



Accelerating Silicon Carbide Power Electronics Devices into High Volume Manufacturing with Mechanical Dicing System

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Abstract

- > Current methods of wafer cutting for silicon carbide (SiC) substrates by semiconductor and chip packaging fabs are prohibiting high volume production required to meet growing demand for more efficient electronic devices
- > Due to the high hardness and brittleness of SiC, chipping (front and back), cracking and micro-cracking, cycle time and cost are the main challenges
- > The industry is looking at other cutting technologies such as laser cutting, micro-Jet dicing and plasma dicing to address the manufacturing issues
- > Alternative solutions such as laser ablation, stealth dicing and plasma dicing, have their problems, especially in running cost
- > Mechanical dicing with improved platform design could address issues related cut quality, cycle time and lower overall running cost to enable future high-volume manufacturing

Introduction

Silicon carbide (SiC) is a wideband gap semiconductor material that has huge potential to enrich our lives by enabling better technology with improved connectivity and efficiency.

It offers many advantages over common silicon (Si) for power applications as it can be doped much higher than silicon to achieve optimal blocking voltage. In addition, SiC high thermal conductivity characteristic enables power devices to operate at higher temperature and faster frequency environments. Many types of devices are being developed today using this material, and soon the world's leading electronic manufacturers will be producing SiC products on a large scale for many high power applications. To date, there have been no mature cutting technologies that can handle this material for high-volume manufacturing.

In this article, we will identify the challenges SiC manufacturers face when they process the wafer using their current dicing equipment. We will explore how an advanced mechanical dicing platform is able to resolve those challenges.

The Challenges

SiC wafers are very difficult to singulate using a dicing platform designed for silicon wafers. Conventional dicing

machines widely used today in the semiconductor industry to cut silicon wafer and chip packaging are not designed to cut hard material. As a result, manufacturers are having extreme difficulties bringing the process to profitable, high-volume manufacturing.

Silicon carbide (SiC) is the third hardest compound material on earth with material hardness of 9.5 on the Mohs scale. The wafers are extremely difficult to cut because they are almost as hard as the diamond wheel they are cut with. These wafers are also brittle and chip easily during the cutting process, causing the blade to wear out quickly. In addition, the cutting process is becoming even more challenging when cutting wafer with small kerf width into small die size (<1mm) on a relatively thin blade (<30 μ m).

Cutting with the blade on conventional mechanical saws is tedious and generates excess heat, resulting in low cycle time, poor cut quality due to excessive die edge chipping and high blade wear. These factors prohibit mass production from being economical or profitable.

Furthermore, current mechanical dicing platforms widely used in the semiconductor industry today are not suitable to cut hard and brittle material like SiC. The inherent machine design structure is prone to produce large die edge chipping (>50 μ m) during the process due to machine and spindle

vibration. To mitigate the issue, engineers have had to significantly slow down the process in order to meet suitable die edge quality they seek. Saw OEMs have since come up with a mitigation plan to improve the die edge quality by introducing the ultrasonic vibration hoping to minimize the edge damage and increase the throughput. This mitigation plan does not show sufficient improvement and does not resolve fundamental issues resulting from the hardware. In fact it increases the overall cost due to the ultrasonic hardware and non-standard blade type required for the process.

For example, it typically takes manufacturers 2 to 3 hours to process a 4" wafer with subpar die edge quality (~10 μ m top and ~30 μ m bottom chipping) and high blade consumption rate (<150M/blade). Running the process at higher cutting speed will increase the bottom chipping to as high as 50 μ m or more. With the cutting speed 10 to 20 times slower than typical semiconductor fab, the process cycle time and overall running cost will prohibit manufacturers from taking their product into high-volume production.

In order for semiconductor manufacturers to move from the SiC device development stage to profitable mass production, these dicing problems need to be resolved.

The Solution

Veeco has designed its dicing platforms specifically for hard, brittle and thicker materials. These systems are widely used in the hard disk drive (HDD) industry to cut Aluminum Titanium Carbide (AlTiC) wafers, which have very similar hardness and brittle characteristics of the SiC wafer. See Figure 1.

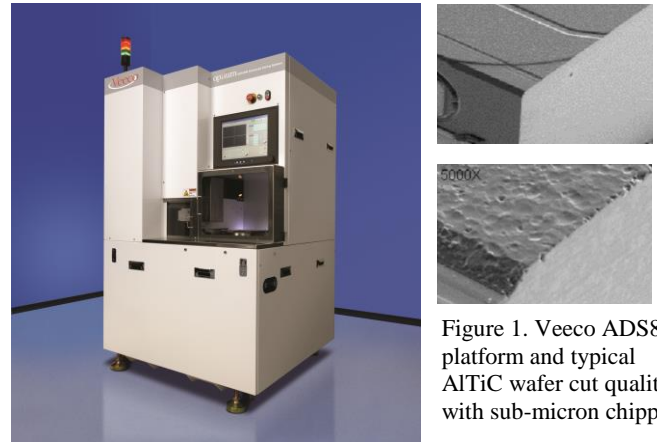


Figure 1. Veeco ADS800 platform and typical AlTiC wafer cut quality with sub-micron chipping

The rigidity of the dicing system structure allows HDD manufacturers to cut their wafers with excellent cut quality (die edge chipping typically less 5 μ m). In addition, because of the rigidity of its structure, manufacturers are able to increase the throughput up to 5 times by adding additional blades to the process.

Similarly, Veeco processed SiC wafers on the ADS800 Advanced Dicing System using a similar process parameter and blade type that has given manufacturers poor cut quality due to excessive die edge chipping and high blade wear. The result is quite contrary to what has been seen before.

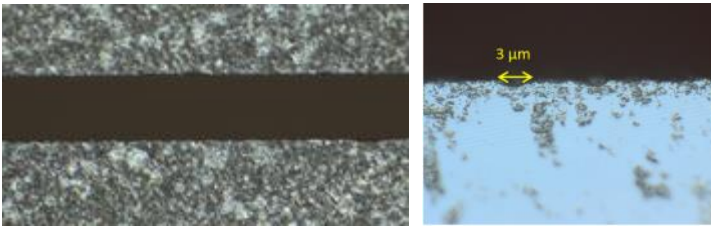
The Result

We are seeing tremendous improvement in die edge quality (Figure 2), blade wear and cycle time. Die edge quality improves by 2 to 3 times with 5 times better blade consumption and 2.5 times faster cycle time.

Die Edge Quality

Die edge quality improves significantly using the ADS800 platform. The front-side chipping reduces from typical 6-13 μ m (conventional dicing platform) to less than 5 μ m (Veeco platform). The back side chipping also reduces from typical 10-50 μ m to less than 10 μ m.

Front-side chipping



Back-side chipping

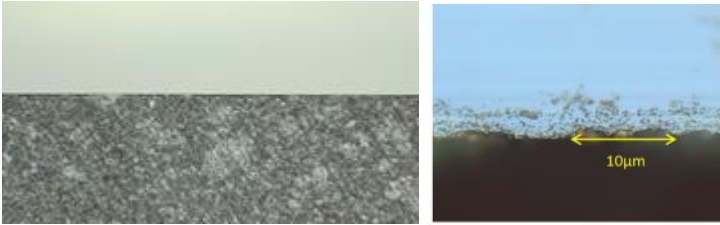


Figure 2: Typical top and bottom cut chipping (<5μm front and <10μm back side chipping)

Furthermore, the demo with various blade width and cutting speed (Figure 3) showed no degradation in die edge quality, signifying room for further improvement in cycle time to demonstrate improved cost of ownership for high-volume manufacturing. Smaller blade width capability enables manufacturers to reduce the kerf width and pack more dies within one wafer leading to higher productivity and profitability.

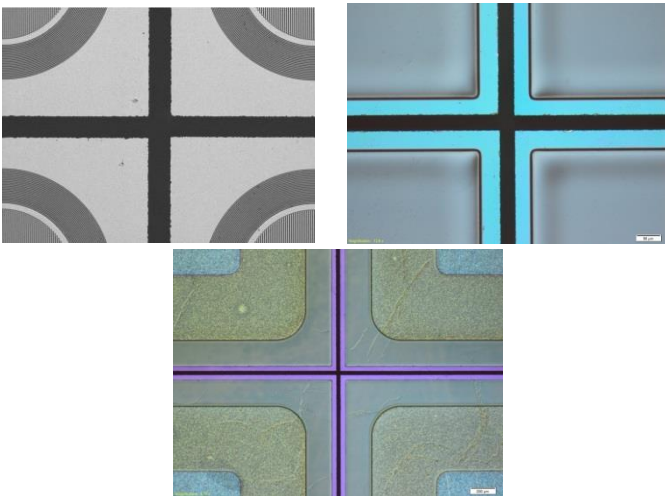


Figure 3: Various blade width (30, 50, 70μm) demos show no degradation in die edge quality.

The results also show potential improvements in side surface roughness (Figure 4) by using smaller grit size blade.

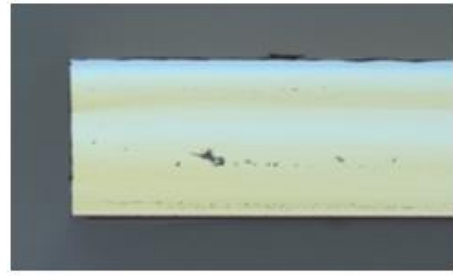


Figure 4: Side surface roughness <2 μm.

Blade Consumption

Blade consumption is a significant cost factors for SiC dicing process. The conventional dicing platform has a very high wear rate. The blade wear is approximately 100 to 500 higher when used on silicon. Blade consumption rate is at 20-150 meter per blade, depending upon the required results and process recipe. For example, accelerated cutting speed improves overall throughput but compromises quality (Figure 5) and increases blade wear rate due to more pronounced platform vibration.

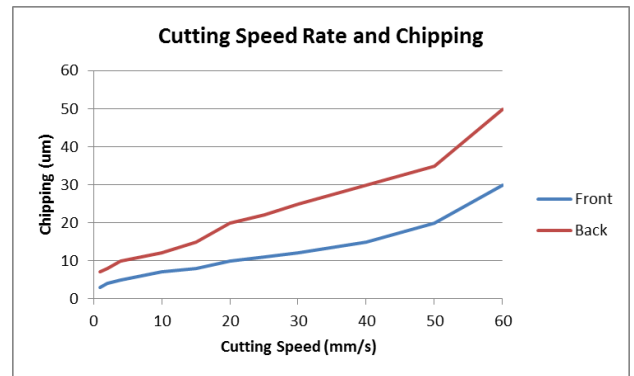


Figure 5: Example of Cutting Speed rate versus front and back side chipping

Besides high blade wear, one of the main reasons SiC manufacturers are getting high blade consumption is blade breakage during dicing process due to mechanical constraints. Machine vibration causes chipping and the large debris from chipping chip the blade as they sporadically becomes loose and destructive during the process. Both of these issues have been improved tremendously by having a rigid platform with minimal mechanical vibration and mechanical constraints in the ADS800 system. This improvement helps lower operating cost with extended blade life while achieving excellent performance in chipping and dicing width.

Throughput

Given the rigidity of the dicing platform, manufacturers can now increase their production throughput by adding additional blades to the cutting process. Unlike a single blade process where quality will be compromised when cutting speed increases, Veeco's multi-blade capability increases cycle time and maintains cut quality by keeping the cutting speed at optimal levels.

The Alternatives

Many manufacturers have looked into different technologies, such as laser ablation, stealth dicing and plasma dicing, to replace mechanical process steps. However, each technology resulted in different sets of challenges or were unable to process SiC wafers in particular products with metallic layers.

For instance, laser ablation induces thermal damage and particle contamination, such as molten residue from the cut, whereas stealth dicing required 5 to 6 passes to completely

dice a typical 350µm thick SiC wafer. The process will not only increase the overall process cycle time but also produce inferior side surface that is not acceptable for product quality resulting from potential reliability issues .

In addition, laser machines are typically 5 times more expensive with 20 times higher overall running cost, particularly for maintenance costs.

The table below shows SiC dicing comparison among conventional stealth dicing and Veeco's standard and multi-blade process platforms. Each technology listed compares cutting speed, cycle time, cut quality such as surface roughness, front and back side chipping and machine maintenance cost. The results show the advantage of Veeco ADS800 platform and a path for manufacturers to take their SiC product into high-volume manufacturing with excellent running cost.

	Conventional Mechanical Dicing	Conventional Mechanical Dicing with Ultrasonic	Stealth Dicing	Veeco Standard Platform	Veeco Multi-Blade Process Platform
Cutting Speed	4 mm/s	10 mm/s	300mm/s (3 passes) 500mm/s (2 passes)	4 mm/s	4 mm/s
Cycle Time	52 min.	20 min.	21 min.	52 min	12 min.
Chipping (Front/Back)	6-13µm/ 10-50µm	6-13µm/ 10-20µm	Near zero chipping	5µm/ 10µm	5µm/ 10µm
Side Surface Roughness	3µm	3.4µm	3.9µm	<2µm	<2µm
Machine Maintenance Cost/year	<\$7,500	<\$7,500	\$300K/Year Laser maintenance	<\$5,000	<\$5,000

Note: Information calculated based upon 3mm by 3mm die on 350µm thick 6 inch SiC wafer.

The Conclusion

Addressing the fundamental dicing challenges and taking the mechanical system to the next level is a winning solution for manufacturers by providing process improvements with excellent device performance and lower manufacturing costs that will enable profitable, high volume production.

Veeco's ADS800 dicing platform has a proven track record in high-volume manufacturing with over 20 years of dicing hard and brittle materials such as AlTiC. In addition, the ADS800 dicing platform enables a multi-blade process that enables increased throughput without compromising cut quality.

Data proves that the platform brings value to SiC manufacturing in the cutting phase for high-volume manufacturing with good die edge quality and excellent cost of ownership.

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