Laser Microjet and Semiconductor manufacturing

The semiconductor manufacturing industry is being faced with many problems in today's fast paced and ever accelerating demand for smaller and more sophisticated devices, to fill the requirements of the global electronics industry. Added to this is the present worldwide shortage of adequate supplies of silicon wafers. **Keith Stay, Technical Writer, Synova** explains.

Manufacture of integrated circuits from silicon or other raw material (GaAs, Ge, SiC, etc.) is a complicated process, with many steps before the final parts emerging from the production line. During this process, the risks of producing defect parts increases as the geometry of the parts decreases. Minimising the risks during the cutting process, where both mechanical and thermal material stress can play a significant negative role on productivity, is one area where improvements are eagerly being sought. Implementing improved wafer-cutting methods with the aim of reducing wastage and maximising yield, is also very high on the agenda for semiconductor fabs.

The main competing methods used today for cutting are diamond blade saws and conventional lasers. The diamond blade saw functions well for cutting simple bulk silicon, but becomes more and more unsuitable as the wafer thickness decreases, is a multi-layered device, or composed of brittle low-k materials. There are also the added negative effects of crack formation or chipping as a result of the mechanical stress applied to the material during the cutting process. The economics of using blade saws also has to be taken into consideration, especially with low-k materials, where blade wear is extremely high due to the hardness of the material.

Conventional lasers could have provided the solution, except for their inherent problems of heat damage and associated chipping, deposition of ablated material, brittle recast layers as well as the poor quality cut for thick materials, due to beam divergence, all points which rule out their use as a viable choice.

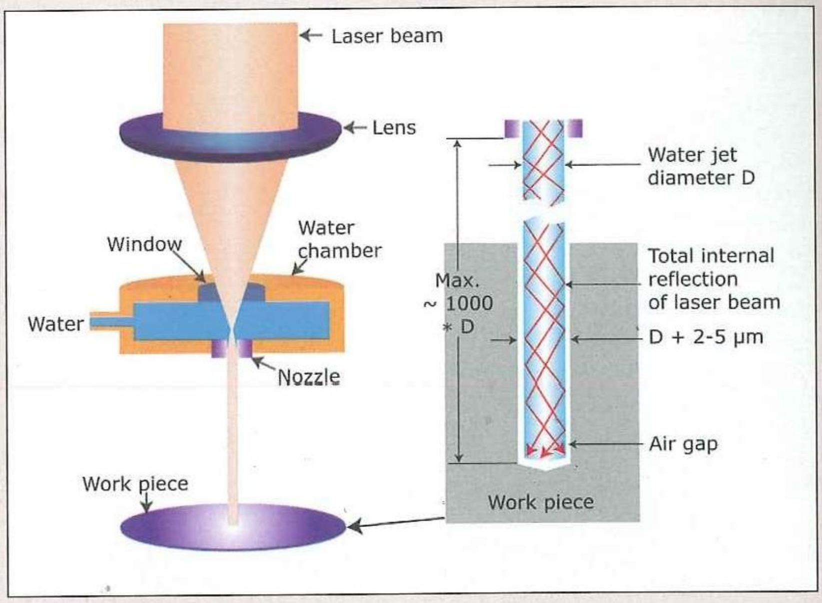

Fig. 1. Basic principle of the water jet guided laser

Solving the problem

The Synova water jet-guided laser system, also known as the Laser MicroJet (LMJ), is a relatively new solution to these problems, which is finding increasing acceptance within the semiconductor manufacturing industry. The advantages to be gained in cutting semiconductor material using this technology are a fast, flexible and economical process, capable of cutting both thin and thick materials to any shape required, with no remnant contamination, no thermal damage and minimal changes to the material structure.

The principle of this patented technology is to couple a high-power pulsed laser beam into a hair-thin, low-pressure water jet as shown in Fig.1.

The laser source can vary from flash-lamppumped IR lasers with pulse widths of 0.4 to 200μs and repetition rates up to 2 kHz, to multimode Q-switched diode pumped lasers operating at 1064, 532, or 355 nm, with pulse widths of 90 to 400 ns, also with repetition rates up to 50 kHz. The only constraint on the laser wavelength is that it must be compatible with the water transmission spectrum. Power levels up to 200W are available using dual laser systems.

The laser beam is coupled to the optical head, where lenses focus the light through a quartz window into a chamber filled with water under low pressure, into the water jet as it exits the nozzle. From this point on, the laser beam is guided along the cylindrical jet by means of the total internal reflection at the at the air/water interface, due to their differences in refractive index. When it reaches the work piece, the laser beam ablates the material by melting and vaporisation.

The diamond or sapphire nozzles have aperture diameters varying between 25 and 100μm. New, smaller nozzles are under development, allowing kerf widths of only 18 μm. Depending on the nozzle diameter, the pressure of the pure de-ionised water, supplied from an external pump, ranges from 50 to 500 bar. However, the mechanical forces applied by the water jet are negligible (less than 0.1 N).

In comparison, the assist gas jet used in conventional laser cutting applies a force of around 1N. Water consumption is very low, averaging only about 1.5 l/hour, making the process very environmentally friendly.

Like the other laser based technologies, the water jet guided laser features omni directional cutting. However, the process speed is higher with thin materials. For example, a cutting speed of up to 300 mm/s can be achieved on 50 μm thick silicon. Furthermore, using a water jet offers several further benefits compared to conventional, 'dry' laser cutting, such as extended working distance and perfectly parallel kerfs walls, as there is no divergence of the beam. The heat affected zone (HAZ) problem, which is inherent with conventional lasers, is also non existent thanks to the water jet, which cools the material between laser pulses. Contamination is eliminated as well, as the water jet expels the molten material more efficiently from the kerf than the assist gas used with conventional laser cutting. In addition, the thin film of water maintained on the surface of the work piece during cutting prevents any deposition of particles on the work piece material surfaces.

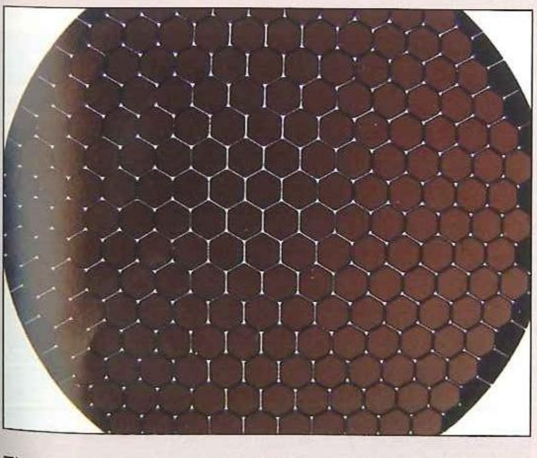

Fig. 3. View of wafer after hexagonal chip dicing with the LMJ

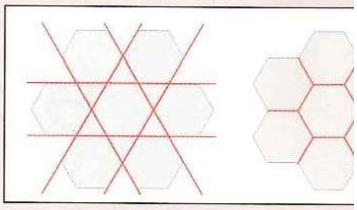

Fig. 2. Comparison of diamond blade saw (left) and LMJ dicing of hexagonal dies (right)

The benefits

An example of the boost in yield that can be achieved is the dicing of hexagonal dies, as shown in Fig. 2. On the left hand side the limitations of using a conventional diamond blade saw for dicing are readily evident, in which large areas of material are wasted. In comparison, the LMJ due to its omni directional capabilities is able to dice leaving minimal wastage. The result is an astounding 33% increase in die yield from each wafer. Added to this is the benefit of improved fracture strength, resulting from not having to halt the cutting at each corner, but cutting a small radius, which allows the laser beam to continue cutting uninterrupted, albeit momentarily at a slightly slower speed.

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Fig. 3. shows a 350 μm thick wafer after dicing has been carried out with a 50 μm nozzle, which clearly shows that the die yield has been maximised from the available surface area and wastage of material has been reduced to the absolute minimum. The actual kerf widths are ~45 μm.

Being able to cut narrow kerfs in the material also means providing more real estate area on the wafer, increasing yield and resulting in less wastage. The LMJ is able to make extremely small

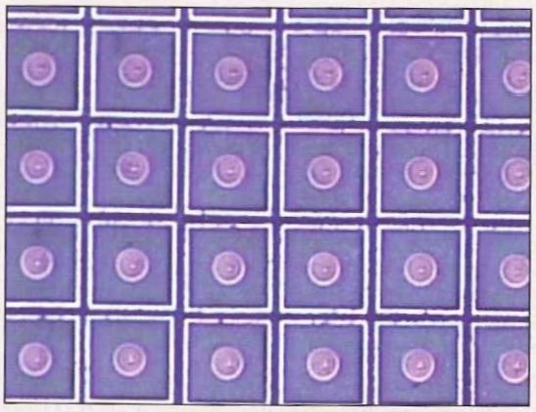

Fig. 4. Microscopic image of diced wafer

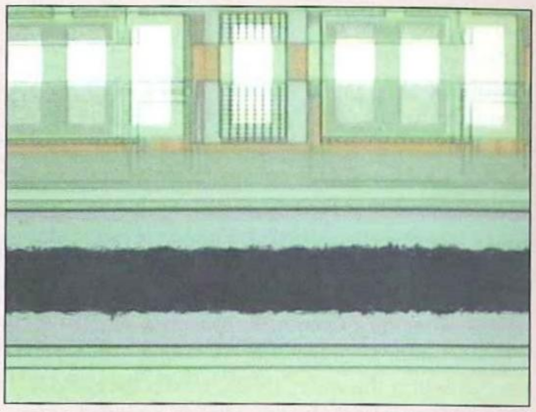

Fig. 5. Microscopic image of kerf cut in low-k silicon wafer

cuts in both thin and thick materials, producing perfectly parallel kerf walls. This is especially important with very small die geometry, as the chip yield will improve with the increased surface area becoming available, due to the reduced dicing street width requirements.

Dicing thin silicon wafer is another process at which the LMJ excels. A good example is the dicing of 75 μm thick silicon wafer with a 7 μm metal top layer. This was carried out a with a 25 μm nozzle installed on the LMJ. The results after dicing are shown in Fig. 4. The actual kerf width is ~22 μm allowing for a large margin in the 40 μm wide dicing street.

Material science

As mentioned earlier, devices made from low k-wafer pose additional difficulties for dicing, which revolve around the material brittleness and the fragility of the top layers, consisting mainly of oxides, metals and low-k silicon. Use of a diamond blade saw requires a dramatic reduction in cutting speed (down to 2 to 3 mm/s) and even then less than optimum results are obtained.

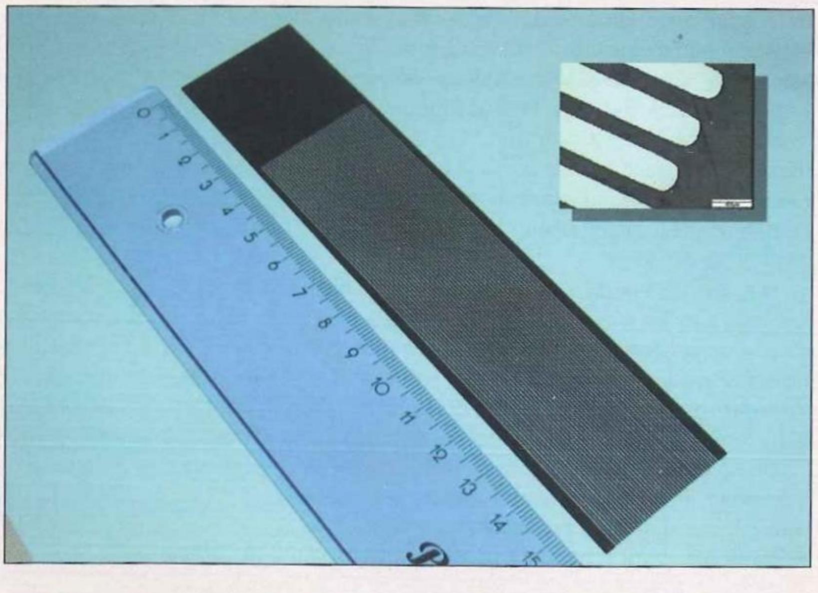

Fig. 6. 'Comb' structure cut from 250μm silicon wafer

The LMJ, however, can dice low-k materials, (200 μm thick in this example) at high speed as shown in Fig. 5, where it can be seen that no chipping of the glass passivation layer has occurred, nor has there been any delaminating of the metal layers. The wafer was diced with a 50 μm nozzle fitted at an overall speed of 100 mm/s.

A final example of the flexibility of the LMJ is the cutting of large and sophisticated x-ray optical elements from 250 μm thick silicon wafer, which demand perfectly parallel and clean cut surfaces. The 'comb' shaped structure shown in Fig. 6, consisted of 40*400 μm wide and 125 mm long 'fingers'. Each cut was made in four passes at 100 mm/s. The quality of the chip free cutting is demonstrated in the insert, which shows the 'comb finger' tips after separation. The resulting parts exhibited no micro cracking, no thermal deformation but high fracture strength.

Conclusion

To conclude this brief article describing the advantages of using the LMJ technology, should be added that it is also ideally suited to many other semiconductor manufacturing processes that have not been covered here.

These include the edge isolation of photovoltaic (PV) cells, where the LMJ is finding an increasing number of customers, for cutting the narrow and shallow grooves on either the front or back surface of the wafer, to provide electrical isolation between the cells active layers. Wafer edge grinding and chamfering for the relief of stresses resulting from blade saw cutting or surface grinding, is another process, where the LMJ has been successfully applied to manufacturing.