Developments in high throughput integrated cell connection equipment

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ABSTRACT

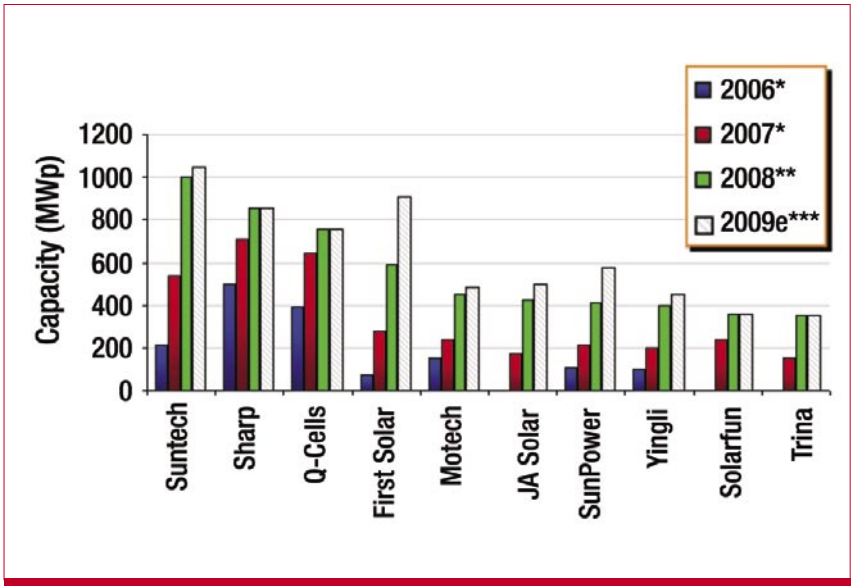
The rapid expansion of high volume manufacturing to meet growing demand in recent years has highlighted the development of increasingly higher throughput machines. This is particularly true in the critical bottleneck process of module assembly, specifically characterised by tabbing and stringing steps. Significant productivity improvements have come about with the development of integrated, highly-automated tabbers and stringers from a range of equipment vendors. However, module assembly remains the most expensive step in conventional c-Si cell production. Equipment suppliers are also challenged to meet the evolving demands of processing thinner wafers and to address overall production cost reduction strategies while meeting yield/throughput goals that are seen as a significant enabler of reducing the cost per watt. This paper provides an insight to the tabbing and stringing processes featuring contributions from some of the major equipment suppliers.

Cell and module production has grown rapidly over the last four years as existing major PV manufacturers have scaled production. New entrants have benefited from low interest finance for jump-starting large-scale production and become cost competitive with larger manufacturers. Not only have the number of new production facilities grown significantly, grid parity goals have driven PV manufacturers to build and operate facilities on an ever-increasing scale.

As can be seen in Figure 1, Suntech, Sharp and Q-Cells are approaching 1GW nominal capacity levels, with other major manufacturers nearing 500MW nominal capacity. Interestingly, the market share of the top 10 manufacturers is declining as new entrants rapidly expand production. According to VLSI Research, the top 10 had a combined market share of 40.1% in 2006, a figure that is expected to decline to only 29.1% by the end of 2009. The market for tabbers and stringers used in PV module assembly grew by over 60% in 2008 to reach a value just over US$200 million, 80% of which is for silicon wafers, the remainder for thin-film and other PV cell technologies.

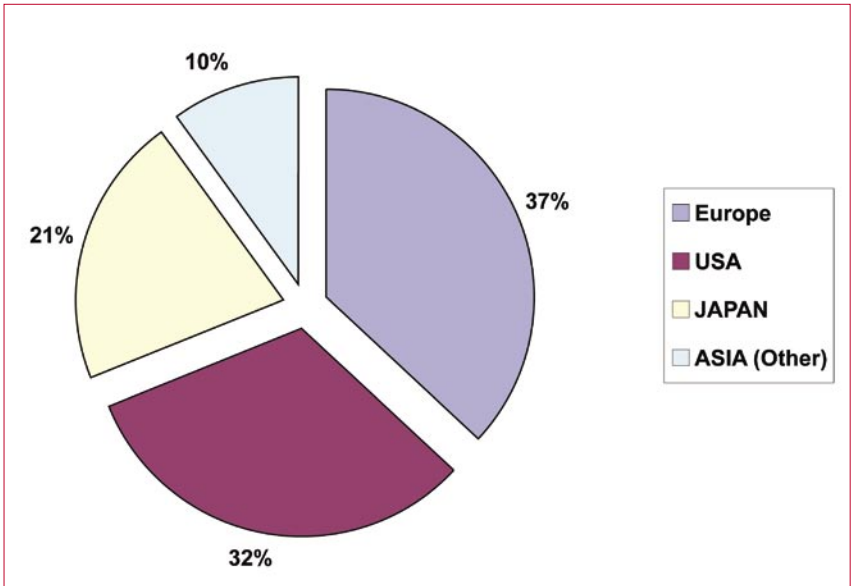
The market is highly fragmented, says John West, Managing Director of VLSI Research Europe. There are over 20 companies supplying equipment capable of connecting solar cells, with the top five companies accounting for 50% of the hotly contested market. The key players in 2008 were 3s Industries, Komax, NPC Corporation and Spire Corporation.

Rapid capacity expansions have quickly led to a need for highly automated and combined tabber/stringer systems (CTS) that can also provide high throughput. As throughput is determined by the amount of wafers that can be processed per hour, a key focus for equipment suppliers is the speed of the systems, a major factor in reducing manufacturing costs.



Source: VLSI Research, 2009.

Figure 1. Top 10 PV manufacturers by revenue.



Source: VLSI Research, 2009.

Figure 2. Combined Tabber/Stringer (CTS) equipment suppliers by region.

However, many of the yield losses encountered in cell processing are found during cell interconnection and therefore impact overall module performance. Electrical and optical losses are introduced at the module assembly stage and can impact typical multicrystalline H-pattern cells' performance by as much as 2.5% [1].

A recent study by CrystalClear [2] calculated that in the production of a typical silicon wafer (multicrystalline, 156x156mm^2, 220µm thickness), the cost of the module alone was €0.67 per Wp.

The study, which started in 2004, found that crystalline silicon PV technology has the potential to reach module manufacturing costs of around €1 per Wp within approximately five years. Efficient silicon utilisation (g/Wp module power), high total area module efficiency, high throughput and high-yield production are factors that will need close monitoring to achieve such a cost in the given timeframe.

High throughput

In a sample survey of some of the leading CTS equipment suppliers, including Spire Corp., Mondragon, Somont and teamtechnik, respondents reiterated that high throughput of their systems continued to be a key customer requirement, especially for high volume manufacturers. teamtechnik's Michael Bay noted that the company's main customer base consists of high-volume PV producers, who tend to assess equipment throughput data in great detail prior to purchasing.

"For high volumes we offer and sell our TT1200, which can run at a cycle time of 3 seconds, or 1200 cycles per hour. At a string of 10 cells, this would mean an output of 1090 cells per hour," noted Bay.

Another leading equipment supplier, Mondragon is well known for its high throughput systems. Mondragon's Xabier Otano noted that throughput had become a key customer concern, and in response developed its TS1200 machine, capable of achieving 1,200 six-inch cells per hour and 1,300 five-inch cells per hour. The company has also seen sales of its TS2400, which provides double the throughput and is essentially two of its TS1200 machines combined.

But Otano cautioned that high throughput is not the sole requirement of customers, and that the contrary is sometimes the case. "On the other hand we are seeing companies that prefer having more machines with lower throughput in order to be able to have parallel production," Otano explained.

Matthias Ruh, SOMONT's head of sales, was another proponent of the importance of looking at other factors that affect purchasing decisions, commenting that "as high throughput at low breakage rates and very good soldering results decide on the profitability, there is a clear trend towards high output. This is key even if you want to install a smaller line for, let's say, a 10MW or a 100MW facility."

SOMONT has developed a high-throughput modular platform, dubbed 'RAPID,' which is suitable for 10MW, 20MW and 40MW (and higher) lines. This corresponds to production rates of 600, 1,200 and 2,400 (and more) cells per hour, respectively, on 10 x 6" cells/string.

By using this modular concept, a smaller production for modules of, for example, 10MW can work with the 'RAPID ONE,' a single soldering line system that has a capacity up to 600 cells per hour. The base version of this system comes with a string phase-out belt. Very large facilities would tend to order, for example, three 'RAPID FOUR' stringers in order to reach capacity of 120MW.

Figure 3. SOMONT's CTS equipment manufacturing facility.

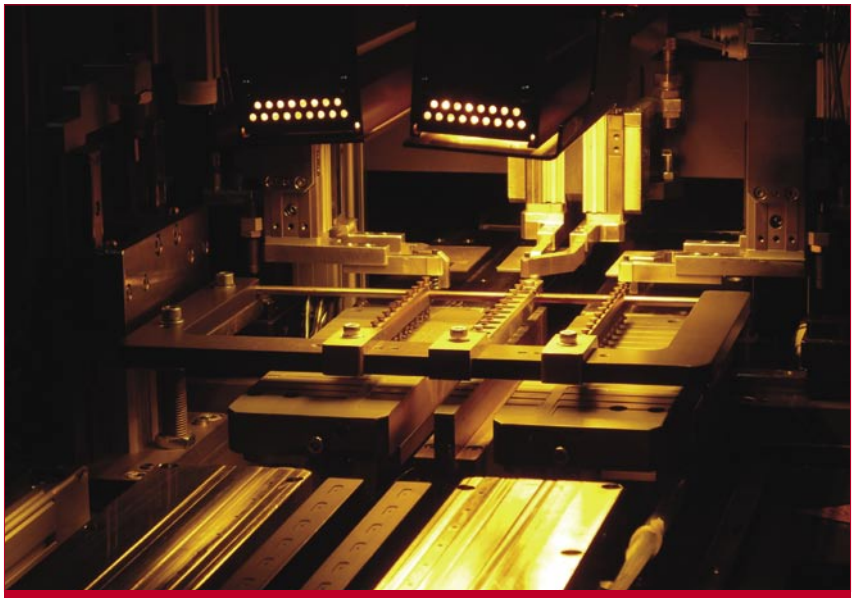


Figure 4. Mondragon preheating station, soldering station and cell holding elements.

Flexibility

David Wissoker of Spire Corp. noted that another key requirement of PV manufacturers is an inbuilt level of flexibility in the CTS.

"Versatility of the system is important," explained Wissoker. "Cells come in different sizes – two or three bus bars – and the equipment lasts for over 10 years so it should accept a variety of cells."

teamtechnik's Michael Bay confirmed the importance of flexibility.

"From our point of view, the key is flexibility regarding material such as new cell types and combinations with new ribbons or flux material. There we have the best possible solution with our laser soldering. Our customers also say that this is the best possible soldering tool for future applications," noted Bay.

Currently, teamtechnik also offers IR lamp soldering technologies (other than laser-based technologies) that can be integrated into its modular machine concept. Nevertheless, the company believes that IR has limited variability as it can only be turned on or off, and sees laser soldering as the technology of the future as it is widely regarded as being much more flexible, allowing the operator to alter the depth, strength and position of the solder beam.

Spire also offers IR lamp soldering for both front- and back-cell contacts in a single step on its Spi-Assembler 6000, addressing another aspect of CTS customers' requirements for platform flexibility.

SOMONT uses a 'soft touch' soldering process for use with very thin cells that can be handled at high productivity rates. The system has a temperature management feature that reduces thermal stress for the cells to a minimum, at the same time guaranteeing quality soldering joints. Refined lay-up stations have been developed for onward string handling.

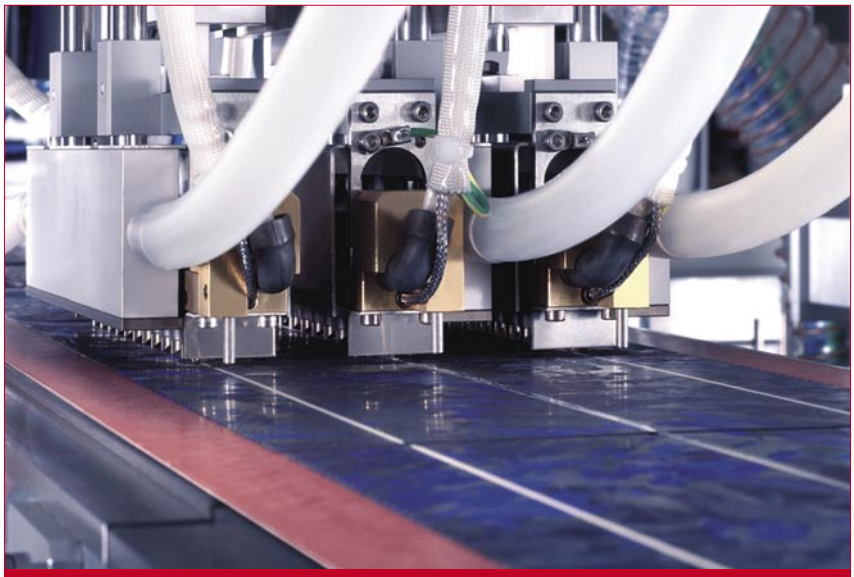


Figure 6. SOMONT's 'soft touch' soldering technology.

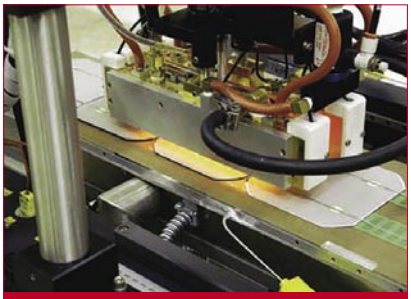


Figure 5. Spire offers single-step IR lamp soldering for both front- and back-cell contacts.

SOMONT's Ruh also stressed the need to have CTS systems capable of handling two and three bus bars, while making the switchover as simple and as fast as possible to improve the overall flexibility of the system, even in high volume environments where changeovers may not be so common.

Mondragon's Otano was also quick to emphasise fast changeovers, as this allows greater flexibility for customers' module designs, something that is becoming increasingly important in the highly competitive marketplace.

"Flexibility is one of the key criteria that our customers are seeking. In the solar market lots of the modules are very similar from one to another. Having a difference in the module design enables our clients to have a different product. Our machine has been developed from the beginning to ensure a quick change on module design, being able to produce very different modules on size and shapes, with a complete variety of personalized parameters (number of cells on string, gap between cells, length of ribbon, gap between strings, angle of the strings on the glass (for BIPV),...), with just the change of recipe on the machine HMI," remarked Otano.

Yield

Throughput and flexibility requirements of CTS systems may have rightly gained more attention from PV manufacturers in recent years. However, suppliers are now being expected to meet the evolving demands of processing thinner wafers.

Although significant declines in polysilicon prices are anticipated as more production comes on-stream over the next few years, the wafer material remains a significant fixed cost. As a result, PV manufacturers are expected to keep wafer cost reduction strategies focussed on the migration to thinner and thinner wafers.

But this approach can lead to higher breakages, both during handling between processing steps but also at the CTS, which generates both mechanical and thermal stresses on the cells. Developments are ongoing to keep breakage at current low levels (approximately 0.5%) when processing 200–220-micron thick wafers in high volume production.

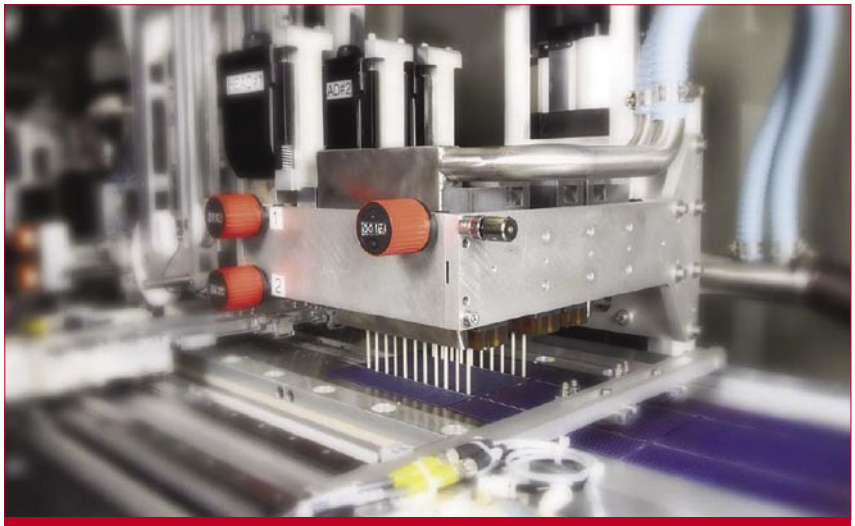


Figure 7. Komax's innovative solder head system.

teamtechnik noted ongoing developments that reduced the number of handling steps as well as minimisation of stress during processes to limit damaged cells. Camera systems that sort out any defective cells from the start are used in the CTS processes. But, as soldering thin cells has become problematic, greater use of tight temperature control in a closed loop environment has become a must, and is now another reason for using lasers over IR lamps, according to teamtechnik.

It stands to reason that poor or faulty contacts are another yield limiter. All of the major CTS suppliers have tackled this fundamental issue, with many new innovations. The Komax Xcell 3400, for example, employs an innovative solder head that uses non-metallic ceramic hold-down pins and non-contact closed-loop thermal feedback to tackle solder bond consistency and quality. Komax also employs a spray fluxing technique, which it claims will accurately apply the exact amount of flux to the top and/or bottom of the cell for correct soldering.

As with the other CTS suppliers, SOMONT took note of technologies that limited yield losses, while highlighting the yield loss potential from material quality, whether at the cell or with different types of ribbon used. The company also emphasised operator training and ease of use of the CTS operating systems as an important contributor to yield, noting that even operators in the most remote locations must be able to work with the systems. The menus for operation must be logical and easy to understand, and in case of a problem the operator must be able to be self-sufficient to retain throughput of the line.

"For this purpose SOMONT offers extensive training and support in our Service & Technology Center (STC) which went operational early this year. The personnel of our customers get a comprehensive training on a full-scale production line," noted Ruh.

Future developments

Driven by new cell designs and thinner wafers, CTS equipment is continuing to adapt to customer needs. The need for flexibility has seen the emergence of lasers for solder bonding though throughput remains a critical factor. Development is ongoing to improve the laser changeover times and shorten refilling cycles to push throughput of this type of technology, as noted by teamtechnik.

Matthias Ruh commented on how improvements in lay-up, cell testers and string testers are ongoing. Elements such as vision control, easy line integration and the corresponding standardised interfacing are being implemented as part of the company's continuous improvement programme based on customer feedback.

Generally, there seems to be a growing demand for Advanced Process Control (APC) capabilities on CTS machines as understanding and consideration of cost of ownership evolves.

"The outlook for 2009 is uncertain, but based on current order backlogs and capex plans of module manufacturers, sales of tabbers and stringers should be at levels comparable to 2008," remarked John West at VLSI Research.

Continued innovation and focus on throughput while lowering cost of ownership has become a key part of the CTS market. Dedication to this cause will be required in the coming years to enable reductions in cost per watt to meet and then exceed grid parity.

References

[1] Späth, M. et al 2008, ECN Solar Energy, *First Experiments on Module Assembly Line using Back Contact Solar Cells*, 23rd European Photovoltaic Solar Energy Conference.

[2] Sinke, W.C. et al 2008, ECN Solar Energy, *CrystalClear*, 23rd European Photovoltaic Solar Energy Conference.