technical faults and site conditions can lead to defects that, if not quickly detected and corrected, will impact the yield. High O&M costs also impact the return on investment and drive Power Purchase Agreement prices up.

PVGuard® also addresses a major concern by grid operators, who fear that an increasing share of fluctuating renewable energy such as PV and wind power and their integration into the electricity grid may jeopardize the stability of the system. Thus, a key challenge is to find a way to make renewable energy production more predictable and reliable.

PVGuard® Supervision Platform protects the investment as it continuously monitors the PV system, constantly updates the plant portfolio and promptly alerts to problems. The SCADA software provides full transparency, maximizes yield outputs and allows for easy asset management in a single platform, independent of the power plants locations and technologies used. Data acquisition and analysis are key to ensure optimal availability and highest long-term performance. The use of technology in PV plant O&M facilitates ground asset management, minimizes the working hours spent on site and plays a crucial role in preventing downtime caused by component failures. This results in higher revenues and enhances the profitability of large scale PV plants.

PVGuard® also helps to stabilize the grid by monitoring, controlling and forecasting the output of a plant and by tracking and reacting quickly to changes that could disturb the integration of solar power into the grid.

Judges Comment:

The PVGaurd® system is designed for owners who manage their own maintenance and operational programs as well as those with a larger portfolio of properties. Utilizing the programs full range of benefits is like having a consultant on staff 24/7.

Solar+Power awards2016

Rural Electrification Development Award

PROINSO

Kepulauan Riau, Indonesia

A FULLY STANDALONE SYSTEM was installed by PROINSO in Kepulauan Riau earlier this year. This project was developed by PT Surya Energi Indotama and is part of the ongoing solar energy developments by the Ministry of Energy and Mineral resource.

The system components consisted of 2 units of Sunny tri Power STP 25000TL-30, 9 units of Sunny Island SI 8.0H with a multicluster box, combined with locally produced monocrystalline PV modules and 1000Ah OPzV batteries.

South & South East Asia account for around 37% of the world's population who have no access to electricity. In many countries, the energy infrastructure is under-developed and only a few towns are adequately electrified which of course provides significant barriers to social development and economic growth.

While conventional grid extensions have been the predominant mode of electrification in the region, this is often not financially viable and there are often other technical and logistical implementation barriers. There is now increasing use of solar photovoltaic technology in the form of off-grid solar systems to provide reliable and sustainable energy access to remote communities. This standalone system in Kepulauan Riau is a perfect example of this. With the installation of a stand-alone PV plant in Kepulauan by PT Surya Energi Indotama, the residents have benefited from a reliable and sustainable electricity source.

The PV plant delivers 300 Wh to each household every day. Such amount of energy is able to power 3 pieces of low power LED lamps at night time as well as other small appliances. The PV plant also powers street lighting along the village passage at night time to provide the village with sufficient lighting. This has had significant positive effects on the resident's quality of life and well-being.

The Ministry of Energy and Mineral Resource as customer and project owner benefit as such projects increase the rural electrification ratio without the need of building new transmission lines to the village which are often technically and economically not possible.

Judges Comment:

Off-grid solar is the best, most practical electrification option for much of the world's rural population. About 37 percent of those without electricity live in South and Southeast Asia. Proinso's standalone photovoltaic systems exemplify what solar can achieve.
The PV plant in Indonesia's Kepulauan Riau supplies residents with enough energy to power essential LED lights, small appliances and street lighting; it enhances safety and enriches daily life in ways previously impossible.

Solar+Power awards2016

Rural Electrification Development Award

Azuri Technologies

HomeSmart™

IN RECENT YEARS, small solar home systems have brought power for the first time to millions of off-grid consumers in sub Saharan Africa, thanks to technological advances in LED lights and mobile payment. The systems store power during the day and provide light, phone charging and other services at night. But all solar home systems have the same problem: on days where there is insufficient sunshine, the systems turn off early at night time, leaving households in darkness. It is difficult for customers to have confidence that the light will work all night – a situation rather like the "range anxiety" often found in electric car users.

Azuri Technologies' HomeSmart™ is the first use of intelligent automation in small solar home systems, designed to provide light every night even in cloudy daytime conditions, and effectively eliminate "solar range anxiety". HomeSmart first works out a performance target by monitoring the customers' typical power usage. This becomes the performance the system aims to achieve under all conditions. At night, if sufficient stored power is available, the system operates like normal.

However, if the stored power is reduced, (because there was insufficient sunshine during the day), the system automatically adjusts the brightness of lights and the rate of phone charging in order to meet the duration of light that the customer is used to. These changes are normally imperceptible to the end user. In this way, HomeSmart brings anxiety-free "permanent light" to consumers for the first time.

Judges Comment:

Azuri's Quad solar home system with HomeSmart power management is provided on a pay-as-you-go basis. It not only brings a new level of quality and intelligence to the rural off-grid market, it also costs a household less than the kerosene and phone charging fees that it is designed to replace.

HomeSmart allows for a much more consistent customer experience, and meets the requirement to deliver simple, accessible power to low-income rural consumers. With HomeSmart™, it is believed that Azuri is the first company to bring such machine-learning processes to the rural off-grid market in Africa.

Conventional solar home systems work well in full sun but on cloudy days, most will turn off early at night, leaving households in darkness. This uncertainty is one of the reasons distributed power is often not considered "proper energy". Customers require certainty that when the light is switched it will work, irrespective of whether the previous day was sunny or cloudy. It is possible to manually dim systems but few people do. The challenge is to have a fully automatic system that delivers just the right quantity of power all through the night. This is what HomeSmart™ does. In a developed nation, intelligent automation may save around 25% of energy costs. Whereas, in a developing nation for off-grid communities it's the difference between being able to see at night and not.

The system actively monitors customer usage to determine a typical expected performance. Then, by accurately monitoring the climatic conditions, the system automatically adjusts the light brightness to meet the user's expected lighting duration. This active optimisation of light brightness, battery charging and load conditions ensures the system delivers the best possible match to the customer's typical daily requirement with the available power. For example, if a customer typically uses power morning and evening, the system will automatically slightly dim the lights in the evening on days when there is less sunshine to ensure power is still available in the morning.

Azuri's Quad solar home system with the HomeSmart power management is provided on a pay-as-you-go basis and not only brings a new level of quality and intelligence to the rural off-grid market, it also costs a household less than the kerosene and phone charging fees being replaced making it effectively "net free" to the consumer.

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Solar+Power awards2016

Module Manufacturing Innovation Award

Eagle Dual

Jinko Solar
Building Your Trust in Solar

EAGLE DUAL is an efficient and durable dual glass module. The standard back sheet has been replaced with a heat-strengthened glass layer within the Eagle Dual module, increasing its resistance to micro-cracking and lowering the risk of the so-called “snail-tracks”. The innovative design reduces module warping, potential induced degradation (PID), light induced degradation (LID), and corrosion from sand, alkali, acid, and salt mist.

Moreover Eagle Dual is the only dual glass module to pass the PID free test under 65°C/85% RH (relative humidity) for 1000 hours. It has also passed dynamic load test, and the standard 5400Pa and 2400Pa static load test. The new dual glass module provides heavy-duty robustness and durability for harsh environments with high temperatures, humidity, strong wind and heavy snow. Those specifications make it the perfect module for all kind of installations no matter the environment.

Jinko Solar Dual-Glass PV modules enable higher Lifetime Energy Yield with their improved yearly degradation level, moreover they have enhanced Durability and Reliability features.

They also permit to save considerably BOS costs and Maintenance costs too related to cleaning.
Resistance to sand, salt mist, acid, alkali as well as to corrosion or delamination caused by moisture ingress or to PID and snail-trails is significantly increased thanks to the double-glass structure of the laminate combined with the protective edge tape.

Judges Comment:

The new dual glass module incorporates a strengthened frame with a heat-strengthened back sheet glass layer that increases its resistance to micro-cracking, thus lowering the risk of ‘snail-track’ generation as well as potential induced degradation (PID), light induced degradation (LID), and corrosion.

Despite their frameless structure, they are certified up to 5400 Pa snow load and 2400 Pa wind load, therefore protecting solar cells from micro-cracking.
The version assembled with transparent EVA increases also light transmission allowing the use of DV modules in applications where light to pass through is required.
Jinko Solar Dual-Glass PV modules are specifically designed and assembled in order to achieve lower degradation levels as shown by the improved warranty terms: 0.5% annual power degradation and 30-year linear power warranty.

They are also designed for high voltage systems of up to 1500 VDC, which enables to install 50 percent longer strings and they have the best possible fire-protection rating, thanks to the fireproof properties of the glass.

PID-resistance is achieved at different levels, starting from the improved solar cell characteristics, the specific encapsulation technology and the frameless structure; the combination of these different features dramatically increases the PID resistance of the modules.

The frameless structure reduces soiling and snow coverage, thus requires less maintenance, while the optional Solar Super Shell Tape designed for dual glass module edge sealing helps to prevent moisture from entering the module therefore improve the reliability significantly.

Solar+Power awards2016

Industry Development Award

MEYER BURGER

Diamond wire saw DW288 series 3

TODAY'S THINNEST WIRES coated with razor-sharp diamonds can cut with high efficiency. This reduces kerf loss and saves money. At the same time, diamond wires account for over half of operating costs. As regards kerf loss, the general rule is: the thinner the wire, the better the material yield and the greater the output. However, thinner wires pose new challenges for solar suppliers. They can twist or break all too easily, particularly at high speeds. It is therefore vital that the machine control system and cutting processes are properly coordinated. The DW288 Series 3 has been specially designed for use with extremely thin wires. A special wire tensioning system rapidly regulates any fluctuations, even at the highest speeds and accelerations, while ultralight pulleys keep fluctuations in the wire tension within narrow limits.

Diamond wires account for the lion's share of operating costs. For too long, their impact on overall costs has been neglected. A wire loses in effectiveness as its diamonds become worn. On standard spools, the wire is wound on top of itself, which increases the abrasion and wear of the diamonds. Meyer Burger developed the Diamond Wire Management System (DWMS). On a specially designed working spool, the wire is wound side by side in a single layer. This eliminates any wire-to-wire contact and boosts the performance of the wire by more than 50 percent.

The third generation: The DW288 Series 3

"Boost productivity at all levels" is the order of the day. This can be achieved by increasing the loading length and also by raising wire speed. Meyer Burger has achieved a precise and consistently reliable wire speed of 30 m/s with the DW288 Series 3. Additional output is made possible by a loading length that has been enlarged to 650 mm. Optimized axis distance and a special high-speed cutting process ensure that the wire is less prone to bowing. This allows further speeding up of the cutting process. In addition, process-based user guidance via touch screen controlling facilitates more intuitive and rapid operation, which in turn reduces downtime between cuts. The throughput has almost been doubled compared to conventional technologies.

Costs can also be saved by cutting thin wafers because it enables more wafers to be obtained from each brick. Many wafers still have a thickness of around 180 μm. Diamond wire technology paves the way for much thinner wafers. The DW288 Series 3 is already used to manufacture wafers just 145 μm thick, with no end in sight to this development. Because today's standard Total Thickness Variation (TTV) of up to 30 μm would be far too high for such thin wafers, it had to be significantly reduced for the DW288 Series 3. Meyer Burger has succeeded in pushing the TTV to below 10 μm thanks to optimized geometry with narrow axis distance, alongside specially developed cutting processes. With high-efficiency cell-coating technologies such as heterojunction, the trend is increasingly towards the thinnest possible wafers.

Judges Comment:

Meyer Burger reduced the wire diameter in its new generation of diamond wire saws while increasing cutting speed – a significant accomplishment given the exacting demands of high volume solar cell manufacturing.

Solar+Power awards2016

PV Tool Award

centrotherm Photovoltaice

PERC AlOx/SiNx stack PECVD solution

CENTROTHERM PHOTOVOLTAICS is offering an aluminum oxide (AlOx/SiNx) PECVD process for advanced mono and multi-crystalline PERC solar cell production. The c.PLASMA AlOx system is based on the well-proven batch-type PECVD equipment platform that has a track record of more than 1000 units installed worldwide and which established as the industry standard for SiNx AR-coating.

The centrotherm direct plasma technology provides superior dielectric AlOx/SiNx stacks with excellent passivation properties in a one-step-process. Since the deposition is entirely confined to the process boats and does not contaminate the reactor chamber, c.PLASMA has a market-leading uptime of more than 98% .This guarantees a continuous wafer flow that is not interrupted by weekly downtimes for chamber cleaning and subsequent process requalification.

The 4 independently operated tubes constitute a redundant design that maintains at least 75% of production load even during process optimization or single tube downtime. Individual R&D recipes may be processed in between production runs without serious impact on throughput and may be transferred to other tubes and/or systems by copy-paste.
The system is equipped with an external space-saving TMA cabinet including the comprehensively designed centrotherm CVC vapor system. This ensures a TMA supply with maximum safety and without escape of liquid TMA. The redundant set of two TMA containers is not pressurized and may be exchanged during operation.

Judges Comment:

Stacks are deposited in one run by just changing the recipe. This is an advantage compared to ALD systems where only one AlOx layer is deposited at a time and the capping layer needs to be added in another system; it is a fast and straight-forward way to begin PERC manufacturing.

Challenge

Driven by the pursuit of increased conversion efficiencies beyond 21%, solar cell manufacturers are necessarily turning towards more complex cell architectures for higher electrical performance.

As a result, PERC technology emerged as the next generation of industrial silicon solar cells. Pre-requisite for a successful implementation is a highly efficient rear surface passivation. Aluminum Oxide (AlOx) with its excellent passivation properties and high negative fixed charge density is perfectly suited to achieve this.

Solution

The c.PLASMA AlOx PECVD system provides the fastest and easiest way to start PERC manufacturing the most cost-effective way. The centrotherm AlOx process shows best passivation properties at thickness 5-25 nm also on uneven surfaces and low surface recombination velocity on p-type wafers.

The complete rear-side stack is manufactured in a single-step process. In the first phase of the process, the AlOx layer is deposited by using TMA and N2O. By only switching the gases to NH3 and SiH4, the SiNx capping layer is formed. Additional process steps, which can be implemented easily into the recipe, will further increase the benefits of the integrated AlOx/SiNx stack. This type of flexibility is unique to batch-type tube furnaces, and we have taken full advantage of it. The stack is compatible with standard Al pastes and shows a high passivation quality after contact firing.

Solar+Power awards2016

Award Winners

PV Materials Enabling Award

Heraeus

SOL326

PV Tool Award

Centrotherm
PERC AlOx/SiNx stack PECVD solution

PV Process Award

HORIBA
Explore the future

Phosphorus oxychloride (POCl3) delivery systems

PV Balance of System Award

Steca Elektronik GmbH
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KIPP & ZONEN SINCE 1830

Smart PV power plant monitoring instruments

Solar Asset Management Award

First Solar
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Industry Development Award

MEYER BURGER

Diamond wire saw DW288 series 3

Module Manufacturing Innovation Award

JinKO Solar
Building Your Trust in Solar

Eagle Dual

Rural Electrification Development Award

Azuri Technologies
HomeSmart

Proinso
Kepulauan Riau

Storage System Award

SMA

Integrated Storage System

Turnkey Project Award

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Solar Award for Excellence: Innovation

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New fabric uses sun to power devices

A bracelet made from fabric woven with special energy-harvesting strands that collect electricity from the sun and motion.

FABRICS that can generate electricity from physical movement have been in the works for a few years. Now researchers at Georgia Institute of Technology have taken the next step, developing a fabric that can simultaneously harvest energy from both sunshine and motion.

Combining two types of electricity generation into one textile paves the way for developing garments that could provide their own source of energy to power devices such as smart phones or global positioning systems.

"This hybrid power textile presents a novel solution to charging devices in the field from something as simple as the wind blowing on a sunny day," said Zhong Lin Wang, a Regents professor in the Georgia Tech School of Materials Science and Engineering.
The research was reported September 12 in the Nature Energy.

To make the fabric, Wang's team used a commercial textile machine to weave together solar cells constructed from lightweight polymer fibres with fibre-based triboelectric nanogenerators. Triboelectric nano generators use a combination of the triboelectric effect and electrostatic induction to generate small amount of electrical power from mechanical motion such as rotation, sliding or vibration.

Wang envisions that the new fabric, which is 320 micrometres thick woven together with strands of wool, could be integrated into tents, curtains or wearable garments. "The fabric is highly flexible, breathable, light weight and adaptable to a range of uses," Wang said. Fibre-based triboelectric nanogenerators capture the energy created when certain materials become electrically charged after they come into moving contact with a different material. For the sunlight-harvesting part of the fabric, Wang's team used photoanodes made in a wire-shaped fashion that could be woven together with other fibres.

"The backbone of the textile is made of commonly-used polymer materials that are inexpensive to make and environmentally friendly," Wang said. "The electrodes are also made through a low cost process, which makes it possible to use large-scale manufacturing."

In one of their experiments, Wang's team used a fabric only about the size of a sheet of office paper and attached it to rod like a small colourful flag. Rolling down the windows in

(Credit: Georgia Institute of Technology)

a car and letting the flag blow in the wind, the researchers were able to generate significant power from a moving car on a cloudy day. The researchers also measured the output by a 4 by 5 centimetre piece, which charged up a 2 mF commercial capacitor to 2 volts in one minute under sunlight and movement.

"That indicates it has a decent capability of working even in a harsh environment," Wang said.
While early tests indicate the fabric can withstand repeated and rigorous use, researches will be looking into its long-term durability. Next steps also include further optimizing the fabric for industrial uses, including developing proper encapsulation to protect the electrical components from rain and moisture.

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Further reading

Jun Chen, Yi Huang, Haiyang Zou, Ruiyuan Liu, Changyuan Tao, Xing Fan, and Zhong Lin Wang, "Micro-cable structured textile for simultaneously harvesting solar and mechanical energy," (Nature Energy, September 12, 2016).
http://dx.doi.org/10.1038/nenergy.2016.138

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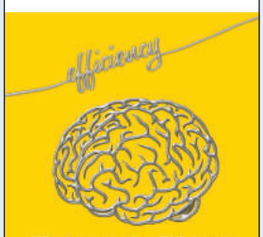

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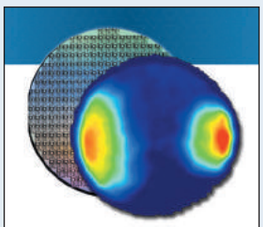

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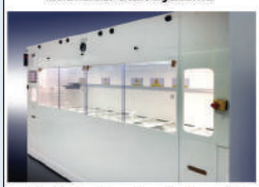

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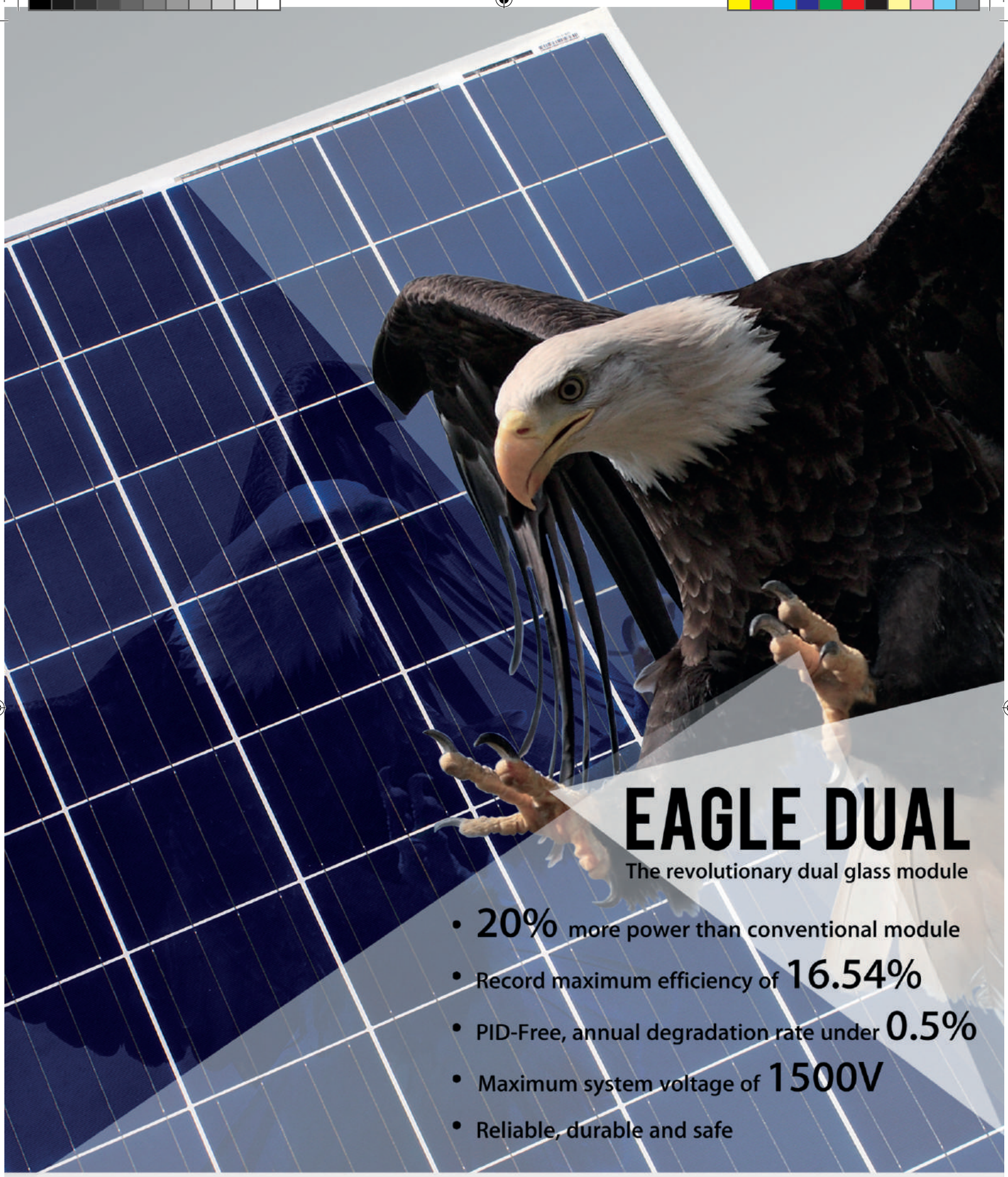

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