Water-jet-guided Laser Technology

A DAMAGE-FREE DICING SOLUTION

BY DELPHINE PERROTTET, PHIL DURRANT, AND BERNOLD RICHERZHAGEN, *Synova*

Many emerging devices depend on thin (below 200 μm) or ultra-thin (final thickness between 50 and 100 μm) wafers and compound semiconductor materials such as GaAs and GaN. For equipment manufacturers, dicing becomes a delicate operation. With such brittle wafers sensitive to mechanical constraints, abrasive sawing is reaching its limits. Laser technology offers advantages — such as flexibility and speed — which might be profitable to chip manufacturers, providing that their limitations — significant heat damage and contamination — are overcome. One solution is the water-jet-guided laser, which was developed to process brittle and sensitive materials without damage. This technology has proven its capabilities in the semiconductor field, where it is used for dicing a wide range of wafer materials.

THE SHORT STORY

The semiconductor market is using more thin wafers and compound materials, which don't hold up well to abrasive sawing methods. Laser technology is one solution, but has its limitations. Another alternative is water-jet-guided laser technology, which can process brittle and sensitive materials without damage.

Water-jet-guided Laser

In 1993, scientists at the Institute for Applied Optics at the Lausanne University of Technology in Switzerland succeeded in creating a laser-light-guiding water jet. The laser beam is focused into a nozzle while passing through a pressurized water chamber. The geometries of the chamber and nozzle are decisive to coupling the energy-rich laser beam into the low-pressure water jet. The hair-thin water jet emitted from the nozzle guides the laser beam by means of total reflection at the transition zone between water and air, in a manner similar to conventional glass fibers. The water jet can thus be referred to as a fluid optical waveguide of variable length (Figure 1).

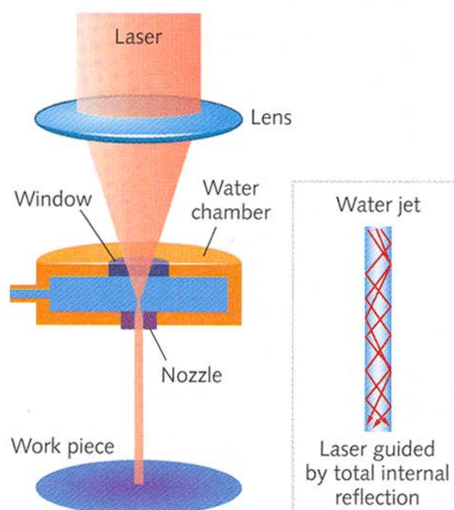

FIGURE 1. Water-jet-guided laser basic principle.

Apart from guiding the laser, the water jet cools the work piece at the exact place where it was cut and heated, simultaneously removing the molten material. An additional device has been developed to reduce the particle contamination level even further. During cutting, a continuous water layer of controlled thickness covers the wafer, preventing particles from attaching to the material surface. Removing the water layer containing suspended particles after cutting guarantees a clean wafer, compared to conventional laser cutting, where contamination can only be avoided by a protective coating.

The low-pressure jet also ensures no mechanical damage to the work piece during dicing. The water-jet-guided laser is efficient on brittle and difficult-to-machine materials such as GaAs, even for thicknesses as small as 50 μm. Additionally, the laminarity of the water jet provides a constant kerf-width equal to the diameter of the jet (between 75 and 22 μm, depending on the nozzle diameter). Another advantage of the water-jet-guided laser is that its speed depends on material thickness – and so is faster on thinner wafers. Operating costs are lower than mechanical methods because there is no tool wear and water consumption is low. In addition, once the nozzle is aligned, it can last for hundreds of hours without being changed. The water-jet-guided laser can achieve almost any shape, while abrasive sawing can only cut in straight lines, which limits the possible geometries.

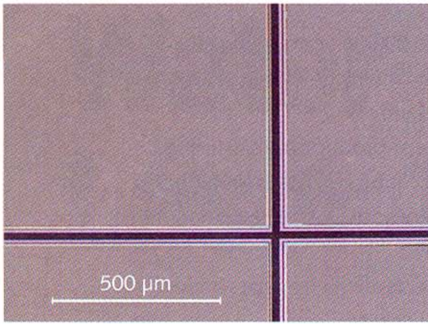

FIGURE 2. Chip-free through-cut in a 100-µm-thick GaAs wafer (kerf width: 25 µm).

Laser dicing

Because of its gentle process, the water-jet-guided laser is well-adapted to thin-wafer dicing. Quality cutting is achieved even at high speed and small kerfs can be produced (down to 22 µm), so chip manufacturers can shrink street widths to increase yield. There are no micro-cracks or chipping, and fracture strength is achieved using this method. Omni-directional cutting (polygon and round dies) is possible, and wafer drilling and marking can be accomplished with the same machine.

Cutting speed depends on wafer thickness; the thicker the material, the greater laser pulse energy is required. Table 1

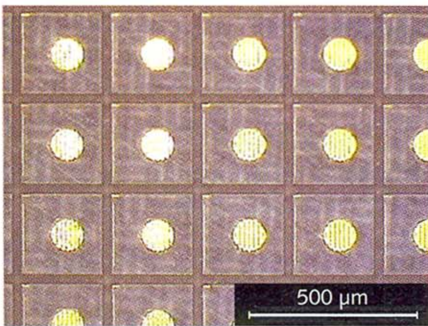

FIGURE 3. Scribing of a SiC wafer (85-µm deep).

shows typical cutting speeds for silicon, depending on the wafer thickness. There is no thickness limit, because the maximum cutting speed at a given wafer thickness depends on the pulse repetition rate, average power, and peak power of the laser. The minimum thickness is currently 50 µm, but is limited by chip manufacturers and not the dicing process.

Another important parameter in the comparison of dicing techniques is the fracture strength of the cutting edges, especially of thin wafers. Mechanical deformation can result in die breakage. Several studies have shown that the water-jet-guided laser causes less damage at the wafer edges than the conventional dicing saw. Conventional lasers present even lower fracture strength because of the heat emitted by the laser.

To mount the wafer, a special tape** that couldn't be cut by the laser, but still allowed water to pass through, had to be developed, and is currently used in production.

Figure 2 shows the quality obtained with GaAs using this technology. There is no chipping due to mechanical stress and low contamination. Unlike saws, the water-jet-guided laser can cut in any direction. For this 100-µm thick GaAs wafer, an infrared fiber laser (1070-nm wavelength, 35-W average power) was coupled into a thin water jet (23-µm diameter). These parameters were chosen to obtain cut quality at high speed (40 mm/s).

Wafer thickness	Typical cutting speed
50 µm	200 to 300 mm/s
100 µm	100 to 120 mm/s
200 µm	50 to 60 mm/s
625 µm	15 mm/s

TABLE 1. Typical cutting speeds for silicon.

With GaAs, safety issues are also paramount, since the material contains 51.8% wt. arsenic. Tests performed with the water-jet-guided laser showed that no arsine gas is detected in the air while cutting GaAs; an improvement compared to conventional laser cutting. All arsenic is concentrated in the wastewater, which should therefore be appropriately filtered or recycled. Thus, water-jet-guided laser dicing of GaAs does not require any additional safety systems compared to sawing.

The water-jet-guided laser has also been adapted to SiC-wafer dicing. High speed can be achieved, while maintaining cut quality at low running costs. Because of SiC hardness, the blade wear is approximately 100 to 500 times more expensive than for silicon when using mechanical methods.

Figure 3 shows an 85-µm-deep scribing in SiC, performed at 26.7 mm/s. For this SiC wafer, a pulsed UV laser (355-nm wavelength, 7.5-W average power) was combined with a 27-µm water jet, resulting in a 28-µm-wide kerf.

Apart from dicing, the water-jet-guided laser is also used in the semiconductor field for edge grinding. The process reduces thin wafer breakage by making a cut or groove around the wafer to remove micro-cracks accumulated in the edge during back grinding. Figure 4 shows the edge of a thin silicon wafer, which was glued to a thicker support wafer with bonding tape. The top 100-µm-thick wafer was downsized using a green laser (532-nm wavelength, 25-W average power) coupled into a 47-µm water jet, which resulted in an overall speed of 65 mm/s.

Conclusions

The results yielded by the water-jet-guided laser in wafer-dicing applications validate the process as a viable alternative to conventional cutting technologies for thin wafer processing, or when delicate materials are used. The heat-affected zone is negligible because the water jet cools the cut edges during laser ablation. Molten material is removed and does not adhere to the wafer. Cutting speeds are high, while achieving a grooved cut. Currently, kerf widths as thin as 22 µm can be reached; new nozzles tested in the laboratory will produce ultra-thin jets of only 17 µm in diameter. **AP**

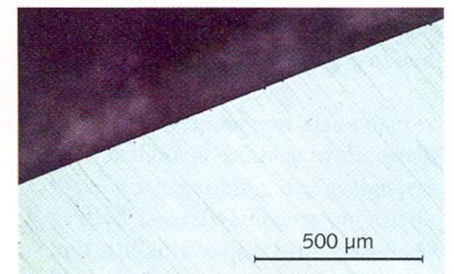

FIGURE 4. Edge grinding of a thin silicon wafer.

*Laser MicroJet

**LaserTape

REFERENCES

Contact the author for a complete list of references.

DELPHINE PERROTTET, technical writer; PHIL DURRANT, VP marketing; and BERNOLD RICHERZHAGEN president and CEO, may be contacted at Synova, Ch. de la Dent-d'Oche, CH-1024 Ecublens, Switzerland; 41/21694-3500.; E-mail: perrottet@synova.ch; durrant@synova.ch; richerzhagen@synova.ch.