rofin

LASERS FOR A SUNNY FUTURE

■ SOLAR POWER ■ LASER ■ ROFIN

WE
THINK
LASER

FOCUS ON FINE SOLUTIONS

ROFIN / Baasel Lasertech –
the headquarter
for micro applications

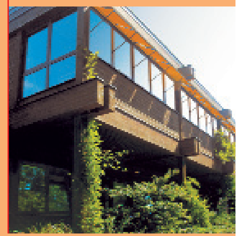
Innovative solutions are
the result of working closely
with our clients

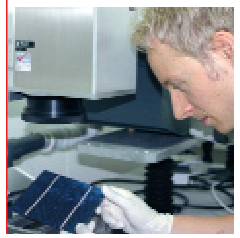
Competence in PV
application development
and lab equipment

17 production facilities
and local customer service
in 50 countries

Solar Power

The future today





Take advantage of our experience

Backed by over 30 years of experience in laser material processing ROFIN offers in-depth knowledge of every single laser application in solar cell manufacturing. For more than a decade now, we have been developing innovative solutions for drilling, cutting/scribing, ablation, edge isolation and marking of silicon wafers as well as thin film applications. ROFIN is putting great efforts in the further development of laser sources and laser process technology, like high-speed scribing based on galvo technology and wafer drilling, to name but a few examples.

ROFIN not only offers laser sources, beam systems and deflection units, but also control and automation engineering, software development including image recognition and processing, high-precision positioning systems and customized system engineering for lab workstations and pilot line equipment. Working closely with our clients and partners we have established great expertise for laser application in PV-manufacturing.

ROFIN is the only supplier worldwide offering a complete range of lasers for processing solar cells. Take advantage of our experience.

With a variety of CO_2, Nd:YAG, disc, diode and q-switch lasers, supplying wavelengths of 1064, 532 and 355 nm and pulse length ranging from picosecond to cw. ROFIN provides the world's widest range of lasers for almost every application. With headquarters in Hamburg (Germany) and Plymouth/Detroit and 25 subsidiaries worldwide, ROFIN is always close to their customers – we are where you are…

Q-switched Disc Laser for
high-speed processing

Laser with galvo head for
high flexibility

Fiber based picosecond laser
for finest thinfilm ablation

High power q-switched laser
for highest ablation rates

PowerLine E

From IR to UV with
highest beam quality

Laser concepts

The dominating sources used for PV-related processes are solid state lasers. This is due to the demand of simultaneously delivering high power, good beam quality, and maximum repetition rates, all of which are needed to realize high processing speeds together with high resolution. ROFIN offers the whole range of solid state laser concepts.

Diode-sidepumped and diode-endpumped solid state rod lasers contain a neodymium-doped rod made of YAG or Vanadate. A tried, tested and field-proven technology which is constantly being developed further.

Due to its exceptional material processing properties, especially the disc laser concept is gaining more and more acceptance in solar cell production The laser crystal is water-cooled from the rear side, causing only a one-dimensional temperature gradient. Compared to a rod, a disc laser offers significant higher beam quality.

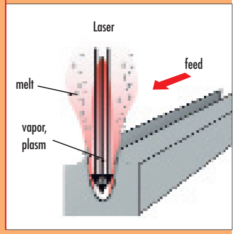
Fiber lasers feature high wall-plug efficiency, rugged and compact design and nearly maintenance-free operation. They are suitable for generating high average powers with good beam quality.

Picosecond lasers are ideal for ablation of very thin layers at a minimum of heat transfer into the material. They come with very high pulse frequencies and allow fast micro and nano processing in photovoltaic applications.

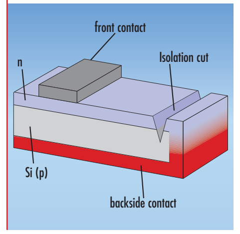
Laser Edge Isolation

Inline processing improves material flow

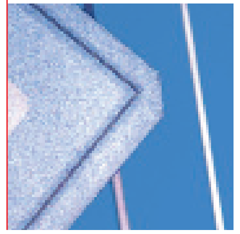
Laser engraving by vapor pressure-induced melt ejection



Edge isolation principal



Laser edge isolation – flexible and fast



Most robust and highly flexible direct part marking

Laser applications on mono- and polycrystalline solar cells

Ablation rates

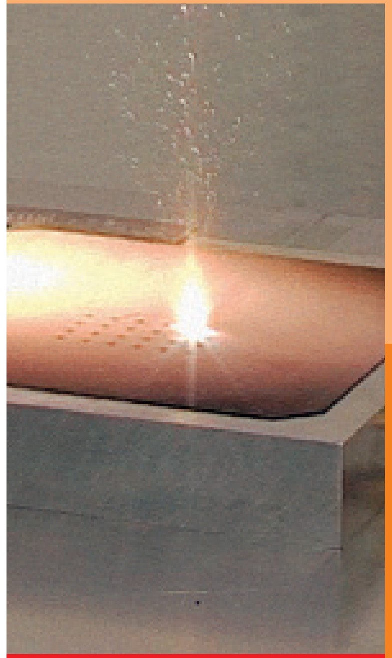
Processing mono and polycrystalline silicon wafers with high intensity, nano-second laser pulses, absorption always takes place on the surface. The material is ablated by vapor pressure-induced melt ejection. One of the most decisive parameters for the ablation depth is pulse duration. Tests have shown that for power densities well above ablation threshold (typ. 108 W/cm^2) scribing depth is nearly a linear function of pulse duration and wavelength play only a secondary role.

Edge isolation

The decisive factor for solar cell performance is the minimization of recom-bination possibilities. Front and rear side must be electrically isolated on the edges. The separation of p- or n-type layers is done by cutting trenches with qs-Nd:YAG or qs-Nd:Vanadate lasers on the front or on the rear side of the wafer. High power density is necessary in order to effectively eject the melt out of the kerf and to avoid re-deposition of the molten material. Compared to plasma etching, the benefit in production of laser scribing are higher yield due to less breakage in handling processes, and improved material flow by inline processing. Apart from that, there is no need for costly etching gases and their disposal. Compared to wet chemical edge isolation the laser process requires much less investment capital, is lower in running costs and the user doesn't have to deal with hazardous chemicals.

Marking

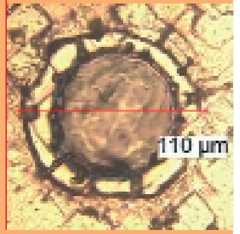
Like any other industrial product solar modules need to be marked and serialized ideally with lasers. The options range from direct marking the aluminum frame over marking labels which are placed under the glass up to glass marking of thin film modules. High end suppliers of crystalline solar cells also provide a serialization of the individual cell. Glass can be marked on the surface with CO_2 laser systems or inside the glass with SHG or THG lasers.



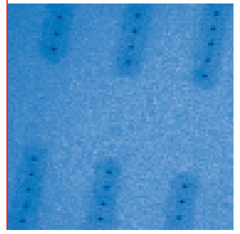
Laser drilling

Larger hole diameters require a relative movement between laser beam and wafer

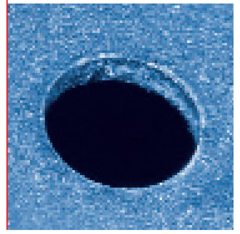
Laser fired contact



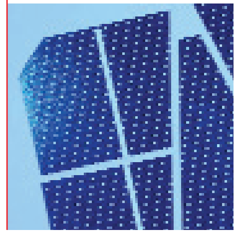
Percussion drilling – extremly high removal rates with processing speeds of up to 5000 holes / second



Whenever reverse contacting is needed, the laser drills the hole



The flexible way – cutting with the laser



Drilling of wafers

The efficiency of solar cells can be increased by eliminating the front side contact grids and bus bars, which would otherwise block quite a substantial amount of light. By means of EWT and MWT, electrical contacts of the front side are transferred to the reverse of the wafer. The realization of this process requires to drill holes of different sizes and numbers. Hole diameters from 50-100 µm are produced by percussion drilling. Larger hole diameters require a relative movement between laser beam and wafer (trepanning, cutting). Extremely high removal rates can be achieved with qs-disc lasers with very high TEM_{00}-average power. ROFIN's StarDisc, operates with up to now unmatched throughput rates, realizing processing speeds of up to 5000 holes/second for percussion drilling and up to 50 holes/second for trepanning.

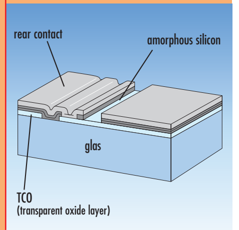
Cutting of wafers

Fast cutting of mono and polycrystalline silicon wafers can be conducted with very high precision and low heat input by using the same ablation process as for edge isolation and drilling. In the past, flash-lamp pumped Nd:YAG lasers were used to melt cut silicon in a single pass with a coaxial gas jet. Due to rapid cooling of the melt layer at the cut edge, micro cracks were formed. New approaches indicate that a multi-pass cutting process without assist gas gives a better surface quality at the edge. With a qs-disc laser, users can expect typical cutting speeds of up to 200 mm/s for a wafer thickness of 0.2 mm. Another approach and similar to a wafer saw is to scribe to a depth of 40-60% of the cross section. To separate the wafer, a subsequent snapping, either manual or fully-automated, is required. Advantage of this process is that the p-n junction on the front side is not being touched and compared to wafer saws the laser requires much less running cost. Typical scribing speeds are in the range of 300-700 mm/s.

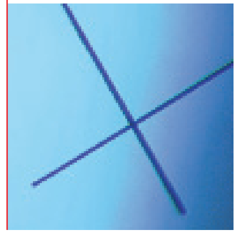
Contacting

An innovative way of contacting the backside of a c-Si wafer is the laser fired contact process (LFC). A thin Al layer is evaporated on the backside and contac-ted with 10-20.000 laser spots typically with a 1064 nm laser. Solar cells can be interconnected to modules by laser soldering or welding. Tiny strips of metal (stringers) are used to link cells together. The amount of heat induced in the stringer and the silicon can be accurately controlled with diode or YAG lasers.

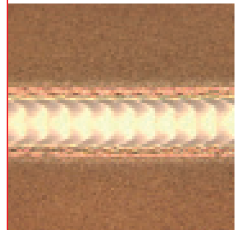
Structure of a thin film cell



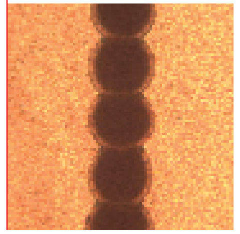
Galvo based thin film scribing – flexible and fast

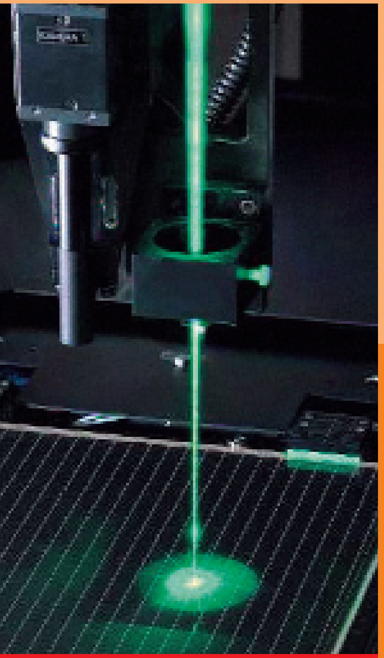


TCO scribing with high p-to-p stability lasers



P2/P3 scribing with 532 nm laser





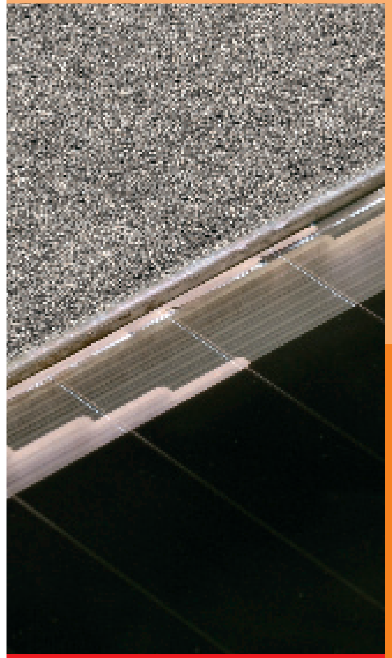
Selective ablation

Thin film ablation at research center Jülich

Laser applications on thin film solar cells

Scribing

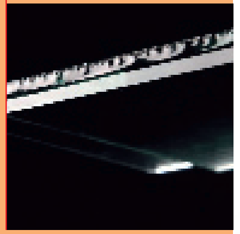
Thin film solar cells are produced through a sequence of vapor deposition and scribing processes called P1/2/3. Standard formats for thin film modules have been 600 x 1200, 1100 x 1300 and 2200 x 2600 mm up to date. The integrated circuits are generated between the different deposition steps by scribing of single layers to achieve electrical isolation and to serially connect individuals cells. The scribing can be done with scribing heads and linear axis or with galvo based technology or a combination of both. Galvo technology offers the possibility of extremely fast processing speeds, linear drives generally come with higher accuracy. Best beam quality lasers (TEM_{00}) with very high repetition rates of up to 200 kHz are used to ablate 20-60 Ìm wide lines at scribing speeds of up to 4000 mm/s, without damaging the glass substrate or layers underneath. Thus, Nd:Vanadate lasers with short ns-pulse duration (up to 60 ns) and very high pulse to pulse stability are the standard laser type for this kind of application. With some compromise also qs-fiber lasers can be used for TCO scribing. The optimum wavelength and pulse duration for the various processes depends on the type of layer. Fundamental (1064 nm) and second-harmonic (532 nm) wavelength are commonly used in the production of a-Si/µ-Si and CdS/CdTe solar cells. Mechanical scribing of thin film solar cells can only be found in CIS technology and picosecond laser are entering this application as well.



Edge deletion

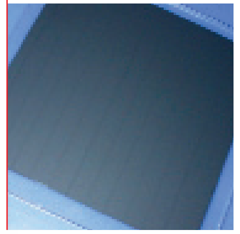
Thin film edge deletion with square spot in action

Two methods in comparison: the upper glass with a rough edge and micro cracks, was scribed and broken. The lower was laser cut and has a smooth and crackfree edge



Edge deletion on CIGS

Edge deletion on a-Si/µSi or CdTe modules



Even double layers can be cut. After lamination the laser provides perfect quality

Edge deletion

For electrical isolation and hermetic sealing of the module, the complete removal of all layers from the edges of fully processed thin film solar cells on glass substrates is required. In order to meet production requirements of a typical 40 MW p.a. manufacturing plant, removal rates have to be in the range of 20-50 cm^2/s. Here, the laser challenges conventional techniques, like sand blasting and grinding. Since standard TEM_{00}-lasers (like Nd:Vanadate lasers used for scribing) do not provide sufficient ablation rates for this application, especially developed high-power qs-lasers are applied. Those diode-pumped Nd:YAG lasers generate an average power of up to 850 Watt at 30 kHz which is guided through a 600 µm step-index fiber, in order to produce a homogenous, flat-top intensity profile. Typical ablation widths are between 0.7 and 1.5 mm at processing speeds of up to 6000 mm/s.
As the nature of the process is a shot by shot application a square spot geometry has the advantage, that the overlapping of several pulses is constant across the processing direction. Square homogeneous spots are offered by square fibers which have been introduced by ROFIN lately. Processing with square homogeneous spots from square fibers allows the optimization of removal applications. Overlapping of pulses is realized by a displacement of subsequent pulses less then one spot width.

Glass cutting

Flat glass is predominantly cut by scribing and breaking. However, this process produces splinters of glass fragments and micro-cracks along the separation line, which reduce the bending strength of glass substrates significantly. A new, patented process, called multiple laser beam absorption (MLBA) is based on the volume absorption through multiple reflection of laser radiation in the glass, using diode-pumped cw-YAG-lasers at the fundamental wavelength. This non-contact procedure produces premium quality edges, which provides increased firmness of the product. This procedure is applicable for coated glass, too, and several glasses can be separated in one processing step, without breaking.

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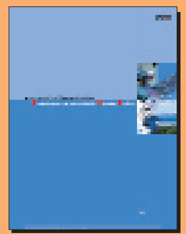
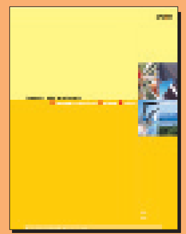
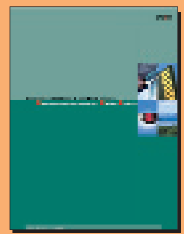


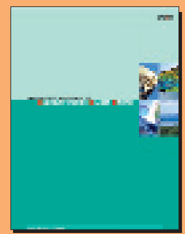
Medical Device Technology



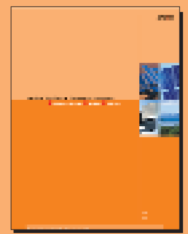
Flexible Packaging



Semiconductor



Jewelry



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SOLUTIONS FROM A SINGLE SOURCE

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