Alternatives for die separation in Semiconductor Back-end Process

Whilst most semiconductor slices are sawn using diamond impregnated wheels, as described in Sawing, other techniques have been used in the past, and are still occasionally encountered.

Back etching

Bell Laboratories revived one of the oldest chip separation techniques when it pioneered beam leads. These were singulated by etching from the back of the wafer, giving a bevel to the die edges, the 54º angle of the cut being caused by the crystal structure of the silicon.

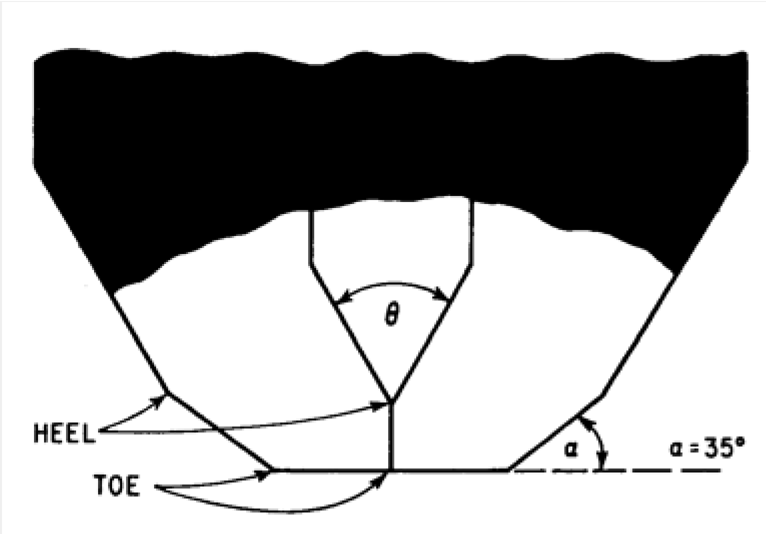
Back etching is expensive in silicon, and requires an extra masking step but has continued to be used for non-planar devices such as high voltage rectifiers. Etching allows the die to be circular if desired, and to have a minimum of discontinuities in the area where the junction meets the die surface.

A typical implementation of this process is to spray a wax resist through a metal mask onto the wafer. Etching then strips away the silicon in the exposed areas, and the wax is finally cleaned from the dice.

Scribe and breakout

As silicon is hard and brittle, and planar devices are generally diffused on relatively thin wafers, a popular and relatively lost-cost separation process much favoured up to the late 1970s was scribing with a diamond point, followed by breaking the wafer by stressing it. This second part of the process can be carried out using a hand roller, or by passing the wafer around a radius in a refined, miniature version of an old-fashioned mangle! In both cases, the scribed wafer is protected by thin sheets of plastic before breaking.

Figure 1: Diagram of facets on a scriber diamond



The business end of a scribe tool is a truncated pyramid (Figure 1). Polcari found that scribing with the relatively blunt heel rather than the toe produced less fragmentation and substrate damage for a given set of conditions, and the settings of tool force and other variables were less critical. He discovered other important factors determining yield:

- **Wafer orientation**. When scribing at right angles to the orientation flat on the wafer, it makes little difference whether the tool moves towards or away from the flat; when scribing parallel to the flat along the <110> planes the direction is critical.
- The scribe should move across the wafer so that it first intersects the bases and then the apexes of the triangles formed by the intersecting <111> lattice planes. Movement along the direction pointed by these triangles results in cleaner,

less fragmented die edges and less debris at separation, regardless of any other equipment settings.

- **Scribing speed** . High speeds lead to tool bounce and die damage near the periphery of the wafer.
- **Tool angle** . All other parameters being equal, there is an optimum angle between the shank of the scribe tool and a line normal to the surface of the wafer. Polcari recommended setting this at 36–38º, and found that a less vertical setting led to fragmentation and wafer damage.
- **Tool force** . Too high a force damages the wafer, and settings of 6.5–10 gm produced optimal results.
- **Tool geometry** . Polcari found that the smaller the angle q (Figure 1), the less force is dissipated laterally along the scribe line and that, as q drops from 60º to 33º, greater numbers of good scribe lines occurred over a wider range of tool forces and scribing angles.

Polcari criticised ‘a lack of care and poor knowledge of critical scribing parameters. Production engineers scribe wafers almost as if they were scratching window glass prior to breaking it, paying little attention to the silicon crystal structure’. Whilst careful use of diamond scribing could indeed give 98–100% yield, manufacturers more frequently experienced yields between 70% and 90%, a situation which became worse with large dice and thin wafers. By the late 1960s, alternatives were therefore being sought.

Laser scribing

The first of these alternative methods was laser scribing, typically using a Q-switched neodymium-doped YAG laser with overlapping pulses, and conventional break-out using rollers. Throughput was increased, because a diamond cut is unidirectional and must be indexed between scribes, whereas a laser can cut adjacent lines in opposite directions. A second advantage of laser scribing was that, unlike a diamond, the beam will cut through oxides and metal on the wafer.

However, the 25–50µm depth of scribe was insufficient for thick wafers, the kerf was wider than the typical diamond cut, silicon was re-deposited over adjacent areas, and scribe depth and width were difficult to control. Even more significantly, laser scribing was a two-step operation, and break-out is always a cause of losses: breaks do not always occur along the scribe lines, leaving dice with chip-outs or excess 'spurs' of silicon. Neither is cleavage vertical, because of the crystal structure of the silicon, and the resulting singulated dice are almost incompatible with die bonder automatic handling, where smooth vertical edges are preferred.

Slurry sawing

The slurry saw approach to wafer dicing was also developed in the late 1960s, by IBM and Taft-Peirce. The wafer is mounted on a thermoplastic holder with a wax such as glycol phthalate, placed in a transfer fixture, aligned with a kerf line pattern using an optical comparator, and moved to the saw. The transfer fixture is pin-aligned and clamped to an indexing table which is then moved toward a spindle holding as many as 20 cutter blades. These are accurately spaced on the same pitch as the dice on the wafer, and never actually touch the wafer.

Sawing begins when a slurry, usually of silicon carbide, is fed through a nozzle to the blades. With a diameter of 100mm, and rotating at 9,000rpm, the blades hurl slurry at the kerf areas, cutting completely through wafer and wax, and leaving a kerf about 120µm wide. The transfer fixture is then indexed by 90º for the second set of cuts at 90º to the first, and after cutting the remaining wax is dissolved with acetone and the chips cleaned.

It was this approach which developed into the saw systems which are currently used in mainsteam manufacture, but with significant modifications:

- Using a **diamond-coated blade** rather than stainless steel and slurry, an adaptation by Cogar which yielded a narrower kerf, was faster, and produced far less chipping at the kerf edge.
- Using a **single saw**. Although the gang sawing principle is still to be found in machining silicon and ceramic, it is hard to set up, less flexible and needs heavy investment in diamond saw blades.
- Using **on-machine alignment** with a vision system on the saw, to eliminate the inaccuracies of transfer jigging.

Source : http://www.ami.ac.uk/courses/topics/0257_ads/index.html