



Designation: F 1530 – 02

Standard Test Method for Measuring Flatness, Thickness, and Thickness Variation on Silicon Wafers by Automated Noncontact Scanning¹

This standard is issued under the fixed designation F 1530; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 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.

1.2 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.

1.3 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 wafer is ideally flat, as when pulled down onto an ideally clean, flat chuck. It does not measure the free-form shape of the wafer.

1.4 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.

1.5 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.6 *This standard does not purport to address all of the safety concerns, 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 limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

F 1241 Terminology of Silicon Technology²

F 1390 Test Method for Measuring Warp on Silicon Wafers by Automated Noncontact Scanning²

2.2 SEMI Standard:

M1 Specifications for Polished Monocrystalline Silicon Wafers³

3. Terminology

3.1 Definitions and acronyms related to wafer flatness may be found in SEMI Specifications M 1.

3.2 Other definitions relative to silicon material technology can be found in Terminology F 1241.

4. Summary of Test Method

4.1 A calibration procedure is performed. This sets the instrument's scale factor and other constants.

4.2 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.

4.3 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 (see figures in Appendix X1).

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

4.4.1 If flatness measurements are required, a reference plane and a focal plane suitable to the application are constructed on the back or front surface as described in Appendix X2.

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

5. Significance and Use

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

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

¹ This test method is under the jurisdiction of ASTM Committee F01 on Electronics and is the direct responsibility of Subcommittee F01.06 on Silicon Materials and Process Control.

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² Annual Book of ASTM Standards, Vol 10.05.

³ Available from Semiconductor Equipment and Materials International, 3081 Zanker Road, San Jose, CA 95134 (www.semi.org).

5.3 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.

5.4 Until the results of a planned interlaboratory evaluation of this test method are established, use of this test method for commercial transactions is not recommended unless the parties to the test establish the degree of correlation that can be obtained.

6. Interferences

6.1 Any relative motion between the probes and along the probe measuring axis during scanning will produce error in the lateral position equivalent-measurement data.

6.2 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.

6.3 The quantity of data points and their spacing may affect the measurement results (see 7.1.2).

6.4 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.

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. The system shall be equipped with an overrange signal. Instrument data reporting resolution shall be 10 nm or smaller.

7.1.1 *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 0.9-in. (22-mm) diameter, 1.3-in. (33-mm) diameter, or other value as agreed upon between participating parties.

7.1.2 *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 axes. This motion must permit data gathering over a prescribed scan pattern within the entire quality area. Data point spacing shall be 2 mm or less, or other value as agreed upon between participating parties.

7.1.3 *Probe Assembly with Paired Noncontacting Displacement-Sensing Probes, Probe Supports, and Indicator Unit*—The probes shall be capable of independent measurement of the distance between the probe site on each surface of the sample wafer and the motion plane. 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. The common axis of these probes is the measurement axis (see Fig. 1). The probe separation D shall be kept constant during calibration and measurement. Displace-

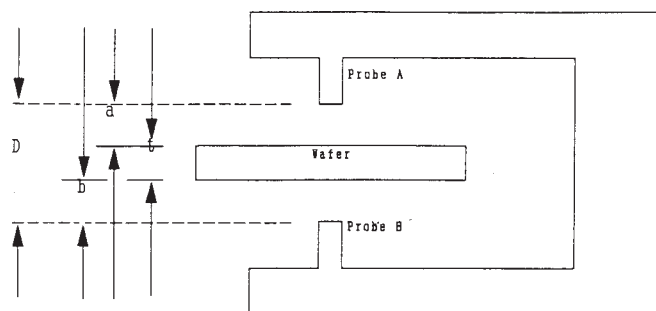


FIG. 1 Schematic View of Wafer, Probes, and Fixture

ment resolution shall be 10 nm or better. The probe sensor size shall be 4×4 mm, or other value to be agreed upon between participating parties.

7.1.3.1 The following equations are derived from Fig. 1. They are used in subsequent calculations as noted.

$$D = a + t + b \quad (1)$$

$$t = D - (a + b) \quad (2)$$

where:

D = the distance between Probes A and B,

a = the distance between Probe A and the nearest wafer surface,

b = the distance between Probe B and the nearest wafer surface, and

t = wafer thickness.

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 system under test and the reference wafer data set (see Annex A1).

9. Suitability of Test Equipment

9.1 The suitability of the test equipment shall be determined with the use of a reference wafer and its associated data set in accordance with the procedures of Annex A1, 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.

NOTE 1—Subcommittee F1.95 is currently developing an instrument repeatability study format.

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 in accordance with the manufacturer's instructions.



12. Procedure

12.1 Prepare the apparatus for measurement of wafers, including selection of data display/output functions and fixed quality area (FQA) by specifying the nominal edge exclusion X .

12.1.1 *Measurement Method*—Global Flatness (G) or Site Flatness (S):

12.1.1.1 If S is chosen, then also specify site array details:

- (1) site size,
- (2) location of sites relative to FQA center,
- (3) location of sites relative to each other, rectilinear or tiled pattern, and

(4) partial sites, included or excluded.

12.1.2 *Reference Surface*—front or back.

12.1.3 *Reference Plane and Area*:

12.1.3.1 For Global Flatness Measurements, Global Reference Plane:

- (1) Ideal backside plane construction, or
- (2) Three-point frontside plane construction, or
- (3) Least-squares frontside plane construction.

12.1.3.2 For Site Flatness Measurements, Global Reference Plane:

- (1) Ideal backside plane construction, or
- (2) Three-point frontside plane construction, or
- (3) Least-squares frontside plane construction.

12.1.3.3 For Site Flatness Measurements, Site Reference Plane:

- (1) Site least-squares plane construction.

12.1.4 *Measurement Parameter*:

12.1.4.1 Global Flatness:

- (1) Total indicator reading, (TIR) or
- (2) Focal plane deviation, (FPD).

12.1.4.2 Site Flatness:

- (1) TIR—each site or maximum value for all sites, or both, or
- (2) FPD—each site or maximum value for all sites, or both, or
- (3) Distribution of these values.

12.2 Introduce the test specimen into the measurement mechanism and initiate the measurement sequence.

13. Calculations

13.1 The instrument is assumed to be direct reading with all necessary calculations performed internally and automatically as follows:

13.1.1 The displacements (distances) between each probe and the nearest surface of the wafer are determined (in pairs) at intervals along the scan pattern. At each measurement location, the sum of the displacements is subtracted from D , yielding the thickness as follows:

$$t = D - (a + b) \quad (3)$$

13.1.2 A data array whose elements are the thicknesses ($t[x,y]$) is constructed.

13.1.3 Reference and focal planes for flatness calculation are constructed as described in Annex A1.

13.2 Calculate thickness and flatness as required by the application as follows:

13.2.1 *Total Thickness Variation*:

$$TTV = t_{\max} - t_{\min} \quad (4)$$

13.2.2 *Global Flatness*:

where:

$$\begin{aligned} f(x,y) &= t(x,y) - (d_F x + b_F y + c_F), \text{ and } x,y \text{ range over the FQA,} \\ GBIR, GF3R \text{ and GFLR} &= f(x,y)_{\max} - f(x,y)_{\min}, \text{ and} \\ GF3D \text{ and GFLD} &= \text{the larger of } |f(x,y)_{\max}| \text{ or } |f(x,y)_{\min}|. \end{aligned}$$

NOTE 2—GBIR equals TTV.

13.2.3 *Site Flatness*:

where:

$$\begin{aligned} f(x,y) &= t(x,y) - (d_F x + b_F y + c_F), \text{ and } x,y \text{ range over the site,} \\ SF3R, SFLR, SFQR \text{ and SBIR} &= f(x,y)_{\max} - f(x,y)_{\min}, \text{ and} \\ SF3D, SFLD, SLQD \text{ and SBID} &= \text{the larger of } |f(x,y)_{\max}| \text{ or } |f(x,y)_{\min}|. \end{aligned}$$

13.3 Record the calculated values.

13.4 For referee or other measurements where the wafer is measured more than once, calculate the maximum, minimum, sample standard deviation, average and range of all measurements on the sample.

14. Report

14.1 Report the following information:

14.1.1 Date, time, and temperature of test,

14.1.2 Identification of operator,

14.1.3 Identification of measuring instruments, including wafer-holding device diameter, data point spacing, sensor size, and measurement method,

14.1.4 Lot identification, including nominal diameter and nominal center point thickness,

14.1.5 Description of sampling plan, and one or more of the following parameters as required by the application:

14.1.6 Centerpoint thickness of each wafer measured,

14.1.7 Thickness variation of each wafer measured,

14.1.8 Flatness of each wafer measured, described as one or more of the following choices:

14.1.8.1 The global flatness, or

14.1.8.2 The maximum value of site flatness as measured on all sites, or

14.1.8.3 The percentage of sites which have a site flatness $\leq$ a specified value, and

14.1.9 Distribution of all sites on all wafers measured, when site flatness is measured.

14.2 For referee tests the report shall also include the standard deviation of each set of wafer measurements.

15. Precision and Bias

15.1 Twenty-three 200-mm diameter, single-side polished silicon wafers were employed in a round-robin experiment.



TABLE 1 Site Information

Site ID	Site Type	Location on Wafer
069	Full	Center
073	Full	60 mm from Center (0°)
075	Partial	FQA Boundary (0°)
135	Partial	Notch (270°)

These wafers represented three different manufacturing processes. All three subsets were bare on the front surface. Two subsets were bare on the back surface and one subset had oxide on the back surface.

15.2 Eight laboratories measured thickness. Six of these laboratories also measured flatness. Each of the twenty-three wafers was measured three times in succession (in three cassette-to-cassette “passes”), on a single day on automatic measurement systems, in accordance with this test method.

15.3 All measurement data were acquired with 3-mm edge exclusion.

15.4 Flatness values were calculated in an array of 15 by 15 mm sites, and a 7.5 mm array offset in both x and y directions, relative to the wafer center. Within this 137-site array, precision statistics were derived for four selected sites, two “full” sites in the central area and two “partial” sites along the FQA boundary, as indicated in Table 1. Fig. 2 shows these sites within the complete 137-site array.

15.5 The number of laboratories, samples, and determinations in this study met the minimum requirements for determining precision prescribed in Practice E 691.

15.6 Statistical calculations derived from these data, in accordance with Practice E 691, include:

15.6.1 r (repeatability, within-laboratory)—95 % repeatability confidence interval, and

15.6.2 R (reproducibility, between laboratory)—the ~95 % confidence interval within which two measurements made at different laboratories are considered statistically to be the same.

15.7 Repeatability and reproducibility ranges are shown in Table 2.

15.8 Fig. 2 contains for plots of repeatability (r) and reproducibility (R) by ordered specimen mean value.

15.9 For more details, refer to the ASTM Research Report.⁴ This contains statements on within-laboratory precision (repeatability) and between-laboratory precision (reproducibility), for 95 % confidence intervals, for each parameter.

16. Keywords

16.1 flatness; noncontact measurement; semiconductor; silicon; thickness; thickness variation; wafers

⁴ Available from ASTM International. Request: F01–1016.