SEMI MF1451-0707 (Reapproved 0421)
TEST METHOD FOR MEASURING SORI ON SILICON WAFERS BY AUTOMATED NONCONTACT 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 noncontacting, 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.

NOTE 1: The front surface may contain regions with upward or downward curvature or both; under some conditions the front surface may be flat.

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 2: 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 3: 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, USA.

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 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

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

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system monitoring may also be used to correct nonrepetitive 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 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 a variety of wafer holding devices (see § 7.1.4.1); results obtained with different geometrical configurations of wafer holding device on the same test samples may differ.

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 does not specify the data point spacing (see § 7.1.4.2); results obtained with different data point spacings on the same test samples may differ.

4 Referenced Standards and Documents

4.1 *SEMI Standards and Safety Guidelines*

SEMI M1 — Specification for Polished Single Crystal Silicon Wafers

SEMI M59 — Terminology for Silicon Technology

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

4.2 *ASTM Standards*[2]

ASTM D4356 — Standard Practice for Establishing Consistent Test Method Tolerances (Withdrawn 2007)

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 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.

[2] ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA; Telephone: +1.610.832.9585, Fax: +1.610.832.9555, http://www.astm.org

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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.

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 § 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 nature and size 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.

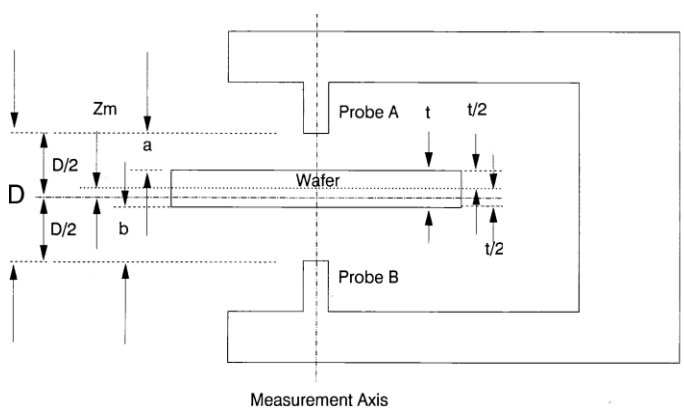

Figure 1
Schematic View of Wafer, Probes, and Fixture

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.

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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 ≤20 µm 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 § 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.

9 Suitability of Measuring Equipment

9.1 Determine the suitability of the measuring equipment with the use of a reference wafer and its reference sori value in accordance with the procedures of § 9.2, or by performance of a statistically-based instrument repeatability study to ascertain whether the equipment is operating within the manufacturer's stated specification for repeatability.

9.1.1 The reference sori value is the average of a number of values obtained for that wafer over a number of 'passes' (repeat measurements). The reference wafer is measured on the measuring equipment under test and its reference sori value is compared against the measured sori value. The acceptable level of the agreement between the reference and measured sori values is to be agreed upon by the parties to the test.

9.2 *Procedure*

9.2.1 Select a reference wafer of appropriate criteria, together with its associated reference sori value.

9.2.2 Measure the reference wafer on the measuring equipment under test to obtain a sample sori value.

9.2.3 Subtract the two sori values to obtain the difference:

$$\Delta_{sori} = Sori_{reference} - Sori_{sample} \tag{1}$$

9.2.4 The metric to be used to determine acceptability is difference, Δ_{sori}. Accept the measuring equipment as suitable for use if this difference is less than a value that is agreed upon between the parties to the test.

NOTE 4: If the measuring equipment is to be used to measure other parameters, such as flatness and thickness variation in addition to sori, the reference and sample sori values may be included in the reference and sample data sets specified in SEMI MF1530, but this is not necessary if only sori measurements are to be made.

10 Sampling

10.1 This Test Method is nondestructive and may be used on either 100% of the wafers in a lot or on a sampling basis.

10.1.1 If samples are to be taken, procedures for selecting the sample from each lot of wafers to be tested shall be agreed upon between the parties to the test, as shall the definition of what constitutes a lot.

11 Calibration and Standardization

11.1 Calibrate the measuring equipment in accordance with the manufacturer's instructions.

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