SEMI M58-1109 (Reapproved 0614)[E]
TEST METHOD FOR EVALUATING DMA BASED PARTICLE DEPOSITION SYSTEMS AND PROCESSES

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[E] This Standard was editorially modified in September 2019 to update footnote information. Changes were made to ¶¶ 8.1.1.1. and 8.1.1.2.

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1 Purpose

1.1 SEMI M52 requires the use of certified reference materials (CRMs) for calibration of scanning surface inspection systems (SSISs). The calibration method is defined in SEMI M53. This Test Method provides the procedure to determine whether a specific particle deposition system, using a differential mobility analyzer (DMA), can produce the required CRMs.

1.2 Both organizations producing depositions internally for in-house use and companies manufacturing depositions for sale can apply this Test Method to ensure that their particle deposition systems provide depositions that meet the requirements of SEMI M52.

2 Scope

2.1 This Test Method covers determination of the deposition peak diameter and the associated expanded relative combined peak diameter uncertainty produced by a particle deposition system and its associated deposition procedures for comparison to the 3% requirement of SEMI M52.

2.2 This Test Method also covers determination of the ability of the deposition system to produce depositions with diameter distributions that are less than 5% full width at half maximum (FWHM) as required by SEMI M52 even when using a particle source with a much wider distribution.

2.3 These tests require that the deposition system employ a DMA (or an equivalent programmable filtering system) to accomplish both peak diameter determination and narrowing of particle source distributions (see Related Information 1).

2.4 This Test Method covers determination of repeatability over a period of one week. Tests can be repeated periodically to determine long term stability. Long term stability of most DMA-based particle deposition systems is believed to be on the order of a year or more, but it is recommended that the tests be repeated on an annual basis or whenever the instrument appears to be out of control.

2.5 This Test Method requires the use of three different kinds of particle distributions with specified characteristics and wafers that have surface characteristics adequate to allow detection of the smallest particles utilized with a capture rate of greater than 95%.

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 This Test Method is limited to use of depositions of PSL spheres, even though the deposition system under test may be capable of depositing particles of other materials.

3.2 When used to make a deposition from a suspension of PSL spheres that does not have an observable certified peak diameter (or if the deposition is made at a size away from the peak of the distribution in the suspension), the uncertainty with which the deposition system evaluates a peak deposition diameter includes bias information determined from measurements on a known standard or standards with extremely narrow distributions. At the time when this test method was developed, only one such standard existed. Therefore if the bias contribution to uncertainty

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is a function of the peak diameter in the suspension, the determination may be in error at peak diameters away from that of the known standard.

3.3 There is the possibility that the deposited particle diameter may differ slightly from the certified value for the bottle containing the suspension because the surfactant in the suspension and contaminants in the water may cause an increase in particle size. This limitation can be avoided by using DMAs with the same spray system, the same purity of dilution water, and the same suspension concentration both to size the particles in the bottle and make the deposition. This possibility may be minimized by using PSL suspension fluids with low non-volatile content to reduce the possibility of non-volatile materials drying onto the particles in the suspension.

4 Referenced Standards and Documents

4.1 *SEMI Standards and Safety Guidelines*

SEMI M50 — Test Method for Determining Capture Rate and False Count Rate for Surface Scanning Inspection Systems by the Overlay Method

SEMI M52 — Guide for Specifying Scanning Surface Inspection Systems for Silicon Wafers for the 130 nm to 11 nm Technology Generations

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

SEMI M59 — Terminology for Silicon Technology

SEMI ME1392 — Guide for Angle Resolved Optical Scatter Measurements on Specular or Diffuse Surfaces

SEMI MF1811 — Guide for Estimating the Power Spectral Density Function and Related Finish Parameters from Surface Profile Data

4.2 *ISO Standard* [1]

ISO 14644-1 — Cleanrooms and Associated Controlled Environments – Part 1: Classification of Airborne Particulates

NOTICE: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 Definitions for terms related to surface scanning inspection systems are found in SEMI M59, SEMI ME1392, and SEMI MF1811.

6 Summary of Method

6.1 Three bottles (A, B and C) of PSL sphere suspensions meeting specific requirements are obtained. Bottle A is a CRM with a certified peak diameter and a very narrow diameter distribution so that no matter how the deposition system functions, the deposition will meet the requirements of SEMI M52. Bottles B (smaller diameters) and C (larger diameters) have much wider distributions and there are no restrictions on peak diameter accuracy.

6.2 Over a five day period, spot depositions of the same number of each of the three PSL sphere sizes are made each morning on one or more wafers and a final scan check of the diameter of spheres in Bottle A is made late in the day.

6.3 The deposited diameters from each bottle, as determined by the deposition system, are recorded on a data sheet.

6.4 At the end of the week the spot depositions are scanned with an SSIS to obtain a histogram for each spot deposition. The FWHM values are obtained from these histograms and recorded. The peak diameter values and particle counts found from the SSIS may also be recorded, but these values are not required to verify the requirements of SEMI M52.

6.5 The results for each bottle are analyzed to determine if the deposition system has a peak diameter expanded relative combined standard uncertainty less than 3% and a deposited FWHM on the wafer of less than 5%, as required by SEMI M52.

[1] 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

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7 Apparatus

7.1 *Particle Deposition System*

7.1.1 The particle deposition system to be evaluated must be available in a clean room of class 4 or better as defined in ISO 14644-1.

7.1.2 The deposition system must have an atomizer that takes the particles from the liquid suspension to an air droplet mist.

7.1.3 The particle deposition system must have a DMA (or an equivalent programmable filtering system) to accomplish both peak diameter determination and narrowing of particle source distributions.

7.1.4 The deposition system must have wafer handling equipment appropriate for the wafers on which the depositions are being made.

7.2 *Surface Scanning Inspection System*

7.2.1 An SSIS appropriate for use with the wafers used and the PSL spheres deposited must be capable of determining the FWHM of each of the depositions made.

7.2.2 The SSIS does not have to be calibrated in accordance with SEMI M53 in order to be used in this Test Method, but the results obtained when the test method is performed can give an indication of the calibration of the SSIS in the size region of the test.

8 Reagents and Materials

8.1 *PSL Spheres*

8.1.1 Three types of PSL liquid sphere suspensions are used in this Test Method.

8.1.1.1 Bottle A is a CRM that contains a suspension of PSL spheres with a relative expanded peak diameter uncertainty much less than 3% and a FWHM less than 5%. It is used in the measurement of (1) peak diameter repeatability and (2) peak diameter bias of the deposition system.[2]

8.1.1.2 Bottle B contains a suspension of PSL spheres with a single well defined peak diameter that is at least 20% smaller than that of the spheres in Bottle A, and a FWHM that is significantly larger than 5%. It is used in the measurement of (1) peak diameter repeatability and (2) FWHM of the deposition system when filtering a smaller diameter with a broad diameter distribution.[3]

8.1.1.3 Bottle C contains a suspension of PSL spheres with a single well defined peak diameter that is at least 30% larger than Bottle A, and a FWHM that, if possible, is larger than 5%. It is used in the measurement of (1) peak diameter repeatability and (2) FWHM of the deposition system when filtering a larger diameter with a broad diameter distribution.

NOTE 1: Because spheres with peak diameters larger than 100 nm often have a FWHM smaller than 5% it may not be possible to secure a bottle with FWHM greater than 5%; in this case use a bottle with as large a FWHM as possible.

8.2 *Wafers*

8.2.1 One or more polished silicon wafers of appropriate diameter that have a high enough surface quality that the smallest PSL spheres deposited can be detected on the SSIS with a capture rate greater than 95% as determined in accordance with SEMI M53.

9 Preparation and Control of Apparatus

9.1 The deposition system under test must be available to run without scheduled, or unscheduled, maintenance or other interruption for the full five day test period.

9.2 Maintain a control chart of the voltage(s) associated with one or more peak diameters on a daily or weekly basis to ensure that the deposition system is under control.

[2] NIST SRM 1963a has a FWHM that is 5.5% of the certified modal diameter, slightly exceeding these requirements. Nevertheless, 1963a is currently the best-known CRM for this Test Method.

[3] NIST SRM 1964 meets these requirements.

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9.3 Repeat the entire test procedure, calculations, and interpretation of results (see §§ 10 through 12) on an annual basis or whenever the control chart shows out of control conditions.

10 Procedure

10.1 Obtain three bottles of suspensions of PSL spheres (A, B and C) as described in § 8. Record the peak diameter certified 1σ relative uncertainty, and %FWHM of the particle distribution in Bottle A on the data sheet. Record the supplier, part number, and lot number for each bottle of suspensions. If available, record the same information for Bottles B and C. An example data sheet is shown in Figure 1 and a completed example is shown in Figure R2-1.

NOTE 2: If desired, the data sheet can be set up as a spreadsheet that automatically completes the calculations discussed in § 11. This spreadsheet is outlined in Related Information 2. If this is done, error messages will appear in the cells that contain the equations to perform the calculations until the data has been entered.

10.2 Record on the data sheet the laboratory name, the contact for the test, the address, telephone number, and e-mail address by which the contact can be reached, and the dates of the test.

10.3 Record on the data sheet the identification of the deposition system under test, including supplier and model number, serial number, and software revision. If the test has been performed previously on this deposition system, enter the date of the last previous test.

10.4 Choose one or more wafers upon which to make the depositions and load the first wafer into the deposition system.

10.5 Choose a value of *N* (between 1000 and 3000) particles for the deposition count and record this value on the data sheet. Use the same value of *N* for all depositions.

10.6 *Depositions on the First Day*

10.6.1 On the morning of the first day of a five day period, scan the particles from Bottle A in the deposition system to find the peak diameter. Record the peak diameter as found by the deposition system in the Day 1 row of the first Bottle A column of the Deposition System Diameter portion of the data sheet. Then use the deposition system, centered at the peak diameter, to make a deposition of *N* particles at a location on the first wafer.

10.6.2 Repeat this procedure for bottles B and C, recording the peak diameter as found by the deposition system in the appropriate Day 1 columns of the Deposition System Diameter portion of the data sheet.

10.6.3 Near the end of the day, make a final peak diameter scan (but not an additional deposition) of bottle A. Record the peak diameter as found by the deposition system in the Day 1 row of the second Bottle A column of the Deposition System Diameter portion of the data sheet.

10.7 Repeat the procedures of ¶¶ 10.6 through 10.6.3 for the next four days, using additional locations on the wafer or on additional wafers.

10.8 At the end of the five days run the wafer (or wafers) on an SSIS, to obtain a histogram for each of the 15 depositions.

10.8.1 Determine the FWHM values in nm obtained from the histograms and record these in the FWHM on Wafer columns of the SSIS Data portions of the data sheet.

10.8.2 If desired, enter the peak diameter values and counts found from the SSIS histograms in the Measured Peak and Count columns of the SSIS Data portions of the data sheet. These values may be used to evaluate SSIS calibration and deposition system count accuracy, respectively, but they are not used to evaluate the deposition system against the requirements of SEMI M52.

11 Calculations (see Note 2)

11.1 Calculate and record the mean diameter in nm to one decimal place and the relative standard deviation as a percentage of the mean of each of the four columns of the Deposition System Diameter portion of the data sheet.

11.2 Calculate and record the Relative FWHM in each appropriate column of the SSIS Data portions of the data sheet by dividing the FWHM in nm by the measured peak diameter in nm and converting to percent with two decimal places.

11.3 Calculate the mean and standard deviation of each of the columns in the three SSIS Data portions of the data sheet.

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