Clean Dicing of Compound Semiconductors Using the Water-Jet Guided Laser Technology

Delphine Perrottet
Communication, Synova SA
Ecublens, Switzerland
perrottet@synova.ch

Sean Green
Sales, Synova SA
Ecublens, Switzerland
green@synova.ch

Bernold Richerzhagen
CEO, Synova SA
Ecublens, Switzerland
info@synova.ch

Abstract

The water-jet-guided laser is a new technology for micro machining that combines a laser beam into a hair-thin, low-pressure water jet for wafer dicing. In addition to silicon, it can dice compound semiconductors such as GaAs, InP and SiC without damage.

Keywords

laser dicing, water jet-guided laser, Laser-Microjet, compound semiconductors, wafer edge grinding.

INTRODUCTION

Chip manufacturers carefully consider the capabilities of a new dicing system – due to contamination, micro-cracks induced by heating or mechanical constraints and edge chipping. Indeed, wafer dicing is a delicate step, which should be as gentle as possible – leaving wafers undamaged.

The common procedure for dicing is the use of mechanical methods, such as abrasive sawing. Although these methods have been used for semiconductor processing for many years, problems remain. Especially with brittle materials (such as GaAs), abrasive sawing tends to create significant chipping along the dicing streets. With very hard materials, such as SiC, blade consumption drastically increases running costs.

Lasers are more flexible tools opposed to abrasive sawing, and work faster on thin wafers. However, they are problematic for semiconductor processing as they generate heat that damages the material and because contamination is unavoidable. Particles on the circuits can be especially damaging.

A successful solution to use lasers for semiconductor processing is the addition of a water jet to the laser system. This water-jet-guided laser is an efficient micro machining process that is used today in the semiconductor, electronics and medical industries.

WATER-JET-GUIDED LASER

The basic principle of the water-jet-guided laser technology is to focus a laser beam into a hair-thin, low-pressure water jet. The water jet then guides the laser beam onto the wafer by total internal reflection at the interface between water and air (see Figure 1).

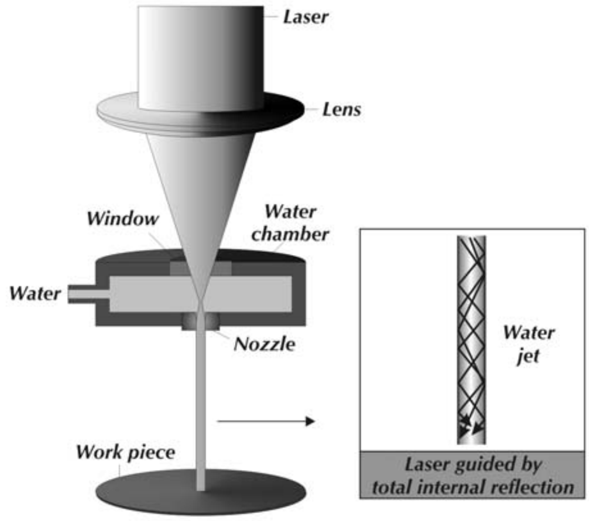

Figure 1: basic principle of the water-jet-guided laser technology.

One of the main advantages of this hybrid system – also called Laser-Microjet – is to prevent heat damage to the material by cooling the cutting edges in between the laser pulses; simultaneously the water jet removes the molten material generated by the laser. Contamination is avoided thanks to a thin water film that covers the wafer surface during the whole process. The particles, already cooled down by the water jet, cannot adhere to the wafer.

The mechanical force of the water jet onto the wafer is negligible, due to the small jet diameter (75 to 23 microns) and the low water pressure. The stable length of the water jet, corresponding to the process' working distance, can be several centimeters long, as it is about 1000 times that of the jet diameter. Because of the perfectly cylindrical shape of the jet in its stable length, kerf walls are parallel.

DICING OF BRITTLE MATERIALS

The Laser-Microjet process can cut through a wide range of semiconductor materials, including the most brittle. Perfect examples of difficult-to-cut materials are low-k wafers [1]. Figure 2 shows a 75-µm thick low-k wafer after Laser-Microjet dicing. The kerf width is 45 µm. A double-frequency Nd:YAG laser (wavelength: 532 nm, average power: 60 W) has been used for this application, achieving an overall speed of 50 mm/s.

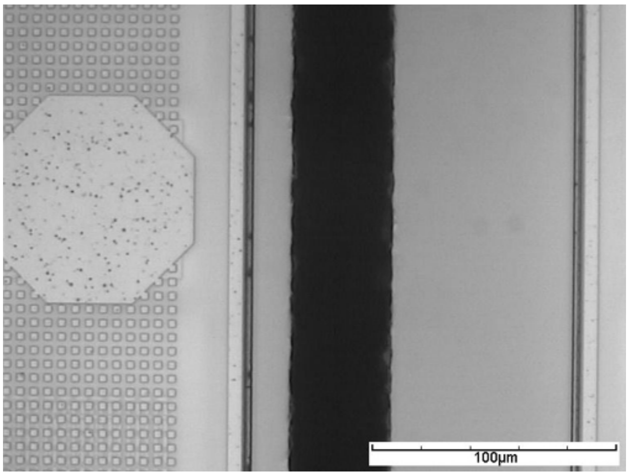

Figure 2: clean through cut of a thin low-k wafer (kerf width: 45 µm).

The Laser-Microjet also applies to GaAs cutting. As with low-k wafers, dicing is delicate due to the brittleness of this compound material. Additionally, safety aspects are important, because of the toxicity of arsenic. Unlike conventional laser cutting, Laser-Microjet processing does not emit gas [2]. All toxic materials remain in the wastewater, and safety issues are thus equivalent to those of abrasive sawing, with a much-reduced water volume to deal with, as consumption of DI water is at least an order of magnitude less.

Figure 3 and 4 show a 100-µm thick GaAs wafer, completely diced at a speed of 40 mm/s. The front side (figure 3) shows no chipping and is free of contamination; the wall (figure 4) has no burrs. The kerf width is 25 µm. An infrared fiber laser was used for this application (wavelength: 1070 nm, average power: 35 W).

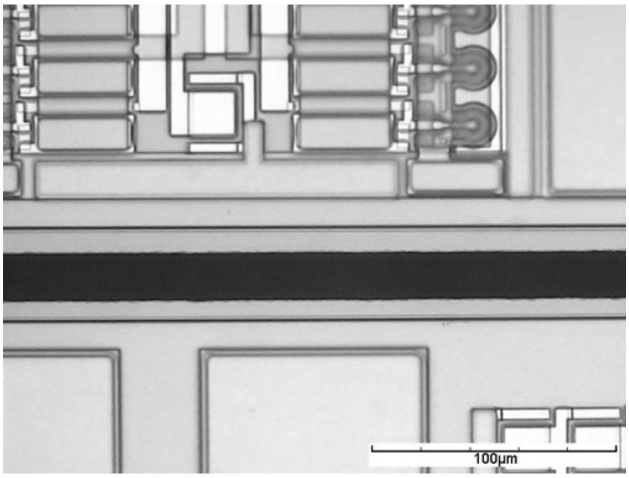

Figure 3: chipping-free dicing of a thin GaAs wafer.

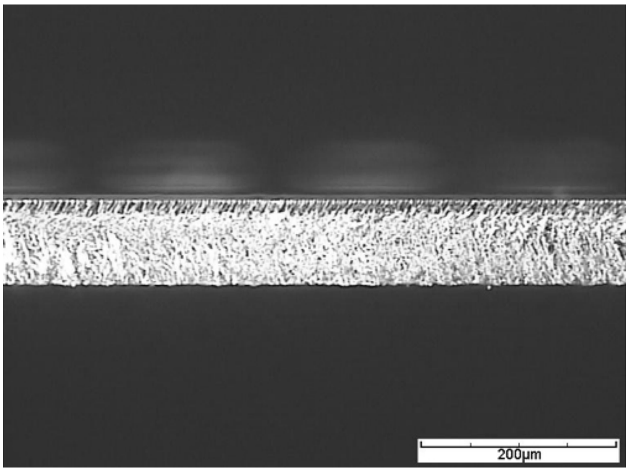

Figure 4: the edge of the thin GaAs wafer shows no burrs.

DICING OF HARD MATERIALS

On hard materials such as SiC, the main advantage offered by the Laser-Microjet technology is a reduction of the running costs, as there is no wear of tools. This is an important issue concerning blades, as SiC is almost as hard as a diamond. The Laser-Microjet process is also faster than abrasive sawing on this type of material [3].

Figure 4 shows the high quality obtained using a double-frequency Nd:YAG laser (wavelength: 532 nm, average power: 10 W). The 25-µm deep scribing was achieved at a speed of 40 mm/s.

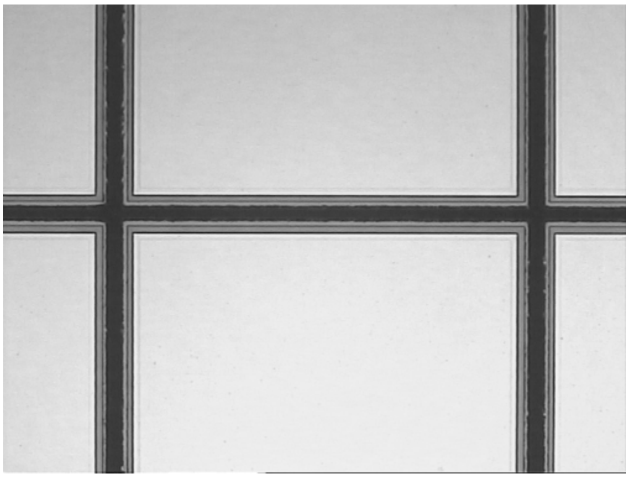

Figure 4: fast scribing of a thin SiC wafer (40 mm/s for a 25-µm deep scribe).

INCREASING FRACTURE STRENGTH OF THIN WAFERS

In addition to dicing and scribing, the water-jet-guided laser is used for a new task called "edge grinding" [4]. This operation consists in removing the outer edge of thin wafers, before or after back grinding, to increase the final strength of the thin wafer. Indeed, it has been observed that most micro cracks generated by back grinding are contained in the wafer edge. These cracks can easily spread in the material, resulting in wafer breaking and loss. Removing this damaged area is therefore an efficient way to reduce breaking, especially during handling.

Figure 5 shows a 725-µm thick silicon wafer grooved in a way so the damaged edge can be removed during the back grinding step. For this application, a diode-pumped Nd:YAG fiber laser was used (wavelength: 1064 nm, average power: 80 W). The nozzle diameter was 75 µm. The wafer was grooved at a distance of 1 mm from the edge and the grooving depth was 80 µm. The resulting process speed was 50 mm/s.

Figure 5: edge grinding of a thick silicon wafer, before back grinding, 1 mm from the edge.

FREE-SHAPE CUTTING

Edge grinding is not the only application that can benefit from the flexibility of the water-jet-guided laser technology. The process can also be used for wafer downsizing – for example, to produce 0.8” wafers from 4” wafers. This particular ability opens up numerous possibilities for chip design that are not conceivable with abrasive saws.

Figure 6 shows a rounded bevel achieved in 650-µm silicon at the speed of 11 mm/s. The 45-µm wide kerf was placed close to the active area of the devices. This kind of design can be used for image sensors.

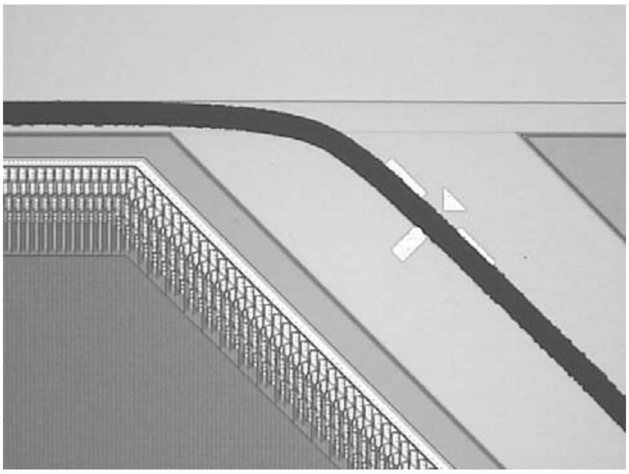

Figure 6: rounded bevel in thick silicon.

Another application is dicing of hexagonal chips. Figure 7 shows corners of hexagonal chips cut with the Laser-Microjet. Corners are rounded and show no burrs. The chip backside is free of chipping. These 350-µm thick wafers were processed at an overall speed of 20 mm/s. The cut was performed close to the edge without damaging the adjacent active area. Other shapes can be designed, such as circular chips.

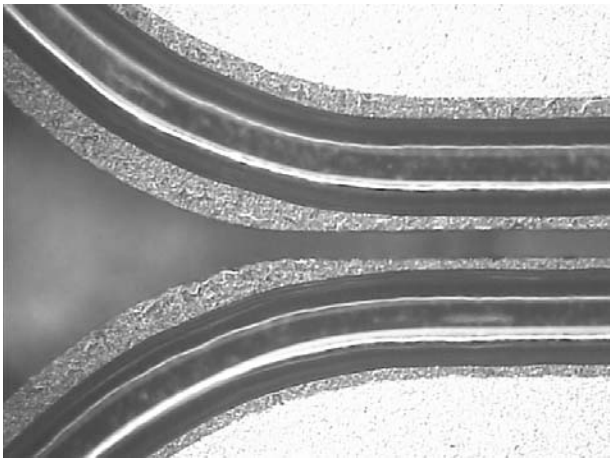

Figure 7: corners of hexagonal chips.

CONCLUSIONS

Further research on the water-jet-guided laser technology aims to use different laser sources, reduce the water jet diameter and adapt the process to emerging semiconductor applications, such as ultra-thin wafers or die-attach films.

REFERENCES

[1] J. Vittu, D. Perrottet and B. Richerzhagen, *Damage-free dicing of low-k wafers*, Future Fab International (MRI / Mazik Media) n°17

[2] N. Dushkina, *Dicing GaAs wafers*, Industrial Laser Solutions (Pennwell), June 2003

[3] C. von Koblinski, G. Lackner, D. Perrottet, M. Wiki and B. Richerzhagen, *Water-guided laser speeds up rate of SiC-wafer dicing*, Compound Semiconductor (IOP Publishing), June 2005

[4] D. Perrottet, J.-M. Buchilly, F. Wagner and B. Richerzhagen, *Reducing breakage of thin wafers to zero: wafer edge grinding with the Laser Microjet*, Semiconductor Manufacturing (SEMI), August 2004

BIOGRAPHY

Delphine Perrottet received in 2002 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.

Sean Green spent some five years with a Japanese manufacturer of dicing machines before joining Synova's team in 2005. Prior to this, Sean was sales manager for a manufacturer of semiconductor ceramics, and before that, he worked for a German vacuum-system supplier, first as a sales engineer, then as North Europe Key Account Manager.

Bernold Richerzhagen received his M.Sc in mechanical engineering from Aachen Polytechnic in Germany (RWTH). After his PhD in micro-technology at the Swiss Federal Institute of Technology Lausanne, Bernold Richerzhagen founded Synova SA in 1997 to develop the water jet-guided laser technology he had invented during his PhD.