Designation: F 534 – 02

Standard Test Method for Bow of Silicon Wafers[1]

This standard is issued under the fixed designation F 534; 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 bow and warp gages employing manual 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 semiconductior 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 1390.

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 application of differential non-contact wafer bow measurements.

1. Scope

1.1 This test method covers determination of the average amount of bow of nominally circular silicon wafers, polished or unpolished, in the free (non-clamped) condition.

1.2 This test method is intended primarily for use with wafers that meet the dimension and tolerance requirements of SEMI Specifications M1.

1.3 This test method can also be applied to circular wafers of other semiconducting materials, such as gallium arsenide, or electronic substrate materials, such as sapphire or gadolinium gallium garnet, that have a diameter of 25 mm or greater, a thickness of 0.18 mm or greater, and a ratio of diameter to thickness up to 250. Wafers to be tested may have one or more fiducial flats provided they are located in such a way that the slice can be centered on the support pedestals (see 7.1.2) without falling off.

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

1.5 *This standard does not purport to address 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 533 Test Method for Thickness and Thickness Variation of Silicon Slices[2]

F 657 Test Method for Measuring Warp and Total Thickness Variation on Silicon Wafers by Noncontact Scanning[2]

F 1390 Test Method for Measuring Warp on Silicon Wafers by Automated Noncontact Scanning [2]

2.2 *SEMI Standard:*

M1 Specifications for Polished Monocrystalline Silicon Slices[3]

2.3 *Federal Standard:*

Fed. Std. No. 209B Controlled Environment Clean Room and Work Station Requirements[4]

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 *bow—of a semiconductor wafer,* the deviation of the center point of the median surface of a free, unclamped wafer from a median-surface reference plane established by three points equally spaced on a circle with diameter a specified amount less than the nominal diameter of the wafer.

3.1.2.1 *Discussion*—If the median surface of a free, unclamped wafer has a curvature that is everythere the same, bow is a measure of its concave or convex deformation, independent of any thickness variation that may be present.

---

[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.

Current edition approved Jan. 10, 2002. Published March 2002. Originally published as F534 – 77 T. Last previous edition F534 – 97.

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

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

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

Positive values of bow denote a convex (mounded) median surface when the wafer is positioned with its front surface up. Conversely, negative values of bow denote a concave (dished) median surface when the wafer is positioned with its front surface up. Although bow may be caused by unequal stresses on the two exposed surfaces of the wafer, it cannot be determined from measurements on a single exposed surface.

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

3.1.4 *median surface—of a semiconductor wafer,* the locus of points in the wafer equidistant between the front and back surfaces.

4. Summary of Test Method

4.1 The wafer is supported, front surface upward, on three points equally spaced on the circumference of a circle whose diameter is slightly smaller than the wafer diameter. The distance between the center point of the front surface and the reference plane formed by the three supporting points is measured with a lightly loaded indicator. The wafer is turned over and the measurement is repeated with the wafer supported at three points directly opposite (through the thickness of the wafer) from the original three points. An average value of the bow of the wafer is calculated from these two measurements.

5. Significance and Use

5.1 The flatness of a wafer surface must be controlled to suit the requirements of fixtures and equipment used in microelectronic processing. Bow is a contributor to the lack of surface flatness of a wafer. Although moderate amounts of bow can be removed during processing by vacuum chucking or by clamping the wafer, excessive amounts of bow cannot be removed in this fashion.

5.2 In particular, photolithographic processes are adversely affected if the front surface of the wafer is not flat.

5.3 This test method is intended for use for materials acceptance and process control purposes. Estimates of the magnitude of bow 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. Measurements made on wafers following a particular processing step will aid in determining the amount of bow introduced by that processing step.

5.4 Bow is only one of several geometrical properties that affect surface flatness. Procedures for determining other such properties are given in Test Method F 533 and Test Method F 657.

6. Interferences

6.1 Since the determination of bow by this test method is based on measurements at a limited number of discrete points, geometrical variations in other parts of the wafer may not be detected.

6.2 Localized thickness deviations in the areas of pedestal contact or of the wafer center may result in erroneous readings. Such localized thickness deviations may be caused by surface defects such as chips, contaminants, mounds, pits, saw steps, waves, and so forth.

6.3 If the curvature of the median surface is not everywhere in the same direction, the deformation of the median surface is not characterized by bow, and the quantity measured by this technique may or may not provide an indication of the deviation of the median surface from a plane (see Test Method F 657).

7. Apparatus

7.1 *Measuring Jig*, consisting of a stainless-steel base and three support pedestals; one jig is required for use with each diameter of wafer to be measured.

7.1.1 The three support pedestals shall be equally spaced (within ±0.005 in. (±0.13 mm)) on the circumference of a circle whose diameter is 0.025 ± 0.005 in. (6.35 ± 0.13 mm) less than the value of the nominal wafer diameter.

7.1.2 Each of the three support pedestals shall have a diameter of 0.125 to 0.250 in. (3.18 to 6.35 mm), inclusive, and project 0.0625 in. (1.59 mm) or more above the base. The height of all three pedestals must be equal to within 0.010 in. (0.25 mm). The top of each pedestal, which serves as the bearing surface, shall be smooth, rounded, and polished, with a maximum surface roughness of 10 µin. (0.25 µm). The radius of curvature of the top surface shall be equal to one half of the pedestal diameter.

7.1.3 Auxiliary pedestals, or guide pins, shall be spaced just outside the nominal wafer diameter to serve as guides for centering the wafer by eye. They shall be as high as, but no more than 0.015 in. (0.38 mm) higher than, the three support pedestals.

7.2 *Indicator and Table*—A displacement-measuring device, mounted rigidly above a smooth, flat table surface with provision for centering and clamping the measuring jig under the stylus of the indicator. The indicator shall meet the following requirements:

7.2.1 *Direction of Travel*—The stylus of the indicator shall move up and down in a direction within 1° of the perpendicular to the reference plane formed by the three pedestals.

7.2.2 *Vertical Adjustment*—The indicator shall be adjustable in the vertical direction to accommodate wafers of different thickness.

7.2.3 *Range*—The indicator shall have a total range between 0.006 and 0.010 in. (150 and 250 µm), inclusive.

7.2.4 *Resolution*—The least count of the indicator shall be 50 µin. or 1 µm.

7.2.5 *Linearity*—The readings shall be linear over the entire range of the indicator within 1 % of the full-scale reading.

7.2.6 *Measuring Force*—exerted by the stylus over the entire range of the indicator, as determined by a spring-tension force gage, shall be less than 28.4 gf (278 mN).

7.2.7 *Stylus Diameter*—The tip of the stylus shall be hemispherical, with a radius between 0.062 and 0.50 in. (1.57 and 12.7 mm), inclusive.

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

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

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 If the specimen wafer does not contain reference flats, such as those specified in SEMI Specifications M 1, the scribe shall be used to place an index mark at a point near the back surface of the wafer.

10. Preparation of Apparatus

10.1 Set up the indicator and jig in the clean facility.

10.2 Orient the measuring jig under the indicator so that the indicator is centered on the support circle (see 7.1.1) and so that two of the three support pedestals are toward the operator. Clamp the jig in place.

11. Procedure

11.1 Adjust the height of the indicator with respect to the jig so that readings made on both sides of the selected specimen will fall within the range of the indicator. Once the indicator is positioned, do not reposition it until all measurements on a particular wafer are completed.

11.2 Center the specimen on the jig, front surface up.

11.2.1 For a wafer with one or more fiducial flats, align the wafer so that the primary flat is closest to the operator and parallel with the line joining the two support pedestals nearest the operator.

11.2.2 For a wafer with an index mark, align the wafer so that the wafer radius at the index mark is perpendicular to the line joining the two support pedestals nearest the operator.

11.3 Observe and record as F_1 the reading of the indicator at this position to the nearest 50 µin. or 1 µm. If a center-zero indicator is employed, be sure to record the sign associated with each reading.

11.4 Turn the specimen over and align the wafer on the jig as in 11.2 and 11.2.1, or 11.2.2, as appropriate, with the back surface up.

11.5 Observe and record as B_1 the reading of the indicator at this position.

12. Calculation

12.1 Calculate the bow, in. (µm) as follows:

$$\text{bow} = (F_1 - B_1)/2$$

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 Description of sampling plan, and

13.1.6 Average bow of each slice measured, in. (µm).

14. Precision [5]

14.1 An interlaboratory evaluation of this test method was conducted in which each of five laboratories measured bow on 14 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. The bow of these wafers ranged from about 0.000 05 to 0.0028 in. (1.3 to 71 µm).

14.2 The variability of the calculated bow was a reasonably linear function of the average bow (though with a small offset and wide scatter). If the mean sample standard deviation relative to the average value is taken as a measure of the standard deviation of the normalized pooled data, the interlaboratory precision (two sample standard deviations) is ±50 %.

---

[5] Supporting data are available from ASTM Headquarters, 100 Barr Harbor Dr., West Conshohocken, PA 19428. Request RR: F01–1003.