5.3 DICING

5.3.1 **Current Industry Characteristics**
  - 5.3.1.1 Development of the Industry
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(Shaded Material is unreleased)

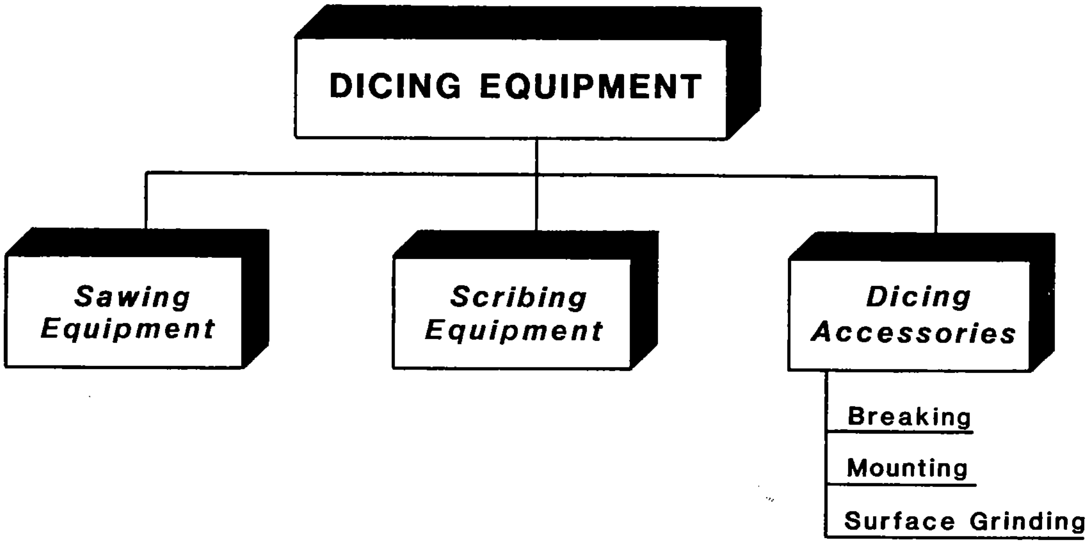
5.3.0 DICING

Dicing equipment is used to cut apart individual die on a wafer. Typically, a dicing saw will cut along the wafer in an unused section between dice that is called the 'street'. Such streets are typically three mils wide. Dicing equipment becomes more critical as 'streets' become narrower.

Issues affecting this market are larger wafer diameters and the trend to automate the entire backend process.

The market for dicing equipment consists of three segments: sawing equipment, scribing equipment, and dicing accessories. This segmentation is shown below, in Figure 5.3.0-1. There is little substructure in this segment except for the dicing accessories equipment market. Sawing and scribing equipment is used to physically separate the die on the wafer. Sawing equipment actually cuts the wafer apart using a diamond impregnated blade. Scribing equipment is similar to glass cutting. Streets are scratched on the wafer. Pressure is then exerted from the back of the wafer causing the wafer to fracture along the scribed lines. Dicing accessories are used in conjunction with sawing and scribing equipment. These include equipment such as surface grinders, tape mounters, wafer mounters, and wafer breaking equipment.

Figure 5.3.0-1



Source: VLSI RESEARCH INC.
2252-6

5.3.1 Current Industry Characteristics

5.3.1.1 Development of the Industry
  - *5.3.1.1.1 Sawing Equipment*
  - *5.3.1.1.2 Scribing Equipment*
  - *5.3.1.1.3 Dicing Accessories*

5.3.1.2 Technology
  - *5.3.1.2.1 Sawing Equipment*
  - *5.3.1.2.2 Scribing Equipment*
  - *5.3.1.2.3 Dicing Accessories*

(Shaded material is unreleased)

5.3.1 Current Industry Characteristics

Dicing equipment is an essential step in the semiconductor manufacturing process. The technology has long been established, though it continues to be affected by trends toward automation.

5.3.1.1 Development Of The Industry

The dicing equipment market dates back to around 1955. Prior to that time, transistors were processed individually. Each transistor consisted of its own tiny slab of germanium. Crystals were cleaved more often than they were sawed. By 1955, whole wafers were being processed. Scribing equipment appeared soon thereafter. Diamond scribing of wafers quickly became one of the essential steps in semiconductor manufacture.

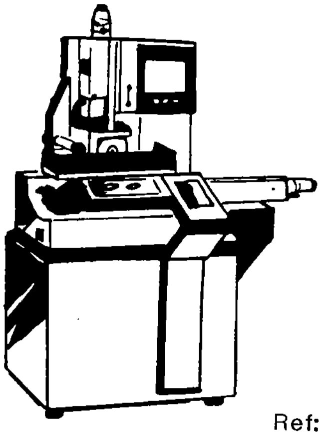
By the early seventies, it was becoming apparent that scribing contributed to low yield. Sawing methods were introduced and they improved yield dramatically. This occurred because sawing caused fewer die fractures. Saws also cut the die edges more squarely and more accurately. This caused downstream improvements and speeded up die attaching.

5.3.1.1.1 Development of the Sawing Equipment Industry

The first dicing saws appeared on the market in the early 1970's. Introduction in 1974 of an ultra-thin cutting wheel by Disco, of Japan, upset the market positioning and changed the market drastically. Other early suppliers of sawing equipment were Tempress, Electroglas, Kras, Motion Dynamics and Farco.

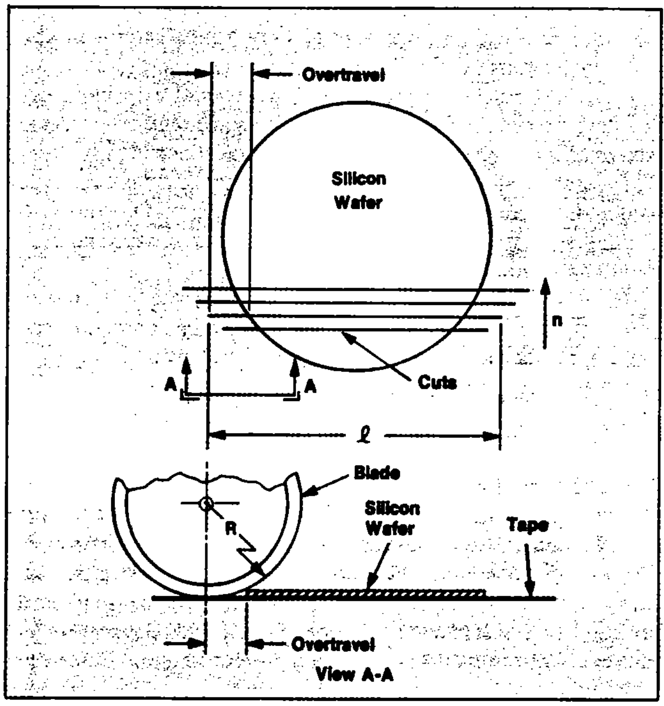
Brief drawings of sawing equipment are shown in Figure 5.3.1.1-1. As mentioned, dicing saws provided an alternative to scribers. Not only did they provide the ability to obtain square edges and cut through thick wafers but also the sawing wheel was very narrow and permitted a reduction in kerf. It dropped the performance from 6 mils to 3 mils. Consequently, semiconductor manufacturers were able to reduce their "street" sizes substantially. Disco subsequently captured virtually all of the Japanese market and then a substantial portion of the American market as well.

American manufacturers entered the market with such ultra-thin saw blades by 1977. By 1979, Tempress' dicing saws had regained much of this market share. Meanwhile, MicroAutomation also emerged and soon became the dominant American supplier. In 1981, MicroAutomation and



Ref: Kulicke and Soffa

Kulicke and Soffa's Model 775 Wafer Dicing Saw



Ref: Solid State Technology/July 1985
2252-8

Saw Position on a Silicon Wafer

Figure 5.3.1.1-1

SAWING EQUIPMENT

Tempress' line of saws were merged by their parent, General Signal. In 1983, the Tempress line of dicing saws were purchased from General Signal by Advanced Semiconductor Materials (ASM). Farco exited the market in 1983.

By 1983, three companies were offering fully automated, in-line, equipment. Disco installed an automatic dicing saw with a cassette-to-netto frame interface in Toshiba's fully automated assembly line in Japan. This saw included a tape mount, an automatic dicing saw and a wafer cleaning station. Kulicke and Soffa soon offered a similar system. MicroAutomation (General Signal) had developed an automated dicing saw system which included a wafer sender, an automatic saw, a wafer cleaning station and a wafer receiver.

Two issues affect the dicing market. The first is the sawing of gallium arsenide (GaAs) and other materials being used for making wafers. The second is the integration of dicing saws with other assembly equipment. They are discussed in the following paragraphs.

The usage of gallium arsenide in semiconductor manufacturing while still relatively small, continues to increase rapidly and remains one of the most rapidly growing semiconductor markets. This is due to the material's high speed characteristics. However, the physical properties of GaAs make it a very difficult material to saw. It is very brittle and chips easily. Consequently, scribing is still the predominant method in use with GaAs, sapphire, alumina, glass and III-V materials. The challenge of sawing GaAs while maintaining the high yields lies mainly with improved saw blades, and then with the saw blade manufacturers, more so than with the equipment manufacturers. Blade manufacturers have met this challenge by designing electroplated blades specifically for the sawing of GaAs surfaces. The high cost of GaAs is also creating the need for still smaller blade thicknesses, due to the need to conserve material on GaAs wafers.

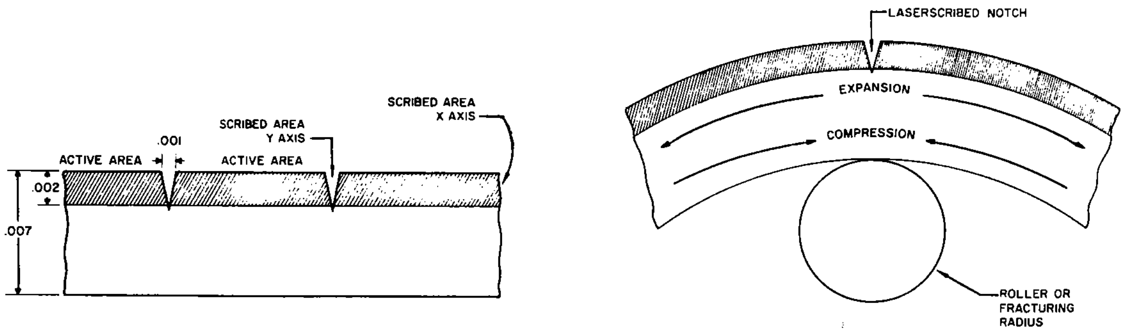
GaAs is just one of many relatively new materials being used to manufacture integrated circuits. Others are sapphire, quartz, garnet, etc. The successful sawing of these substrates become increasingly important as they move from R&D application into pilot line production and then to full-scale production. Blade manufacturers need to perfect the sawing of these materials. Otherwise the manufacturers of sawing equipment will stand to lose some of the growing market share in the dicing market to scribers.

The sawing of new materials represents about the only technical problem encountered today in sawing. Most other technical improvements needed for high yield sawing have already been incorporated into the sawing equipment. For example, mid-eighties dicing saws could automatically load and unload a magazine of wafers. Most saws also use an optical pattern recognition system to locate the streets on a wafer, they also automatically clean and dry the wafer before loading.

The latest step has been automated transfer of fully loaded magazines. These systems interface dicing saws with other types of assembly equipment. It is what manufacturers call computer integrated handling. This provides interfaces between dicing saws, die bonders, and subsequently wire bonders. Most manufacturers have previously been hesitant to try bolting together more than one piece of equipment. This is due to throughput disparities between different types of equipment. For example, one dicing saw can serve four or five die bonders. The same is true when comparing die bonders to wire bonders. Additionally, when equipment is bolted together the in line process is only as reliable as the least reliable piece of equipment. These problems are eliminated with computer automated handling systems. A host computer is used to coordinate all of the different pieces of equipment on an assembly line. The Shinkawa SIL-1001 system maps the wafer. This data is stored in a host computer. It is then sent to dicing. Lot identity information is then transmitted to a host computer to verify that the correct dicing program is stored in the saw's memory. Dicing saw manufacturers have been incorporating this ability into their equipment in the eighties. General Signal and Shinkawa have various levels of flexible automated systems. The current market size of saw equipment is shown in Section 5.3.9.

5.3.1.1.2 Development of the Scribing Equipment Industry

Scribing equipment appeared in the late 1950's. The first scribers to be used were diamond tipped and scratched the wafer "streets" so the wafers could be fractured and separated. Diamond scribing equipment utilizes a diamond tip tool to scratch the wafer surface along its streets. In principle it is similar to a glass cutting tool. Laser scribers were subsequently developed. Figure 5.3.1.1-2 shows wafer breaking after scribing.



Ref: General Signal (Electroglas)
2252-9

Scribed Streets

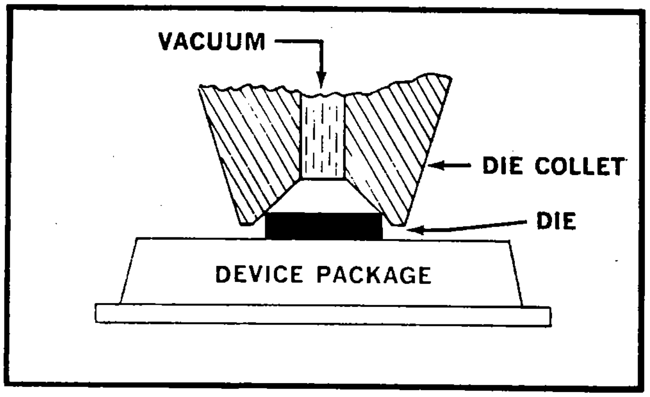
Breaking a Scribed Street

Figure 5.3.1.1-2

WAFER BREAKING AFTER SCRIBING

Laser scribing is similar to diamond scribing in the sense that it also grooves the wafer surface. The only physical difference between diamond and laser scribing is that a laser produces a cone-shaped groove in the surface rather than a V-shaped one. Laser scribers are unsuitable on applications that require a vertical walled die. The advantages of laser scribers over diamond scribers are that they have a high throughput and they can cut non-square dies. Additionally, laser scribers do not have blades that wear out.

Scribing equipment suppliers have long been faced with the issue of yield losses due to non-square edges. Square edges are important. Non-square edges cause handling problems to occur, when attempting to accurately attach die. On scribed die, the edge location may vary by several mils. Dies that are non-rectangular or non-square may not be picked up by the collet during die attach. In situations where the collet is able to pick up a non square die, throughput is reduced, since the collet has difficulty in creating a vacuum seal with the die. See Figure 5.3.1.1-3. Section 5.3.2.4 discusses how problems such as these have caused a major shift from scribing equipment to sawing equipment.



Ref: Kulicke and Soffa
2252-49

Figure 5.3.1.1-3

DIE COLLET WITH SQUARE DIE

However, scribing equipment has been found to offer one advantage over sawing equipment. That is its finer cutting path. Street sizes can be kept under two mils. This is especially important for discrete devices, where typical die sizes are only 22 mils or less to a side. Also, discrete devices are usually die-attached by using solder reflow or epoxy. This eliminates the problems associated with a eutectic attaching system. As a result, there has been some reluctance to shift from scribers to saws by manufacturers of discrete devices. Also, the low price of diamond scribers has contributed to longer product lifetime. Diamond scribers are used in small production applications where if saws were used, many saw changes would be required. Laser scribers have no price advantage over saws.

As previously mentioned, saws had virtually wiped out the use of scribing equipment. But it did not die out altogether because scribing equipment has been able to find small niches. The increased use of Gallium Arsenide (GaAs) in the early-eighties was one contributor to the continued use of scribing equipment. This was due to two reasons that have offset the disadvantages of scribing equipment that were mentioned earlier. First, GaAs is a very difficult material to saw, since the material is inherently brittle and chips easily. Secondly, wafers made from GaAs have narrower streets in order to conserve material. This is due to the relative high cost of a GaAs wafer as compared to a silicon wafer.

However, improvements in dicing saw techniques continue, thereby, lessening a need for scribing equipment. As this shift continues to occur, the GaAs industry may see the same shift towards dicing saws that occurred with silicon. Therefore, although GaAs has given scribing equipment a boost, it could be short lived.

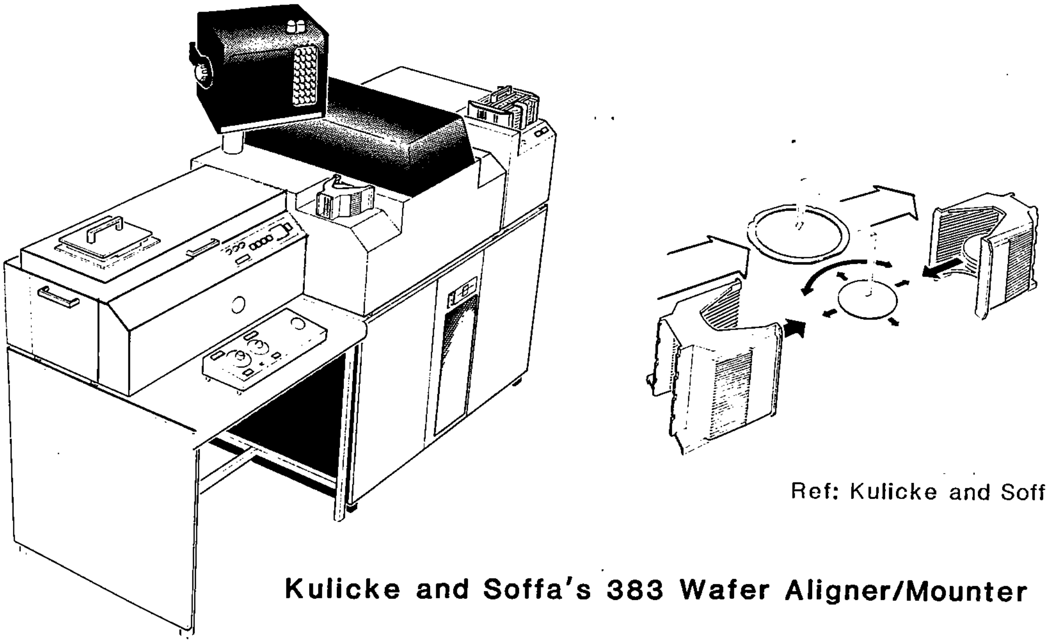
The market forecast for scribing equipment is shown in Section 5.3.9.1.

5.3.1.1.3 Development of the Dicing Accessories Industry

Wafer breaking equipment was the first dicing accessory to be developed. It is used to break wafers along the scribe fractures following scribing. Consequently, the dicing accessories market developed alongside the scribing equipment industry.

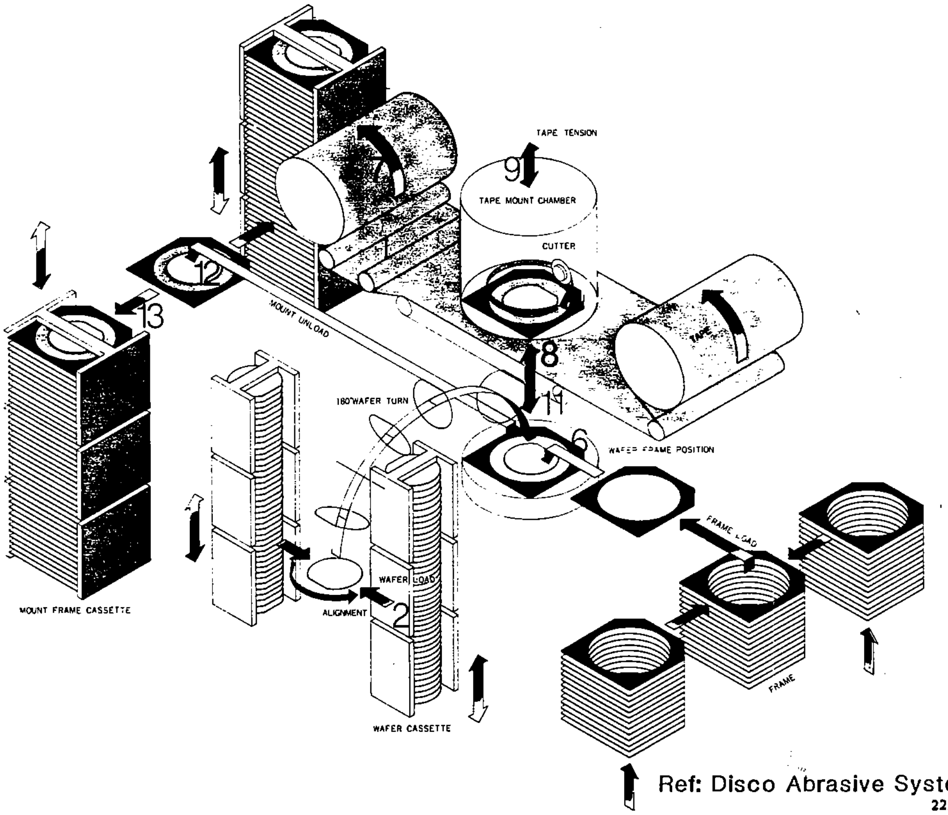
The dicing accessory market covers all equipment used in and around the dicing area that is indigenous to semiconductor manufacture. This includes: surface grinders, tape mounters (netto film), wafer mounters, and wafer breakers. Brief drawings of this equipment are shown in Figure 5.3.1.1-4.

After a wafer leaves wafer processing, it goes through a series of operations before it is diced. For example, a surface grinding operation is done to thin the wafer. This increases heat dissipation, removes 'getter' lattice structure defects, and aids sawing throughput and blade wear. Following surface grinding the wafer is moved along to an area where it is then mounted onto a netto film. However, before this can occur the netto film must be placed onto a metal frame. Usually these two operations are married in one piece of equipment. This is done to reduce particulate contamination of the netto film prior to mounting the wafer. Particulates reduce the adhesion qualities of the film, and cause dicing difficulties.



Ref: Kulicke and Soffa

Kulicke and Soffa's 383 Wafer Aligner/Mounter



Ref: Disco Abrasive Systems
2252-10

Disco Abrasive Systems' DFM-A150 Wafer Mounting System

Figure 5.3.1.1-4

DICING ACCESSORIES

Wafer mounting onto the netto film is the last operation which occurs before dicing of the wafer. However, after a wafer has been diced it may still need to go through a breaking operation. This will not be necessary if the wafer has been completely sawn through. However, if the wafer has only been partially sawn through or if it is scribed, it must be broken before the die can be removed from the wafer.

Wafer breaking equipment is almost as old as the diamond scriber market. It arose from a need to eliminate yield losses due to improper fracturing techniques. Improper fracturing can result in yields dropping to as low as 40%. This is substantial, considering that yields are typically above 99% when a wafer is sawn completely through.

In the past, wafer breaking equipment has been virtually a perfect complement to sawing equipment. However, this is changing somewhat due to the reduced need for breaking of partially sawn wafers.

The market history and forecast for dicing accessories is shown in Section 5.3.9.

5.3.1.2 Technology

The technology section will be included in future updates of Section 5.3. It will contain descriptions of the technologies used by sawing, scribing and dicing accessories equipment.