Principles of Dicing

By Gideon Levinson

Background
Dicing (or diamond-wheel sawing) is used in the microelectronics industry for die separation and also for fine, accurate, partial and cut-through of exotic, very hard and brittle materials. The wide range of materials processed makes it necessary to use different blades. These may be based on hard or soft binders, with various diamond particle sizes. Large-scale production and high productivity rely on low, consistent blade wear and superior cut quality as demanded by today's sophisticated industrial environment.

History and Other Separating Techniques
Other techniques have been used, mainly for die separation.

Diamond Scribing
This is the oldest separating method, mainly used for silicon & GaAs wafers. In Figure 1 a diamond tip, with an angle of about 125i, scribes a shallow scratch on the wafer. The edge quality of a scribed and broken die is poor. Breaking produces dies that are irregular in size and shape.

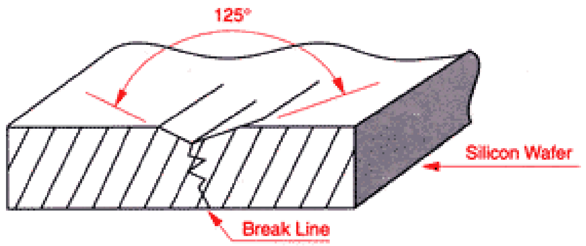


Figure 1. Diamond Scribe

Laser Scribing
This technique is used mainly to separate hard alumina substrates. In laser scribing, a laser beam moves rapidly along a street producing cone-shaped perforations. The dies are then broken apart, as in diamond scribing. The edge of a laser-cut die is not smooth because the scribe-line consists of a series of holes burned out of the top of the substrate. Mechanical and cosmetic edge quality are limitations in laser scribing (Figure 2). Laser scribing is a fast technique and is being used in large-scale production where quality is not the main consideration.

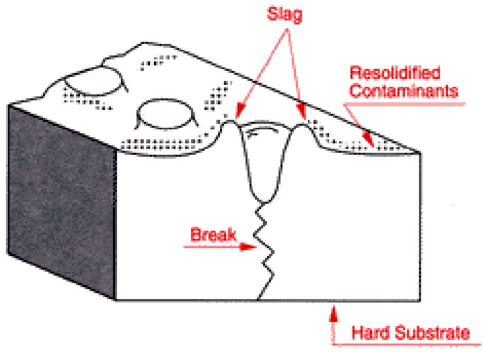


Figure 2. Laser Scribe

Diamond Wheel Dicing
This is the most common technique in the industry. The cut quality is higher than other techniques. Also, it is possible to keep cut width, depth, and straightness as well as edge quality under tight control (Figure 3).

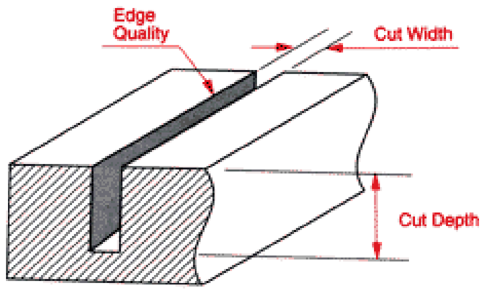


Figure 3. Dicing with Diamond Blade

Blade Basics
A diamond blade is actually a ring composed of abrasive grains (diamond particles) held together by a binder - either nickel or phenolic resin or metal-powder sintering. Each individual diamond particle acts as a single-cutting tool, pushing a chip of material ahead of it. As there are many diamond particles on a blade edge, there are therefore many single-cutting tools pushing out the substrate material and creating a kerf (Figure 4).

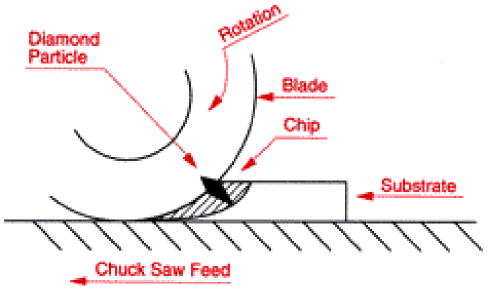


Figure 4. Single Diamond Machining Mechanism

Blade Binders

Materials used nowadays in the microelectronics industry exhibit a wide range of hardnesses, from relatively soft to extremely hard and brittle. This large variety requires a range of soft and hard blade binders.

A hard and brittle material requires a soft blade binder. A phenolic resin binder is used on those materials to achieve free cutting action, with very fine chip-free kerfs. Cutting performance is based on the binder's ability to release dulled diamonds and expose, new sharp ones at the same time.

On softer, less brittle substrates a harder matrix is necessary. Nickel and metal sintered binders are normally used for these applications. The nickel-type blade is a state-of-the-art electro formed product. It has a very hard nickel matrix, with diamonds distributed homogeneously through it. This bond is the key for very low wear. The Metal Sintered blade is in between the Resin and the Nickel binders, it is a very uniform matrix and has better wear characteristics than the nickel matrix and therefore is less loading.

Choosing the right binder is a matter of experience. See Figure 5 for a blade selection table; however, as each application is unique, it should be used only as a guideline. Final selection should be done only after the process has been optimized in production mode.

Figure 5. Blade Selection Guidelines

Material	Nickel	Resinoid	Metal Sintered
Alumina		53 mic.	
Ferrite	3-6 mic	9 mic.	2-4mic. 3-6mic.

Glass		45 mic.	
Garnet		35 mic.	
Barium titanate		45 mic.	17mic.
Kovar		53 mic.	
Quartz		30 mic.	

Diamond Selection

It is important to control the quality, purity, size and reliability of the diamond particles in order to ensure superior kerf quality and long blade life. With nickel electro formed and metal sintered blades the best results are obtained by using well-formed, strong, blocky, single-crystal diamonds. (see Figure 6).

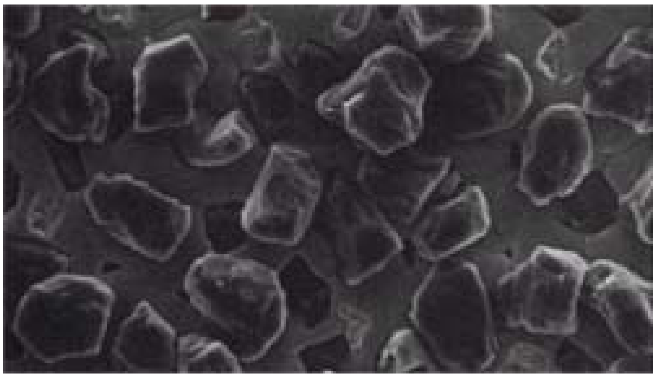


Figure 6. Strong, Blocky, Single Crystal Diamonds

In resin-bonded blades friable diamond particles are used to achieve self-sharpening, free cutting action. The diamond particles are coated with a nickel alloy in order to improve the diamond-resin bond. The coating also sinks the heat generated during cutting (see Figure 7).

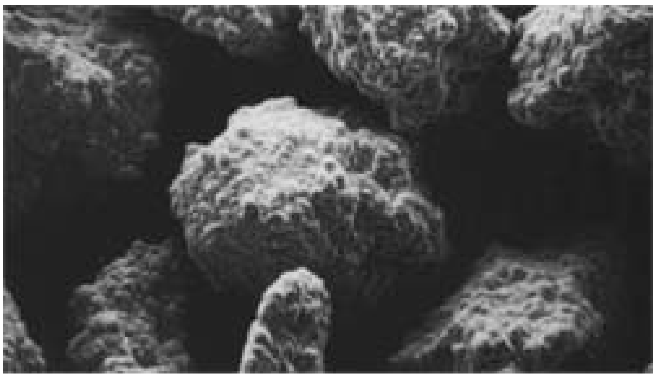


Figure 7. Friable Diamonds Coated with Nickel Alloy

Again, selecting the right diamond size for each application is a matter of experience and process optimization. See Figure 5 for general guidelines.

Blade and Substrate Cooling

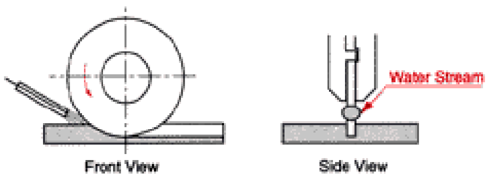


Figure 8. Front View and Side View

Cooling of the blade and the substrate is basic and essential for any dicing application. Following are the main basic points to be aware of:

- Alignment of the cooling nozzles with the blade and substrate.
- Cooling pressure - consult the recommendations of the manufacturer of the saw
- The ability of the blade to cool itself. We have discussed this when mentioning blade binders, resin bond. More on this in the section about blade dressing.

Cutting heavy substrates .100 to .500 thick creates cooling and overloading problems. Nozzle alignment and coolant pressure are not the only solutions. A serrated blade is used for these applications (see Figure 9).

The serrated blades are designed for freer cutting with less load. The slots eliminate continuous contact between blade and material, and improve cooling of both blade and substrate. Nickel & Metal Sintered serrated blades are a standard product. Resinoid serrated blades can be made on request.

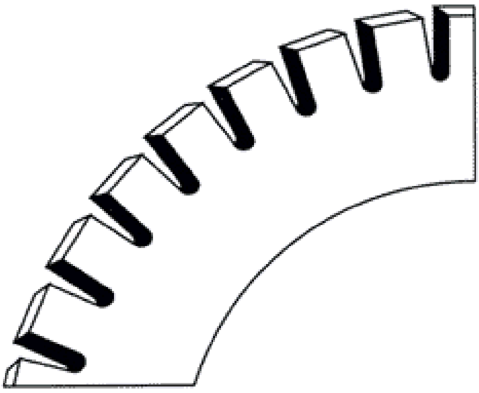


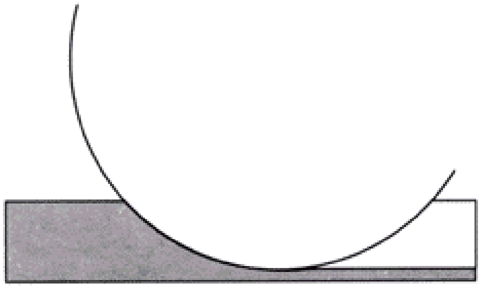
Figure 9. Serrated Blade

Advantages and Disadvantages of Serrated Blades

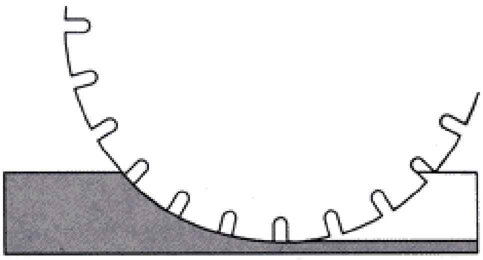
Advantages:

1. Less contact between edge and substrate, which translates into less load during cutting.

Better cooling, due to serrations.



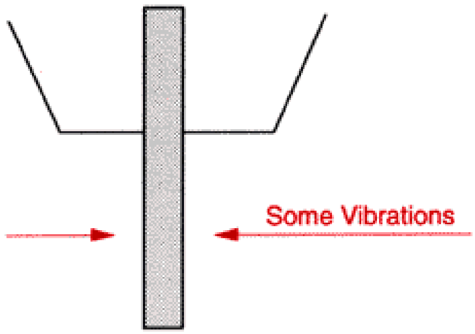
Contact on Regular Blade



Less Contact on Serrated Blade

Disadvantages

Kerf width is not as accurate as with regular blades.



Less Contact on Serrated Blade

Another solution for cooling blades on heavy substrates is the ADT high cooling flange (Figure 10). This unique design spreads the coolant from the center of the flange to the outer edge of the blade on both of its sides. The high velocity (spindle r.p.m.) translates into high pressure on the coolant, which is forced to the bottom of the kerf. The high cooling flange makes a standard cooling nozzle unnecessary.

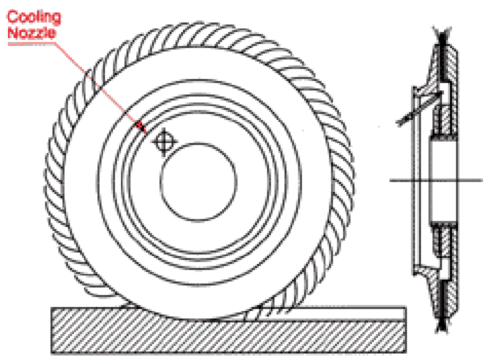


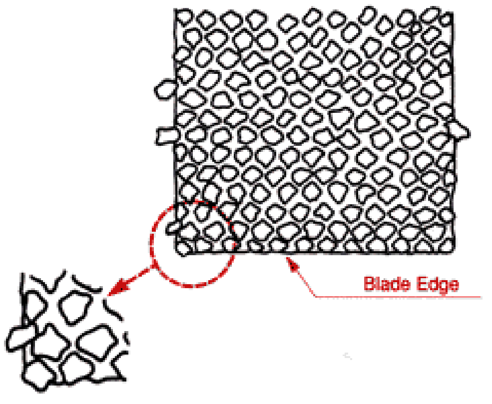
Figure 10. High Cooling Flange

Dressing

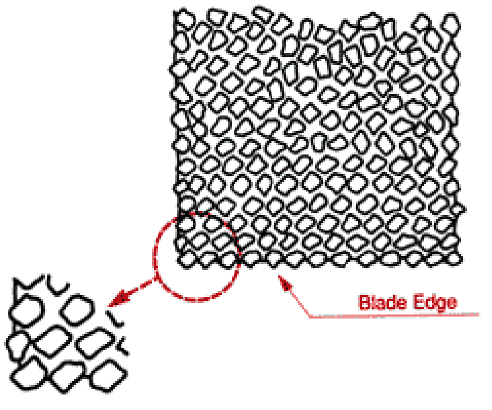
One of the most important steps to assure accurate dicing is dressing the blade before cutting. Dressing is important for the following reasons:

- Excess binder material or loose diamond particles are machined off - see Figure 11.
- The binder holding the diamonds is machined off, exposing the diamonds
- It trues the outside diameter runout o It trues the blade edge geometry see Figure 12.

Minimizes the load, creates a cooler and freer cut.



Blade Before Dressing



Blade After Dressing

Figure 11. Nickel Bond Dressing

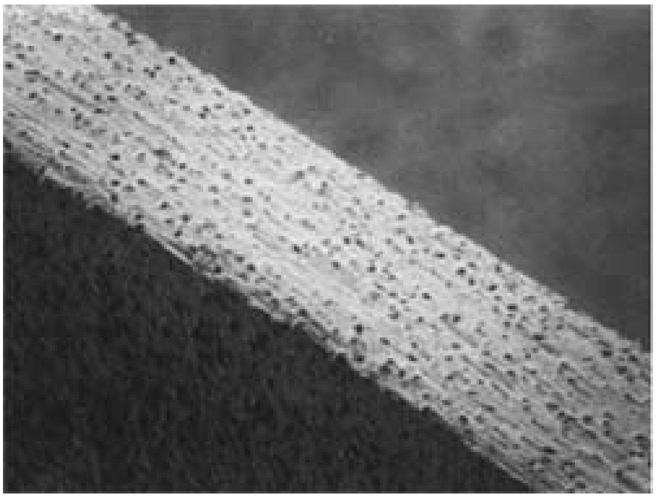


Figure 12. Blade Edge After Grinding

Dressing Techniques
The best method is grinding the blade in the same flange that is being used on the saw. This will result in a perfect run out of the blade on the saw.

Grinding can be done on a cylindrical grinder (Figure 13) or on a dressing machine. The dressing wheel used is a silicon carbide type, with about 320 mesh.

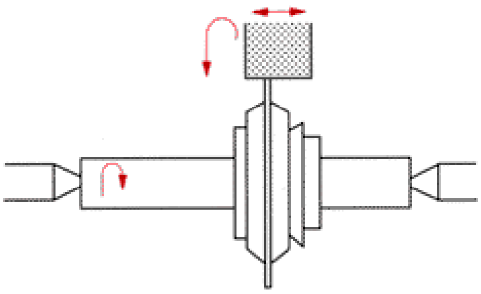


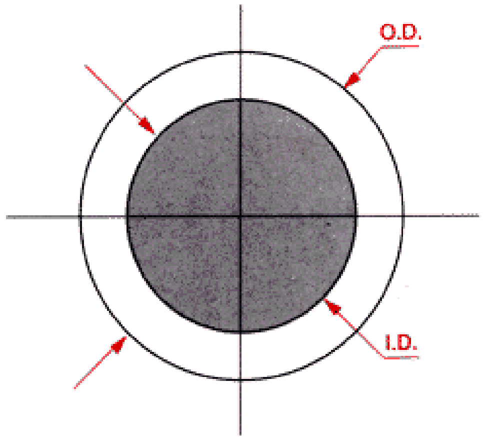
Figure 13. Blade Grinding on a Cylindrical Grinder

All our Metal Sintered blades are predressed [edge grounded]. Our nickel blades (.005" thick and over) are predressed [edge ground]. However, for a perfect runout and better performance, it is important to grind them as mentioned.

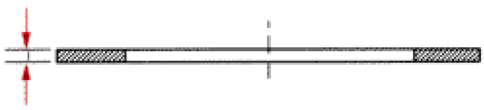
All our Resinoid blades are edge grounded; however, Resinoid blades require minimum dressing because of their soft binder and their ability to self-dress. For most applications, a resinoid blade may be used without special dressing requirements.

Dicing Glossary

Blade Parameters
Blade O.D. - outer diameter
Blade I.D. - inside diameter



Blade Thickness:



Diamond Grit - diamond size in microns or in mesh
Blade Binder - the matrix holding the diamonds: nickel, resin, metal powder sintering
Serrated Blades - have slots on their edge, for better cooling
Cutting Parameters
Spindle r.p.m. - spindle revolutions per minute
Feed rate - table speed [inch per sec.]
Index - the distance between the cuts (see Figure 14)
Cut depth: (see Figure 14)
Cut length - the substrate size to be diced
Mounting method - how the substrate is clamped (vacuum, magnet, glue, wax, tape)
Cut width: (see Figure 14)
Chipping - Chipping on edge of cut Ð [top side & back side]
Kerf - cut
Substrate - Material type: ceramic, silicon, etc.
Thickness: (see Figure 14)

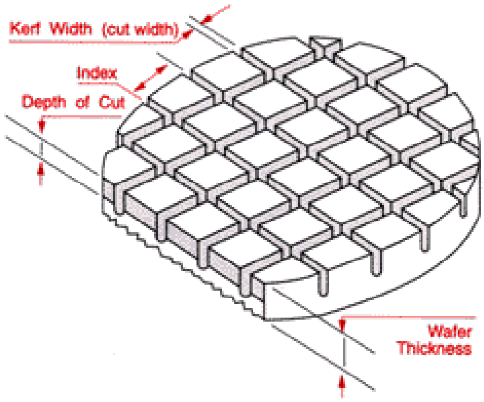
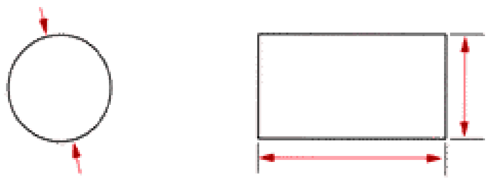


Figure 14. Wafer Parameters

Substrate size: diameter or any other outside dimensions
Street width: the distance between dies



Wafer: a round flat substrate

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