



Designation: F 951 – 02

## Standard Test Method for Determination of Radial Interstitial Oxygen Variation in Silicon Wafers<sup>1</sup>

This standard is issued under the fixed designation F 951; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 This test method covers test site selection and data reduction procedures for radial variation of the interstitial oxygen concentration in silicon slices typically used in the manufacture of microelectronic semiconductor devices.

1.2 This test method is intended as both a referee and production test through selection of an appropriate test position plan.

1.3 The interstitial oxygen content may be measured in accordance with Test Methods F 1188 or F 1619, DIN 50438/1, JEIDA 61, or any other procedure agreed upon by the parties to the test.

NOTE 1—Test Method F 1366 is not based on infrared absorption measurement and it measures total oxygen content, not interstitial oxygen content. It is also a destructive technique. However, it can be used to determine the radial variation of the oxygen content if suitable modifications of the test procedure are made.

1.4 Acceptable thickness and surface finish for the test specimens are specified in the applicable test methods. This test method is suitable for use on chemically etched, single-side polished and double-side polished silicon wafers or slices with no surface defects that could adversely change infrared radiation transmission through the test specimen (subsequently called slice), provided that appropriate test methods for oxygen content are selected.

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 533 Test Method for Thickness and Thickness Variation of Silicon Wafers<sup>2</sup>

<sup>1</sup> 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.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 10.05.

F 1188 Test Method for Interstitial Atomic Oxygen Content of Silicon by Infrared Absorption<sup>2</sup>

F 1366 Test Method for Measuring Oxygen Concentration in Heavily Doped Silicon Substrates by Secondary Ion Mass Spectrometry<sup>2</sup>

F 1619 Test Method for Measurement of Interstitial Oxygen Content of Silicon Wafers by Infrared Absorption Spectroscopy with p-Polarized Radiation Incident at the Brewster Angle<sup>2</sup>

#### 2.2 DIN Standard:

DIN 50438/1 Test of Materials for Semiconductor Technology; Determination of Impurity Content in Silicon by Infrared Absorption; Oxygen<sup>3</sup>

#### 2.3 JEIDA Standard:

JEIDA 61 Standard Test Method for Interstitial Atomic Oxygen Content of Silicon by Infrared Absorption<sup>4</sup>

#### 2.4 ANSI Standard:

ANSI/ASQC Z1.4-1993, Sampling Procedures and Tables for Inspection by Attributes<sup>5</sup>

### 3. Summary of Test Method

3.1 Instruments are selected and qualified according to the test procedure chosen.

3.2 Measurements are made at the specified test locations and a relative oxygen variation is calculated by one of four available plans.

### 4. Significance and Use

4.1 The presence of oxygen can be beneficial to certain manufacturing operations by preventing the formation of process-induced defects. To the extent that this is true, it becomes important that the oxygen be uniformly distributed over the entire slice.

<sup>3</sup> DIN 50438/1 is the responsibility of DIN Committee NMP 221, with which ASTM F01 maintains close liaison. DIN 50438/1 is available from Beuth Verlag GmbH, Burggrafenstrasse 4-10, D-1000, Berlin 30, Germany.

<sup>4</sup> JEIDA 61 is the responsibility of the JEITA Silicon Wafer Committee, with which ASTM F01 maintains close liaison. JEIDA 61 is available from the Japan Electronics and Information Technology Industries Association, 3rd Floor Mitsui Kaijo Bldg. Annex 11, Kanda Surugadai 3-chome, Chiyoda-ku, Tokyo 101-0062, Japan.

<sup>5</sup> Available from American National Standards Institute, 1819 L Street N.W., Washington, DC 20036.

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4.2 Multiple test plans are included to satisfy a variety of requirements. The characteristic shape and magnitude of oxygen concentration distributions in crystals are functions of the crystal growth process. Although the specified test plans are intended to cover oxygen concentration distributions which are typically found, other distributions may occur. In such cases, it may be necessary to use test positions other than those specified in order to adequately describe the distribution pattern.

4.3 This test method may be used for process control, research and development, and materials acceptance purposes. In the absence of an interlaboratory evaluation of the precision of this test method, its use for materials acceptance is not recommended unless the parties involved establish the degree of correlation which can be expected (see Section 11).

## 5. Interferences

5.1 Variations of optical thickness can be caused by thickness or surface finish variations, or both.

5.2 Beam size differences from instrument to instrument can cause errors when the beam area is smaller than the aperture used in this test method.

## 6. Apparatus

6.1 *Infrared Spectrophotometer*, as required by the test method for interstitial oxygen measurement.

6.2 *Thickness Measurement Equipment*, as required by the test method.

6.3 *Fixturing*, capable of positioning test slices to the tolerances required in each plan, including a fixed  $7.0 \pm 0.5$ -mm circular aperture centered on the infrared beam.

## 7. Sampling

7.1 Sampling plans must be agreed upon by the participants.

7.2 For acceptance testing, ANSI/ASQC Z1.4-1993, normal level, must be used unless other agreements have been made.

## 8. Procedure

8.1 Place test slice in the fixture apparatus and position in accordance with the test plan to be used (See Annexes, Fig. A1.1, Fig. A2.1, Fig. A3.1, and Fig. A4.1).

8.1.1 The spectrophotometer infrared beam is directed through the 7-mm aperture which is located adjacent to the test slice. The test slice is moved, relative to the stationary beam and aperture to the test sites of the appropriate plan.

8.1.2 Slice thickness must be known for each position to  $\pm 0.5\%$  of the nominal slice thickness or measured at each position in accordance with Test Method F 533.

8.1.3 For referee situations mark the side of the test slice facing the spectrophotometer infrared source in a noninterfering manner.

8.2 Measure and record oxygen content at each position.

8.2.1 Keep all controllable instrument parameters constant during a test sequence (number of scans, temperature, reference slice, resolution, etc.).

8.3 For referee testing applications, repeat the test plan sequence four additional times.

## 9. Calculations

9.1 Calculate the radial oxygen variation (ROV) for the sample plan selected:

9.1.1 *Plan A—Two Positions* (Fig. A1.1):

$$ROV = \frac{(\text{Edge} - \text{Center})}{\text{Center}} \times 100 \quad (1)$$

9.1.2 *Plan B—Three Positions* (Center and Two Edges, Fig. A2.1):

$$ROV = \frac{(\text{Avg of Edge Values}) - \text{Center}}{\text{Center}} \times 100 \quad (2)$$

9.1.3 *Plan B-1—Five Positions* (Fig. A2.1): ROV is the larger of the values found from the equation in 9.1.2 and the following:

$$ROV = \frac{(\text{Avg of R/2 Values}) - \text{Center}}{\text{Center}} \times 100 \quad (3)$$

9.1.4 *Plan C—Five Positions* (Fig. A3.1):

$$ROV = \frac{(\text{Avg of Edge Values}) - \text{Center}}{\text{Center}} \times 100 \quad (4)$$

9.1.5 *Plan D—Multiple Positions* (Fig. A4.1):

$$ROV = \frac{(\text{Individual High} - \text{Individual Low})}{\text{Center}} \times 100 \quad (5)$$

NOTE 2—All edge positions are located from the center of the IR beam to the slice edge. All other non-center positions are located such that the center of the IR beam is located as given by the dimensions in Fig. A1.1, Fig. A2.1, Fig. A3.1, and Fig. A4.1.

9.2 For referee tests, calculate and include the average ROV, as follows:

$$ROV = (ROV1 + ROV2 + ROV3 + ROV4 + ROV5)/5 \quad (6)$$

## 10. Report

10.1 Report the following information:

10.1.1 Date, operator, and affiliation,

10.1.2 Description of test method used,

10.1.3 Number of slices and their identification,

10.1.4 Sample descriptions including nominal resistivity, thickness, diameter, and surface finishes,

10.1.5 Sample plan used,

10.1.6 Instrument factors,

10.1.6.1 Manufacturer/model,

10.1.6.2 Resolution,

10.1.6.3 Apertured beam size,

10.1.6.4 Differential or air reference method,

10.1.6.5 Measurement wavelength region,

10.1.7 ROV results, and

10.1.8 Any unusual relevant conditions.

## 11. Precision

11.1 The test method precision is directly dependent on the precision of the individual oxygen measurements. If the only sources of precision errors are the individual measurements, the radial oxygen variation precision can be computed for each sampling plan.

## 12. Bias

12.1 No reference standards are available for oxygen variation, so it is impossible to determine bias except for that of the