

Angled Top-down Grind Method for Improved Via Filling Analysis

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Via filling analysis methods are mostly based on obtaining vertical cross-section images of the via. While these pictures provide a clear and easy way of visualizing the filling profile, sample preparation is generally tedious and can often lead to unexposed voids, unless the cross-section is taken straight through the centerline. A less intuitive — but more effective — method is to perform a horizontal cross-section, but its implementation usually requires even more elaborate hardware to control the grinding depth. This article illustrates a novel method where the sample is prepared with a grind set at an arbitrary angle that, in turn, exposes multiple vias with horizontal cross-sections at different depths. Not only does this method allow a 3-D reconstruction of the via, it also provides more statistical information of the filling performance over a greater area. With this additional information, one can then separate systematic effects, such as a bad process recipe, from other random effects, such as incomplete wetting or surface contamination.

Cross-sectioning vias

The current norm for via-fill analysis is to obtain a vertical cross-section, either by using grinding/lapping techniques

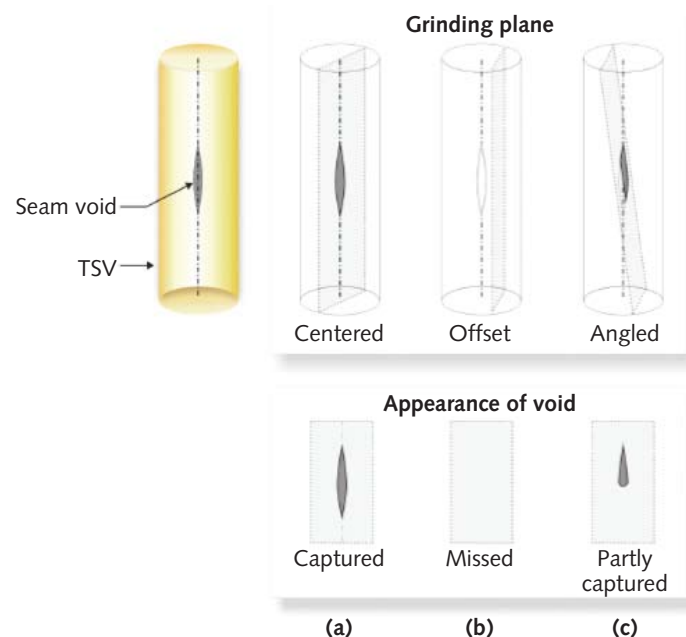


Figure 1: In order to detect some of the voids, a very accurate cross-section needs to be obtained. This example illustrates a seam void in the center of the via. Only the cross-section in (a) will expose the void properly.

or focused ion beam (FIB). While the result is easy to interpret, the sample preparation can be tedious and expensive and, unless multiple cross-sections are done, some voids may remain hidden. This is especially the case for TSVs, as the most typical void pattern is a thin center seam running vertically along the length of the via, shown in Figure 1. In this case, it requires a very accurate cut right through the center of the via, as illustrated in Figure 1(a). The cross-section plane in (b) will completely miss the void, while (c) may only expose a small portion of the void, which could be too small to notice during inspection. One alternative is to perform multiple cross-sections horizontally. This is generally equally tedious, as one has to alternate between the sample preparation and inspection. In addition, using normal grinding methods, knowing exactly how much material is removed during each grinding step requires a very elaborate setup. The angled top-down (ATD) method described here addresses these issues: it attempts to obtain multiple horizontal cross-sections after performing a single grind step. The key requirements are that multiple vias are lined up in a line spanning some distance, and the via depth is known.

ATD Grind

Rather than doing a true parallel horizontal cut, the ATD method purposely cuts the top surface at an arbitrary shallow angle as shown in Figure 2.

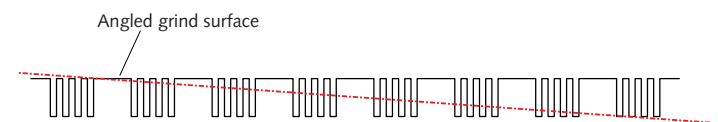


Figure 2: ATD grind plane cuts a row of vias at an angle, exposing vias at multiple depths.

This, in effect, exposes multiple vias along the cut surface, where each via is progressively exposed at a deeper depth. As long as the angle is shallow enough, the cross-section will be near horizontal and, thus, approximate a true cut that is parallel to the surface. Since the last exposed via visible represents the cross-section at the furthest bottom, the lateral material removed would correspond to the depth of the via at this location. With this information, the depth of any intermediate via can be interpolated by measuring the horizontal spacing of the vias. This allows one to determine the depth of each exposed via without measuring the actual vertical distance, as illustrated in Figure 3.

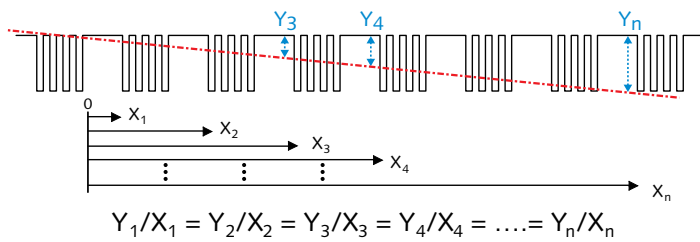


Figure 3: The depth of a particular via can be determined by measuring its spacing distances rather than the actual via depth.

The advantages of this method are as follows:

- The sample preparation is easy and straightforward without the need for elaborate hardware setup.
- One single cut exposes multiple vias. Furthermore, if the vias are arranged in a matrix, then this increases the sample size even further, allowing one to collect statistical information from these vias. This information may help determine whether the process is influenced by some random effects (such as incomplete wetting), or suffering from some systematic problem (such as a poor process).
- Since the depth of an exposed via can be calculated, multiple cross-sections can be used to reconstruct a 3D representation of the via.
- A larger area of the wafer can be inspected with each prepared sample, rather than just a few individual vias.

Examples of the ATD grind method

Figure 4 shows a via matrix of varying sizes (3µm, 5µm, 10µm and 15µm squares) after the ATD grind. As the grind surface cuts from the top to bottom, one can see the background change from copper to the oxide layer into the silicon. For this particular recipe, the 3µm and 5µm vias

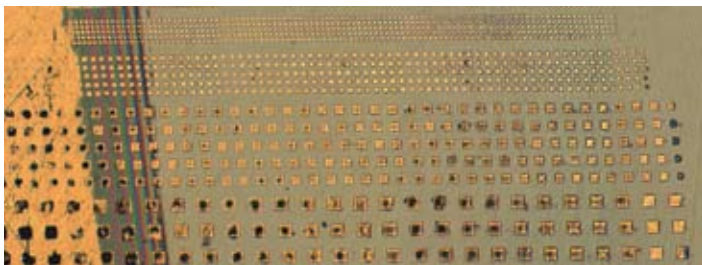


Figure 4: Picture of sample after ATD. The left side corresponds to the wafer surface with the Cu still intact. The right side corresponds to the via bottom. (Wafer courtesy of SEMATECH.)

were fully filled, whereas the largest via size (15µm) is still mostly empty, with only some Cu covering the sidewalls. Figure 5 shows an area of the ATD where most vias are fully filled, but some vias exhibit voids in the center. This may indicate that a particular process may not have a wide enough process window, or some localized contaminant is affecting the fill performance of those particular vias. Figure 6 shows how several ATD cross-sections can be used to reconstruct the void pattern of a particular via that failed to plate properly.

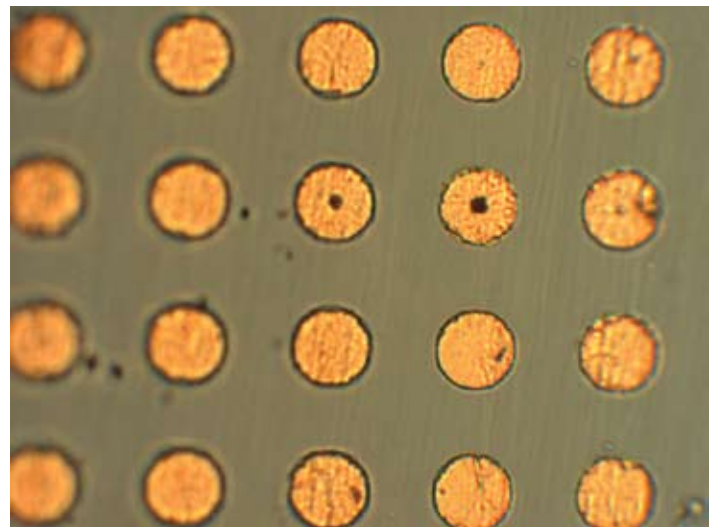


Figure 5: Sample showing random voids.

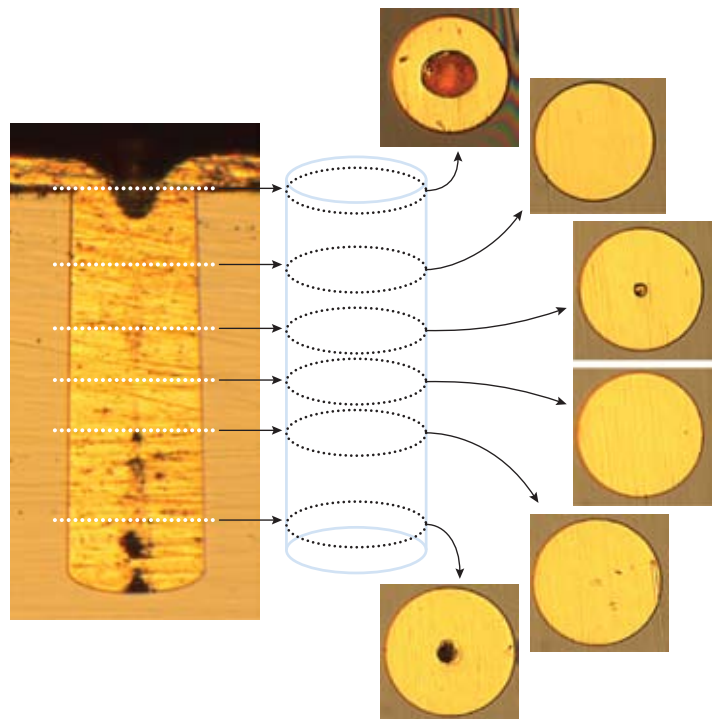


Figure 6: Using ATD cross-sections to re-construct void pattern of the via. A typical vertical cross-section is shown on the left for comparison purposes.

Summary

The ATD grind method represents an easy and economical way of sample preparation for the purpose of analyzing TSV fill performance. This method can be performed by anyone who is already set up in preparing standard vertical cross-sections. The resulting information obtained from this method provides more data than a typical cross-section, be it for reliability inspection or for studying the fill behavior of a particular process.

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