Thin Wafer Dicing Issues and New Technology Cost of Ownership

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According to market experts, the thin wafer market will grow 3 to 30 percent by 2007. This growth is fueled in large part by the ability of thin wafer technology to allow staked packaging for the IT industry and significantly improved power dissipation for power devices – a critical requirement for reducing die size. Thin wafer technology increases the function density of IC packaging to enable the development of more portable electronics. To ensure rapid growth of the thin wafer market, the semiconductor industry requires a new method for high-quality, low-cost wafer dicing. Synova SA has developed a water-jet-guided laser wafer dicing system to meet this need.

Wafer Dicing Issues

The first process of semiconductor device assembly is wafer dicing. Most semiconductor wafers in use today are composed of silicon. Silicon wafers are cut from single crystal silicon ingots. Diamond is a diamond cubic crystal structure formed by two face center cubic structures, which is the hardest material in the world (on the Mohs Hardness Scale, diamond measures 10 and silicon measures scaled 7 [1]). Diamond saws have thus been used for more than 30 years in silicon wafer dicing and mass semiconductor device assembly production.

A typical diamond saw wheel blade uses grit sized between 1 and 40 microns and has a rotating speed of about 20,000 to 40,000 RPM.[2] Many factors can affect the cutting quality (front- and back-side chipping, and kerf width) of a diamond saw, including: blade thickness, blade diameter/exposure, bonding type (resin or metal), cutting speed, coolant type/volume and coolant nozzle shape/water jet direction. Each of these must be properly selected in order to ensure heat and silicon dust are efficiently removed during the cutting process. Typically, a smaller grit size, higher blade wheel RPMs and a slower cutting speed yield better quality, but decrease the units per hour of the dicing process.

The dies inside power devices are different than those inside IT, communication or smart card application devices in that they have a back metal layer, which works as a terminal connecting to a lead frame that collects current from another terminal at the front side of the die. In order to deposit back metal onto the backside of silicon wafers, back grinding and chemical etching are necessary. Back grinding, which is used to thin silicon wafers, increases metal-silicon adhesion because it expands the contact area of the rough surface. Back grinding also decreases contact resistance, which is critical for power devices.

The disadvantage of diamond back grinding is that it can cause serious wafer damage, which, under the mechanical constraints of sawing, can lead to die chipping and hidden micro damage. Back chemical etching can be used to reduce some of the internal stress caused by diamond back grinding. However, it cannot repair all damage, and any remaining internal mechanical stress can lead to outright failures or, for power devices, device reliability problems in the field due to possible frequent large surging current.

Traditional "thick" wafers are between 150 and 300 microns thick. As wafers are thinned to less than 80 microns, wafer handling and dicing become serious issues, especially with larger diameter wafers (200 mm and 300 mm). Unlike traditional thick wafers, these ultrathin wafers are highly flexible and bendable because they have lost much of the silicon bulk that supports their original rigidity; additionally, they are supported by a flexible base – the tape. As a result, ultrathin wafers cannot be handled as rigid materials, and the diamond saw settings used to cut "thick" silicon wafers can actually deform or break them because of the significant impact force.

A front-end dicing engineer must adjust the dicing parameters through a series of design of experiments to find the limitations of dicing over a range of wafer thicknesses. For thin wafers, the engineers may have to set different feed speeds for different channels (X or Y axis), change dicing saw spindle RPMs, change coolant conditions, etc. That can be a daunting task indeed for a high-mix assembly facility, such as the International Rectifier Tijuana Mexico facility, which produces hundreds of different thickness-wafers with a total production volume of 18 million units per week.

New Technology Cost of Ownership

A few years ago, Synova developed a water-jet-guided laser wafer dicing technology. Since 2000, the company has sold 45 machines, including to Infineon, a leading semiconductor company.

Laser technology has extensive applications in the semiconductor manufacturing industry, including wafer marking, noncontact wafer flatness measurements, transparent thin-film thickness measurements, and device package marking. Like wafer marking, silicon wafer laser dicing uses much higher power than for other laser applications to not only scribe the surface but also to cut though the entire wafer.

High laser energy is absorbed in a very narrow area, heating the material to its melting temperature, which may also result in material evaporation. With traditional "dry" lasers, when the laser beam is applied

		Cost of Ownership (Euros / hour)		
		Saw	LMJ	Comparison
	Investment	10	15.93	
Consumption	DI water	2.40	0.23	
Consumption	Blades	3.75	0	
Consumption	Lamps	0	1.20	
Consumption	Glasses, Nozzles	0	0.60	
Consumption	Electricity	0.40	0.90	
Consumption	Air/Nitrogen	1.56	0.52	
Other Costs	Cleanroom	0.85	0.91	
Other Costs	Operator	11.39	6.83	
Total Running Costs		20.35	11.19	

Wafer thickness: 50 μm		Wafer thickness: 200 μm	
Number of machines for identical throuput		Number of machines for identical throuput	
Saw	6	Saw	1.8
LMJ	1	LMJ	1
Cost saving using the Laser-Microjet		Cost saving using the Laser-Microjet	
Per year	-1.2 million Euros	Per year	-0.2 million Euros
After 5 years	-5.9 million Euros	After 5 years	-1.01 million Euros

Table 1. Comparison of cost of ownership between diamond saw and water-jet-guided laser for wafer dicing.

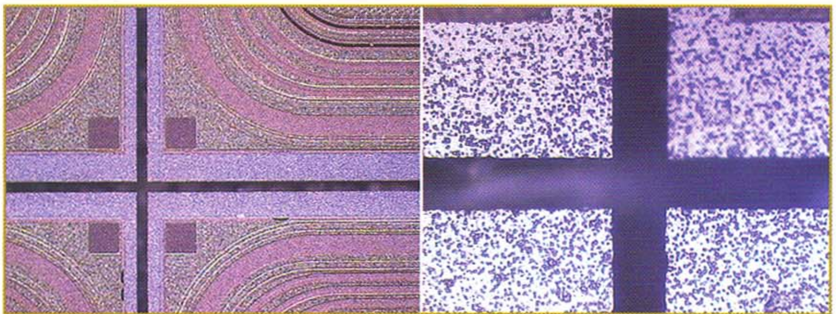

Figure 1. Microscope images of 65 μm-thick silicon wafers diced with the water-jet-guided laser technology; cutting speed: 100 mm/s (84 sec. per wafer).[5]

to a silicon wafer as a marking tool, a venting tube is needed to absorb the vapor to avoid residue accumulation, since wafer cutting with "dry" lasers produces significantly more residue that can cause burn marks and contaminate the wafer surface. Particle contamination is still so important, however, that a protection coating is needed.

In contrast with these "dry" lasers, Synova's water-jet-guided laser system uses a micro water jet that serves as a perfect optical guide for concentrating the laser energy. In addition, the water beam cools the working area. The water jet also cleans up the working area by sweeping away the residue. One of the most important advantages is that the force of the micro water jet is less than 0.1 N [3], which significantly reduces the risk of chipping that can occur especially on thin wafers using diamond saws, as there is no deformation resulting from a direct force. In addition, the water usage associated with the water-jet-guided laser system is significantly less than with diamond saws. In our assembly production line, the water usage for one diamond saw is about 102 L/hr, including cutting and cleaning. The water consumption of the hair-thin water beam (only 25 to 50 um in diameter) in the Synova system is only 1 L/hr.[3]

Another advantage of laser cutting using this technology is that it can cut thin wafers at much higher speeds. For a 200 micron-thick silicon wafer, a laser can cut 50 mm per second. A diamond saw can cut 2.5 mils to 20 mils-thick silicon wafer with a maximum speed of 3 inches (75 mm) per second, according to our experience. For a 50 micron-thick silicon wafer, the water-jet-guided laser can cut up to 200 mm per second.[4]

International Rectifier sent a 65 micron-thick power die Hex 4.6 HEXFET wafer to Synova, where an LDS 200A system was tested at 100 mm/sec and 200 mm/sec. Cutting results were very good, as can be seen in Figure 1.

Conclusion

The water-jet-guided laser is a new method for cutting semiconductor wafers, which requires no complicated adjustments for spindle speed, cutting wheel selection or water jet setting – instead, it requires only a laser beam software setting. For ultrathin silicon wafers, the micro jet can cut two to three times faster than the conventional diamond wheel with high-quality kerfs. High throughput, significantly lower DI water usage, and the lack of blade and spindle maintenance costs provide much improved cost of ownership compared with the conventional diamond saw. Table 1 shows the cost savings according to the data collected from Synova's study and International Rectifier's Tijuana Mexico assembly facility.

References

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About the Author

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Dr. Weimin Liang received his M.S. and Ph.D. in electrical engineering from the University of Kentucky. He has been working for International Rectifier for 11 years and developed the thin wafer assembly process.