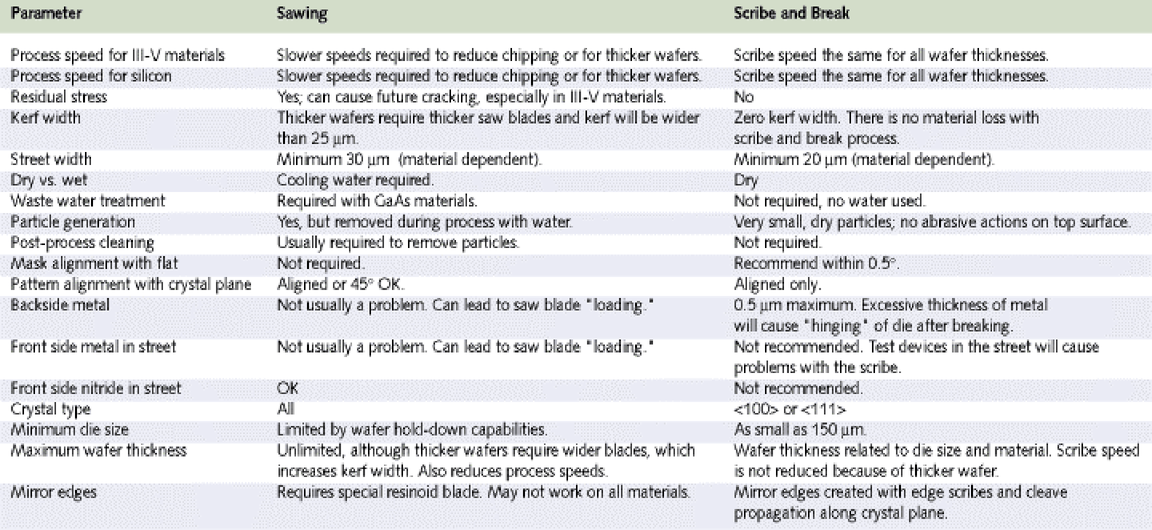
THE BACK-END PROCESS: STEP 11 - SCRIBE AND BREAK

BY MATTHEW S. ACKER

Die separation of thin silicon wafers and delicate III-V substrates creates challenges for traditional saw dicing. Sawing requires the introduction of high-pressure cooling water and lubricants to cool the blade and reduce friction. The cooling water can damage circuits and pollute sensitive devices. Sawing often leaves a residual film that requires washing of the wafers in a scrubber, which also creates more stress on the wafer surface. The abrasive action of the saw blade often leaves residual stresses in the sides of the die, which can later cause cracking during thermal stressing of the device.

Scribe and break die separation is an alternative to saw dicing. The features of scribe and break die separation are especially beneficial with thin silicon wafers; delicate III-V materials; hard materials, including sapphire, glass and ceramics; and ultra-clean devices (Table 1).



Parameter	Sawing	Scribe and Break
Process speed for III-V materials	Slower speeds required to reduce chipping or for thicker wafers.	Scribe speed the same for all wafer thicknesses.
Process speed for silicon	Slower speeds required to reduce chipping or for thicker wafers.	Scribe speed the same for all wafer thicknesses.
Residual stress	Yes; can cause future cracking, especially in III-V materials.	No
Kerf width	Thicker wafers require thicker saw blades and kerf will be wider than 25 µm.	Zero kerf width. There is no material loss with scribe and break process.
Street width	Minimum 30 µm (material dependent).	Minimum 20 µm (material dependent).
Dry vs. wet	Cooling water required.	Dry
Waste water treatment	Required with GaAs materials.	Not required, no water used.
Particle generation	Yes, but removed during process with water.	Very small, dry particles; no abrasive actions on top surface.
Post-process cleaning	Usually required to remove particles.	Not required.
Mask alignment with flat	Not required.	Recommend within 0.5°.
Pattern alignment with crystal plane	Aligned or 45° OK.	Aligned only.
Backside metal	Not usually a problem. Can lead to saw blade "loading."	0.5 µm maximum. Excessive thickness of metal will cause "hinging" of die after breaking.
Front side metal in street	Not usually a problem. Can lead to saw blade "loading."	Not recommended. Test devices in the street will cause problems with the scribe.
Front side nitride in street	OK	Not recommended.
Crystal type	All	<100> or <111>
Minimum die size	Limited by wafer hold-down capabilities.	As small as 150 µm.
Maximum wafer thickness	Unlimited, although thicker wafers require wider blades, which increases kerf width. Also reduces process speeds.	Wafer thickness related to die size and material. Scribe speed is not reduced because of thicker wafer.
Mirror edges	Requires special resinoid blade. May not work on all materials.	Mirror edges created with edge scribes and cleave propagation along crystal plane.

Table 1. Comparison of sawing with scribe and break for singulation.

Scribe and break separation of semiconductor wafers is accomplished by creating a stress in the wafer and then fracturing the wafer along the stress line. To break the wafer, a scribe line must be created in the wafer surface along the streets where the break is desired. This line creates a stress concentration factor, so the wafer breaks along it after applying force. A combination of the reduction in the cross-sectional area of the wafer and the sharpness of the bottom of the scribe line create the stress concentration factor. The sharpness of the bottom of the scribe has a much larger effect on the stress concentration factor than does the depth of the scribe.

Scribe methods that create the stress concentration factor do so mainly by a reduction in the cross-sectional area of the wafer. When scribing using a saw, the saw produces a stress concentration factor by reducing the cross section of the wafer. The reductions are typically 50 to 80 percent of the thickness of the wafer.

Laser scribes create a cross section reduction in two ways. The first is similar to the saw with a continuous cut along the street at a certain depth. The second method involves pulsing a series of holes through the wafer spaced an equal distance apart, which is the more typical method for ceramic wafers.

In chemical etching, the cross section of the wafer is reduced with a process in which there is a chemical reaction that removes material at the desired location.

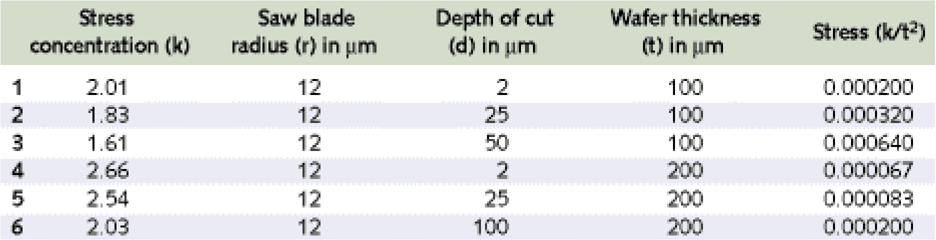
Diamond scribing produces a high stress concentration in the wafer because of the sharpness of the diamond. The depth of the cut is not as important as the sharpness of the cut. A typical diamond cut is 3 to 5 µm deep. Diamond scribing produces the narrowest kerf width of all wafer separation methods. The diamond scribe creates a "V" profile in the wafer surface, and the width of the scribe on the surface is less than 5 µm.

Stress Concentration Comparison

To compare the stress concentration of saw and diamond scribe, we assume each will use the same break method. Equation (1) defines the stress concentration factor (k) in terms of the saw blade radius (r), depth of cut (d), and wafer thickness (t). The standard "mechanics of materials" equation determines the stress concentration factor for a hyperbolic groove in a material surface. The "k" value is then used to determine the maximum bending stress at the surface due to an applied bending moment.

(1) $k = (0.355(t-d)/r) + 0.85)1/2 + 0.08$

This equation is used to calculate the maximum stress for two wafers (100 µm and 200 µm). Each wafer was sawed with a 25-µm wide saw blade with a full radius of 12 µm. Each wafer was saw scribed to various depths. With a diamond scribe, the depth of the scribe is small in comparison to the thickness of the wafer. A typical scribe is 2 to 3 µm deep and the wafer thickness is 100 µm or greater.



	Stress concentration (k)	Saw blade radius (r) in µm	Depth of cut (d) in µm	Wafer thickness (t) in µm	Stress (k/t^2)
1	2.01	12	2	100	0.000200
2	1.83	12	25	100	0.000320
3	1.61	12	50	100	0.000640
4	2.66	12	2	200	0.000067
5	2.54	12	25	200	0.000083
6	2.03	12	100	200	0.000200

Table 2. Stress concentration with a saw scribe.

Table 3 shows calculations of the stress of the two wafers using a diamond scribe. Each wafer was scribed with a new tool (radius of 0.05 µm) and a slightly used tool (radius of 0.10 µm).

	Stress concentration (k)	Diamond scribe radius (r) in μm	Depth of cut (d) in μm	Wafer thickness (t) in μm	Stress (k/t^2)
1	26.74	0.05	2	100	0.002670
2	18.94	0.10	2	100	0.001894
3	37.77	0.05	2	200	0.000943
4	26.74	0.10	2	200	0.000669

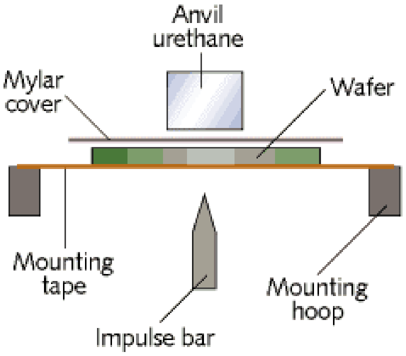
Table 3. Stress concentration with a diamond scribe.

Examination of Table 3 shows: 1.) a worn diamond tool produces considerably less stress than a new tool; and 2.) the stress in a 200 µm thick wafer is about one-third the stress in a 100 µm thick wafer. A comparison of Tables 2 and 3 shows: 1.) the 100 µm thick diamond scribed wafer has four times the stress of the same wafer saw cut to a depth of 50 percent; and 2.) saw scribes produce much lower stress concentration in the wafer than diamond scribes.

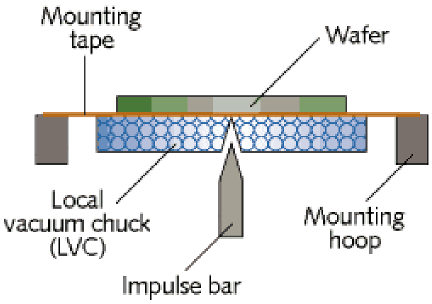
Breaking Methods

Static bending: Static bending is the break method used by most machines and by hand. A bending force is applied to the wafer at a level that will cause the wafer to crack along the scribe. It is typically how roller breakers work.

Impact breaking: This method breaks with an impact or shock to the wafer. There is no sustained loading on the surface of the wafer that can cause damage to the wafer, and the energy available for breaking can be much higher, allowing for thicker wafers to be processed.



Contact method with anvil



Non-contact method with LVC

Figure 1. (a) Anvil and (b) non-contact break methods.

Anvil Method: The anvil restricts the movement of the wafer in the vertical direction when the impulse bar contacts the bottom of the wafer (Figure 1a). The wafer is covered with a 50-µm thick piece of clear Mylar during the breaking process. The bottom surface of the anvil is urethane with a shore hardness of 80. The anvil is ground flat across its entire length. During the break process, the top of the Mylar is pushed against the anvil.

Non-contact Method: This method does not require an anvil; the wafer is held from the bottom with vacuum (Figure 1b). The vacuum is applied through the local vacuum chuck to the bottom of the mounting tape before each break. After the break, the vacuum is released and the wafer is indexed for the next break. There is no contact with the top surface of the wafer.

In general, the non-contact method is used for wafers where the anvil may damage the top surface of the wafer. Wafers that benefit from a non-contact approach include MEMS devices, air bridge devices and biotech wafers **AP**

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Advanced Packaging November, 2001