

SEMI MF1451-0704

TEST METHOD FOR MEASURING SORI ON SILICON WAFERS BY AUTOMATED NON-CONTACT SCANNING

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1 Purpose

1.1 Sori can significantly affect the yield of semiconductor device processing.

1.2 Knowledge of this characteristic can help the producer and consumer determine if the dimensional characteristics of a specimen wafer satisfy given geometrical requirements.

1.3 Changes in wafer sori during processing can adversely affect subsequent handling and processing steps. These changes can also provide an important process monitoring function.

1.4 This test method is suitable for measuring the sori of wafers used in semiconductor device processing in the as-sliced, lapped, etched, polished, epitaxial or other layer condition and for monitoring thermal and mechanical effects on the sori of wafers during device processing.

2 Scope

2.1 This test method covers a non-contacting, nondestructive procedure to determine the sori of clean, dry semiconductor wafers.

2.2 This test method employs a two-probe system that examines both external surfaces of the wafer simultaneously.

2.3 The test method is applicable to wafers 50 mm or larger in diameter, and approximately 100 μm and larger in thickness, independent of thickness variation and surface finish, and of gravitationally induced wafer distortion.

2.4 This test method is not intended to measure the flatness of either exposed silicon surface. Sori is a measure of the distortion of the front surface of the wafer.

2.5 This test method measures sori of a wafer corrected for mechanical forces applied during the test. Therefore, the procedure described gives the unconstrained value of sori.

NOTE 1: This sori is indicated by the acronym "GFLYFER" in Appendix 2, Shape Decision Tree, of SEMI M1.

2.6 This test method includes several methods for canceling gravity-induced deflection which could otherwise alter the shape of the wafer.¹

NOTE 2: One of these methods, the Representative Wafer Inversion Method, is covered by a patent held by ADE Corporation, 80 Wilson Way, Westwood, MA 02090-1806.

NOTICE: This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory or other limitations prior to use.

3 Limitations

3.1 Any relative motion along the probe measuring axis between the probes and the wafer holding device during scanning will produce error in the measurement data. Vibration of the test specimen relative to the probe-measuring axis will introduce error. Such errors are minimized by system signature analysis and correction algorithms. Internal system monitoring may also be used to correct non-repetitive and repetitive system mechanical translations. Failure to provide such corrections may cause errors.

3.2 If a measured wafer differs substantially in diameter, thickness, fiducials, or crystal orientation from that used for the gravitational compensation procedure, the results may be incorrect. Estimates of the errors in gravity induced deflection for differences in diameter and thickness are shown in Related Information 1. If the crystal orientation of the sample to be measured differs from the crystal orientation of the gravity-compensation wafer, then the measured sori value may differ from the actual sori value by up to 15%. Error tables for fiducial variation have not been generated.

3.3 Different methods for implementing gravitational compensation may give different results. Varying

¹ Poduje, N., "Eliminating Gravitational Effect in Wafer Shape Measurements," *NIST/ASTM/SEMI/SEMATECH Technology Conference, Dallas, TX*. Technology for Advanced Materials/Process Characterization, February 1, 1990.

levels of completeness of implementing a method may also give different results.

3.4 Mechanical variations in wafer holding devices between systems may introduce measurement differences. This test method allows the use of one of several different diameters of wafer holding devices (see Section 7.1.4.1); comparisons of results obtained with different geometrical configurations may be affected by these differences.

3.5 Most equipment systems capable of this measurement have a definite range of wafer thickness combined with sori (dynamic range) that can be accommodated without readjustment. If the sample moves outside this dynamic range during either calibration or measurement, results may be in error. An over-range signal can be used to alert the operator and measurement data examiners to this event.

3.6 The quantity of data points and their spacing may affect the measurement results. This test method defines only a maximum data point spacing (see Section 7.1.4.2); results obtained with different data point spacings may differ.

4 Referenced Standards

4.1 SEMI Standards

SEMI M1 — Specifications for Polished Monocrystalline Silicon Wafers

SEMI MF1241 — Terminology of Silicon Technology

SEMI MF1530 — Test Method for Measuring Flatness, Thickness, and Thickness Variation on Silicon Wafers by Automated Non-contact Scanning

4.2 ASTM Standard

D 4356 — Practice for Establishing Consistent Test Method Tolerances²

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

5 Terminology

5.1 Definitions

5.1.1 *mechanical signature, of an instrument* — that component of a measurement that is introduced by the instrument and that is systematic, repeatable, and quantifiable.

5.1.2 *median surface, of a semiconductor wafer* — the locus of points equidistant from the front and back surfaces of the wafer.

5.1.3 *reference plane, of a semiconductor wafer* — a plane from which deviations of a specified surface of the wafer are measured.

5.1.4 *reference plane deviation (RPD)* — the distance from a point on a reference plane to the corresponding point on a wafer surface.

5.1.4.1 *Discussion* — The front surface of a dome-shaped wafer is considered to have positive RPD at its center; the front surface of a bowl-shaped wafer is considered to have negative RPD at its center.

5.1.5 *sori, of a semiconductor wafer* — the algebraic difference between the most positive and the most negative deviations of the front surface of a wafer that is not chucked from a reference plane that is a least squares fit to the front surface.

5.1.5.1 *Discussion* — The front surface may contain regions with upward or downward curvature or both; under some conditions the front surface may be flat.

5.1.6 *thickness, of a semiconductor wafer* — the distance through the wafer between corresponding points on the front and back surfaces.

5.2 Definitions of other terms related to silicon material technology can be found in SEMI MF1241.

6 Summary of Test Method

6.1 A calibration procedure is performed to set the instrument's scale factor and other constants. If the representative wafer inversion method is used for gravity correction, the calibration procedure also determines the mechanical signature of the instrument and the effect of gravity on the wafer.

6.2 The wafer is supported by a small-area chuck with front surface up.

6.3 Both external surfaces are simultaneously scanned along a prescribed pattern by an opposed pair of probes to obtain a set of values of the distances between each surface and the nearest probe. In each case, both members of the pair of distances is taken at the same value of the x and y coordinates.

6.4 The paired displacement values are used to construct the median surface.

6.5 A correction for gravity effects on the median surface is made either by subtracting a gravity correction obtained (1) from measurements on a representative wafer or (2) from theoretical considerations or by repeating the scan with the wafer inverted.

² Available from ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428, Tel: 610-832-9500, Fax: 610-832-9555, Website <http://www.astm.org>. Appears in Volume 14.02 of *Annual Book of ASTM Standards*.

6.6 One half the thickness at each point is added to the corrected median surface to construct the corrected front surface.

6.7 A least-squares reference plane is constructed from the corrected front surface.

6.8 The reference plane deviation (RPD) is calculated at each measured pair of points.

6.9 Sori is reported as the algebraic difference between the most positive RPD and the most negative RPD.

7 Apparatus

7.1 *Measuring Equipment*, consisting of wafer holding device, multiple-axis transport mechanism, probe assembly with indicator, and system controller/computer, including data processor and suitable software.

7.1.1 The equipment shall be direct reading with all necessary calculations performed internally and automatically as outlined in Section 11.2.

7.1.2 The equipment shall be equipped with an over-range signal.

7.1.3 Instrument data reporting resolution shall be 100 nm or smaller.

7.1.4 The measuring equipment contains the following subsystems:

7.1.4.1 Wafer-holding device, for example a chuck whose face is perpendicular to the measurement axis, and on which the wafer is placed for the measurement scan. The diameter of the wafer holding device shall be agreed upon between the parties to the test.

7.1.4.2 Multiple-axis transport mechanism, which provides a means for moving the wafer-holding device, or the probe assembly, perpendicularly to the measurement axis in a controlled fashion in several directions. This motion must permit data gathering over a prescribed scan pattern covering the entire fixed quality area. Data point spacing to be used shall be agreed upon between the parties to the test.

7.1.4.3 Probe assembly with paired non-contacting displacement-sensing probes, probe supports, and indicator unit (see Figure 1).

7.1.4.3.1 The probes shall be capable of independent measurement of the distances a and b between the probed site on each surface of the sample wafer and the nearest probe surface.

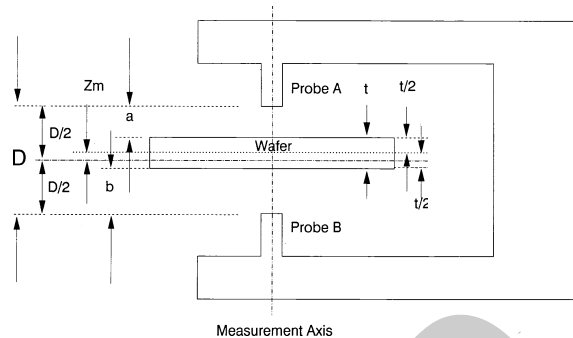


Figure 1
Schematic View of Wafer, Probes, and Fixture

7.1.4.3.2 The probes shall be mounted above and below the wafer in a manner so that the probed site on one surface of the wafer is opposite the probed site on the other.

7.1.4.3.3 The common axis of these probes is the measurement axis.

7.1.4.3.4 The probe separation D shall be kept constant during calibration and measurement.

7.1.4.3.5 Displacement resolution shall be 100 nm or smaller.

7.1.4.3.6 The probe sensor size shall be 4 mm by 4 mm, or other value to be agreed upon between the parties to the test.

7.1.4.3.7 Measuring equipment employing either the Representative Wafer Inversion Method or the Sample Wafer Inversion Method for gravity compensation must provide precise positioning in both measurement orientations so that measurements are taken at identical locations for each orientation of the sample.

8 Materials

8.1 *Set-up Masters* — suitable to accomplish calibration and standardization as recommended by the equipment manufacturer.

8.2 *Reference Wafer* — with a reference sori value $\leq 20 \mu\text{m}$ that is used to determine the level of agreement between the sori value obtained by the measuring equipment under test and the reference sori value (see Section 9).

8.3 *Representative Wafer* — required only if the Representative Wafer Inversion Method is used for the gravity correction. A representative wafer shall be identical in nominal diameter, nominal thickness, fiducials, composition and crystalline orientation to those being measured. Its sori need not be known.