

SEMI 3D22-1219

GUIDE ON MEASUREMENTS OF OPENINGS AND VIAS IN GLASS

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1 Purpose

1.1 Through glass vias is an emerging technology in the semiconductor industry. Definitions for openings in glass have been described in SEMI 3D11, and a specification for glass as substrate for semiconductor applications with or without openings has been laid out in SEMI 3D16. However, there are few or no agreed upon test methods for measuring the physical and dimensional properties of through glass vias or other openings in glass or the pattern or structures. This Guide will discuss existing test methods for openings and propose new methods.

2 Scope

2.1 This Guide is for glass substrates with openings that will be used in semiconductor packaging and will cover all common types of openings in glass, including through glass vias (TGV), blind vias in glass, and other openings.

2.2 This Guide covers glass substrates that are intended for permanent bonding applications.

2.3 This Guide will also cover alignment of vias.

2.4 This Guide describes the process by which TGV (through-glass vias) geometric measurements are taken, using automated optical inspection (AOI) tools.

NOTICE: SEMI Standards and Safety Guidelines do not purport to address all safety issues associated with their use. It is the responsibility of the users of the Documents to establish appropriate safety and health practices, and determine the applicability of regulatory or other limitations prior to use.

3 Limitations

3.1 This Guide will not cover metrology for filled vias or other openings.

3.2 This Guide does not provide information on processing or handling of the glass base material, substrate or finished product.

3.3 Manufacturing of the base material or any openings are not subject of this Guide.

4 Referenced Standards and Documents

4.1 SEMI Standards and Safety Guidelines

SEMI 3D2 — Specification of Glass Carrier Wafers

SEMI 3D11 — Terminology for Through Glass Via and Blind Via in Glass Geometrical Metrology

SEMI 3D12 — Guide on Measuring Flatness and Shape of Low Stiffness Substrates

SEMI 3D16 — Specification for Glass Base Material for Semiconductor Packaging

NOTICE: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 Abbreviations and Acronyms

5.1.1 *AOI* — automated optical inspection tool

5.1.2 *BV* — blind via

5.1.3 *CD* — critical dimension

5.1.4 *CTE* — coefficient of thermal expansion

5.1.5 *MCS* — machine coordinate system

5.1.6 *PCS* — part coordinate system

5.1.7 *TGV* — through glass via

5.1.8 *TTV* — total thickness variation

5.2 Definitions

NOTE 1: Further definitions may be found in SEMI 3D11.

5.2.1 *alignments* — alignment of two coordinates systems.

5.2.2 *A-side* — the side facing up the glass substrate when the TGV or openings are formed.

5.2.3 *B-side* — the side opposite to the A-side.

5.2.4 *center X position* — the position based on the mid-point between the maximum dimension in the *X* plane.

5.2.5 *center Y position* — the position based on the mid-point between the maximum dimension in the *Y* plane.

5.2.6 *diameter* — the diameter of the fit circle of the TGV opening in any particular horizontal plane.

5.2.6.1 *Discussion* — There is no requirement that this diameter pass through any geometrical center or centroid of the TGV opening. Sometimes, two diameters need to be determined, the major diameter with the longest chord and the minor diameter with the shortest chord.

5.2.7 *machine coordinate system* — the coordinate system of the measurement tool.

5.2.8 *part coordinate system* — the coordinate system of the to be measured component or part.

5.2.8.1 *part* — the glass substrate with TGVs to be measured.

5.2.9 *roundness* — roundness is parameter indicating how far a shape deviates from a perfect circle, which has a roundness of zero.

5.2.10 *waist* — the smallest circumference of an hour-glass or irregular shaped object that is neither the bottom nor the top opening.

6 Measurements of Through Glass Vias

6.1 Environmental Considerations

6.1.1 All geometric TGV measurements will need to take place in a cleanroom with regulated temperature and humidity. The average ambient temperature should be recorded with the measurement. The temperature should be controlled to $\pm 0.5^{\circ}\text{C}$, otherwise a change in dimensions is to be expected depending on size, thickness, and CTE of the glass substrate.

6.1.2 An average relative humidity between 35% and 65% should be maintained.

6.2 Measurement Aspects

6.2.1 There are three aspects of a TGV of which the quantities center *X* position, center *Y* position, diameter, and roundness are measured. They are A-side, B-side, and waist. A TGV wafer or panel has two sides. From one side, the serial number can be read forwards. This side is the side facing up as the TGV's are formed and is referred to as the A-side. The other side, from which the serial number can be read backwards, is the B-side. Intuitively, A-side measurements are taken with the microscope facing and focused on the A-side. B-side measurements are taken with the microscope facing and focused on the B-side.

6.3 Measurement of Center Point, Diameter, and Roundness

6.3.1 There are different ways for measuring center point, diameter, and roundness, depending on the used tool.

6.3.2 Each AOI tool takes measurements by processing microscope images. Regardless of the tool, this processing begins by fitting a circle to the image of a TGV. The exact algorithm by which a circle is fit to a TGV varies from tool to tool. For instance, one tool may use canny edge detection to find many edge points around the TGV and compute a least-squares fit circle to them. Another tool may compute a circle from eight feret diameters taken at different angles.

6.3.3 Example Diameter

6.3.3.1 When combined with information about where the microscope was located in space (stage X and Y coordinates), the center of the fit circle determines the reported center X and center Y position of the TGV.

6.3.3.2 The diameter of the fit circle is reported as the diameter of the TGV.

6.3.4 Example Roundness 1

6.3.4.1 Roundness may be defined as the difference between the maximum and minimum radii (distances from the center point to edge points); see Figure 1, where the roundness equals $R_2 - R_1$. A perfect circle's radii are all equal, thus the roundness would be zero. As another example, a unit square's maximum radius is $\sqrt{2}/2$ and its minimum radius is $1/2$. Its roundness is the difference, approximately 0.2071.

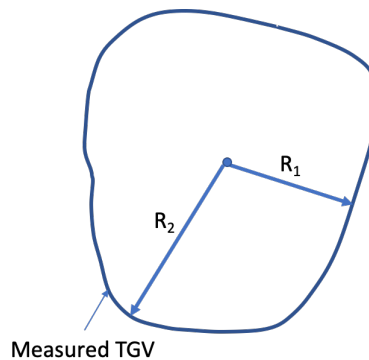


Figure 1
Roundness, as Measured from the Center of the Feature

6.3.5 Example Roundness 2

6.3.5.1 An alternate definition of roundness is that it is the difference between the radius of the minimum circumscribed circle and the radius of the maximum inscribed circle. In this case the center of one circle doesn't always correspond with the one of the other. See Figure 2, where the roundness equals $R_2 - R_1$. For a perfect circle, these circles are identical, thus the roundness would be zero.

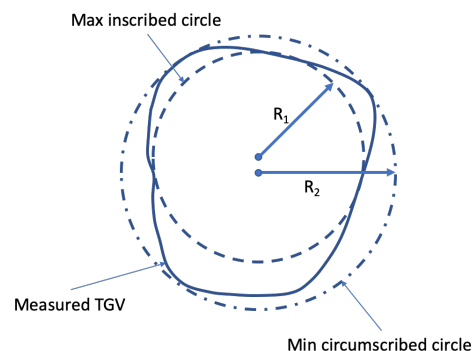


Figure 2
Roundness, as the Difference Between the Radii of Inscribed and Circumscribed Circles

6.4 Measurement of Vias With Tapered Shape

6.4.1 The taper can be measured by comparing the A-side opening to the B-side opening.

6.4.2 Or, if there is a straight tapered shape as shown Figure 3, the taper angle θ can be calculated using

$$\theta = \tan^{-1} \frac{D_A - D_B}{2t} \quad (1)$$

with D_A , D_B and t being the measured diameters of the A-side and B-side and thickness of the substrate.

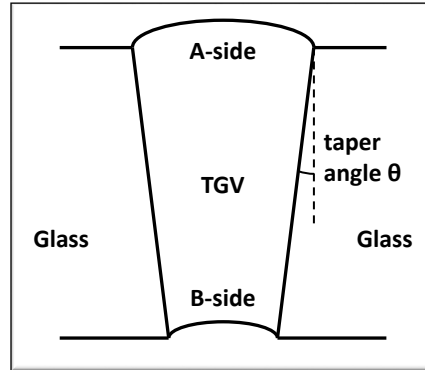


Figure 3
Cross-Section of a TGV with Tapered Shape

6.5 Measurement of Via Waists

6.5.1 For waist measurements, the TGV is illuminated from the side opposite of the wafer or panel to the microscope. Focus is set to the approximate center of the wafer or panel's thickness. The intent is to measure the narrowest cross-section of the TGV which is referred to as its waist (see Figure 4).

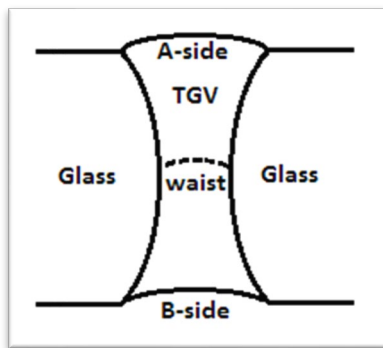


Figure 4
Cross-Section of a TGV with Waist

6.6 Measurement of Alignments

6.6.1 There is more than one way to measure alignment, depending on the tools being used. Mostly, one TGV is used as a fiducial, and a second TGV is used; however, the second fiducial may introduce some positional error on its own. Choosing more TGVs with equal y-coordinates may help minimize positional errors.

6.6.2 *Example 1* — When a TGV's center X and Y positions are measured, the coordinate system on which the measurement is taken is the machine coordinate system (MCS). For example, if the AOI tool has a large, rectangular staging area, one corner may be the position of the origin: (0, 0). The corners at opposite ends of that corner's edges would then be the X and Y extrema (XMAX, 0) and (0, YMAX), respectively. A TGV panel (or wafer) also has its own coordinate system called a part coordinate system (PCS). This coordinate system can be defined in numerous ways. Some of the most pertinent methods will be described later in this Document. As a simple example, the center

of the part could define the origin and the X -axis could be defined as being parallel to the longest edge. The process of translating and rotating position data taken on an MCS to a PCS is called alignment.

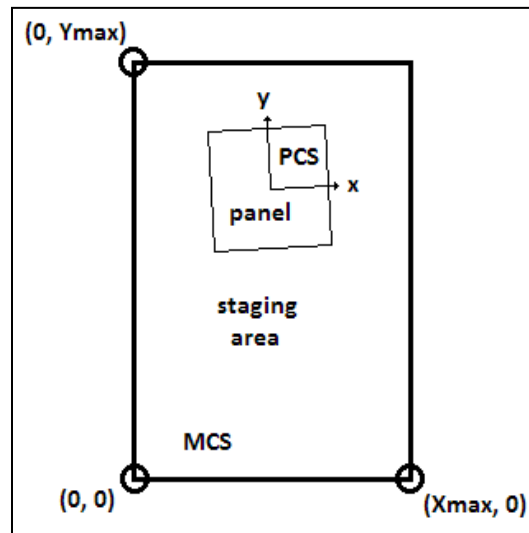


Figure 5
Depiction of a Panel Placed on the Staging Area of an AOI Tool

6.6.2.1 In Figure 5, two coordinate systems are illustrated: one based on the staging area (MCS) and one on the panel (PCS).

NOTE 2: Any given point can be expressed in each coordinate system.

6.6.3 Example 1: 2-Point Alignment

6.6.3.1 The 2-Point Alignment procedure requires alignment to two fiducials in order to realign coordinates on the MCS to the PCS. The primary fiducial is typically established in the bottom left corner of a panel (rectangular part) pattern or left center of a wafer (circular part) pattern. To do so, the MCS coordinates shift so that the bottom left measured coordinate is in the same exact location as the bottom left pattern coordinate in the nominal TGV positions. With the pattern coordinate and measured coordinate overlapping, the origin is established. The primary fiducial determines translation of the measured coordinate plane.

6.6.3.2 A second fiducial must be established to determine measured coordinate plane rotation. This fiducial is typically selected from TGV's in the bottom right corner of a panel pattern or right center of a wafer pattern. The MCS coordinates are rotated until the angle between the primary and secondary fiducials' coordinates are equal to the angle between them in the nominal pattern. The rotation is then established. Now that the coordinates have been realigned from the MCS to the PCS, the nominal coordinate pair for each TGV can be subtracted from its measured, aligned coordinate pair to obtain the TGV displacements.

6.6.3.3 If a pattern is received with two easily-identifiable reticle patterns located roughly near the left and right edges of a pattern, it is assumed the alignment procedure will use A TGV in each of them as the primary and secondary fiducial, respectively, rather than using the fiducial selection process described above.

6.6.4 Example 2: Least Squares Alignment

6.6.4.1 The alignment least sensitive to the minor positional deviations of any one TGV is the least-squares alignment. It takes into account the position of each TGV to establish a coordinate system. This section describes the alignment routine from a theoretical perspective and then provides a more concrete example.

6.6.4.2 A method of least-squares aligning an existing set of measured X , Y TGV coordinates to their nominal coordinates is by using the Kabsch algorithm. The sets of nominal and measured coordinates are arranged into 2 N-