GERMANY

When Hardness Meets Precision: Innovative Machining of Technical Ceramics for Semiconductor Manufacturing

The handling of wafers for the semiconductor industry plays just as important a role in the quality of components as the actual machining process itself. Maximum precision and low wear are essential requirements here. High-performance ceramics such as silicon carbide (SiC), silicon nitride (SiN), and similar materials are ideal for this application thanks to their properties such as high fracture toughness and low thermal expansion. However, the advantages of these technical ceramics are accompanied by properties such as very high hardness or high strength, which make machining them very challenging. Alternative methods such as laser machining offer a solution here. Depending on the ceramic, material thickness, and geometry, various laser technologies are available to achieve the best possible processing results. LCP Laser-Cut-Processing GmbH offers many of these technologies in-house. This article focuses on water-jet-guided laser machining and its application to SiC and SiN.

Silicon carbide (SiC) and silicon nitride (SiN), as well as their variants, are materials that are very popular today. Their applications range from high-temperature applications such as the lining of steel furnaces and waste incineration plants to composite materials as components in gas turbines and other refractory products. Other areas of application include sealing rings, soot filters, and brake discs in the automotive industry, as well as structural and functional ceramics. The materials are also used in the electronics industry/power electronics, for example as SiC MOSFETs, diodes, and power modules for PV inverters, industrial drives, fast charging stations, wind power, and railway drives. As SiN substrates, they are carriers for SiC power modules or are used as SiC housing ceramics in high-temperature and high-voltage modules.

These materials are becoming increasingly important in the semiconductor industry owing to their properties: on the one hand, they are needed directly in chip production and, on the other hand, for manufacturing equipment. Examples include ceramic substrates, heating elements, holders, and wafer-handling components such as grippers, pins, and chucks/carriers. The materials owe their wide range of applications to their combination of special properties. Excellent oxidation and corrosion resistance, low density, and a low thermal expansion coefficient are combined with high thermal conductivity and very high hardness and strength. It is precisely this strength and hardness that make machining these two materials very challenging. For such materials, alternatives such as laser machining can be considered, or, as in this particular case, water-jet-guided laser machining.

Keywords:
precision laser machining of technical ceramics, SiC/SiN micro-machining, water-jet-guided laser (WJL), semiconductor manufacturing, high-performance ceramics

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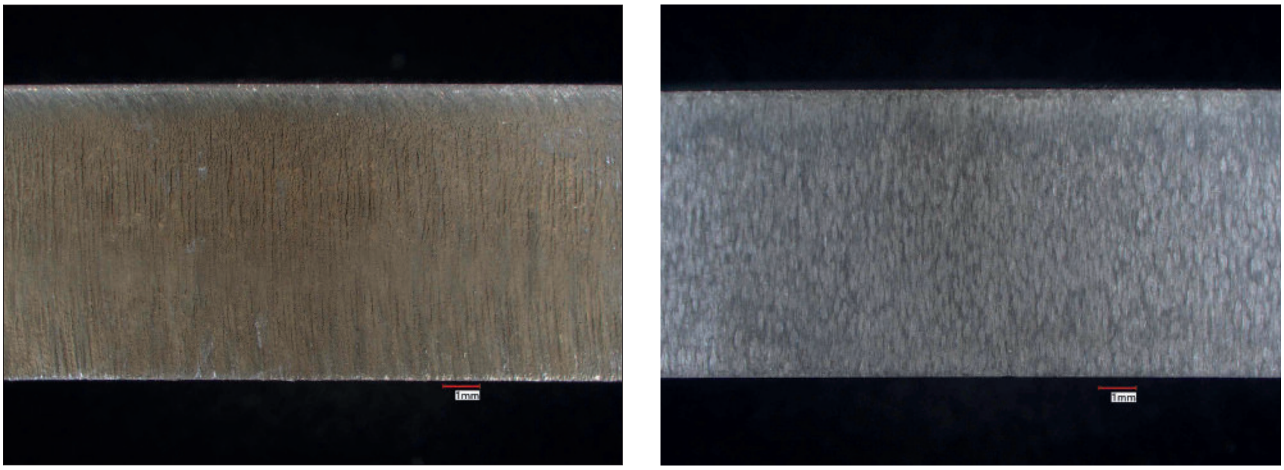

Fig. 1
Comparison between laser melting cutting (left image) and water-jet-guided laser technology at SiN with a material thickness of 7,8 mm (right image)

Water-jet-guided laser material processing
In water-jet-guided laser machining, a thin laminar water jet is generated into which a laser beam is guided. The laser beam is guided to the workpiece by multiple reflection at the inner edges of the water jet, as in an optical fibre. The laminar water jet, which is constant over several millimetres, ensures that the intensity of the laser beam is distributed evenly. The caustic effect that is otherwise typical for a laser beam is eliminated, and almost vertical cutting edge angles (deviation <1°) can be achieved. The water jet also cools the workpiece, reducing the thermal impact. This low thermal impact and the perpendicular cut edges mean that, in most cases, post-machining of the cut edges is unnecessary, in contrast to edges formed by means of conventional laser machining.
The cut gap is normally in the range of the water jet diameter, which can be varied between 30 and 100 µm using different nozzles. The cut gap remains constant over the entire processing length, allowing aspect ratios of over 100 : 1 to be achieved.

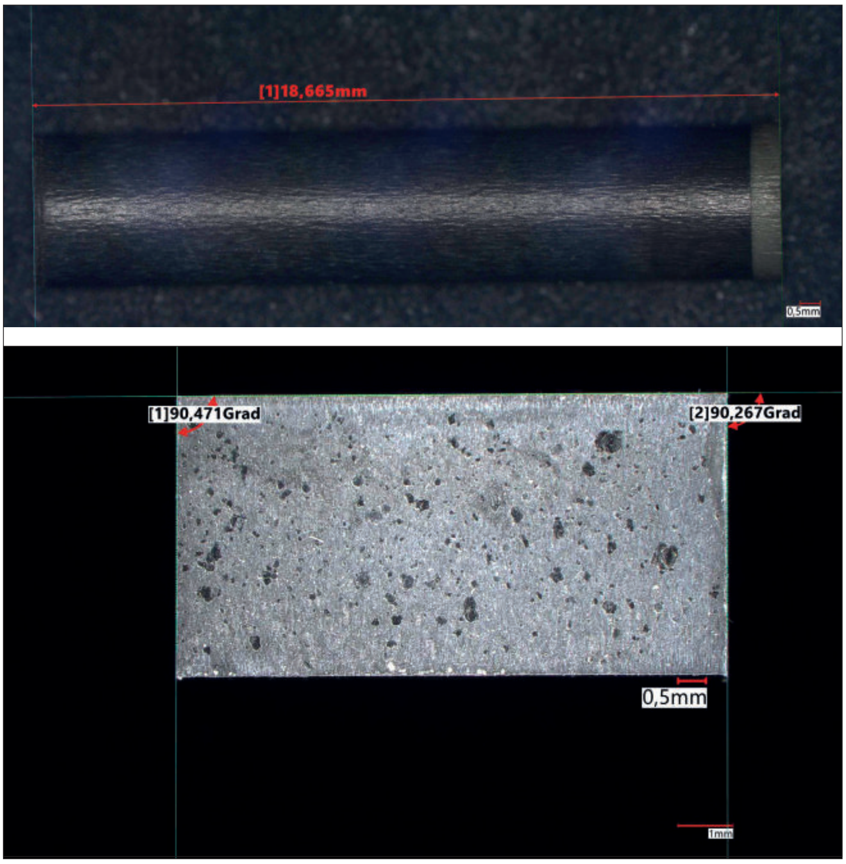

Fig. 2
Examples of vertical cutting edges. Top image: Drill core through 18,665 mm thick SiN with a calculated cutting edge angle of 89,83°. Bottom image: Cuboid made of 5 mm thick SSiC with an average cutting edge angle of 90,369°

Comparison with conventional laser cutting processes
A key difference between conventional laser fusion cutting and water-jet-guided technology is the basic mode of operation. In fusion cutting, the material is melted by the laser and pushed out of the cutting gap by a process gas. The cutting process usually takes place in a single pass. This can result in deposits on the cut edge or at the exit in the form of burrs. In contrast, in water-jet machining, the material is melted by laser pulses and thus removed. The material is removed upwards or to the sides. This process is repeated several times until the desired geometry is achieved.
Fig. 1 shows a comparison of a cut edge made by cutting through 7,8 mm thick SiN. The image on the left clearly shows de-

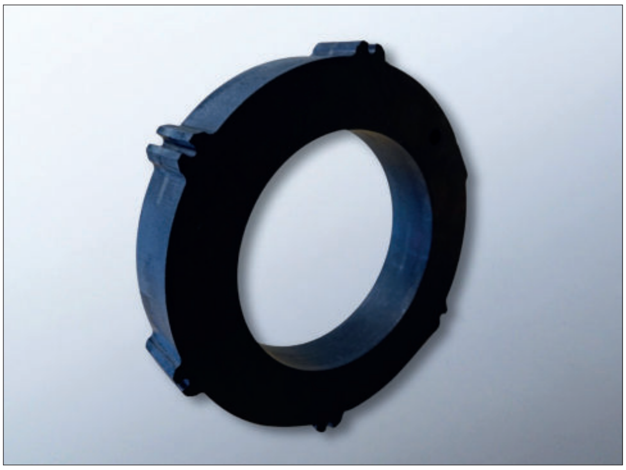

Fig. 3
Example components made of 7,8 mm SiN (left image) and 4 mm SSiC (right image)

posits and grooves on the cut edge. These would have to be removed by post-machining steps such as sandblasting or grinding. In comparison, the cut edge of the material cut with water-jet-guided laser technology does not require post-machining.

Laser material processing with vertical cutting edges

In contrast to the caustic effect that occurs with laser radiation when it is focused, water-jet-guided laser technology makes it possible to achieve a consistent intensity distribution of the laser radiation over several millimetres in the working area. In this way, vertical cut edges can be produced by means of laser machining. Fig. 2 shows examples of the results of machining 18,7 mm thick SiN (top image) and 5 mm thick SSiC (bottom image).

The drill core in Fig. 2 above has a measured cutting edge angle of 89,83°, and the cuboid in the lower image has an average cutting edge angle of 90,369°. These values may vary slightly depending on the material thickness, machined geometry, and material. Overall, cutting edge angles in the range of 90 ± 1° are achievable for both materials.

Water-jet-guided laser material processing – more than just cutting

Thanks to the ablative nature of the technology and the free-form programming that laser machining usually enables, even complex geometries can be produced reliably and repeatably. This is illustrated by the two examples in Fig. 3.

Fig. 3 on the left shows a flange made of 7,8 mm thick SiN. This technology allows complex geometries to be produced from hard, brittle materials without tool wear or tool changes. In addition, it is possible to machine workpieces over a large area, enabling the machining of pockets, blind holes, and similar features. With achievable tolerances of ±30 µm, the technology fits perfectly into the portfolio of LCP Laser-Cut-Processing GmbH as a service provider for sophisticated laser precision machining of special materials.