Successful integration of Laser-Microjet for GaAs-wafer dicing

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Abstract For several years, the water jet guided laser has been actively used for semiconductor processing. Its particular features offer many benefits to chip manufacturers, including absence of thermal and mechanical damage, negligible contamination and parallel kerfs. Recently, North Carolina-based RF Micro Devices, a leading manufacturer of integrated circuits for wireless communication, has chosen to include the Laser-Microjet system in its production line for thin GaAs-wafer dicing. The system is currently under qualification for integration in production and results are very promising.

1. Introduction

If silicon has dominated the semiconductor market for more than three decades, new III/V semiconductor materials such as GaAs are increasingly used because of their higher speed and the possibility of miniaturization. Indeed, GaAs offers several performance advantages over pure Si, including high frequency operation, improved signal reception, better signal processing in congested frequency bands, and greater power efficiency.

GaAs, however, is delicate to process; as it is a brittle material, dicing can be an especially difficult task. Since the water jet guided laser (Laser-Microjet) has proven to be more gentle to the samples being cut it offers significant advantages for GaAs processing.

2. Laser-Microjet Technology

The Laser-Microjet was developed in the nineties for medical applications and today is used for precision micro machining in a wide range of industrial fields, including semiconductors. The basic principle of this technology is to use an ultra-thin water jet to guide a laser beam to the work piece. To achieve this, the laser beam is focused through a transparent window into a nozzle placed at the bottom of a water-filled chamber. The cylindrical water jet produced below the nozzle will guide the laser beam by means of total internal reflection at the water/air interface, similarly to conventional glass fibers (see Figure 1).

The capabilities and performances of this process are different from those of conventional dry lasers. First, because the water jet is cylindrical, kerf walls are parallel. The working distance – corresponding to the stable length of the jet – can be several centimeters long, depending on the jet diameter. Therefore, there is no need of focus control.

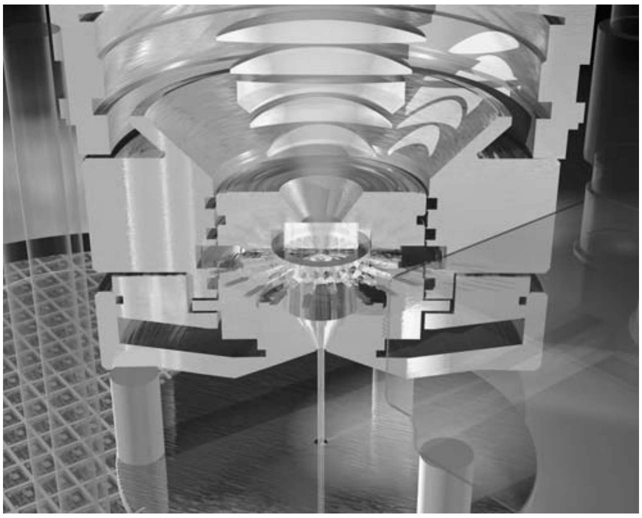

Figure 1 – Focusing a laser beam into water creates a "water-jet guided laser"

Second, heat damage is nonexistent, since the water jet cools the edges between the laser pulses. The temperature of the cut edge rapidly decreases to the water temperature and heat generated by the laser is not conducted further into the material. The negative effects of heating, such as micro cracks, oxidation, structural changes or low fracture strength, do not appear.

Contamination is greatly reduced, as the water jet, whose pressure ranges from 50 to 500 bars, develops a high kinetic energy fully dedicated to the removal of the molten material. Additionally, a thin water film is generated on the wafer surface during the process, preventing particle deposition. Since the water jet is very thin (diameter ranging from 20 to 100 microns), the mechanical force applied on the wafer is negligible (less than 0.1 N). As a result, the process does not generate chipping or micro-cracks.

Therefore, the Laser-Microjet is able to process a wide range of compound semiconductor materials, including GaAs, InP and SiC.

3. GaAs-wafer dicing

Conventional dicing technologies experience various problems with GaAs. Abrasive sawing generates mechanical constraints on the wafer, resulting in chipping and even breakage. Dicing speed is low and wide streets are needed. The diamond scribe-and-break method suffers yield problems. Furthermore, this method has difficulties with backside metal layers. The process is not reliable enough and machine operator intervention is often needed. Conventional “dry” lasers generate heat damage, contamination on the wafer surface and slag. Additionally, toxic gas products are emitted during dicing.

Because of its particular properties, the Laser-Microjet is well suited for processing of brittle materials such as GaAs. Processed wafers are free of chipping and micro-cracks, and contamination is negligible. Additionally, recent data indicates that LMJ diced chips have high fracture strength. Another important aspect of Laser-Microjet dicing, compared to dry laser cutting, is the absence of toxic gas emission. 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. Cutting speed increases on thinner wafers. 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 porous, allowing the water to pass through it.

Other laser sources can also be used for this application like frequency-doubled lasers (wavelength: 532 nm). Recently, tests have also been conducted with a UV laser (wavelength: 355 nm). The results show very smooth cut edges.

The two photos below (Figure 2) show the typical cutting quality of the Laser-Microjet process. There is no visible contamination on the wafer; the dicing process does not damage circuits. Kerfs are clean and constant. The process generates no chipping, even at the chip corners. Kerf width on these pictures is 23 microns.

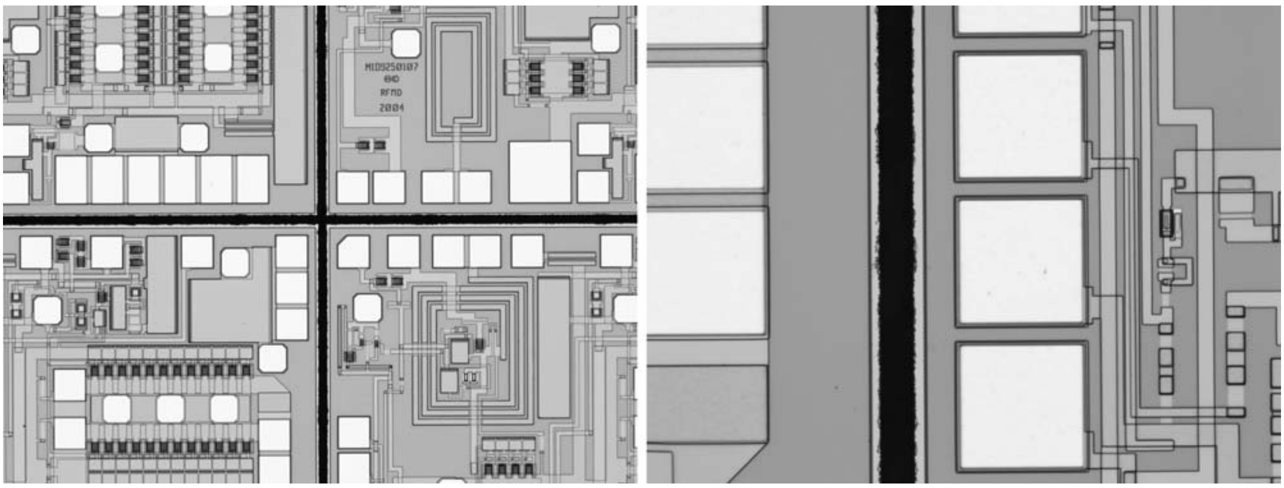

Figure 2 – Typical cutting quality of the Laser-Microjet process on GaAs (source: RF Micro Devices)

4. Laser-Microjet in production

A leading manufacturer of compound semiconductors, RF Micro Devices, has recently decided to acquire a fully-automatic dicing system based on the Laser-Microjet technology for production of GaAs IC’s. For RFMD, benefits include high cutting speed, absence of chipping, narrow kerf width, absence of toxic particles and high kerf quality. After a convincing test phase, RF made the choice to acquire a *LDS 200 A* for its site of Greensboro, USA (see Figure 3). RF’s LDS is currently in production qualification and is used every day in this context. The qualification process progresses well and the start of 24-hour production is planned soon.

With this first promising installation, the water jet guided laser confirms its place in the market of thin compound semiconductors.

Figure 3 – Automatic “Laser Dicing System” featuring the Laser-Microjet process, used for dicing of 200 mm wafers