TECHNOLOGY HIGHLIGHTS

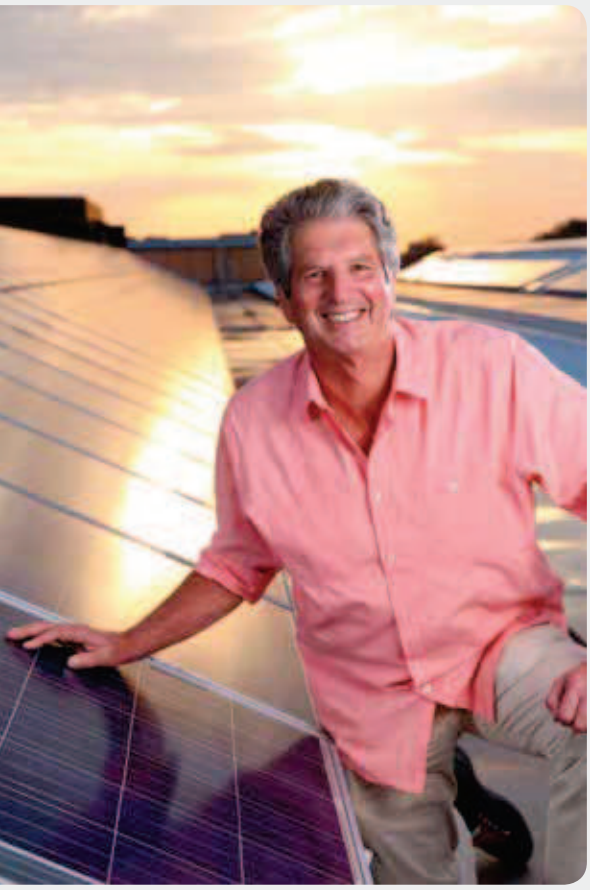
Change is the only constant: An ancient adage, but particularly true of the evolutionary nature of our PV's revolutionary technology.

The second edition of **pv magazine's** Technology Highlights feature includes 38 entries from PV production equipment, technology and materials companies spanning the wafer, cell and module supply chain and production processes. And high praise has be leveled at the leading entrants.

"One key strength of the (solar) industry lies in the diversity of engineering skills and creativity being brought to bear worldwide on improving each and every step both in cell and module manufacturing and in subsequent field deployment," said Professor Martin Green, from the renowned solar research group at the University of New South Wales. Green reviewed the leading entries, commenting that these innovations "are key to the improved performance and ongoing cost reductions expected from the PV industry over the coming decade."

"These products provide a superb cross-section of recent progress," concluded Green. For the first time this year, **pv magazine** assembled an international jury of PV experts to produce a ranking of the entries and select winners of the 2016 Technology Highlights awards. Eight finalists for the inaugural **pv magazine** Technology Highlights Award were selected from the entrants by the jury and their comments on each of the highly-ranked technologies have been included throughout the 20 page feature.

Cell and module testing equipment and wafering tools and processes have emerged as outstanding entrants to Technology Highlights 2016. After review, deliberation and debate, the jury has selected the following awardees:



TECHNOLOGY HIGHLIGHTS 2016 AWARD WINNERS

Meyer Burger
DW288 Series 3 diamond wire solution

Eternal Sun
Climate Chamber Solar Simulator

"Technology to watch"
DSM Anti Soiling Coating

Runners up
366 Technologies' Direct Wafer
BT Imaging LIS R3 inspection tool

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

AWARD JURY

Xiaoting Wang,
Bloomberg New Energy Finance

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

Finlay Colville,
Solar Media Ltd

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

Andrea Viaro,
Jinko Solar Europe

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

Arno Stassen,
Heraeus Group

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

Andrew Blakers,
Australian National University

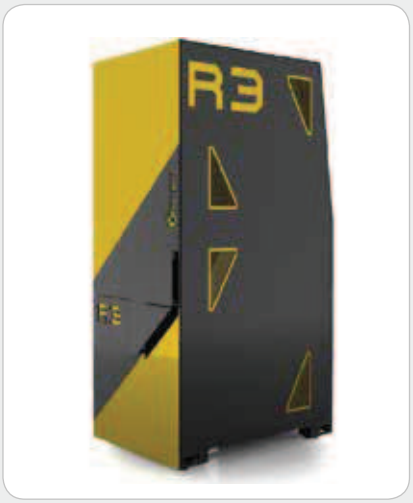
Professor Andrew Blakers is a Professor of Engineering at the Australian National University (ANU). His research interests are in the areas of photovoltaic and solar energy systems, silicon solar cell technology, concentrator solar cells, components and systems and sustainable energy policy.

Goetz Fischbeck,
Smart Solar Consulting

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

TECHNOLOGY HIGHLIGHTS RUNNER UP

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



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

BT Imaging's new technology can inspect all types of materials from silicon ingots, bricks, wafers, cells and even mini-modules. It offers a large number of inspection techniques. For example, the tool includes photoluminescence imaging, electroluminescence imaging, electrically-biased photoluminescence imaging, quasi-steady-state-photoconductance, injection dependent lifetime, calibrated lifetime imaging, series resistance imaging, IV testing, Suns-V_{oc} curves, Imaging for J_o, R_S, V_{oc}, J_{mpp}, and efficiency, front surface and bulk photoluminescence defect analysis for cells, multicrystalline wafer defect algorithms and monocrystalline wafer defect algorithms.

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

–

Jury comment

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

–

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

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

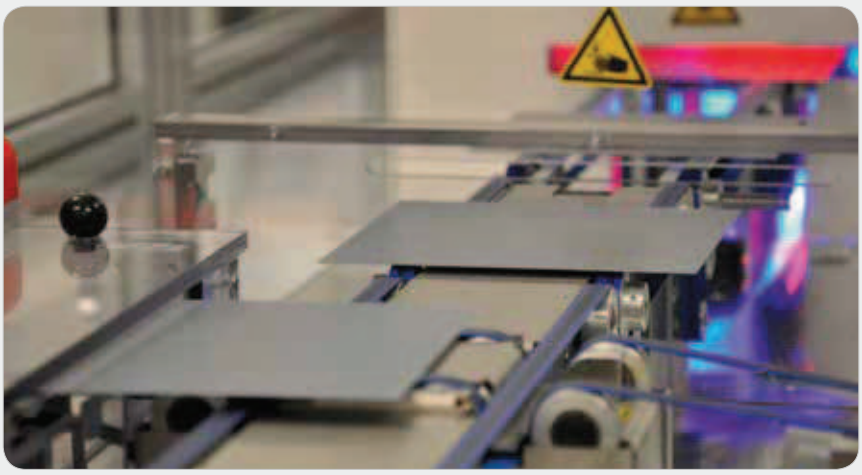
U.S.-based 1366 Technologies is rolling out its Direct Wafer solution, where wafers are formed from molten silicon. The developer claims its process is the first and only kerfless wafer technology to make 156 mm standard thickness wafers.

1366 Technology says that its Direct Wafer solution needs only half of the silicon, one third of the energy, and half of the capital to create a standard PV wafer. The innovation grows wafers one at a time, every 20 seconds, formed as a sheet on the surface of a melt "like ice on a lake." When a wafer is removed and cut to size with a laser, any trimmings are recycled into the melt.

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

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

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



–

Jury comment

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

–

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