

SEMI P35-1106 (Reapproved 0913)

TERMINOLOGY FOR MICROLITHOGRAPHY METROLOGY

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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.

1 Purpose

1.1 Clear and commonly accepted definitions are needed for efficient communication and to prevent misunderstanding between buyers and vendors of metrology equipment. The purpose of this Document is to provide a consistent terminology for the understanding and discussion of metrology issues important to microlithography.

2 Scope

2.1 The scope of this Document is limited to the definitions of metrology terms used in microlithography. Every attempt is made to keep these definitions consistent with relevant international standards and common usage. This Document is not intended to describe a measurement procedure, but rather an approach to defining a measurand in a useful and unambiguous way.

2.2 The present focus of this Document is on feature-related metrology and measurands important for the definition and control of lithographic processes.

2.3 This Document does not attempt to discuss statistical considerations, which are covered in SEMI E89 and elsewhere.

2.4 This Document is expected to grow as more terms are added in future revisions.

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 Referenced Standards and Documents

3.1 SEMI Standards and Safety Guidelines

SEMI E89 — Guide for Measurement System Analysis (MSA)

SEMI P28 — Specification for Overlay-Metrology Test Patterns for Integrated-Circuit Manufacture

3.2 ANSI/NCSL Standards¹

ANSI Z540.2-1997 — US Guide to the expression of Uncertainty in Measurement

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

4 Some Metrology Issues

4.1 *Measuring Linewidth* — Any measurement of length or position contains an unknown error whose influence on subsequent application of the measurement data is best described by the measurement uncertainty (see ¶ 3.2). The problem of measuring feature sizes on photomasks or integrated circuit wafers (e.g., linewidth) is complicated by the fact that a feature is a three-dimensional object whose exact shape is generally not known. The metrology problem is further complicated when the object is microscopic and only its magnified image can be measured.

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4.2 Feature measurement data are usually reduced to one or a few parameters because the additional data needed to describe the complex actual feature shape are seldom available and may be immaterial to the subsequent application of the measurement data.

4.3 The first rule of metrology is to define exactly what is to be measured. The approach used here, in light of the previous paragraphs, is to construct a simple idealized geometric shape, or *feature model* (Figure 1), which approximates a real object of complex shape. This model, whose size and center position are well defined, is substituted for the real feature in application of the measurement data. A model can be refined to better approximate the actual feature shape by adding degrees of freedom, requiring more parameters to describe the measurement. For example, a line might be represented by a rectangular cross section (with width and height) or better represented by a trapezoidal cross section (with base width, height, and two wall angles). The differences between the model and the actual shape of the feature contribute to the overall measurement uncertainty of the size or position of that feature.

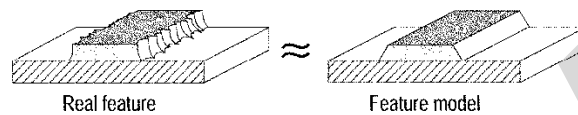


Figure 1
The Feature Model Approximates the Size and Shape of the Feature

4.3.1 The feature model may be further abstracted to suit the purpose of the measurement by defining bounding boxes to represent the inner and outer limits on the space occupied by the feature. In the nonexistent case of an ideal feature, the feature, the feature model, and the bounding boxes would all coincide.

4.4 The aim of the approach embodied here is to facilitate interpretation of metrology results for a feature (and the feature's subsequent performance—see Appendix 1) in the most realistic terms, and in light of any possible additional knowledge about that feature.

4.5 There are many possible reasons for measuring a feature's size or placement. Consequently the following definitions may include options or alternatives, to be selected by the user to best fit the purpose of the measurement.

5 Definitions

5.1 Defined terms appearing in the definitions of other terms are *italicized*. Where more than one definition is given for a term, the one most appropriate to the application is to be chosen. Some of these definitions describe certain usage options as 'the default.' That option is assumed to apply unless otherwise specified.

5.1.1 *bounding box* — a user-specified geometric shape with a planar face lying in the *reference plane* and with user-specified orientation in the *reference plane*, intended to represent limits or bounds on the position and size of the *feature*. See Figure 2 for an example. The bounding box need not be rectangular.

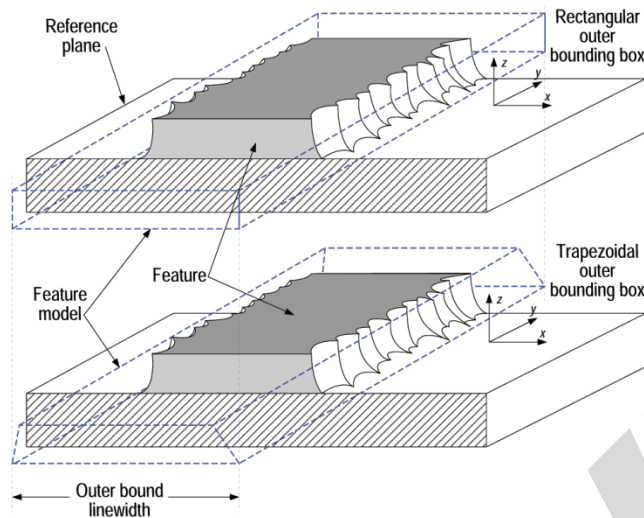


Figure 2
Two Possible Bounding Box Choices for a Line Feature

NOTE 1: The term ‘bounding box’ is used here for convenience, but the word ‘box’ may not always be considered appropriate. Terms like ‘bounding figure’ or ‘bounding surface’ may be used instead, if desired. A *bounding box* may coincide with a *feature model*.

5.1.1.1 *outer bounding box* — smallest bounding box encompassing the feature.

5.1.1.2 *best fit bounding box* — *bounding box* best fitting the *feature*, with user-defined criteria of best fit.

5.1.2 *calibration* — set of operations that establish, under specified conditions, the relationship between values of quantities indicated by a measuring instrument or measuring system, or values represented by a material measure or reference material, and the corresponding values realized by standards (see ¶ 6.1).

5.1.3 *centerline* — (a) the locus of the *centroids* of successive line segments, in the limit as the segment length vanishes. (b) a line or surface midway between opposing *feature edges*.

5.1.4 *centroid* — the geometrical center of an object. The coordinates of the centroid of an object are $C_u = \iiint u \, dV / \iiint dV$, where the integral is over the volume V of the object and u can be x , y , or z .

5.1.4.1 *centroid measurement uncertainty* — parameter that characterizes the dispersion of the values that could reasonably be attributed to the position of the *centroid* or the *placement* of an object in the reference plane coordinate system (see *measurement uncertainty*).

NOTE 2: The edges of the feature form part of the boundary of the integral defining the centroid; edge position uncertainty leads to integral boundary uncertainty and thus to centroid uncertainty. The *centroid measurement uncertainty* of a *feature* described by *inner* and *outer linewidth bounding boxes* is the combined uncertainties of the measured centroid position of the *mean linewidth bounding box* and of the positions of the line’s edges between these *linewidth bounding boxes*, taking into account possible opposite edge correlations. (These correlations can result in *feature placement* or *pitch uncertainty* that is less than the corresponding *linewidth uncertainty* because many features have some degree of mirror image symmetry between opposite edges.)

5.1.5 *feature (lithographic)* — region within a single continuous boundary, and attached to a *reference plane*, that has a defining physical property (parameter) that is distinct from the region outside the boundary. (Adapted from SEMI P28.)

NOTE 3: In general a feature is a three-dimensional object, but some features can be adequately modeled as two-dimensional objects.

5.1.5.1 *feature boundary* — surface defined by a user-specified property, such as a threshold, maximum gradient, etc., of the parameter distinguishing that *feature* from its surroundings. Open features, such as vias or spaces between lines, may be bounded in height by an additional plane parallel to the *reference plane*.

5.1.5.2 *feature edge* — that part of the *feature boundary* used to define the feature size or linewidth. The criteria used must be specified.

5.1.5.3 *feature height* — dimension of the specified *bounding box* perpendicular to the *reference plane*. May also refer to feature depth below the substrate, as in contact holes. Although *feature height* is sometimes referred to as *feature thickness*, this usage is not recommended because ‘thickness’ sometimes alludes to ‘width.’

5.1.5.4 *feature model* — a solid geometrical shape, with well-defined parameters (e.g., length, width, height, centroid, etc. [see Figure 1]), meant to approximate the actual shape of a *feature boundary*.

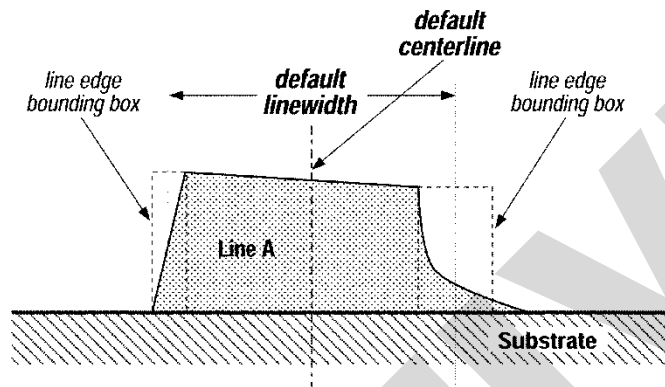


Figure 3

Example of line cross section showing possible *line edge bounding boxes* and the resulting *default centerline* and *linewidth*. Since the top of Line A is not parallel to the substrate, the generalized *linewidth bounding box* definition (b) is used. Line edge asperities at the substrate were judged not to be relevant to the function of this feature and were excluded from the *outer line edge bounding boxes*.

NOTE 4: A rectangular solid is often used to represent a line; a different extruded polygon may better represent the shape of the line. A hemisphere may best represent a solder bump. The more complex the model, more degrees of freedom are available to better fit the model to the feature, and more dimensional parameters are needed to describe the feature's size. The *feature model* is a simplified geometric approximation of the actual *feature*, the *bounding boxes* represent limits on the space occupied by the *feature model*. The size or position of a *feature* can be described by the size or position of the *feature model* with appropriate uncertainties, or by the sizes or positions of the *bounding boxes*. This choice is left to the user, and in many of these definitions the terms can be interchanged. *Bounding boxes* are useful because they make the measurement uncertainty explicit, and because an application of the measurement data may require only inner or outer bounds.

5.1.5.5 *feature placement* — (a) coordinates describing the position of the *centroid* of the specified *bounding box* projected onto the *reference plane* relative to a coordinate system in that plane. (b) coordinates describing positions of the *feature's edges*.

5.1.5.6 *feature size* — dimensions of the specified feature model or bounding box.

5.1.5.7 *nominal feature size* — the intended or specified dimension of a *feature*.