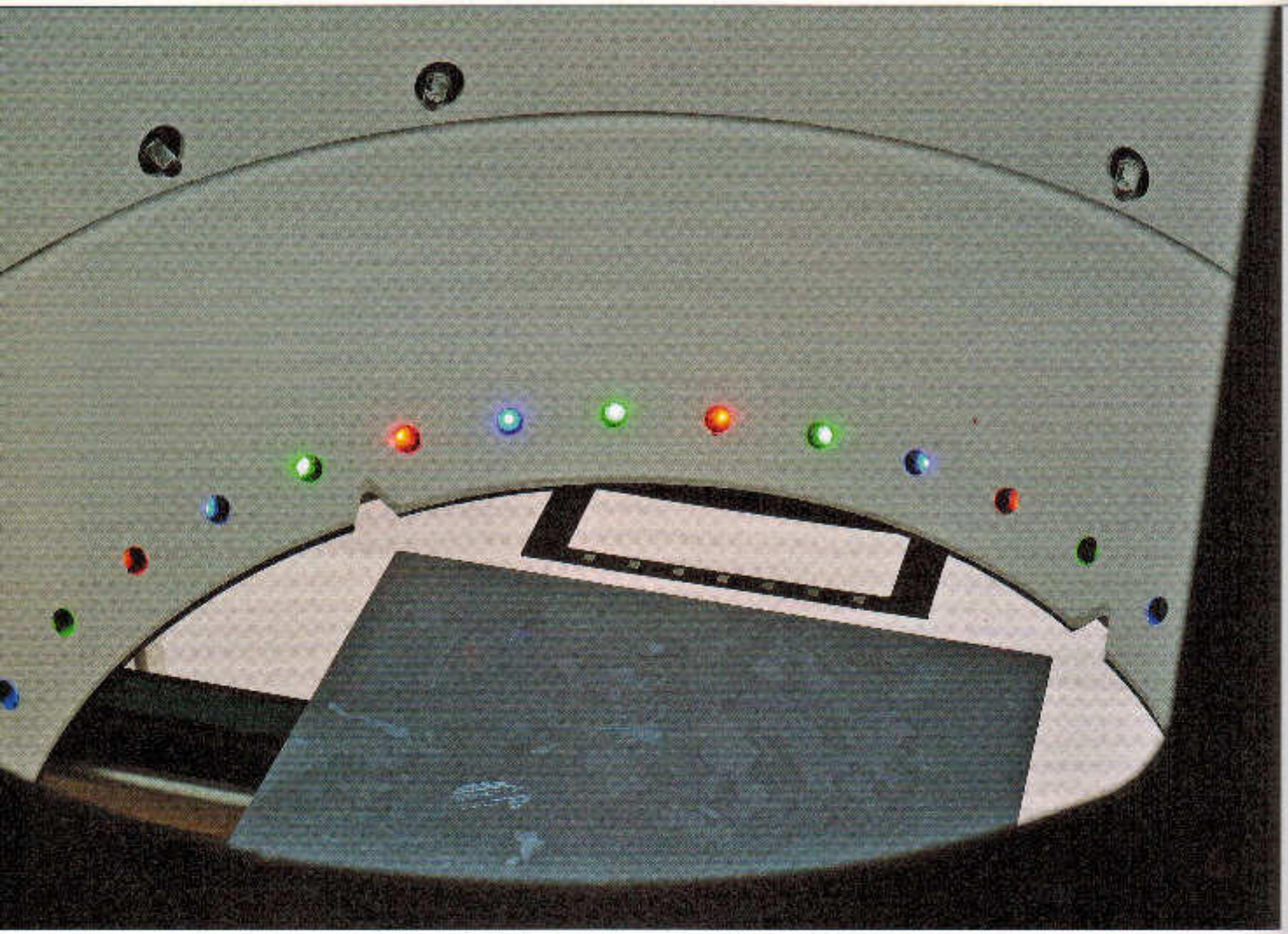

Photo: ISRA VISION AG

The trend towards high efficiency and more advanced cell technologies requires advanced automated cell testing. Pictured here: Isra Vision's in-line wafer inspection to measure the geometry and detect surface defects.

Bright spots in cell testing

Solar cell inspection: The move away from manual solar cell testing by China's PV manufacturers and the trend in high efficiency cell technologies is generating demand for automated and advanced cell-testing tools.

For companies that make solar PV testing equipment and systems, the foreseeable future is looking more positive as global demand for PV modules rises again. Trends in PV cell production, such as high efficiency technologies, demand more advanced PV cell testing approaches, with testing equipment companies – both western and Chinese – looking to meet demand for more automated and in-line cell testing systems.

According to ENF's most recent ranking, which is from 2012, the Chinese company Gsolar Power topped the board of the 10 leading manufacturers of cell testing and sorting equipment, followed by Applied Materials and Berger Lichttechnik, with the three together accounting for over 50% of the market.

China opportunities

Gsolar Power is somewhat unique among Chinese PV equipment manufacturers, in being one of very few with a TÜV/CE certification and with a track record of exporting solar cell testing machines and related equipment to Europe, including Germany and France, the U.S., as well as Asia, including Japan and Taiwan. The company is behind the first Chinese-developed cell-testing tool based on electroluminescence (EL) imaging.

Like other Chinese suppliers of cell testing equipment the company has largely benefited from demand for manual cell testing tools from predominantly domestic PV cell and module producers. As the industry shakeout continues, leaving only companies that are able to invest in technology for delivering higher efficiency cells, demand for manual cell testing is waning. Unlike many of its Chi-

nese competitors, Gsolar has invested in automated equipment for cell testing, which will compete with the advanced systems that European and U.S. companies provide. The company has recently developed an automated cell sorting system, deploying both EL as well as more advanced photoluminescence (PL) technology.

EL and PI. techniques work by both generating images of solar cells that reveal localized shunts, series resistance, and areas of charge carrier recombination, as well as other defects. EL works by applying a forward voltage and current to cause localized irradiance due to carrier recombination, while PI. uses light irradiation for the same purpose. But whereas EL imaging relies on the detection of relatively bright signals and can only be employed at the final stage of solar cell manufacturing, PL imaging can be applied even before cell strings, to wafers and ingots, providing better visibility of defects earlier on in the manufacturing process.

However, Gsolar Power faces tough competition from other suppliers of advanced automated cell testing systems, many of which are in Europe. These companies are also relying on new business as a result of the increasing emphasis on cell technology and R&D among China's remaining PV cell and module makers.

Isra Vision, in Germany, is one such competitor. According to Guido Eberhardt, General Manager at the company, "More than half of all solar cells are produced in China, while the use of inspection systems has limited penetration. Where previously cell inspection had occurred manually, in most cases new technologies demand the use of automatic optical systems."

In contrast, cell manufacturers in countries such as Taiwan, South Korea and Germany typically use automated optical inspection systems in many process steps. "The aim is to exploit the potential of production as much as possible and to ensure the profitability of production. Here, the potential for new systems is largely limited to new processes and layouts, and to new inspection technologies, but In China the potential for cell testing and inspection machines is much greater," he adds.

KEY POINTS

- Chinese PV cell manufacturers are ditching manual cell testing in favor of automated cell testing technologies, creating a new wave of demand for companies such as Greateyes, Gsolar and Isra Vision.
- The trend towards high efficiency and more advanced cell technologies, such as n-type and multijunction, requires advanced automated cell testing.
- As well as new markets such as China, companies are also seeing demand for upgrades from cell manufacturers looking to replace older EL-based systems with newer PL-based cell testing technologies.

Broad portfolio

Isra Vision's PV industry portfolio includes a contactless PL inspection system. Launched in 2012, Yieldmaster PL includes crystal defect classification and series-resistance measurements, for rapid in-line inspection of wafers and cells. Contactless measurement avoids potential cracks or breaks caused by electrical contacting required for EL or previous PL in combination with series resistance measurements. Isra Vision, which supplies inspection systems for several industries, including glass, films, and plastics, is one of a few equipment suppliers that – during the PV industry downturn – chose to further invest in its PV business, taking over GP Solar and GP Inspect in 2013.

With the acquisition Isra Vision lays claim to inspection systems for each processing step in PV manufacturing, from wafer through to module production, supplying in-line as well as standalone and lab-based equipment.

Standalone systems for wafer and cell quality classification include the Test Unit, which stacks separate wafers and cells, for testing and sorting by quality, based on the measured results. The system is suitable for manufacturers with existing production lines or with limited production space. "This system is one example of a product designed for PV cell lines that is making the transition from manual process steps to automated ones," explains Eberhardt. With the acquisition of GP Solar, Isra Vision has not only grown market share but has a broader portfolio of testing systems to offer customers, ranging from crystalline wafers to modules as well as thin film PV technologies.

Photo: BERGER Lichttechnik GmbH & Co. KG

Berger Lichttechnik sees a recovery especially for production equipment for higher efficiency cells.

High efficiency cells

Key trends in wafer and cell production – namely the thinning of electrical contact layers and the implementation of high efficiency cell technologies – will increase the demand for advanced cell testing systems. To produce increasingly high efficiency cells – to make higher output modules – requires more complex and additional processing steps. Therefore, the new cell designs, or architectures, and steps that enable production of high efficiency cells need in-line quality control systems able to support these additional processes. "Inspection systems support production by detection of faulty materials and process deviations. In addition, materials can be identified in which an adjustment of process parameters leads to an increase in efficiency of the final cell," explains Eberhardt.

For the production of high efficiency cells, Isra Vision's approach includes highly accurate efficiency estimates on the wafer entrance, inspection of new process steps for a variety of coating technologies and new contact layout. "In achieving progressively narrower layouts, the resolution requirements of the inspection systems are getting bigger. However, as precise measurements over the entire cell are becoming increasingly important, the use of low-cost line scan cameras is inappropriate here," says Eberhardt. Isra Vision relies on special cameras that can detect both small local structures as well as the dimensions of the whole cell exactly. He adds: "The aim is to manufacture a solar cell having a high efficiency at low production costs. To this end, various technologies have been tested in the past. Which technology will prevail is still unclear. Certainly the demands on inspection systems are steadily increasing."

Isra Vision's Print-Q FS.Cam system can be used to detect defects on the solar cell's metal grids and their contacts on the front side, down to ranges of less than 30 µm, a technical feature of high efficiency solar cells with thinner front contacts.

Berger Lichttechnik also suffered in terms of low sales during the past two years, as customers suspended orders or looked for lower cost alternatives. "Now we see a recovery of the market, especially for production equipment for higher efficiency cells, so our full spectrum simulation technology and high efficiency testing technology is seeing increasing demand again," says Kai Kopplin, from the company's sales team.

For advanced cell technologies, such as n-type cells, multilayer and multijunction cells, the company has developed two approaches. "A long pulse flasher with a flash time of 2 x 25 ms covers most high efficiency requirements by longer sweep time. For high capacity cells like SunPower's, or HIT cells, we have developed a special high efficiency (HE) system using special sub-IV-curves to analyze stability for each point of the final IV-curve in a reliable and traceable way," Kopplin explains.

Berlin-based Greateyes' PV cell and module testing equipment is based on taking measurements of PV cells using either EL or PL-based imaging or both. The company has developed four main platforms for the PV industry. Lumisolarcell is designed to carry out EL and LED-based PL imaging of solar cells, wafers, and thin film substrates and is suitable for R&D as well as inspection in production lines. Lumisolarmobile carries out EL imaging of solar cells and modules as a standalone or integrated system. Applications include measurements within laboratories as well as mobile stations. The third platform, Lumisolarprofessional, is designed to carry out EL imaging of solar modules, providing high-resolution and excellent image quality. Applications include inspection and quality control in production, as well as R&D. The fourth platform, Lumisolaroutdoor, provides EL imaging of solar modules on-site, without dismantling modules in situ.

The market is picking up again

After the solar market downturn in recent years, the market is picking up again with Greateyes expecting better business in 2014, from existing markets as well as new markets. Like other players in the sector, Europe – the initial main market for the company's PV testing systems – has given way to Asia, including China, as the company's most important market.

"We expect more positive developments within the cell testing market," says Katharina Mangold, from Greateyes' marketing department, adding

"Solar companies which survived up to now have recovered from the market downturn in the last few years and have the budget to invest in PV inspection systems."

In particular the company is seeing increased demand for contactless PL-based testing systems, in order to minimize damage or breakages of cells, which are thinner and, therefore, more fragile.

In terms of developing systems for high efficiency solar cells, Greateyes has ongoing R&D programs to modify its inspection technology to meet these requirements. "In terms of technologies like multijunction cells there is more to detect, as the materials used, as well as the composition of those materials, are becoming more and more complex. Cell testing equipment manufacturers have to respond to the pace of fast-developing technologies and keep up by being flexible and innovative," says Mangold.

The company collaborates with customers, developing systems based on their requirements. "This is something that distinguishes us from other PV cell inspection system manufacturers," says Mangold. The company is able to customize the four main platforms to a large extent, based on a customer's specific requirements.

For example, Lumisolarprofessional, for EL imaging of PV modules, is really comprised of three further system configurations. One is designed for the inspection of completed modules in the laboratory, or bottom load. The second system is suitable for what is known as top load inspection, or in-line inspection during PV cell production, such as prelaminates – inspection of modules before lamination. The third system is for R&D. "These subgroups can be divided further. For example, for R&D, there is the Lumisolarprofessional R&D60 and R&D240. Both of these systems can be customized, as in produced in every size," says Mangold.

Gsolar Power is also improving and enhancing its cell testing tools as the industry adopts high efficiency cell processes, by designing new cell contacting probe mechanics, for example, as contacts get thinner, as well as further integrating EL and PL technologies. High efficiency cells also demand longer flash times, compared with more conventional cells, so this is an area the company is also focusing on.

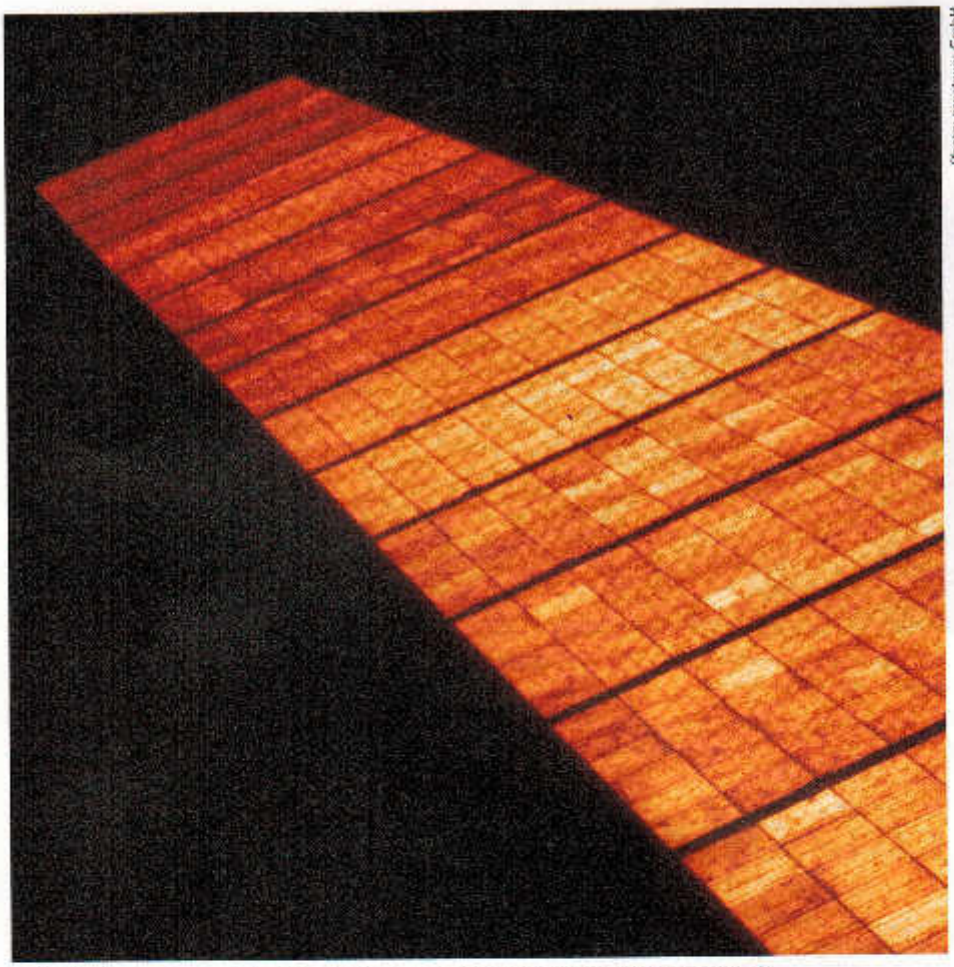

Photo: greateyes GmbH

The Berlin-based company Greateyes has developed four main platforms for the PV industry.

The future

The use of inspection systems in PV cell production is becoming increasingly important in order to achieve the maximum efficiency and profitability. Whether for simple tasks, such as positioning or break monitoring, up to monitoring of process parameters, which are partly invisible to the human eye, automatic inspection systems are already an essential step in the production of high-end PV cells.

In future, Gsolar, Isra Vision and Greateyes see lots of opportunity as PV cell manufacturers, especially those in China, adopt more advanced, automated cell testing procedures and processes.

"With a PV testing system, PV cell manufacturers guarantee a high quality product which is increasingly important in a highly competitive market," says Greateyes' Mangold, who describes two types of demand that are driving demand. These include new markets, such as China, but also important for the company is the demand for upgrades, where cell and module manufacturers have already been using automated inspection tools but are now looking to spend money on converting their older tools – typically EL-based – with new systems – typically PL-based.

According to Berger Lichttechnik's Kopplin: "Due to the very high capacity we have already delivered in the past we are only expecting small growth and an upgrading of older systems."

Gsolar, which mainly supplies China, expects its market share, in terms of demand for manual cell testing machines, to shrink, but is ready for the next wave of demand with its automated PV cell sorter systems, based on EL and PL technologies.

For a segment of the PV equipment industry that has had to ride out some tough market conditions, the PV industry's transition to one that is leaner, more streamlined and more focused on PV cell technology, the long-term outlook for PV cell testing system suppliers is looking pretty positive. According to Kopplin: "Without advance testing tools, development of advanced and high efficiency cell concepts and production cannot be achieved." ◆

Sara Ver-Bruggen