Background Statement for SEMI Draft Document 4703
Revision of SEMI MF533-0706
TEST METHODS FOR THICKNESS AND THICKNESS VARIATION
OF SILICON WAFERS

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supporting documentation. In this context, “patented technology” is defined as technology for
which a patent has issued or has been applied for. In the latter case, only publicly available
information on the contents of the patent application is to be provided.

This letter ballot is intended simply to add the 0 deg positioning of the five-point and nine-point
profile radial thickness variation measurement for notched wafers. No changes are made to the
original method for flatted wafers.

This ballot will be reviewed by the Int’l Test Methods Task Force and adjudicated by the Silicon
Wafer Committee during their SEMICON West meetings in San Francisco, CA, in the week of
SEMIDraft Document 4703  
Revision of SEMI MF533-0706  
TEST METHODS FOR THICKNESS AND THICKNESS VARIATION  
OF SILICON WAFERS  

These test methods were technically approved by the Global Silicon Wafer Committee and are the direct responsibility of the North American Silicon Wafer Committee. This edition was approved for publication by the global Audits and Reviews Subcommittee on date tbd. It was available on www.semi.org in month tbd and on CD-ROM in month tbd. Original edition published by ASTM International as ASTM F 533-77T. Last previous edition SEMI MF533-0706.

1 Purpose

1.1 Wafer thickness and thickness variations must be controlled to suit the requirements of fixtures and equipment used in microelectronic processing. Estimates of these parameters, based on a representative sample from a given lot of wafers, aids in determining whether or not wafers from that lot are acceptable for the intended processing steps.

1.2 Wafers that are too thin may break during normal processing operations. Wafers that are too thick may cause mechanical jamming. Wafers with thickness outside the desired tolerance may not have appropriate thermal mass or electrical resistance for certain processing steps.

1.3 Excessive thickness variations may cause problems with mechanical handling of the wafers during processing. In addition, such variations may cause deviations from surface flatness that adversely affect photolithographic processes. The effect of thickness variations on photolithographic processes depends on the line width and registration requirements of individual circuit designs, as well as on the specific optical and mechanical design of the photolithographic processing equipment being used.

1.4 These test methods are intended for use for materials acceptance and process control purposes. These test methods may be applied at any point during the processing of unpolished wafers into polished wafers or substrates.

1.5 When this test method for flatted wafers was developed in the 1970s, non-contact thickness gages employing manual wafer positioning, which are the basis of this test method, were in routine use. More recently, faster, automated instruments have replaced these manual gages for most common uses in the semiconductor industry. In these automatic systems, microprocessors or microcomputers are used to control wafer positioning, operate the instrument and to analyze the data (see SEMI MF1530).

1.6 Despite the fact that these test methods are not commonly used in its present form, they embody all the basic elements of the measurement method and a simple analysis of data. Thus, this standard provides useful guidance in the fundamentals and application of differential non-contact wafer thickness measurements. They are also suitable for use with very large diameter wafers before the automatic systems become available.

2 Scope

2.1 These test methods cover measurement of the thickness of silicon wafers, polished or unpolished, and estimation of the variation in thickness across the wafer for both flatted and notched wafers. For flatted wafers of 200 mm diameter or less, a five-point pattern offset from the bisector of the primary flat is used. For notched wafers of 200 mm diameter or more, either a symmetrical five-point or nine-point pattern is used.

NOTE 1: DIN 50441/1 is an equivalent method.

2.2 These test methods are intended primarily for use with wafers that meet the dimension and tolerance requirements of SEMI M1. However, they can be applied to circular silicon, wafers or substrates of any diameter and thickness that can be handled without breaking.
2.3 This test method is suitable for both contact and contactless gaging equipment. Precision statements have been established for each in the case of the five-point method applied to flatted wafers.

2.4 The values stated in inch-pound units are to be regarded as the standard for measurements on wafers of 3 inch diameter or less while the metric units are to be regarded as the standard for measurements on wafers of 100 mm diameter or more. The values given in parentheses are for information only.

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 guides and determine the applicability of regulatory or other limitations prior to use.

3 Limitations

3.1 Since the determination of total thickness variation by this test method is based on measurements of wafer thickness at only five sites, irregular geometrical variations in other parts of the wafer will not be detected.

3.2 Local changes in thickness at any site may result in erroneous readings. Such local changes in thickness may be caused by surface defects such as chips, contaminants, mounds, pits, saw steps, waves, and so forth.

4 Referenced Standards and Documents

4.1 SEMI Standards

SEMI M1 — Specifications for Polished Monocrystalline 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 DIN Standard

50441/1 — Determination of the Geometric Dimensions of Semiconductor Slices; Measurement of Thickness

4.3 Federal Standard

Fed. Spec. GGG-G-15C — Gage Blocks and Accessories (Inch and Metric), Nov. 6, 1970

4.4 ISO Standard

ISO 14644-1 Cleanrooms and associated controlled environments — Part 1: Classification of airborne particulates

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

5 Terminology

5.1 Terms used in this standard relating to silicon and other semiconductor technology are defined in SEMI M59.

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1 Deutsches Institut für Normung e.V., standards are available in both English and German editions from Beuth Verlag GmbH, Burggrafenstrasse 6, 10787 Berlin, Germany, Telephone: 49.30.2601-0, Fax: 49.30.2601.1263, Website: www.beuth.de.


3 International Organization for Standardization, ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland. Telephone: 41.22.749.01.11; Fax: 41.22.733.34.30 Website: www.iso.ch; also available in the US from American National Standards Institute, New York Office: 11 West 42nd Street, New York, NY 10036, USA. Telephone: 212.642.4900; Fax: 212.398.0023 Website: www.ansi.org, and in other countries from ISO member organizations.
6 Summary of Test Method

6.1 The thickness of the wafer is measured at its center and at four or eight other sites whose positions are defined with respect to the primary flat or notch or other index mark. Two of the sites fall along a diameter and two along a second diameter, perpendicular to the first.

6.2 The thickness measured at the center of the wafer is generally taken as the nominal thickness of the wafer.

6.3 The maximum difference between any two of the five-thickness measurements is taken as the total thickness variation of the wafer.

7 Apparatus

7.1 Thickness Gage, suitable for measuring the thickness of semiconductor wafers over the anticipated range. The least count of the instrument shall be no larger than 0.0001 in. or 2 μm. The contact area for contact-type gages shall not exceed 0.003 in.² or (2 mm)². For contactless gages, the probed area shall not exceed 0.2 in.² or (129 mm)².

NOTE 2: Thickness ranges for standard silicon wafers are given in SEMI M1. A thickness gage covering the range from 0.005 to 0.050 in. or (0.13 to 1.3 mm) should be adequate for most wafers. A wafer with thickness outside this range may be mechanically accommodated by the gage; an appropriate offset is then applied to the value indicated by the gage.

7.2 Fixture, to support the wafer during thickness measurements. The fixture shall include provision for rotating the wafer about its center in the wafer plane and sufficient markings to facilitate positioning of the wafer so that thickness measurements can be made within 0.08 in. (2 mm) of each specified measurement site (see Figure 1).

7.3 Clean Facility — A controlled-environment work station satisfying the Class 7 requirements of ISO 14644-1.

7.4 Scribe — A scribe or other means for producing an index mark on the wafer, if required.

7.5.1 Thickness Calibration Standards — A set of thickness standards, traceable to the National Institute for Standards and Technology, whose nominal thickness values range from 0.005 to 0.050 in. or (0.13 to 1.27 mm) in steps of 0.005 ± 0.001 in. or (0.13 ± 0.025 mm).

7.5.2 Standard thickness values shall be known to within 10 μm or (0.25 μm).

7.5.2.1 For contactless gages, the calibration standards shall have an area of at least 0.25 in.² or (1.6 cm²) with a minimum side length of 0.5 in. or (13 mm). The thickness variation must be less than 0.0001 in. or (2 μm, as determined for any two points 1 in. or (25 mm) apart. For further details, see Fed. Spec. GGG-G-15C.

7.5.2.3 For contact gages, normally available standards of 0.36 by 1.12 in. or (9.1 by 28.4 mm) shall be acceptable.

8 Sampling

8.1 This test method is intended to be used on a sampling basis. Procedures for selecting the sample from each lot of wafers to be tested shall be agreed upon by the parties to the test, as shall the definition of what constitutes a lot.

9 Test Specimen

9.1 Generally, the specimen wafer does not contain has a primary flat or a notch, such as is specified in SEMI M1, to indicate the orientation on the measuring fixture.

NOTE 3: If the wafer does not have such a fiducial, a scribe may be used to place an index mark at a point near the periphery of the back surface of the wafer.
9.2 Ensure that the specimen has an identifiable surface to enable interlaboratory location of measurement sites.

9.2.1 If the front and back specimen surfaces are different in appearance, specify the front surface.

9.2.2 If both surfaces are identical, an indication or mark identifying the surface to be measured, which will not interfere with the measurement, shall be placed on the surface of the specimen taken as the back surface.

NOTE 3: Small adhesive labels and certain felt-marking pens have been found satisfactory for this purpose.

10 Calibration

10.1 From the set of calibration standards, select a standard with a thickness within 0.005 in. or (0.13 mm) of the nominal thickness value of the specimen wafer.

10.1.1 Calibrate every day for production testing and for each set of specimens for referee tests.

10.2 Following the manufacturer's instructions, adjust the thickness gage reading so that the measured value of the calibration standard is within 0.0001 in. or (2 μm) of its stated value.

NOTE 4: It is recommended that contactless gages use NIST-traceable calibration standards made of the same semiconductor material as the specimen, rather than metal standards.

10.3 Without further adjustment, measure and record the thickness values of the calibration standards 0.005 in. or (0.13 mm) larger and smaller than the standard used in 10.2 (see Figure 2).

Figure 1 Figure 2

Required Thickness Gage Calibration Characteristics

10.3.1 If the recorded values are not within 0.0001 in. or (2 μm) of their respective standard values, consider the gage unsatisfactory for the purposes of these test methods.

NOTE 5: Consult the manufacturer's instructions for the gage to make sure that the difficulty is not one of procedure.
11 Procedure

11.1 Select the wafer to be tested and load it in the fixture with the front surface up and the perpendicular bisector of the primary flat, notch, or other index mark points along the vertical axis (see Figures 2 and 3).

NOTE: Site 1 is at the nominal wafer center. Sites 2 and 4 are on the reference diameter that is 30 deg from the perpendicular bisector of the primary flat. Sites 3 and 5 are on the diameter that is perpendicular to the reference diameter.

Figure 2
Sites for Thickness Measurement on Flatted Wafers

Figure 3
Sites for Thickness Measurement on Notched Wafers. R is nominal radius.

11.2 In all cases, locate Site 1 at the nominal wafer center.

11.2.1 For flatted wafers, locate Sites 2 and 4, 6 mm from the wafer edge on the reference diameter that is 30 deg from the perpendicular bisector of the primary flat, and locate Sites 3 and 5, 6 mm from the wafer edge on the diameter that is perpendicular to the reference diameter (See Figure 2).

11.2.2 For notched wafers, locate Sites 2 and 4, 6 mm from the wafer edge on the reference diameter that bisects the notch; locate Sites 3 and 5, 6 mm from the wafer edge on the diameter that is perpendicular to the reference diameter; locate Sites 6 and 8 at half the nominal radius on the reference diameter; and locate Sites 7 and 9 at half the nominal radius on the diameter that is perpendicular to the reference diameter (See Figure 3).

11.3 Position the probes of the thickness gage within 0.08 in. (2 mm) of the center of the wafer (Site 1, see Figure 1). Measure the thickness at this position to the nearest 0.0001 in. or 2 μm and record the value as the center point thickness, \( t_1 \).

11.4 Move the wafer so that the probes of the thickness gage are positioned within 0.08 in. (2 mm) of Site 2 (see Figure 1). Measure the thickness at this position to the nearest 0.0001 in. or 2 μm and record the values as \( t_2 \).

11.5 Rotate the wafer clockwise 90 deg so that the probes of the thickness gage are positioned within 0.08 in. (2 mm) of Site 3 (see Figure 1). Measure the thickness at this position to the nearest 0.0001 in. or 2 μm and record the value as \( t_3 \).

11.6 Again rotate the wafer clockwise 90 deg so that the probes of the thickness gage are positioned within 0.08 in. (2 mm) of Site 4 (see Figure 1). Measure the thickness at this position to the nearest 0.0001 in. or 2 μm and record the value as \( t_4 \).
11.611.7 Again rotate the wafer clockwise 90 deg so that the probes of the thickness gage are positioned within 0.08 in. (2 mm) of Site 5. Measure the thickness at this position to the nearest 0.0001 in. or 2 μm and record the value as \(t_5\). If this is the last Site to be measured, go to §12, Calculation.

11.8 For wafers with a nine-point pattern, move the wafer so that the probes of the thickness gage are positioned within 0.08 in. (2 mm) of Site 6. Measure the thickness at this position to the nearest 0.0001 in. or 2 μm and record the values as \(t_6\).

11.9 Again rotate the wafer clockwise 90 deg so that the probes of the thickness gage are positioned within 0.08 in. (2 mm) of Site 7. Measure the thickness at this position to the nearest 0.0001 in. or 2 μm and record the values as \(t_7\).

11.10 Again rotate the wafer clockwise 90 deg so that the probes of the thickness gage are positioned within 0.08 in. (2 mm) of Site 8. Measure the thickness at this position to the nearest 0.0001 in. or 2 μm and record the values as \(t_8\).

11.11 Rotate the wafer clockwise 90 deg so that the probes of the thickness gage are positioned within 0.08 in. (2 mm) of Site 9. Measure the thickness at this position to the nearest 0.0001 in. or 2 μm and record the value as \(t_9\).

12 -Calculation

12.1 Subtract the smallest from the largest measured value of thickness and record this difference as the total thickness variation.

13 Report

13.1 Report the following information:

13.1.1 Date of test,

13.1.2 Identification of operator,

13.1.3 Type and model gage used,

13.1.4 Lot identification, including nominal diameter and thickness,

13.1.5 Number of points measured on each wafer (5 or 9)

13.1.6 Description of sampling plan, and

13.1.7 For each wafer measured:

13.1.7.1 Center-point thickness, in. (μm),

13.1.7.2 Total thickness variation, in. (μm), and

13.1.8 Calibration data, standard thickness value, and measured values for those standards (see ¶¶10.1 and 0.8 respectively).

14 Precision

14.1 Contact-Type Gages

14.1.1 An interlaboratory evaluation of this test method was conducted in which each of five laboratories made measurements on 15 flatted wafers nominally 2 in. (51 mm) in diameter with center-point thickness in the range from 0.0049 to 0.0172 in. (124 to 437 μm), inclusive, and average thickness in the range from 0.0048 to 0.0170 in. (122 to 432 μm), inclusive.

14.1.2 Although the experimental measurement procedure was as described in this test method, the measurements were made at different locations on the wafer, and quantities different from those prescribed
in this test method were calculated. The original data were reanalyzed to establish the precision of the determination of the quantities specified in ¶13.1.7. The change in measurement locations is not expected to affect the precision of this test method.

14.1.3 The variabilities of the measured center-point thicknesses were nearly independent of the magnitude of the wafer thickness. For this situation, the sample standard deviation provides a measure of the variability.

14.1.3.1 If the mean sample standard deviation of the measurements of center-point thickness is taken as a measure of the standard deviation of the pooled data, the interlaboratory precision (two sample standard deviations) of this measurement is estimated to be ±0.00050 in. (±12.6 μm).

14.1.4 The variabilities of the total thickness variation over the ranges from 0.00011 to about 0.0018 in. (2.8 to 46 μm) and from 0.00005 to 0.0006 in. (1.3 to 15 μm), respectively, were reasonably linear functions of the average value (though with a small offset and wide scatter). For this situation, the standard deviation relative to the mean value provides a measure of the variability.

14.1.4.1 If the mean relative sample standard deviation of measurement of total thickness variation is taken as a measure of the standard deviation of the normalized, pooled data, the interlaboratory precision (two sample standard deviations) of this measurement is estimated to be ±60%.

14.2 Contactless Gages

14.2.1 An interlaboratory evaluation of this test method was conducted in which each of nine laboratories made measurements on 13 flatted wafers that had center point thicknesses in the range from 0.00652 to 0.03059 in. or (165 to 772 μm). The wafers used had nominal diameters from 2 in. to 125 mm as specified in SEMI M1. Wafers with sawn, etched, and polished surfaces were included. None of the wafers in this evaluation had been used in the earlier test of contact-type gages.

14.2.2 The variability of the measured center-point thickness was a reasonably linear function of the thickness magnitude and independent of wafer surface finish and diameter. The two-sigma standard deviation of the center-point thickness measurement is estimated from these data as follows:

\[
\text{two-sigma standard deviation} = 0.0036 \times \text{thickness} + \text{constant}
\]

where:

\[
\text{constant} = 0.09 \text{ if the thickness and two-sigma standard deviation are in mils (0.001 in.) and constant} = 2.3 \text{ if the thickness and two-sigma standard deviation are in micrometers.}
\]

14.3 The variability of the measured total thickness variation (TTV) was independent of both average TTV and wafer thickness. Over the ranges of wafer thickness given in ¶14.2.1 and TTV less than 0.0012 in. (30.6 μm) the two-sigma standard deviation of measured TTV was less than 0.0002 in. (5.1 μm).

15 Bias

15.1 Because calibration standards are used in conducting this test, the bias encountered is expected to be small.

16 Keywords

16.1 semiconductor; silicon; thickness; thickness variation; total thickness variation; wafer

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