Designation: F 533 – 02

Standard Test Method for Thickness and Thickness Variation of Silicon Wafers [1]

This standard is issued under the fixed designation F 533; 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.

INTRODUCTION

When this test method 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 Test Method F 1530.

Despite the fact that this test method is not commonly used in its present form, it embodies all the basic elements of this test method and a simple analysis of data. Thus, it provides useful guidance in the fundamentals and appplication of differential non-contact wafer thickness measurements.

1. Scope

1.1 This test method [2] covers measurement of the thickness of silicon wafers, polished or unpolished, and estimation of the variation in thickness across the wafer.

1.2 This test method is intended primarily for use with wafers that meet the dimension and tolerance requirements of SEMI Specifications M 1. However, it can be applied to circular silicon, wafers or substrates of any diameter and thickness that can be handled without breaking.

1.3 This test method is suitable for both contact and contactless gaging equipment. Precision statements have been established for each.

1.4 The values stated in inch-pound units are to be regarded as standard. The values in parentheses are for information only.

1.5 *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 1530 Test Method for Measuring Flatness, Thickness and Thickness Variation on Silicon Wafers by Automated Noncontact Scanning [3]

2.2 *SEMI Standard:*

Specifications M 1, for Polished Monocrystalline Silicon Wafers [4]

2.3 *Federal Standards:*

Fed. Std. No. 209B Clean Room and Work Station Requirements, Controlled Environment [5]

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

3. Terminology

3.1 *Definitions:*

3.1.1 *back surface—of a semiconductor wafer*, the exposed surface opposite to that upon which active semiconductor devices have been or will be fabricated.

3.1.2 *front surface—of a semiconductor wafer*, the exposed surface upon which active semiconductor devices have been or will be fabricated.

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

3.1.4 *total thickness variation, TTV—of a semiconductor wafer*, the difference between the maximum and minimum values of the thickness of the wafer.

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[1] This test method is under the jurisdiction of ASTM Committee F01 on Electronics and is the direct responsibility of Subcommittee F01.06 on Electrical and Optical Measurement.

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[2] DIN 50441/1 is an equivalent method. It is the responsibility of DIN Committee NMP 221, with which Committee F01 maintains close liaison. DIN 50441/1. Determinaton of the Geometric Dimensions of Semiconductor Slices; Measurement of Thickness, available from Beuth Verlag, Gmbh, Burggrafenstrasse 4-10, D-1000 Berlin 30, Federal Republic of Germany.

[3] *Annual Book of ASTM Standards*, Vol 10.05.

[4] Available from Semiconductor Equipment and Materials International, 805 East Middlefield Rd., Mountain View, CA 94043.

[5] Available from GSA Business Service Centers in Boston, New York, Atlanta, Chicago, Kansas City, Mo., Fort Worth, Denver, San Francisco, Los Angeles, and Seattle.

[6] Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

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4. Summary of Test Method

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

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

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

5. Significance and Use

5.1 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, will aid in determining whether or not wafers from that lot are acceptable for the intended processing steps.

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

5.3 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.

5.4 This test method is intended for use for materials acceptance and process control purposes. This test method may be applied at any point during the processing of unpolished wafers into polished wafers or substrates.

6. Inferferences

6.1 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.

6.2 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.

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} (2 mm^2). For contactless gages, the probed area shall not exceed 0.2 in.^{2} (129 mm^2).

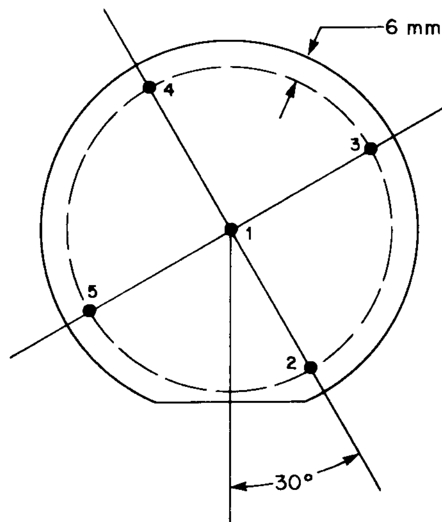
NOTE 1—Thickness ranges for standard silicon wafers are given in SEMI Specifications M 1. A thickness gage covering the range from 0.005 to 0.050 in. (0.13 to 1.3 mm) should be adequate for most nonstandard wafers.

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 Fig. 1).

7.3 *Clean Facility*—A controlled-environment work station satisfying the Class 10 000 requirements of Fed. Std. No. 209B.

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

7.5 *Thickness Calibration Standards*—A set of thickness standards, traceable to the National Bureau of Standards, whose nominal thickness values range from 0.005 to 0.050 in. (0.13 to 1.27 mm) in steps of 0.005 ± 0.001 in. (0.13 ± 0.025 mm).



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

FIG. 1 Sites for Thickness Measurement

7.5.1 Standard thickness values shall be known to within 10 µin. (0.25 µm).

7.5.2 For contactless gages, the calibration standards shall have an area of at least 0.25 in.^{2} (1.6 cm^2) with a minimum side length of 0.5 in. (13 mm). The thickness variation must be less than 0.0001 in., or 2 µm, as determined for any two points 1 in. (25 mm) apart. See Note 5.

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

NOTE 2—Further details are available in Fed. Spec. GGG-G-15C.

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 between the parties to the test, as shall the definition of what constitutes a lot.

9. Test Specimen

9.1 If the specimen wafer does not contain reference flats, such as those specified in SEMI Specifications M 1, use the scribe 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 specimen.

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. (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. (2 µm) of its stated value.

NOTE 4—It is recommended that contactless thickness gages use 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. (0.13 mm) larger and smaller than the standard used in 10.2 (see Fig. 2).

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

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.

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

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

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

11.5 Again rotate the wafer clockwise 90° so that the probes of the thickness gage are positioned within 0.08 in. (2 mm) of Site 4 (see Fig. 1). Measure the thickness at this position to the nearest 0.0001 in. or 2 µm and record the value as t_4.

11.6 Again rotate the wafer clockwise 90° so that the probes of the thickness gage are positioned within 0.08 in. (2 mm) of Site 5 (see Fig. 1). Measure the thickness at this position to the nearest 0.0001 in. or 2 µm and record the value as t_5.

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 of thickness gage used,

13.1.4 Lot identification, including nominal diameter and thickness,

13.1.5 Description of sampling plan,

13.1.6 For each wafer measured:

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

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

13.1.7 Calibration data, standard thickness value, and measured values for those standards (10.1 and 10.3, 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 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 432µ m), 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 13.1.6. 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

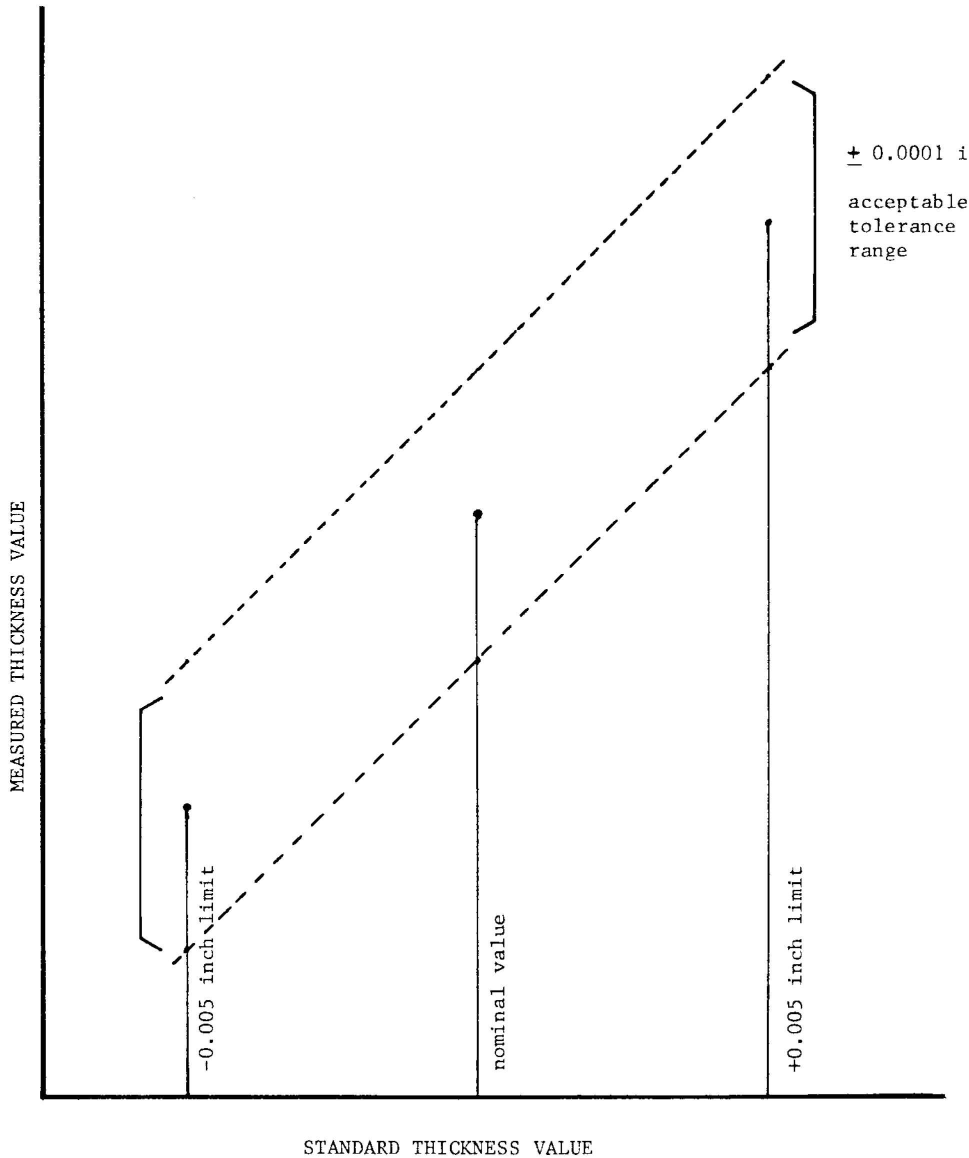


FIG. 2 Required Thickness Gage Calibration Characteristics

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 variability 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 wafers that had center point thicknesses in the range from 0.00652 to 0.03059 in. (165 to 772 μm). The wafers used had nominal diameters from 2 in. to 125 mm as specified in SEMI Specifications M 1. 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:

$$(\text{two} - \text{sigma standard deviation}) = 0.0036 \ (\text{thickness}) + (\text{constant})$$

where:

constant = 0.09 if the thickness and two-sigma standard deviation are in mils (0.001 in.) and

constant = 2.3 if the thickness and two-sigma standard deviation are in micrometres.

14.2.3 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. (5.3 µm).

15. Keywords

15.1 semiconductor; silicon; thickness; thickness variation; total thickness variation; wafer

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