

# SEMI P24-94 (Reapproved 1104) CD METROLOGY PROCEDURES

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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 The purpose of this document is to establish uniform procedures for metrology systems for the litho-metrology task. It does not address how these systems will be applied to solve problems, nor does it address other contributors to process variations such as thermal wafer processing, exposure tool focus control, materials, etc.

1.2 *Background* — Fundamental to manufacturing is the gauging or measurement process. It is required initially to develop a usable manufacturing capability and then to verify that what is being manufactured conforms to specification/expectation.

## 2 Scope

2.1 This document discusses determining the performance of gauging/measurement systems for a very specific application—the lithography section of integrated circuit wafer fabrication. This document in many cases, will be applicable to IC mask-making, in which case the word “mask” can be substituted for “wafer.”

2.2 It is acknowledged that the final measurement for a fabricated wafer is the electrical functionality. However, the intermediate lithographic measurements can be useful in prediction and control of final functionality. This document is intended to be useful for this litho-metrology application, irrespective of the technology employed.

2.3 Measurement results and system performance depend on the sample(s) used. Therefore, performance for different systems or the same system at different times can only be appropriately compared when the measurements are obtained with a sample of the same material composition.

2.4 The parameter addressed is precision. Additional important parameters are reliability and cleanliness, which have been addressed by other SEMI Standards.

**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 E10 — Standard for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM)

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

### 3.2 ASTM Standards<sup>1</sup>

ASTM C609 — Standard Test Method for Measurement of Small Color Differences Between Ceramic Wall or Floor Tile

ASTM D1129 — Standard Terminology Relating to Water

ASTM D4790 — Standard Terminology of Aromatic Hydrocarbons and Related Chemicals

<sup>1</sup> American Society for Testing and Materials, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA, 19428-2959, Phone: 610.832.9585, Fax: 610.832.9555, <http://www.astm.org>

ASTM E180 — Standard Practice for Determining the Precision of ASTM Methods for Analysis and Testing of Industrial and Specialty Chemicals

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

## 4 Applications

4.1 *linewidth measurement* — this task is to measure linewidths as defined by SEMI P19.

NOTE 1: Pitch is not addressed in this document.

4.2 *contact hole measurement* — contact and via hole area measurement is a different application which may use the same definitions and procedures as line-width measurement.

## 5 Terminology

### 5.1 Definitions

5.1.1 *precision* — the degree of agreement of repeated measurements of the same parameter expressed quantitatively as the standard deviation, computed from the results of a series of controlled determinations [ASTM D1129, D-29].

5.1.2 A frequency plot of measurements taken with random error illustrates precision. The spread or variation of measurement in test A is smaller than that in test B. The results of test A are more precise than the results from test B. See Figure 1.

NOTE 2: Any test procedure used needs to differentiate between system and wafer contribution.

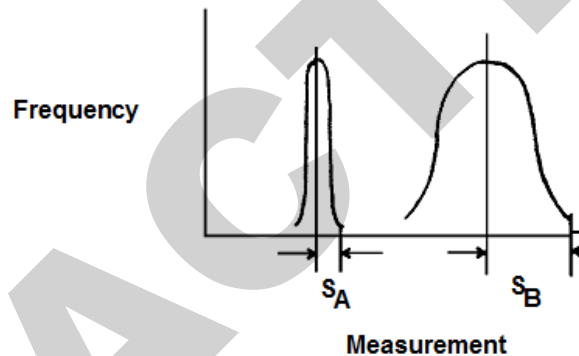


**Figure 1**  
**Generic Frequency Plot**

5.1.3 *repeatability* — the standard deviation of results obtained by the same operator using the same instrument in successive measurements [ASTM C609, C-21]. The same system parameters need to be used. The degree to which the individual operator affects the measured result is a critical parameter and must be identified and benchmarked.

NOTE 3: The degree to which the individual operator affects the measured result may be a critical parameter and must be identified.

5.1.4 *reproducibility* — the precision of a test method expressed in terms of agreement expected between measurements made in different laboratories using similar apparatus and the same procedure [ASTM D4790, D-16].

5.1.5 *stability* — the standard deviation of means of groups of measurements taken at specified intervals over an extended period of time.

NOTE 4: The means are used to avoid including the measurement precision. Stability is a characterization of the system independent of precision. It is important to use a stable sample so that system stability, independent of the sample, is determined.

5.1.6 *standard deviation* — a measure of the dispersion of a series of results around their average, expressed as the square root of the quantity, obtained by adding the squares of the deviations from the average of the results and

dividing by the number of observations minus one. It is also the square root of the variance and can be calculated as follows:

$$s = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n - 1}} \quad (1)$$

where:

$s$  = estimated standard deviation of the series of results

$X_i$  = each individual value

$\bar{X}$  = average (arithmetic mean) of all values, and

$n$  = number of values

The following forms of this equation are more convenient for computation, especially when using a calculator:

$$s = \sqrt{\frac{\sum x^2 - (\sum x)^2 / n}{n - 1}} \quad (2)$$

or

$$s = \sqrt{\frac{n \sum x^2 - (\sum x)^2}{n(n - 1)}} \quad (3)$$

where:

$\sum x^2$  = sum of the squares of all the individual values.

$(\sum x)^2$  = square of the total of the individual values.

$n$  = number of values.

$s$  = estimated standard deviation.

NOTE 5: Care must be taken in using either of these equations that a sufficient number of decimal places is carried in the sum of the values and in the sum of their square so that serious rounding errors do not occur. For best results, all rounding should be postponed until after a value has been obtained for  $s$  [ASTM E180, E15].

## 6 Procedures to Benchmark Precision

### 6.1 Precision Types

**6.1.1 Static Precision** — A series of measurements made of a single feature where, for each measurement, the information is reacquired and reprocessed. The minimal intervention required to repeat the measurement will be used. The standard deviation will be calculated based on the sample data.

**6.1.2 Z (Axis Adjustment) Precision** — A series of measurements is made of a single feature where it is necessary to refocus before each measurement (without intentional movement in the  $x$  and  $y$  axes before each measurement). The standard deviation will be calculated based on the sample data.

**6.1.2.1 Dynamic Precision** — Make one measurement of grouped line and space features at  $n$  number of sites on a focus/exposure matrix wafer, which includes typical size and side wall angle variations. Remove the wafer from the system, then reload and remeasure. Compute the dynamic precision,  $3s$ , by the double sample method (see ¶ 7.1.3).

**6.1.2.1.1** A total of 1 size  $\times n$  sites  $\times 2$  repeats =  $2n$  measurements per wafer  $\times 3$  passes =  $6n$  measurements required.

**6.1.2.1.2** 10 is a minimum recommended value for  $n$ .

**6.1.2.1.3** This may also be redone for different thicknesses of lines to be measured and repeated for each of the wafer types in the process.