Dicing of wafers by patented water-jet-guided laser: the total damage-free cut

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The water-jet-guided laser is a new machining process increasingly employed in the semiconductor and other high-tech industries. This technology uses a low-pressure, hair-thin water jet to guide a laser beam by means of total internal reflection that takes place at the water-air interface, in a manner similar to conventional glass fibers. Thanks to the water jet, there is no heat damage and no contamination, contrary to conventional laser-based processes. Additionally, the mechanical force is negligible. Therefore, the water jet guided laser is a perfect process for wafer dicing. It can machine a wide range of semiconductor materials, including brittle materials such as GaAs; it is especially efficient on thin wafers. Furthermore, the hourly running costs are significantly lower than with mechanical methods, since there is no tool wear. Besides semiconductor processing, it is used for various micro-machining tasks, such as manufacturing of metal masks, medical devices, solar cells and inkjet-printer heads.

Key words: Laser, Dicing, Water-jet-guided laser, GaAs, Thin wafers

1. Introduction

The most common dicing method – abrasive sawing – shows today its limitations when confronted with the new requirements of the semiconductor industry. The increasing use of brittle materials, such as GaAs, and the reduction of wafer thickness, indeed, are problematic trends for diamond saws, which generate chipping and cracking in thin compound wafers.

If lasers offer some interesting features, such as absence of mechanical constraints and free-shape cutting, the deepness of the heat-affected zone and the amount of contamination are unacceptable for semiconductor processing.

The water-jet-guided laser, using water to cool the material and remove molten material, is a hybrid laser technology that does not suffer from the usual laser's drawbacks. The process is especially fast on thin wafers (thickness < 100 microns) and with brittle materials.

2. Water-jet-guided laser

The basic principle of the water-jet-guided laser (also called Laser Microjet®) implies that a laser beam is focused into a nozzle while passing through a pressurized water chamber. The water jet emitted from the nozzle guides the laser beam by means of total internal reflection that takes place at the water-air interface, in a manner similar to conventional glass fibers. The water jet can thus be referred to as a fluid optical wave-guide of variable length (see **Fig.1**).

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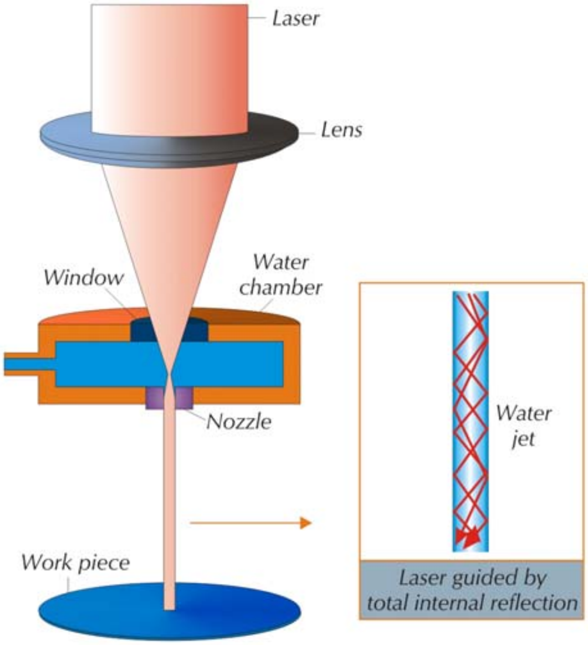

Fig.1 Basic principle of the water-jet-guided laser.

Several parameters can be adapted to optimally meet the requirements of a specific application. The lasers used are either flash-lamp-pumped pulsed IR lasers with pulse durations of less than 100 µs, or multimode diode-pumped Q-switched lasers, operating at 1064 nm (infrared), 532 nm (green), or 355 nm (UV). Regarding the water jet, pure de-ionized and filtered water, pressurized between 150 and 500 bars – depending on the nozzle diameter –, is used. As the jet is only "hair thin", the water consumption is very low (about 1 liter per hour at 300 bar water pressure). The nozzles are made of sapphire or diamond in order to generate a long, stable water jet, and their diameter ranges from 25 to 150 microns. Because of its specific characteristics, the water-jet-guided laser cannot be associated to conventional laser-based techniques.

In conventional laser cutting, the laser is focused on the work piece that has to be cut. The beam has a conical shape before and after the focal point. Therefore, the working distance is short. On the contrary, when using a water jet to guide the laser beam, the working distance corresponds to the part where the water jet is stable. This part is usually several centimeters long, depending on the size of the nozzle – about 100 times longer than with a standard-focused laser. After the nozzle, the microjet is perfectly cylindrical and constant, resulting in an excellent kerf parallelism after processing and the possibility to reach an increased cutting depth.

The main problem with laser-based cutting technologies is heating, since the cut is achieved by melting the material. A major advantage of the use of water is the prevention of heat damage within the material by cooling the cutting edges between the laser pulses. The heat-affected zone is greatly reduced, so that the usual negative effects (such as micro-cracks, oxidation or low fracture strength) are eliminated.

Removing the molten material generated by laser ablation is the second major problem. In conventional laser cutting, an assist-gas stream is added to the cutting system; however, this technique is not efficient, because of the low density and compressibility of the gas. Using a water jet is a significant improvement, as the kinetic energy of the water passing through the kerf is much higher in order to remove the molten material.

Adding a protective coating to the material is the common solution in conventional laser cutting to avoid particle deposition on the surface of the work piece. This increases costs, as two additional steps are required. Such operations are not necessary with the Laser Microjet because the system generates a thin water film on the surface of the piece, where the particles, already cooled by the water-jet, remain in suspension.

3. Laser Microjet for wafer dicing

Because it is a damage-free process, the Laser Microjet is particularly adapted to brittle-material processing and dicing of thin wafers. Recent studies conducted by a chip manufacturer [1] proved that dies cut with the Laser Microjet have higher fracture strength than those diced with an abrasive saw (for blank silicon, the die fracture strength is about 1.3 times higher). On thinner wafers, the cutting speed can be increased, while maintaining a high cutting quality.

A good example of difficult-to-process compound semiconductor is gallium arsenide (GaAs). After Laser Microjet dicing, GaAs wafers are free of chipping and micro-cracks, and contamination is negligible (see **Fig.2**). Compared to dry laser cutting, toxic gas emission is negligible. Indeed, all toxic material remains in the wastewater, and safety issues are thus equivalent to those of abrasive sawing, with a much-reduced volume of water to be dealt with, as consumption of DI water is more than an order of magnitude less.

The most efficient setting for GaAs processing with the Laser-Microjet is to use an infrared fiber laser (wavelength: 1064 nm, average power: 40 W) coupled with a very small nozzle. A typical cutting speed with this laser source for a 125-micron thick GaAs wafer is 40 mm/s. As a 25-micron nozzle can be used in this case, the resulting kerf is 23-micron wide. During the whole dicing process, the wafer is maintained on an adapted tape (called LaserTape®) which is resistant to the laser and which is porous, allowing the water to pass through it.

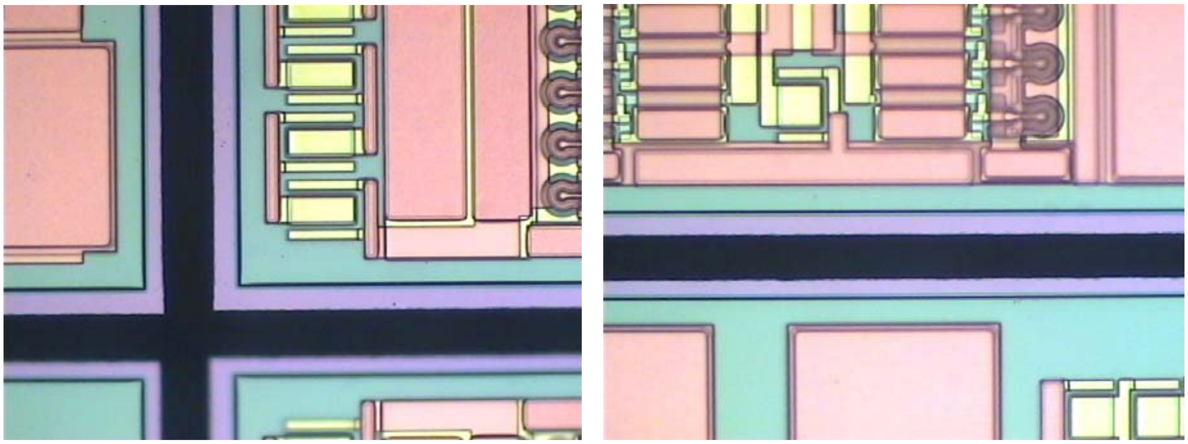

Fig.2 A 23-micron wide kerf has been achieved in a 100-micron thick GaAs wafer at a speed of 40 mm/s using an infrared fiber laser coupled with a very thin water jet; circuits are unaffected.

Very clean and chipping-free dicing is also achieved with low-k wafers. Because low-k layers are especially brittle, chipping is unavoidable with mechanical methods. Using the Laser Microjet, the active area of the dies is undamaged (see **Fig.3**).

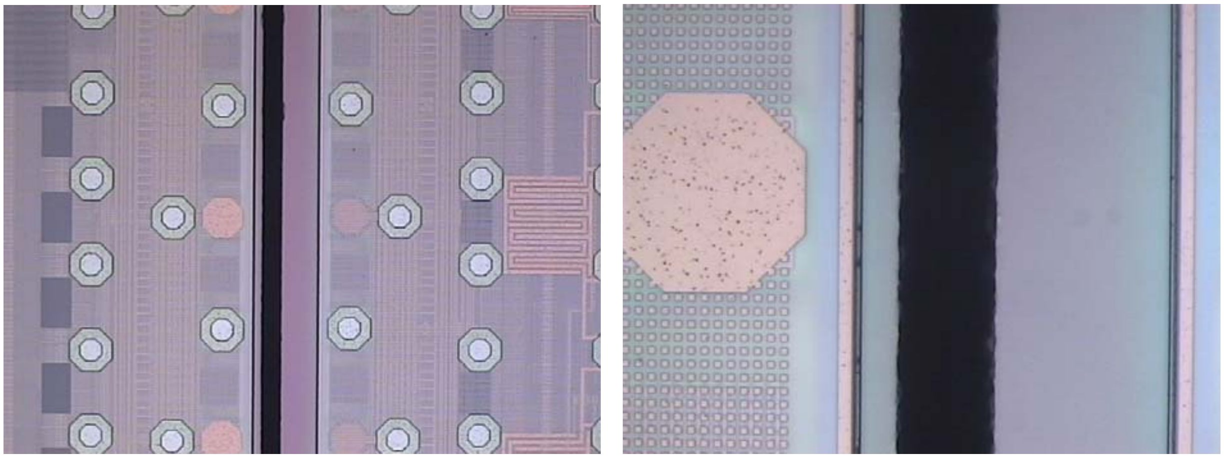

Fig.3 Front side of a 75-micron thick low-k wafer, diced with a green Nd:YAG laser (wavelength 532 nm, average power 60 W) guided in a 45-micron water jet, resulting in a 49-micron wide kerf; through cutting has been achieved at a speed of 50 mm/s.

4. Conclusions

Fundamentally different from conventional lasers, the Laser Microjet opens totally new possibilities in precision micro machining. With the problems of contamination and thermal damage surmounted, thanks to the ultra-thin water jet, the Laser Microjet is able to process even the most brittle and sensitive materials such as compound semiconductors. Compared to abrasive sawing, the most significant advantage is the absence of mechanical constraints. Indeed, the water jet, because of its small diameter and low pressure, applies a negligible force to the work pieces (less than 0.1 N). As there is no mechanical contact between the tool and the material, and thus no tool wear, the hourly running costs are significantly lower than with mechanical methods. A recent study conducted by a major chip manufacturer [2] showed that on silicon dicing, hourly costs are reduced by about 45% compared to traditional abrasive sawing.

Besides semiconductor processing, the Laser Microjet is used for various micro-machining tasks such as cutting of metal masks (stencils for PCBs and evaporation masks for OLED flat displays), manufacturing of medical devices (including stents), edge isolation of solar cells, slotting of inkjet-printer heads, cutting of hard-disk-drive heads, diamond tools, etc.

References

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