

SEMI MF657-0707^E (Withdrawn 0914)

TEST METHOD FOR MEASURING WARP AND TOTAL THICKNESS VARIATION ON SILICON WAFERS BY NONCONTACT SCANNING

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NOTICE: This Document was balloted and approved for withdrawal in 2014.

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1 Purpose

- 1.1 Warp and thickness variation of silicon wafers can significantly affect the yield of semiconductor device processing.
- 1.2 Knowledge of these characteristics can help the supplier and customer determine if the dimensional characteristics of a particular wafer satisfy given geometrical requirements.
- 1.3 Changes in wafer warp during processing can adversely affect subsequent handling and processing steps
- 1.4 This Test Method is suitable for measuring the warp and TTV of silicon wafers used in semiconductor device processing in the as-sliced, lapped, or polished condition and for monitoring thermal and mechanical effects on the warp of silicon wafers during device processing.

2 Scope

- 2.1 This Test Method covers a noncontacting, nondestructive procedure to determine the warp and total thickness variation (TTV) of clean, dry silicon wafers in a free (unclamped) condition. The procedure uses a three-point back surface reference plane for determining warp.
- 2.2 This Test Method is applicable to circular silicon wafers from 50 mm (or 2.0 in.) to 200 mm in diameter, and 100 µm (or 0.004 in. approximately) and larger in thickness, independent of thickness variation and surface finish. The test method is applicable to wafers of semiconductors other than silicon with these same physical characteristics.
- 2.3 This Test Method is not intended to measure surface flatness; warp, which is not to be confused with flatness, is a bulk property of the wafer. Warp may be caused by unequal stresses on the two exposed surfaces of the wafer. It cannot be determined from measurements on a single exposed surface. The median surface may contain regions with upward or downward curvature or both; under some conditions the median surface may be flat.
- 2.4 This Test Method measures warp and TTV of a wafer with no mechanical force except gravity applied during the test. Therefore, the procedure described gives the unconstrained value of warp or TTV. Gravity-induced deflection alters the shape of the wafer and is included in the measurement.
- 2.5 For application to wafers of diameter 3 in. or smaller, the values stated in inch-pound units are to be regarded as the standard whether or not they appear in parentheses; the values stated in acceptable metric units are for information only. For application to wafers of diameter larger than 3 in., the values stated in acceptable metric units are to be regarded as the standard; the values stated in inch-pound units are for information only.

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 In this Test Method, both TTV and warp are determined using a specified partial scan pattern; thus, the entire surface is not sampled and use of another scan pattern may not yield the same result.
- 3.2 Most equipment systems capable of this measurement have a definite range of wafer thickness combined with warp which can be accommodated without readjustment. Any values observed while in an over-range condition are invalid.
- 3.3 This Test Method does not completely separate thickness variation from warp. In some cases, the median surface may be flat but still show a non-zero value for warp.
- 3.4 Running probes off the test specimen during the scan sequence gives false readings.
- 3.5 Any change in the reference plane during scanning produces error in the indicated measurement equal to the axial vector value of the deviation at the probe axes at the points of largest and smallest differences. If such changes occur, there is the possibility that an incorrect location may be identified as an extremum.
- 3.6 Non-parallelism of the reference plane to the granite base surface produces an error in the indicated measurement proportional to the non-parallelism.
- 3.7 Foreign particles (dirt) between the measuring ring and surface plate introduce error.
- 3.8 Vibration of the test specimen relative to the probe-measuring axis introduces error.

4 Referenced Standards and Documents

4.1 *SEMI Standards and Safety Guidelines*

SEMI M1 — Specification for Polished Monocrystalline Silicon Wafers

SEMI M59 — Terminology for Silicon Technology

4.2 *ANSI Standards*¹

ANSI/ASME B46.1 — Surface Texture (Surface Roughness, Waviness, and Lay)

4.3 *United States Federal Standards*²

GGG-P 463C — Surface Plate, Granite

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

5 Terminology

- 5.1 Terms relating to silicon and other semiconductor technology are defined in SEMI M59.

6 Summary of Test Method

- 6.1 The wafer is supported by three hemispherical points on a reference ring, and both surfaces are simultaneously scanned along a prescribed pattern by both members of an opposed pair of probes.
- 6.2 The displacements (distances) between each probe and the nearest surface of the wafer are determined (in pairs) at intervals along the scan pattern.
- 6.3 Half the difference between the largest and smallest of the differences of the paired displacements is taken as a measure of the warp.
- 6.4 The difference between the largest and smallest of the sums of the paired displacements is taken as a measure of the total thickness variation.

¹ American National Standards Institute, 25 West 43rd Street, New York, NY 10036, USA; Telephone: +1.212.642.4900, Fax: +1.212.398.0023, <http://www.ansi.org>

² Available from <http://www.everyspec.com>

7 Apparatus

7.1 *Warp Measuring Equipment* — Consisting of movable reference ring, fixed probe assembly with indicator, guide, and surface plate as follows:

7.1.1 *Reference Ring* — Consisting of a closed base and three hemispherical support pads (refer to Figure 1); a different size ring is required for use with each diameter of wafer to be measured (refer to Table 1). Each reference ring shall be fabricated of a metal whose thermal coefficient of expansion shall not exceed $11 \times 10^{-6}/^{\circ}\text{C}$ (or $6 \times 10^{-6}/^{\circ}\text{F}$) at laboratory temperatures; be at least 19 mm (or 0.75 in.) thick, with the bottom surface lapped flat to within 250 nm (or 10 μm .); have an outside diameter approximately 50 mm (or 2 in.) larger than the nominal diameter of the specimen wafer with which it is intended to be used; and incorporate the following features:

7.1.1.1 *Three Hemispherical Support Pads* — Used to define the plane of the reference ring and equally spaced within $\pm 130 \mu\text{m}$ (or ± 0.005 in.) on the circumference of a circle whose diameter is 6.35 mm (or 0.250 in.) less than the nominal diameter of the wafer as given in SEMI M1. The support pads shall be fabricated from tungsten carbide, or from a material of the same or greater hardness, have a nominal diameter of 3.18 mm (or 0.125 in.), and project 1.59 ± 0.13 mm (or 0.0625 ± 0.0050 in.) above the upper surface of the reference ring. The upper bearing surface of each support pad shall be polished, with a maximum surface roughness R_A of 250 nm (or 10 μm .), measured with 0.8 mm (or 0.31 in.) cutoff in accordance with ANSI/ASME B46.1.

7.1.1.2 *Three Cylindrical Guide Pins* — Used to assist the operator to position the specimen wafer by eye, spaced approximately equally on the circumference of a circle whose diameter is nominally equal to the sum of the diameter of the pin and the maximum allowable wafer diameter as given in SEMI M1. The guide pins shall be at least 380 μm (or 0.015 in.) higher than the support pads (refer to Figure 1).

7.1.1.3 *Probe Parking Position* — Cut-out area in the reference ring outside the nominal wafer diameter to permit the ring to be positioned so that the probe assembly is out of the way for specimen or precision flat insertion and removal (refer to Figure 1).

NOTE 1: The plane defined by the reference ring is the plane tangent to the three pads.

NOTE 2: It is recommended that the guide pins be fabricated from a hard plastic material.

7.1.2 *Probe Assembly with Indicator* — Paired, non-contacting, displacement-sensing probes, probe supports, and indicator unit. The probes shall be capable of independent measurement of the distance between the probed site on each surface of the specimen slice and the plane of the reference ring. The probes shall be mounted above and below the specimen position in a manner so that the probe site on one surface of the specimen is opposite the probed site on the other. The common axis of mounting shall be perpendicular ($\pm 2^{\circ}$) to the plane defined by the reference ring. The upper probe mount shall incorporate a positioning adjustment to accommodate the wafer thickness range desired. The indicator unit shall be capable of displaying the output from each probe individually and of being manually reset. The assembly shall satisfy the following requirements:

7.1.2.1 Probe-sensing area (probed site) diameter shall be in the range from 1.55 to 5.75 mm (or 0.062 to 0.225 in.),

7.1.2.2 Displacement resolution of 250 nm (or 10 μm .), or better from a probed site,

7.1.2.3 Displacement range (for each probe) of at least ± 0.010 in. (± 0.25 mm) about the nominal zero position,

7.1.2.4 Linearity within 0.5% of the full-scale reading, and

7.1.2.5 For instruments operating in an automatic data-sampling mode during scan, sampling capability of at least 100 data points per second.

NOTE 3: The probe-sensing principle may be capacitive, optical, or any other noncontacting means suitable for determining the separation between probe and silicon surface; noncontacting is specified to prevent the probe from deflecting the specimen wafer.

NOTE 4: The indicator unit may conveniently incorporate (1) means for calculating and storing sums or differences of paired displacement measurements and for identifying the maximum and minimum values of these quantities, (2) means for zero-reading adjustment, and (3) switch-selectable display of stored calculated values, individual probe measurements, and the like. The display may be digital or analog (dial); digital readout is recommended to eliminate interpolative errors on the part of the operator.

7.1.3 *Guide* — Means for restricting the motion of the reference ring so that the probe mounting axis does not approach closer to the edge of the specimen wafer than 6.78 mm (or 0.267 in) except at the parking position.

NOTE 5: Depending on the design of the apparatus, a matching guide may be required for each reference ring.