

Water-guided laser speeds up rate of SiC-wafer dicing

The sheer hardness of silicon carbide means that dicing wafers that are based on the material gives device manufacturers a big headache. Now, a novel laser technique – that uses a water jet to cool the material between pulses of the laser – developed by Swiss company Synova may offer a solution, as Infineon Technologies engineers have discovered.

SiC is a wide-bandgap semiconductor offering many advantages over common silicon for power devices, as it can be doped to a much higher level to achieve a specific blocking voltage. As a result, SiC is an attractive solution for many carrier devices, such as Schottky diodes, extending their voltage operation to more than 3000 V. SiC devices are also able to withstand high temperatures.

These new power devices based on SiC dice are produced from 2 and 3 inch wafers. Today's most common tools for SiC-wafer dicing are diamond blades or tips, and these are what many device manufacturers use in their SiC fabs currently. However, because SiC is such a hard material – very nearly as hard as diamond – problems arise when using mechanical wafer-dicing techniques.

Blade wear

One important issue is blade wear, which for SiC is approximately 100 to 500 times as high as that for silicon. Where nearly 3 km of silicon can be cut with one diamond blade, only 10 m of SiC can be processed.

Additionally, the sawing blade may occasionally be damaged. This is because at the beginning of each new dicing line the blade penetrates the wafer edge at a sharp angle, which can cause the blade to break. The smaller the wafer diameter, the more likely it is that the blade is damaged or breaks.

Figure 1 shows a SiC wafer diced with standard diamond sawing equipment. Along the kerf, slight chipping can be seen due to mechanical effects caused by the blade. Additionally, the wall of the wafer has suffered from blade loading.

Although conventional lasers emitting in the ultraviolet (UV), green and infrared have been used to cut SiC, they are not ideal because the machining process tends to cause heat damage and particle contamination.

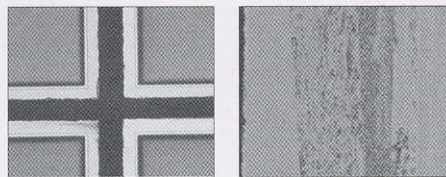


Fig. 1: This Infineon SiC wafer, diced with an abrasive saw, shows slight chipping along the kerf on the front side (left image) and blade loading on the wall of the wafer (right). The kerf width is 45 µm.

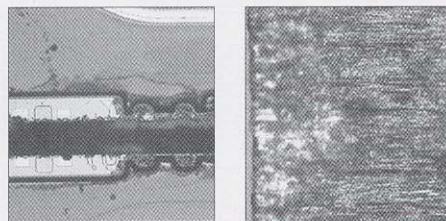


Fig. 2: Processed with an ultraviolet laser that had not been optimized for cutting, this SiC wafer shows burning effects along the kerf (left) and wall (right).

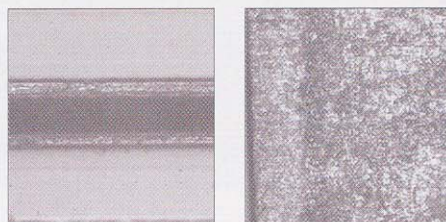


Fig. 3: The water-jet-guided laser does not burn or chip the SiC wafer. There is less contamination compared with dry laser cutting, and non-adhering particles can be removed using a standard cleaning process.

Lasers typically remove material by a melting, vaporization or ablation mechanism, all of which tend to generate a heat-affected zone in the target material. Additionally, molten material is not always completely removed during cutting by the assist gas, which is directed co-axially with the laser beam, and

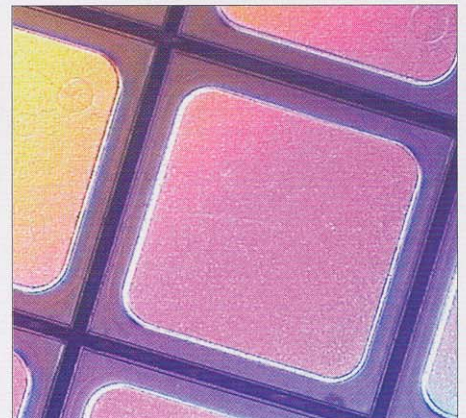
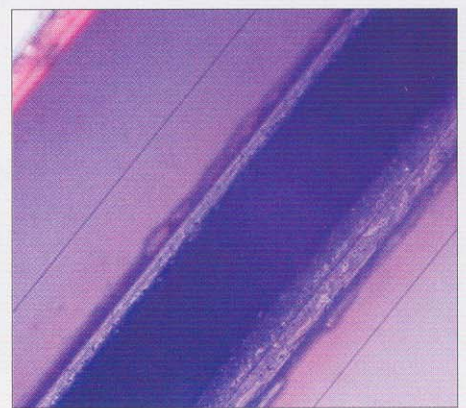


Fig. 4: (Above and below) Synova's water-jet-guided laser can cut through a 380 µm thick SiC wafer.



Figures 1 to 4 show structured SiC substrate wafers. They were made specifically for testing the dicing equipment, so the resulting devices have not been electrically tested. No layer was present in the streets.

this can result in droplets being deposited on the surface of the wafer.

The results of tests performed by Infineon in collaboration with a UV-laser manufacturer were inconclusive (see figure 2). The conditions for these tests were standard for the dry UV-laser cutting of SiC. Along the kerf, the

material has been burned and many particles and burrs are visible on the front side of the wafer, as no protective layer (such as a photoresist) has been used. The wall of the wafer also shows side burning, while more than 10 passes of the laser were necessary to cut through the wafer completely.

Although the output of the UV laser had not been optimized for cutting, further tests were not carried out because of the poor-quality dicing achieved. Indeed, the possible improvements that may have resulted from laser optimization are not expected to have been sufficient to produce high-quality cutting, with no particle generation or heating effects.

Having concluded that neither abrasive sawing nor dry laser cutting are ideal solutions for SiC-wafer dicing, Infineon decided to test the feasibility of a different laser-based process, featuring a high-power beam guided by a narrow jet of water.

Water-guided laser

The basic principle of the water-jet-guided laser involves focusing a laser beam into a nozzle while passing it through a pressurized water chamber. The water jet emitted from the nozzle guides the laser beam by means of total internal reflection that takes place at the water-air interface, in a manner similar to conventional glass fibers. Thus, the water jet can be thought of as a fluid optical waveguide of adjustable length.

One of the major differences of this technology compared with conventional laser dicing is that there is no thermal damage. This is because the water jet cools the material between laser pulses. Another advantage is that the water jet removes molten material during the cutting process, which reduces contamination. A water film is maintained on the surface of the wafer while the laser cuts, acting as a protective layer and preventing particle deposition.

As with other laser methods, the water-jet-guided technique does not generate mechanical damage, such as chipping or cracking, because it is a non-contact process. The force applied by the water jet is negligible (less than 0.1 N), as its diameter ranges from 75 to 25 μm with a pressure of between 50 and 500 bar.

Several laser-beam characteristics can be adapted to improve the cutting quality and speed on each specific type of wafer. For example, to cut the 380 μm -thick SiC wafer shown in figure 4, a pulsed, infrared laser (wavelength 1064 nm, average power 56 W) was combined with a 40 μm -diameter jet.

In production, using the water-jet-guided laser for silicon cutting has reduced hourly running costs by about 45%.

Although SiC dicing dominates today's chip production, the water-jet technique does offer several advantages.

First, the water-jet technique is faster than mechanical methods, especially when processing thinner wafers. For example, for the 380 μm -thick wafer shown in figure 4, the cutting speed was improved by 40% compared with abrasive sawing. Second, laser methods cut down on the cost of ownership, since there is no need to replace the diamond blade or saw.

Water consumption is also kept to a minimum, amounting to around 1 liter per hour at 300 bar water pressure. Finally, individual devices are not weakened by the dicing step, as the process generates no thermal or mechanical damage to the wafer edge and wafer surface, although it should be noted that SiC devices diced with this method have not been tested electrically. Ultimately, however, the laser tool should ensure higher yields and faster wafer processing.

Benefits for SiC chipmakers

The water-jet-guided laser is expected to generate substantial cost savings for SiC chip manufacturers. In production, using the water-jet-guided laser for silicon cutting has reduced hourly running costs by about 45%. This is mainly because the blades do not have to be replaced and there is also a reduced operator cost. And, since SiC is a much harder material than silicon, causing more frequent blade replacements, cost savings associated with this material could be even greater.

Allowing a damage-free, clean and fast cutting process without expensive maintenance costs associated with tool wear, the water-jet-guided laser holds great promise for next-generation SiC-wafer dicing. ●

Further reading

Compound Semiconductor January/February 2004 p27.

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