GaAs-Wafer Dicing Using the Water jet Guided Laser

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Abstract

Semiconductor wafers are getting thinner and thinner. GaAs wafers are not excluded by this trend. Since new dicing technologies are required for wafer thicknesses less than 150 µm. Significant differences are noted among existing dicing methods. Abrasive sawing does not provide the desired cutting speed and yield because of mechanical damage (cracking, chipping). Cutting with conventional lasers should be avoided because of significant heat damage and safety issues (arsenic oxides). The Laser-Microjet, which combines a laser and a water jet, is currently the most promising technology for thin wafer dicing. It is faster and cleaner than any other process on thin GaAs wafers and generates an impressive kerf quality. The water jet, combined with a thin water film on the wafer surface, removes any deposition generated by laser ablation. No toxic gas is emitted, since all toxic material is carried away by water. The Laser-Microjet also allows omni-directional cutting, which is impossible with blades. Specifically, it can cut at 45° to the crystal plane. Edge grinding of thin wafers represents one application of omni-directional cutting, reducing breakage by removing the sensitive wafer edge containing micro-cracks.

INTRODUCTION

Continuing demands for higher speed and increasing miniaturization have driven the wireless and broadband communications industries to use higher-performing semiconductor materials than silicon, such as gallium arsenide (GaAs); today, production technologies must be better adapted to this new growing market as thin GaAs wafer processing (between 50-µm and 150-µm thick) is problematic, especially during chip singulation. This is due primarily to the material's properties, since GaAs is particularly brittle. At that stage, the wafer already has a high value. The current drive toward higher production volumes at lower costs makes it critical to use a dicing method that achieves the highest yield.

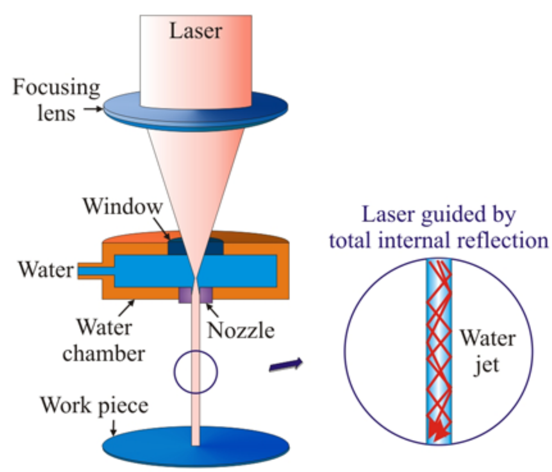
The various dicing methods show significant differences with respect to cutting speed and quality. Abrasive sawing induces mechanical constraints, which are critical in the case of thin wafers. Chipping and cracking are frequent. Streets must be widened, which means fewer chips per wafer. Cutting speed also is very low, resulting in low yield. Conventional dry lasers generate an important heat load and, in addition, toxic arsine oxides are emitted. The scribe and break method still does not provide satisfying yield because of occasional wafer or die breakage.

Although traditional dicing technologies have improved over the years, they should be replaced as wafers become thinner and as the use of costly and critical materials increases. The most promising solution today for thin GaAs wafer dicing is the water jet guided laser (Laser-Microjet), a revolutionary technology coupling a laser and a water jet.

LASER-MICROJET PRINCIPLE

The concept of the Laser-Microjet is to couple a pulsed laser beam with a hair-thin, low-pressure water jet. The basic principle is to focus a laser beam into a nozzle while passing through a pressurized water chamber. The low-pressure water jet emitted from the diamond nozzle guides the laser beam by means of total internal reflection at the water/air interface, similar to conventional glass fibers (see Figure 1).

FIGURE 1
PRINCIPLE OF LASER-MICROJET: COUPLING THE LASER BEAM INTO THE WATER JET



The water jet thus acts as a stable fluid optical wave-guide of variable length. In addition to its guiding function, it has two other primary effects. First, it cools the material between the laser pulses so the heat-affected zone is negligible. Second, thanks to its high momentum, it removes most of the molten material generated by laser ablation. Additionally, a thin water film on the material prevents particles from adhering to the wafer surface. The Laser-Microjet is therefore significantly different from the dry laser, which pose the major disadvantages of contamination and heat damage.

The Laser-Microjet also offers advantages over abrasive sawing. It is a faster process; depending on the material, up to 10 times faster. Furthermore, the mechanical force applied by the water jet is negligible (less than 0.1 N), in contrary to sawing. This force is also much lower than the force applied by the assist gas in conventional dry laser cutting.

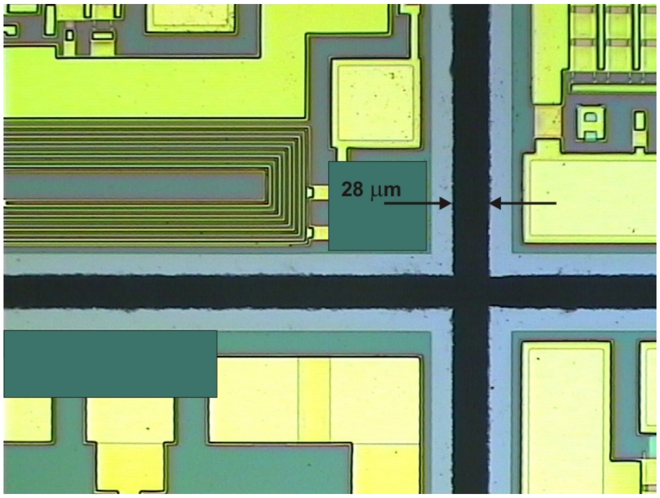
The Laser-Microjet is therefore an efficient technology for semiconductor processing, including III-V composite materials as well as silicon. Its main applications in this field are thin wafer dicing (through-cutting), scribing and edge grinding. Recent developments on nozzles have enabled stable cutting with a micro-jet as thin as 25 µm.

The main advantages of GaAs cutting with the Laser-Microjet are: high speed; no mechanical forces; no cracking or chipping; low kerf width; no contamination; no toxic products; and possibility to cut through back metal. In addition, it can cut at 45° to the standard crystal orientation. Omni-directional cutting offers the desirable application of edge grinding of thin wafers. Thus, by removing the edge of wafers, micro-cracks generated by back grinding are eliminated, thereby reducing wafer breakage.

GaAs wafer cutting and Laser-Microjet

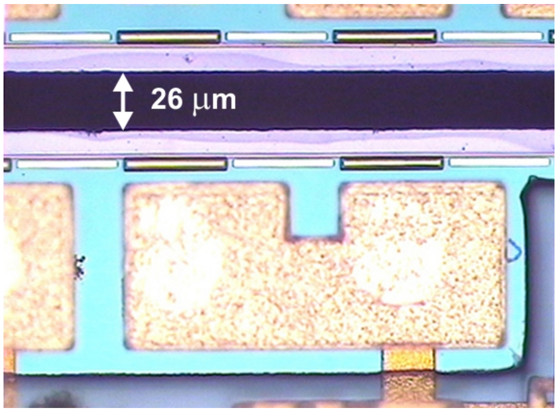
Usually, the Laser-Microjet is applied for through-cutting. Figure 2 shows the typical quality obtained with the LMJ process on GaAs wafer. There is no chipping due to mechanical stress and very low contamination. For this 100-µm thick GaAs wafer, a fiber laser (wavelength 1064 nm, average power 100 W) has been coupled into a thin water jet (diameter 27 µm). These parameters were chosen to obtain high cut quality at high speed. Speeds up to 80 mm/s have been achieved.

FIGURE 2
28-um wide through-cut in a 100-um thick GaAs wafer: a chipping-free cut



1) Particle contamination: the Laser-Microjet produces little contamination, since the water jet used to guide the laser beam onto the work piece also efficiently removes most of the molten material. An additional device has recently been developed to reduce particle contamination level even further. During cutting, a continuous water layer of controlled thickness covers the wafer, preventing the particles from attaching to the material surface. Removing the water layer containing suspended particles after cutting guarantees a clean wafer. The result is especially impressive compared to conventional laser cutting. Figure 3 provides an example of the cut quality. For this 100-µm thick wafer, a Q-switched Nd:YAG laser (wavelength 1064 nm, average power 50 W) has been coupled into a water jet of 25 µm diameter. Even at high speed (60 mm/s), the cut quality is excellent.

FIGURE 3
26-um wide through-cut in a 100-um thick GaAs wafer: a chipping-free cut at 60 mm/s



2) Toxicity of GaAs ablation: safety issues are paramount during cutting since compound GaAs contains 51.8%wt arsenic. Tests performed with the Laser-Microjet (see Table

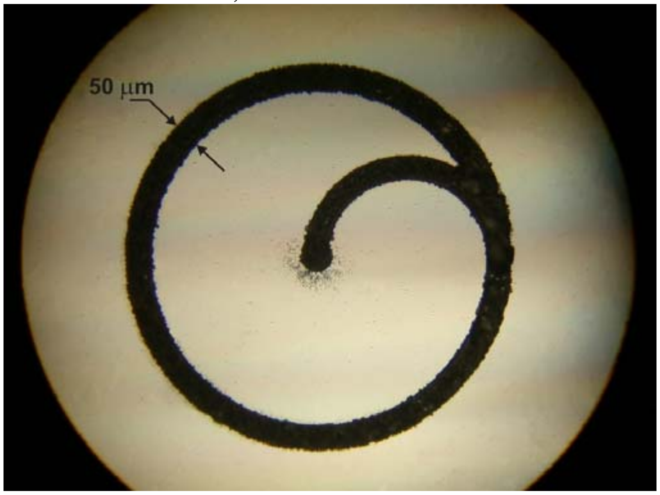
1) showed that no arsine gas is detected in the air while cutting GaAs. This represents a significant improvement compared to conventional laser cutting [1]. All arsenic is concentrated in the wastewater, which should therefore be appropriately filtered or recycled. Thus, Laser-Microjet dicing of GaAs does not require any additional security systems comparable to sawing.

TABLE 1
RESULTS FROM THE GAAS TRIAL RUN: ARSENIC CONCENTRATION

Arsine gas [ppm]	Not detected
Concentration of As in air [µg/m^3]	130 (in cutting chamber) 4 (outside machine)
Concentration of As in water [µg /L]	62700
Wipe sample results [µg/cm^2]	30 (in cutting chamber) 0.062 (next to machine)

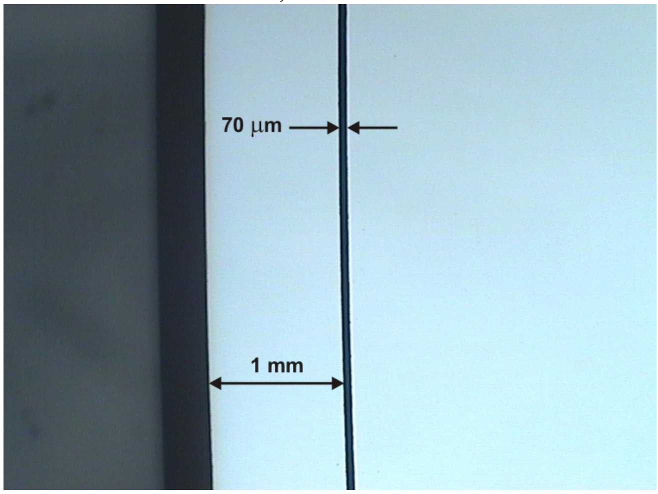
3) Omni-directional cutting: unlike saws, the Laser-Microjet can cut in any direction. Specifically, it is possible to cut at 45° to the main crystal plane. Free-shape cutting – also known as free form or arbitrary cutting – of thin wafers has become increasingly important for various applications in microelectronics, in which arbitrary-shaped chips are used. Figure 4 shows a 178-µm thick GaAs wafer cut with the Laser-Microjet at a speed of 15 mm/s.

FIGURE 4
FREE-SHAPE CUTTING IN A 178-UM THICK GAAS WAFER; KERF WIDTH 50 UM; CUTTING SPEED 15 MM/S



4) Edge grinding of thin wafers: edge grinding is intended to reduce thin wafer breakage. It consists of a cut or a groove around the wafer to remove micro-cracks accumulated in the edge. This operation can be performed either before or after back grinding, depending on the application. Figure 5 shows a wafer grooved using a diode-pumped fiber laser (wavelength 1064 nm, average power 80 W) and a 75-µm nozzle. The wafer has been grooved at a distance of 1 mm of the edge and the grooving depth was 80 µm. The resulting process speed was 50 mm/s.

FIGURE 5
EDGE GRINDING OF A WAFER, 1 MM FROM THE EDGE AND 80-UM DEEP



CONCLUSIONS

The Laser-Microjet is currently the most promising technology for thin wafer dicing, especially when thickness is less than 150 µm or when delicate materials are used. It has proven better able to dice thin GaAs wafers than any other dicing methods, such as sawing, conventional dry laser and scribe and break techniques. The heat-affected zone is negligible thanks to the water jet that cools the cut edges during laser ablation. Molten material is efficiently removed and does not adhere. Cutting speeds are much higher than with sawing (up to 80 mm/s in 100-µm thick GaAs), while achieving an excellent cut quality. Currently, kerf widths as thin as 25 µm can be achieved; new nozzles being tested in the laboratory will produce ultra-thin jets of only 17-µm diameter. Regarding safety, only conventional procedures are required (wastewater treatment). Finally, omni-directional cutting allows wafer edge grinding, reducing wafer-breakage.

ACKNOWLEDGEMENTS

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ACRONYMS

LMJ: Laser-Microjet