Stress Release Increases Advantages of Laser-Microjet Dicing

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Thin semiconductor wafers are rapidly gaining in popularity thanks to their significant performance advantages, such as heat evacuation, flexibility and usefulness for stacked packaging. Current estimates project thin wafers' market share will grow from 5% today to as much as 30% in the next two years. Because of their brittleness, however, key operations such as handling remain delicate, making high die fracture strength a critical parameter to achieve.

At a Glance

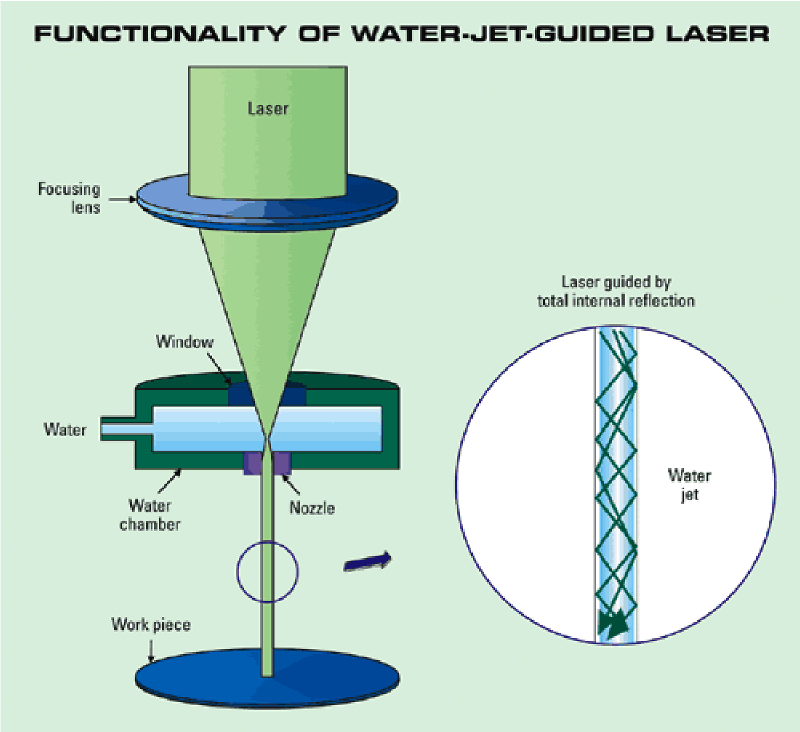
As thin wafers gain in popularity, die fracture strength is becoming more of a critical parameter. Results from recent studies show that dicing by water-jet-guided lasers provides significantly higher strength than saw dicing when combined with backside etching.

Die fracture strength is influenced by three back-end processing operations: backgrinding, stress release and dicing. Stress-release methods — usually chemical mechanical polishing (CMP), spin etching, dry etching or dry polishing — partially remove the damages generated by backgrinding of the wafer backside, while dicing generates additional damages on the die edges. However, because backgrinding and dicing damage overlap, it's usually difficult to measure the influence of each operation on the wafer die. This is particularly true when using the most common dicing tool, abrasive saws.

While lasers are considered a superior approach to saws for wafer dicing, conventional lasers are still susceptible to causing heat damage and contamination. A new damage-free laser technology — a water-jet-guided laser beam (or Laser-Microjet) — generates virtually no additional damage on the wafer die, delivering significantly higher die fracture strength than these other approaches.

Water-jet-guided lasers

A water-jet-guided laser focuses a laser beam into a nozzle while passing through a pressurized water chamber (Fig. 1). The low-pressure water jet emitted from the diamond nozzle guides the laser beam via total internal reflection at the water/air interface, in a manner similar to that of conventional glass fibers.



1. In water-jet-guided systems, a laser focuses a beam into a nozzle while passing through a pressurized water chamber. The low-pressure water jet emitted from the diamond nozzle guides the laser beam via total internal refection at the water/air interface.

In addition to its guiding function, the water jet's main advantages over conventional lasers are its efficient removal of all molten material (preventing deposition on the wafer) and its ability to cool the edges of the kerf, so that the heat-affected zone is negligible. Additionally, the mechanical force applied by the water jet on the work piece is very low (<0.1 N).

This approach employs either flash-lamp-pumped pulsed Nd:YAG lasers with pulse durations of <100 µsec, or short-pulsed Q-switched lasers, emitting at 1064, 532 or 355 nm. The water jet uses pure deionized and filtered water, pressurized at 50-500 bars. The nozzles are composed of sapphire or diamond to generate a long, stable water jet; their diameter range is 25-100 µm. Because of the "hair thin" jet, the laser consumes very little water — ~1 L/hr. Currently, the key application for the water-jet-guided laser is micromachining of silicon and other semiconductor materials.

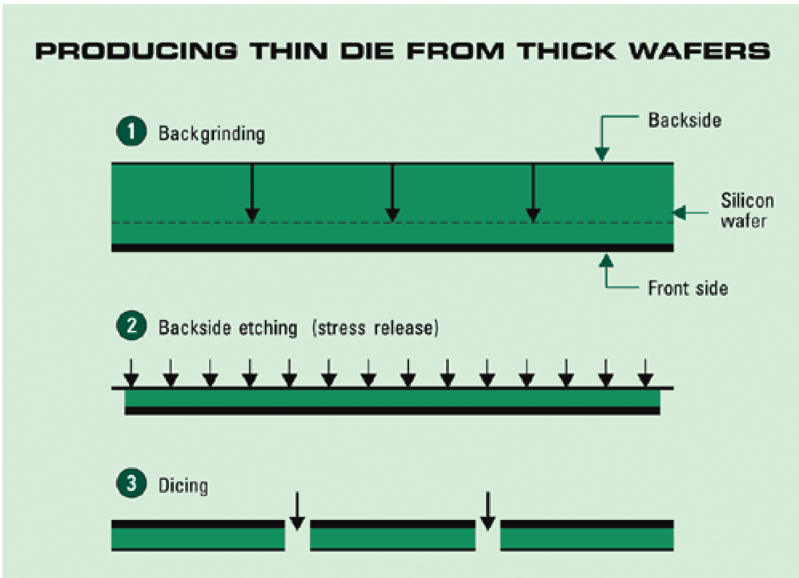
Testing die fracture strength

Recently, Synova, which invented water-jet-guided laser technology, and Infineon Technologies conducted a joint study whose objective was to determine the influence of stress release and dicing on die fracture strength. A series of wafers, ground and etched to different levels, were diced, alternately employing abrasive sawing and Laser-Microjet cutting, and the fracture strength of the resulting die was then tested and analyzed.

The samples used in the study were 6 in. bare silicon wafers. After backgrinding, the resulting thin wafers were etched to obtain a final thickness equal for each sample (Table). The wafers were then diced into 15 mm^2 chips (Fig. 2), using abrasive saws for half the wafers and water-jet-guided laser technology for the other half.

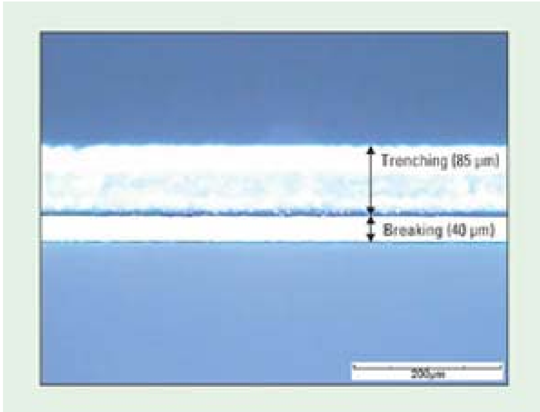
Grinding and Etching of the Samples (in µm)

Ground to	125	135	150
Etched	0	10	25
Final wafer thickness	125	125	125



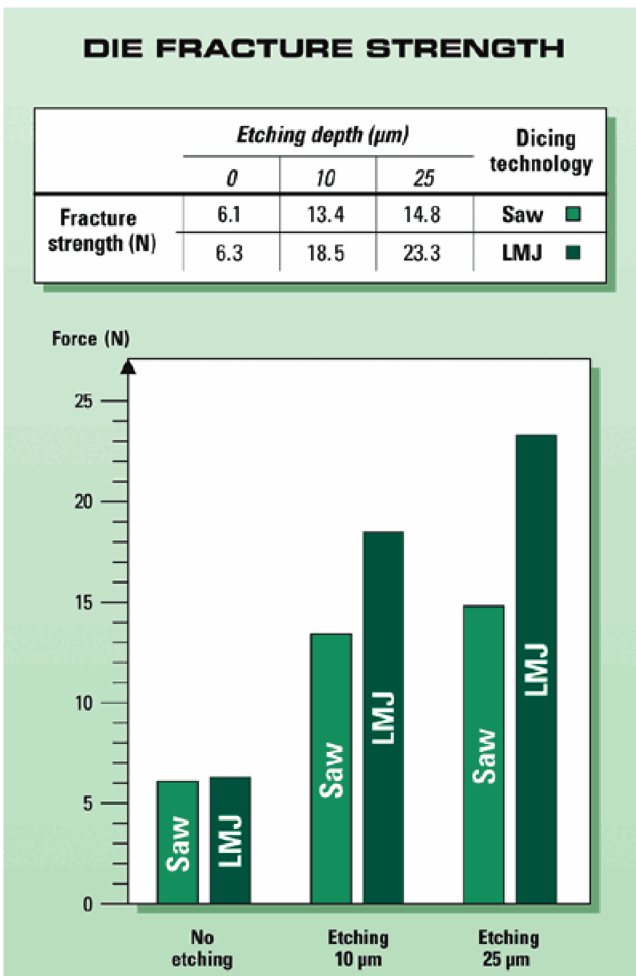
2. In the study of die fracture strength, researchers used a combination of backgrinding and etching to produce thin die from a thick wafer.

Dicing with the Laser-Microjet was performed using trenching over ~80% of the wafer thickness and subsequent splits, as this method gives the best results in terms of fracture strength. An infrared fiber laser (wavelength of 1064 nm, average power of 50-60 W) was coupled with a 50 µm nozzle, generating a 46 µm water jet and achieving a trenching speed of 50 mm/sec. Figure 3 illustrates the quality of Laser-Microjet trenching — the bottom line is very regular and the kerf is clean.



3. A microscope image of a die edge after trenching with the water-jet-guided laser shows that the bottom line is very regular and the kerf is clean.

Finally, for each split, 49 die were subjected to a three-point bending test. A vertical force was gradually applied on the center of the die's front side; with its extremities positioned on two parallel bars, the die bends and then breaks when a force corresponding to the die fracture strength has been reached. The average values obtained for each set of differently etched die are represented in Figure 4 .



	Etching depth (µm) 0	10	25	Dicing technology
Fracture strength (N)	6.1	13.4	14.8	Saw
	6.3	18.5	23.3	LMJ

4. For each split, 49 die were subjected to a three-point bending test, showing the benefit of backside stress release on die fracture strength.

These results illustrate the influence of backside stress release on die fracture strength. Indeed, when wafers are not etched (i.e., no stress is released), the damage generated by backgrinding is so significant that dicing-process damage is negligible by comparison; the die fracture strength is therefore nearly equivalent with both technologies. However, because etching reduces the damage on the wafer surface, when it is applied after backgrinding, the damage caused by dicing is more apparent. With 10 µm deep etching, the difference between sawing and Laser-Microjet cutting is already noteworthy, while the die fracture strength is significantly higher. Although sawing and Laser-Microjet cutting diverge even more when deeper etching (25 µm) is used, deep etching is likely unnecessary, as even slight etching increases the fracture strength, since most of the stress is concentrated in a very thin layer at the die surface.

Conclusion

In recent years, water-jet-guided laser technology has been actively used for precision semiconductor machining. The process is clean and generates no additional damage, including negligible heating and mechanical force. When a stress-release method is applied prior to Laser-Microjet dicing, die fracture strength is up to 1.5× higher than with an abrasive saw. As water-jet-guided lasers are increasingly used for dicing a wide range of semiconductor materials, such as silicon, GaAs, InP and SiC, they are expected to become the premier solution for wafer dicing.

Author Information

Werner Kröninger has worked for Infineon since 1995 as a process engineer in various front-end fields, and today is senior staff engineer for pre-assembly topics. He previously worked for the Fraunhofer Institut in Würzburg (ISC), and also led projects at Rodenstock Precision Optics, Munich. He received his M.Sc. in physics from the University of Regensburg.

Delphine Perrottet joined Synova last year as the company's press contact, after having worked in the literary trade as a publisher. She received her M.Sc. in micro-engineering from the Swiss Federal Institute of Technology Lausanne.

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