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Light of the world: Building success in photovoltaic manufacturing

by by Darren Brown, DEK

Growing pressure to utilize renewable energy sources is driving up sales of solar panels globally. Under these conditions current suppliers can achieve rapid growth and new manufacturers can seize the opportunity to enter the market. Production equipment and techniques are also changing, to deliver higherperforming products at high quality and in high volumes.

Capacity and opportunity
Demand for solar panels is greater than current manufacturing capacity. There are several reasons for this. Effective government incentives on renewable energies are encouraging individual homeowners to install generating equipment capable of fulfilling a proportion of the total domestic requirement. Another factor is the trend for high-profile businesses to be seen to commit to sustainable practices. Premises that can support large solarcell installations, such as a supermarket site, enable these companies to derive an impressive percentage of their energy requirements from renewable sources.

Production capacity is increasing, however. Some new projects recently reported by Semiconductor International include the expansion of the QS Solar plant in Shanghai, China to 75MW, and a new plant of 64MW capacity to be built by Schott Solar in Santa Fe, New Mexico, USA. Since global demand for solar panels is calculated in Watts, production planners tend to size a plant to match their ambitions in terms of market share. Companies can then “pay as they grow” by buying-in extra capacity. Thisapproach also simplifies planning for start-ups.

In fact, the barriers to new companies entering this market are currently low. Solar, or photovoltaic (PV), cell technology is relatively straightforward, and easy to understand and produce, and the equipment can be planned and installed almost as a shrink-wrapped production line meeting the required capacity. This represents an attractive opportunity for many types of manufacturing businesses with sufficient real-estate to install a production line and suitable management and logistical competencies.

PV manufacturing techniques
There are currently two manufacturing technologies for PV cells. Those fabricated on bulk silicon substrates currently account for more than 90 percent of global production. These are built up using thick-film production techniques, by depositing an array of fine current-collector fingers on the topside of the substrate, applying an aluminium metallization layer to the bottom side, and then creating a series of wider bus bars for electrical interconnection purposes. The bus bars are usually deposited as a silverbased compound around 2mm wide. In this way, the PV cell is built up through a sequence of processes, each of which is relatively easy to implement and control using the latest equipment now emerging to service the growingnumber of PV cell producers.

Thin-film PV technology is a newer alternative, which not only allows cell arrays to be fabricated on silicon but also enables substrates such as flexible polymer, steel or glass sheets to be used. This will allow energy harvesting capabilities to be embedded directly in windows and other panels for office buildings, warehouses and many otherlocations.

Screen printing is the process of choice for PV cell production. The equipment and processes are robust. Current leading-edge equipment is easily capable of meeting the accuracy and repeatability requirements to produce PV cells at high yield rates. The typical requirement for line width when depositing current collectors on a bulksilicon PV array, for example, is 100 microns. Some vendors of screen printing solutions are able to achieve significantly greater accuracy. DEK, for example, has a successful track record in the semiconductor packaging industry, and is able to produce interconnects for chip-scale packages using advanced screen printing capabilities. Conversely, screen printing is also effective to produce relatively thick deposits at high speeds.

Screen printing also offers benefits in thin-film PV cell production. For example, some emerging techniques to boost energy conversion efficiency will require intricate deposit patterns to produce multiple cell types on a single substrate. These allow the array as a whole to be sensitive to the widest possible range of wavelengths, and thereby harvest more energy from light falling on the panel. Screen Largeprinting is able to achieve complex deposit shapes, to produce these multi-cell arrays, at lower cost than other processes such as vapor deposition and jetting.

Accurate design and production of stencils and emulsion screens is critical to the success of screen printing in any precision industrial application. PV cell fabrication is no exception. A number of technologies are applicable, including laser-cut or electro-formed metal stencils, as well as emulsion screens created by etching the required image in a fine, coated mesh. These hold the key to producing a variety of ultra-fine features, heavy deposits or complex patterns in a single operation to sustain continuous high throughput.

Turnkey production line

A generic PV cell production line comprises a sequence of printing and drying stages to create the bottom-side metallization, bus-bar, and top-side current-collector layers. After the final printing stage, the cell is fired in a furnace.At the beginning of the line, a cassette loader delivers the unprinted wafers into the first printer. Subsequenthandling includes an automated inverter to allow printingon both sides of the wafer, and an unloader at the end ofthe line to stack the completed PV cells ready for collection.Figure 1 shows a complete production line in sequence ofequipment and processes.

Setting up a PV cell assembly facility is barely more complex than buying and installing the production line. It can be commissioned as a standard, off the shelf, turnkey installation. A typical modern production line is rated at 1200 units per hour (UPH), allowing easy synchronization with other production activities. Predictable performance allows users to scale production easily to achieve the desired overall capacity expressed in MegaWatts. Screen printing processes particularly easily replicated, using costeffective equipment.

DEK, for example, offers a complete production-line solution for bulk-silicon wafer-based PV metallization. This combines its automated technologies for handling PV silicon substrates with high-volume, high-precision screen printing expertise and drying technology from BTU. This metallization line easily meets the current benchmark speed of 1200 UPH, and is therefore able to integrate directly with other complementary processes that make up a complete PV production facility.

A number of accelerator technologies are also available to support future speed increases when the industry requires. These include dual-lane printing, for example. This technique is already proven in the surfacemount electronic assembly market. Another expected development is to increase the printable area for thin film PV cells, so increasing the total effective throughput. Large-format printing solutions are already available to meet this demand, based on existing technologies developed for manufacturers of large backplane assemblies for telecom switches and Internet servers. This shows how suppliers to the emerging world PV cell production market must demonstrate a robust roadmap capable of delivering throughput in excess of 2400 UPH going forward.

Technical trends and challenges

Among the important technical trends within PV cell development, manufacturers are using progressively thinner silicon wafers. The typical thickness is now being reduced from around 220-200 micron to the region of 180-150 micron. This is partly a response to the general shortage of silicon caused by the rapid ramping of production volumes worldwide. Another benefit is that the overall weight of the panel is reduced. This translates into advantages such as easier transportation and installation. However, the thinner wafers are more vulnerable to damage in production. Poor handling or clamping mechanisms are major contributors to lost yield through breakage. Improved solutions such as the enhanced wafer support and automatic vision alignment are required.

Another major cause of wafer damage is bending due to thermal expansion. Mismatches in the thermal expansion coefficient (CTE) of materials deposited in the top and bottom sides of the wafer can cause the substrate to bow and crack. So-called “low-bow” techniques designed to address these CTE mismatch hazards will demand improved process control for closer matching between the top- and bottom-side deposits.

Changes in the sequence of deposition processes are also expected. New “hot-melt” technology for fabrication of bus bars and current collectors, for example, could replace the conventional print/dry sequence. This process uses a preheating stage to allow a liquid-metal deposit to be printed at elevated temperature. The deposit subsequently solidifies through natural cooling. Hot melt is expected to eliminate the drying stage and thereby achieve faster throughput.

Operational enhancements

This rapid growth in global demand for PV cells will also bring logistical challenges for manufacturers. Technical support from equipment suppliers is a key issue. PV cell production has been a low volume, niche activity for the majority of its history. The traditional companies supplying capital equipment tend to be organized accordingly.

As a result, maintenance, service and process support infrastructures are not normally configured to serve large numbers of customers operating in diverse global areas. In addition, equipment design, production practices and factory capacity are also now struggling to keep pace with accelerating demand.

The key issue is that historically low sales volumes for PV panels have warranted reliance on bespoke equipment, built to special order. With the transition to a high-volume global market, capital equipment suppliers must make use of more modern techniques, including basing machine designs on standardized functional blocks and modular construction techniques to meet customer requirements more quickly and at lower overall cost. Historically, a lead-time of some eight months has been the norm among equipment suppliers. This is set to reduce dramatically, to around 12 weeks and shorter.

As an example of how equipment design is changing from the ground up to address the revolution going on in the PV cell market, the DEK PVP1200 machine is built around a common control platform shared with its surfacemount and semiconductor-packaging equipment. This allows new customer orders to be fulfilled rapidly, and also helps ensure a cost-effective solution. In addition, the company operates manufacturing sites in Europe and China, and is therefore able to supply local markets quickly and efficiently. For PV array manufacturers, this reduces lead-times for machine delivery, ensures higher quality and reliability,

and also improves maintenance and the supply of spare parts.

Already some established suppliers to the PV industry are struggling to satisfy their existing customer bases. To succeed in the future, PV cell producers will require the levels of support and attention currently enjoyed by manufacturers of PCs, cellphones, gaming terminals, telecom equipment and other high-volume electronic products. These are the types of customers that major suppliers in the SMT industry, including DEK, have successfully supported for the past few decades, delivering total solutions for surface-mount assembly.

Forward-looking strategy
Solar energy appears to have come of age. Valuable help has come in the form of effective government incentives for consumers, as well as public pressure on businesses to adopt greener energy policies. Sales of PV panels are increasing rapidly, and continued strong acceleration is expected in markets spanning Asian, American, European and African territories.

This represents a tremendous opportunity for suppliers of PV products, including established manufacturers and new market entrants. But many equipment suppliers are not prepared for the increased technical, logistical and customer-support demands that this emerging age will impose. For manufacturers seeking a leading position going forward, selecting a technology partner with a credible roadmap and suitable support infrastructure will be critical to achieving success.

India and China recording fastest growth

PV manufacturers in emerging economies are particularly well placed to benefit from the market's low barriers-to-entry and the relatively straightforward solar cell technology. Capacity is growing faster in India and China than in other areas. Germany, for example, has the highest total PV manufacturing capacity, but growth is slower than in Asia. Currently there are an estimated 50+ companies producing PV cells in China alone, including indigenous businesses and foreign investors.

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Figure 1

Industry demands accelerate

As consumer demand for solar panels increases, the PV industry's requirements on resolution, repeatability, flexibility and high-speed throughput are now expected to increase more quickly than at any time in the past. Increasingly, manufacturing businesses will need to ensure that their partners are able to deliver solutions that not only meet current technical requirements but also help them scale capacity quickly and easily in response to rapid developments in the market.

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