Process Optimization of Dicing Microelectronic Substrates

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1. BACKGROUND - Market Needs

The microelectronics industry is constantly seeking improved yields in a wide variety of complicated dicing applications. Continuous efforts are being made to improve both cut quality and through-put. Some new materials have been introduced that require new processes (blades and saws). These trends are accompanied by continuous efforts to further miniaturize die sizes, in order to maximize the number of dies per substrate. To achieve these goals, it is necessary to optimize the dicing process.

The following article is divided into two major parts. The first part is an overview of the different requirements in dicing microelectronic substrates. The second part discusses the various dicing parameters to be considered when attempting to optimize a dicing process.

2. Major Dicing Parameters Requiring Optimization

The following are the most common parameters to be improved and optimized:

- Cut Quality
- Through-put
- Cost of Process

2.1. Cut Quality

While in many cases improving the cut quality is just a matter of achieving better yields, in many other cases it requires complicated new die and substrate designs. The following criteria are related to cut quality:

2.1.1. Edge Quality - Chipping

A major problem mainly on very brittle substrates, there are two areas of edge chipping: top side and bottom side. (See Fig. 1)

Top Edge

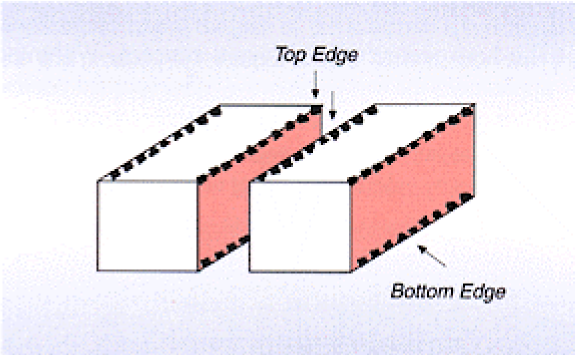

Fig. No. 1 - Top and bottom chipping

Both top and bottom edges behave very differently during dicing. The following is a short discussion of both sides:

Top Side Chipping

Different types of chipping occur on the topside. The most common type is a continuous line of small cracks similar in size, with some slightly larger chipping along the edge. (See Fig.2)

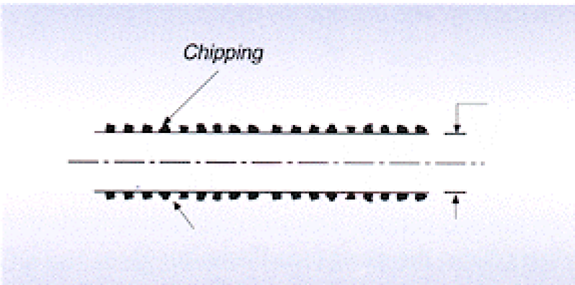

Fig. No. 2- Common top side chipping

This type of chipping occurs mainly due to the following:

- The major reason for chipping is the diamond impact into the material during dicing; larger diamonds usually cause larger chipping.
- The table speed (feed rate) affects the chipping size. Higher feed rates cause each diamond particle to remove more material on each rotation of the blade. This, in turn, causes higher temperatures and higher load during the dicing process and, therefore, more chipping.
- Poor coolant is always a significant contributing factor to chipping. This will be discussed later in more detail.

- Vibration caused by many factors is also a major reason for chipping. This will also be discussed later in more detail.

- Poor mounting, causing the substrate to move during the dicing, will cause chipping.

Another type of chipping is a "shell" type, where the geometry has a shell shape. (See Fig. No.3)

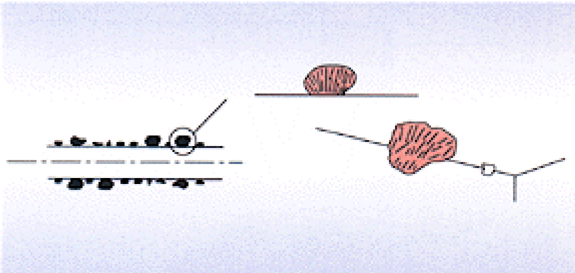

Fig. No.3- "SHELL " Type chipping

The reasons for 'shell" chipping are the same as mentioned above, except that the material structure is brittle, and breaks off in a shell shape. The problem with "shell" type chipping is that the chips are large and cause damage to the die metalizations.

On some very brittle materials small micro-cracks may grow on the edge and damage the dies.

Burrs on Edge

Burrs are a common problem when dicing soft metals or substrates with soft metalization on the top or bottom side. Dicing PC boards is an example, with soft metalization layers on top and bottom. This soft metalization tends to cause burrs during the dicing. (See Photo No. 1)

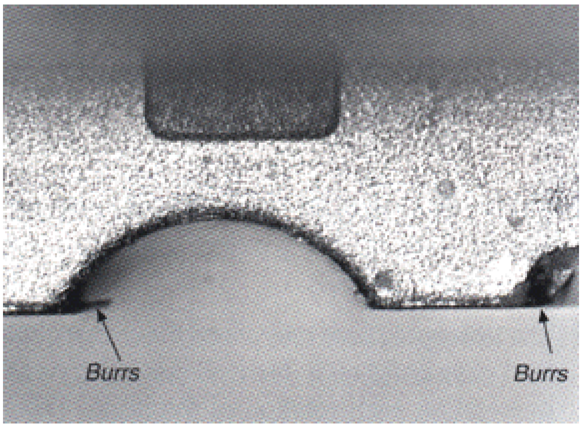

Photo No. 1 - Soft copper burrs on a P.C.B substrate

Bottom Side Chipping:

When dicing through, chipping on the bottom is a major problem. In many cases the substrate has stress at the bottom surface and is released when dicing through, causing large chipping. The following are some major points causing chipping at the bottom side:

- Higher temperatures on the bottom cut due to poor coolant: (See Fig. No.4)

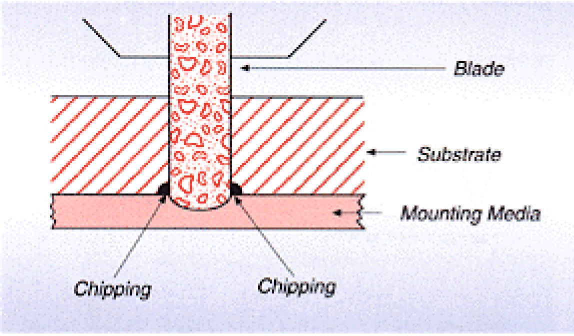

Fig. No. 4 - Bottom side chipping

- The mounting media, which in many cases is a soft PVC tape or a glue/wax media to a solid substrate, overloads the blades causing high temperatures and chipping.

- Poor mounting with air gaps between the substrate and the mounting media will act as an unsupported area and will cause chipping. (See Fig. No.5)

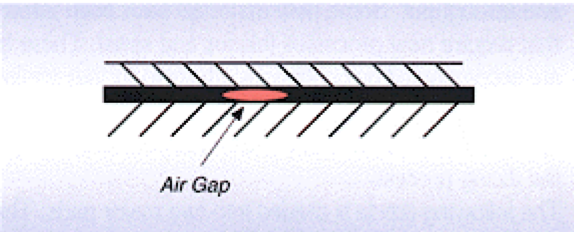

Fig. No.5 - Air gap

- Cut into tape is not deep enough. The radius on the blade edge causes a small lip on the substrate at the contact point with the tape. The lip breaks off the substrate during the cutting process. (See Fig. No.6)

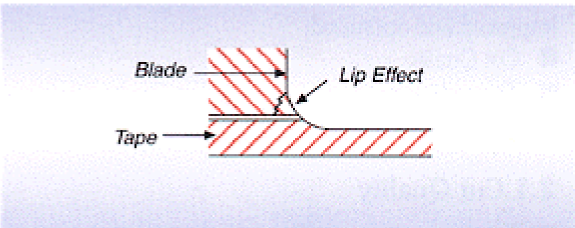

Fig. No.6 - The Lip Effects

Most of the other criteria for chipping mentioned in the top side chipping discussion, also affects the chipping on the bottom side.

2.1.2. Kerf Geometry

Kerf Width

The kerf geometry is always a concern. Within some applications the kerf width is the only important parameter, either an open tolerance or with a tighter tolerance. In most cases the kerf is just to separate dies or to trim larger substrates by indexing the y-axis on the saw. (See Fig. No.7)

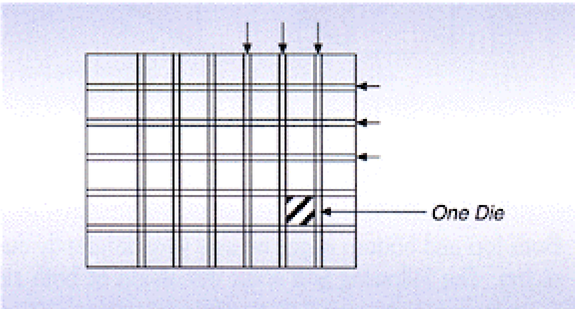

Fig. No.7 - Separating dies

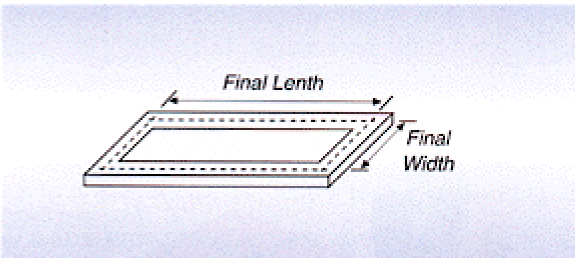

Fig. No.8 - Trimming large dies

On other applications the kerf width size is of major importance. The only way to achieve a tight kerf in some extreme cases is by dual cutting and using the accuracy of the saw: (See Fig. No.9)

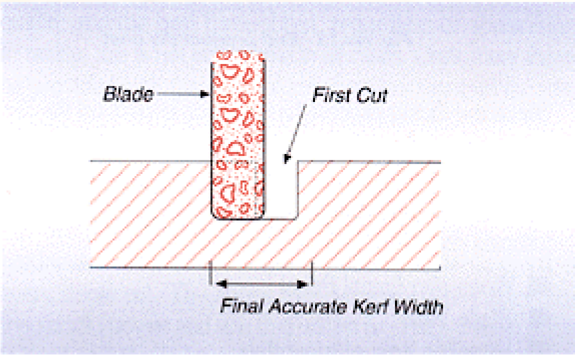

Fig. No. 9 - Accurate kerf by dual dicing

Obviously, it is always preferable to dice any kerf in one pass, as a thin blade may bend due to unbalanced load on the second cut.

Kerf Perpendicularity

The kerf perpendicularity is extremely important for applications where the side of the substrate is functional in the end product, or tolerance is tight, such as substrates that need to be inserted into a package.

Almost all the parameters can affect the kerf perpendicularity. This will be discussed later. The following are a few kerf geometries that affect the perpendicularity:

(See Fig. No.10)

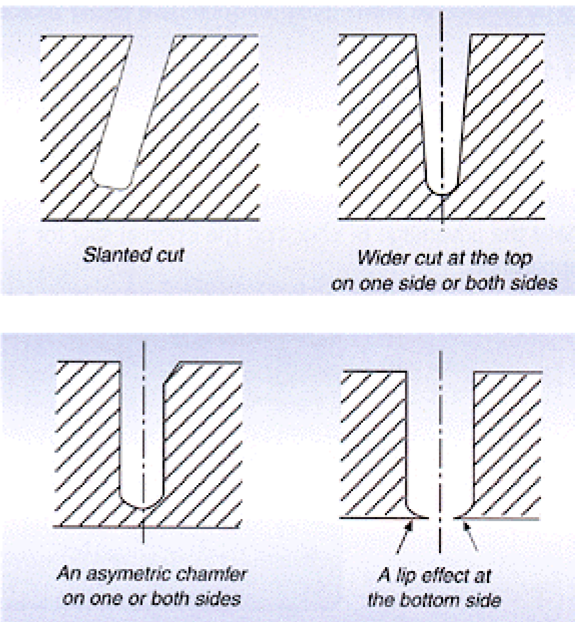

Fig. No.10 - Wrong kerf geometries

Kerf Straightness

The kerf straightness is observed when looking at the top side of the substrate. All blade and cutting parameters can affect the kerf straightness. These factors will be discussed later. The following are a few top views showing kerf straightness problems: (See Fig. No. 11)

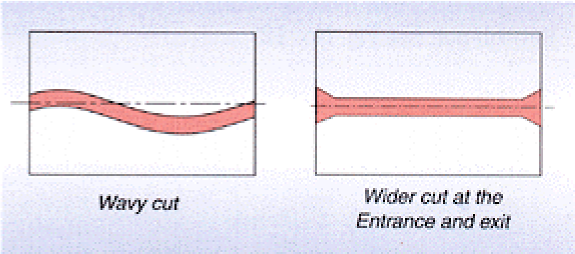

Fig. No. 11 - Top view of kerf problems

Surface Finish

The surface finish of the kerf is a function of the material characteristics being diced, along with the blade and cuffing parameters. In many cases of dicing brittle materials, the surface finish will also affect the top and bottom edge. One major application for good surface finish is optical type filters that usually are lapped after the dicing. A good surface finish may eliminate or reduce the time required for lapping. The following are two photos of typical surface finishes:

(See Photos No. 2 and 3)

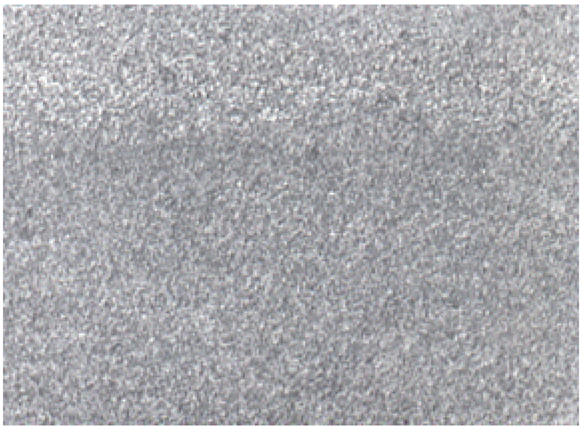

Photo No. 2 - Glass substrate diced with a resinoid blade

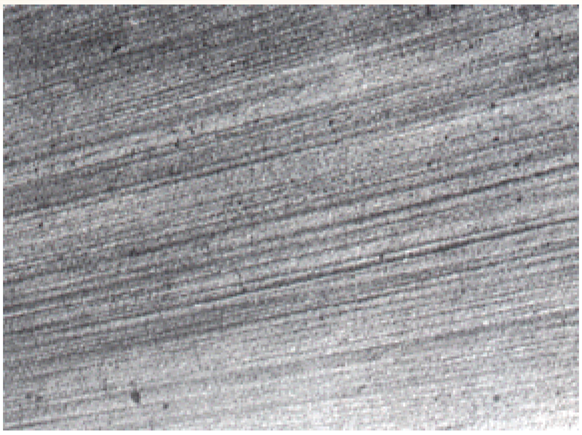

Photo No. 3 - TIC substrate diced with a nickel blade

Through-put

While some customers are concerned mainly with achieving high quality, others' main priority is through-put. In general, through-put is more units per hour (UPH) with no drop in quality. The question of how much it is possible to increase speed while still maintaining quality is a major issue. The following is an illustration showing the application characteristics that must be optimized in order to improve through-put: (See Fig. No.12)

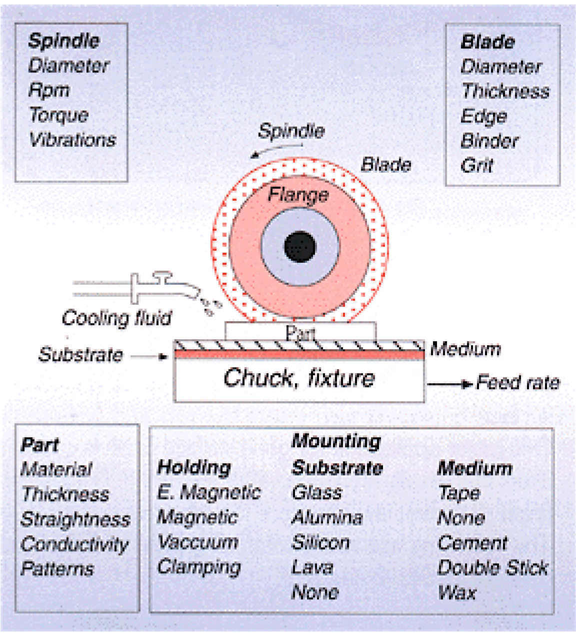

Fig. No.12 - Application characteristics

2.3. Cost of Process

The total cost of the end product is a factor of all the production processes and raw materials involved in the manufacturing process. (See Fig. No. 13)

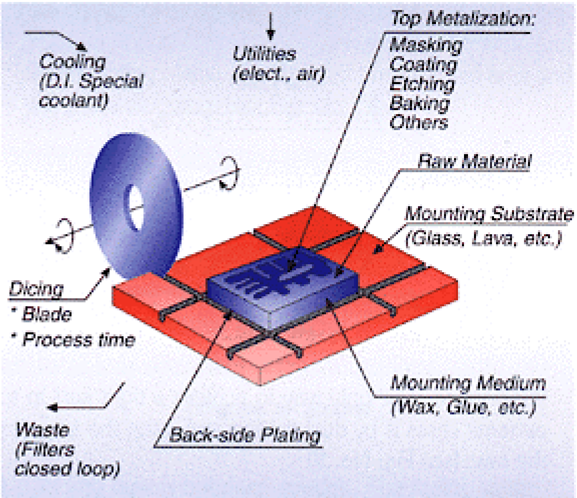

Fig. No. 13 - End product die cast

Since the dicing process has a major impact on the die cost it must be optimized in order to reduce the costs. Failing to reduce the dicing cost may cause the product to become obsolete. The following are parameters affecting the dicing process costs:

- Blade cost (Initial Price)
- Blade Wear
- Handling time of mounting
- Speed of the dicing process (Feed rate)
- Mounting material
- Utilities
- Waste Handling
- Initial investment

3. Process Parameters to Be Optimized:

3.1. General

It is important to understand that when trying to optimize a dicing process, all the parameters involved must be considered.

In some cases only a few parameters must be optimized. In others it is necessary to optimize most of them.

The following is a discussion of the various dicing parameters to be considered when trying to optimize a dicing process.

3.2. Type of saw

Choosing the right saw for the right application is a key issue and will affect both the quality and cost of the end product.

Customers planning to buy a new saw for a specific application have the advantage of choosing the optimal saw for their application.

Some customers use existing saws already on their production lines, not designed for their current application. In such situations, the only parameters which can be optimized are the blade and process parameters.

The following are the process requirements and the saw features that should be considered: (See also Fig. 19)

The main process requirements are:

- The volume of material to be removed (cut depth & kerf width)
- Material hardness
- Cut Quality
- Through-put
- Special requirements

Most customers seek the most powerful saw, the best cut quality and the best through-put, regardless of application. In reality, this is not achievable in all cases. Customers should be provided with the optimal saw features required for what is most important in their application.

3.2.1. Spindle type

The first parameter that should be considered is the material hardness and the total volume of material to be removed on every single cut. The above two parameters will determine the spindle power and size that will be required. If the material is hard and the volume of material to be removed is high, than the load on spindle will be high and a high torque spindle is needed. High torque spindles are usually in the 4" O.D. range to fit 4" O.D. blades up to 5" O.D. The most popular blades are 4.5" - 4.6" O.D. The larger blade O.D. of 4.5" and 4.6" has significant advantages in terms of blade life and blade stability during the dicing process compared to a 2" standard blade. (See Fig. No.14 & 15)

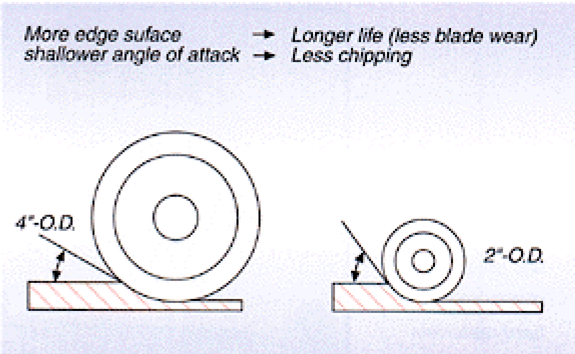

Fig. No.14 - 4" Spindle Compared to 2"

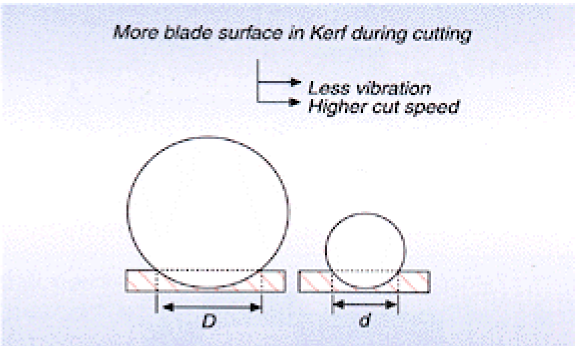

Fig. No.15 - 4" Spindle Compared to 2"

When choosing the right spindle it is important to check the output torque performance at lower spindle speeds. The output power specified on air bearing spindles usually specifies the maximum torque at the maximum spindle speed, while on most applications a much lower spindle speed is used. (See Fig. No.16)

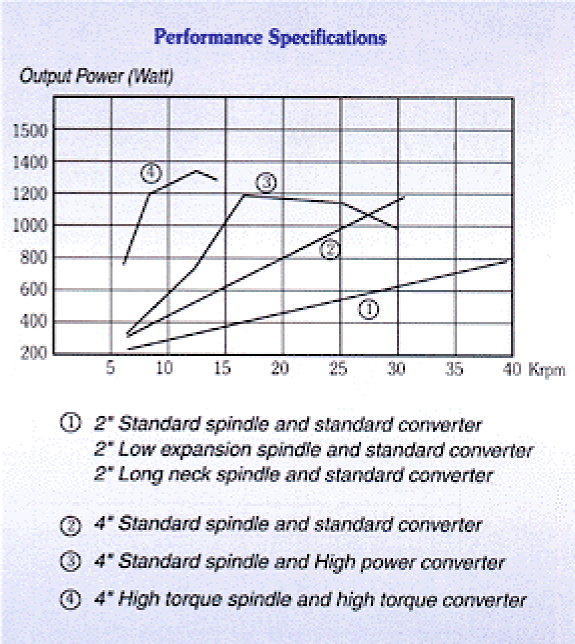

Fig. No.16 - Kulicke & Soffa Standard Spindle Performance Specification

Another important factor when choosing the right saw is the spindle mounting. It is important to have a short spindle nose and a firm spindle mounting to the saw. A long, unsupported spindle nose will cause vibrations and kerf geometry variation. This is more crucial when dealing with hard materials that tend to load the blade. (See Fig. No.17)

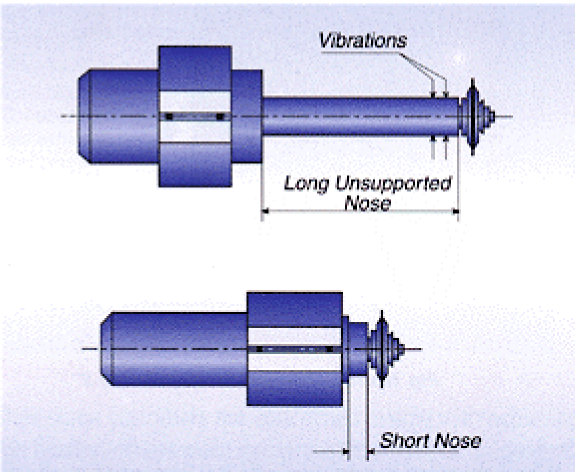

Fig. No.17 - Spindle mounting

A 2" spindle is the best choice for very brittle materials requiring relatively thin kerfs where the main focus is cut quality. The load on those applications is not too high. In addition, vibrations/runout is easier to maintain on a 2" spindle.

The following is a general list of materials and the spindle size that is normally used for these materials: (See Fig. No.18)

MATERIAL	TYPICAL SPINDLE DIAMETER
Hard Alumina	4"
Titanium Carbide	4"
Green Ceramics	4"
Thick Pyrex/Glass	4"
Bismuth Telluride	4"
Thin Glass	4" and 2"
Quartz	4" and 2"
Sapphire	4" and 2"
Lithium Niobide	4" and 2"
Lithium Tantalite	2"
Silicon	2"
GaAs	2"
PZT	2"

Fig. No.18 - Spindle size per material

3.2.2. Saw Construction

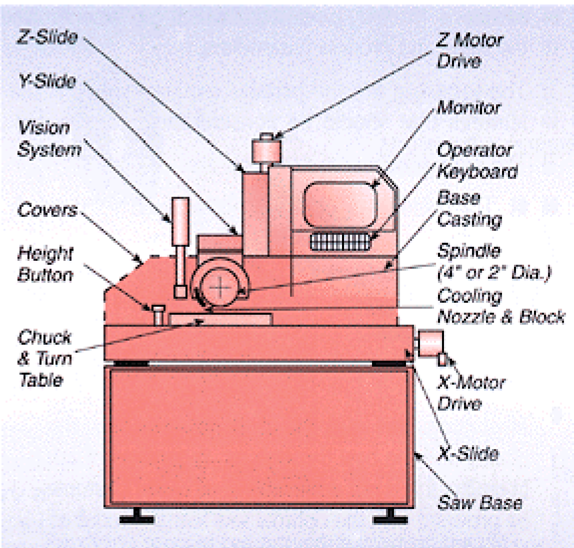

Fig. No.19

A rigid, vibration-free saw is a function of saw construction. Small bench type saws will vibrate more than self-constructed cast iron made saws. A stress relieved cast iron construction is always better than aluminum castings.

The type of slides is also important for stability and movement accuracy. Air slides, mainly on the table feed are of importance when dicing brittle materials.

Photo. No.4 is a photo of the K&S 984 precision dicing saw for hard materials. This saw is a rigid stable construction of stress relieved cast iron combined with high torque 4" air bearing spindle and air slides on "x" axis and "y" axis.

Photo. No. 4 - K&S 984 precision dicing saw for hard materials

3.2.3. Saw features

Customers can choose from a wide variety of features when selecting a saw for a specific application. The following is a list of the major features per application requirements on K&S hard material dicing saws.

FEATURES	APPLICATION
X and Y - Travel (up to 14" on K&S)	Large substrate design
High torque spindle or high power	For hard and thick substrates

converter	
Extended Z travel	For very thick substrates or special mounting jigs
Higher magnification optics	For better observation and alignment of substrate. Smaller patterns, higher accuracy
5" blade O.D. capability (0.6" cut depth)	For thick substrates
Spindle load meter	For monitoring the dicing load on hard and thick substrates
Non contact height	For thin blades' protection, non-conductive blades and where standard height is not possible
Custom Chucks	For complicated substrates geometries and for mass production applications
PRS systems (Pattern Recognition System)	For auto-aligning and automatic quality check functions
Dry process configuration	High consumption suction system to remove material residues whenever water use is restricted
APC application software package	For unique application such as: Angle cutting Chopping Multiple index/cut depth combination Variable cut depth Others
High accuracy model - (984 HA) or Linear Encoder on Std. -Y- Axis	For very accurate cutting requirements
High speed - X & Y option	For softer materials that require more -UPH- less accuracy

3.3. Blade Optimization

Choosing and optimizing the right blade for the right application requires a basic understanding and a lot of experimentation. Fig. No. 20 is a sketch showing the blade parameters to be optimized.

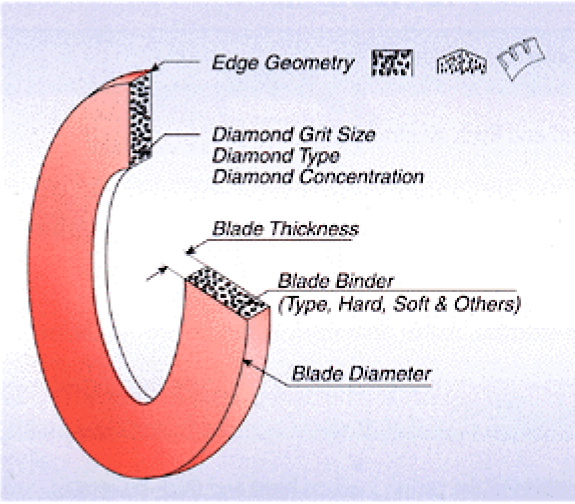

Fig. No.20 - Blade parameters to be optimized.

The following is a discussion of the different parameters:

3.3.1. Blade type - (matrix)

Today a large variety of materials are diced in a production mode. These materials can be very hard, hard and brittle, dead soft, or soft and brittle.

For hard and brittle materials, a relatively soft blade matrix should be used, usually a phenolic resin binder. The soft resin type binder blades wear out fast but perform with very fine chip free kerfs. The cutting performance is based on the ability of the binder to release dulled diamonds and expose new sharp diamonds at the same time. On softer, less brittle materials, a harder matrix should be used. Nickel electroformed and metal sintered matrixes are normally used. The harder blade matrixes hold the diamonds for a long time; this is the main reason for improved blade life. This improved bond requires the use of extremely hard diamond particles in order to maintain their sharp edges for a long time.

Most blade manufacturers use a few standard blade binders for resinoid, nickel and metal sintered blades. These standard matrix binders are designed for most of the substrates being used in the microelectronic industry. However, a fine tuning of the blade matrixes can be performed in order to optimize the dicing process. This fine tuning requires special attention from the blade manufacturer and a good understanding of the process. In most cases the blade optimization includes changes in the manufacturing process that are confidential for each customer's requirements.

The main challenge when making blades for very brittle materials is the ability to change the blade matrix to a softer matrix that will wear out the diamonds faster in order to maintain clean cuts with minimum chipping (See Fig. 21). Changing the wear characteristics of a resinoid blade is more than changing the hardness of the phenolic resin. It is a function, and in many cases a combination, of the diamond type, the diamond concentration, special fillers and other factors.

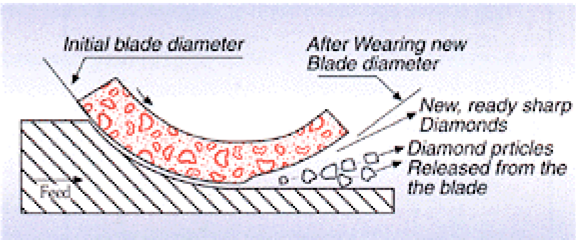

Fig. No.21 - Resinoid Blade Wear Mechanism

3.3.2. Diamonds in the Blade Matrix

Choosing and treating the right diamond type, the right diamond size and the right diamond powder distribution range is a key issue when optimizing a dicing blade for a specific application.

Diamond Type - Background

In the past, natural diamond powders were the only type of diamonds used in manufacturing of diamond wheels and dicing blades. Natural diamonds come from different geographical areas and have different characteristics, mainly different shapes and organic contaminants. Their availability may become a problem in the future. The limitation of natural diamond availability and characteristics led to the development of synthetic type diamonds. These are the main product types used today in manufacturing diamond wheels and dicing blades. Synthetic diamonds are manufactured in a wide range of different toughness ranges and shapes for various industrial applications.

The main advantage of synthetic diamonds is their controlled manufacturing process. What is available today will be the same in years to come. This is of extreme importance in manufacturing dicing blades.

The cost of synthetic diamonds compared to natural diamonds in the micron ranges is virtually the same. It is not an issue when choosing the right diamond for a specific application.

Diamond Shape and Diamond Characteristics

Many different diamond shapes and characteristics are available today. Each type is designed for specific industrial applications and specific quality requirements. The diamonds used for manufacturing thin dicing blades vary for each blade binder and can be fine tuned in order to optimize the blade performance. In general, the most efficient particle shape is a strong blocky sharp-edged shape. A blocky particle is stronger than any other shape. It displays a more homogeneous wear which is important in nickel and metal sintered blades (See Photo No. 5).

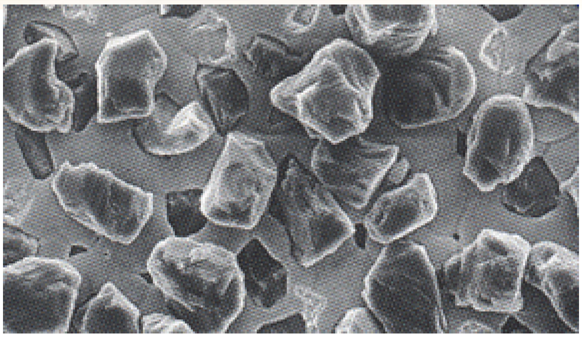

Photo No.5- Strong blocky, single crystal diamond

For very hard and brittle materials, more friable particles are being used in a resin bond matrix for more free-cutting action. The diamond particles can be used with a nickel alloy coating in a variety of different % of weights. The nickel alloy coating improves the wear characteristics and acts as a heat sink during the dicing process. (See photos 6 and 7)

The different % of nickel weight coated on the diamond particle can be used to optimize the blade performance on special application requirements.

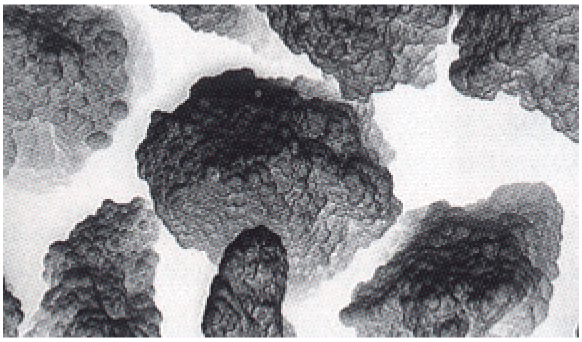

Photo No. 6- Friable, Irregular Shape Coated

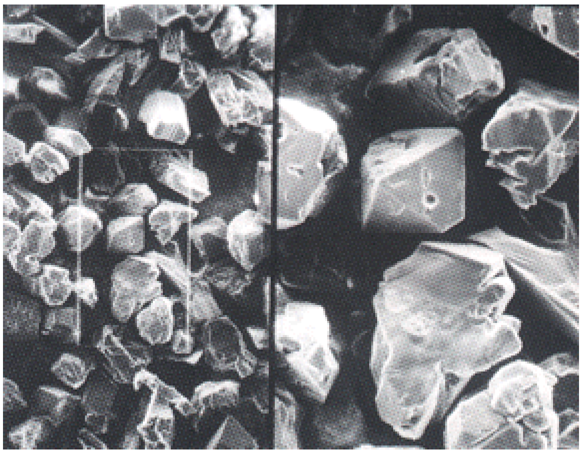

Photo No.7 - Friable irregular shape without coating

The diamond particle - dicing mechanism

Each diamond particle on the blade edge acts as a single cutting tool and digs into a small portion of the substrate material on every revolution of the blade. Since there are many diamond particles on the blade edge, they all create the diced kerf. (See Fig. No. 22)

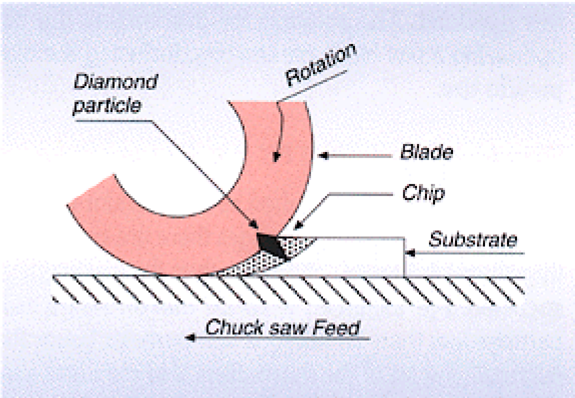

Fig. No.22- Dicing Mechanism

Diamond Size

The diamond size is a major player in the results of any dicing process. The diamond size determines the load and the edge quality of the kerf during the dicing process. A large diamond particle will dig out a large portion of the substrate material and a small diamond particle will proportionally dig out a small portion. This digging action is the reason for higher loads when using smaller diamond particles at a given feed rate. (See Fig. No. 23)

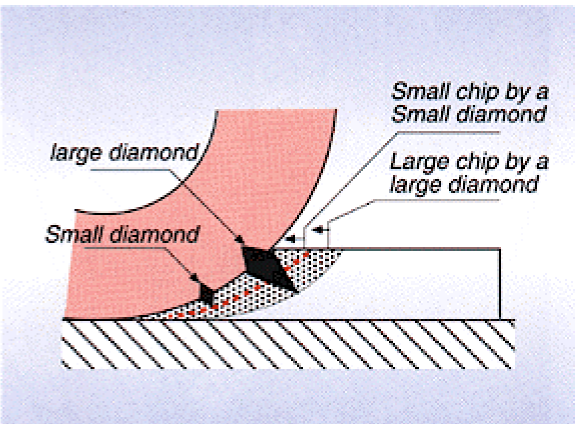

Fig. No. 23- Small & Large diamond dicing mechanism

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The required size of the diamond particle is determined by the hardness and the brittleness of the material being diced.

For free cutting of hard materials, large diamond particles are used in the blade matrix. However, good edge quality requires smaller diamond particles to minimize chipping. When used on hard materials, the smaller diamond particles tend to overload the blades, creating high temperatures, material damage, and in some cases, even blade failure or saw overload. The solution for overloading the blade is optimizing a few blade parameters, including the diamond particle size.

Diamond Distribution Range

A diamond range is specified by a minimum to maximum particle size. In all powder ranges there are particles smaller than the minimum size and larger than the maximum particle specified. For example, a 10-20 micron range will have particles less than 10 microns and particles larger than 20 microns. The art of the micronizers is to minimize almost to -0- the particles outside of the specified range.

The other factor that plays a major role in the performance of any dicing blade is the distribution curve and the particle mean size.

The following is an example of two diamond powders specified as 8-20 microns (See Fig. No. 24). The 2 powders have a different mean size which is seen in the distribution curves. Powder "A" has a nice homogeneous range with a mean size of 11.73 microns and powder "B" has a much higher curve with a mean size of 15.12 microns. Powder "A" may perform well on a specific application. Powder "B" may perform with less load due to the higher percentage of larger particles but may cause a rougher cut quality.

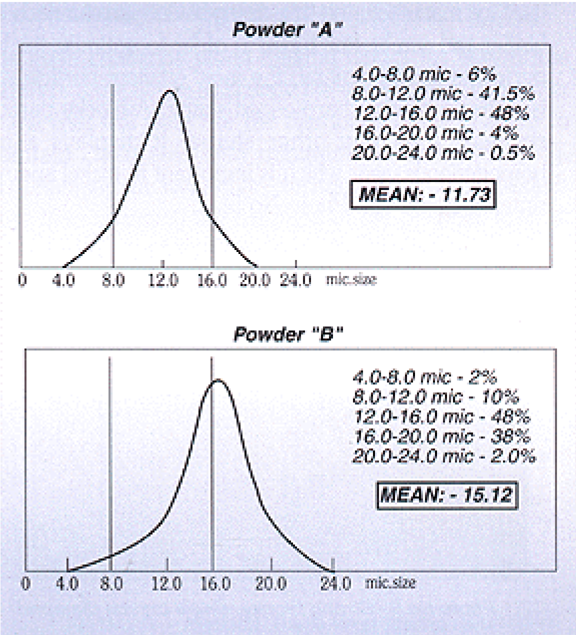

Fig. No. 24 - 8-20 micron diamond distributions

The above example employs a different mean size, in order to better illustrate the diamond distribution issue. In reality, powders for specific applications do not vary so much. To meet today's tough quality requirements, it is very often necessary to optimize the diamond distribution curve in order to achieve a clean cut with minimum loading during the dicing process. The loading of the blade will also affect the blade life.

Diamond Concentration

The diamond concentration also has a major impact on cut quality and process through-put. On nickel electroformed blades the control on the diamond concentration is a function of the plating parameters. On resinoid and metal sintered blades it is controlled by the amount of diamond powder added to the powder mix.

The international standard for diamond concentration is calculated by the weight of diamonds per cubic volume:

72 carats/1^3 inch = 100% diamond concentration of binder and diamond matrix

OR

4.4 carats/cm^3 = 100% diamond concentration of binder and diamond matrix

1 carat of diamonds = 0.2 gr.

Any lower concentration is proportionally calculated from the above formulation.

A higher diamond concentration acts as a harder, less wearing matrix. A lower diamond concentration acts as a softer, more wearing matrix with better cut quality characteristics.

In a higher diamond concentration matrix the distance between the diamonds is relatively small. There is not enough space for the powder residue created during the dicing process. This is one of the main reasons for blade overloading, which results in poor cut quality. (See Fig. No. 25)

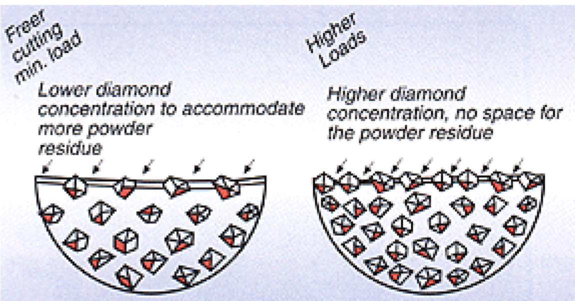

Fig No. 25 - High & low diamond concentrations

Higher diamond concentrations are used to maintain a blade geometry. (See Fig. No. 26)

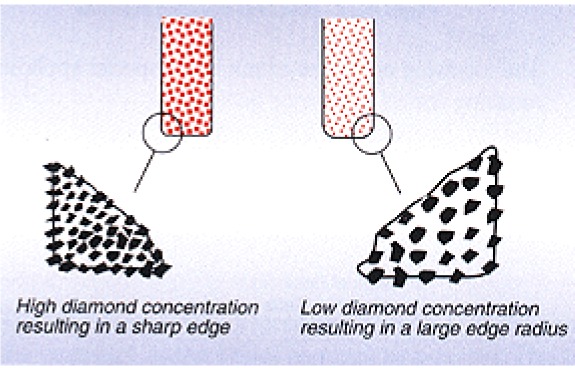

Fig. No. 26 - Diamond concentrations affecting the blade edge geometry

A lower diamond concentration matrix has a larger spacing between the diamond and will accommodate more powder residue from the dicing process. This results in freer cutting with less load and better cut quality. (See Fig. No.25)

A lower diamond concentration matrix will wear out faster which is a disadvantage in some applications.

Finding the best diamond concentration for the best cut quality and with minimum blade wear is a key parameter in optimizing any dicing process.

3.3.3. Blade edge geometry

The edge is the part that actually performs the dicing. In many applications the geometry of the blade edge is extremely important and should be optimized. The following are a few applications requiring special edge geometries in order to achieve cut quality and other special requirements.

Dicing through into tape

As discussed earlier, one of the most common problems when dicing through into tapes is chipping at the substrate contact with the tape. There are many reasons for chipping at the back side of the substrate. One major reason is the blade edge. It is known that the blade edge wears during the dicing process, causing a radius on both sides of the edge. This radius copies its shape to the bottom of the substrate leaving a small lip that breaks off. (See Fig. No. 27)

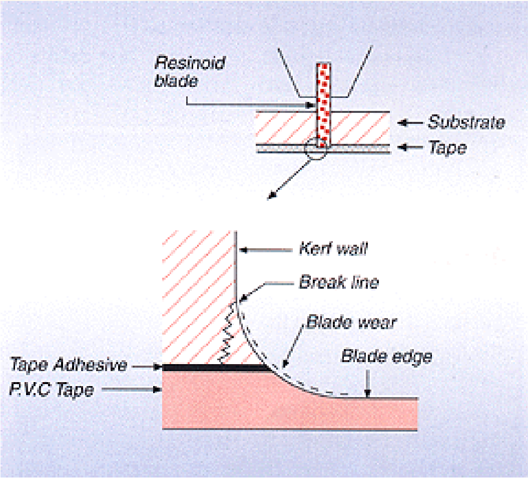

Fig. No.27 - The lip effect when dicing through into tape

To alleviate this problem a flat edge should be maintained at all times. A flat edge can be achieved by grinding on a cylindrical grinding machine, preferably on the same flange used on the saw. This is very important in order to maintain the blade edge runout to the flange and saw spindle.

To maintain the blade edge geometry for a long time it is necessary to optimize the blade matrix and the cutting parameters.

For more information on dicing through - see the MicroSwiss article "Dicing Through Hard and Brittle Materials in the Microelectronic Industry."

Dicing thick substrates

Dicing thick substrates in the range of .200" (5 mm) and over, creates high loads during the dicing process. In order to minimize these loads and create a freer dicing process, a blade with serrations on the edge can be used. (See Fig. No. 28)

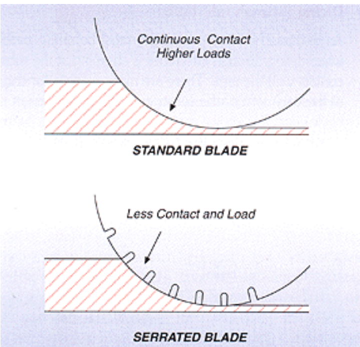

Fig. No.28 Standard & serrated blades

The slots on a serrated blade actually cause less contact between the blade and the substrate material. This reduces the loads, improving the cooling of the blade and substrate.

The slots on the blade edge also help to clean the kerf from the powder residue created during dicing. (See Fig. No. 29)

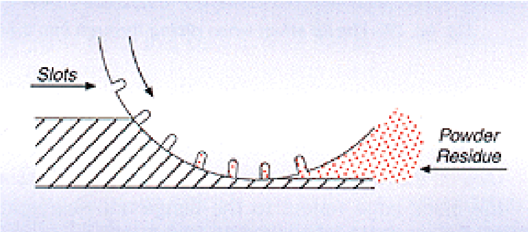

Fig. No.29- Powder residue washed out of the kerf

MicroSwiss has a large selection of Nickel serrated blades in all diameters, starting from 2" up to 5" O.D. Specially designed slot geometry or a special number of slots can easily be made with special tooling.

Slots can also be performed on resinoid blades. This is usually done only on thicker blades designed for thicker substrates.

It should be said that serrated blades minimize the loads during the dicing, but they have the limitation of dicing wider kerfs and the disadvantage of wearing faster. To optimize and reduce the above disadvantages, a blade optimization can be performed in order to minimize the number of slots and change the slots geometry.

Special kerf geometries

Some applications require special kerf geometries. To achieve those unique geometries, blades with special edge geometries should be used. In most cases those geometries are grounded on special universal grinding machines using silicon carbide grinding wheels. (See Photo No. 8)

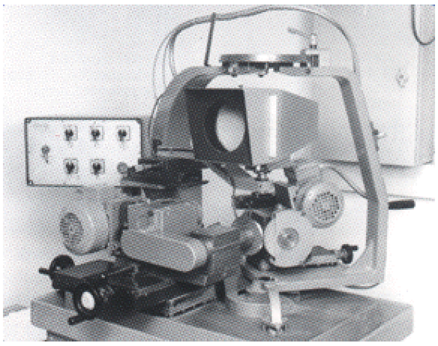

Photo No. 8 - Grinding dressing machine

The following are a few examples of special applications requiring special blade edge geometries: (See Fig. No. 30, 31 & 32)

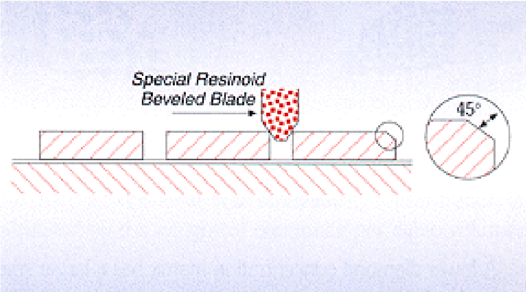

Fig. No.30- Grinding beveled edges on ceramic substrates

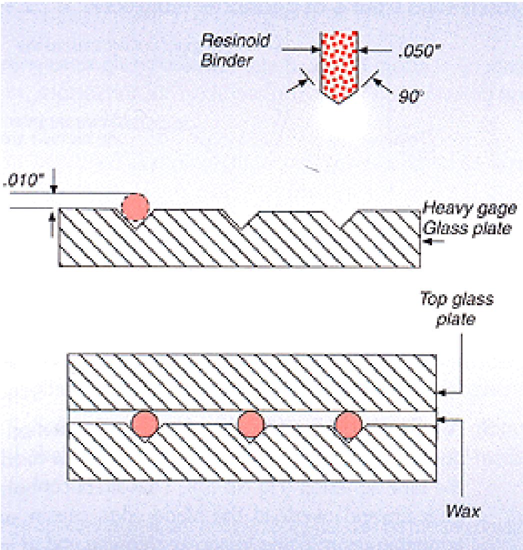

Fig. No .31 - Grinding -V- grooves in a glass fixture for mounting and trimming fiber optics

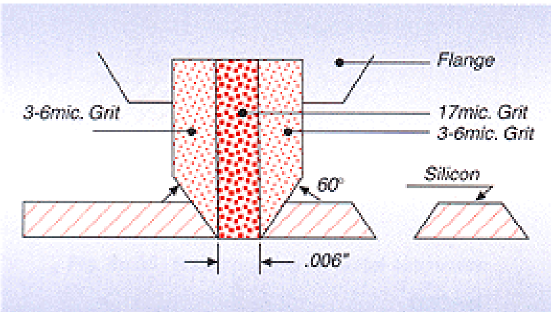

Fig. No.32 - Grinding a trapezoid groove in a unique silicon application with a special nickel binder flange set

General

The art of dicing (grinding) special geometries is in maintaining the geometry of the blades as much as possible. This is achieved by improving the wear characteristics in the blade matrix.

3.4 Substrate mounting

Mounting substrates to be diced partially, in most cases, is relatively easy and does not require special attention. Parts can be mounted by all available mounting methods. The reason for the easy handling and, in most cases, the trouble-free dicing is the fact that the parts or dies are connected stiffly to the base substrate and do not move during the dicing process.

Dicing through, however, is very different and creates both mounting and quality problems. The smaller the dies, the more difficult and critical is the mounting. Almost any cut through application must be optimized. The following is a discussion of the different mounting techniques and parameters to be optimized.

3.4.1. Tape mounting

This is the most common mounting method used in dicing microelectronic substrates. It is used mainly because of its easy handling and the fact that it is a mounting media for the dicing process and later on for the die bonding process. The most common tape is a PVC tape .003" (0.076 mm) thick that is available with different adhesive tackiness characteristics. The mounting is carried out either manually or with wafer mounting systems. The mounting goal is to have a good, uniform contact between the substrate and the tape without any air bubbles, dust or dirt particles between the substrate and the tape. The tape is then mounted to a frame of different designs, depending on the saw type. The frame is a stiff handling media for easy handling to the saw, on the saw and outside of the saw to the die bonding process. Photo No. 9 is an example of a tape mounted application on a K&S saw.

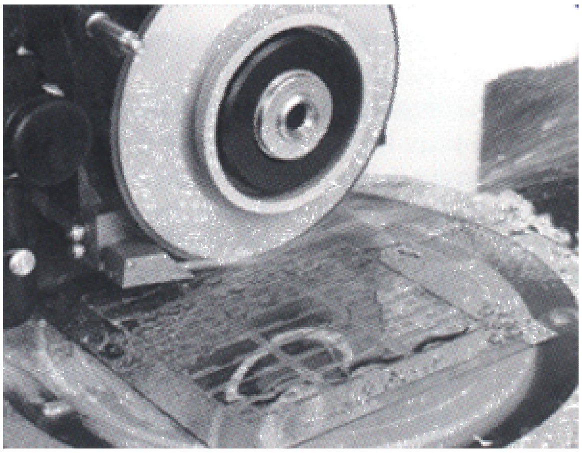

Photo No.9- Glass application mounted to a .003" tape

Main problems and process optimization when dicing through into tapes:

1) Most tapes are made of soft PVC with a thin layer of adhesive. (See Fig. No. 33)

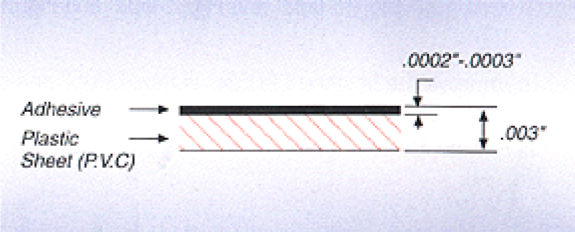

Fig. No. 33

The PVC tape by nature is soft and overloads any dicing blade. Blade overloading means blade clogging, and therefore high temperatures that cause material damage mainly at the back side of the substrate. Photo No. 10 shows material damage at the back side of a silicon wafer.

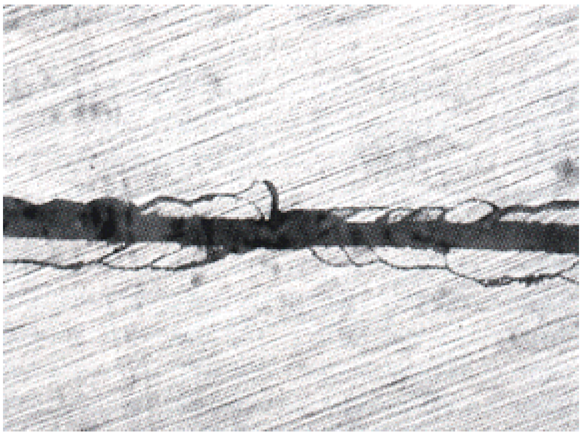

Photo No. 10 - Back side chipping of a silicon water

Overloading the blade can cause other problems such as wavy cuts, slanted cuts, blade side vibrations, and top chipping, material micro-cracks and blade failure.

To minimize the blade overloading in the tape, the following should be considered:

- On hard materials using relatively thick blades, try to use the thinnest blade possible in order to minimize the load. Optimizing the thinnest blade requires other considerations like blade vibrations, minimizing the blade exposure and others.
- Slow down the feed rate.
- Use the largest diamond possible for the material being diced. Larger diamonds, on the other hand, may cause larger chipping so the size needs to be optimized.
- Make sure the coolant is perfectly aligned and is adequate in pressure and quantity.
- Try to use the newly developed tapes like the -UV- tapes which are made of polyester, a harder tape that will not load up the blade as the PVC tape.

2) Dicing through - the lip effect -

(See "dicing through into tape" and Fig. No. 27.)

To improve the lip effect, a thicker tape (.005" and over) should be used in order to make sure the cut is straight and there is no lip effect on the back side of the substrate. (Fig. No. 34)

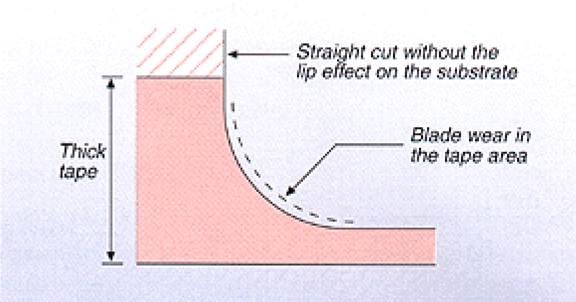

Fig. No.34 - Blade wear in the tape area

When dicing hard materials using resinoid blades, harder blades should be used in order to minimize the edge wear.

3) Another problem related to blade wear when dicing through into tapes is contact between the blade edge and the tape adhesion. (Fig No. 35) This direct contact will gum up and overload the blade edge causing high temperatures resulting in access chipping and in some cases blade failure. To overcome this problem, the blade edge should penetrate into the PVC area .001" - .0015". (See Fig. No. 35)

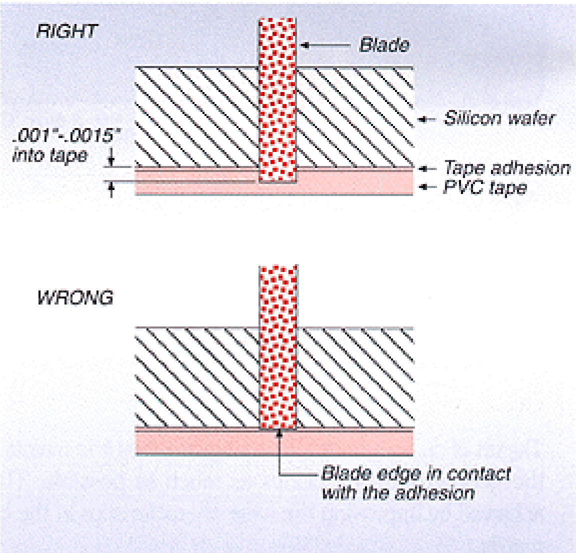

Fig. No. 35 - Blade edge location in tape

Using a thicker tape can also help. It enables cutting deeper into the tape. In addition, it can help eliminate the contact between the blade edge and the adhesion.

3.4.2. Wax/glue: Mounting to a hard base media

Waxing or gluing the substrate to a solid media is, in most cases, superior for blade performance. The following are the main advantages:

- Improved clamping characteristics compared to tape mounting. This is a major advantage when dicing small die sizes.
- The ability to dice much deeper into the base media results in much better quality mainly on the back side of the substrate - no lip effect.
- A firm mounting eliminates any die movement, especially when dicing the second index - improving the cut quality.
- Soft or hard base media can be chosen in order to control the blade wear and to act as a cleaning (dressing) media for the blade.
- Substrates that are not perfectly flat can be mounted with wax or glue. The wax/glue compensates by filling in gaps. (Fig. No. 36)

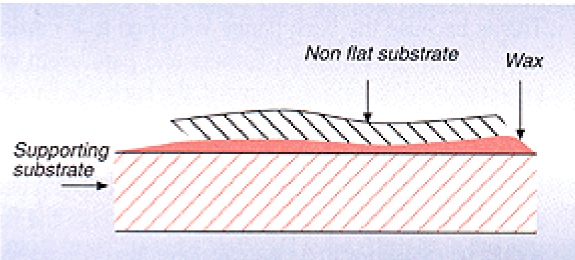

Fig. No.36- Wax mounting on unflat substrates

Main disadvantage and points to be optimized:

- Some waxes have relatively higher melting points which may damage the die components. In these cases, a lower melting point wax type or an optimized glue, should be used.
- Handling is the main disadvantage of wax/glue mounting over tape mounting. Hot plates should be used for the wax mounting and chemicals to dissolve the wax or glue. The final cleaning of the dies is also time consuming a major disadvantage over tape mounting. On most wax/glue materials the process can be optimized to minimize the above problems.

3.4.3. Mechanical Fixturing for Substrate Mounting

Mechanical clamping is preferable on some applications for the following reasons:

- Easy handling

- Fast loading and unloading for high volume production
- The geometry of the substrate is such that only specially designed mechanical clamping can actually be used. Fig. No. 37 is a typical example:

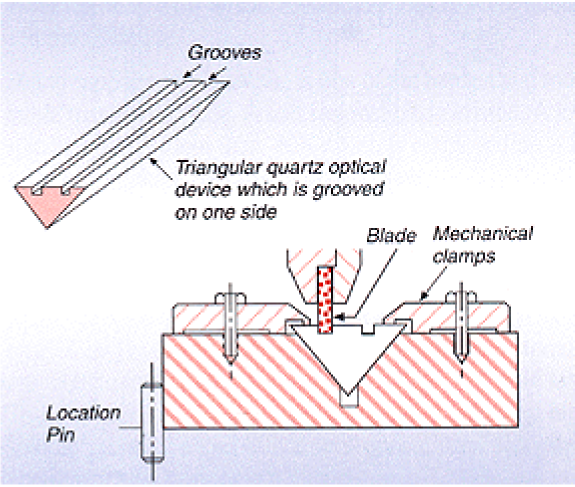

Fig. No.37 - Mechanical Mounting

Typical points to be optimized by mechanical clamping:

- Easy and fast handling
- Maintaining and improving the substrate mounting accuracy
- Optimizing the best fixture raw material for maximum fixture life cycle

General

For more detailed information on mounting substrates, please refer to the Micro-Swiss article, "Dicing Through Hard and Brittle Materials in the Micro-Electronic Industry".

3.5. Blade & Flange Mounting

Proper blade mounting in a flange set in good condition is of major importance when dealing with high quality dicing applications.

3.5.1. Flange Condition

The following sketch Fig. No.38 shows the most important areas for checking and correction:

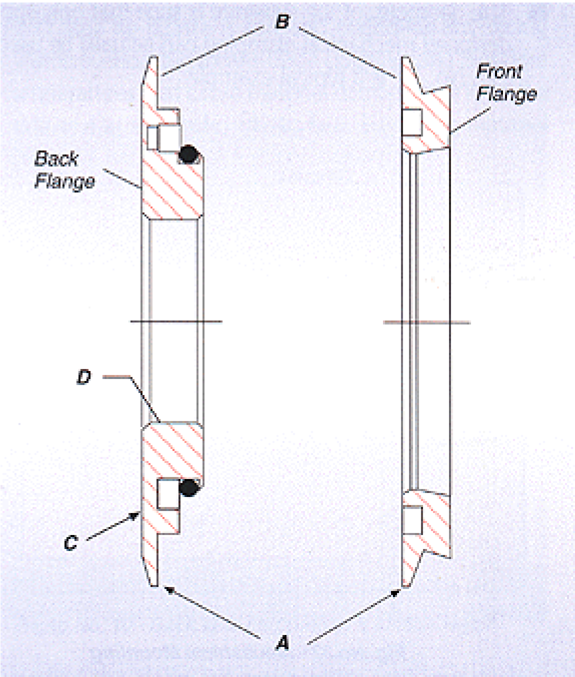

Fig. No.38-A standard 2" flange design

A & B are the most important points to check. Any small scratch or nick on the flange edge will cause improper blade mounting. This can lead to slanted cuts, blade wobbling and therefore wider cut, more chipping or blade breakage. Fig. No. 39 shows a blade deflecting due to edge damage on one side of the flange set.

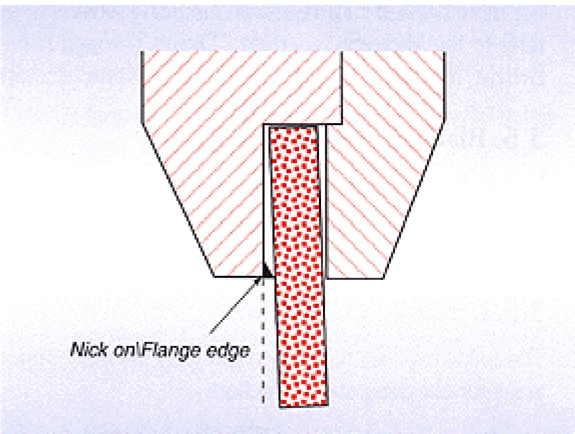

Fig. No.39 - A Slanted blade due to flange/edge defect

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Area "C" (Fig. No. 38) facing the spindle back mounting flange is of extreme importance as it affects the blade side runout.

Diameter "D" (Fig. No. 38) with time can be worn out, causing a loose fit on the spindle which will affect dynamic balancing; in this case, the back flange should be replaced.

If A, B, and C, are slightly damaged, they can be corrected by hand lapping with a fine Arkansas stone. Micro-Swiss offers small lapping kits for this job (photo No.11).

Photo No.11 - Lapping kit

Micro-Swiss 4" to 5" flange sets feature a unique design, with the back flange mounted to a bushing. While this requires more handling, it also provides greater accuracy. This is because the back flange is lapped to a maximum tolerance of 0.OO2mm on flatness and parallelism which improves the side runout. If needed, the back side flange can be relapped to machine out any damage.

It is important to check the spindle diameter and the spindle back flange for any small scratches. When changing blades, all flange parts and spindle areas in contact with the flange should be cleaned with a cleaning solvent.

A major reason for flange damage is small dies lifting off during the dicing process. To overcome this problem, a mounting optimization should be performed, as previously discussed.

3.5.2. Flange and Spindle Nut Torquing

While clamping the flange sets, it is a good idea to monitor and torque both the flange and spindle nuts. Different operators may over-tighten or under-tighten the flange nut and spindle nut.

Undertightening the flange nut may cause the blade to spin freely in the flange during the dicing. This will result in poor quality and severe damage to the flange set.

Overtightening the flange nut can cause a deflection on the flange edge which may affect the blade performance. (See Fig. No.40)

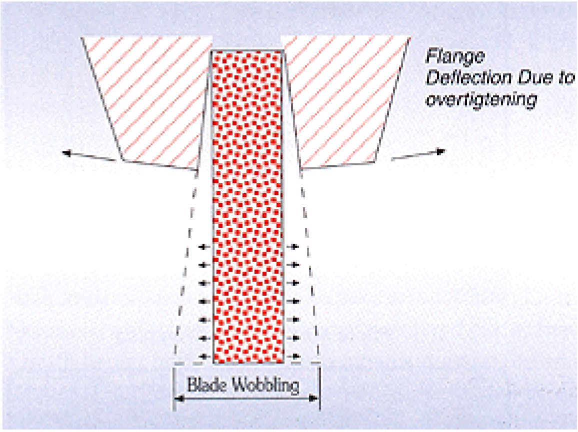

Fig. No.40 - Flange Over tightening

A controlled, accurate dicing process requires some torquing optimization. The following are preliminary recommendations and guidelines. However; every application should be optimized in order to achieve the best results. This is most important when tightening 4" flange sets.

4" flanges- 31±3 - inch x Lb. (360 +- N x cm)

4" spindle nut (on K&S saws)- 31±3 - inch x Lb (360 +- 30 N x cm)

2" spindle nut (on K&S saws)- 22±2 - inch x Lb (254 +- 23 N x cm)

A loose spindle nut can cause serious damage to the spindle and the flange, at the spindle rotation starting point. On most saws, the nut is designed to be clamped in the opposite direction of the spindle rotation.

A torquing kit for the 4" saws and 2" saws is available from Micro-Swiss.

3.6. Dicing Parameters

Optimizing the cutting parameters is always a key issue for any dicing application.

The main parameters are spindle speed and feed rate, or a combination of both. Optimizing the cutting parameters is also a factor of defining the requirements: is it quality only, is it through-put, or is it a combination of both? The number of applications and the variety of different requirements is so high that it is impossible to cover them all in a short discussion.

The following are basic principles that should help clarify the technical variations involved in optimizing cutting parameters.

Most saws and blade vendors will provide general recommendations for each application. However, every application should be optimized in production mode to meet specific requirements.

3.6.1. Spindle Speed

As mentioned before, air bearing spindles have a peak torque at a given spindle speed. Some materials must be diced at lower r.p.m.'s. This affects the spindle load, the cut quality and the blade life.

Dicing sapphire, for example, is one of the hardest and most brittle materials to dice. A soft resinoid blade is used. A low spindle speed of less than 20K r.p.m. is employed on a 2" saw and less than 10K r.p.m. on a 4" saw.

The reason for using a low spindle r.p.m. is to cause the blade to wear out fast in order to maintain a chip free cut. Another extreme example is dicing green ceramic (unfired) which at this stage is considered a soft material. A hard nickel type blade is used for this application and most customers are looking for high through-put of over 10"/sec. feed rate. To be able to dig out and get clean cuts, a relatively high spindle r.p.m. of about 30K r.p.m. on a 2" saw is needed, and over 14K r.p.m. on a 4" saw.

To put it simply, higher spindle r.p.m.'s will result in a harder dicing action, where each diamond will dig out a small portion of the substrate in each rotation. Conversely, a lower r.p.m. will result in a softer dicing action where each diamond will dig out a larger portion of the substrate in each rotation. This will result in higher blade wear but will expose new, fresh diamonds, resulting in a cleaner cut.

To summarize, the cut quality requirements and the material characteristics will determine optimal parameters. The substrate thickness is also a factor, as thick substrates will even further overload the blades.

3.6.2. Feed Rate

Optimal feed rate is a combination of the cut quality requirements, material characteristics and the substrate thickness.

In some cases soft but very brittle materials will also require slower feed rates.

Higher feed rates require dicing out substantial quantities of material in a short time. The loads are high and the blade and substrate temperatures are even higher.

Higher temperatures in most cases will affect the cut quality and the blade life. So when optimizing the feed rate, the above parameters and quality requirements should be considered.

3.6.3. Cut Depth

Cut depth is, in most cases, a function of the substrate thickness. When dicing into thin tapes, the penetration into the tape is .001" - .002" (0.025 - 0.050 mm). But when dicing into a thick holding media, waxed or glued to the substrate, the cut depth can then be .005" - .010" (0.13 -0.25 mm). It should be optimized depending on the cut quality and blade loading.

3.7. Dressing

"Dressing a blade" is the process of treating the surface of the blade in contact with the substrate material in order to enable it to freely penetrate into the material, minimize loads, and perform with good cut quality. Dressing blades can be done by the following methods:

- Chemical etching (nickel binders)
- Chemical electrical etching (nickel binders) Photo No. 12
- Grinding (all blade types) Photo No. 13
- Surface lapping (all blade types) Photo No. 14
- On-line dressing on the dicing saw (all blade types) Photo No. 15

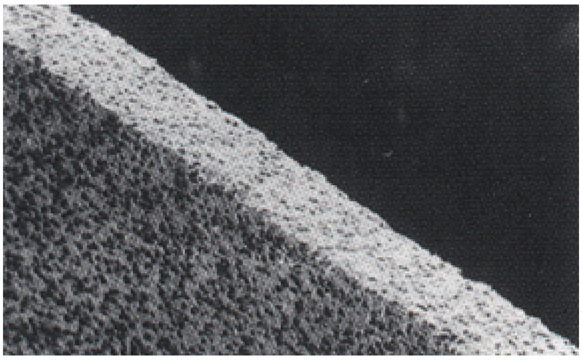

Photo No.12 - Chemical Electrical etching

Photo No.13- O.D. Grinding

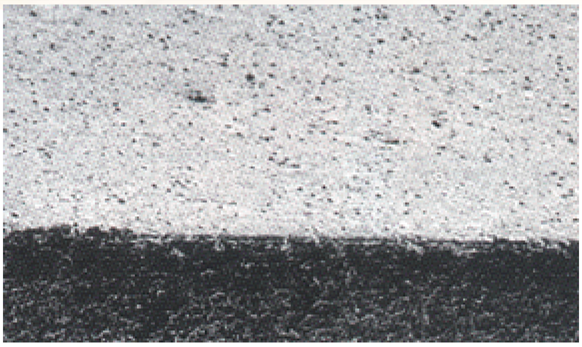

Photo No. 14- Surface lapping

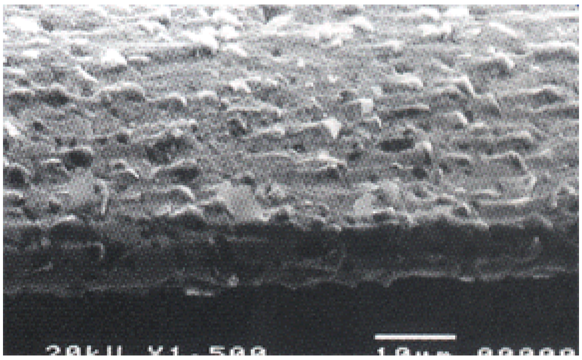

Photo No.15 – On-line dressing

The idea of dressing a blade is to machine off any loose diamonds from the blade edge and the blade sides (Fig. No. 41), to expose the diamonds mainly on the edge but also on the sides (Fig. No. 42), to get a perfect runout of the O.D. to the spindle and to achieve a good side runout.

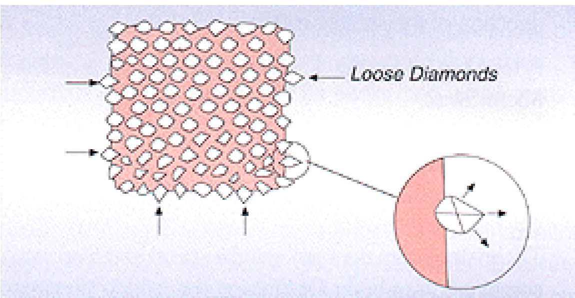

Fig. No.41 - Dressing out loose diamonds

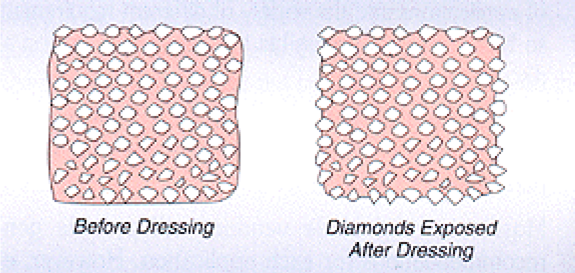

Fig. No.42 - Dressing to expose diamonds

It is important to note that blades without well exposed diamonds do not penetrate easily into the material. It will tend to push the material, creating high loads, high temperatures and poor cut quality. In some cases, it can cause blade breakage.

There is a major difference between different blade binders. Resinoid blades by nature have a soft binder and in most cases will require minimum dressing, if at all. Resinoid blades will easily be dressed in the material being diced. Resinoid blades are called "self resharpening blades" by the industry. Nickel electroformed blades and metal sintered blades have a much harder binder and a much more aggressive dressing is needed in order to achieve the above mentioned goals. The following is a short discussion of the different machining/dressing methods:

3.7.1. Chemical and chemical electrical etching

This method is used only by the blade manufacturers mainly on nickel electroformed blades. It is a very delicate, controlled process and the main purpose is to chemically or chemically/electrically machine off the blade binder in order to expose the diamonds.

3.7.2. O.D. Grinding

Both users and manufacturers can perform O.D. grinding on all blade types. The main purpose of grinding the blade edge is to get a nice flat edge concentric to the inside diameter and to have an open material structure with diamonds exposed on the edge.

The grinding can be performed on any cylindrical grinding machine using a silicon carbide wheel. The wheel matrix (hardness and grit size) must be optimized according to the blade matrix, the grinding machine and the edge quality required. The dicing blade rotation speed is always much slower than the silicon carbide wheel and should be optimized to the saw type. The reason for using a slower speed of the diamond blade is to achieve a machinability effect on the blade. Using a higher blade rotation will create very high wear of the silicon carbide wheel while minimizing machinability effect of the blade. It is very important that both the diamond blade and the silicon carbide wheel rotate in the same Direction, rather than in opposing directions, as in conventional grinding. (Fig. No.43).

Movement in opposite directions may damage the diamonds' sharpness.

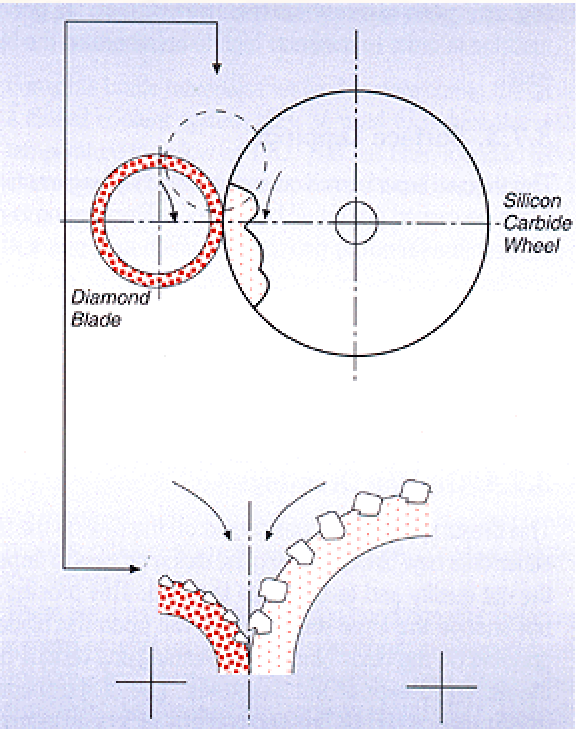

Fig. No. 43 - O.D. Grinding principle

If grinding is performed by the user, it is always preferable to employ the flange that is used on the saw in order to achieve the best runout on the dicing saw. The infeed of the silicon carbide wheel is small, about .0001" (0.0025 mm) on each pass and must be optimized depending on edge quality requirements. Mounting the flange set on the grinding machine is extremely important; the flange must run between centers on an arbor with a runout accuracy of 0.001 mm max. (See Fig. No. 44)

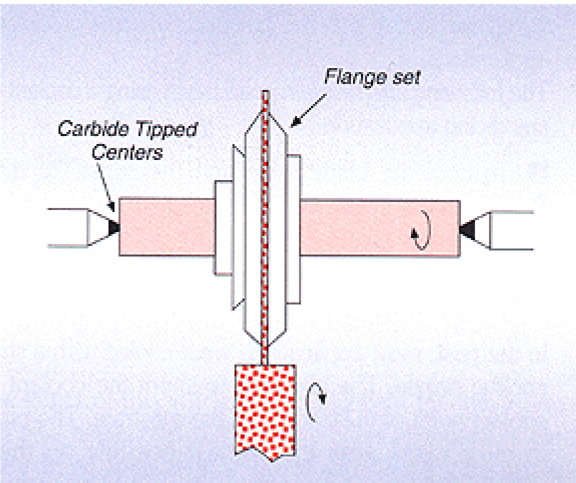

Fig. No. 44 - O.D grinding on a cylindrical grinder

A good cooling system should be maintained on the grinding machine in order to minimize high temperature on the blade edge.

3.7.3. Surface Lapping

This process is performed on sophisticated lapping machines. It can be carried out on all blade types. The lapping is part of the manufacturing process, in which an open surface structure is created on both sides of the blade, resulting in an even load during the dicing process.

Lapped blades can maintain thickness accuracy of .000050" (0.00127 mm) and even better. This lapping process is obligatory in many gang applications.

3.7.4. On-Line Dressing

This dressing process is performed on the saw by the user, either on a new blade or during the dicing process to improve the cut quality and to minimize the load. This process will not change the edge shape. But it will open the blade by grinding off the blade binder and cleaning any residue from the dicing to expose the diamonds. The dicing media is usually a silicon carbide dressing board or stick or an aluminum oxide stick. The dressing media is mounted to the saw chuck. The blade penetrates into the board or stick at low feed rates.

The table speed, spindle speed, cut depth and number of passes should be developed and optimized for each application. The dressing board or stick grit and hardness should also be optimized. On today's newly developed saws, a dressing program of how many cuts at what speed and depth can be programmed in order to achieve optimal quality.

3.8. Coolant

Cooling the blade and the substrate is a requirement for any dicing application with the exception of some green ceramic applications.

The following are the main goals when using a coolant during any dicing application:

- To cool the blade edge and the substrate material
- The coolant acts as a lubricant to minimize friction between the blade and the substrate material.
- The coolant helps to wash out the powder residue from the dicing process.

In the past, most applications were cooled with a standard cooling nozzle. The idea was to shoot the coolant at the contact point of the blade with the substrate. The pressure, in most cases, was the highest possible on the saw.

Today, there are many new types of applications which require unique cooling systems in order to meet special quality requirements.

The following are a few ideas and methods for cooling applications requiring special cooling attention:

3.8.1. Applications with a high blade thickness-to-exposure ratio

The coolant becomes a major factor on applications requiring a high ratio between the blade thickness and blade exposure. The main considerations are that the coolant reach the bottom of the cut in order to maintain a 90 straight cut, which is usually the main problem. A small cooling nozzle diameter combined with a high water pressure will in this case cause the blade to vibrate which will cause wider cuts and more chipping. Another major problem is blade deflecting causing slanted cuts. (See Fig. No. 45)

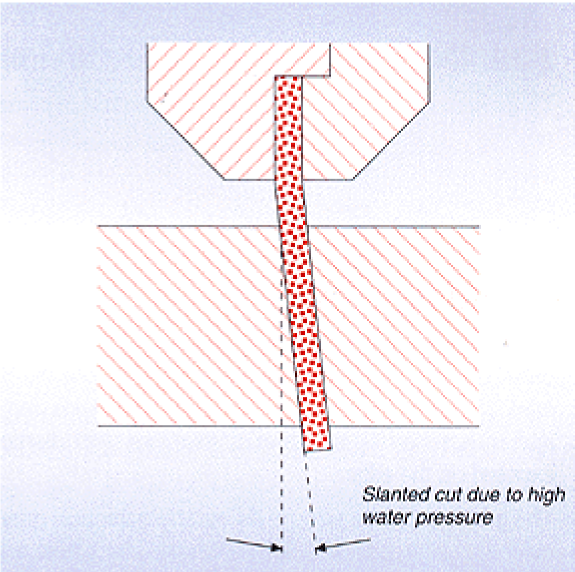

Fig. No. 45 Slanted cut due to high water pressure

To overcome these problems a much wider cooling nozzle should be developed to produce a high volume of water coolant flow with a much lower pressure. The cooling nozzle can be mounted far from the blade to eliminate any side forces that may affect the blade stability.

3.8.2. Dicing thick substrates

Dicing thick substrates of over .100" (2.5 mm) creates quality problems related to the cooling process. The main problem with thick substrates is cooling the bottom of the cut. (See Fig. No.46)

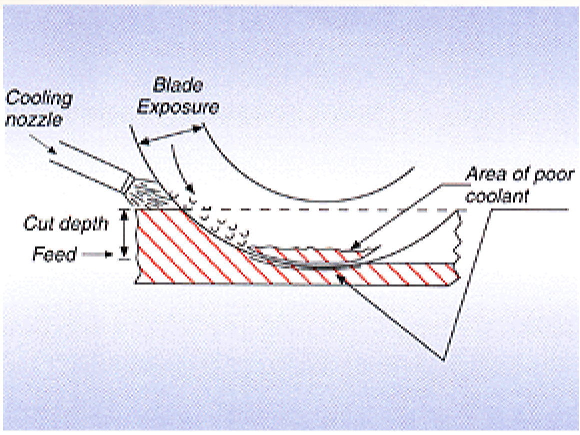

Fig. No. 46 - Poor coolant on thick substrate

Two options are available to overcome this cooling problem on thick substrates:

- Adding 2-5% of an organic macro molecule additive to the coolant water lowers the surface tension of the water and helps the coolant to penetrate better to the full depth of the kerf. The coolant also acts as a lubricant which helps minimize the load during the dicing process. Among the organic additives available are biodegradable solutions or what are called "green" solutions for the environment.

  The additives can be added as a mist to the coolant line or mixed with the water in a closed loop system.

- Another way of getting the coolant to the bottom of a deep kerf is by using the Micro-Swiss high cooling flange set. (See Fig. No. 47)

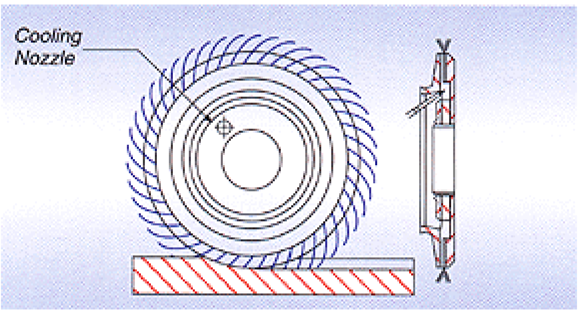

Fig. No.47- High Cooling Flange Set

This unique design spreads the coolant from the center of the flange to the outer edge of the blade on both sides. The high velocity (spindle r.p.m.) translates into high pressure on the coolant, which is forced to the bottom of the kerf. High cooling flange sets are available on 4" saws and on 2" saws.

3.8.3. Reducing top side chipping on brittle materials

For some brittle materials that tend to chip during the dicing, a closed coolant system may be used to reduce the water temperature to as low as 1OC. This has been found to reduce chipping. Of course, the temperature must be optimized for each application.

A major issue when considering a closed cooling system is to have a continuous filtration system to clean out any residue from the dicing process.

3.9. Balancing

In many applications, the demand for superior cut quality and high yields requires a perfect, dynamically balanced dicing system. For some customers, dynamically balancing the flange set every time they change blades is a daily routine process; other customers should seriously consider adapting this process.

There are a few vendors providing good dynamic balancing systems or what is called "precision vibration measurement", analysis, and balancing instruments. The system works similarly to balancing commercial car wheels.

The instrument measures the high unbalanced pick mass and location and advises the operator on what mass to add and in what location. The system is capable of balancing the flange set to a submicron vibration level.

Adding the mass can be done by adding small set screws to the front flange grip or by adding small metal pieces to the inner side of the flange grip, cut from an aluminum sheet or similar. The metal sheets are coated with a layer of adhesive (See Fig. No.48).

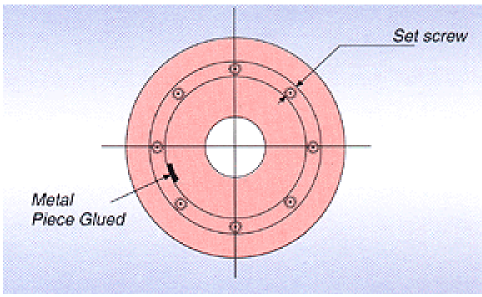

Fig. No.48 - Front Flange - Balancing

Summary:

The intent of this article was to highlight the major issues and parameters related to dicing process optimization. Since every dicing application is unique and different, the saw and dicing parameters are tailor-optimized for each application. Micro-Swiss ultra modern application laboratory offers its customers support services for new applications; however, the final optimization should be performed in production mode by the customer.