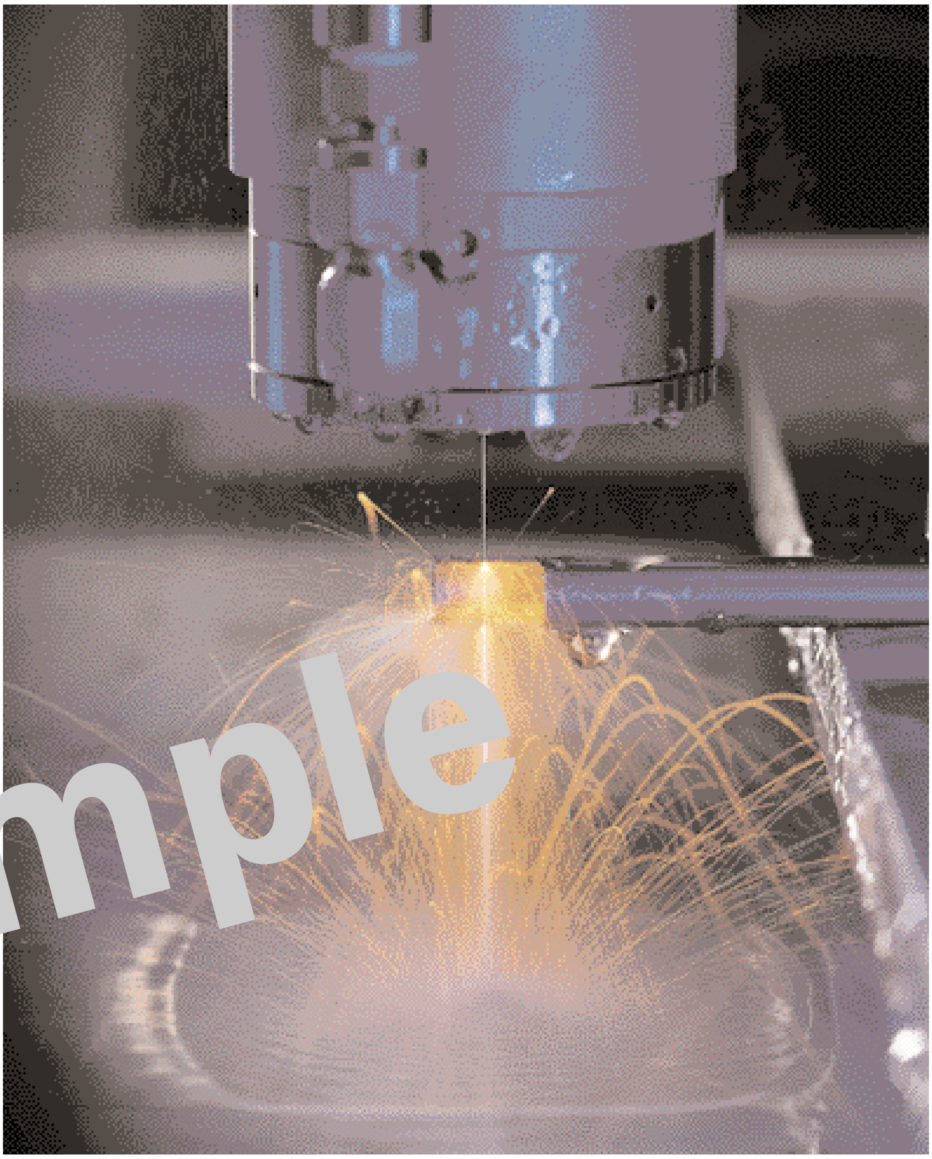
COOL HEAT THAT CUTS

CUTTING WAFERS WITH SAWS CAN BE FRAUGHT WITH PROBLEMS. LASERS HAVE BEEN TOO HOT TO BE EFFECTIVE. A SWISS INVENTION OF A WATER COOLED LASER IS BREAKING NEW GROUND. DR. BERNOLD RICHERZHAGEN IS DIRECTOR OF SYNOVA SA, SWITZERLAND AND HERE SPEAKS ABOUT THE NEW PROCESS.



The laser has been used successfully as a cutting tool for almost twenty years now, primarily in the field of metal processing. The main advantages of laser cutting over mechanical cutting were its great flexibility, high speed, small cutting width and high precision. These very same advantages were expected to provide a solution for dicing silicon wafers in the semiconductor industry. Yet although silicon as a material is well absorbed by the laser beam, the problems of crack formation, chipping and deposits of silicon slag meant that lasers could not be used for the process of chip singulation.

All efforts to assist the laser in overcoming this problem failed, such as submerging the wafer in water, using very short pulses or applying protective coatings to the wafers. It wasn't until the combination of laser and waterjet that the problem could be solved.

The new process

In 1993, Scientists at the Institute for Applied Optics at the Lausanne University of Technology succeeded in creating the "Laser-Microjet".

The laser beam was focussed in a nozzle while passing through a pressurised water chamber. The geometry of the chamber and nozzle are decisive to coupling the energy-rich laser beam in the waterjet. The low pressure waterjet 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 fibres. The waterjet can thus be referred to as a fluid optical waveguide of variable length.

As a pulsed laser was used, the continuous waterjet was able to immediately re-cool the cut, resulting in only slight depth of thermal penetration, see figure two for comparison.

Cutting Speeds

Wafer thickness	Cutting speed
100 (m	120 mm/sec
200 (m	80 mm/sec
300 (m	40 mm/sec
500 (m	20 mm/sec
700 (m	10 mm/sec
1000 (m	6 mm/sec
1500 (m	3 mm/sec
2000 (m	1 mm/sec

The cutting speed depends on the wafer thickness, as the thicker the material, the greater the requisite laser pulse energy.

The maximum cutting speed at a given wafer thickness depends only on the pulse refresh rate and the mean output of the laser, thus ruling out actual limit values. The minimum cutting width is actually 50 microns, but nothing limits a reduction of the cutting width in the near future.

Chipped edges

One major problem of conventional saw cutting is the resultant chipping, which can

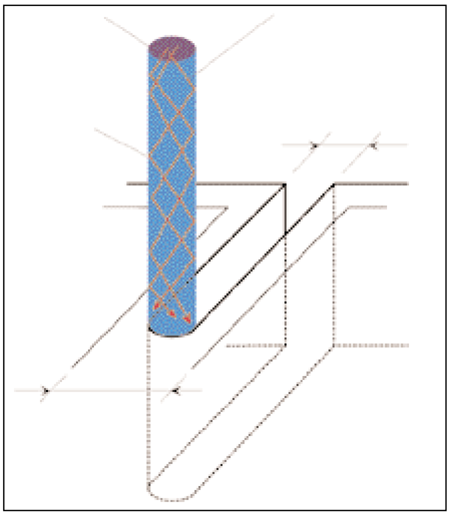


Fig. 1. Cutting with water jet guided laser conventional laser cutting, Laser-Microjet cutting

lead to destruction of the die. Chipping is almost thoroughly dispensed with in the case of the Laser-Microjet. Figure three shows the edge of a cut produced with the Laser-Microjet.

Mechanical deformation (bending) can result in a fracture of the die and its failure. A recent study made by a European chip manufacturer has shown that the water jet laser cut causes significantly less damage at the wafer edges than the conventional dicing saw. Two independent bending tests (with ball and bar) have yielded the same results: a two-fold increase in fracture strength.

The reason for the poor fracture strength of the conventional laser is the strong heating by the laser. In the case of the diamond blade, the micro-defects caused by the blade lead to a limited strength. The MicroJet shows a significantly higher fracture strength making this process very well suited for thin wafer dicing. The edges of the cut display a molten surface. Therefore, the edge surface has a fine structure with no open pores.

The saw can only cut in straight lines, with the geometry of the cut being limited to one dimension. The laser, however, is punctiform and allows two-dimensional processing, thus meaning that any contour imaginable can be cut. As a result, both holes and slots can now be drilled on one and the same machine - an application for which a particle jet with the associated compromises was hitherto used.

Wafer fixation

The solution is to use a special tape, that differs from conventional tape in quite a few respects. The prerequisites of such a tape are that it must not be cut with the laser but the water jet must be able to pass through it. Such so-called LaserTape has already been developed and is currently in the test phase.

The running costs of a convential saw are high on account of the consumption of diamond-edged saw-blades and DI-water. Furthermore, the manufacturing process has to be stopped for a tool change, and the actual change performed manually. Whilst more expensive to purchase, the laser has extremely low running costs.

Evaluation

For two years, chip manufacturers have been evaluating the suitability of the new dicing process. The first applications cannot be done by the conventional sawing process like cutting of round dies. Here, the new laser technique has already proven in tests that the reliability, resulting quality and speed fulfil expectations. Another similar application is the drilling of via holes or slots which has been already evaluated.

An European chip manufacturer has tested successfully the water jet guided laser for dicing of thin wafers such as smart cards. A customer study for laser dicing of GaAs wafers is currently in progress. The first results are very promising.

Not Silicon

Silicon is the most used material in the semiconductor industry. Light (laser), water and Silicon fit perfectly together. Beside Silicon, the water jet guided laser is suited for any material which absorbs the laser beam at the wavelength of 1064 nm. That means any other semiconductor material i.e. Gallium-Arsenide or Germanium. The mechanical fragility is not important, only the optical absorption has to be high enough. A lot of ceramics can be cut, for example Aluminum-oxyde, Silicon Nitride or Silicon Carbide. Almost any metal is suitable for the laser, the only limitation is the thickness. Highly reflective material such as copper, gold and silver can be cut up to 0.1 mm. Transparent materials like glass or Quartz can not be cut because the absorption is too low, Sapphire can only be grooved. Material combinations like metal coated wafers do not represent a difficulty for the laser as long as their thickness is not more than 0.1 mm.

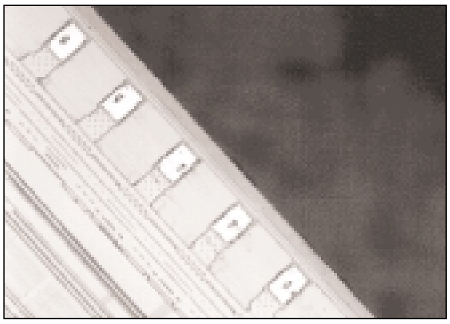


Fig. 3. No chipping on the die edge

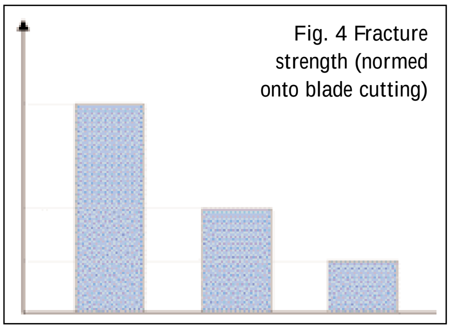


Fig. 4 Fracture strength (normed onto blade cutting)

The technique of the water jet guided laser is under continuous further development. One objective is to reduce the water jet laser beam diameter to 35 microns, which is technically feasible. Recently, a laser came on the market that allows the focussing to such small diameters maintaining a sufficient average laser power. New smaller water jet nozzles are currently under evaluation.

Since there is no physical limitation in the cutting speed, it will be possible in future to increase the dicing speed significantly thanks to new laser sources with higher average power. A speed of 200 mm/s and more is realistic. Finally, shorter wavelengths will be tested in combination with a smaller water jet. This new laser copper should produce a better cut than the 1064 nm beam, which means the system can be used to cut materials used for chip scale packaging.

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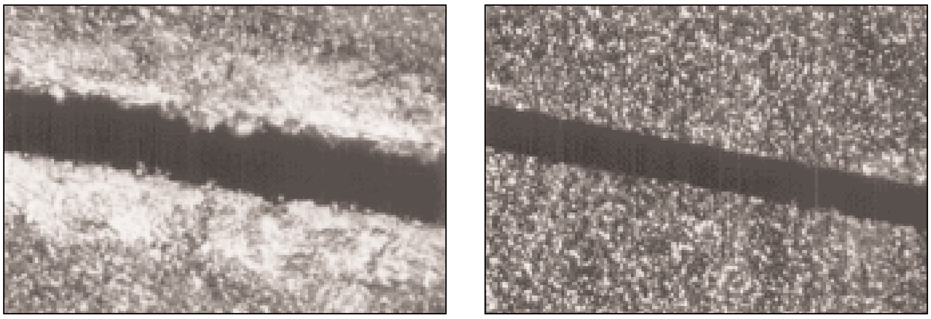

Fig. 2 Comparison between conventional laser cutting of silicon and Laser-Microjet cutting