

SEMI M50-1104

TEST METHOD FOR DETERMINING CAPTURE RATE AND FALSE COUNT RATE FOR SURFACE SCANNING INSPECTION SYSTEMS BY THE OVERLAY METHOD

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1 Purpose

1.1 SEMI M52 defines capture rate (CR) requirements to be met by a scanning surface inspection system (SSIS) to be used for the 130 nm technology generation. Similar requirements appear in specifications for SSISs to be used in other applications.

1.2 This test method provides a framework for the determination of the CR, false count rate (FCR) and cumulative false count rate (CFCR) of an SSIS as a function of latex sphere equivalent (LSE) size of localized light scatterers (LLS).

NOTE 1: In the context of this document the term “size” refers to the LSE diameter.

2 Scope

2.1 This test method defines the SSIS capture rate and discusses its usage in industry specifications.

2.2 This test method addresses calculating and reporting SSIS capture rate from measurements of either PSL depositions or other LLS on wafers in LSE units.

2.3 Specific wafer surfaces (by wafer product, type of film or type of polish) that may affect the measured capture rate and false count rate of an SSIS are to be agreed upon between suppliers and users.

NOTICE: This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory or other limitations prior to use.

3 Limitations

3.1 This test method is limited to use on unpatterned wafers.

3.2 This test method is limited to use on calibrated scanners operated in a production mode.

4 Referenced Standards

4.1 SEMI Standards

SEMI E89 — Guide for Measurement System Capability Analysis

SEMI M52 — Guide for Specifying Scanning Surface Inspection Systems for Silicon Wafers for the 130-nm Technology Generation

SEMI M53 — Practice for Calibrating Scanning Surface Inspection Systems Using Certified Depositions of Monodisperse Polystyrene Latex Sphere on Unpatterned Semiconductor Wafer Surfaces

4.2 ISO Standard¹

ISO Guide 30:1992 — Terms and Definitions Used in Connection with Reference Materials

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

5 Terminology

5.1 Definitions

5.1.1 *capture rate (CR)* — the probability that an SSIS detects an LLS of latex sphere equivalent (LSE) signal value at some specified SSIS operational setting.

5.1.2 *certified reference material (CRM)* — reference material, accompanied by a certificate, one or more of whose property values are certified by a procedure which establishes its traceability to an accurate realization of the unit in which the property values are expressed, and for which each certified value is accompanied by an uncertainty at a stated level of confidence. [ISO Guide 30:1992]

5.1.3 *cumulative false count rate (CFCR)* — number of false counts of size S_f or larger, that are expected to be recorded by an SSIS at some specified operational setting as a function of S_f . CFCR may be found by averaging false counts over multiple scans.

¹ International Organization for Standardization, ISO Central Secretariat, 1, rue de Varembe, Case postale 56, CH-1211 Geneva 20, Switzerland. Telephone: 41.22.749.01.11; Fax: 41.22.733.34.30 Website: www.iso.ch

5.1.4 *false count (FC)* — laser-light scattering event that arises from instrumental causes rather than from any feature on or near the wafer surface; also called false positive.

5.1.4.1 *Discussion* — False counts would not be expected to occur at the same point on the wafer surface during multiple inspection scans, and hence they could be considered as random “noise” that could be identified by examining the results of repeated scans.

5.1.5 *false count rate (FCR)* — mean total number of false counts per wafer that an SSIS reports at some specified SSIS operational setting.

5.1.6 *repeat counts* — LLSs that are found in a later scan within the scanner *XY* uncertainty distance of their location as found on an earlier scan.

5.1.6.1 *Discussion* — The implication is that if defect density is low enough, then a repeat count results from detecting the same LLS event again and is not the result of SSIS noise. Besides the absolute position of the LLS, an additional matching condition may be the LSE signal of the LLS.

5.1.7 *scanner XY uncertainty* — square root of the sum of the squares of the one-sigma standard deviations in the reported *X* and *Y* locations of the SSIS under test, as determined under repeatability conditions.

5.1.8 *true count* — laser-light scattering event that arises from the localized light scatterers (LLS) being investigated.

6 Summary of Method

6.1 The *XY* coordinate uncertainty of the SSIS under test is either known or determined under repeatability conditions, without removing the wafer from the stage between scans.

6.2 The reference wafer to be used in this test is selected.

6.3 The selected wafer is scanned *Z* times on the SSIS under test. The first two scans are used to qualify the reference wafer before continuing with the remaining *Z*–2 scans.

NOTE 2: Typical values for *Z* are between 30 and 100 scans.

6.4 The scans are analyzed to determine and record the number of times each LLS event occurs in each location (to within a distance approximately six times the scanner *XY* uncertainty) during the *Z* scans. The capture rate, standard size deviation, false count rate, and cumulative false count rate are determined from this data set.

7 Apparatus

7.1 *SSIS under test* — installed in its position of use with clean room rating recommended by the manufacturer.

7.2 *Off-line analysis software program* — to track each observed count and determine the capture rate, standard size deviation, the number of false counts at each LLS size, the false count rate, and the cumulative false count rate.

NOTE 3: The analysis software may be incorporated into the SSIS, if desired.

8 Test Specimens

8.1 Use any wafer with (1) natural LLS with density <10 LLS/cm² and (2) a surface roughness typical of the wafers to be measured in production (see Section 2.3).

8.1.1 The minimum distance between any two LLS found during any one scan and used in the data set to be analyzed shall be larger than six times the scanner *XY* uncertainty. Clusters of LLS (found in any one scan and closer together than six times the scanner *XY* uncertainty) and scratches must be excluded during the analysis.

8.1.2 Determine the scanner *XY* uncertainty from previous knowledge, from the scanner manufacturer specifications, or from the positional accuracy determined under repeatability conditions in accordance with Appendix 1.

8.2 Alternatively, a wafer with deposited polystyrene latex spheres can be used to evaluate the capture rate more accurately at a specific particle size. The same particle density, particle spacing, and defect cluster conditions as in Section 8.1 should be observed.

NOTE 4: The wafer with deposited PSL spheres may or may not be certified reference material.

9 Procedure

9.1 Qualify the wafer for appropriate LLS number (see Section 8.1) prior to taking CR and CFCR data as follows:

9.1.1 Scan the wafer once and determine position, P_m , and size, S_m , of each of the M_1 detected LLS events with $m = [1, 2, \dots M_1]$.

9.1.2 To determine that there are enough repeating LLS events to make the CR calculation meaningful, scan the wafer a second time and compare the detected LLS events with respect to the positions of those detected during the first scan. Define the total number of LLS events that repeat their position in the first scan to within six times the scanner *XY* uncertainty as M_2 . Consider the wafer qualified for the test if the share of

repeat LLS events on the wafer, M_2 , is larger than 0.75 M_1 . Make certain that the conditions of Sections 8.1 and 8.1.1 are fulfilled for both wafer scans.

9.2 Scan the wafer a total of Z times to obtain CR, FCR, and CFCR data (see NOTES 3 and 6). Record each LLS event detected during the Z scans according to its position P and size S .

NOTE 5: The two scans obtained in Sections 9.1 through 9.1.2 can be used as part of this data set, but the wafer must remain on the scan stage during the entire set of Z scans to perform the measurement sequence under repeatability conditions.

10 Analysis

10.1 Initial Analysis

10.1.1 Determine the locations on the wafer where an LLS event has been detected at least once by comparing all recorded positions (within the constraint of the six-sigma XY uncertainty) of the multiple scans as reported by the SSIS. These locations, L_i , with $i = [1, 2, \dots, N]$ represent the complete set of LLS events to be used in the analysis. Each location is characterized by the number of scans H_i , in which the LLS event at that position has been detected, and by the H_i reported sizes S_{ih} , where $h = [1, 2, \dots, H_i]$, for the LLS event.

10.1.2 Consider those of the N events with $H_i = 1$, (i.e., events seen only once) as false counts. Order these events by decreasing size, S_i . Index them by $f = [1, 2, \dots, F]$, with $f = 1$ representing the largest size and $f = F$ representing the smallest.

10.1.3 Consider those events that were seen at least twice during the Z scans ($H_i \geq 2$) to be true counts.

NOTE 6: The sequence of analysis steps given below is intended to be representative and illustrative. The actual algorithms used in the analysis software may differ from these as long as the same result is achieved.

10.2 Analysis of True Counts

10.2.1 Determine the average size $\langle S_i \rangle$ of each true count ($H_i \geq 2$) as follows:

$$\langle S_i \rangle = \frac{1}{H_i} \sum_{h=1}^{H_i} S_{ih} \quad (1)$$

10.2.2 Calculate the size dependent capture rate, $CR(\langle S_i \rangle)$, for every true count as follows:

$$CR(\langle S_i \rangle) = \frac{H_i}{Z} \quad (2)$$

10.2.3 Plot $CR(\langle S_i \rangle)$ versus $\langle S_i \rangle$ as in the example in Figure 1, and interpolate or fit the data to discriminate against outlying points.

NOTE 7: The following equation for c_s , in percent,

$$c_s = 100 \left[1 - \exp\left(\frac{s_0 - s}{c_0}\right) \right], \quad (2a)$$

may be used to fit the plotted $CR(\langle S_i \rangle)$ data. Here, c_s is the fitted value of $CR(\langle S_i \rangle)$, s is the size ($\langle S_i \rangle$), s_0 is the size at zero probability of capture, and c_0 is a curvature factor that determines the point at which the probability of capture approaches 100%. As c_0 and s_0 constitute a sufficient parameter set to describe completely $CR(\langle S_i \rangle)$, they can be used for reporting, together with the chi-square goodness of the fit test statistic result.

NOTE 8: Note that there are a few points below the principal curve in Figure 1. These points may have arisen from added particles that appeared on the wafer during the test. They should be neglected in fitting any curve to the capture rate data.

10.2.4 Calculate the standard deviation of size S_i for all true counts as follows:

$$\sigma(S_i) = \sqrt{\frac{1}{H_i - 1} \sum_{h=1}^{H_i} (S_{ih} - \langle S_i \rangle)^2} \quad (3)$$

10.2.5 Plot the standard deviation of size, $\sigma(S_i)$, versus the mean size, $\langle S_i \rangle$, for all true counts as shown in the example in Figure 2.

NOTE 9: Again, note the same outliers in Figure 2. These can be neglected in any analysis of the standard deviation data.

10.3 Analysis of False Counts

10.3.1 Divide the total number of false counts, F , by the number of scans, Z , to get the false count rate, FCR :

$$FCR = \frac{F}{Z} \quad (4)$$

10.3.2 Analyze the false count rate as a function of size to determine the cumulative false count rate, $CFCR(S_i)$, at each size, S_i , by taking the total number of false counts of size equal to or greater than S_i , and dividing by the number of scans, Z :

$$CFCR(S_i) = \frac{F_i}{Z}, \quad (5)$$

where F_i is the largest value of the index associated with the count (or counts) of size S_i .

10.3.3 Plot $CFCR(S_i)$ as a function of S_i as shown in the example in Figure 3.

11 Report

11.1 Report the following information:

11.1.1 Operator identification;