

SEMI M77-1015 (Reapproved 0421) TEST METHOD FOR DETERMINING WAFER NEAR-EDGE GEOMETRY USING ROLL-OFF AMOUNT (ROA)

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1 Purpose

- 1.1 Wafer near-edge geometry can significantly affect the yield of semiconductor device processing.
- 1.2 Knowledge of near-edge geometrical properties can help the producer and consumer determine if the dimensional characteristics of a specimen wafer satisfy given geometrical requirements.
- 1.3 The roll-off amount (ROA) metric is suitable for quantifying near-edge geometry of wafers used in semiconductor device processing.
- 1.4 Consideration should be given to the use of this or other proposed edge geometry metrics as a process control tool rather than a material exchange specification.

2 Scope

- 2.1 This Test Method covers calculation of the near-edge geometry metric ROA.¹
- 2.2 Calculation of ROA is based on height data that are representative of a height data profile associated with one or more of the front surface, the back surface, or thickness.
- 2.3 This Test Method covers selection of the point at which the ROA is determined and the reference line to be utilized for this determination.
- 2.4 This Test Method is applicable to categories of wafers specified in SEMI M1 used in advanced IC manufacturing.
- 2.5 This Test Method has been shown to be suitable for quantifying near-edge geometry to improve CMP performance at wafer edge.^{2,3} ROA values in that study were measured using an edge-referenced coordinate system. On the other hand, measurement systems for high volume production geometry (e.g., whole-wafer flatness) use a center-referenced coordinate system.
- 2.6 This Test Method allows for the use of either an edge-referenced or a center-referenced coordinate system.
- 2.7 There are other metrics for near-edge geometrical properties, some of which quantify more specific aspects. These are outside the scope of this practice.
- 2.8 This Test Method does not cover acquisition of the height data array. However, it gives the required characteristics of the height data array.

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 Deficiencies of data such as inadequate spatial resolution, mispositioning, noise, etc. in the height data array used to calculate the ROA may lead to erroneous results.

¹ Kimura, M., Saito, Y., Hiroshi, H., and Yakushiji, K. "A New Method for the Precise Measurement of Wafer Roll off of Silicon Polished Wafer." Jpn. J. Appl. Phys. **38** (1999): p. 38.

² Japan Electronics and Information Technology Industries Association (JEITA) Technical Report, "The Impact of Edge Roll-off on CMP performance." JEITA EMR-3001, 2004.

³ The development of edge roll off measurement method for silicon wafers by JEITA Silicon Technologies Committee is hereby acknowledged. This method, "Edge Roll-Off Measurement Method for Silicon Wafers." was published as a standard in the JEITA EMR series.

3.2 The selection of the reference segment, the ROA measurement point, the measuring surface, and the type of the reference line is to be decided between the relevant parties. To make these conditions clear, a method for reporting ROA is provided in ¶ 10.1.8.

3.3 Because the diameter tolerance of 200 or 300 mm wafers is ± 0.2 mm (see SEMI M1, Table 8) and of 450 mm wafer is ± 0.1 mm (see SEMI M1, Table 9) the difference from nominal to real radius may be up to ± 0.1 mm for 200 mm and 300 mm and may be up to ± 0.05 mm for 450 mm wafer. This difference may significantly affect the ROA calculation by shifting the positions of the measurement and reference segment points between the edge-referenced and center-referenced cases by the radius difference. Since the wafer surface height changes rapidly along the radius, the difference between ROA values determined with edge-referenced coordinates and center referenced coordinates can be significant.

3.4 Due to the existence of notch, the edge reference measurement is not applicable to the notch area, except 450 mm notchless wafer.

4 Referenced Standards and Documents

4.1 SEMI Standards and Safety Guidelines

SEMI M1 — Specification for Polished Single Crystal Silicon Wafers

SEMI M20 — Practice for Establishing a Wafer Coordinate System

SEMI M59 — Terminology for Silicon Technology

SEMI M67 — Test Method for Determining Wafer Near-Edge Geometry from a Measured Thickness Data Array Using the ESFQR, ESFQD, and ESBIR Metrics

SEMI M68 — Test Method for Determining Wafer Near-Edge Geometry from a Measured Height Data Array Using a Curvature Metric, ZDD

SEMI M70 — Test Method for Determining Wafer Near-Edge Geometry Using partial Wafer Site Flatness

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

5 Terminology

5.1 General terms, acronyms, and symbols used in silicon wafer technology are listed and defined in SEMI M59.

5.2 Other Terminology

5.2.1 Abbreviations and Acronyms

5.2.1.1 *ERO* — edge roll off

5.2.1.2 *L-ROA* — linear referenced ROA

5.2.1.3 *P-ROA* — polynomial referenced ROA

5.2.1.4 *ROA* — edge roll off amount

5.2.2 Definitions

5.2.2.1 *center referenced* — property of a measurement or calculation with the radial measurement position established using the wafer center as the origin.

5.2.2.2 *edge referenced* — property of a measurement or calculation with the radial measurement position established using the physical edge as the origin.

5.2.2.3 *edge roll off (ERO)* — surface deviations of a large-diameter silicon wafer near the edge, but excluding effects due to wafer edge profiling, surface roughness, and global bending, such as warp, of the wafer.

5.2.2.4 *edge roll off amount (ROA)* — the displacement from the reference line at the measurement point in the edge vicinity of an un-chucked wafer. ROA is defined as positive in the direction away from the reference line.

5.2.2.5 *edge roll off measurement point* — the radial position where the edge roll off is measured. It is labeled x_0 for an edge-referenced measurement or r_0 for a center-referenced measurement.

5.2.2.6 *linear-referenced ROA (L-ROA)* — the roll off value when a straight line is employed as the reference.

5.2.2.7 *near edge geometry* — the topography of a surface of a large diameter silicon wafer in the outer region of the fixed quality area (FQA).

5.2.2.8 *physical edge* — the farthest extremity of the wafer. It is used as a reference point of an edge-referenced coordinate system when finding the profile of the edge region.

5.2.2.9 *polynomial-referenced ROA (P-ROA)* — the roll off value when a cubic curve is employed as the reference.

5.2.2.10 *reference line* — either a straight line or a cubic curve extrapolated by curve fitting from a section of an ideal surface that does not include edge roll off.

5.2.2.11 *reference segment* — the section of the ideal surface that does not include edge roll off.

6 Summary of Test Method

6.1 Measurement positions and measurement coordinate system are selected.

6.2 The ERO measurement point and the reference segments end points are selected and reported.

6.3 The type of reference line used is selected and reported.

6.4 Height data arrays of one or more of the front surface, the back surface, or thickness are acquired along the radial direction at the measurement positions.

6.5 The ROA is calculated for each measurement position.

6.6 ROA is reported for each measurement position and surface(s) analyzed.

6.7 Statistical quantities for ROA, as agreed upon by the parties to the test are calculated and reported for each wafer.

7 Apparatus

7.1 *Measuring Equipment* — Suitable for acquiring the height data array over the entire FQA, except for instrument-dependent exclusion areas, and transferring it to the calculation equipment.

NOTE 1: A test method for acquiring the height data array is outside the scope of this Test Method.

7.1.1 The equipment shall perform all necessary calculations and corrections needed to produce the height data array internally and automatically, including instrument-dependent exclusion areas. The equipment shall be equipped with a means of detecting and either deleting or identifying invalid data (over-range signal).

7.1.2 Height resolution shall be 10 nm or smaller.

7.1.3 Height data array data point spacing shall be 0.1 mm or less.

7.1.4 The acquisition spatial resolution shall be appropriate for the height data array data point spacing and shall be agreed upon between the parties to the test.

7.2 *Calculation Software* — To perform the calculations of this Test Method and to provide outputs of the results, including statistical parameters as agreed upon by the parties to the test.

8 Procedure

8.1 Define recipe for calculation:

8.1.1 Select edge-referenced or center-referenced coordinates (see ¶ 3.3 for cautionary warnings).

8.1.2 Select the measurement position(s).

NOTE 2: Recommended positions are the following eight angular ones, 0°, 45°, 90°, 135°, 180°, 225°, 275°, and 315° for 200 mm, 300 mm and notched 450 mm wafers (see Figure 1a) and 0°, 45°, 90°, 135°, 180°, 225°, 270°, and 315° for 450 mm notchless wafers (see Figure 1b) as defined in the $R-\theta$ coordinate system of SEMI M20 (see Figure 1). This Test Method does not define the measuring method for the notch portion of the wafer and its neighborhood.