# Free-shape cutting of thin semiconductor wafers with Synova Laser MicroJet®

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In this paper we present the capabilities of the Synova Laser MicroJet® for free-shape cutting and compare the results for thin Silicon and GaAs wafers with UV laser cutting and fs laser ablation. Free-shape cutting of thin semiconductor materials is of great importance for various applications in microelectronics and medicine, where chips with arbitrary shape are used. The traditional cutting techniques suffer from limitations of different nature, while the flexible laser cutting inherits a strong thermal effect. Here we discuss our experience with the Laser MicroJet® free-shape cutting process.

## Introduction

Free-shape cutting, also known as free-form or arbitrary cutting, of thin semiconductor wafers has become increasingly important for various applications in microelectronics and medicine, in which chips with arbitrary shape are used. For example, multi project wafers, which contain T-junctions, round chips (high voltage diodes), complete electrical circuits on silicon (pacemakers), etc. The most used, improved and still strongly preferred saw dicing technique cannot provide the required flexibility and two-dimensional freedom. The abrasive jet, another traditional technique used for cutting materials when arbitrary shapes or inner contours are required, is also not applicable for thin wafers due to the mechanical force and stress. Lasers have the advantage of omni-directional cutting, better accuracy, and practically non-wearable parts. Laser induced etching [1,2] is a proved process technology for high accuracy laser fabrication of three-dimensional microstructures, but it is applied only for micro-mechanical components. The laser beam technology has an accuracy intermediate between etching and mechanical cutting, but has an inherently strong thermal effect. Due to the heat induced microcracks, the mechanical fracture strength of the chips cut with lasers is lower compared to the cut with saw, and therefore laser dicing did not find broad application in microelectronics. There are promising results for UV laser cutting [3] and femtosecond laser ablation [4,5], where the heating zone and the plasma absorption were reduced by using very short laser pulses and small wavelengths, but they are still in a research level and do not provide reasonable cutting speed.

Synova laser MicroJet® machines bring in action an innovative technology, which combines the advantages of the water jet cooling effect with the flexibility, high precision and speed of the laser cutting. We demonstrate here the capabilities of the Synova Laser MicroJet® for free-shape cutting of Silicon and GaAs wafers.

## Free-shape cutting with Synova Laser MicroJet®

Laser MicroJet® is the name of the water-jet guided laser beam technology given by its inventor Bernold Richerzhagen. The laser beam of a pulsed Nd:YAG laser is coupled in a tiny water jet and is guided to the working piece by means of total internal reflections like in a glass fibre. High quality diamond nozzle with a diameter of 40 to 150 μm forms a highly laminar low-pressure water jet (100 to 400 bar), which provides a nearly force free cutting. A detailed theoretical and experimental study of the process of laser grooving of composite materials with the aid of an off-axial water jet showed that a reduction of up to 70 percent of the heat-affected zone might be achieved when using a water jet [6]. The laser irradiation interacts with the matter during the action of the laser pulses (duration of 200 ns to 1 ms), while the water jet immediately cools and cleans the kerf between the pulses. Wafers with thickness less than 300 μm can be cut with a Q-switched Laser MicroJet® (average output 62 W) with a single pass. In such a case, the water jet takes almost all particles from the kerf and, as a result, a clean kerf with high quality is obtained. Compared to conventional laser cutting of silicon it is no longer necessary to protect the chips during the cutting process using a resistant paint layer that has to be stripped off after the cutting process. The main advantage of the technology being still the enhanced fracture strength of the structures compared to the conventional laser cutting. In fact, the fracture strength of the structures cut with the MicroJet® technology are as high as those obtained with the diamond saw in spite of the free-form capacity of the tool.

The cutting speed depends on the wafer thickness and material, layered structures, and the used laser parameters – energy per pulse and pulse repetition frequency and pulse duration. When dicing straight lines it might be as high as 120 mm/s for wafers with thickness of 100 μm, while in the case of arbitrary cutting it depends also on the contour shape and the size of the smallest elements, such as the radius of curvature and the angle of zig-zag lines. The diameter of the water jet determines the kerf width, and thus, the smallest elements that might be cut. For example, the smallest radius of curvature that might be still cut with high quality is equal to the diameter of the nozzle, i.e., the diameter of the water jet, and the diameter of the smallest circle is twice the diameter of the nozzle.

Figures 1-3 demonstrate the capabilities of the Laser MicroJet® for cutting of arbitrary contours on silicon (Figures 1 and 2) and GaAs/Ge wafers (Fig. 3) with thickness 100 μm and 180 μm, respectively. The scale shown on Fig. 1 is 1 mm, while on Fig. 2 is 0.1 mm. Figures 1a and 2 show the tiniest s-line (radius of curvature 60 μm) and hole (diameter 110 μm) that might be cut with a nozzle of 60 μm diameter. Fig. 4 illustrates some problems that appeared when the starting point for cutting is on the wafer and which might be eliminated with careful optimisation of the cutting parameters and the starting contour. The very first pulse coming immediately after the opening of the shutter is very strong bearing the most of the accumulated in the resonator energy and, when falls on the wafer, forms a crater. Due to this effect and problems of the water evacuation in sack-holes, the machine tool is much more adapted for cutting and trepanning style drilling than for stable drilling. However, stable drilling is also possible for very thin samples.

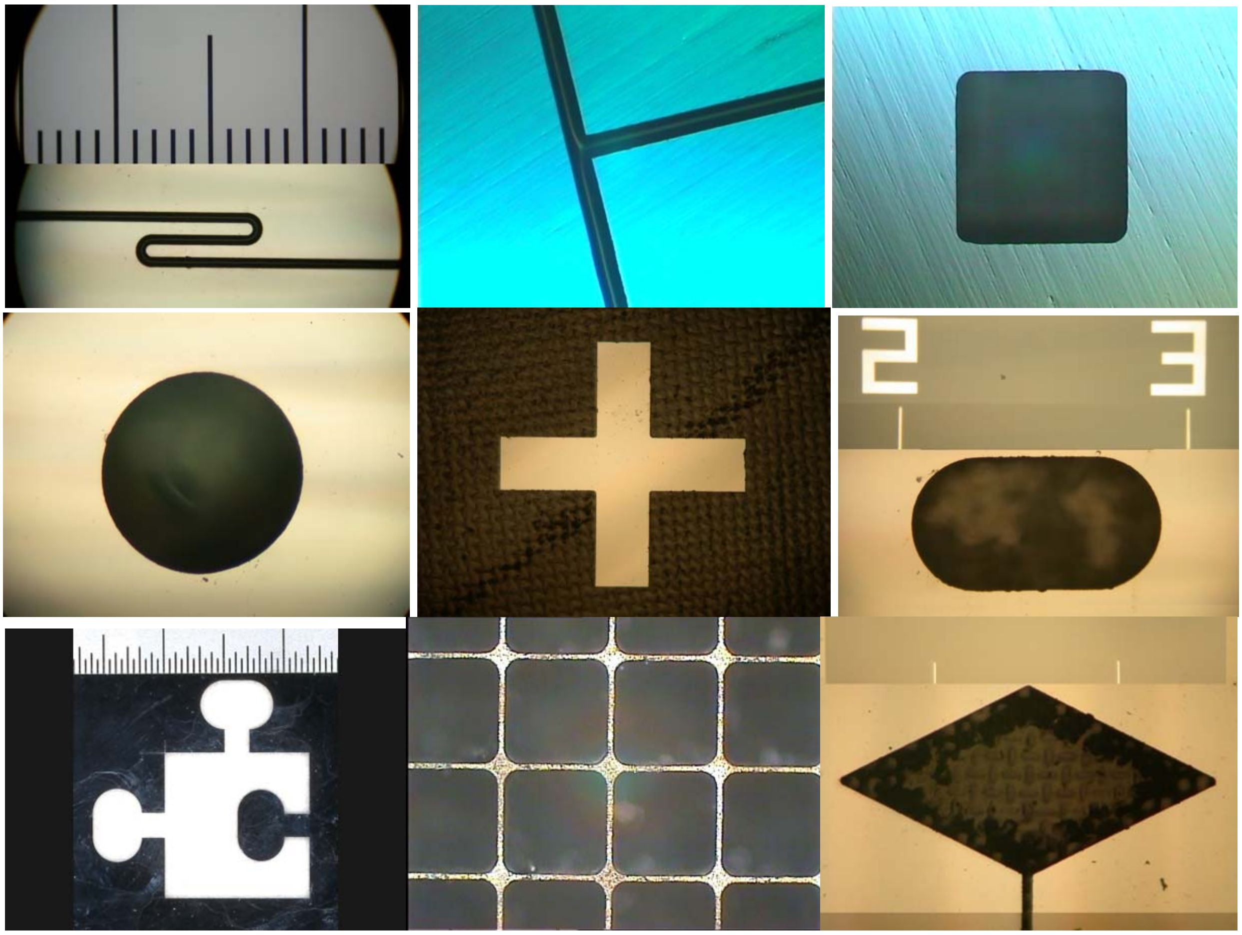

Figure 1. Contours with different shape cut with the Laser MicroJet® from a Si wafer with thickness 100 μm.

## Conclusion

While the processing of silicon by Nd:YAG lasers with harmonic generation and femtosecond laser ablation is still merged in the research and development attitudes, and encounters major problems due to the need of precise focusing of the laser beam onto the sample surface, the Laser MicroJet® technology is already commercially available for many applications in microelectronics and medicine that require free-shape cutting. It provides higher cutting speed, lower tolerances and burr and crack free edge quality when cutting thin Si and GaAs wafers.

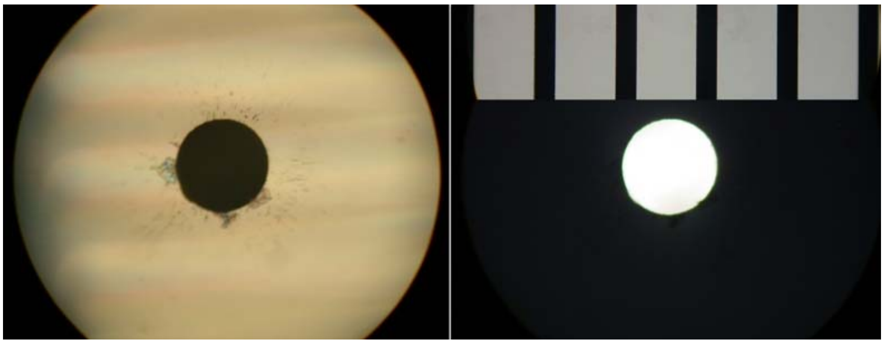

Figure 2. The smallest circle cut with a nozzle with diameter of 60 μm has a diameter of 110 μm. One division from the scale corresponds on 0.1 mm.

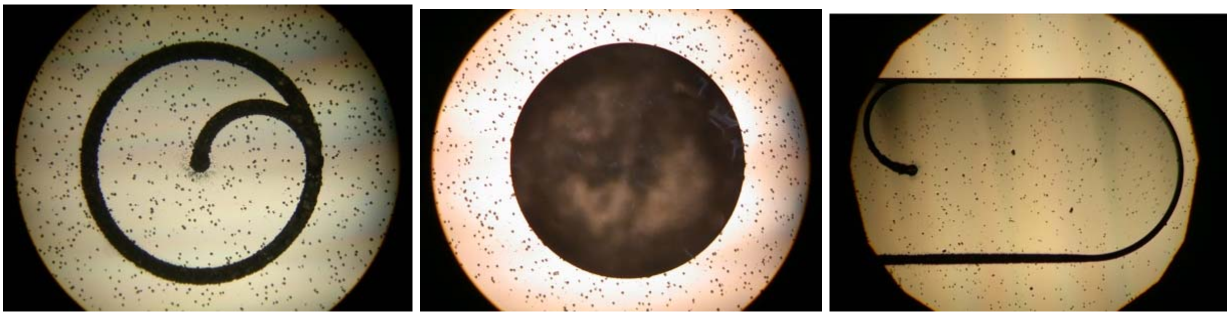

Figure 3. Contours with different shape cut with the Laser MicroJet® from a GaAs/Ge wafer with thickness 180 μm.

Figure 4. The strong initial laser pulse forms a crater and might break the wafer.

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