Designation: F 928 – 93 (Reapproved 1999)

Standard Test Methods for Edge Contour of Circular Semiconductor Wafers and Rigid Disk Substrates[1]

This standard is issued under the fixed designation F 928; 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 These test methods[2] provide means for examining the edge contour of circular wafers of silicon, gallium arsenide, and other electronic materials, and determining fit to limits of contour specified by a template that defines a permitted zone through which the contour must pass. Principal application of such a template is intended for, but not limited to, wafers that have been deliberately edge shaped.

1.2 Two test methods are described. One is destructive and is limited to inspection of discrete points on the periphery, including flats. The contour of deliberately edge-shaped wafers may not be uniform around the entire periphery, and thus the discrete location(s) may or may not be representative of the entire periphery. The other test method is nondestructive and suitable for inspection of all points on the wafers periphery except flats.

1.3 The nondestructive test method may also be applied to the examination of the edge contour of the outer periphery of substrates for rigid disks used for magnetic storage of data.

NOTE 1—Reference to wafers in the remainder of this standard shall be interpreted to include substrates for rigid disks unless the phrase "of electronic materials" is also included in the context.

1.4 The values stated in SI 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 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:*

E 122 Practice for Choice of Sample Size to Estimate a Measure of Quality for a Lot or Process[3]

2.2 *Military Standard:*

MIL-STD-105D Sampling Procedures and Tables for Inspection by Attributes[4]

2.3 *SEMI Standards:*

SEMI M1, Specifications for Polished Monocrystalline Silicon Wafers[5]

SEMI M9, Specifications for Polished Monocrystalline Gallium Arsenide Slices[5]

3. Summary of Test Methods

3.1 Both test methods employ optical means to project a shadow of the edge contour at substantial magnification on a screen. In applying Method A (destructive) the sample wafer is cleaved or broken along a diameter. A sharply focused image of the cross section of the wafer is obtained over a sufficiently large region near the edge with the aid of an optical comparator or projection microscope. In Method B (nondestructive) the unbroken wafer is back lighted with collimated (parallel) light such that a sharply defined shadow of the wafer edge is projected on a screen. In this test method the wafer is not altered in any way.

3.2 By either test method, the contour of the wafer edge profile image is compared to a template that has been mounted or projected on the screen. The template defines a permitted zone through which the edge contour must pass.

4. Significance and Use

4.1 The edges of circular wafers of electronic materials are frequently required to be shaped after cutting the wafers from the ingot. Contouring the wafer edge reduces the incidence of chipping and minimizes epitaxial edge crown and photoresist edge bead during subsequent processing of the wafer. Similarly, edges of rigid disk substrates are frequently edge shaped.

4.2 The test methods described here provide means to determine that the wafer edge contour is appropriate to meet specifications, such as SEMI M1 or SEMI M9, which are intended to provide wafers avoiding the difficulties enumerated above.

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[1] These test methods are under the jurisdiction of ASTM Committee F-1 on Electronics and are the direct responsibility of Subcommittee F01.06 on Silicon Materials and Process Control.

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[2] DIN 50441/2 is equivalent to Method B of this standard. It is the responsibility of DIN Committee NMP 221 with which Committee F-1 maintains close technical liaison. DIN 50441/2, Measurement of the Geometric Dimensions of Semiconductor Slices; Testing of Edge Rounding, is available from Beuth Verlag GmbH, Burggrafenstrasse 4-10, D-1000 Berlin 30, FRG.

[3] *Annual Book of ASTM Standards*, Vol 14.02.

[4] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

[5] Available from the Semiconductor Equipment and Materials International, 805 East Middlefield Road, Mountain View, CA 94043.

4.3 Method A is recommended for examining the edge profile of flatted regions of the wafer.

4.4 Method A is best suited for referee purposes. Method B is appropriate for routine process monitoring such as alignment of wafer edge grinders, routine quality control and incoming/outgoing inspection purposes. In view of the uncertainty of precisely locating the intersection of the contour and the wafer surface when carrying out Method B, use of this method for commercial transactions is not recommended unless the parties to the test establish the degree of correlation that can be obtained.

4.5 Method B is suitable for examining the outer circumference or rigid disk substrates; metallic rigid disk substrates cannot conveniently be cleaved.

5. Interferences

5.1 In Method B, the profile of the parallel surfaces of the wafer may not be sharply focused at distances exceeding approximately 0.5 mm (0.020 in.) from the extreme wafer edge toward the wafer center. This uncertainty in the wafer surface location may cause inaccuracy in positioning the wafer with respect to template lines. It may also make it difficult to determine whether the wafer edge profile lies within the permitted zone at point B of the template. These difficulties can be overcome by aligning a straight edge to the wafer surface by direct contact, observing the shadow extension in the sharply focused region, and extrapolating the straight line edge of the template reference. In applying this technique, exercise care to avoid damaging or contaminating the wafer surface.

5.1.1 This limitation renders Method B unsuitable for determining the distance between the front and back wafer surfaces. The edge contours near the front and back surfaces of the wafer must be inspected separately.

5.2 In Method B, attempting to view the complete wafer periphery, except flats, through wafer rotation necessitates frequent focus adjustment due to variations in wafer roundness and fixturing precision, including wafer centering.

5.3 By either test method, any foreign material such as large particles or high spots on the wafer surface in the light path will present a false edge contour by masking the true contour shape.

5.4 It is not always feasible to provide a uniform radius or bevel to the edges of wafers because silicon, gallium arsenide, and many other electronic materials as well as glass disk substrates are both hard and brittle. Wear of grinding tools, process variations, and the presence of flats on the circumference of wafers cause practical contours to have varying shapes. For this reason, templates are used that define an allowed range.

5.5 If a television system is used, the user is cautioned that distortions in the horizontal and vertical deflections may occur. (See 9.2.)

6. Apparatus

6.1 For Method A, an optical comparator or projection microscope capable of 100× magnification with viewing screen large enough to permit display of an area 1 by 1 mm (0.04 by 0.04 in.).

6.2 For Method B, a collimated light source (coherent or incoherent) and a television system, consisting of a camera, lenses to give 100× magnification and TV monitor capable of displaying a 1 by 1-mm (0.04 by 0.04-in.) area.

NOTE 2—An adjustable camera mount, slice holding fixture, or lens adjustment is desirable for sharp focusing.

6.3 *Fixture*, for holding the wafer to be tested. The fixture must provide means for positioning the wafer such that the plane of the surface of the wafer is parallel to the viewing direction. The fixture should be arranged in such a way that its position and orientation in a plan perpendicular to the viewing direction can be adjusted conveniently, or alternatively, the template can be moved. Optionally, for Method B, the fixture can provide means for rotation of the wafer about its axis of symmetry. The design of the fixture for Method B should be such that the wafer may be loaded, held in position, and unloaded with minimum risk of contamination or damage to the wafer.

6.4 *Template*, having transparent regions defining the area through which the contour of the edge of the wafer must pass and a semi-transparent region bounding the space. An example of a template is given in Fig. 1. Instructions for constructing templates are given in Section 10.

6.5 *Gage Block or Precision Rod*, with dimensions approximately the same as the thickness of the wafer to be tested and accurately known for use in establishing the magnification of the apparatus.

6.6 *Rule*, 150 mm (6 in.) long with scale gradations of 0.5 mm (0.02 in.) or less.

7. Sampling

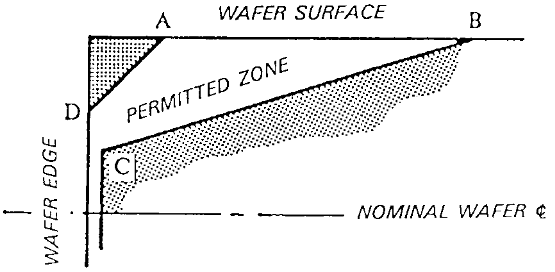
7.1 Unless otherwise specified, Practice E 122 shall be used. When so specified, appropriate sample sizes shall be selected from each lot in accordance with MIL-STD-105D. Inspection levels shall be agreed upon between the supplier and purchaser.

7.2 The number and location of the test points on the periphery of each wafer shall be agreed upon between the supplier and purchaser.

8. Specimen Preparation

8.1 For Method A, cleave or fracture the wafer along a diameter.

NOTE 3—This may be conveniently accomplished by positioning the wafer over a small diameter rod and pressing downward on both sides. (Alignment by eye is sufficient.) If required by the sampling plan, cleave additional pieces along the edge of the wafer.



NOTE 1—Only half is used to emphasize that these methods are not intended for measurement of thickness.

FIG. 1 Template Showing One Half of Water Cross Section

9. Determination of Magnification Factor

9.1 For Method A, adjust the comparator or microscope to the magnification to be used for the test. Using a gage block or precision rod of accurately known dimensions, follow the comparator or microscope manufacturer's instructions to establish object-to-image magnification to three significant figures.

9.2 For Method B, position a gage block on the fixture (see 6.3) such that the known dimension can be measured in the vertical direction on the screen using an appropriate rule. Measure the image vertical dimension to the nearest 0.02 in. (0.5 mm) and adjust magnification until the desired magnification for the test is obtained. Reposition the gage block such that the screen image of the known dimension can be measured in the horizontal direction. Adjust magnification to give the same value as the vertical.

NOTE 4—Television systems may have distortions in either vertical or horizontal deflection circuits caused by improper settings of vertical or horizontal size or linearity. If magnification in both horizontal and vertical directions is not equal to the desired resolution, recalibration of the television system may be required.

10. Preparation of Template

10.1 Multiply each of the chosen or specified template coordinates by the magnification factor.

10.2 Prepare on transparent material a full-scale template having the dimensions calculated in 10.1 with a projected image accuracy of ±0.5 mm (0.020 in.).

10.3 Mount the template on the screen such that the images of the wafer surfaces are parallel with the corresponding template lines. Alternatively, the template can be electronically generated or projected by the optical system.

11. Procedure

11.1 *Method A;*

11.1.1 Mount the test specimen in the fixture with the cleaved or broken surface of the wafer facing the objective lens and approximately perpendicular to the viewing direction.

11.1.2 Adjust the comparator focus such that a sharp image of the wafer is seen on the screen.

11.1.3 Position the wafer by appropriate motion of the fixture so that the contour profile image is tangent to the overlay template at both the edge and front surface.

11.1.4 Determine whether or not the contour of the edge of the wafer between the points of tangency lies entirely within the permitted zone of the template. If the specification has other requirements, such as those relating to the specific shape of the profile, inspect the profile image for adherence to such conditions.

11.1.5 Repeat 11.1.3 and 11.1.4 with the opposite side of the contour profile image tangent to the overlay template at both the edge and the back surface.

11.1.6 If the test specimen includes the full diameter, reverse the fixture on the comparator table to permit the edge contour at the opposite end of the wafer diameter to be seen on the screen and repeat 11.1.2-11.1.5.

11.1.7 If additional parts of the wafer were prepared as test specimens, repeat 11.1.1-11.1.5 for each.

11.1.8 Record as "passed" those wafers for which all observed edge contours lie entirely within the permitted zone and which meet all other specification requirements.

11.2 *Method B*:

11.2.1 Mount a whole wafer in the fixture.

11.2.2 Adjust the focus of the apparatus to give the sharpest image of the extreme edge of the wafer as seen on the screen.

11.2.3 Position the wafer by appropriate motion of the fixture so that the contour profile image is tangent to the overlay template at both edge and front surface (see 5.1).

11.2.4 Determine whether or not the contour of the edge of the wafer between the points of tangency lies entirely within the permitted zone of the template. If the specification has other requirements, such as those relating to the specific shape of the profile, inspect the profile image for adherence to such conditions.

11.2.5 Rotate the wafer in the fixture while continuously observing the contour. Due to diameter and roundness tolerances, the specimen contour profile image may move with respect to the overlay template while rotating the specimen. Adjust wafer or template position and focus as required to assure proper judgement of template fit. Repeat 11.2.3 and 11.2.4 at specified points in accordance with the sampling plan.

NOTE 5—Flatted regions of the wafer periphery cannot be evaluated by this test method.

11.2.6 Repeat 11.2.3-11.2.5 with the opposite side of the contour profile image tangent to the overlay template at both the edge and the back surface.

11.2.7 Record as "passed" those wafers for which all edge contours examined lie entirely within the permitted zone and which meet all other specification requirements.

12. Report

12.1 Report as a minimum the following information:

12.1.1 Date of test,

12.1.2 Name of person conducting the test,

12.1.3 The lot number of other identification of the material,

12.1.4 Method used, A or B,

12.1.5 Position(s) on the wafer periphery that were examined,

12.1.6 The number of wafers in the lot,

12.1.7 The number of test wafers, and

12.1.8 The number of accepted wafers.

13. Precision and Bias

13.1 Although these test methods do not return a test result, an interlaboratory test was conducted to determine the reliability of the nondestructive Method B when applied to silicon wafers. In this test, a lot of 25, 125-mm diameter, edge profiled, silicon wafers was tested in accordance with Method B against the edge contour template and other requirements of SEMI M1. The wafers were measured by nine different organizations using several types of commercially available edge contour measuring instruments, all of which had similar optical systems. In one case the magnification use was 60× instead of 100× as specified in 6.2.

13.1.1 In no case was a wafer judged to be within the specification requirements by all participants. Only three wafers were judged by all participants to fail, but different participants reported different reasons for failure; the other 22 wafers were judged to pass by some aand to fail by others, but again the same failure mode was not always reported. Most of the difficulty centered around determination of whether or not the edge profile extended further into the wafer than 0.508 mm (the specified location of point B in the SEMI template). Some participants reported failure on the front of the wafer, some on the back, and some reported that failure occurred because the contour passed inside point C. These results confirm the difficulties with locating the wafer surface indicated in 5.1. No participant reported use of the straight-edge technique suggested in 5.1, so the efficacy of that procedure was not evaluated in the test.

13.1.2 The results also confirmed the difficulties with interference from particulate contaminants. Several observers reported protrusions or sharp points on the wafer periphery, but these were not generally reported. Examiniation of the wafers under conditions in which the edge of the wafer could be accessed during the test showed that such apparent protrusions could be removed by blowing or wiping with lens cleaning tissue.

13.1.3 Detailed results of the test are contained in an ASTM Research Report.[6]

13.2 At the recommended magnification, 100×, a dimension of 25 µm (0.001 in.) at the object plane will produce a screen image of 2.5 mm (0.1 in.). The smallest size details of edge contours to be inspected by these test methods are of comparable dimensions.

14. Keywords

14.1 contour; edge contour; gallium arsenide; optical comparator; projection microscope; rigid disk; semiconductor; silicon; wafer

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[6] Supporting data are available from ASTM Headquarters, 100 Barr Harbor Dr. West Conshohocken, PA 19428. Request RR:F01–1008.