Water-Jet-Guided Laser Achieves Highest Die Fracture Strength

Delphine Perrottet, Jean-Marie Buchilly and Bernold Richerzhagen
Synova SA

Werner Kröninger
Infineon Technologies AG

Thin Wafer Dicing

While less than 5 percent of today's semiconductor wafers are thin (<150 µm), in the next two years that percentage could increase to 20 or 30 percent. In addition to offering thinner packages, thin wafers also provide improved heat evacuation and a certain degree of flexibility. However, the flexibility achieved for dies based on these wafers depends significantly on die fracture strength. This is the result of two factors: surface fracture strength and edge fracture strength. After applying precise stress release methods like chemical mechanical polishing, spin etching and dry polishing, which remove damage on the backside of the wafer after grinding, die fracture strength is currently determined primarily by edge fracture strength. The next step toward increased die strength is, thus, to improve dicing.

Until recently, abrasive sawing was the only wafer dicing process available and was performed after back grinding; that is, directly on thin wafers (DAG). Grooving thick wafers before back grinding (DBG) improves die fracture strength by reducing backside chipping. However, a new cutting process – the water-jet-guided laser (Laser-Microjet) – provides a significantly higher die fracture strength.

The Laser-Microjet, which uses a water jet to guide a laser beam, is currently used to cut, scribe and drill a wide range of materials. Deep trenching has proven to be the best method for use with thin semiconductor wafers. The wafer is not cut all the way through and the remaining thickness (between 10 and 20 percent) breaks with a slight pressure from the backside. This reliable and simple technique guarantees high backside fracture strength, increased speed and absence of backside contamination. In addition, no specific tape is necessary.

An important study was conducted recently by Synova and Infineon to determine which singulation method provides the highest die fracture strength: dicing after grinding, dicing before grinding or Laser-Microjet cutting. Conventional dry laser cutting was not considered because of poor fracture strength.

Setup

Two methods are available to determine the die's fracture strength: 3-point or 4-point and ball-ring bending. The principle is to use a controlled force to bend the die until it breaks. The force required to break the die determines its strength. The ball-ring method provides information primarily about surface strength, so it does not clearly detect damage produced by dicing. The 3-beam bending method was chosen for this study because it is well suited to measuring the influence of edge damage, allowing even small chips to be checked.

On a 3-beam setup, the die's extremities rest on two parallel pins, while a vertical force is applied through a third pin located in the middle of the die (see Figure 1). The force is increased consistently until the die breaks and is recorded on a PC, together with the bending radius.

All test samples were 125-µm thick production silicon wafers from the same >>

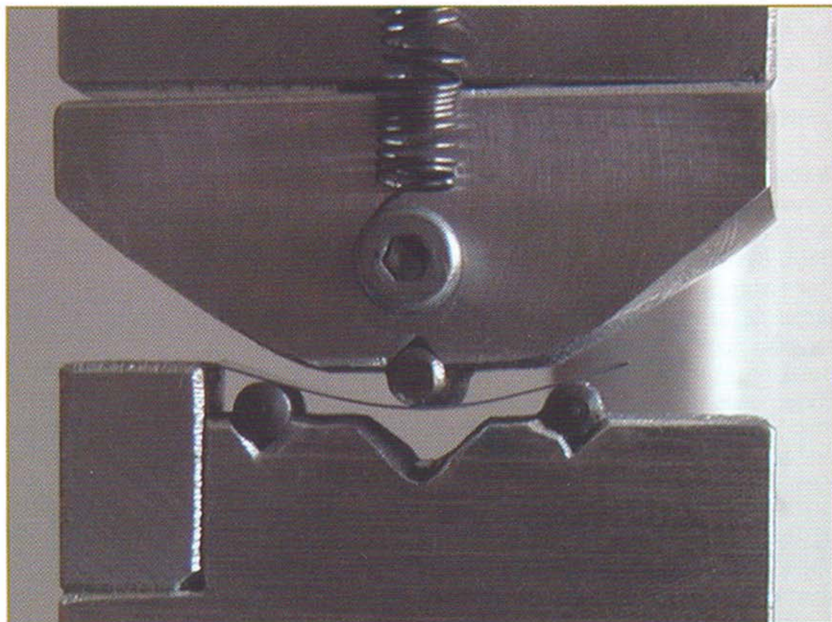

Figure 1. Die bending under the effect of the vertical force during the breaking process on a 3-point bending test.

>> batch and were ground and polished. After using the different methods to dice them into 10 mm-by-10 mm chips, the samples were removed carefully from the dicing support (dicing tape, grinding tape or LaserTape), avoiding any damage to edges. All tested wafers were then analyzed on both sides, since front and backside values may change based on the dicing process. Around 25 dies were tested for each parameter to determine representative average values.

Results

The first observation noted during the tests was that dies cut with the Laser-Microjet broke into hundreds of small pieces, suggesting that the strength may be very high. The three independent measurements summarized below confirm that initial impression.

Force Required To Break Dies

In a 3-point bending test, the curve of applied force as a function of deflection provides the die's fracture strength, since the maximum value achieved during the test corresponds to the breakage value. High force means high die fracture strength (see Figure 2).

Table 1 compares Laser-Microjet trenching (LMJ) and standard sawing (DAG). For an equivalent kerf width, the force is around 50 percent higher with the LMJ than with saws for both sides. Moreover, the dicing speed is higher with the Laser-Microjet because, in contrast to laser-based technologies, saws are slower when working on small thicknesses.

Weibull Distribution

Another interesting analysis concerns Weibull distributions, which characterize fracture probability. The Weibull strength (see Figure 3) is the strength required to break 63 percent of dies. The Weibull modulus shows the distribution of other breaking probabilities: high value corresponds to low deviation in strength. This parameter is equivalent for sawing and Laser-Microjet dicing, and is thus not represented on the graph.

With respect to strength, the Laser-Microjet reaches 810 MPa (front side) while the DBG method remains at around 530 MPa. These results confirm the previous conclusion, which found that the Laser-Microjet increased the die fracture strength by 50 percent.

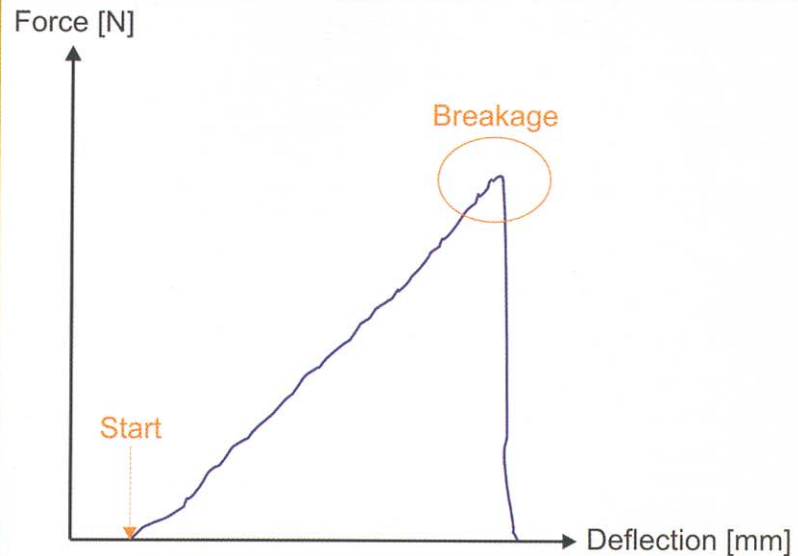

Figure 2. The typical force-deflection graphic for a die-breaking test.

Dicing technology	Dicing speed	Kerf width	Fracture strength (average force [N])	
			Front side	Back side
Saw	25 mm/s	45 µm	X (6.7)	Y (6.8)
LMJ	50 mm/s	46 µm	1.5 X (10.1)	1.6 Y (11)

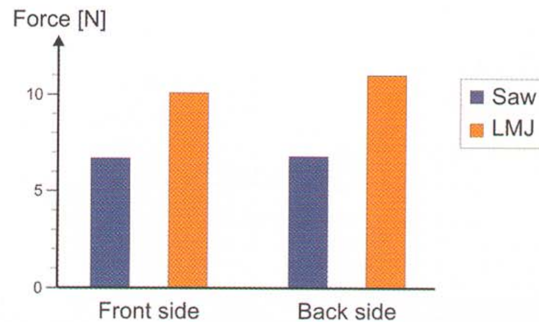

Table 1. Die fracture strength: comparison between the saw and the Laser-Microjet. [source: Synova SA]

Dicing Of Etched Thin Wafers

The last analysis compares Laser-Microjet and traditional dicing of grinded and etched thin wafers. DBG is not studied since, for many wafers, it is not applicable (due to backside processes). Figure 4 illustrates the process: the thick wafer is thinned with back grinding; then backside etching is applied, which removes stress from the backside caused by the previous step; finally, the dies are singulated from the front side. As no stress release method is applied after dicing, the 3-point bending test shows damages generated by dicing only.

Coherent to the results of the previous tests, the Laser-Microjet process generates a die fracture strength significantly higher than sawing (1.3 times higher).

Conclusions

A primary concern of manufacturers using thin wafers is dicing while maintaining a high fracture strength. Three

independent studies comparing different singulation methods have reached the same conclusion: trenching by water jet guided laser technology achieves the highest die strength. While dicing before grinding does improve die fracture strength compared to conventional sawing, it still produces damage and is not applicable for wafers with backside processes. The stress release by etching after grinding improves the die strength. However, the lead of the Laser-Microjet process, compared to traditional sawing, is still nearly the same. ■

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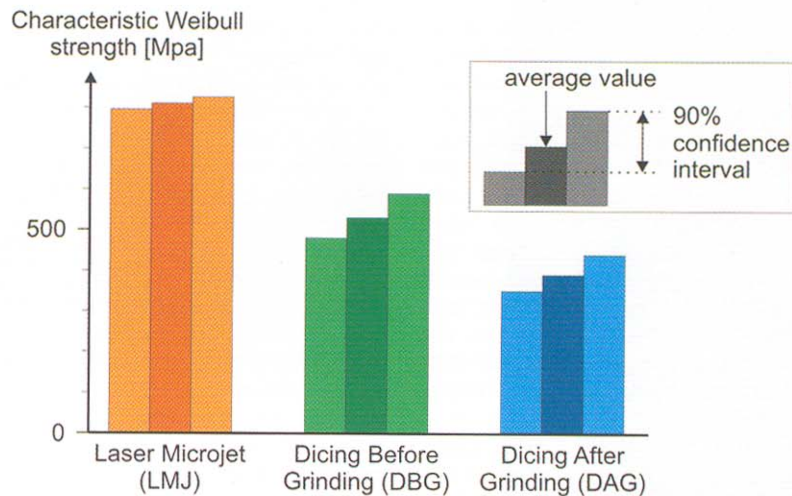

Figure 3. Characteristic Weibull strength for three dicing techniques. [source: Fraunhofer-Institute for Mechanics of Materials]

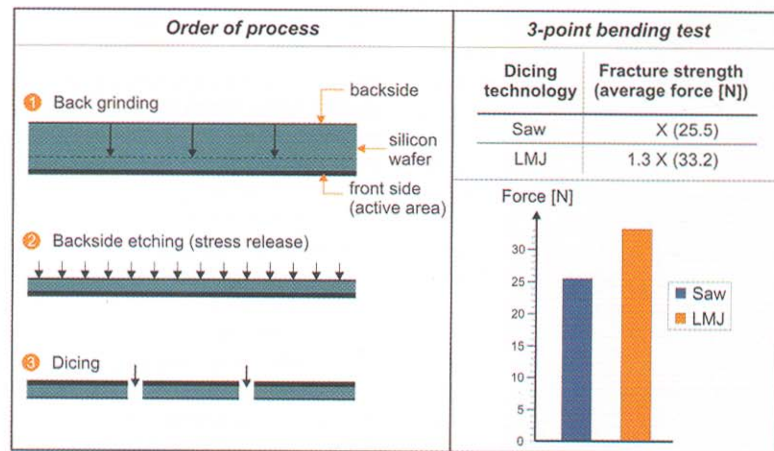

Figure 4. Dicing on etched thin wafers: process (left) and results on a 3-point bending test (right). Absolute values differ from those in Table 1 because those depend on the setup. [source: Infineon Technologies]

Biographies

Delphine Perrottet
Delphine Perrottet received her M.Sc. in micro-engineering from the Swiss Federal Institute of Technology Lausanne. She then worked in the literary trade as a publisher. In 2004, she joined Synova SA as their press contact.

Jean-Marie Buchilly
Jean-Marie Buchilly received his M.Sc. in micro-engineering from the Swiss Federal Institute of Technology Lausanne. He then joined Synova SA as one of the engineers of the semiconductor research team.

Bernold Richerzhagen
After receiving his M.Sc. in mechanical engineering from Aachen Polytechnic and his Ph.D. in micro-technology from the Swiss Federal Institute of Technology Lausanne, Bernold Richerzhagen is acknowledged as the inventor of the water-jet guided laser technology. He is CEO of Synova SA, founded in 1997.

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