# On a roll with laser scribing

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With climate change a concern for many around the world, huge efforts have been made over the years to find and establish sources of energy other than burning coal and oil. Solar cells are one such alternative. While silicon-based solar cells have been around for a long time, new concepts focus on making flexible, light-weight products that can be applied in situations where the classic efficient but heavy and rigid Si-cells cannot.

One such approach is the CIGS solar cell, i.e. copper indium gallium selenide. This can be manufactured on flexible plastic films, as the absorbing layer is only a few microns thick, thus still being flexible. In fact, the technology for producing this kind of solar cell in a roll-to-roll (R2R) process has been in use for several years now. 3D-Micromac provided the first R2R tool for CIGS solar cell development back in 2015. Using web widths of up to 1.3m, the process has now reached a level of maturity that makes large-scale production a viable option.

In the production process of CIGS solar cells, there are a number of steps that are often performed using laser ablation. These process steps are usually referred to as P1, P2, P3 and P4.

P1 refers to the scribing of the bottom electrode, thus creating the overall layout of the final solar module. The P2 and P3 scribes are the scribes in the absorbing and the top electrode respectively, while the P4 scribe creates a full insulation at the edge of the module (fig.1).

## New challenges

In 2018, one of our clients, a renowned player in the PV industry, asked for help to improve the production capacity of its existing R2R laser tool from R&D level to a mass production tool. The customer had an all-in-one R2R tool made by 3D-Micromac in

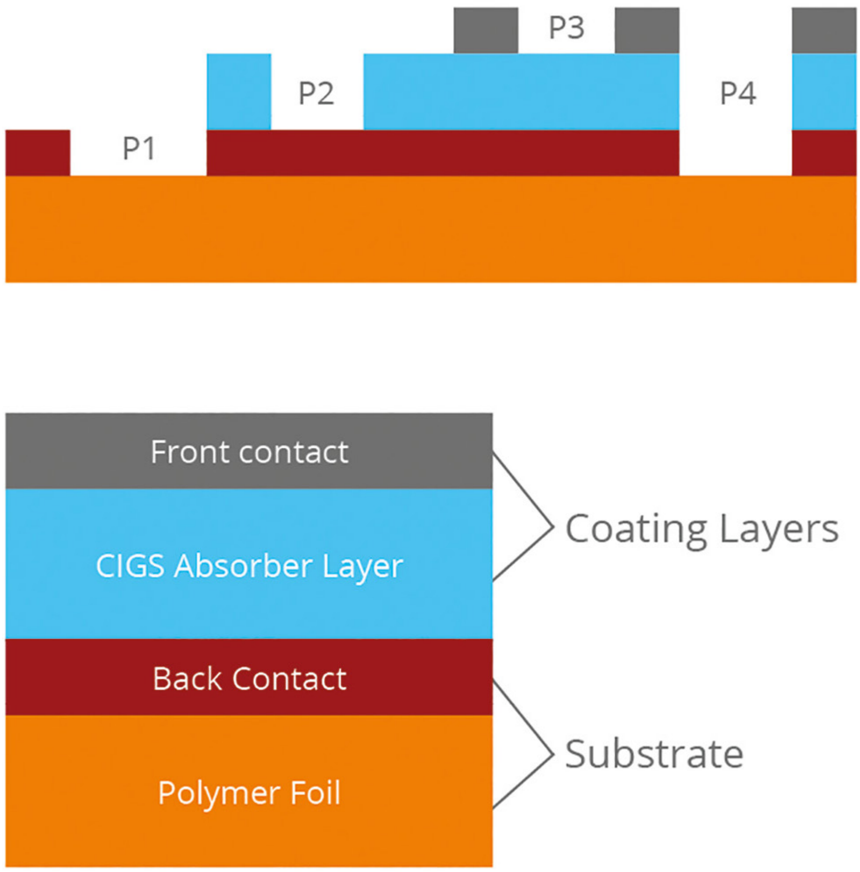


Fig. 1: Schematic of CIGS solar cell layers and laser scribes

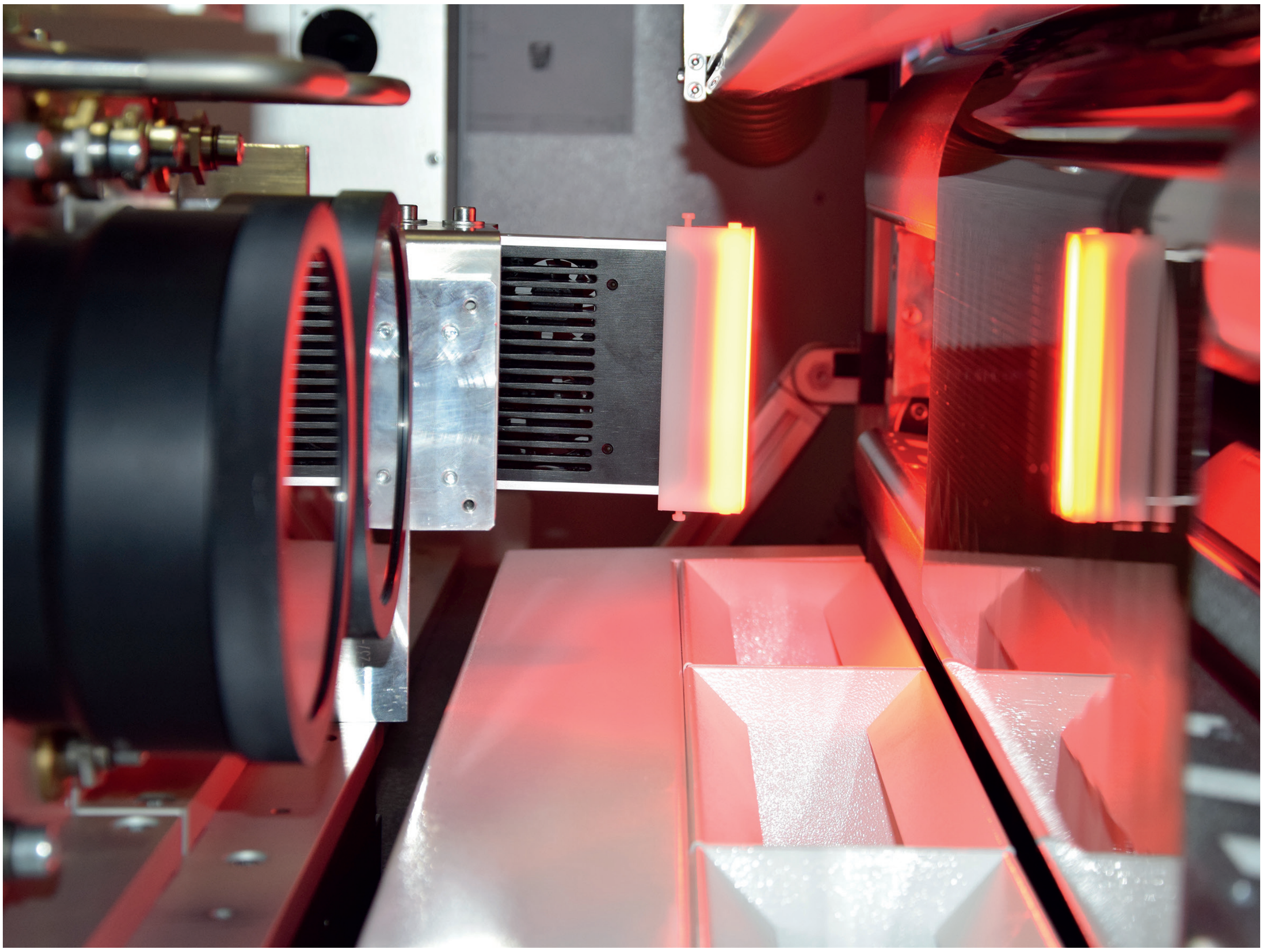

Fig 2. Transmitted light camera for the inspection of the thin film

2015. With this tool they were able to develop the necessary production processes and to run small-scale production necessary for market introduction purposes.

The task at hand now was to up-scale the existing R2R laser tool that was used in development and building the knowledge and understanding of the finer details of the processes. The overall goal was to increase production capacity from a small fab, R&D-level to a full-blown manufacturing plant.

Not only would this require multiple laser tools to keep up with incoming rolls of partially processed solar modules, but also each tool would have to handle increased throughput for each of the processes mentioned previously. The tools would be part of a larger manufacturing site, where tracking of individual rolls during production was the key to detecting production issues early on, thus keeping high levels of throughput and quality.

Previously, there was one R2R laser tool that would do all the processes in sequence. Through years of operating and tweaking the tool, the customer's engineers knew it inside out and could quickly react to deviations in the processes. In the new factory, many tools would work simultaneously and each would be required to reliably provide the same scribing results. At the same time, the tools should be simpler to operate than the previous R&D all-rounder tool.

## All new or back to the roots?

The dilemma at the beginning of the project was whether to keep the basic concept of the current R&D tool, or to go for a new line of dedicated tools. In favor of sticking to the existing design was the fact that the tool could do all required processes. The overall design proved to be robust and reliable.

However, there were also some drawbacks. For example, the large footprint and the limited throughput of the P2 process. The decision was made to design two new types of machines: one dedicated to P1 and P4, the other one dedicated to doing P2 and P3 simultaneously.

## The solution

As mentioned earlier, the existing tool could perform all necessary production steps, but had limited throughput, especially for the P2 process. Simply making it bigger would not be a viable solution, as this would have increased the already large footprint even further. The new tools would have to share the good characteristics of the R&D tool, while optimizing the throughput, footprint and ease of use.

The new tools operate in a step and repeat mode, similar to the previous tool. In this mode, the web is stepped forward and then fixed in position. Cameras detect the previous scribes and align the next set of scribes to the previous ones. Meanwhile, another set of cameras checks the previous scribes for width, separation distance and other characteristics: see Figure 2. Adjustments in camera setup, lighting and image processing greatly improved the detection rate and quality, especially for the notoriously hard to detect P2 and P3 scribes.

Fig. 3: Cross-web stage of P2/P3 tool with four scan heads and cameras

The laser scribes are carried out by galvanometer scanners moving on a cross-web axis across the width of the web. Complex algorithms optimize the interaction between the scanners and axis to achieve the maximum throughput for any given solar module layout. To speed up the P2 process, the P2/P3 tools now feature three beam paths for this process compared to the single beam path of the original R&D tool. (fig. 3)

As the P1 process is the first to create features on the previously plain surface, the P1/P4 tool also labels each individual solar module with a QR code, as well as a human readable label. Throughout the production process, these codes provide tracking information that is needed to see the current status of each roll of material and to detect possible issues along the production chain.

A major improvement in the new tools was the modification of the web path. In the previous tool, the web traveled in an enclosed canal low above the ground, so the operator could walk over the 1.3m wide web. However, experience had shown that despite the encapsulation, dust and particles still got onto the web, apparently induced by the vibrations caused by the operator stepping on the enclosure.

The new tool features a web path that is guided over the operator instead. This new arrangement also presented the possibility to place the rewinder and unwinder at the

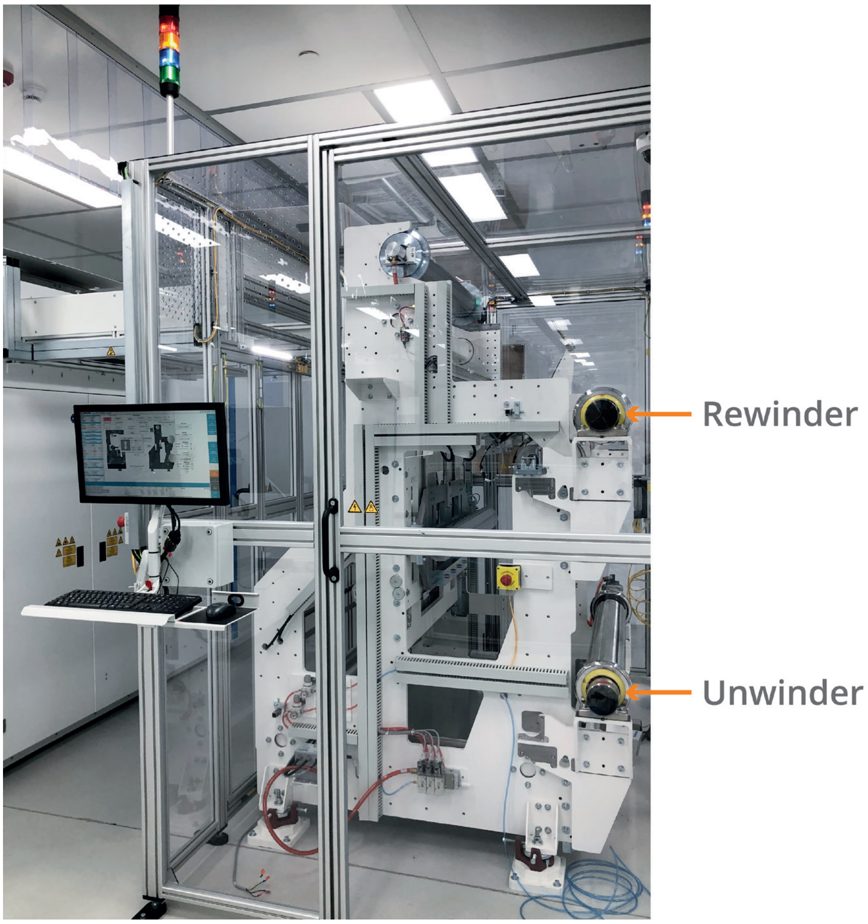


Fig. 4: Unwinder and rewinder are combined into one unit, allowing loading/unloading material from the same side; the integrated control panel is fully adjustable in angle and height


Fig. 5: The microFLEX laser system for CIGS solar cell structuring. For reasons of occupational safety, the access to the microFLEX is regulated via safety gate systems

same side of the tool (fig. 4), allowing for easier loading and unloading as well as a dramatically reduced footprint.

Though both machine types perform different processes, a major objective was to use common parts and assemblies across both types. This would reduce not only the maintenance cost and effort, and provide better component prices through bulk acquisition, but also make things easier for the operators through shared features, functionalities and operating concepts.

## Conclusion

The transition from an R&D/small-scale production setting to large-scale industrial production operation holds many challenges. The right solutions greatly improve the performance of the new production site.

In the context of this project, the right solution meant having dedicated machines for the process steps and optimizing each one based on the experience gained from the previous R&D machine. For the P1/P4 machines, the throughput was increased by nearly 30% compared to the previous R&D tool. For the P2/P3 machines, it was doubled by adding more lasers specifically for the P2 process. With all-in-all five new tools (two P1/P4, three P2/P3 tools), the total annual production capacity now is above 500,000 m² per year.

At this point in the factory's ramp-up phase, the laser tools have already proved to be reliable and more than up to the task of producing high-quality material for subsequent production steps in the factory.