Rapid Routes to Planar Polishing

The planarising technique of materials lapping and polishing is essential for providing microscopy samples for failure analysis, materials research, quality control and related fields. New polishing methods provide both rapid and accurate micro-sections of wafers, packaged components and other processed materials, with the use of a calibrated polishing base and a positioning device.

Planar polishing involves the preparation of a relatively large surface on a relatively short workpiece, typically back-end semiconductor wafers or dies which have been through etching, metallisation and other related processes.

In traditional lapping and polishing processes, planarity is maintained by using a conditioning ring arrangement on a machine that incorporates a suitable controlled reciprocating roller-bar mechanism and conditioning rings (fig 2). A precision polishing jig (fig 3), which incorporates a conditioning ring, offers the ultimate accuracy in flatness, parallelism and control. However, by its nature, the preparation process is slow. This method of sample holding is widely used in large scale semiconductor production, where chemical mechanical polishing (CMP) techniques, using colloidal silica and alumina suspensions, rely on the high planarity of the plate surface in relation to the silicon (or gallium arsenide) wafer and its carrying jig. Systems used to process modern wafers, which can be 8 inches or, more frequently, 12 inches in diameter, can cost more than 20 times as much as a typical failure analysis planar polisher workstation.
Under certain circumstances, small errors in absolute flatness (eg 3 µ m cm⁻¹) are tolerable in exchange for substantially faster results. The development by ULTRA TEC Manufacturing Inc of a planar positioner in which the workpiece is held against the lapping surface so that only the workpiece itself makes contact, has provided such a means of rapid and reproducible material removal.

Compared to the precision polishing jig, which holds the workpiece and ‘rides’ the lap in a co-dependent unitised system, the planar positioner (fig 4) is independently located next to the rotating lap. This produces a degree of freedom, and the source of the flatness error, which must be maintained at a small tolerable level with accurate equipment.

A system to perform fast planar polishing requires a base with a ‘true-running’ mechanical rotational lapping surface, and a firm planar positioning device, which includes:

- an accurate vertical direction linear positioning feature,
• controllable pressure of the workpiece relative to the lapping surface,
• accurate alignment for parallelism in relation to the lapping surface, as it holds and rotates the workpiece,
• the facility for the workpiece to move downward, as material is being removed, through a small section of a relatively large arc as the final desired flat condition is approached.

In the fast-result system, the lapping surface is held accurately in relation to the planar positioner by means of a shared reference surface. The reference surface is a flat plate that is parallel to the surface of the lap, and holds the Micropositioner stands together with the various electrical controls.

Since the planar positioner holds the workpiece parallel to the lapping surface, any rotational runout of that lapping surface (up and down dimensional variation when measuring the rotating surface) will reflect as an error on the workpiece. Maintaining that runout at a minimum is therefore important.

Using a 20 cm diameter lapping disc, it is reasonable that the runout can be held between 1 and 2 µm cm⁻¹, an amount that is usually tolerable on most specimens. Better runout is possible and may become necessary for large specimens for which fast-results are required. To obtain such improvement, special attention is needed in setting up the machine, one major technique being rotation of the polishing plate on its platen so that the errors of those elements are offset and cancel out.

The Planar Polishing system requires a workpiece positioning device in relation to an independent lapping surface. Apart from the required firmness of the positioner, a vertical direction control, provision for controlling polishing pressure and the accuracy of the rotating element are all important.

Like the opposing lapping disc, the rotating element of the positioner must rotate with minimum runout, and as in the case of the lapping disc, that accuracy is a matter of equipment construction. The construction of the workholder rotating element would have a runout of 1-2 µm cm⁻¹ (similar to the rotating lapping disc). The runout errors are not strictly additive. The rotation of the lapping disc and the rotation of the workholder are randomised in relation to each other - the workholder both oscillates over the lapping surface and rotates in out-of-phase speeds. For example, the workpiece may rotate at 10 rpm and the lapping disc at several hundred. Ideally, both speeds would be variable, which would be useful in optimising the results.

The positioner includes an adjustment for the parallelism of the workholder relative to the lapping surface. This adjustment allows for the ‘zeroing-out’ of tolerance errors introduced by a workholding plate, and other random errors. It is important that for rapid processing, only the workpiece itself is in contact with the lapping surface. The most significant contributor to speed, however, is that the final flat condition is reached by the lowering workpiece moving through an arc as it is rotated. This is most quickly performed if the workpiece is rotated relative to the blade.

A 360° rotation makes the operation fastest. As the blade passes though a workpiece, if the latter is rotating, contact occurs only a point of tangency. By contrast, if the workpiece is not rotating relative to the blade, a very long surface of contact between the blade and the workpiece develops and the blade needs to work very hard (compounded by the mechanical properties of the sample), and can stall. With rotation, the blade does not need to overcome the resistance of the workpiece and the task becomes easy.

In grinding/polishing material from a disc, if the workpiece is rotating and lowering through an arc, a similar situation arises: the contact between the workpiece and the lapping surface corresponds to a line. Thus a very small section of the workpiece is
in contact with the lapping surface and the operation can proceed quickly. Due to the relative rotational motions of the lap and the planar polisher, the work interface moves through a cone shape, which continually flattens until the desired preset removal of material is complete.

The nature of the planarity error in this type of fast-result system is different from that of the traditional on-the-lap method. Any error in absolute planarity will be conical, with higher measurements in the centre of the rotation and progressively lower toward the circumference of the workpiece.

The planar polisher has three additional characteristics:

- There is a stop mechanism which signals completion and halts the polishing action.

  The mounting plate which holds the workpiece can be removed and remounted so that a following workpiece can easily be mounted while the positioner is still working on a prior workpiece. This feature also allows the operator to remove the workpiece on its mounting plate for microscopic examination, and then remount it if further material removal is required. This is a benefit in failure analysis applications where several polishing iterations may be required to remove several coating or metallisation layers one at a time, or to view possible sources of microelectronic component failure at different depths.

- The planar polisher is readily replaced by workholders to allow edge polishing of similar components for optical or electron microscopy.

The ‘fast-result’ planar polishing system is advantageous when there is a need for quick results, eg in quality control operations, or when the virtual ‘no-error’ accuracy that the Precision Polishing Jig provides is not required. So it represents an acceptable compromise in the interest of practicality for the busy modern laboratory. The equipment cost is also significantly lower.

Until a particular process is well defined, there is a need for the operator to do some experimentation with different sizes and different types of material, primarily with speeds and pressures, and with the lapping surface itself, to obtain optimum results. Typically, lapping films coated with diamond or oxide/carbide fixed abrasives provide the most convenient and accurate surfaces.

The high planarity of the finish produced by planar polishing allows the researcher or failure analysis engineer to view known-depth areas of circuitry (fig 5). Such iterations of a typical polishing process taking place down to the Metal 1, Metal 2 and polysilicon levels of the die. This information allows decisions to be made on process validation and improvement, as well as standard quality assurance tests to be carried out for batch to batch variation.
In terms of the accuracy in planarity that the process provides, there are other random errors in addition to the sources discussed above. Empirical results confirm typical total errors of less than 7 µm across workpieces approximately 1.5cm square, and statistically 95% of results < 10 µm. This gives sufficient accuracy for the surface preparation of microchips, by back or front thinning, and other large diameter components, to accurately and reproducibly reveal details of structural and process integrity.

Further reading


Figure 1 Typical planar polished semiconductor structure under an optical microscope (x250)

Figure 2 Maintaining plate flatness in traditional lapping and polishing operations

Figure 3 A precision polishing jig for the control of sample flatness, loading and parallelism in planarising processes

Figure 4 A planar polishing system, the Ultrapol 1200, showing the calibrated polishing base, micropositioned polishing head and planar polishing attachment
Figure 5 Typical planarised surface of semiconductor structure (x1500). The breadth of the lightbands seen on the surface is indicative of the overall planarity of the lapping and polishing process.