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# viewpoint

# Solar eclipse in China?

China's economic woes were long in the making. Growth slowed since 2012. Some analysts point to 2008's Great Recession as the start of a long slide. Yet despite early storm clouds, global financial markets shrugged-off worries thanks to positive governmental reports.

China's sustained 30-year growth record depended on selling inexpensive goods outside its borders at solid margins. This model had worked well for others. But as seen in Japan, export-reliant economies go off the rails if domestic consumers don't also buy what a country makes.

Basic rules of macro-economic balance hit China hard this summer as capacity kept outpacing demand. The Chinese Central Bank devalued the Yuan to make exports more affordable. But this was an inescapable signal long feared outside China. Financial markets worried 'slow' growth might become 'no' growth. The selling began. A trickle became a tumult. Trouble traveled across the globe through Asia, the Middle East and Europe, hitting North America in the waning days of August; the Dow Jones Industrial Average saw triple-digit losses.

What does this mean for China and its robust solar industries? The good news is that even though growth has slowed, China is still a major solar player. Chinese leadership forecast adding 17.8 gigawatts of capacity in 2015; it has so far added 7.7 GW. Analysts like Adam James of GTM Research believe China will add 14 GW in 2015. At that level China is still committing to solar faster than anyone else. If they finish 2015 near James' target, China will have more solar capacity than the world had in 2010.

But is there a shadow over China's solar horizon? One indicator may be declining electrical consumption growth. Nine percent of China's solar capacity sits idle while power utilization grows at just 1.3 percent – the slowest rate in 10 years. So why build solar plants when demand slips? China has a simple strategy – invest now / build transmission lines in the years to come so eastern industrial centres can support demand as it resumes.

Overall economic indicators paint a cautiously optimistic picture for the China's long-term prospects. Yet their overly export-driven economy has to change. China has signalled it intends to get its house in order, a good sign for solar and other Chinese industries. The hard part is waiting for sustainable growth and to see if the lessons of 2015 translate into positive economic reforms.

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

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

**Sales 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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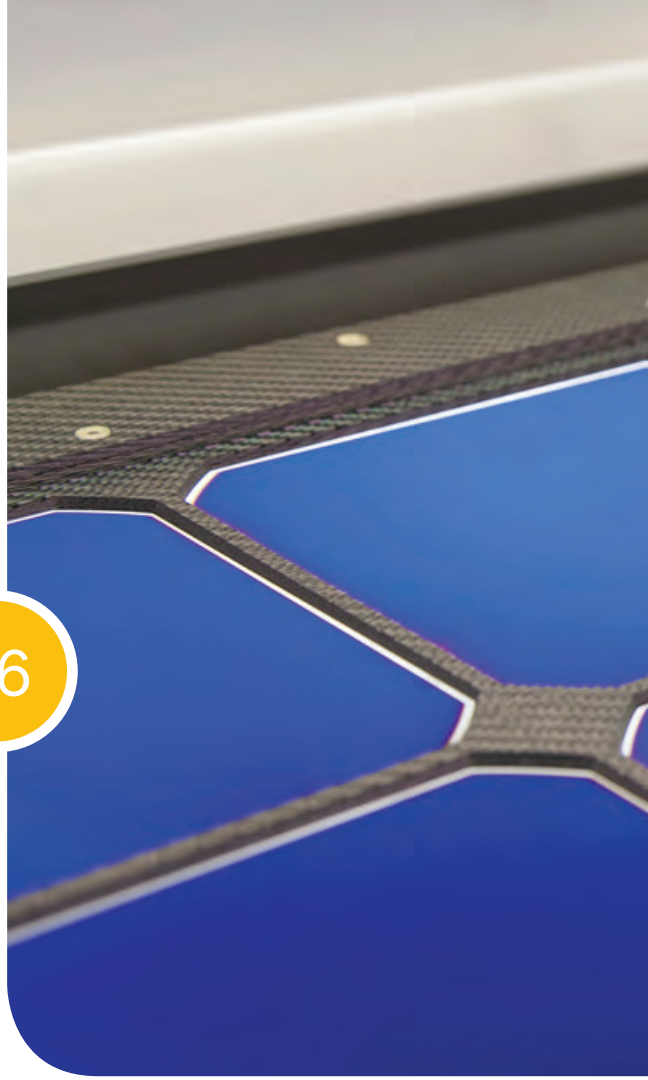
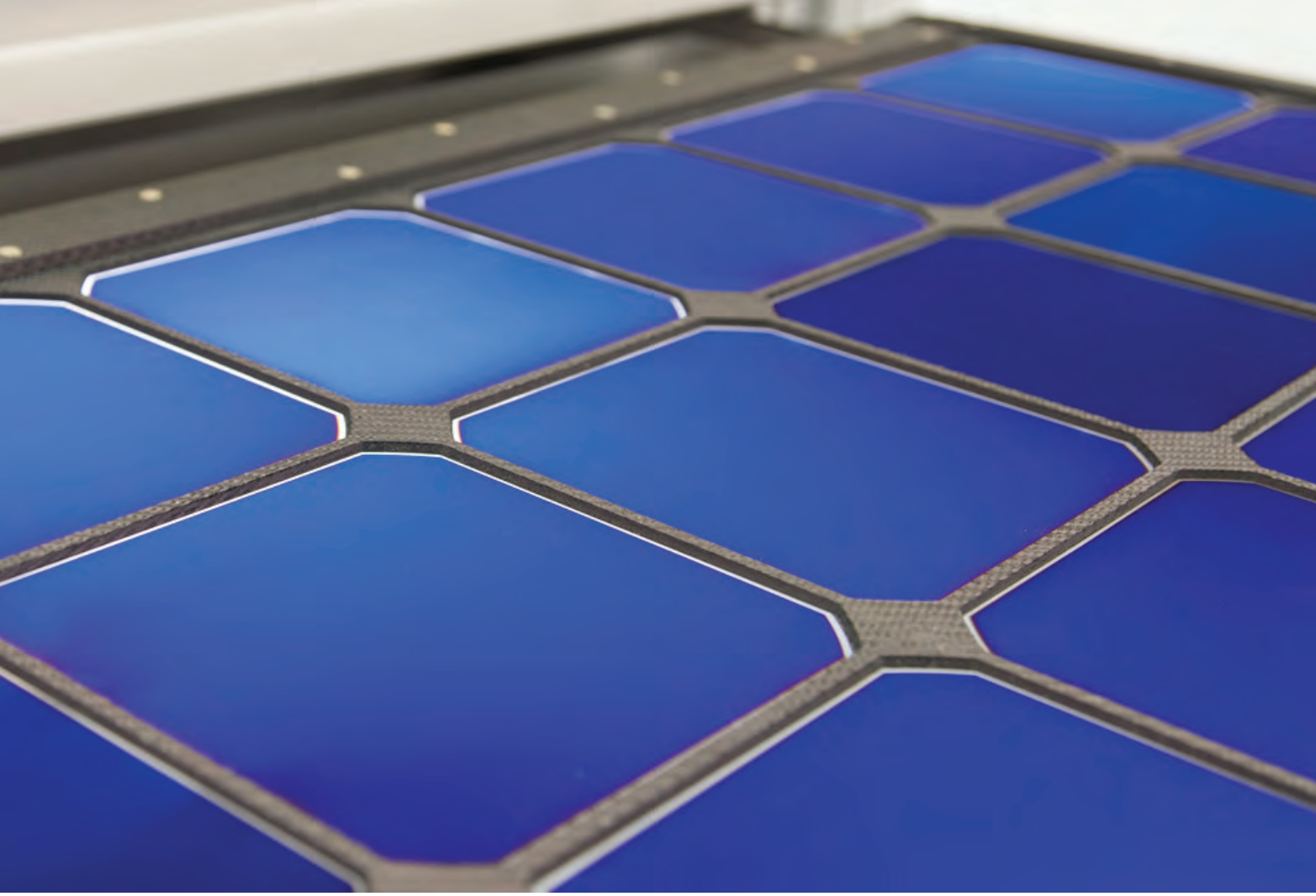
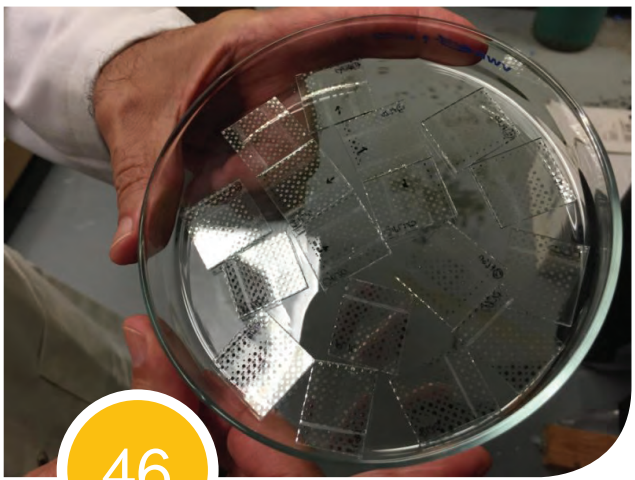






## research...





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## industry news...



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# US DoE announces $1 billion in clean power loan guarantees

THE U.S. DEPARTMENT OF ENERGY has announced over one billion dollars (USD) in loan guarantees to fund the expansion of distributed clean energy systems in America, including $24 million for 11 specialised projects aimed at creating a new class of concentrated solar panel.

The funding will come from the DoE's Loans Programs Office (LPO) as part of President Barack Obama's new Clean Power Plan, which mandates U.S. States cut carbon pollution from the power sector by 30 per cent below 2005 levels by 2030. The LPO was established to help emerging distributed energy technologies such as rooftop photovoltaic (PV) energy systems, wind power plants and energy storage overcome market barriers to investment. Energy Secretary Ernest Moniz says the new funding will help accelerate the growth of America's clean economy.

A specialised program called MOSAIC (Micro-scale Optimized Solar-cell Arrays with Integrated Concentration) will award 11 teams across America $24 million to develop innovations in solar technology to create a new class of highly efficient "flat-plate" rooftop solar panel.

MOSAIC solar panels use thousands of tiny lenses to concentrate light onto an array of PV cells to achieve higher solar-to-electricity conversion. Known as micro-scale concentrated PV, these small rooftop CPV systems produce far more energy than conventional modules according to the DoE.

"This micro-CPV approach addresses the constraints of conventional CPV, which, while highly efficient, has not been widely adopted due to its high cost, large size, and expensive solar tracking systems. Project teams will address these limitations by developing innovative materials, micro-scale manufacturing techniques, panel architectures, and tracking schemes."

Solutions include a solar panel with built-in sun-tracking, such as Panasonic Boston Lab's system – an array of lenses shifts according to the sun's movements across the sky, ensuring the panel's PV cells are always absorbing sunlight. Another is California Institute of Technology's new CPV panel for regions of low direct sunlight, which incorporates a luminescent solar concentrator sheet fabricated with quantum dots that enhances energy output by converting the high energy spectrum into light suitable for special wide bandgap micro PV cells sandwiched under the sheet. Additional low bandgap cells convert the remaining low-energy into electricity.

# Welspun breaks ground on Punjab's largest solar project

WELSPUN RENEWABLES, India's largest solar energy generator has set up its first solar power project – the Bhatinda 34 MW (DC), in Punjab. This is the largest commissioned solar capacity to come up in the state. Like all its projects before, Welspun Renewables has developed it ahead of committed deadlines, in 5 short months.

It will annually be feeding 48 million units of clean & emission free energy into the Punjab state grid, for next 25 years. Spread across 140 acres in state's Bhatinda district, in the next 25 years the project will have mitigated 1,331,525 tons of CO2 emissions. The company is among the first few to set up a project in Punjab.

Speaking on the occasion Mr. Vineet Mittal, Vice Chairman Welspun Renewables said "More than ever we need to exponentially build up the country's renewable energy quotient Development is a necessity and to make it sustainable it has to be driven by clean emission free energy. Developed well within committed timelines, our projects are benchmarks in project management and optimal plant performance. Our 34 MW (DC) solar power plant is our first step in the state in this direction. While powering the state's industries, we will also be working with our neighboring communities towards sustainable living."

In response to Punjab state's growing energy demands, a cumulative 4200 MW solar target has been announced for the state by Shri Bikram Singh Majithia, Honorable Cabinet Minister of Revenue, Rehabilitation and Disaster Management; Information & Public Relations and Non Conventional Energy. In the Punjab capacity auction, bidders in the selection process were evaluated on their technological competence and Welspun Renewables' subsidiary Welspun Solar Punjab Pvt.

# BKW acquires Solare Datensysteme

SOLARE DATENSYSTEME has been acquired by BKW AG, a power production and distribution utility with its headquarters in Berne, Switzerland. The company also provides gas and heat through a number of subsidiaries or partner companies.

BKW is entering into the PV service business, responding to the growing customer needs to produce energy themselves and to have smart consumption management. With BKW, Solare Datensysteme GmbH gains access to power trading and additional potential customers. BKW has over 1,000,000 customers in Switzerland alone, not to mention its strong BKW customer base in Germany, France and Italy.

Solare Datensysteme GmbH can also expand its product portfolio to include other renewable energy sectors. Solare Datensysteme GmbH (SDS), based in Geislingen-Binsdorf, has developed and distributed its Solar-Log devices and customer-specific web solutions with its Solar-Log Portal. Its solutions go beyond just PV plant monitoring for smart energy and include feed-in management and numerous system enhancements that effectively support operators and installers around the world. The specialist for inverter independent "Made in Germany" monitoring systems, SDS products are used in 65 countries to monitor more than 1.33 million MPP trackers with a total output of over 9.9 gigawatts.

For BKW, the acquisition of SDS is another step towards implementing its strategy of becoming a provider of comprehensive energy solutions. BKW is expanding and strengthening its expertise in the area of energy efficiency, developing its know-how in the promising market for PV monitoring and the optimization of self-produced power consumption. Together BKW and SDS will continue to develop innovative solutions in the area of building technology and optimization of self-consumption.

As a company that develops manufacturer-independent solutions, SDS is well prepared to take advantages of synergies with Ampard, for example, a start-up company that BKW has a stake in. SDS and BKW will develop joint solutions and products for energy management that can be globally marketed.

"We are delighted to have found a strong partner like BKW, which also shares our values and is close to us geographically," says Frank Schlichting, CEO of Solare Datensysteme. "And this means our key unique selling point of vendor independence will remain unaffected". Suzanne Thoma, CEO of BKW, underscores the importance of the acquisition: "BKW is looking forward to working on some exciting and pioneering projects with its new subsidiary and welcomes all SDS employees to the BKW family".

# Crystalsol announces fully printed flexible pv film using silver nanowires

CRYSTALSOL GMBH and Cambrios Technologies has successfully developed fully printed flexible solar cells using silver nanowires from Cambrios.

Solar cells from the pilot production line at crystalsol are shipping into low volume consumer products. crystalsol expects large volume product shipment into building integrated photovoltaics market to begin in the near future.

"Our proprietary printed solar cell technology successfully achieves highly efficient solar cells that are thin, lightweight and flexible allowing our solar films to be integrated into building facades, chassis of vehicles as well as clothing/accessories for consumer applications," said crystalsol CEO Rumman Syed.

"The highly conductive ClearOhm silver nanowires from Cambrios enables us to move to a fully printed solar cell architecture and achieve the high throughput and cost structure required for success in this competitive market segment."

crystalsol's thin film-based photovoltaic (PV) module production process is based on roll-to-roll printing, enabling high throughputs and exceptional cost structure. This improved production approach is expected to reach large scale within the next 18 months.

# New tool for absolute temperature

K-SPACE ASSOCIATES has released its latest product, kSA SpectraTemp, a self-calibrating absolute source temperature measurement tool.

k-Space CEO, Darryl Barlett, commented, "Absolute temperature is a very difficult parameter to measure. With kSA SpectraTemp, if the source radiation is blackbody-like, an absolute temperature is instantly determined."

kSA SpectraTemp is a non-contact, optically-based technique for measuring the temperature of semiconductor wafers, metals, ceramics, and more. It is based on patented technology that analyzes the spectral radiation profile utilizing a solid-state spectrometer, resulting in, the company says, fast data acquisition and real-time temperature measurement. The user simply reads the temperature from the screen. MOCVD and other thin-film deposition facilities can use it to measure absolute temperature on wafer carriers, providing more accurate temperatures and tool-to-tool matching. As facilities adopt this technology and gain temperature control, device yield and quality will improve.

# Siemens to build 70 MW solar facility in Nigeria

SIEMENS and CT Cosmos, a Nigerian firm based in Abuja, have concluded a memorandum of understanding to construct a 70 MW alternating current (MWac) photovoltaic (solar) power facility estimated at $170 million in Panyam, Plateau State.

The project, which is expected to be completed in a less than two-year period, will supply the power produced into the national grid. Existing solar plants in Nigeria are few, due to the relative high cost of generating solar power.

However, this cost has declined in recent years as a result of enhanced technologies like those offered by Siemens. One major attraction of solar power plants is the short construction time-frame; completion period for a solar plant could be as short as 12 months, whereas construction of traditional gas/coal fired power stations could take as much as one to three years longer. The Chief Executive of CT Cosmos, Mr. Phillip Chukwueke, disclosed that his firm selected Siemens as technical partner for the construction of the Solar Power facility due to the company's proven expertise in delivering high quality solutions, technical support and services.

The 70 MWac solar power plant is the first in a series of large solar power generating facilities proposed by CT Cosmos for various sites in Nigeria. Chukwueke stated that solar power is now approaching parity with traditional sources of energy and expressed his optimism that in the not too distant future it would become more cost effective to generate electricity from the sun than from hydro and thermal sources.

Siemens General Manager, Power and Gas, -Nasir Giwa, expressed Siemens commitment to delivering the, project and stated that "Siemens looks forward to working with CT Cosmos in delivering state-of-the-art technology and services to the Nigerian people who urgently require stable electricity to help meet the

country's rapid development."

Nigeria is said to have 485.1million MWh/day of solar energy in natural units and enjoys an average of 6.2 hours of daily sunshine. Solar Power solutions are therefore highly relevant for the region and CT Cosmos is well positioned to leverage the country's solar resource in its bid to close the glaring power supply gap in the country. The project will be located near Jos, in the Plateau region of Nigeria which has minimal cloud cover and records one of the highest solar radiation indices in the country as per SolarGIS latest baseline data.

# SkyPower awarded 200 MW of PV projects in India

SKYPOWER has been awarded 200 MW in the Telangana, India solar competitive tender process.

The State of Telangana, under the leadership of Chief Minister Rao, has proven to be one of the most advanced jurisdictions in India to embrace solar energy and is forward thinking in its efforts to adopt solar as a means to help grow its economy and provide families with access to lower-cost electricity.

This 200 MW award from Telangana is in addition to the 150 MW of projects awarded to SkyPower in the State of Madhya Pradesh in July, for a total of 350 MW. Once built, the projects from both states are anticipated to be in excess of 400 MW of solar nameplate capacity.

SkyPower considers India to be one of the key solar markets in the world that holds tremendous growth potential as is evident by the Government's commitment to rapidly increasing the country's electrification rate and helping to support and foster the growth of what clearly is a trillion dollar industry.

"India is leading the world in deploying solar, not only with its significant targets but by it very actions. It is truly an example for others to follow," said Kerry Adler, President and Chief Executive Officer of SkyPower Global.

SkyPower plans to actively and competitively participate in various other states and processes in the months ahead.

# TSMC to cease CIGS manufacturing

TSMC has announced that its subsidiary TSMC Solar will cease manufacturing operations at the end of August 2015 as TSMC believes that its solar business is no longer economically sustainable. "TSMC continues to believe that solar power is an important source of green energy and that solar module manufacturing remains a robust and growing industry, but despite six years of hard work we have not found a way to make a sustainable profit," said Steve Tso, chairman of TSMC Solar and senior VP of TSMC. "Upon ceasing manufacturing operations at TSMC Solar, our most important concern will be the continued employment of our workers there."

TSMC estimates that charges related to closing the solar subsidiary's fab will impact third-quarter 2015 earnings per share by NT$0.07. Remaining solar panel inventory will be installed at TSMC buildings and facilities.

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# Silfab increases module capacity to meet North American demand

SILFAB SOLAR has announced it is increasing production, expanding its facility and breaking monthly production records at its North American photovoltaic solar module manufacturing facility.

"Our expansion enables Silfab to meet growing U.S. customer demands in a solar market seeking more locally-made modules"

The current plant expansion, which will bring annual production to more than 300 megawatts, is necessary to meet strong demand from its North American partners that recognize the multiple advantages brought by Silfab's automated production process and increased efficiency outputs. The expansion, which includes an upgrade of existing equipment to manufacture five-busbar modules, now places Silfab among the top four PV solar production facilities in North America. The plant expansion will be completed in the third quarter of 2015 and already has added 30 new clean-tech jobs.

"Solar companies seeking to provide customers with the latest advancements in ultra-high efficiency and other innovations at competitive prices are recognizing the Silfab advantage. Our superior production line delivers unmatched quality, reliability and durability," said Paolo Maccario, Silfab's Chief Operating Officer. "We are pleased by the ongoing positive response to our unique offering and our more than 30 years of solar industry expertise." Silfab Solar helped pioneer smart module technology, glass on glass solutions and bifacial modules. The North American manufacturing process is one of the most automated in the world, and combines Silfab's decades-long history in the PV market with technology and production techniques borrowed from the most advanced assembly systems in the world.

"Our expansion enables Silfab to meet growing U.S. customer demands in a solar market seeking more locally-made modules," Geoffrey Atkins, head of business development. "Silfab has and will continue to secure long-term, strategic customers who seek a local supplier that can deliver modules with maximum module efficient and power density."

Silfab Solar opened its North American manufacturing plant in 2011 with a 90-megawatt (MW) annual capacity.

# Midsummer gets €1 million grant

THE SWEDISH solar energy company Midsummer has receives a loan of around €1 million (10 million SEK) from the regional development agency Almi Företagspartner Stockholm Sörmland AB. The loan is meant to support Midsummer's focus on production and sales of the DUO machines used for the production of flexible CIGS thin film solar cells.

Swedish regional development agency Almi Företagspartner AB has now decided to grant Midsummer the investment loan, part of which is guaranteed by the European Investment Fund, EIF. The purpose is to provide Midsummer with increased resources for research and development of machinery for the production of thin film solar cells, known as DUO machines. "Our loan intends to provide opportunity for innovative companies to develop innovations and business ideas that provide growth and profitability," said Fredrik Larsson, Financial Advisor, Almi Företagspartner Stockholm Sörmland AB. "We sold a DUO system this spring to a foreign multinational company, which is yet another proof of the market potential for our system", said Sven Lindström, CEO, Midsummer. "The DUO is a compact, fully automated system for production of CIGS solar cells. It is designed for high productivity, operational stability and superior material utilisation".

Midsummer's customers are manufacturers of flexible thin film solar cells worldwide. An increasing number of companies see the benefits of the technology as it can be easily integrated in buildings (BIPV) - a rapidly growing segment.

Fredrik Larsson continued: "Through the funding we hope to provide Midsummer with the opportunity to develop and pursue its commercialization. It is hoped that Midsummer can become a model for other Swedish environmental technology companies. It will be interesting to follow the company on its journey".

# GE signs its largest battery energy storage project

GE has announced it will provide Coachella Energy Storage Partners (CESP) with a 30-MW battery energy storage system as part of CESP's supply contract with the Imperial Irrigation District (IID). Representing GE's largest energy storage project to date, the plant will be located in California's Imperial Valley, approximately 100 miles east of San Diego. The facility will aid grid flexibility and increase reliability on the IID network by providing solar ramping, frequency regulation, power balancing and black start capability for an adjacent gas turbine.

"We chose GE as the energy storage system provider for this project because they supplied the most comprehensive solution at a competitive price," said Mike Abatti, president of CESP. "GE is well-positioned to serve the needs of the project and will remain a stable, reliable technology provider as the energy storage industry evolves."

GE will provide CESP with an integrated energy storage solution, configured using GE's Mark* VI plant controls, GE Brilliance* MW inverters, GE Prolec transformers, medium-voltage switchgear and advanced lithium ion batteries housed in a GE purpose-built enclosure. The plant will be operated by ZGlobal, an engineering collaborator with CESP, for the first 18 months, after which control will transfer to the IID. "This project is a game changer to the energy industry and will be one of the largest battery storage plants in the western United States," said Ziad Alaywan, P.E., a California energy veteran and president & CEO of ZGlobal Inc. "We are confident in GE's technology and look forward to a successful project."

The deal marks GE's third project using lithium ion battery technology since expanding its portfolio in recent months, joining recent announcements with Con Edison Development in California and Convergent Energy + Power in Ontario.

"While we always strive to provide competitive pricing, what really differentiates GE is the fact that we listen to our customers and help craft a customized energy storage strategy," said Anne McEntee, president and CEO of GE's renewable energy business.

"We focus on full system performance rather than individual component pieces, allowing customers to match power production with demand in real time and utilize grid assets more efficiently."

GE anticipates project construction will begin early 2016, with commercial operation scheduled for the third quarter of 2016.

# China Sunergy win 260 MW bid

CHINA SUNERGY CO., LTD has announced that CEEG (Nanjing) Renewable Energy Co., Ltd, a subsidiary of China Sunergy, has won a bid to supply 260 MW of PV modules to China Power Investment Corporation, a state-owned comprehensive energy group with a term of 12 months, starting from July 2015. The modules will be utilized by China Power Investment Corporation to construct a number of ground power projects in various locations across China.

Mr. Tingxiu Lu, Chairman and CEO of CSUN commented, "We are delighted to provide our high-quality modules to China Power Investment Corporation, a leading solar energy developer.

The winning of the bid demonstrates our ability and proven experience in supplying large-scale solar power plants. As the demand of solar energy products continuously grows in China,

We expect the Company will further deepen its cooperation with China Power Investment Corporation, and we look forward to identifying and engaging similarly strategic opportunities in both Chinese and overseas markets in the near future."

# Rural electrification increases contributions to green economy

THE RURAL ELECTRIFICATION FUND OFFICE (RE) plans to buy and distribute 4,404 solar home systems (SHS) and 24 institutional solar systems in 2015/16. It is also working on a new five-year project for the purchase and distribution of 200,000 SHS and 600,000 improved cook stoves.

These projects are part of Ethiopia's climate resilient green economy facility.

Managed under the auspices of the Alternative Energy Technology Development & Transformation Directorate of the Ministry of Water Irrigation & Energy (MoWIE), the programme works with different donor organisations to deliver the SHS and institutional solar systems to parts of the country that are not connected to the national grid.

The directorate is also forming a new team for the new SHS and stove project, says Yisehak Seboka, RE head at the Ministry.

MoWIE bought 11,488 SHS in the last fiscal year, which ended on July 7, 2015, and the installation of these systems will take place in the first quarter of the current fiscal year 2015/16. For a total of 25,000 SHS, in the past two budget years, the RE was allocated 1.5 billion Br

out of the requested 2.5 billion Br in the fiscal year 2014/15. Similarly, the budget allocation for this fiscal year is half the requested amount.

There are 700 technicians in the country that will be given refresher training and will start installation, says Yisehak. The purchase and distribution of SHS are based on demand assessment made at the wereda level by local authorities.

Those who express demand cannot change their minds once the order is made, says Yisehak.

SHS' cost is also decreasing compared to the purchase cost in the past two fiscal years.

In 2013/14, the cost of a 130 watt SHS was 22,000 Br, which fell to 16,000 Br in the following fiscal year. The Office distributes SHS between eight and 130 watts. MoFED had approved only half of the 52 million Br budget that had been requested for the RE, which uses government budget for salaries, per diems and training.

Responding during the Budget hearing, Abraham Tekeste (PhD), state minister for Finance & Economic Development said that RE had more financial resources from donors including the United Nations Development Programme (UNDP), Power Africa, Energy Plus, the World Bank, and the United Nations Capital Development Fund (UNCDF). These donors contribute 80pc to 85pc of the total budget, the balance coming from the government, according to Yisehak.

In addition to the distribution of SHS, the programme will engage in off-grid investment plan implementation, which includes the participation of the private sector in the generation and selling of electricity.

The new project, dubbed 'Promoting Sustainable Rural Energy Technology for Household & Productive Uses', will last for five years starting from 2016. Contributors include UNDP, the Global Environment Fund and UNDCF with four million dollars, 900,000 dollars and 800,000 dollars, respectively.

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# Off grid-based new, renewable projects get promoted in India

OFF GRID-BASED new and renewable energy projects are being promoted in Bhopal India.

As many as 29,000 solar streetlights have been installed in major municipal corporations and other cities. Farmers are being motivated to install solar tube wells under solar drinking water pump scheme in remote areas of the State.

From 2008-09 to date, over 11,000 solar streetlights have been installed in various areas of the State. In major municipal corporations, 18,000 LED based solar streetlights have been installed.

Under Solar Photovoltaic Power Plant Project, 5.64 MW solar power plants have been installed to energise naxalite affected areas' police stations, chowkies and community health centres.

Power supply process has been started by preparing mini grid for power generation from alternative sources of energy under decentralised distribution generation (DDG) programme in 23 naxalite affected villages of Shahdol, Umaria, Sidhi and Singrauli districts. So far, this work has been completed in 13 villages.

Under rural electrification scheme, 594 villages in remote areas of the State have been energised with solar power. This has benefited 46,000 families.

Union Government's Energy Efficiency Bureau is conducting "Star Levelling" Programme to gauge functioning of energy-efficient appliances. Efforts are also being made to implement its recommendations in the State.

So far, over 300 alternative energy shops have been set up at development block and divisional level by Madhya Pradesh Energy Development Corporation for publicity and marketing of appliances of alternative energy as well as energy-efficient electric appliances.

# High Throughput Production Equipment for Laser Processing of Crystalline Solar Cells

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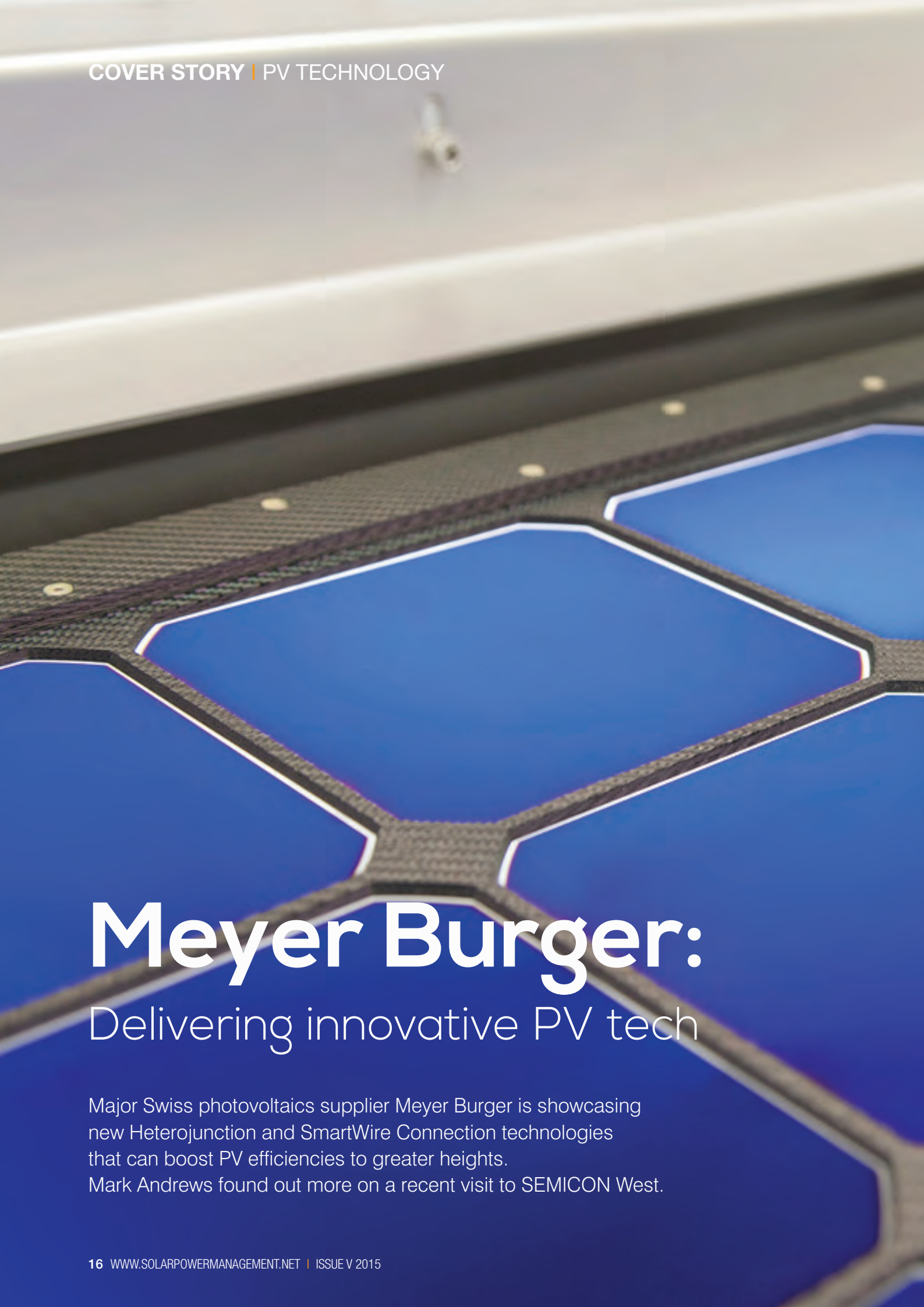
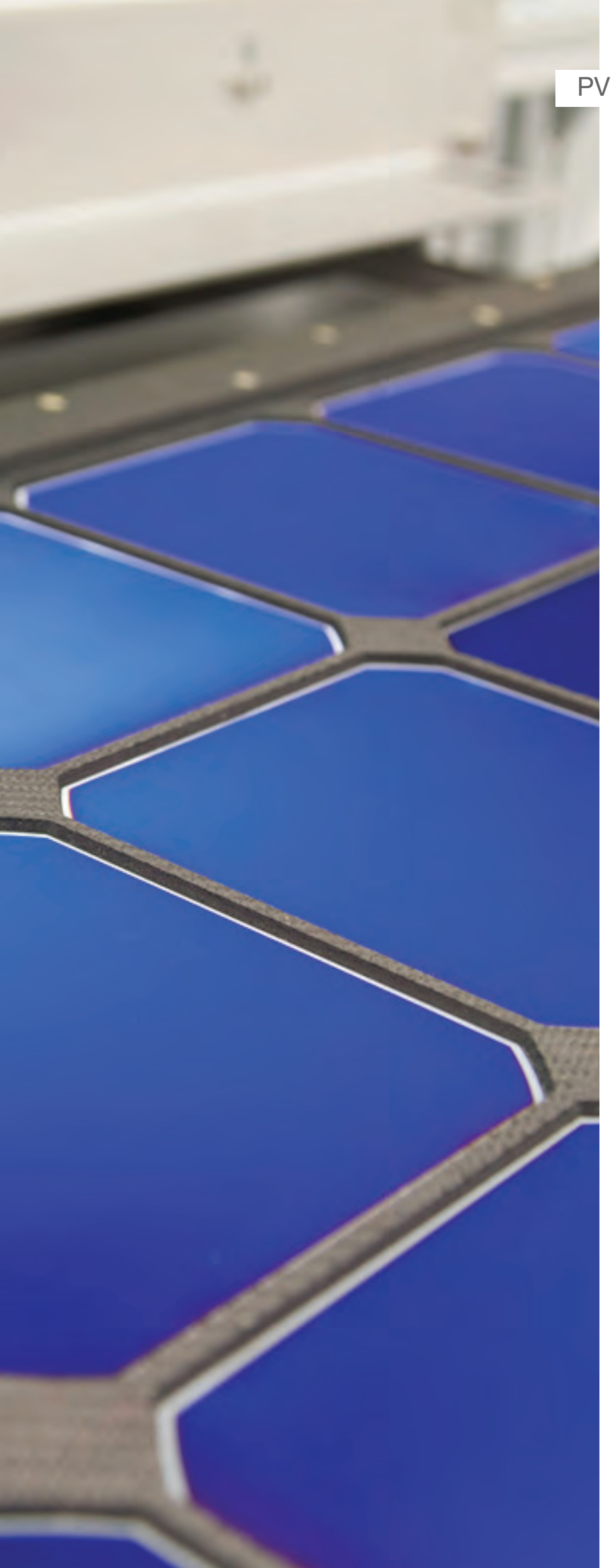


# Meyer Burger:

## Delivering innovative PV tech

Major Swiss photovoltaics supplier Meyer Burger is showcasing new Heterojunction and SmartWire Connection technologies that can boost PV efficiencies to greater heights.
Mark Andrews found out more on a recent visit to SEMICON West.



Left: Heterojunction cells.
Image courtesy Meyer Burger

ANY TECHNOLOGY delivering better performance wins marketplace attention. Whether the total package can shake-up solar markets is in the details: the place this story begins.

Swiss photovoltaics supplier Meyer Burger is an established industry leader. Their precise, reliable and innovative approaches to core technologies have enabled the company's many customers to achieve success through advanced wafer processing and manufacturing techniques. Meyer Burger is known for its innovative manufacturing processes for wafers, solar cells, solar modules and solar systems as well as expertise that extends to enhanced coating technologies and other synergistic programs.

While Meyer Burger continues to deliver highly competitive wafer processing solutions the company is looking for future growth through their new high performance Heterojunction (HJT) cell architecture. While core HJT principles were first commercialized by Sanyo and Panasonic, Meyer Burger is taking a new approach worth examining.

Important benefits of the company's Heterojunction technology emerge by seeing how it compares utilizing levelized cost of electricity (LCOE) values. As the name implies, calculating LCOE 'levelizes' factors influencing a cell's performance including the operational environment, balance of system (BOS) costs, maintenance and many other variables that tend to fall into either local- or system-level parameters.

LCOE calculations reveal a strong efficiency benefit. Meyer Burger's Heterojunction performance is superior to standard mono and mc-Si cells by at least 2 full points. Temperature coefficient is also dramatically lower: >-0.25 percent/°C compared to -0.43 percent/°C (or greater) from competing technologies. Another standout is module lifetime: 40 years for modules with Heterojunction cells and 25 for others, which is also borne out in degradation figures – just 0.1 percent for Heterojunction and 0.35 percent for the other technologies.

Despite the impressive gains that LCOE figures demonstrate, Heterojunction innovation isn't the whole story. Meyer Burger is also changing the basics of how PV cells collect energy. Busbars have long been a mainstay for collecting electricity from solar radiation. Three to five bars and heavy silver

Cell conection station for SmartWire Connection Technology. Image courtesy Meyer Burger

fingers collect electrical energy in many gigawatts of installed global solar power capacity. Meyer Burger developed a new way to eliminate the busbar, an approach it calls SmartWire Connection Technology (SWCT).

The fine details in this case are more than 2,600 individual fingers and strands that eliminate heavy busbars, resulting in PV cells that are measurably more efficient while being less prone to breakage. Combine the efficiency of Heterojunction technology with SmartWire Connection Technology and it is clear to see that a new approach to PV cell performance has been achieved.

## Elegance in the details

Global PV cell manufacturers depend upon suppliers' technology and their own innovation. Despite the dynamic nature of solar manufacturing, new ideas are generally not rushed into production due to the stakes and costs involved. Meyer Burger spent years developing and improving its Heterojunction technology in partnership with the PV Center of the Swiss Center for Electronics and Microtechnology (CSEM), and its own Meyer Burger Research SA.

In close cooperation with its research partner, Meyer Burger began research in 2008 and has achieved record setting levels of module performance with its innovative high efficiency Heterojunction cell technology.

Heterojunction technology differs from other silicon-based PV cell architectures by placing nanometer thick layers of amorphous silicon onto both sides of mono crystalline silicon wafers using PECVD techniques. HJT efficiency is higher than standard cells' efficiency – Meyer Burger HJT cells start at 22 percent average cell efficiency. The HJT process is also more economical in that it requires fewer steps and smaller quantities of expensive materials. Heterojunction combines the advantages of crystalline silicon solar cells with the absorption

| | Standard mc-Si | Standard mono | Heterojunction |
|---|---|---|---|
| Module efficiency | 15.6 percent | 17.2 percent | 19.2 percent |
| Temperature coefficient | –0.46 percent/K | –0.43 percent/K | –0.2 percent/K |
| Cell cost per piece | $1.67 | $2.19 | $2.19 |
| Module manufacturing costs | $45/m$^2$ | $45/m$^2$ | $45/m$^2$ |
| 60-cell module price | $172 | $203 | $203 |
| Module lifetime in years | 25 | 25 | 40 |
| Area-related BOS costs | $62/m$^2$ | $62/m$^2$ | $62/m$^2$ |
| Power-related BOS costs | $260/kW | $260/kW | $260/kW |
| PID+LID 1st year | 3 percent | 3 percent | 0 percent |
| Long-term degradation | 0.35 percent/yr | 0.35 percent/yr | 0.1 percent |
| O&M costs per year | 2 percent of CAPEX | 2 percent of CAPEX | 2 percent of CAPEX |
| PR (excluding temp. effect) | 0.9 | 0.9 | 0.9 |
| Discount rate (WACC) | 4 percent | 4 percent | 4 percent |
| **Additional assumptions for cash flow calculations** | | | |
| Interest rate | 4 percent | 4 percent | 4 percent |
| Inflation rate | 2 percent | 2 percent | 2 percent |
| Energy value (discounted to year 0) | $0.15/kWh | $0.15/kWh | $0.15/kWh |

Credit: Courtesy Meyer Burger, data source 2014

and passivation characteristics of amorphous silicon used in thin film technology. The excellent surface passivation of the a-Si:H layers results in efficiencies that exceed many other products – 327 Watts in a standard 60-cell module.

## Finer lines / better performance

While developing their core Heterojunction process, Meyer Burger also looked at ways to change the way PC cells collect energy. Busbars have been and remain a standard collection architecture used in many cell types. But heavy silver busbars and soldered connection points that have proven fragile over time prodded R&D initiatives to conserve silver, cut costs and improve electricity collection.

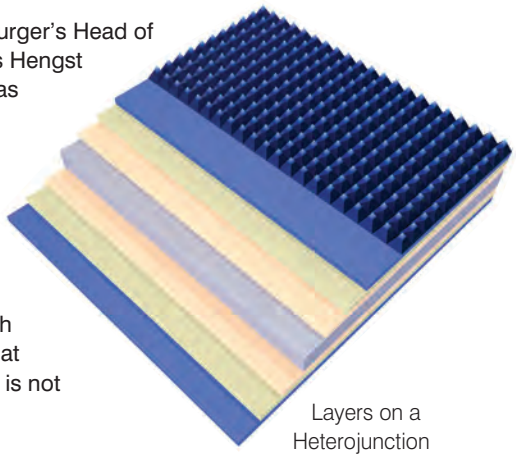
In comparison to conventional busbar cell design approaches, Meyer Burger's SmartWire Connection Technology (SWCT) uses less silver. How much less? Less than 2.4gr of silver per 60 cell module, and in the process Meyer Burger's approach (SWCT + HJT) can boost energy collection up to 5.7 percent compared to a 3 busbar cell.

In SWCT, making channel current connections is accomplished when silicon layers are encapsulated by lamination. SWCT utilizes a dense contact matrix of up to 2,660 points on each cell compared to the 165 contacts in a typical three busbar cell. While heavy busbars and thicker conventional silver 'fingers' need to be fired and soldered at high temperature, thinner SWCT fingers adhere through lower temperature processes, again saving materials and energy. SWCT fingers are electrically connected in a close grid, creating superior contact adhesion which helps prevent micro-cracks and cell breaks. Heterojunction cells using SmartWire are also less susceptible to transportation and installation damage. These cells don't require the heavy metal support framing associated with traditional solar panel modules, which again reduces cost and prolongs the lifetime of PV cells and modules.

Saving silver and other materials means saving money. Meyer Burger's approach can reduce silver consumption to <2.4gr per 60 cell module. As a further bonus, SmartWire Connection technology is compatible with all silicon PV cell technologies including next-generation finger metallization techniques, and of course, Meyer Burger's own Heterojunction architecture.

## In the field / on the roof

While comparative product analyses demonstrates real performance advantages when Heterojunction architecture is paired with SWCT energy collection technology, the ultimate test is how these new technologies perform in the field. Meyer Burger's Head of Customer Relations, Thomas Hengst and Product Manager Thomas Helbig are on the front lines.



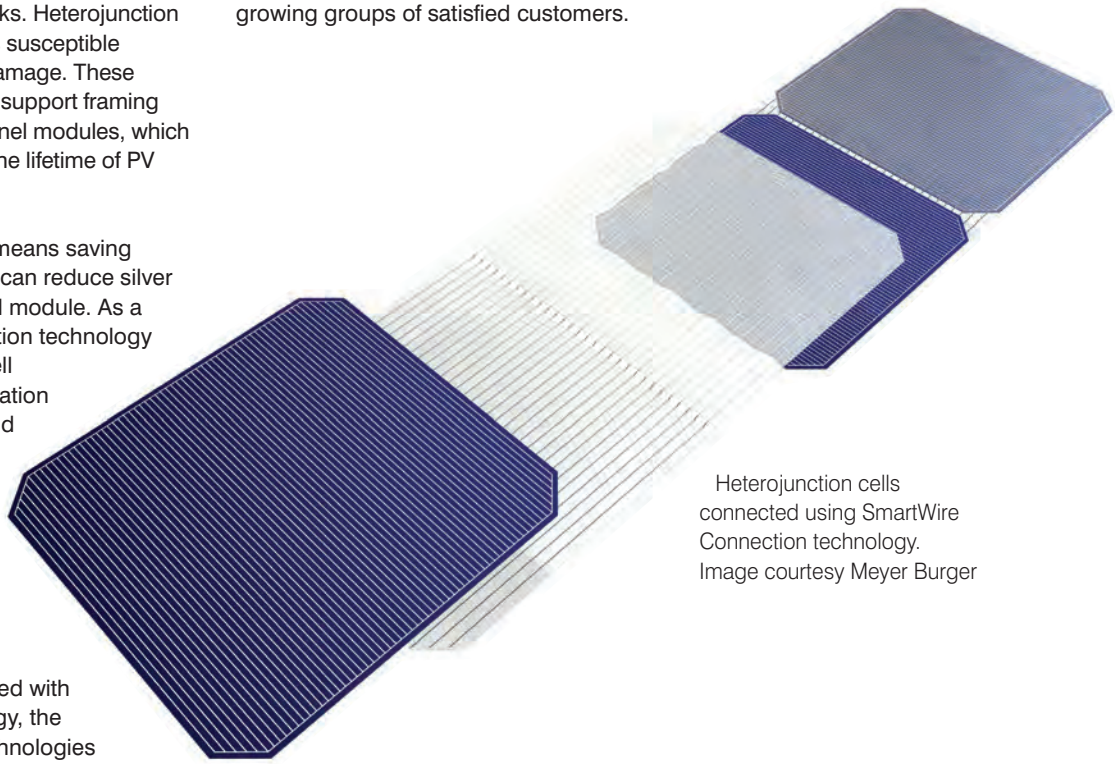
Layers on a Heterojunction cell. Image courtesy Meyer Burger

"Our approach from the beginning was to make the new technologies competitive and at a price that can be a new industry standard," said Hengst. "High efficiency is important, but that means little if the technology is not competitively priced.

Most company's talk about their product in terms of very large scales that are not meaningful in residential or small commercial applications. Meyer Burger's technology definitely competes at all levels and is also appealing in larger projects."

Another area that differentiates Meyer Burger's approach is in-field testing. According to Hengst the efficiency figures the company offers have been proven outside tightly controlled laboratory settings; making sure manufacturable product performance is comparable to R&D results – it's a hallmark of their overall programs.

Like Hengst, Thomas Helbig has been with Meyer Burger for a lengthy tenure. Both have seen Heterojunction and SmartWire Connection technologies mature to the point that competitiveness and performance are winning over customers. Hengst and Helbig believe this will translate into growing groups of satisfied customers.



Heterojunction cells connected using SmartWire Connection technology. Image courtesy Meyer Burger

> “Meyer Burger is again demonstrating that evolving core technologies and creating new PV processes will drive successful solar power development. With Heterojunction cell architecture and SmartWire Connection Technology, the choices of how to generate electricity from the sun keep getting better and better.”

“Balance of system costs account for around 50 percent of total PV installation expense. Thanks to significantly higher efficiencies with HJT/SWCT modules, the BOS advantage is about 11 percent,” noted Helbig. “The durability and reliability of SmartWire Connection technology offers the best protection against environmental influences.

Our tests have shown a lifespan of more than 40 years, which is far superior to other cell types. It’s a new technology, a new approach, so we understand the public will need to learn about its benefits. But the more they know, the more they’ll want Heterojunction and SmartWire. It will become one of the future standards for PV cells.”

## Made for the real world

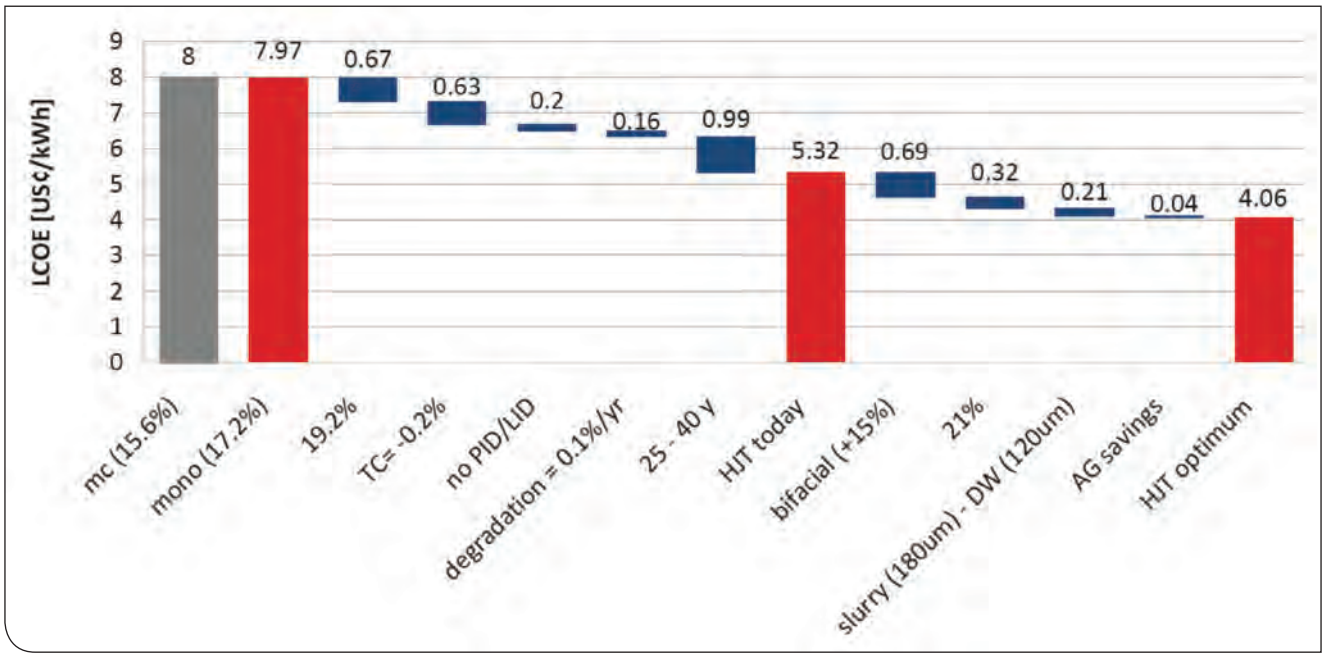
Many technologies will play important roles as photovoltaic energy helps reshape the world’s ability to cleanly and economically meet growing electricity requirements. Solar’s contribution to reducing global warming is also well established.

Heterojunction and SmartWire Connection technologies are appealing thanks to their high efficiency, simplified production, robust performance and longer lifetimes.

Meyer Burger is again demonstrating that evolving core technologies and creating new processes will drive successful solar power development.

With Heterojunction cell architecture and SmartWire Connection Technology, the choices of how to generate electricity from the sun keep getting better and better.

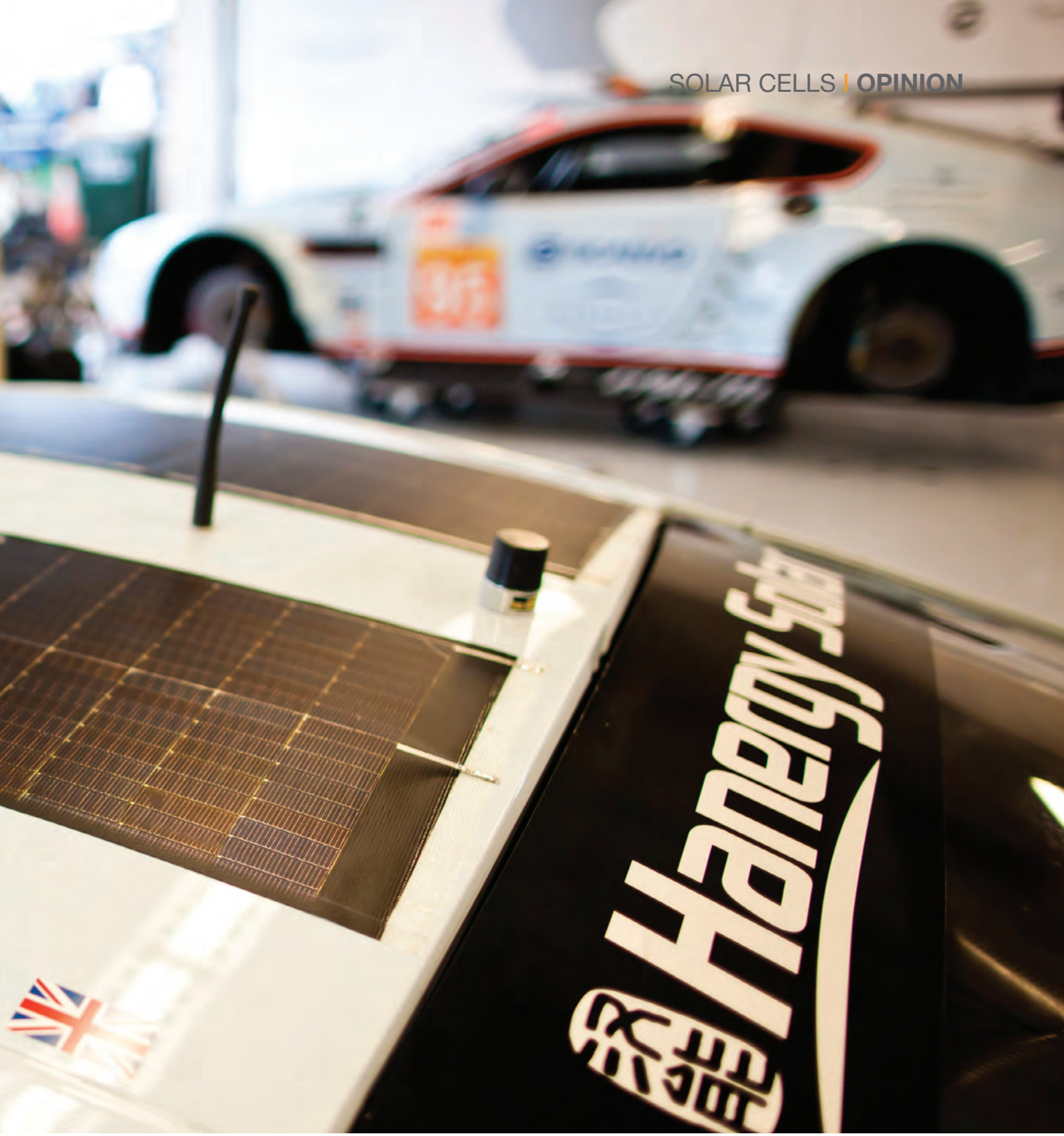





Credit: Courtesy Meyer Burger, data source 2014


# Uncovering new opportunities for III-V cells

Terrestrial opportunities for III-V cells are not limited to concentrating photovoltaics: These devices can also form flexible, efficient power sources for unmanned aircraft, smartphones, tablets and automobiles. By Robert Parenti from Alta Devices

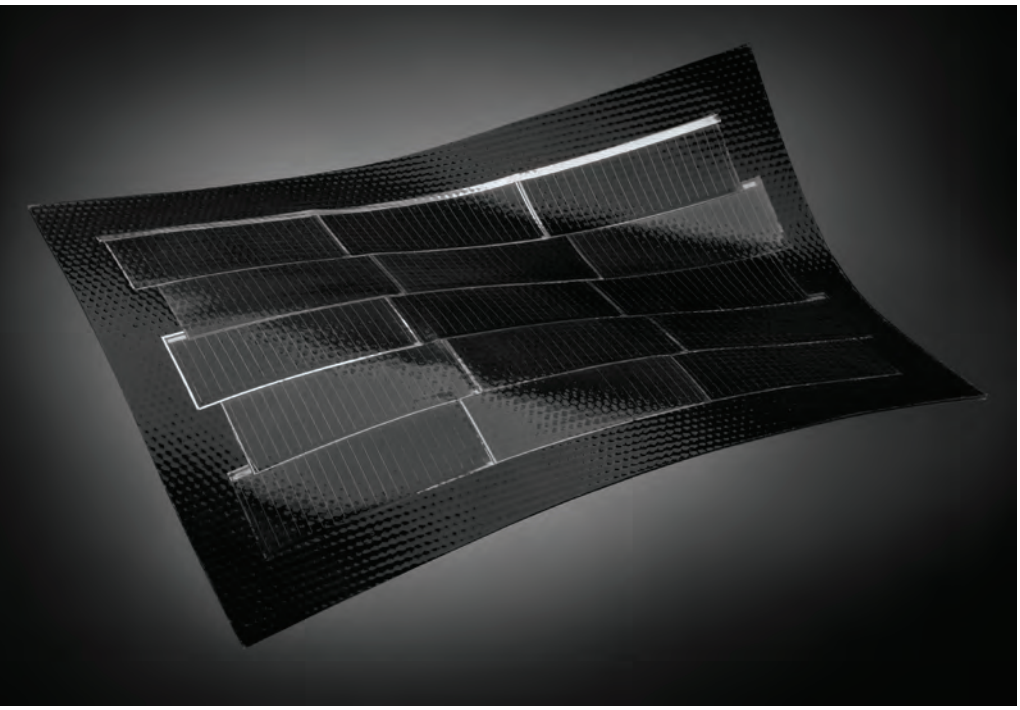



When Neil Armstrong took his first steps on the moon on July 20, 1969, the Cold War Space Race came to an end.

That most famous of days of the twentieth century was a high point for the US, which had been battling with Russia since the 1950s to be the leading force in space exploration. The communist superpower drew first blood, thanks to its successful launch of the first two satellites, Sputnik 1 and 2, but it didn't stay ahead for long. Five months later the US fought back with the launch of Explorer 1, before breaking new ground on 17 March 1958 with the launch of Vanguard 1 – the first satellite to be powered by solar cells.

This satellite, which is still orbiting the world today, features cells made from silicon. It is this form of solar technology that has been used on many of the proceeding satellites – but its ascendancy has not lasted to today, due to the development of the GaAs and III-V solar cells in 1970 by Zhores Alferov from the Ioffe Physico-Technical Institute of the USSR Academy of Sciences.

These compound semiconductor cells are superior to those based on silicon, by being more robust to moisture, radiation, and ultraviolet light; boasting the highest efficiencies (solar-to-mechanical energy); and exhibiting



extremely low degradation with temperature increases.

Thanks to these strengths, by 1990 GaAs had surpassed silicon as the most widely adopted solar technology in space, and today single and multi-junction III-V solar panels are considered the industry standard.
That is not to say, however, that III-V cells are faultless. Weaknesses include being rigid, heavy and limited in size, and having wafer costs around two hundred times those of silicon. The latter impediment has restricted their use to government-funded projects, mainly in space. But what would be possible if GaAs cells were cheap, lightweight, flexible, and durable – and delivered all these attributes while maintaining a high efficiency?

At Alta Devices of Sunnyvale, California, we are working on turning this vision into a reality. The mission of our company, which was founded in 2008 by academics Harry Atwater of Caltech and Eli Yablonovitch of the University of California, Berkeley, is to bring mobile power to the masses. To succeed in this endeavor we have developed a process that allows us to grow and separate thin films of GaAs from the top of single crystal wafers, which can be reused, thereby slashing substrate costs. Another strength of this process is the high efficiencies that can be realized – in 2011 we propelled the single-junction solar cell efficiency record to 28.8 percent. This is close to the theoretical limit, and surpasses the best silicon solar cells, which can offer an efficiency of up to 25 percent.

On top of this efficiency benefit, GaAs thin-film cells deliver additional advantages: They weigh less, and because they are flexible, they can wrap around curved surfaces.

Simply looking at the efficiency figures fails to provide a full appreciation of the superiority of GaAs cells over those made from silicon. Due to the higher bandgap of GaAs, electrons generated in the photovoltaic process are excited to higher energies, enabling higher aerial power densities. What's more, cells made from this binary alloy convert light into energy across the entire visible and into the near infrared spectrum, making them suited to not only the outdoors, but also cloudy, low light, and even indoor applications. Although a handful of silicon-based materials can provide power indoors, their efficiencies are almost three times lower than those of GaAs.

Our claim of the superiority of GaAs over silicon is backed up by independent studies conducted by the National Renewable Energy Laboratory (NREL). This investigation revealed that our GaAs solar cells produced more energy than those made from silicon when operated under the same conditions – and when conditions changed, due to an increase in temperature, the reduction in performance was much smaller.

The strengths of solar cells made from thin films of GaAs and other III-V materials will allow them to operate in new markets, rather than fight for use in large solar panels that line roofs and traverse the Western deserts of the US. Thanks to their high aerial power densities, these materials can thrive within the relatively untouched mobile markets. Their inherent properties, which are particularly suited to providing power indoors, would allow them to win sales in automotive, unmanned aerial system, portable power, wearable, smart phone, tablet, and Internet of Things (IoT) markets. It should even be possible to extend the battery life of low-power IoT and wearable devices indefinitely, by coupling thin-film GaAs solar cells with the latest energy-harvesting chips.

Cutting the cord with mobile solar technology is not just a benefit to those in developed nations – it could also make a big difference to the lives of those living in the poorer nations of the world. Here, the demand for devices that connect to the internet is rising fastest. Last year alone, while web usage on mobile devices increased 25 percent globally, it shot up by 40 percent in Africa, despite the vast majority of those living there having limited access to electricity. Traditional power grids cannot keep pace with this rising demand, but this gap can be plugged by smarter and cleaner solutions, such as thin-film GaAs solar technologies.

Given the abundance of gallium and arsenic, which are relatively inexpensive to extract and obtain, there is no reason why there cannot be a world filled with GaAs solar cells. And their cost should not hold back sales, thanks to the manufacturing processes that we have developed for mass production of highly efficient thin-film cells. So following decades of development and deployment on satellites, the time has now come for GaAs solar cells to come back to earth with a splash.

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### FAST FACTS

- Solar power will dominate the world energy supply in just 15 years*
- The UAE is pushing forward over 1GW of PV with bids from Masdar and DEWA showing that there are significant opportunities for business.*
- Egypt now has a target to generate 20% of its energy from renewable sources by 2020. The country's leading solar production line will have an annual capacity of 4300 MW by 2017**
- In 2015, there were 154 exhibiting companies from the solar sector occupying a gross space of 7,200 square metres, with more than 6,500 solar industry professionals in attendance.

* Source: MESIA report ** Source: NREA (small solar systems / large solar and wind plants)

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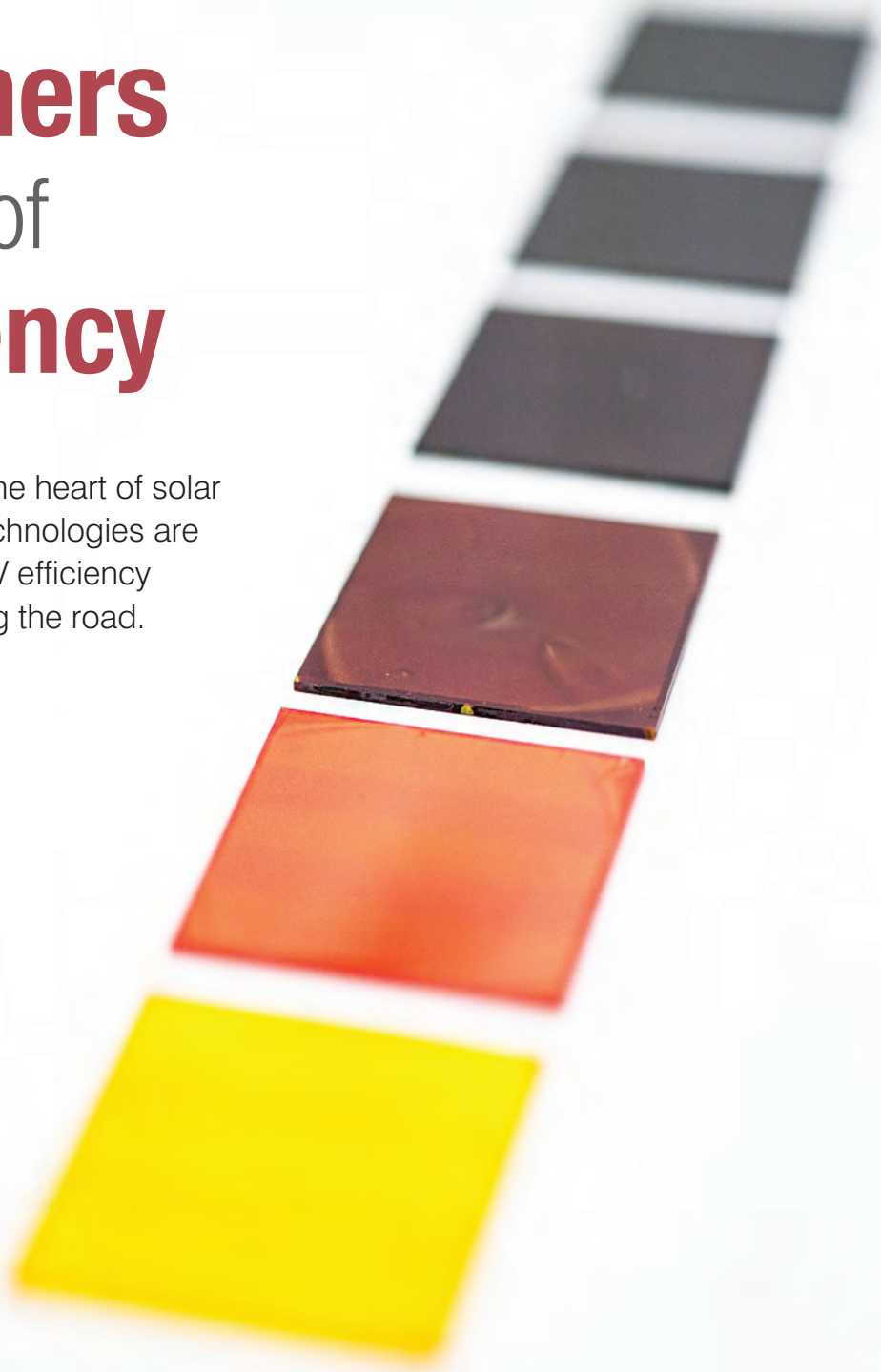
# Researchers push edges of PV efficiency



It's a particle. It's a wave. It's the heart of solar power. New processes and technologies are emerging that show today's PV efficiency standards are just a stop along the road.

While equality fires human aspiration, it's something that the physical world finds infrequently. Nature is amazingly complex, so when two things look alike or seem equal, they seldom are.

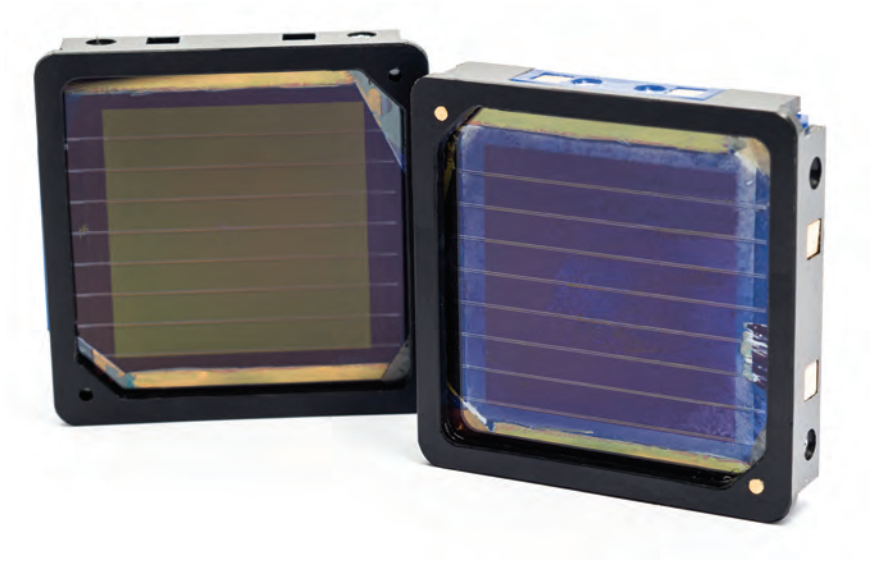
Consider light. It's a 'given' in daily living, but without it solar cells don't function. While one ray of light looks much like another, cell designers know all light is not equal or particularly useful when it comes to generating electricity.

A tiny portion of the entire spectrum drives today's thin film and silicon wafer photovoltaic technology. What if we could change that and find new ways to use wasted light?

Understanding how light reacts in the presence of different compounds is at the heart of new research to extend the efficiency of solar technologies. If that research can be taken from labs into manufacturing, efficiencies of 30 percent or more are possible in the near-term future.

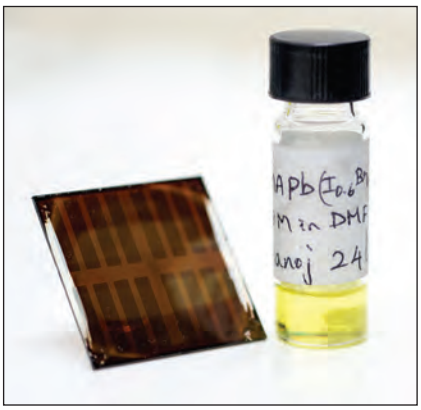
A wave of attention-grabbing thin film photovoltaic (TFPV) announcements were made in recent weeks, including news for leading nano electronics researcher imec concerning a perovskite technology breakthrough. Imec, in cooperation with the Solliance R&D partnership, announced in July that they had achieved an active area efficiency of nearly 12 percent. That's a long way from 30 percent. But what if you could add 12 percent to 20 percent (today's leading PV benchmark.) The combined numbers look fantastic.

Imec's latest achievements in perovskites can be applied to stand-alone applications such as building integrated photovoltaics (BIPV) or to complement existing silicon-based PV, boosting their efficiency to 30 percent or more. The advances in perovskite technology are impressive.



Nevertheless, a PV cell uses only a portion of the visible light photons it encounters. A new way to boost efficiency was announced in August at the 250th meeting of the American Chemical Society. Simplifying the very complex process as presented at the meeting, researchers showed they can change a portion of the spectrum—blue light—into different wavelengths that work with today's PV cells. While the discovery was complex, manufacturing the product is not only cost-effective, but downright simple according to leading researcher, Challa V. Kumar, Ph.D.

Kumar said his team found a way to use organic dyes inside a protein-lipid hydrogel to individually encase dye molecules that was densely packed enough and with the right quantum properties to be practical and useful.



The dyes act like colored lenses, converting photons in the 350 to 600nm range to the 600 to 1,000 nm wavelength—the 'sweet spot' where conventional PV cells readily convert light to electricity.

In other work that could benefit a variety of photovoltaic technologies including perovskites, researchers at the HZB Institute of Nano-architectures for Energy Conversion in Germany found that PV cell performance curves for both dark and open circuit voltage to be highly dependent on the silicon wafer's doping concentration. But unlike what they expected to find, the tiny microcircuit connections do not behave like a typical Schottky junction. In n-type silicon cells, the conductive organic layer behaves like a p-type semiconductor and not like a conductive metal.

The implications of the research point to new approaches for optimizing devices by tuning doping material interface properties.

In manufacturing research by the US Department of Energy, the SLAC National Accelerator Laboratory and Stanford University a new technique was discovered that could double the output of inexpensive polymer solar cells by using a microscopic 'rake' to apply light harvesting compounds.

Polymer-based photovoltaic products have many cost and manufacturing advantages compared to silicon wafer PV cells. But today's polymers are far inferior when it comes to usable electricity. Even though they can be applied onto many surfaces just like perovskites, they convert about 5 percent of the energy received vs. the 20-22 percent of today's best commercial silicon PV cells. The problem with polymers is in the manufacturing. Think of a viscous liquid binding two types of molecules that collect and store energy. In liquid form they tend to separate and dry into irregular, large clumps when applied using a small blade, which is today's manufacturing standard. The dried clumps dramatically reduces current generation performance.

Researchers discovered that by forcing the polymers through a slightly angled 'rake' of rigid, nano-scale bristles the large polymer molecules untangle and mix with each other, ultimately drying into tiny nanometer-sized crystals of uniform size and enhanced electrical properties. Everything else in the process stays the same, keeping costs low and manufacturing simple.

Solar technology is evolving rapidly. From advances in perovskites that boost efficiency, to tunable PC cells, to 'lenses' that enhance PV efficiency, all the way to new processes that makes polymers more productive, a future is being created in which photovoltaic technology not only contributes to the global power budget, but drives it.



Polymer-based photovoltaic products have many cost and manufacturing advantages compared to silicon wafer PV cells. But today's polymers are far inferior when it comes to usable electricity

solar awards 2015

# SHORTLIST 2015

The 7th Solar Industry Awards are announced and the shortlist represents products and innovations of excellence that have driven the industry forward.

## PV Materials Award

**3M**
Solar Encapsulant Film EVA9100 & EVA9110T

DuPont® Solamet™ photovoltaic metallization pastes

**SIKA**
SikaMelt - 9185 IA

**GR2L**
Argon recovery

## Turnkey Project Award

**Onyx Solar**
BIPV turnkey projects

**SolarWorld Americas**
Engineering, Procurement & Construction (EPC) for Large-Scale Solar Projects

## Project Development Award

**IBC SOLAR AG**
EnFa - The Energy Factory

Power Clouds INTERNATIONAL
Zero Emissions Initiative

**SAFT & Acciona Energia**
Eurogia + ILIS project

SOLARRESERVE®
The Letsatsi and Jasper Projects

## Turnkey Equipment Award

**Intevac, Inc**
Energi

**Schmid Group**
Geminus

**Singulus Stangl Solar GmbH**
Equipment for wet chemical processes for wafer fabrication

**Spire Solar Inc**
Turnkey PV line equipment

## PV Process Award

**crystalsol GmbH**
powder photovoltaic modules

**Luvata**
Sunwire

**MBJ Services GmbH**
Mobile PV-Testcenter 2.0

**www.solarinternationalawards.net**

## PV Tool Award

VCM Printing Technology

**Despatch Industries**
Safire firing furnace

microDICE OTF

**Meyer Burger Technology AG**
PCB Touch

## PV Balance of System Award

**NEXTracker**
Self-Powered Tracker (SPT)

Module Level Inverter System

RS1 - the ultimate clamp

**SunLink Corporation**
Ballasted GMS Foundation

## Energy Usage Enabling Award

**Columbus Group**
Clean water aquifer recharge & water harvesting

**KOSTAL Industrie Elektrik GmbH**
PIKO BA System Li

**SMA Solar Technology AG**
Sunny Boy 1.5/2.5

Solar thermal technology with integrated energy storage

## Integrated O&M / Solar Asset Management Award

**Alectris**

**First Solar Energy Services**

## Industry Development Award

**Meyer Burger Technology AG**
PCBTOUCH

**Panasonic Eco Solutions**
End-to-end solar solution

Solar thermal technology with integrated energy storage

**Trina Solar Limited**
Virtual Factory tour - PV Digital Transformation

## Module Manufacturing Innovation Award

**JinkoSolar Holding Co., Ltd**
Maxim Solution

**Panasonic Electric Works Europe**
N285

**Hanwha Q CELLS**
Q.PLUS-G4 270-280:

**REC Solar EMEA GmbH**
REC TwinPeak Series

## Rural Electrification Award

**Phocos AG**
Solar charge controllers and components

**PROINSO and OXIS Solar Centre**
Project Helios

Rural Electrification - Indonesia

**Steca Elektronik GmbH**
Steca Tarom MPPT 6000-M

Presentations will be on September 15 2015
Reichshof Hamburg - CURIO Collection by Hilton.

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# Putting CPV on rooftops

High-efficiency CPV could become a reality for rooftops by uniting microscale solar cells with a planar microtracking concentrator technology

BY Jared Price and Chris Giebink from the Pennsylvania State University and Xing Sheng and John Rogers from the University of Illinois at Urbana-Champaign.

PROSPECTS for concentrating photovoltaics (CPV) are at an all-time high. Driven by a maturing industry and increasing emphasis on the value of high efficiency, the global installed capacity of CPV is forecast to triple to 1 GW over the next five years.

None of this capacity, however, will be installed on rooftops, which is where a significant proportion of solar panels are being deployed by the broader PV industry. Amidst this growing trend toward decentralized power generation, the conspicuous absence of rooftop CPV begs the question: Is CPV missing an opportunity?

Creating a viable CPV technology for rooftops is not trivial because it requires overcoming both practical and aesthetic challenges. While standard PV panels are compact and can mount flush with the roof, CPV modules are traditionally bulky, requiring a precision tracking system to orient each module toward the sun throughout the day. These aspects are not problematic for ground-mounted systems where there is ample space to move and prevent shading. But on rooftops they are a non-starter: Space and structural support are limited, and there is a need to preserve aesthetic appeal, because few of us would want to have the equivalent of an array of mini satellite television dishes scattered across our roof.

A radically different CPV architecture is therefore needed, which must deliver the efficiency of a traditional system, but do so in the form factor of standard, fixed-panel PV.

Our team at Penn State University and the University of Illinois at Urbana-Champaign is making progress on this front by combining a translation-based tracking technology with microscale photovoltaic cells embedded inside the concentrator optic itself. The result is a quasi-static CPV panel less than 1 cm-thick that operates at fixed tilt with an imperceptible amount of movement. Over the course of a sunny day, such a panel could deliver 50 percent more energy than a state-of-the-art silicon equivalent.

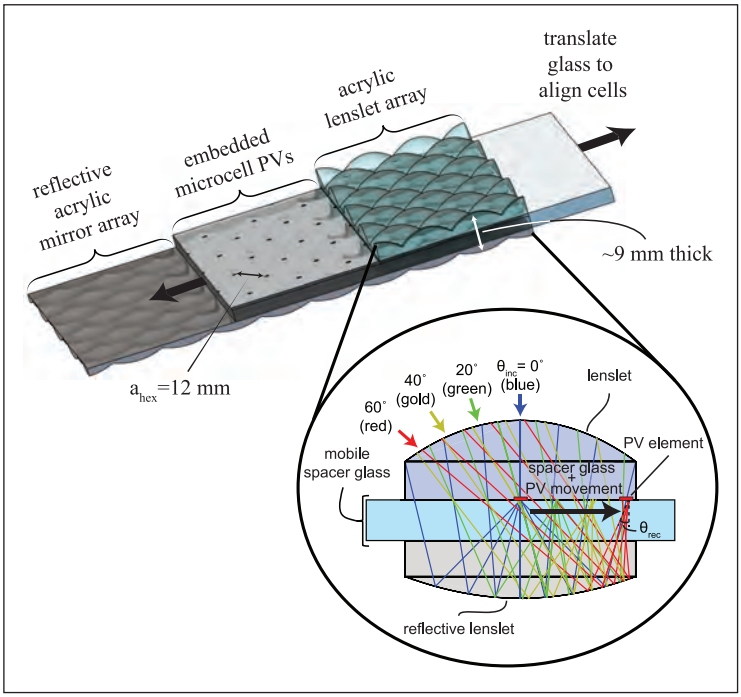


Figure 1. Moving the cells relative to the lens ensures that sunlight is concentrated on the device throughout the day.

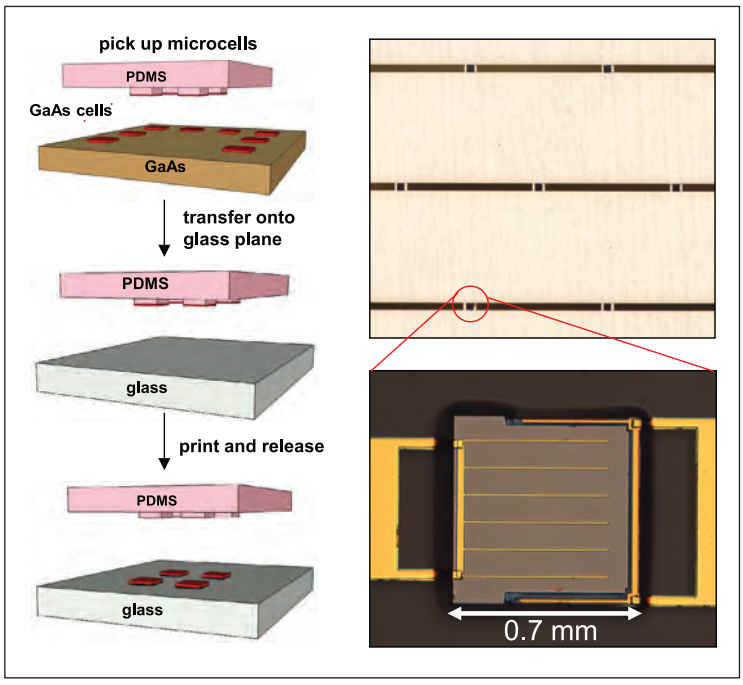


Figure 2. The transfer-printing process that is used to produce microcell arrays has a very high throughput

## Embedded microtracking

To accomplish solar tracking without reorienting the panel, we have adopted a planar translation-based approach, with optics that remain fixed while PV cells slide laterally to follow the moving focal spot (see Figure 1).

This type of design is not a new idea. The performance of various forms of translational tracking have been explored before, but their utility has been limited by image field curvature, which degrades the focal spot in the solar cell plane for light incident at oblique angles beyond about 20°. This is a substantial drawback, because a latitude-tilted panel sees sunlight incident at angles of up to 60° over the course of 8 hours. Consequently, previous translational tracking schemes could only operate efficiently for a few hours each day.

We resolved this problem by adopting a folded optical path. With this configuration, light is refracted by a top lenslet, reflected by a bottom lenslet and finally focused on an intermediate plane – a sheet of glass patterned with a corresponding array of solar cells. The interfaces between this plane and those of the top and bottom lenslet arrays are lubricated by optical oil, which also serves to eliminate parasitic reflections.

Tracking is achieved by sliding the middle solar cell sheet laterally. Sunlight is focussed on cells that have an area of less than 1 mm$^2$, enabling the size of the associated lenslets and the thickness of the overall concentrator stack to be kept small. By employing this design, cells are embedded in a 'microtracking' panel that can accept light over a 120° full field of view, which corresponds to operation for more than 8 hours per day. Incoming radiation is focused by a factor of more than 200, and daily average optical losses are kept below 15 percent.

## Microscale cells

The benefits of the microcells are more than just enabling a compact panel. Thanks to their small size, the power delivered to each of these cells is orders-of-magnitude lower than that impinging on a conventional CPV cell, which is typically around 1 cm$^2$ in size. This simplifies thermal management to such an extent that, according to our work and that of others, the cell does not require active cooling.

Another advantage of working with microcells is that they have a lower series resistive loss. This leads to a more robust performance when the cell faces the inherent illumination non-uniformity of the microtracking concentrator focal spot.

Our fabrication of the microcell sheet begins with the growth of the device structure on a GaAs substrate

by MOCVD. Inserted between the device stack and the substrate is a lattice-matched AlGaAs sacrificial layer, which is removed by wet etching to separate the cells from the substrate.

The resulting chips, which are only a few micrometers thick, are picked up with a soft elastomeric stamp and placed precisely on a glass (sliding middle sheet) substrate with a high-throughput process, known as micro-transfer printing. This process can print millions of cells per hour with a yield exceeding 99.5 percent while producing micrometre-scale placement accuracy (see Figure 2). Following transfer of the cells, metal interconnects are deposited to create a network that optimizes the power produced by the module.

We evaluated our microtracking design by fabricating a small-scale prototype incorporating seven, series-connected GaAs microcells. These were sandwiched between a pair of custom, 3D-printed, plastic lenslet arrays made by our collaborators at LUXeXcel, Inc.

Testing involved measurements in the lab, and then outdoors during several sunny days in central Pennsylvania, where the panels were held at a fixed tilt (see Figure 3). Despite a relatively large surface-form-error in the printed lenslets, for over 6 hours we could maintain a factor of 100-150 increase in the short-circuit current compared to that of an adjacent bare cell. Turning to commercial off-the-shelf planoconvex glass lenses improved the concentration factor to 200 suns and extended the operating time to 8 hours.

Taken together, these initial results have validated the basic microtracking concept and set the stage for testing at a larger scale. When this is carried out, we will improve the concentrator performance by optimizing the lenslet optics for higher concentration and by applying an anti-reflection coating to improve their optical efficiency.

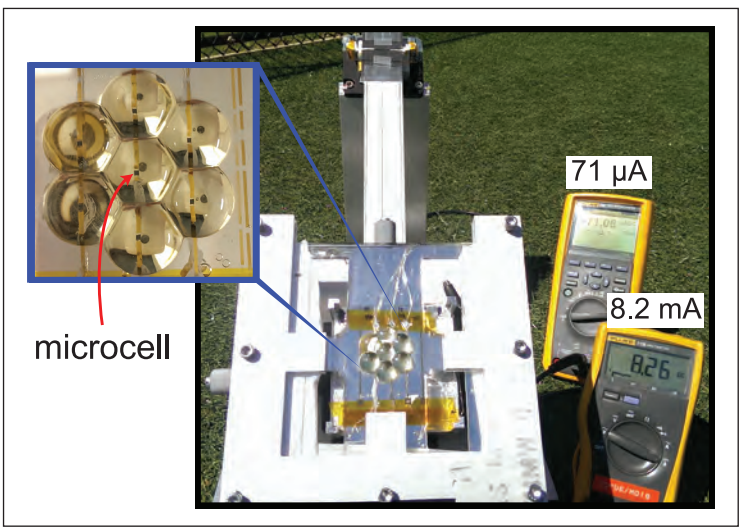


Figure 3. Outdoor testing of a small-scale prototype using three-dimensional-printed lenslet arrays.

## To higher efficiencies

In addition to improving the optical performance of our concentrator system, we are also pursuing ultra-high efficiency cells by moving to quadruple junction, four-terminal devices. By transfer-printing different sub-cells on top of one another, we avoid the current- and lattice-matching issues that have challenged monolithic four-junction cells to date. This approach expands the range of feasible sub-cell materials and opens up the possibility of increasing the number of junctions to five or more.

We have used transfer printing to combine a InGaP/GaAs/InGaAsNSb top cell with a germanium

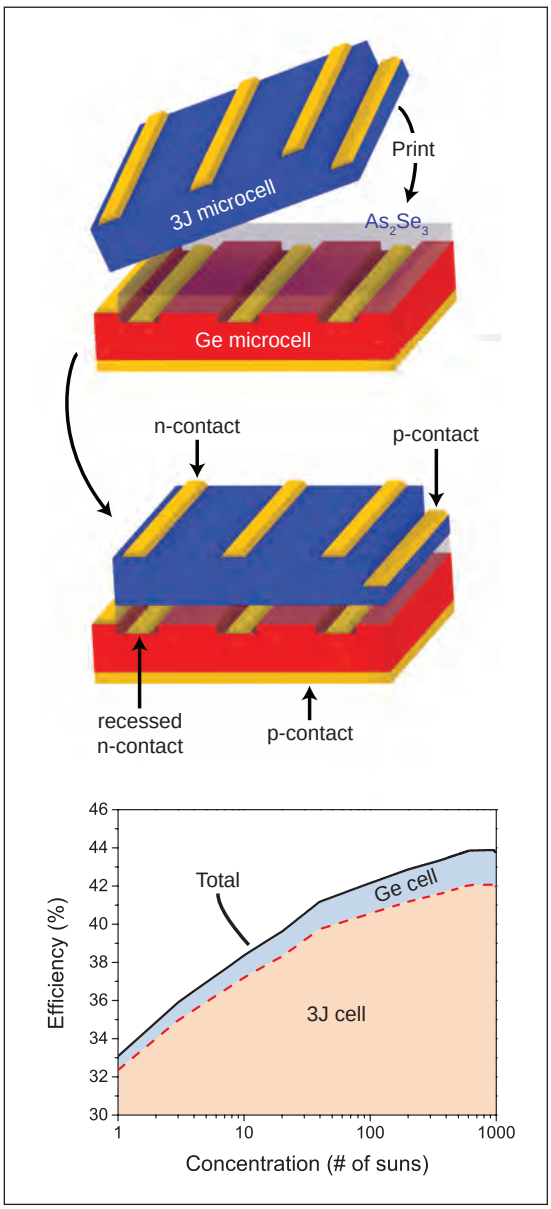


Figure 4. A mechanical assembly approach can create four-junction microcells that deliver a higher efficiency than their triple-junction predecessors at a range of concentrations.

bottom cell. The resulting four-junction photovoltaic delivers a total efficiency of 44 percent at 1000 suns (see Figure 4). Extrapolating our concentrator performance together with these high efficiency cells suggests that a microtracking CPV panel could deliver 50 percent more energy over the course of a sunny day than a state-of-the-art silicon module of equivalent size.

Delivering high-performance is no guarantee of success for rooftop CPV – modules will also have to deliver long-term operational reliability, while retailing for a price that makes them competitive with existing PV panels. It is likely that the key to reliability will be environmentally-robust plastic or glass lenslet arrays, since all the cells, moving interfaces and lubricating oil are sealed and protected within the concentrator stack. Making meaningful cost projections at such an early development stage is tricky, but the combination of wafer recycling, high-throughput transfer printing and inexpensive injection-moulded optics indicates that the ingredients are there for a low-cost system.

It is important to emphasize that microtracking CPV complements – rather than competes with – conventional CPV. The latter is ideal in applications where space and movement are not constrained, while our microtracking approach opens up an opportunity to deliver a step-change in the efficiency in constrained-space rooftop and urban installations. This expands the number of markets that CPV can serve, and we hope that it will accelerate the broader adoption of this technology.



**Further reading**

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ees electrical energy storage

POWER CLOUDS was founded in Singapore in 2013. Since its inception, the company has pursued an aggressive growth plan to bring a utility-scale photovoltaic (PV) installation online in Romania, with an additional plant under construction in Japan that is set to begin operating in the fall of 2015.

The company CEO, Roberto Forlani, recently spoke with 'Solar International' and described his vision for brining utility-scale PV installations to communities that are looking for ways to 'go green' while meeting long-term power requirements. Power Clouds was recently acquired by a US-based World Assurance Group Inc company and has offices in Miami (Florida); Tokyo; and Bucharest (Romania). It plans to open a new office in Dubai, where the company is consolidating relationships with local communities that share an emerging view in the Middle East that despite vast oil reserves, long-term economic progress and environmental responsibility will belong to power generation technologies that are non-polluting and independent of finite fossil fuels. Solar International interviewed the Company CEO, Roberto Forlani.

# Utility-scale PV company eyes **global opportunities**

Photovoltaic developer Power Clouds has set its sights on growth in Europe, the Mideast, Asia and the U.S. 'Solar+Power Management' talks with CEO Roberto Forlani about the company's growth and market approach.

**Q** Mr. Forlani, in two years you have made giant strides. How can Power Clouds be defined today?

**A** Power Clouds is a global green energy company and we continue to identify and develop renewable energy projects worldwide. We identify optimum locations for our solar plants and then develop each project from concept through the construction phase, and then operate them over the long-term. With operating plants in Romania and activities in Japan and other locations around the world, the company has a core team of experts and project managers who operate at the international level. A few weeks ago our team was joined by a new CFO, Vincent Browne. Vincent has been a senior level executive with extensive experience with U.S. public companies in both operational and financial management roles. He enhances our management team as we continue to grow the business around the world.

**Q** What makes the success of Power Clouds unique are the numbers of people involved in the project of shared facilities. How is it possible to participate in the project?

**A** The success of Power Clouds is the result tens of thousands of people across the world who share common values, dreams and ambitions that put these values and aspirations into practice through a business plan. Power Clouds allows people of all walks of life to participate in and generate the savings created by solar power without having to (personally) install expensive and clumsy systems in their own homes or offices.

Instead, they buy an actual 'photovoltaic power unit' (panel) that is then installed in a utility scale solar park owned and operated by Power Clouds. This way they can participate in the long-term value created without the disruption to their lives of

> “More and more people in the world feel the need to
> of consumption and management of energy, just as with
> proposing a model of energy development, on a world-wid

personally buying panels, installing them or taking a sizeable risk with their capital. In effect, it is like storing your data in the Cloud, only for solar power instead.

**Q** In the past, you have said that a just and sustainable energy model can be created through the direct involvement of people. Do you remain convinced of this?

**A** More and more people in the world feel the need to contribute on a personal basis to the changing patterns of consumption and management of energy, just as with water or mobility. Power Clouds is going in this direction, proposing a model of energy development, on a world-wide scale, based on the concept of the sharing economy. Namely, an economy where individual citizens can personally contribute to the production and distribution of electrical energy and enjoy economic returns as a dividend based on their investment level.

**Q** You now have operational plants in Romania and another under construction in Japan. How do you choose the countries in which to operate?

**A** We choose them by considering a mix of parameters, not only economic ones. After assessing the selling price of the energy produced in the country, we calculate certain technical parameters such as energy transmission and construction costs; we evaluate fiscal and administrative parameters, but above all we analyze the socio-political stability, and the respect for human rights and levels of corruption in the country. If all these elements are favorable for us, at this point the dialogue with local developers, or directly with government agencies, begins.

**Q** Could a country also apply to accommodate your plants?

**A** Yes, and in fact it is increasingly the case that we are contacted directly by the territories interested in accommodating us. This is definitely a positive sign for us, one that attests to the quality and appeal of our projects.

**Q** Can you tell us a little more about the experience under way in Japan?

**A** We arrived in Japan at a point that there was an ongoing change in the national energy system. After the tragic events of Fukushima, the country debated the need for a change of course and, with great courage, has chosen to implement a gradual abandonment of nuclear power in favour of renewable sources.

The first plant is expected to be inaugurated in the autumn in Otaru, and we will take this opportunity to invite 200 people from different countries around the world to participate in a new Power Clouds Experience modeled after that of Nucet in Romania. These events have become a fixed point for us, and ones that we value greatly, because it allows us to meet the participants of the project in person, and to share with them the excitement of yet another goal achieved.

> contribute on a personal basis to the changing patterns water or mobility. Power Clouds is going in this direction, e scale, based on the concept of the sharing economy"

**Q** The Company now has offices in markets that are important for the industry such as the US and plans for the UAE ... ?

**A** Certainly. The branch based in the US in Miami has a dual function: it is the headquarters of the public company (name?), that we expect will open up greater opportunities to attract capital to develop larger projects than those carried out to date, and the other is related to our entry into the United States solar market as a whole. Dubai was chosen in view of the great sensitivity of the Arab countries towards the renewable energy market and, consequently, of the many business opportunities that may arise there.

**Q** This international approach has also led to you being members of the Global Compact of the United Nations. A fascinating challenge?

Definitely a prestigious position for us that we approach with our heads held high. In late July, we presented our Communication On Progress to the United Nations, in which we describe our daily commitment to comply with the ten principles of the Global Compact - the international initiative that includes companies most committed to sustainability issues and to Corporate Social Responsibility. These Principles embrace the areas of Human Rights, Anti-Corruption, the Environment and Labour.

**Q** Finally, you have just announced the creation of the Zero Emissions Initiative. What is that about?

**A** It's a project fully in line with our core mission. Here too, it's a matter of financing the construction of new solar power plants. Only this time the protagonists of the business model will be the companies that want to offset the CO2 emissions generated by their products through plants based on renewable resources that we're planning to build. All these companies, as well as making a green gesture, will also get certification that their products or services are compensated for under the initiative. The certification is issued after our assessment of environmental impact, based on the highest international standards in the industry.



# PeerEnergyCloud PROJECT

A project funded by the German Federal Ministry for Economy and Technology has provided insight to how energy companies and their customers benefit from combining data analytics from smart home and smart meter technologies with residential solar energy production.

IN EUROPE, the tables are beginning to turn on fossil fuels. Renewable sources of energy, such as solar panels, wind turbines and hydroelectricity have become increasingly popular over the past 40 years and are slowly replacing the oil, coal and gas that powered our lives for so long. With governments under pressure to deliver sustainable energy at a good price, renewable energy has become a key part of many national energy policies.

This is particularly true for Germany. A country famed for its progressive environmental policies, Germany is the world's leading producer of photovoltaic energy (38.2 GW cumulative installed capacity). The solar trend is powered by the easy availability of panels which people can install on their homes, and the unobtrusive nature of the panels themselves – unlike other renewable sources which are dependent on specific geographic features and are disruptive to their surroundings. Germany is unique in its high density of privately owned solar panels, which facilitated the project. Another attractive quality of solar panels is their ability to scale – you can quite easily buy a solar panel privately and install it on your roof, but equally they have the potential for large-scale installation. German farmers often make extra money by renting out their field to a solar farm, and big companies are investing in solar. Furthermore, the solar industry in Germany is something that is expected to continue growing as traditional energy sources such as nuclear are phased out.

However, producing your own energy has a big impact. As communities transition from consumer to producer there is a considerable amount of energy flowing back into the grid. This new dynamic has meant that the amount of energy in the grid at any one time is completely unpredictable. The original grid infrastructure was designed to handle energy coming from outside, supplied regularly. Energy companies, often faced with far too much or far too little energy, were forced to 'throw away' or sell excess energy, or explore the stock market for expensive solutions when there isn't enough to meet the demand. This is inconvenient and regarded as a waste of time and money. It was clear that they needed better ways of learning in real time how demand might be changing and what should be the best response. This is where IoT comes in.

The German Federal government recognised early on the need to develop smarter forecasting methods and chose AGT International to provide the analytics involved in an intuitive Smart Grid solution. AGT has a proven track record of innovating with IoT analytics technologies and runs a major research and development centre in IoT analytics in Darmstadt near Frankfurt.

## Collecting the data

Saarlouis is a small German town bordering France, where the German Federal government funded the €4.8million PeerEnergyCloud (PEC) project to establish a more efficient and intelligent energy service for almost 40,000 residents. Saarlouis, with its self-contained energy grid, was the perfect place for the project.

AGT International has provided the advanced analytics capable of collecting and analysing the deluge of data from the Internet of Things (IoT) sensors and devices installed in every room in participating households. This has provided a pilot on analysing very detailed energy consumption behaviours to give power companies greater, real-time visibility of the demand on its service.

For three years, 50 houses in Saarlouis were fitted with smart devices on all of their power outlets to measure patterns of voltage and power consumption. This data was shared back into AGT's wireless network every two seconds, providing considerably more information to the utility company than the one data-point typically collected each year when customers' meters are physically read. This high frequency of data input gave greater visibility into household behaviour and allowed AGT to conduct comprehensive predictive analysis. A system that only works with aggregated or average data will not allow this to happen as accurately.

Solar installations in Saarlouis were part of the study. The analytics provided by AGT help to predict both power consumption and production, providing a modern solution

that is specifically tailored to handle the unpredictable influx of information that renewable energy produces.

The data collected and analysed by AGT technology was able to identify anomalies in energy consumption while the customer-facing dashboard allowed homeowners to recognise whether a device was faulty or using too much energy, ultimately saving both parties money. It also gave the homeowner the power to choose how much data they shared at any given time, protecting their privacy if they felt uncomfortable about sharing too much of their daily power consumption room by room.

The IoT analytics were also used for maintenance purposes. Data patterns were tracked to help spot issues early on, and therefore helped prevent failures in solar panel installations. This is crucial when often the failure of one panel can prevent the entire array from working. Analytics systems can act as an early indicator of what is needed before it fails, crucial to preventing blackouts and energy surges which can have a detrimental impact on the resident.

Another benefit of the AGT approach was how the data was analysed 'on the edge' – at the device, or very close to it. Some actions need to be taken in real time because they cannot tolerate any delay between the sensor-registered event and the reaction to that event. This is extremely true of industrial control systems when sometimes there is no time to transmit the data to a remote cloud. This distributed model was used to great effect in Saarlouis to ensure that all data was harnessed and distributed quickly and efficiently.

## Making changes and moving forward

As part of the PeerEnergyCloud project, AGT was able to gain a much deeper understanding of how analytics can help to predict power supplies and use them to the best effect. This meant that the energy providers were able to monitor and accurately distribute the right amount of energy in the grid – making everything work more efficiently and economically. Alongside this, the use of cloud technology in conjunction with smart home sensors and monitoring of residential solar power panels tested the feasibility of collecting and analysing higher volumes of energy consumption and supply data on a regular basis. This means moving from the collection of tens of thousands of data values from today's smart meters to potential hundreds of millions of data values when newer sensor data is accessed and analysed.

Data privacy was an important issue for the residents, so throughout the PeerEnergyCloud project focused on ensuring that encryption protocols matched up to German privacy laws and maintaining an open dialogue with participants. This fostered a community of satisfied and well-informed residents.

The project has been so successful that since it ended in 2014 the AGT platform has remained within the community, capturing data and feeding into the analytics dashboard used by customers and the local power companies. Gadi Lenz, Chief Scientist at AGT International commented: "This was a fantastic opportunity for AGT to provide the analytics required to make this project possible. Implementing a Smart Grid to support energy efficiency and cost reduction has benefited Saarlouis enormously and we look forward to repeating this project elsewhere and replicating the positive results."

## Next steps?

AGT recently announced that it is participating in one of the European Union's Horizon 2020 Lighthouse Projects. AGT will be working with the German city of Cologne on a five year project to demonstrate how European cities can grow and become "smarter" through technology. Cologne is one of three European cities, alongside Stockholm and Barcelona, to be chosen for the EU GrowSmarter scheme to accelerate the development of sustainable cities. The project aims to achieve a 60 percent saving in primary energy consumption costs, a similar reduction in emissions from buildings and traffic and increase the proportion of renewable energy supply to 60 per cent by 2020.

AGT will be providing the project with advanced analytics to support the building and running of low energy neighbourhoods, integrated infrastructures for waste and energy and sustainable mobility including smart traffic management and electric vehicles. AGT's success as part of the PeerEnergyCloud commended them to the Lighthouse project, where they were up against 60 other companies for a place as partner.

AGT is also hoping, through the GrowSmarter initiative, to help support development of new battery technology to store the energy from solar panel installations. AGT will work together with the battery and panel vendors to harness the data collected from sensors and see how this can be used in improving solar array performance. The connected homes of Cologne will be the perfect place to fully realise the smart city dream that was first demonstrated in the PeerEnergyCloud project.



# New PV inverters for the UK market

Chinese inverter manufacturer targets industry UK with lightweight devices.

CHINESE PV INVERTER manufacturer Zeversolar are launching their Zeverlution series, on the UK market. With the new inverters, Zeversolar believes it has developed a cost-effective solution for investors and installers in the UK.

"The UK solar market has many uncertainties due to current announcements that the feed-in tariff will be cut and ROCs will be ending in April 2016," said Zeversolar's UK sales manager Michael Middlemast, adding: "As such, the market is unsure of the direction it is heading in and investors do not have confidence."

Zeversolar has adapted its product portfolio to meet the requirements of the UK market. During the market re-launch in 2014, the manufacturer saw strong interest from UK-based customers and has since been able to increase activities significantly, especially during the second half of 2014.

"We have seen that business models in the residential market space very well match our offer for investment-driven decision makers," said Middlemast, adding: "In the residential segment, the change from a subsidy-driven market model to a self-sustaining market model is present in many markets and the focus on increasing self-consumption has become more and more evident. However, the market should be better supported by the government until we achieve grid parity."

In addition to its collaboration with specialist dealers and general contractors, Zeversolar's focus in the UK is on project business, social housing, communities and investment companies. The company will offer its customers a complete product range for residential and commercial roofs and for large-scale PV power plants. In addition customers are supported by free training courses, webinars and design software.

## New string inverters for homeowners

With the new Zeverlution series, the Chinese manufacturer has now developed inverters combine high efficiency with extremely low weight and will come to the UK market in summer. The six new string inverters in the Zeverlution series have nominal powers of between 1.0 and 3.68 kilowatts. Here, Zeversolar uses a patented topology that halves efficiency losses. An additional semiconductor switch prevents the energy from shuttling back and forth between the line choke and the input capacitor. This is because the switches inside the inverter that regulate the flow of current between the input and output open and close at high clock speeds, which means that inverters are constantly fluctuating between feeding and not feeding, resulting in oscillations in the feed-in current and conversion losses. On the Zeverlution devices, the new pulsing and the additional switches now ensure that the current cannot flow back to the input capacitor during the freewheeling period, which reduces losses and thereby increases efficiency.

Because this design also calls for fewer power electronics components, reliability increases at the same time while the

weight is reduced considerably. At a maximum of 7.3 kilograms, the new devices only weigh half as much as their predecessors and can therefore be transported and installed very easily.

## Step-up converter for greater flexibility

In the Zeverlution 1000S, 1500S and 2000S devices, a step-up converter converts the input voltage generated by the PV modules to a higher output voltage. Consequently, fewer PV modules need to be switched in series, which increases flexibility in the system design. The inverters achieve efficiency ratings of up to 97 percent .

## Efficiency ratings of up to 98.7 percent

The two new Zeverlution 3000 SE and Zeverlution 3680SE devices, however, work without a step-up converter and attain efficiency ratings of up to 98.7 percent . To ensure that the design is flexible regardless, the inverters are compatible with smart modules and power optimizers (known as DC optimizers).

While the power optimizers are already integrated into the smart modules and replace the conventional socket, they can also be connected separately to any module. The power optimizers ensure that each PV module is working at its maximum power point (MPP) at all times. This prevents yield losses caused by partial shading, as individual shaded or defective modules do not affect the entire string.

## New inverter for commercial applications

In July, Zeversolar launched the Zeverlution Pro 33K inverter for commercial applications on the market. It has a nominal power of 33 kilowatts and a maximum efficiency rating of 98.5 percent , and weighs only 58 kilograms. The device has two independent MPP trackers and works in a wide MPP range and with a maximum input voltage of 1,000 volts. It begins to operate even at a very low start voltage of 250 volts, which further increases yield. The device


works using the Modbus RTU (remote terminal unit) communication protocol.

## Safety thanks to integrated protective devices

DC and AC overvoltage protection devices are already integrated into the new development. They ensure that damage to electrical and electronic devices due to excessive voltages is avoided. When under load, they create equipotential bonding between the connected conductors. This prevents voltage peaks from destroying the connected devices.

Because continuous measurement of insulation resistance (Riso) in operation is not possible in the case of transformerless inverters such as the Zeverlution Pro 33K, the resistance must be measured before each instance of connection to the grid and residual currents monitored during operation. This is particularly important in the case of inverters without galvanic isolation, as even a single short circuit can cause considerable damage. Finally, the electrical potentials are not separated from each other here, and only adequate insulation to ground prevents stray current from flowing out via ground. Consequently, a patented method of measuring insulation resistance is already integrated into the Zeverlution Pro 33K.

“Zeversolar offer investors and installers a cost-effective yet reliable solution. With our Zeverlution range, we hope to continue this trend and increase our installation base,” said Middlemast.

# Sol-gel capacitor dielectric offers record-high energy storage

Researchers have developed a new material that provides an electrical energy storage capacity with both a high energy density and power density.

USING A HYBRID silica sol-gel material and self-assembled monolayers of a common fatty acid, researchers have developed a new capacitor dielectric material that provides an electrical energy storage capacity rivalling certain batteries, with both a high energy density and high power density.

If the material can be scaled up from laboratory samples, devices made from it could surpass traditional electrolytic capacitors for applications in electromagnetic propulsion, electric vehicles and defibrillators. Capacitors often complement batteries in these applications because they can provide large amounts of current quickly.

The new material is composed of a silica sol-gel thin film containing polar groups linked to the silicon atoms and a nanoscale self-assembled monolayer of an octylphosphonic acid, which provides insulating properties. The bilayer structure blocks the injection of electrons into the sol-gel material, providing low leakage current, high breakdown strength and high energy extraction efficiency.

“Sol-gels with organic groups are well known and fatty acids such as phosphonic acids are well known,” noted Joseph Perry, a professor in the School of Chemistry and Biochemistry at the Georgia Institute of Technology. “But to the best of our knowledge, this is the first time these two types of materials have been combined into high-density energy storage devices.”
The research, supported by the Office of Naval Research and the Air Force Office of Scientific Research, was reported July in the journal Advanced Energy Materials.

The need for efficient, high-performance materials for electrical energy storage has been growing along with the ever-increasing demand for electrical energy in mobile applications. Dielectric materials can provide fast charge and discharge response, high energy storage, and power conditioning for defense, medical and commercial applications. But it has been challenging to find a single dielectric material able to maximize permittivity, breakdown strength, energy density and energy extraction efficiency.

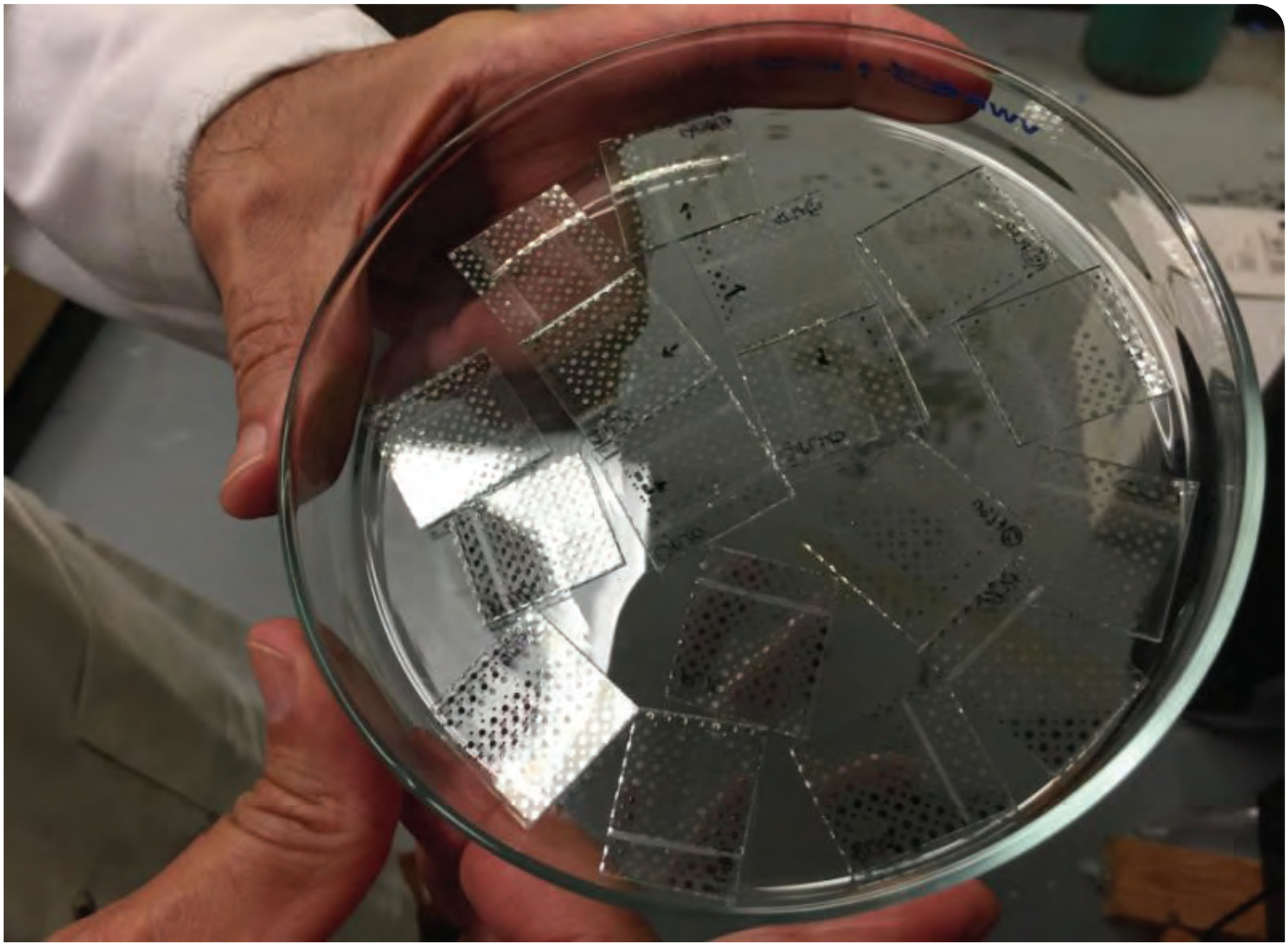
Perry and colleagues in Georgia Tech’s Center for Organic Photonics and Electronics (COPE) had been working on other capacitor materials to meet these demands, but were not satisfied with the progress. The hybrid sol-gel materials had shown potential for efficient dielectric energy storage because of their high orientational polarization under an electric field, so the group decided to pursue these materials for the new capacitor applications.

Using an aluminized mylar film coated with the hybrid sol-gel capacitor material, they showed that the capacitor could be rolled and re-rolled several times while maintaining high energy density, demonstrating its flexibility. But they were still seeing high current leakage. To address that, they deposited a nanoscale self-assembled monolayer of n-octylphosphonic acid on top of the hybrid sol-gel. Less than a nanometre thick, the monolayer serves as an insulating layer.

“Our silica sol-gel is a hybrid material because it has polar organic groups attached to the silica framework that gives the sol-gel a high dielectric constant, and in our bilayer dielectric, the n-octylphosphonic acid groups are inserted between the sol-gel layer and the top aluminium layer to block charge injection into the sol-gel,” Perry explained. “It’s really a bilayer hybrid material that takes the best of both reorientation polarization and approaches for reducing injection and improving energy extraction.”

In their structures, the researchers demonstrated maximum extractable energy densities up to 40 joules per cubic centimetre, an energy extraction efficiency of 72 percent at a field strength of 830 volts per micron, and a power density of 520 watts per cubic centimetre. The performance exceeds that of conventional electrolytic capacitors and thin-film lithium ion batteries, though it doesn’t match the lithium ion battery formats commonly used in electronic devices and vehicles.

“This is the first time I’ve seen a capacitor beat a battery on energy density,” said Perry. “The combination of high energy density and high power density is uncommon in the capacitor world.”



*Credit: John Toon, Georgia Tech*

*These are samples of the new hybrid sol-gel material are shown placed on a clear plastic substrate for testing.*

Researchers in Perry's lab have been making arrays of small sol-gel capacitors in the lab to gather information about the material's performance. The devices are made on small substrates about an inch square.

"What we see when we apply an electric field is that the polarization response -- which measures how much the polar groups line up in a stable way with the field -- behaves in a linear way," said Perry. "This is what you want to see in a capacitor dielectric material."

The next step will be to scale up the materials to see if the attractive properties transfer to larger devices. If that is successful, Perry expects to commercialize the material through a start-up company or SBIR project.

"The simplicity of fully solution-based processes for our dielectric material system provides potential for facile scale-up and fabrication on flexible platforms," the authors wrote in their paper. "This work emphasizes the importance of controlling the electrode-dielectric interface to maximize the performance of dielectric materials for energy storage application."

In addition to Perry, the research team included Yunsang Kim, Mohanalingam Kathaperumal and Vincent Chen from the Georgia Tech School of Chemistry and Biochemistry; Yohan Park from the Georgia Tech School of Materials Science and Engineering; Canek Fuentes-Hernandez and Bernard Kippelen from the Georgia Tech School of Electrical and Computer Engineering, and Ming-Hen Pan from the Naval Research Laboratory.



**Journal Reference:**
Yunsang Kim, Mohanalingam Kathaperumal, Vincent W. Chen, Yohan Park, Canek Fuentes-Hernandez, Ming-Jen Pan, Bernard Kippelen, Joseph W. Perry. Bilayer Structure with Ultrahigh Energy/Power Density Using Hybrid Sol-Gel Dielectric and Charge-Blocking Monolayer. Advanced Energy Materials, 2015; DOI: 10.1002/aenm.201500767

# Rice finding could lead to cheap, efficient metal-based solar cells

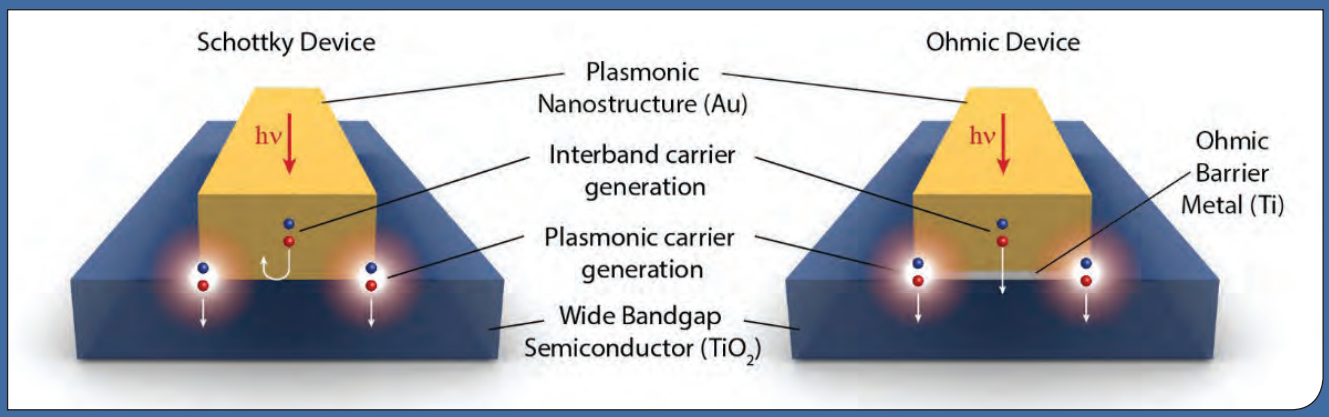
New research from Rice University could make it easier for engineers to harness the power of light-capturing nanomaterials to boost the efficiency and reduce the costs of photovoltaic solar cells.

ALTHOUGH THE DOMESTIC solar-energy industry grew by 34 percent in 2014, fundamental technical breakthroughs are needed if the U.S. is to meet its national goal of reducing the cost of solar electricity to 6 cents per kilowatt-hour.

In a study published July 13 in Nature Communications, scientists from Rice's Laboratory for Nanophotonics (LANP) describe a new method that solar-panel designers could use to incorporate light-capturing nanomaterials into future designs. By applying an innovative theoretical analysis to observations from a first-of-its-kind experimental setup, LANP graduate student Bob Zheng and postdoctoral research associate Alejandro Manjavacas created a methodology that solar engineers can use to determine the electricity-producing potential for any arrangement of metallic nanoparticles.

LANP researchers study light-capturing nanomaterials, including metallic nanoparticles that convert light into plasmons, waves of electrons that flow like a fluid across the particles' surface. For example, recent LANP plasmonic research has led to breakthroughs in color-display technology, solar-powered steam production and color sensors that mimic the eye. "One of the interesting phenomena that occurs when you shine light on a metallic nanoparticle or nanostructure is that you can excite some subset of electrons in the metal to a much higher energy level," said Zheng, who works with LANP Director and study co-author Naomi Halas. "Scientists call these 'hot carriers' or 'hot electrons.'"

Halas, Rice's Stanley C. Moore Professor of Electrical and Computer Engineering and professor of chemistry, bioengineering, physics and astronomy, and materials science and nanoengineering, said hot electrons are




Rice researchers selectively filtered high-energy hot electrons from their less-energetic counterparts using a Schottky barrier (left) created with a gold nanowire on a titanium dioxide semiconductor. A second setup (right), which did not filter electrons based on energy level, included a thin layer of titanium between the gold and the titanium dioxide. CREDIT: B. Zheng/Rice University.

particularly interesting for solar-energy applications because they can be used to create devices that produce direct current or to drive chemical reactions on otherwise inert metal surfaces.

Today's most efficient photovoltaic cells use a combination of semiconductors that are made from rare and expensive elements like gallium and indium. Halas said one way to lower manufacturing costs would be to incorporate high-efficiency light-gathering plasmonic nanostructures with low-cost semiconductors like metal oxides. In addition to being less expensive to make, the plasmonic nanostructures have optical properties that can be precisely controlled by modifying their shape.

"We can tune plasmonic structures to capture light across the entire solar spectrum," Halas said. "The efficiency of semiconductor-based solar cells can never be extended in this way because of the inherent optical properties of the semiconductors."

The plasmonic approach has been tried before but with little success.Zheng said, "Plasmonic-based photovoltaics have typically had low efficiencies, and it hasn't been entirely clear whether those arose from fundamental physical limitations or from less-than-optimal designs."

He and Halas said Manjavacas, a theoretical physicist in the group of LANP researcher Peter Nordlander, conducted work in the new study that offers a fundamental insight into the underlying physics of hot-electron-production in plasmonic-based devices.

Manjavacas said, "To make use of the photon's energy, it must be absorbed rather than scattered back out. For this reason, much previous theoretical work had focused on understanding the total absorption of the plasmonic system." He said a recent example of such work comes from a pioneering experiment by another Rice graduate student, Ali Sobhani, where the absorption was concentrated near a metal semiconductor interface.

"From this perspective, one can determine the total number of electrons produced, but it provides no way of determining how many of those electrons are actually useful high-energy, hot electrons," Manjavacas said.

He said Zheng's data allowed a deeper analysis because his experimental setup selectively filtered high-energy hot electrons from their less-energetic counterparts. To accomplish this, Zheng created two types of plasmonic devices. Each consisted of a plasmonic gold nanowire atop a semiconducting layer of titanium dioxide. In the first setup, the gold sat directly on the semiconductor, and in the second, a thin layer of pure titanium was placed between the gold and the titanium dioxide. The first setup created a microelectronic structure called a Schottky barrier and allowed only hot electrons to pass from the gold to the semiconductor. The second setup allowed all electrons to pass.

"The experiment clearly showed that some electrons are hotter than others, and it allowed us to correlate those with certain properties of the system," Manjavacas said. "In particular, we found that hot electrons were not correlated with total absorption. They were driven by a different, plasmonic mechanism known as field-intensity enhancement."

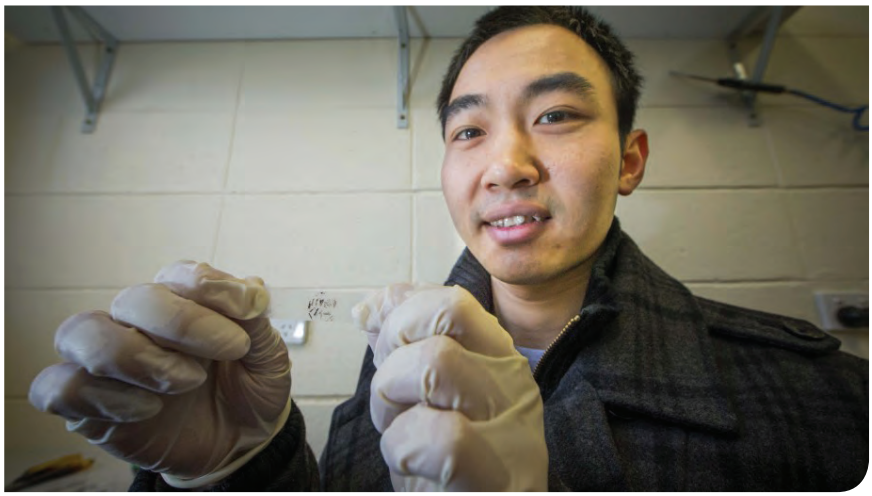
LANP researchers and others have spent years developing techniques to bolster the field-intensity enhancement of photonic structures for single-molecule sensing and other applications. Zheng and Manjavacas said they are conducting further tests to modify their system to optimize the output of hot electrons.

Halas said, "This is an important step toward the realization of plasmonic technologies for solar photovoltaics. This research provides a route to increasing the efficiency of plasmonic hot-carrier devices and shows that they can be useful for converting sunlight into usable electricity."

Additional co-authors include Hangqi Zhao and Michael McClain, both of Rice. The research was supported by the Welch Foundation, the Office of Naval Research and the Air Force Office of Science and Research.

# Sticky tape opens path to better solar cells

A new breakthrough could lead to better solar cells made possible by a roll of sticky tape.



SCIENTISTS studying thin layers of phosphorus have found surprising properties that could open the door to ultrathin and ultralight solar cells and LEDs.

The team used sticky tape to create single-atom thick layers, termed phosphorene, in the same simple way as the Nobel-prize winning discovery of graphene.

Unlike graphene, phosphorene is a semiconductor, like silicon, which is the basis of current electronics technology.

“Because phosphorene is so thin and light, it creates possibilities for making lots of interesting devices, such as LEDs or solar cells,” said lead researcher Dr Yuerui (Larry) Lu, from The Australian National University (ANU). “It shows very promising light emission properties.” The team created phosphorene by repeatedly using sticky tape to peel thinner and thinner layers of crystals from the black crystalline form of phosphorus.

As well as creating much thinner and lighter semiconductors than silicon, phosphorene has light emission properties that vary widely with the thickness of the layers, which enables much more flexibility for manufacturing.

“This property has never been reported before in any other material,” said Dr Lu, from ANU College of Engineering and Computer Science, whose study is published in the Nature serial journal Light: Science and Applications.

“By changing the number of layers we can tightly control the band gap, which determines the material’s properties, such as the colour of LED it would make. “You can see quite clearly under the microscope the different colours of the sample, which tells you how many layers are there,” said Dr Lu.

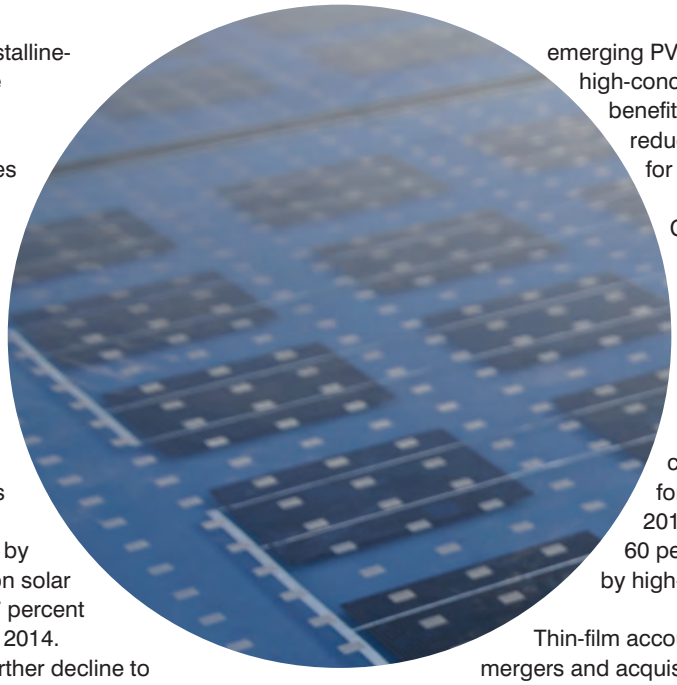
Dr Lu’s team found the optical gap for monolayer phosphorene was 1.75 electron volts, corresponding to red light of a wavelength of 700 nanometers. As more layers were added, the optical gap decreased. For instance, for five layers, the optical gap value was 0.8 electron volts, a infrared wavelength of 1550 nanometres. For very thick layers, the value was around 0.3 electron volts, a mid-infrared wavelength of around 3.5 microns.

The behaviour of phosphorene in thin layers is superior to silicon, said Dr Lu. “Phosphorene’s surface states are minimised, unlike silicon, whose surface states are serious and prevent it being used in such a thin state.”

> Because phosphorene is so thin and light, it creates possibilities for making lots of interesting devices, such as LEDs or solar cells”
>
> Dr Yuerui (Larry) Lu, from The Australian National University (ANU)

# CIGS could become a solar game changer

Is sun is setting on traditional solar technologies as they approach theoretical conversion limit?



WHILE CONVENTIONAL crystalline-silicon solar technologies are approaching their theoretical conversion limit, alternative photovoltaic (PV) technologies are setting the bar higher and higher, gradually changing the landscape of the global solar market, according to 'Chasing the Sun: Searching for Game Changers in Disruptive Photovoltaic Technologies', by Innova research.

In this new report, Innova has estimated that the share of solar PV production capacity by conventional crystalline-silicon solar technology accounts for 84.7 percent of the total global capacity in 2014. This share is forecasted to further decline to 78.4 percent by 2019 encroached by the emerging PV technologies. Innova Research believes that CIGS and CPV have the greatest potentials and will become the game changers in the global solar market.

In the report, alternative solar technologies are analysed and ranked based on a matrix analysis of key technologies indexes, patent publications, and mergers and acquisitions activities. Innova research classified the emerging solar technologies into three major categories, namely thin-film PV, including CIGS, CdTe, thin film-silicon; concentrated PV (CPV), including LCPV and HCPV, and the third generation solar technologies, including organic PV (OPV), dye-sensitised solar cell (DSSC), copper zinc tin sulphide (CZTS), quantum dot (QD), and perovskite solar cells.

Nancy Wu, research director of Innova Research and the lead author of the report said: "Thin-film and CPV technologies are poised for large commercialisation in the near future while the 3rd generation PV technologies will still have a long way to go towards that goal. We believe that the winners among the emerging PV technologies will be CIGS and high-concentrating PV (HCPV), both are benefiting from their outstanding cost reduction potentials and the feasibility for massive adoptions."

CIGS leads the thin-film PV expansion with production capacity growth from an estimated 1.8 GW in 2010 to a forecasted 5.6GW in 2019, followed by CdTe, from 2.5GW to 3.5 GW for the same period. Meanwhile, the production capacities for CPV modules are forecast to grow from 1.5GW in 2010 to 2.4 GW in 2019, with over 60 percent of the capacity contributed by high-concentrating PV in 2019.

Thin-film accounts for the largest number of mergers and acquisitions in the alternative solar technology field, followed by CPV, with 24 and 14 deals closed, respectively, from 2010 to 2014. The total dollar values of mergers and acquisitions in the thin-film and CPV fields were estimated at $1.08 billion and $247 million, respectively, in the same period.

US leads the IP publications in CdTe, CIGS, and CZTS, while Asian countries, including China, Japan, and South Korea are catching up in DSSC, QD, and perovskite PV technologies in the past five years. The increasing research focuses on the alternative solar PV technologies, particularly on their efficiency enhancement and the stability of the systems, will greatly drive up their commercialisation in the next few years.

The report, 'Chasing the Sun: Searching for Game Changers in Disruptive Photovoltaic Technologies' is part of the Innova Research Renewable Energy and Environmental Technologies service.

# Challenge to classic theory of 'organic' solar cells could improve efficiency

New research findings contradict a fundamental assumption about the functioning of 'organic' solar cells made of low-cost plastics, suggesting a new strategy for creating inexpensive solar technology.

COMMERCIALIZATION of organic solar cells has been hindered by inefficiencies, but the findings point toward a potential path to create a new class of solar technology able to compete with standard silicon cells.

"These solar cells could provide a huge cost advantage over silicon," said Muhammad Ashraful Alam, Purdue University's Jai N. Gupta Professor of Electrical and Computer Engineering.

Plastic solar cells might be manufactured using a roll-to-roll process similar to newspaper printing.

"This has been the hope for the last 20-25 years," said Bryan Boudouris, an assistant professor of chemical engineering. Because organic solar cells are flexible they could find new applications that are unsuitable for rigid silicon cells such as photovoltaics integrated into buildings, and they have the potential to be lower-cost and less energy-intensive to manufacture than silicon devices. However, a critical bottleneck has prevented development of organic solar cells efficient enough to compete with silicon solar technology.

"Now it appears there is no fundamental reason why organic cells have to be less efficient than silicon," Alam said. Findings are detailed in a research paper appearing (August) in Proceedings of the National Academy of Sciences. The work was spearheaded by former doctoral student Biswajit Ray, who has graduated.

"Biswajit had the courage, conviction, and persistence to do a series of difficult experiments, and was ably supported at various stages by doctoral students Aditya Baradwaj and Ryyan Khan," Alam said.

The primary bottleneck to more efficient organic solar cells is rooted in the fundamental workings of the organic photovoltaic technology. As the semiconducting material is illuminated with light, electrons move from one energy level to another. Due to the atomic structure, the electrons in the semiconductor occupy a region of energy called the "valence band" while the material is in the dark. But shining light on the material causes the electrons to absorb energy, elevating them into a region of higher energy called the "conduction band." As the electrons move to the conduction band they leave behind "holes" in the valance band, generating so-called electron-hole pairs in the plastic solar cells called excitons.

"Because the electron is negatively charged and the hole is positively charged, they like each other so much that they orbit around each other," Ray said. "You have to keep these two separated or they will recombine and you will not generate current."

This "charge separation" is maintained by inserting numerous structures called bulk heterojunctions, a design that has been a challenge to manufacture in a high-speed, large-scale and reproducible manner.

"You can think of these heterojunctions almost like knives cutting through the material to separate the electrons and holes," Alam said. "These heterojunctions have to be distributed throughout so that no matter where the electron-hole pair is generated you can cut them."

This requirement limits the efficiency of organic solar cells, a bottleneck established by research more than two decades ago. However, Ray showed through detailed computational modeling that a fundamental assumption about the organic solar cells was incorrect, eliminating the need for heterojunctions.


Doctoral student Aditya G. Baradwaj (at left), professor Muhammad A. Alam (centre) and doctoral student Ryyan Khan, operate a solar simulator. They are members of a research team led by former doctoral student Biswajit Ray and also involving assistant professor Bryan Boudouris reporting new findings that contradict a fundamental assumption about the functioning of "organic" solar cells made of low-cost plastics. The findings suggest a new strategy for creating inexpensive solar technology. Credit: Purdue University image/John Underwood.

"He kept saying he didn't need to invoke excitons in order to explain many of the experimental results," Alam said. "It turns out that the original experiment was misinterpreted."
This misinterpretation arises from the design of organic cells. The cells have two metal contacts, one on top and one on the bottom of the device, and each is made of different types of metal. Because of this configuration, incoming sunlight generates an electric field concentrated at the bottom of the cell, which allows the electron-hole pairs to readily recombine. Ray proposed flipping the contacts so that the electric field forms at the top of the cell instead of at the bottom, allowing for better charge separation.

"He inverted the structure and explained that the inefficiency is taking place because the electron-hole pairs are not staying separated," Alam said. Simulations showed flipping the configuration allowed for better charge separation and higher efficiency, and then laboratory experiments by Ray, Baradwaj and Khan validated the new concept. The findings also suggest the design of organic solar cells can be simplified, representing a major potential innovation, Ray said. Whereas conventional organic solar cells are made by mixing two types of polymers, the new design requires only one polymer.

"Currently, you have to design the solar cells according to how well two organic materials mix together in order to produce these numerous heterojunctions," Boudouris said. "But if you only needed one polymer instead of two, the manufacturability on the large scale could be very much improved, so this is an exciting development."

Findings also suggest that producing the cells out of purer polymers could result in more efficient solar cells, and the research likely will lead to a better understanding of the physics of how organic solar cells operate, Alam said.
Much of the experimental work was performed in the Purdue Solar Energy Utilization Laboratory, formed with funds from the National Science Foundation, which allows specialists from different fields to collaborate. The research is ongoing, and Khan will continue to work on a new class of solar cells that do not require bulk heterojunctions.

The research was funded by the U.S. Department of Energy through DOE's Center for Re-Defining Photovoltaic Efficiency through Molecule Scale Control, the National Science Foundation's Network for Computational Nanotechnology, and the U.S. Air Force Office of Scientific Research.

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# Smooth robot movements reduce energy consumption

*By managing industrial robots, energy consumption can be greatly reduced.*

BY MINIMIZING the acceleration of industrial robots, energy consumption can be reduced by up to 40 percent -- while retaining the given production time. This is the result of a new optimization algorithm that was developed by researchers at Chalmers University of Technology.

Optimization of the robot's movements reduces acceleration and deceleration, as well as the time the robot is at a standstill since being at a standstill also consumes energy.

"We simply let the robot move slower instead of waiting for other robots and machines to catch up before carrying out the next sequence. The optimization also determines the order in which the various operations are carried out to minimize energy consumption -- without reducing the total execution time," says Professor Bengt Lennartson who initiated the research together with, among others, General Motors. The optimization never changes the robot's operation path, only the speed and sequence. "Thus, we can go into an existing robot cell and perform a quick optimization without impacting production or the current cycle," says Bengt Lennartson.

To achieve safe optimization, several robots moving in the same area need to be coordinated. The optimization tool will therefore initially identify where robots may collide, and the entry and exit positions for each collision zone, and for each robot path.

"The first test results have shown a significant improvement, such as a 15 to 40 percent energy reduction, but the results are still preliminary. In order to estimate the actual energy savings, further testing in industry is required," says Kristofer Bengtsson, who is responsible for the implementation of the new optimization strategy.

In robot-intensive manufacturing industries, such as bodywork factories in the automotive industry, robots consume about half of the total energy used for production. The optimization program starts by logging the movements of each robot during an operations cycle, as well as any collision zones. This information is processed by the optimizer, which generates new control instructions that can be directly executed by the robots.

"The goal is to make this kind of optimization standard, and included in robots from the start. At each adjustment of the operating sequences, a new optimization is conducted by default. But as we all know, it takes time to bring a development product into a robust production process, with several years of engineering work," says Kristofer Bengtsson.

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