LASER ON SAPPHIRE: FOR THE NEW SUPER DISPLAYS

"Thermal" laser cutting and "cold" ablation enable efficient production of sapphire displays

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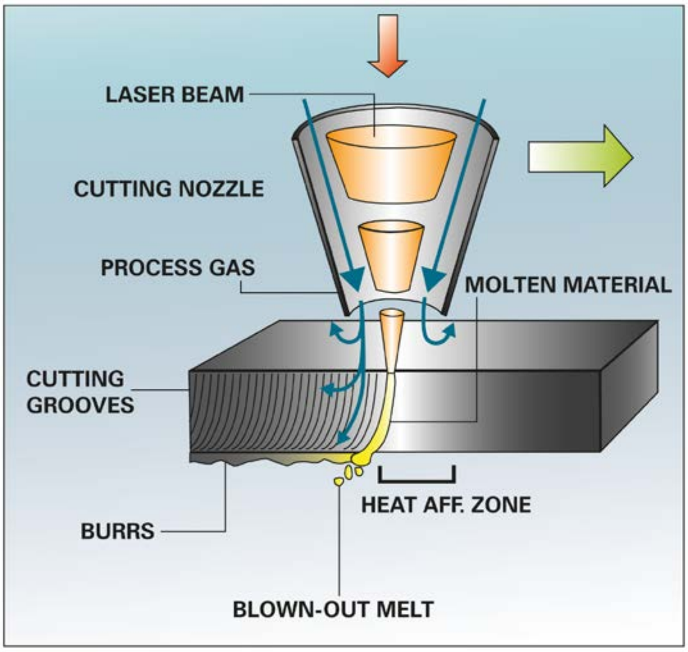
Sapphire is the material of the hour when it comes to cover glasses that are scratch and impact-resistant, yet flexible too. Having long been used for watch glasses or as cover or filter glasses for camera lenses, now it is increasingly being used for cell phone displays as well. Sapphire glass is made of colorless plates of synthetic corundum, i.e. minerals produced with molten aluminum oxide. In fact, sapphire glass is not strictly speaking a glass, as it does not have a glass-like amorphous structure, but rather a crystalline structure. With a hardness of 9 on the Mohs scale, sapphire is the second-hardest of all transparent materials after diamond.

With its particular properties, sapphire glass offers advantages over the chemically hardened glass often used in the display industry. Displays can be produced efficiently from the extremely brittle sapphire material, but only with the benefit of laser processing. The high-tech machine maker Manz from Reutlingen, Germany has developed two distinct processes for this, which have two quite different strengths depending on customer requirements: "Thermal" laser beam cutting with short pulse lasers in the microsecond range, and the "cold" ablation method for removing the sapphire substrate with ultra-short pulse lasers, which have pulse durations in a range of a few picoseconds. The latter offer a greater quality of cutting edges, but they are also more expensive than the fiber lasers required for "thermal" laser cutting of sapphire with up to 300 watts of mean output power.



Caption: With laser beam cutting of brittle materials the material is melted in the interaction zone and is removed from the cutting edge with support from the process gases.

No microcracks or chippings

"Thermal" laser cutting is well suited for cutting out the outer contours of cover glasses as well as for cutting inner contours, e.g. holes for cameras, LEDs, or loudspeakers. Typically the glass substrates have a thickness of up to a millimetre, and after cutting they are "polished down" to a final thickness ranging from 600 and 800 micrometres. In this case, the cutting action is a melting process: The glass substrate is melted through the introduction of energy to the interface, the melts are blown out from the interaction zone with a relatively high pressure. This way there are no residues of the cut material on the cutting edge that could harden again after cooling and diminish the edge quality. With "thermal" laser processing of sapphire, there are no micro cracks or chipping of the material. This increases break resistance and bend resistance in the material.

With the "thermal" cutting process, various inert gases are used: In this way the oxygen is eliminated, which also has a positive effect on the edge property. Depending on customer requirements, the parameters pulse duration, gas, pressure, speed, and process repetition – i.e. the number of "passages" – can be flexibly configured. The cutting results will vary. But the cutting edges have one thing in common: They all have a 90 degree angle.

The laser system designed by Manz uses up to four cutting heads simultaneously and thus four substrates can also be processed at the same time – and at cutting speeds of up to 50 millimetres per second. The actual operating time of the laser increases significantly with this sort of parallel operation and the throughput of this type of Manz system is substantially higher compared to other systems. The cutting head and substrate constantly move along orthogonal linear axes and this allows cutting of all two-dimensional geometries.

Caption: Multiple cutting heads in a laser system provide maximum throughput and an optimization of operating time.

Ultra-short pulse times for white edges

With "cold" ablation of the sapphire glass with a picosecond laser, the material being cut is not melted, but rather vaporized. This becomes possible because of the extremely short pulse duration and the resulting very high pulse peak output. The cutting head is permanently installed and no longer moves along a linear axis. The laser beam is diverted with a high-speed scanner. In addition, picosecond lasers are no longer fiber-based, as they are configured through free beam propagation using reflective mirrors.

With "cold" ablation with a picosecond laser, the quality of the cutting edge is even higher than with thermal laser beam cutting and there is less roughness of the edge. Although thermal cutting with higher throughput is possible, the resulting black interfaces still have to be painstakingly polished if necessary to meet quality requirements. It is precisely here that the main advantages of picosecond lasers really shine through: Though the process speed is somewhat lower than with "thermal" laser beam cutting, there is an instant improvement in terms of the quality of the resulting white cutting edge, along with less roughness. There is therefore less effort required for post-polishing, if it is necessary at all. The purchase costs for a picosecond laser are higher than a fiber laser. But in addition to the greater edge quality, such ultra-short pulse lasers have additional advantages that quickly make the higher price worthwhile: Interfaces produced with a picosecond laser can have an incline, or a "taper", of up to 10 degrees for example. This increases the breaking resistance of the finished displays. The variable-intensity material removal from the edge can be quite easily clarified for example using the Gaussian intensity distribution.

An additional specification often desired by customers which should improve the break resistance of displays is the chamfering of the interface – a partial chamfering of the cutting edge, e.g. to a material depth of 30 to 50 micrometres and a 45 degree angle. This form is likewise only possible with a picosecond laser – depending on the process parameter settings. Even coated sapphire substrates can be cut with picosecond lasers, as these only cause minimal damage to the surface. With the "thermal" process, a clean cut through the coated material is not possible, as there the surface is melted and the coating is thus destroyed.

For a long time, the efficient use of sapphire substrate, for example for cover glasses for smart phones, was not possible. Manz now offers its customers not one but two possible laser processes to lower manufacturing costs. Depending on the desired results, the customer therefore has the choice of which approach is more suitable for their particular needs.

Caption: Depending on the process selected, you can either choose a higher quality white cutting edge or a black edge with lower edge quality in laser cutting.