Damage-Free Dicing of SiC Wafers by Water-Jet-Guided Laser

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Abstract

Since several years, the water-jet-guided laser technology has been used for a wide range of precision applications, including wafer dicing. It has proven its capacities to process not only silicon, but also more brittle semiconductor materials such as GaAs or low-k wafers. It has recently been tested on another compound material, which is known for its hardness: SiC. Compared to abrasive sawing, the water-jet-guided laser offers higher speed for the same quality at reduced running costs, as there is no blade wear.

INTRODUCTION

Silicon carbide (SiC) is a wide-bandgap semiconductor that offers many advantages over common silicon for power devices, as it can be doped much higher than silicon to achieve a given blocking voltage. In addition, SiC devices are able to withstand high temperature environments.

CONVENTIONAL TECHNIQUES FOR SIC-WAFER DICING

Mechanical methods such as abrasive diamond blades or tips are generally used to dice SiC wafers. The main drawback of these processes is tool wear – because SiC hardness is 96 percent that of a diamond, blade wear is approximately 100 to 500 times higher than for silicon. Additionally, the sawing blade can occasionally break due to mechanical constraints.

Conventional lasers are not used for wafer dicing because of heat damage and particle contamination. Indeed, lasers remove material by heating it until it melts or vaporizes, generating a heat-affected zone in the material along the kerf and inside the cut. The assist gas, co-axial to the laser beam during cutting, does not completely remove the molten material; particles and burrs are present on the front side of the wafer if no protective layer (such as photoresist) is used.

As abrasive sawing and dry laser cutting are not satisfying solutions for SiC-wafer dicing, chip manufacturers have lately tested the feasibility of other processes, including a new laser-based technology, the water-jet-guided laser.

WATER-JET-GUIDED LASER

The basic principle of the water-jet-guided laser (also called Laser-Microjet) is laser beam that 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 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 Figure 1).

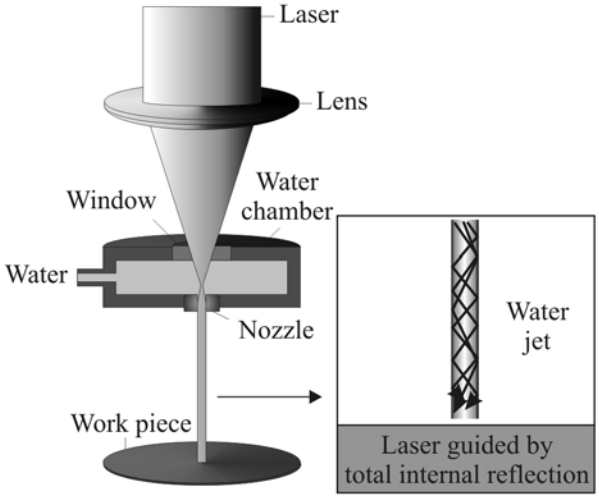

Figure 1 Water-jet-guided laser

This new process should not be confused with a conventional dry laser [1]. One of the major differences is the absence of thermal damage, due to the water jet that cools the material between the laser pulses. Another advantage is the low level of contamination, as the water jet removes the molten material from the cut. In addition, a water film is maintained on the wafer surface during the process, acting as a protective layer and preventing particle deposition. Because the force applied by the water jet is negligible (less than 0.1 N), the process does not generate mechanical damage such as chipping or cracking.

Different laser sources (different wavelengths and powers) can be used. The water-jet diameter ranges from 75 microns down to 25 microns with a pressure between 50 and 500 bars.

WATER-JET-GUIDED LASER FOR SIC-WAFER DICING

Several years ago, the water-jet-guided laser was successfully introduced into the production of silicon-based devices (dicing and edge grinding). The process was then applied to compound semiconductors such as GaAs, which is processed today without chipping even at high speeds.

During the past few months, the Laser-Microjet has also been applied to SiC.

The most important benefit of the Laser-Microjet for wafer dicing compared to conventional cutting techniques is the reduced running cost, since there are no concerns about tool wear and blade replacement. The hourly running cost for silicon processing is reduced by about 45 percent compared to abrasive sawing, mainly due to the price of blades which have to be replaced and to the resulting operator cost [2]. Water consumption is strongly reduced – around 1 liter per hour at 300 bar water pressure. Since SiC requires more frequent blade replacements than silicon, the cost savings using a system with no mechanical contact – such as the water-jet-guided laser – is quite significant.

In addition, the water-jet-guided laser is faster on SiC than saws, which is also important in terms of cost reduction. Speed is further increased on thinner wafers.

EXAMPLES

With the water-jet-guided laser, several parameters can be adapted to improve the cutting quality and speed for each specific type of wafer – mainly the laser parameters and water jet diameter.

To cut the 380-µm thick SiC wafer shown in Figure 2, a pulsed, infrared laser (wavelength 1064 nm, average power 56 W) was combined with a 40-µm water jet. SiC dies are free of contamination. For this thick wafer, the cutting speed is improved by 40 percent compared to abrasive sawing.

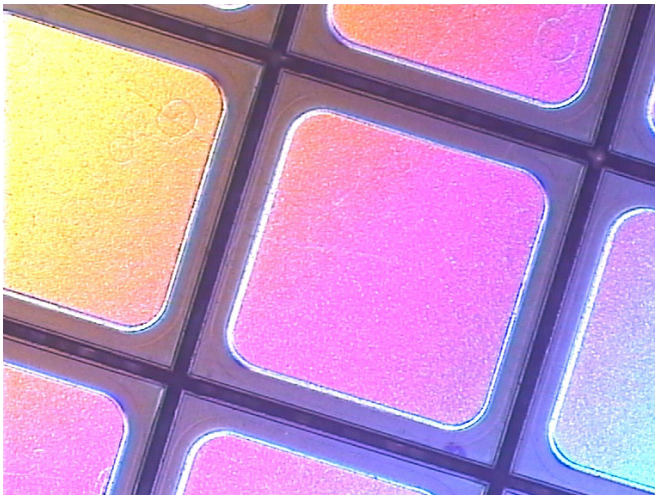

Figure 2 Through-cutting of a thick SiC wafer [source: Infineon Technologies]

A good speed can be achieved, while maintaining a high cut quality. For example, the 25-µm deep scribing shown in Figure 3 was performed at 40 mm/s. For this SiC wafer, a pulsed, green laser (wavelength 532 nm, average power 10 W) was combined with a 23-µm water jet, resulting in a 25-µm wide kerf.

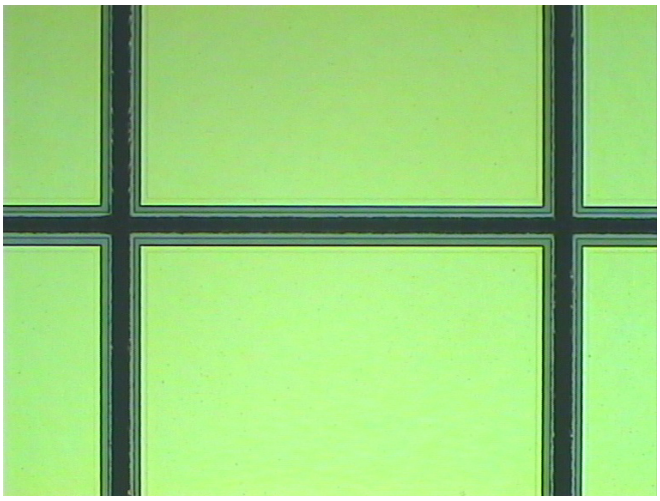

Figure 3 Fast scribing of SiC

CONCLUSIONS

With no damage to the material, no contamination and reduced running costs due to high speed and absence of tool wear, the water-jet-guided laser is a machining technology that cannot be overlooked for SiC.

ACKNOWLEDGEMENTS

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