Cutting through with cell technology

Despite the promising market outlook for solar energy due to the increasing global demand for alternative energy, PV manufacturers face numerous challenges. They must strive to lower their production costs while enhancing the efficiency and quality of their solutions. To keep ahead of the stiff competition, market players are poised to adapt their technology to constantly changing needs.

Both silicon raw materials and wafers are affected by exploding costs, with silicon wafer prices in particular a key factor for PV modules. Rising costs for their raw materials are the driving force behind the trend towards large-sized silicon wafers, which allow for lower production costs. In 2021, 166mm and 182mm silicon wafers became a common size in the market. 182mm and 210mm-sized cells are expected to become the major segments in the near future.

Improving module efficiency is an effective tool for reducing module prices. Many manufacturers have introduced different component solder stacking techniques in recent years. By applying this technology, the currently common values for spacing between the cells have been reduced from 2-5mm to 2-0.5 mm.

This change decreases the redundant area of the cells while improving the efficiency of the modules as the gaps between the cells in the modules are enabled to generate electricity, and reduce the power density and electricity costs.

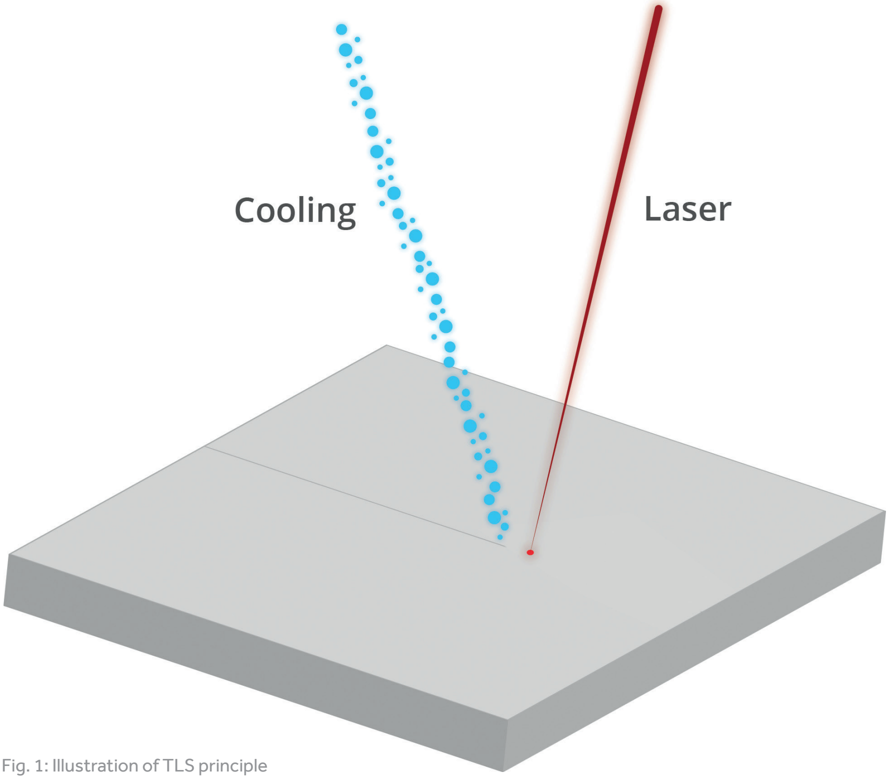

Fig. 1: Illustration of TLS principle

Cell cutting fueling recent advances in PV manufacturing

In recent years, cutting solar cells into half cells has become a key strategy for PV manufacturing by enabling remarkable gains in power output and mechanical strength at the module level. This trend has been accompanied by the switch to larger full-cell formats and the related increase in module power ratings[1].

Cutting cells into half and third-cells or even shingles compensates for the increased power loss associated with the higher cell currents from larger wafer areas. Thus, ensuring that cell cutting remains at the heart of PV manufacturing for the foreseeable future.

Cutting layouts ranging from half- to shingled cells without compromising throughput or yield

TLS is a well-known process that came from the micro-electronics industry. The process

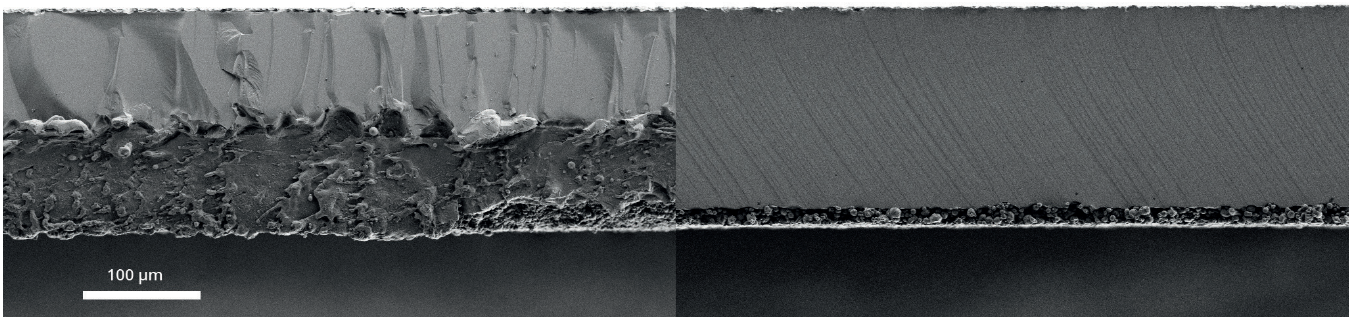

Fig. 2: Comparison of separation edges: left a laser-processed edge with subsequent breaking, right a TLS edge

is well established in cutting half-cells, working with leading manufacturers for many years.

The TLS process is a damage-free laser dicing technique for brittle materials such as silicon, silicon carbide, and gallium arsenide. It relies on the application of a defined and controlled stress field imposed by a laser-based heating and subsequent cooling. Thus, a crack is guided through the entire cell and two half-cells are obtained.

Because TLS is a cleaving process, an initial scribe, or I-scribe, is required to give the separation a well-defined starting point. However, this I-scribe is significantly smaller compared to conventional scribes for subsequent mechanical breaking. In fact, it is only a few micrometers deep, wide and long.

After this initial scribe, the substrate is heated locally by a laser and subsequently cooled down by a mist of DI water. A stress field comprised of tensile and compressive stresses is generated by skillfully superimposing the heated and cooled area. There, a fissure can be introduced that is independent of any possible grain boundaries or preferred breakage directions.

Advantages of TLS for cell separation

Compared to conventional separation technologies, TLS impresses with its clean, micro-crack-free edges. No crystal damage occurs on the separation edge, damage which is otherwise common to date due to the displacement of re-solidified silicon in the ablation region.

As opposed to laser cutting, no bulging and no formation of particles occur, because the substrate is merely heated and not vaporized. The mechanical stability of TLS processed solar cells is significantly greater than conventionally processed solar cells. The process leaves no residue.

This leads to a significant higher module power gain of at least 2W and less module power degradation. The innovative cooling process enables a faster temperature take-out than any other process which leads to best results on silicon layers and further temperature sensitive coatings or depositions.

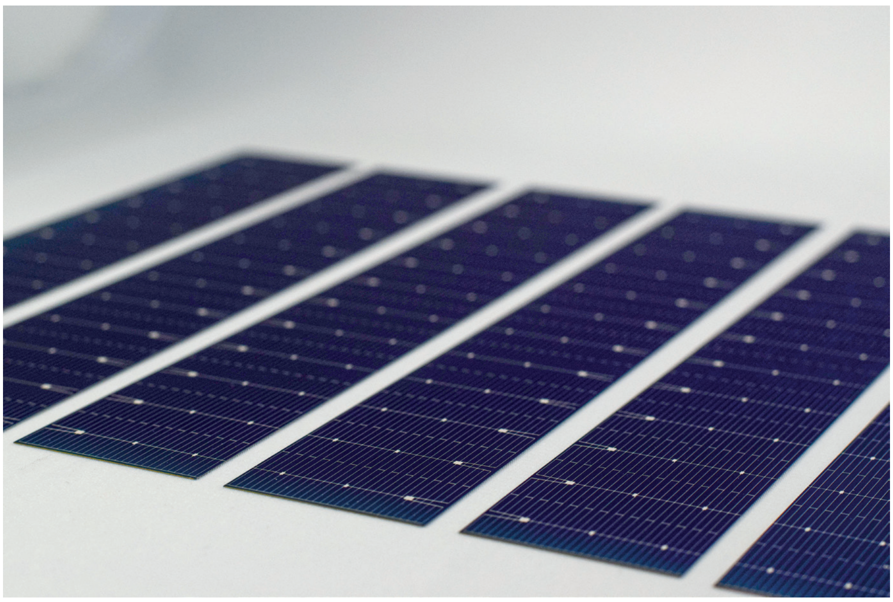

Fig. 3: The enhanced contour-to-area-ratio of ever-smaller cell strips makes the edge quality a crucial factor in choosing the right cutting technology

Current industry-standard modules with cut cells are produced with a half-cell layout which requires a cut in the middle of the cell. In this layout the modules benefit from a higher efficiency. By using TLS the electrical characteristics are further optimized. The separated cells have up to 40 percent higher mechanical strength compared to ablative laser processes and enable a lower power degradation over the solar module's life cycle.

With the next generation of modules, the so-called shingling modules, the benefits of TLS cut cells are gaining momentum. Shingling modules not only guarantee an even higher efficiency and module power output compared to half-cell modules, but are especially interesting for rooftop applications due to their aesthetic look. However, a shingling module architecture requires the cells to be cut in multiple strips.

One cut is needed for half-cell modules and up to five cuts for shingling modules. By increasing the number of cuts, the contour-to-area-ratio is enhanced at the same time. This affects both the mechanical and electrical characteristics of the separated cell stripes. In general, this results in higher recombination losses at the cutting edge of the solar cell.

Therefore, the effects of the cutting technology are more significant when the number of cell cuts rise. Due to the perfect edge quality resulting from the TLS process, the edge recombination is significantly reduced compared to laser scribe and break processes[2].

In addition, applying a post-metallization process, also referred to as 'edge passivation', can further reduce the recombination losses at the cutting edge and may therefore be an ideal solution for the shingling concept for highest performance increase.

Results from Fraunhofer ISE's patented Passivated Edge Technology (PET) on TLS cut cells show that TLS separated shingle strips can regain half the loss that is induced

Fig 4: The new microcell MCS laser cutting system by 3D-Micromac. The new tool enables highest throughputs of more than 6,000 wafers per hour by using TLS

due to separation with an increase in pFF of up to +0.7%abs. This gives TLS a clear advantage in comparison to the laser scribe and break approach.

Furthermore, it proves that a low damage separation process with smooth edges such as TLS is required to completely benefit from the advanced edge passivation process. The Fraunhofer ISE Passivated Edge Technology consists of aluminium oxide deposition with a subsequent annealing process[3].

Advanced laser machines and services

A few months ago, 3D-Micromac completely redesigned its existing cell cutting system, which had been introduced to the market as far back as 2016 and has been a major success story since then. However, the tool was limited to doing one single cut on PV cells. Due to the changing market requirements, customers are longing for more flexibility: the option to cut cells into three or more pieces without compromising throughput is becoming a major requirement.

With this in mind, 3D-Micromacs engineers have developed a future proven machine that was introduced by the company as microCELL MCS in autumn 2021. The microcell MCS is a very flexible platform, allowing customers to perform half-cell, third-cell, even shingled cell cutting while keeping throughput at more than 6,000 wph, independently of host wafer sizes.

Two major advantages of the TLS process are the flexibility and reproducibility when it comes to switching between different cell types. The system is especially suitable for solar cells with temperature-sensitive coatings or depositions such as heterojunction technology (HJT) cells, TOPCon cells as well as perovskite tandem cells, which are expected for commercial use in three to four years.

The transition from one cell type to another only requires some parameter changes to the cutting process itself. These changes are minor and mainly recipe-driven, affecting only parameter settings such as laser power applied and cutting speed. Additional hardware or product upgrades are not required.

3D-Micromac operates its own fully equipped application lab staffed with experienced application and process engineers to provide support to customers in the development of new processes. Feasibility studies and the cutting of cells as contract manufacturing service are offered as well. This way, 3D-Micromac can show the potential of the TLS process for any cell technology. The company is able to support customers with contract manufacturing as a first step, and has been doing so successfully for many years.

In summary, increasing supply chain issues such as higher cost of raw materials in combination with changing market requirements alter the landscape of the PV industry. Especially with the shift to larger cell sizes such as M10 and M12 and the subsequent need to cut the cells in 2 or more pieces, the requirement for a high quality cell cutting process has become even more important.

3D-Micromac has cemented its technology leadership by adapting its innovative TLS cell cutting equipment to full flexibility, being able to cover 1/2-1/6 cut cells at the highest possible throughput and edge cutting quality. TLS has become the technology of choice within the industry and with the outlook of new tandem cell technologies emerging in the future, a non-destructive and low temperature TLS process will be of even higher importance.

www.3d-micromac.com

References

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