High-speed dicing of GaAs wafers with water-guided laser

J Manley,[a] D Perrottet,[b] F Wagner,[b] R Housh,[b] B Richerzhagen,[b]
[a]Synova-USA, Inc., 345 West San Juan Ave., Phoenix, AZ 85013, USA
[b]Synova SA, Ch. De la Dent-d’Oche, 1024 Ecublens, Switzerland

Abstract Developing new technologies for wafer dicing has become urgent as wafers become thinner and new materials are used. In particular, processing thin gallium arsenide (GaAs) wafers is a delicate operation, because of the mechanical and chemical properties of the material. As the mechanical dicing methods are unsatisfying regarding these requirements, the Laser Microjet offers today the best solution for high-speed dicing of GaAs wafer. It is faster and cleaner than any other process, and generates a high kerf quality. Furthermore, the process has the property of omni-directional cutting, no contamination and no toxic arsine gas is emitted during cutting.

1. Introduction

The continuing demands for higher speed and increasing miniaturization have driven the wireless and broadband communications industries to use semiconductor material with higher performances than silicon, such as the brittle and difficult-to-handle gallium arsenide (GaAs). Today, production technologies need to become more adapted to this new growing market. Indeed, the use of thin GaAs wafers (thickness from 150 μm down to 25 μm) creates problems, especially when they reach the last stage of the front end – chip singulation. Because GaAs is very brittle and fragile, sawing methods do not provide the desired cutting speed and yield. Furthermore, considering that dicing is one of the last steps means that the wafer has the highest value at that stage; because of the drive toward higher production volumes at lower costs, it is paramount to employ the dicing method that achieves the highest yield.

2. State of the art

Amongst the various existing dicing methods, several important differences can be observed. Saws induce mechanical constraints, critical in the case of thin wafers: consequent chipping, as well as broken corners or chips, is frequent, even with decreased speed. Because of this, the streets have to be widened, meaning producing fewer chips per wafer. The dicing speed of a saw is very low. Conventional dry lasers generate an important heat load and furthermore toxic arsine gas is emitted. As for the scribe and break method, it still does not provide satisfying yield because of occasional wafer cracking.

Although the traditional methods have been improved over the years, they will be replaced as wafers become thinner and more costly and critical materials are employed. The most promising alternative today is the Laser Microjet, a revolutionary technology coupling a laser and a water jet.

3. Laser Microjet Principle

The concept of the Laser Microjet (LMJ) is to couple a pulsed laser beam into a low-pressure water jet in order to cut, scribe, drill holes, etc. in any kind of materials. Its 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, in a manner similar to conventional glass fibers (see Figure 1).

The water jet acts thus as a stable fluid optical wave-guide of variable length; it has three process critical functions:

1. Guiding the laser beam to the work piece;
2. Removing molten material;
3. Cooling the work piece.

The Laser Microjet has two main advantages upon sawing. First, the mechanical force applied by the water jet on the wafer is negligible (less than 0.1 N), at least 10 times lower than the one applied by the assist gas in conventional laser cutting (force ranging typically from 1 to 5 N), and of course much lower than the one applied by blades. This is a very important characteristic when dealing with fragile materials and thin wafers. Second, in the case of thin wafers, the Laser Microjet cuts up to 10 times faster than the saw.

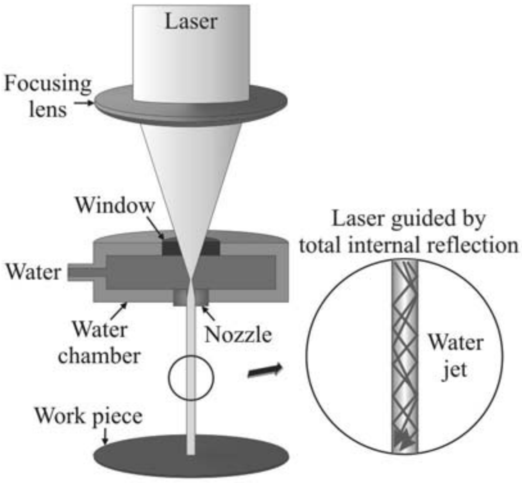

Figure 1 - Principle of the coupling unit: coupling the laser beam into the water jet

The process is also very different from conventional dry lasers, since the processed material sustains only negligible heating, and the particle contamination is much lower. This is due to the combination of the water jet and a thin water film: the water jet pressure ensures an efficient rinsing and removes the molten material from the cut; the generated particles are held in suspension in the water film and can be easily removed when the wafer is completely cut, as they do not attach to the surface.

The Laser Microjet is an efficient alternative for semiconductor applications, processing Silicon as well as III-V materials; its main applications in this field are thin wafer dicing (thru-cut), scribing and edge grinding. The recent research on nozzles made stable cutting with a Microjet as thin as 25 μm possible.

In the particular case of gallium arsenide (GaAs) processing, the Laser Microjet has the advantages of non-toxicity (no gas, all toxic substances are absorbed in the water) and omni-directional cutting – in particular, it is able to cut at 45° to the standard crystal orientation. Another application is edge grinding for thin wafers, where a small stripe all around the wafer is removed, eliminating micro-cracks at the wafer edge and reducing breakage to almost zero.

4. GaAs cutting and Laser Microjet

Dicing of thin GaAs wafers with the Laser Microjet is usually achieved by through cutting. This is the case for the 100-μm thick GaAs wafer shown in Figure 2. For this wafer, a Q-switched Nd:YAG laser (wavelength 1064 nm, average power 50 W, pulse repetition rate 35 kHz) has been coupled with a thin water jet (diameter 25 μm, pressure 400 Bar). These parameters were chosen with the purpose of obtaining an excellent cut quality at high speed; a cutting speed of 60 mm/s has been reached.

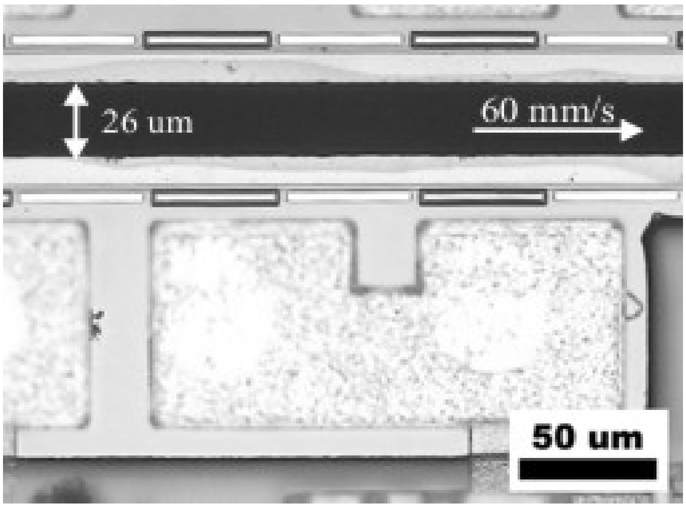

Figure 2 – 26-μm wide through-cut in a 100-μm thick GaAs wafer: a chipping-free, neat cut at 60 mm/s

4.1 *Particle contamination*

Compared to conventional laser-based technologies, the water jet guided laser technology produces a much smaller amount of particles, since the water jet used to guide the laser beam onto the work piece also removes efficiently most of the molten material. Recently, an additional device has been developed in order to reach a particle contamination level close to zero: during cutting, a continuous water layer of controlled thickness covers the wafer, avoiding the particles to attach to the wafer surface. After cutting, removing the water layer with the suspended particles in a controlled way guarantees a clean wafer.

4.2. *Toxicity of GaAs ablation*

Pure compound GaAs contains 51.8%wt arsenic, a very toxic substance; therefore, safety issues are paramount when cutting GaAs. Tests performed with the Laser Microjet show that no arsine gas is detected in the air while cutting GaAs wafers, an important difference to classical laser cutting [1]. Almost all Arsenic is concentrated in the wastewater, which should therefore be appropriately filtered or recycled. Compared to sawing, GaAs dicing with the Laser Microjet does not require any additional security systems.

4.3. *Omni-directional cutting*

Contrary to saws, the Laser Microjet is able to cut in any direction; in particular, 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 chips with arbitrary shape are used.

4.4. *Edge grinding of thin wafers*

Edge grinding consists in cutting a wafer around its edge so as to remove the micro-cracks accumulated there. This operation can be performed either before or after the grinding, depending on the application. After edge grinding, thin wafer breakage is reduced to zero [2].

5. Conclusions

The Laser Microjet is the most promising technology for thin wafer dicing, especially when thickness is below 150 µm or when delicate materials (regarding their mechanical and chemical properties) are used. It has proven today its capacities for dicing of thin GaAs wafers ahead of all other dicing methods, including saws, conventional dry lasers and scribe and break techniques. With the water jet cooling between the laser pulses, the heat-affected zone is negligible; the molten material is efficiently removed and cannot damage nearby components. Cuts are regular and clean, and kerf width as thin as 26 µm can be realized. In fact, new nozzles are currently being tested in Laboratory, producing ultra-thin Microjets of 17-µm diameter only. Cutting speeds are higher than with any other process, and only conventional safety procedures are required (mainly wastewater treatments). Moreover, with the ability of cutting in any direction, the Laser Microjet is indeed a technology able to revolutionize the domain of wafer dicing.

References

[1] N. Dushkina N 2003 *Dicing GaAs wafers* (Industrial Laser Solutions).

[2] Sibailly O, Wagner F, Richerzhagen B 2004 *Laser-Edge Grinding of Thin Wafers with the Water-Jet-Guided Laser* (Future Fab International **16**).