

SEMI MF847-0316 (Reapproved 0222) TEST METHOD FOR MEASURING CRYSTALLOGRAPHIC ORIENTATION OF FLATS ON SINGLE CRYSTAL SILICON WAFERS BY X-RAY TECHNIQUES

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NOTICE: Paragraphs entitled ‘NOTE:’ are not an official part of this Standard or Safety Guideline and are not intended to modify or supersede the official Standard or Safety Guideline. These have been supplied by the global technical committee to enhance the usage of the Standard or Safety Guideline.

NOTICE: The section symbol (§) is used to reference a numbered section, paragraph, or header and all subordinate paragraphs, headers, and embedded material (i.e., EXCEPTIONs, lists) therein. The paragraph symbol (¶) is used to reference a particular numbered paragraph and embedded material therein. When duplicated (i.e., §§ and ¶¶) the symbols are used to reference more than one section or paragraph, respectively.

1 Purpose

1.1 The orientation of flats on silicon wafers is an important materials acceptance requirement. The flats are used in semiconductor device processing to provide consistent alignment of device geometries with respect to crystallographic planes and directions.

1.2 The orientation of a wafer flat is the orientation of the surface of the flat (on the edge of the wafer). Flats are usually specified with respect to a low-index plane, such as a (110) plane. In such cases the orientation of the flat may be described in terms of its angular deviation from the low-index plane.

1.3 This Standard covers two test methods for determining flat orientation.

1.4 Either one of these test methods is appropriate for process development and quality assurance applications. Until the interlaboratory precision of these test methods has been determined, it is not recommended that they be used between supplier and customer unless correlation studies are completed satisfactorily.

2 Scope

2.1 This Test Method covers the determination of α , the angular deviation between the crystallographic orientation of the direction perpendicular to the plane of a fiducial flat on a circular silicon wafer, and the specified orientation of the flat in the plane of the wafer surface.

2.2 This Test Method is applicable for wafers with flat length values in the range of those specified for silicon wafers in SEMI M1. It is suitable for use only on wafers with angular deviations in the range from -5° to $+5^\circ$.

2.3 The orientation accuracy achieved by this Test Method depends directly on the accuracy with which the flat surface can be aligned with a reference fence and the accuracy of the orientation of the reference fence with respect to the X-ray beam.

2.4 Two test methods are covered as follows:

- *Test Method A* — X-Ray Edge Diffraction Method, §§ 8.1 through 8.6.
- *Test Method B* — Laue Back Reflection X-Ray Method, §§ 9.1 through 9.5.

2.4.1 Test Method A is nondestructive and is similar to Test Method A of SEMI MF26, except that it uses special wafer holding fixtures to orient the wafer uniquely with respect to the X-ray goniometer. The technique is capable of measuring the crystallographic direction of flats to a greater precision than the Laue back reflection method.

2.4.2 Test Method B is also nondestructive, and is similar to ASTM E82, and to DIN 50433-3, except that it uses ‘instant’ film and special fixturing to orient the flat with respect to the X-ray beam. Although it is simpler and more

rapid, it does not have the precision of Test Method A because it uses less precise and less expensive fixturing and equipment. It produces a permanent film record of the test.

NOTE 1: The Laue photograph may be interpreted to provide information regarding the crystallographic directions of wafer misorientation; however, this is beyond the scope of the present test method. Users desiring to carry out such interpretation should refer to ASTM E82, to DIN 50433-3, or to a standard X-ray textbook.^{1,2} With different wafer holding fixturing, Test Method B is also applicable to determination of the orientation of a wafer surface.

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

NOTICE: SEMI Standards and Safety Guidelines do not purport to address all safety issues associated with their use. It is the responsibility of the users of the Documents to establish appropriate safety and health practices, and determine the applicability of regulatory or other limitations prior to use.

3 Limitations

3.1 The alignment of the flat against the reference fence may be affected by the straightness of the flat. In the unlikely event that the flat profile is convex, the flat orientation may not be unique. More often the flat surface will touch the reference fence along two lines perpendicular to the wafer surface at two points. In this case, the orientation determined is that of the plane through the two lines on the plane perpendicular to the wafer surface that passes through the two points. In the latter cases, the orientation determined is that which is obtained in subsequent processing of the wafer when the alignment is between the flat and a reference fence.

3.2 Misalignment of the various fixtures degrades both the interlaboratory reproducibility and the absolute accuracy of both test methods. The single-instrument repeatability is not degraded provided the fixturing is rigid.

4 Referenced Standards and Documents

4.1 *SEMI Standards and Safety Guidelines*

SEMI M1 — Specification for Polished Single Crystal Silicon Wafers

SEMI M59 — Terminology for Silicon Technology

SEMI MF26 — Test Method for Determining the Orientation of a Semiconductive Single Crystal

4.2 *ANSI Standards*³

ANSI/ASQ Z1.4 — Sampling Procedures and Tables for Inspection by Attributes

4.3 *ASTM Standards*⁴

ASTM E82 — Standard Test Method for Determining the Orientation of a Metal Crystal

ASTM E122 — Standard Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process

4.4 *DIN Standards*⁵

DIN 50433-3 — Testing of Semi-Conducting Inorganic Materials; Determination of the Orientation of Single Crystals by Means of Laue Back Scattering (Withdrawn)

¹ Wood, E. A. *Crystal Orientation Manual*, Columbia University Press, New York, NY, 1963.

² Barret, C. S., and Massalski, T. B. *The Structure of Metals*, 3rd edition, McGraw-Hill, New York, NY, 1966.

³ American National Standards Institute, 25 West 43rd Street, New York, NY 10036, USA; Telephone: +1.212.642.4900, Fax: +1.212.398.0023, <http://www.ansi.org>

⁴ ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA; Telephone: +1.610.832.9585, Fax: +1.610.832.9555, <http://www.astm.org>

⁵ Deutsches Institut für Normung e.V., Available from Beuth Verlag GmbH, Burggrafenstrasse 6, D-10787 Berlin, Germany; Telephone: +49.30.3601.0; Fax: +49.30.2601.1260; <http://www.din.de>

4.5 Other Documents

Code of Federal Regulations, Title 10, Part 20, Standards for Protection Against Radiation⁶

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

5 Terminology

5.1 Terms relating to silicon technology are defined in SEMI M59.

6 Hazards

6.1 These test methods use X-radiation; it is absolutely necessary to avoid personal exposure to X-rays.

6.1.1 It is especially important to keep hands or fingers out of the path of the X-rays and to protect the eyes from scattered secondary radiation.

6.1.2 The use of commercial film badge or dosimeter service is recommended, together with periodic checks of the radiation level at the hand and body positions with a Geiger-Muller counter calibrated with a standard nuclear source.

NOTE 2: The present maximum permissible dose for total body exposure of an individual to external X-radiation of quantum energy less than 3 MeV over an indefinite period is 1.25 R (3.22×10^{-4} C/kg) per calendar quarter (equivalent to 0.6 mR/h [1.5×10^{-7} C/kg·h]) as established in the *Code of Federal Regulations*, Title 10, Part 20. The present maximum permissible dose of hand and forearm exposure under the same conditions is 18.75 R (4.85×10^{-3} C/kg) per calendar quarter (equivalent to 9.3 mR/h [2.4×10^{-6} C/kg·h]). Besides the above stated regulations, various other government and regulatory organizations have their own safety requirements.

6.1.3 It is the responsibility of the user to make sure that the equipment and the conditions under which it is used meet applicable regulations.

7 Sampling

7.1 Unless otherwise specified, ASTM E122 shall be used.

7.2 When so specified, appropriate sample sizes shall be selected from each lot according to ANSI/ASQ Z1.4.

7.3 Inspection levels shall be agreed upon between the parties to the test.

8 Test Method A — X-Ray Edge Diffraction Method

8.1 Summary of Test Method

8.1.1 In this test method a holding fixture that uniquely orients the wafer being tested with respect to its geometric features is used to position the wafers with respect to the X-ray goniometer.

8.1.2 The goniometer is rotated to determine the Bragg angle with respect to the geometric features by X-ray diffraction from the crystallographic planes of the wafer edge, first with the wafer front surface up and then with front surface down.

8.1.3 The average angular deviation is calculated from the goniometer readings.

8.2 Apparatus

8.2.1 *X-ray and Goniometer Apparatus* — In accordance with ¶ 5.1 of SEMI MF26, except that the X-ray beam shall be collimated using a vertical slit.

8.2.2 *Wafer-Holding Fixture* — To orient the sample wafer uniquely with respect to the X-ray goniometer (refer to Figure 1). The fixture must include a vacuum hold-down with a flat horizontal surface and a reference fence perpendicular to this surface. These components establish an x-y axis that is fixed with respect to the goniometer and the X-ray beam. The exact dimensions of the fixture depend on the layout of the X-ray apparatus. The critical features are:

⁶ Published in Federal Register, Nov. 16, 1960. Available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.