SEMI MF1530-0707 (Reapproved 0512)
TEST METHOD FOR MEASURING FLATNESS, THICKNESS, AND TOTAL THICKNESS VARIATION ON SILICON WAFERS BY AUTOMATED NONCONTACT SCANNING

This Standard was technically approved by the Silicon Wafer Global Technical Committee. This edition was approved for publication by the global Audits and Reviews Subcommittee on December 24, 2011. Available at www.semiviews.org and www.semi.org in May 2012; originally published by ASTM International as ASTM F1530-94; previously published July 2007.

NOTICE: This Document was reapproved with minor editorial changes.

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1 Purpose

1.1 Flatness, thickness and thickness variation are vital factors affecting the yield of semiconductor device processing.

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

1.3 This Test Method is suitable for measuring the flatness and thickness of wafers used in semiconductor device processing in the as-sliced, lapped, etched, polished, epitaxial or other layer condition.

2 Scope

2.1 This Test Method covers a noncontacting, nondestructive procedure to determine the thickness and flatness of clean, dry, semiconductor wafers in such a way that no physical reference is required.

2.2 This Test Method is applicable to wafers 50 mm or larger in diameter, and 100 µm (0.004 in.) approximately and larger in thickness, independent of thickness variation and surface finish, and of wafer shape.

2.3 This Test Method measures the flatness of the front wafer surface as it would appear relative to a specified reference plane when the back surface of the water is ideally flat, as when pulled down onto an ideally clean, flat chuck. It does not measure the free-form shape of the wafer.

2.4 Because no chuck is used as a measurement reference, this Test Method is relatively insensitive to microscopic particles on the back surface of the wafer.

2.5 The values stated in SI units are to be regarded as the standard. The values given in parentheses 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 Any relative motion between the probes and along the probe measuring axis during scanning produces error in the lateral position equivalent-measurement data.

3.2 Most equipment systems capable of this measurement have a definite range of wafer thickness combined with sori/warp (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 overrange signal can be used to alert the operator and measurement data examiners to this event.

3.3 The quantity of data points and their spacing may affect the measurement results (see ¶ 7.1.5.2).

3.4 Site flatness measurements may be affected if the site boundaries and corners do not contain data array elements. This effect may be reduced through interpolation techniques.

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4 Referenced Standards and Documents

4.1 *SEMI Standards and Safety Guidelines*

SEMI M1 — Specifications for Polished Single Crystal Silicon Wafers

SEMI M20 — Practice for Establishing a Wafer Coordinate System

SEMI M59 — Terminology for Silicon Technology

SEMI MF1390 — Test Method for Measuring Warp on Silicon Wafers by Automated Noncontact Scanning

4.2 *ASTM Standard*[1]

ASTM E691 — Standard Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

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

5 Terminology

5.1 Acronyms related to wafer flatness parameters as defined in SEMI M1, Appendix 1, Flatness Decision Tree, are summarized in Table 1.

NOTE 1: The most commonly specified flatness measurements for advanced IC production in 2004, the time of the last revision of this Standard, are SFQR with a site size of either 26 by 8 mm or 25 by 8 mm and GBIR (TTV).

5.2 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. This sets the instrument's scale factor and other constants.

6.2 The wafer is supported by a small-area chuck and is scanned along a prescribed pattern by both members of an opposed pair of probes.

6.3 The paired displacement values are used to construct a thickness data array ($t[x,y]$). This array represents the front surface of the wafer when the back surface of the wafer is ideally flat, as when pulled down onto and ideally clean, flat chuck.

6.4 The data array is used to produce one or more of the parameters required by the application.

6.4.1 If flatness measurements are required, a reference plane and a focal plane suitable to the application are constructed on the back or front surface.

6.5 Thickness or flatness, or both, values are calculated and reported, as required.

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 measuring equipment shall have means to input the choices listed in the Procedure (see § 12).

7.1.2 The measuring equipment shall be direct reading with all necessary calculations performed internally and automatically as outlined in § 13.

7.1.3 The system shall be equipped with an overrange signal.

7.1.4 Instrument data reporting resolution shall be 10 nm or smaller.

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7.1.5 The measuring equipment contains the following subsystems:

7.1.5.1 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.

7.1.5.2 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 within the entire fixed quality area. Data point spacing shall be agreed upon between the parties to the test.

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

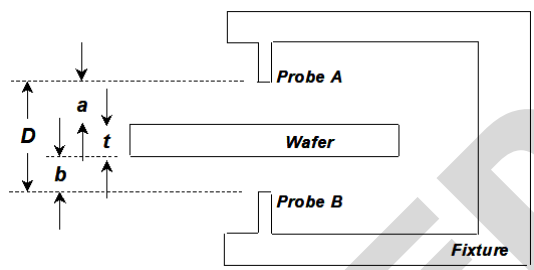

Figure 1
Schematic View of Wafer, Probes, and Fixture

7.1.5.3.1 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.

7.1.5.3.2 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.

Table 1 Acronyms for Wafer Flatness Parameters

Acronym	*Measurement Method*	*Reference Surface*	*Reference Plane*		*Measurement Parameter*
			Construction	*Area*	
GBIR	Global	Back	Ideal back surface	Entire FQA	Range (TIR)
GF3R	Global	Front	Three-point		Range (TIR)
GF3D	Global	Front	Three-point		Deviation (FPD)
GFLR	Global	Front	Least squares	Entire FQA	Range (TIR)
GFLD	Global	Front	Least squares	Entire FQA	Deviation (FPD)
SBIR	Site	Back	Ideal back surface	Entire FQA	Range (TIR)
SBID	Site	Back	Ideal back surface	Entire FQA	Deviation (FPD)
SF3R	Site	Front	Three-point		Range (TIR)
SF3D	Site	Front	Three-point		Deviation (FPD)
SFLR	Site	Front	Least squares	Entire FQA	Range (TIR)
SFLD	Site	Front	Least squares	Entire FQA	Deviation (FPD)
SFQR	Site	Front	Least squares	Site	Range (TIR)
SFQD	Site	Front	Least squares	Site	Deviation (FPD)
SFSR	Site	Front	Least squares	Sub-site	Range (TIR)
SFSD	Site	Front	Least squares	Sub-site	Deviation (FPD)

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

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

7.1.5.3.5 Displacement resolution shall be 10 nm or better.

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

NOTE 2: Precise site flatness measurement requires measurement points located closely enough to reveal the surface topology in detail. It is recommended that site flatness be measured using a data point array with adjacent points separated by 2 mm or less. It is also recommended that the data set used to calculate site flatness have data at each site corner and along each site boundary. This makes the effective site measurement area equal to the site size.

8 Materials

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

8.2 *Reference Wafer* — With total thickness variation (TTV) value and flatness value similar to the product or process to be monitored and with a data set that is used to determine the level of agreement between the data set obtained by the measuring equipment under test and the reference wafer data set (see § 9).

9 Suitability of Measuring Equipment

9.1 Determine the suitability of the measuring equipment with the use of a reference wafer and its associated data set 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 wafer data set is a set of thickness or flatness parameters based on corrected data in that all possible interferences have been removed and the data has been replanarized in accordance with this method.

9.1.2 Each reference wafer (artifact) is accompanied by its own data set, the reference data set (*RDS*), in which each parameter value is the average of a number of values obtained for that parameter over a number of 'passes' (repeat measurements). The artifact is measured on a measurement equipment under test and its *RDS* is compared against the resultant-measured sample data set. Delta-parameter and other values are computed from the differences. The parameter used to determine agreement between the artifact and the measuring equipment under test and the acceptable level of this agreement is to be agreed upon between the parties to the test.

9.2 *Procedure*

9.2.1 Select a reference wafer of appropriate criteria together with its associated reference data set (*RDS*).

9.2.2 Measure the reference wafer on the measurement equipment under test to obtain a sample data set (*SDS*).

9.2.3 Subtract the two data sets on a parameter basis to obtain a difference data set (*DDS*):

$$RDS - SDS = DDS \tag{1}$$

9.2.3.1 The *DDS* represents the differences between the measurements made on the measuring equipment under test and the reference data set. The *DDS* contains many values.

9.2.4 The simplest metric that can be used to determine acceptability is maximum difference, the largest absolute value in the *DDS*. This represents the worst-case disagreement between the results obtained from the measurement equipment under test and the reference data. Accept the measurement equipment as suitable for measurement if the maximum difference is less than a value that is agreed upon between the parties to the test.

9.2.5 More complex calculations may also be used to determine acceptability. For example, a histogram of the parameter values of the *DDS* along with statistical measures (mean, sample standard deviation, etc.) may be used. These measures may be compared to application-specific limits or used to provide insight into the nature and source of the difference, or both, as arranged by agreement of the parties to the test.

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.

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