Gentle wafer dicing

DELPHINE PERROTTET

USING A WATER-JET-GUIDED LASER TO DICE SEMICONDUCTOR WAFERS RESULTS IN NEGLIGIBLE HAZ AND REDUCED CONTAMINATION

Wafer dicing, one of the last steps in the conversion of the wafer to chips, is an indispensable and delicate step in the manufacture of integrated circuits. Until recently, abrasive sawing was the only process for wafer dicing. However this process has struggled to fulfill the requirements of new semiconductor devices based on thin wafers and compound semiconductors.

Conventional laser processing offers advantages over saws, but it generates a large amount of debris that adheres to the wafer surface. This debris is hard to remove and it may damage nearby structures. These lasers also create a significant heat-affected zone; heating generates micro-cracks, which decrease the die fracture strength. For these reasons, lasers have not been popular for wafer dicing.

A few years ago a laser-based technology was successfully used in the semiconductor field for wafer dicing. A hybrid process based on laser and water jet technologies, the water-jet-guided laser is a fast and efficient solution for thin wafer dicing, grooving, and edge grinding. It can process a wide range of materials, including compound semiconductors. Because it has the advantages of the conventional laser without its drawbacks, it succeeds where abrasive saws do not.

The basic principle of the water-jet-guided laser (also called Laser-Microjet) is that a laser beam is focused into a nozzle while passing through a pressurized water chamber. The water jet emitted from the nozzle guides the laser beam by means of total internal reflection that takes place at the water-air interface, in a manner similar to conventional glass fibers. The water jet can thus be referred to as a fluid optical waveguide of variable length (see Figure 1). Because the water jet diameter ranges down to 20 µm, very small kerfs are possible. The maintenance costs for the whole system are low, as there is no tool wear and the water consumption is negligible.

The advantages of this process can be explained through four fundamental differences existing between it and conventional laser processes. In conventional laser cutting, the laser beam is divergent and the working distance is short. When a water jet guides the laser beam, the working distance—corresponding to the area where the jet is cylindrical and constant—can be up to several centimeters long, resulting in constant kerf width and no need for focus-distance control.

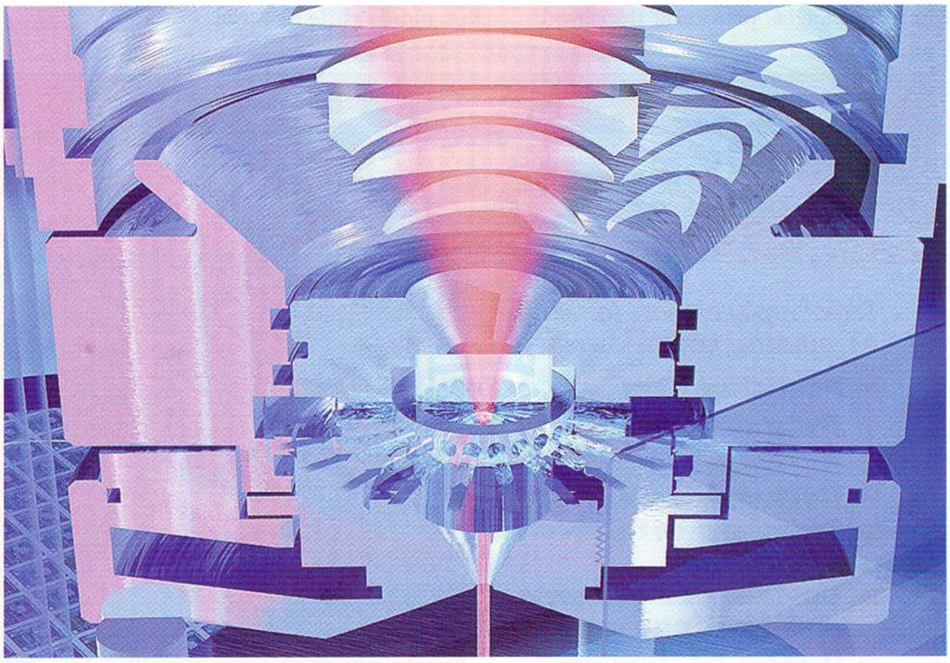

FIGURE 1. The Laser-Microjet principle.

The water jet prevents heat damage to the material by cooling the cut edges between the laser pulses; the heat-affected zone (HAZ) is negligible compared to conventional lasers. The water jet also expels the molten material; it is about 800 times more efficient than the assist gas used in conventional laser cutting. The result is a burr-free edge and a higher melting efficiency.

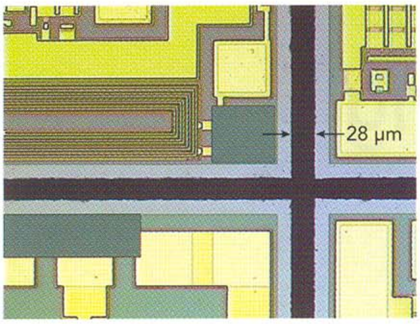

FIGURE 2. Clean 28-µm wide through-cut in a 100-µm thick GaAs wafer.

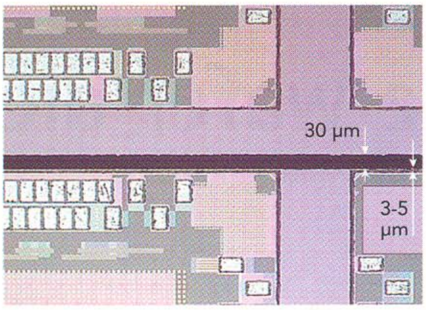

FIGURE 3. Chip-free 30-µm wide through-cut in a 100-µm thick low-k wafer.

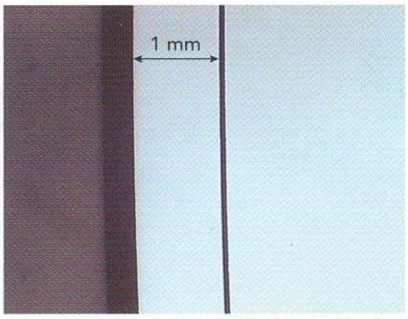

FIGURE 4. Grooving in a 725-µm thick silicon wafer, 1 mm from the edge

In conventional laser cutting, the protective coating added to the material to avoid contamination significantly increases costs (two additional steps); with the water-jet-guided laser technology, a water film is generated on the material surface where the particles, already cooled by the water jet, remain in suspension.

Dicing

The water-jet-guided laser is especially efficient with thin wafers offering thinner packages, providing improved heat evacuation and a degree of flexibility. After the last front side process, some wafers are mechanically ground to a thickness ranging from 200 µm to 50 µm, in an operation called back grinding. The difficulty in the dicing process is to avoid generating micro-cracks that could lead to die breakage. In a recent study the water-jet-guided laser reached significantly higher die fracture strength than abrasive sawing (about 1.3 times higher for silicon dies). The process is a very "gentle" one that can be used to dice even more brittle materials.

Gallium Arsenide (GaAs)**—**GaAs, the most used compound semiconductor, is difficult to dice because of its brittleness. Mechanical methods (blade sawing and scribe-and-break) are standard for GaAs singulation but they create chipping, even with reduced speed. The Laser-Microjet is much faster, and does not generate mechanical or thermal damages. Any toxic byproduct material is concentrated in the wastewater, which has to be filtered. There is no gas emission as in conventional dry laser cutting.

Figure 2 shows the typical quality obtained with the process on a thin GaAs wafer from a major chip manufacturer. There is no chipping due to mechanical stress and no contamination. For this 100-µm-thick GaAs wafer, a fiber laser beam (wavelength 1064 nm with average power 100 W) has been coupled into a thin water jet (diameter 27 µm). These parameters were chosen to obtain high cut quality at high speed (up to 80 mm/s).

Low-k wafers**—**These wafers, whose top layers have a low dielectric constant, tend to peel and chip during dicing due to the brittleness and fragility of the top layers. Abrasive sawing, because it generates mechanical stress, does not produce satisfactory results. Even with decreased speed, chipping and crack formation are unavoidable. A solution using both laser and saw improves the cut quality but also greatly increases costs. The water-jet-guided laser is advantageous in this case because it generates clean cuts, with no chipping, in a single step.

Figure 3 shows a 100-µm-thick low-k wafer, from another major chip manufacturer, diced with the Laser-Microjet. It is free of contamination and shows no thermal damages, burrs, or chipping. The dielectric features are not affected. The processing speed was 50 mm/s for a kerf width of 30 µm. The dicing can be carried out very close to the active area (3 to 5 µm from the die), so manufacturers can design wafers with narrower streets.

Edge grinding

In addition to dicing, this technology is also used to solve the problem of breakage during handling. The back grinding process (used to reduce the wafer thickness) creates a "knife-edge," which contains micro-cracks that cannot be removed with stress-release methods, such as etching. Crack propagation may result in wafer breakage. Today, there is no technology that can grind or polish the knife-edge. The solution is to completely remove it. The water-jet-guided laser is the only process able to meet the requirements of this application. This operation, called edge grinding, removes the outer 0.5-2 mm of the wafer, so micro-cracks cannot propagate to the rest of the wafer.

Edge grinding can be performed before or after back grinding. Figure 4 shows a 725-µm thick silicon wafer that has been grooved before back grinding. When the wafer becomes thin (after back grinding), the knife-edge containing micro-cracks is separated from the rest of the wafer. A 75-µm nozzle has been used and the grooving speed was 50 mm/s.

Conclusions

The hybrid water-jet-guided laser process offers negligible HAZ and reduced contamination to provide the semiconductor industry a gentle tool able to process every kind of brittle material. It is also used for other applications such as cutting of stencils, solar cells, medical devices, or hard materials for the tooling industry. ✷

Delphine Perrottet is press contact at Synova SA. She can be reached at perrottet@synova.ch.