

SEMI P47-0307 (Reapproved 0513) TEST METHOD FOR EVALUATION OF LINE-EDGE ROUGHNESS AND LINEWIDTH ROUGHNESS

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NOTICE: This Standard or Safety Guideline has an Inactive Status because the conditions to maintain Current Status have not been met. Inactive Standards or Safety Guidelines are available from SEMI and continue to be valid for use.

NOTICE: This Document was reapproved with minor editorial changes.

1 Purpose

1.1 The purpose of this Document is to identify standard procedures for calculating the indices for the following two kinds of line roughness to characterize materials and processes for fine line pattern fabrication, especially in the integrated circuit manufacturing environment. The first index is related to the deviation of actual line-edge position from the ideal one (line of best fit) and is called 'line-edge roughness' (LER). The second index defines variation in the local linewidth and is called 'linewidth roughness' (LWR).

2 Scope

2.1 The scope of this Document is limited to description of the length of the edge or line (evaluation length) and the sampling interval in measurements, recording and presenting the LER or LWR of lines. The procedures described here can be generalized for other intended shapes (e.g., circles and arcs). Evaluation length determines the lowest observed spatial frequency, and the sampling interval determines the highest observed spatial frequency, while the sampling conditions and noise are properly considered.

2.2 The scope of this Document is limited to the apparent LER or LWR obtained by processing the two-dimensional image (signal intensity) of the observed line pattern, such as a result from critical dimension scanning electron microscopy (CD-SEM), atomic force microscopy (AFM), or other methods.

2.3 This Document describes measurand (see SEMI P35, ¶ 5.1.9) obtained from the two-dimensional image data.

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 scope of this Document is limited to evaluation length and sampling interval. Other measurement conditions (e.g., ¶ 13.2), which may influence LER or LWR measurement results are not included in the scope of the discussion.

3.2 The discussion in this Document can be applied to the calculation method of the estimator.

4 Referenced Standards and Documents

4.1 SEMI Standards and Safety Guidelines

SEMI P19 — Specification for Metrology Pattern Cells for Integrated Circuit Manufacture

SEMI P35 — Terminology for Microlithography Metrology

SEMI P36 — Guide of Magnification Reference for Critical Dimension Measurement Scanning Electron Microscopes (CD-SEMs)

4.2 ASME Standard¹

ASME B46.1 — Surface Texture, Surface Roughness, Waviness and Lay

4.3 ISO Standard²

ISO 4287 — Geometrical Product Specifications (GPS) – Surface Texture: Profile Method – Terms, Definitions and Surface Texture Parameters

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

5 Terminology

5.1 Abbreviations and Acronyms

5.1.1 *CD* — critical dimension

5.1.2 *LER* — line-edge roughness (line edge roughness)

5.1.3 *LWR* — linewidth roughness

5.2 Definitions

5.2.1 *line-edge roughness (or line edge roughness)* — the perpendicular point-to-point deviation of the feature's edge from the feature model's edge. [SEMI P35]

5.2.2 *linewidth roughness* — the deviation of the point-to-point linewidth from the average width of the specified linewidth feature model. [SEMI P35]

6 Relationship Between This Document and Referenced Standards

6.1 *Line-Edge Roughness (LER)* — LER is the fluctuation of the line-edge positions. LER and line-edge position obtained from the feature model (i.e., physical aspects of these two terms) are described in SEMI P35 (and shown in § 5.1 of this Standard). In this Document, on the other hand, a set of line-edge position data (denoted as x_{Li} or x_{Ri} in ¶ 9.6.1 of this Document) calculated from the two-dimensional image of the feature are described. Namely, the apparent LER in the image is described. The LER obtained from the two-dimensional image, which is described in this Document, is the practical approximation of the feature's LER described in SEMI P35.

6.2 *Linewidth Roughness (LWR)* — LWR is the fluctuation of the local linewidth. The term 'linewidth' is defined in SEMI P19 as an index for evaluating a feature size. The linewidth and LWR obtained from the feature model are also described in SEMI P35 (and shown in § 5.1 of this Standard). As well as the case of LER, the apparent LWR in the image is described in this Document. It is the practical approximation of the feature's LWR described in SEMI P35. The term 'edge roughness' is also defined in SEMI P36 as an index calculated from the image data, which corresponds to R_{max} in this Document.

7 Methodology Outline

7.1 When evaluating LER or LWR, the continuous pattern edge along a certain line length, is usually represented by a set of discrete data points. Thus, the following two parameters are very important. The first one is the evaluation length of the measured line. The second one is the sampling interval of discrete edge points measured along the line. This Document identifies LER or LWR as functions of these two parameters, and defines the procedure for LER and LWR measurements.

8 Tool and Samples Used for This Test Method

8.1 Microscope or measurement instrument with sufficient resolution.

8.2 Specimen consisting of edge pattern of an intended (e.g., linear) shape on a substrate (for LER) or specimen consisting of a line pattern on a substrate (for LWR). For observing patterns on a reticle, the obtained results are for

¹ American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990, USA; Telephone: +1.973.882.1170, Fax: +1.973.882.1717, <https://www.asme.org>

² International Organization for Standardization, ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland; Telephone: +41.22.749.01.11, <http://www.iso.org>

the reticle pattern only, and may not be applicable for the pattern fabricated by transferring the reticle pattern to another surface.

9 Procedure

9.1 Aligning the Sample — Put the line pattern approximately perpendicular to the x -direction (i.e., the line is set parallel to the y -direction), which is defined below. In case of using scanning microscope, the x -direction is the scan direction. In other cases, it is defined as the direction of horizontal edge of the image (see Figure 1). The rotation can be calculated after the line-edge detection and can be corrected, if necessary; therefore, the alignment need not be perfect, but better alignment results in a smaller correction.

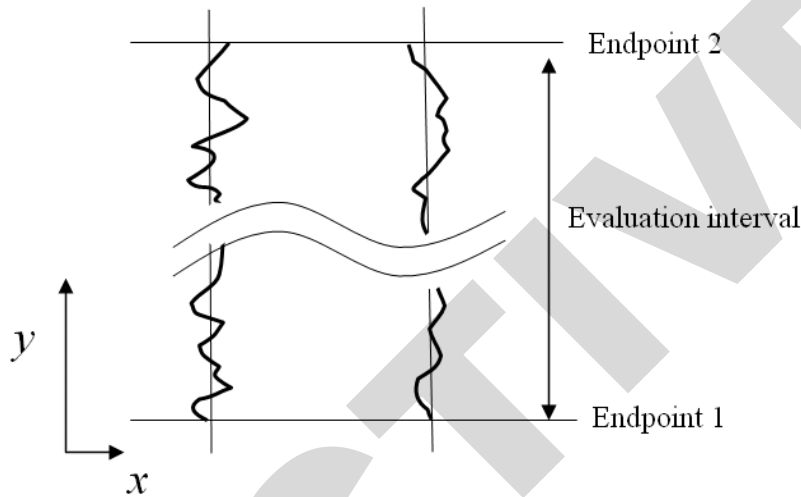


Figure 1
Image of Line Pattern, Axes and Evaluation Interval
(Solid Curves are Edges of the Pattern)

9.2 Image Acquisition — Acquire the two-dimensional signal intensity distribution corresponding to the line pattern identified in ¶ 8.2 by a microscope or any other appropriate instrument identified in ¶ 8.1.

9.3 Defining the Measurement Area — Pick endpoints for the evaluation on the above-described signal intensity distribution (see Figure 1). The continuous section of line between these endpoints is called the evaluation interval. The length of the evaluation interval (length of the area of interest) is called evaluation length and denoted as L hereafter. The evaluation interval may not be constructed by stitching together discontinuous sections of line of total length L .

9.4 Deciding the Edge-Detection y -Coordinates — Divide the evaluation interval into n equal small intervals in the y -direction (see Figure 2). The length of each of these n small intervals measured along the y -direction (sampling interval) is denoted as Δy . The y coordinate of the center of each small interval is denoted as $y_1, y_2, \dots, y_n$. These are called edge-detection y -coordinates (see Figure 2). The number n is equal to $L/\Delta y$.