

SEMI M52-0706

GUIDE FOR SPECIFYING SCANNING SURFACE INSPECTION SYSTEMS FOR SILICON WAFERS FOR THE 130 nm, 90 nm, 65 nm, and 45 nm TECHNOLOGY GENERATIONS

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NOTICE: This document was completely rewritten in 2006.

1 Purpose

1.1 This guide provides recommendations for specifying Scanning Surface Inspection Systems (SSIS) for the 130 nm, 90 nm, 65 nm, and 45 nm technology generations. The number and size of localized light scatterers (LLS) on silicon wafers are specified by customers of silicon wafer suppliers and are usually part of Certificates of Compliance. Suppliers of silicon wafers and their customers might measure these parameters using equipment provided by different manufacturers of such equipment or using different generations of equipment from one supplier. Therefore, standardization of various aspects of such measurement equipment both improves data exchange and data interpretation and aids in procurement of appropriate tools.

2 Scope

2.1 This guide outlines and recommends basic specifications for SSIS equipment used for the 130 nm, 90 nm, 65 nm, and 45 nm technology generations as driven by the 2003 edition of the International Technology Roadmap for Semiconductors (ITRS)¹ and in the forecasts of the major manufacturers of semiconductor devices.

2.2 The guide covers generic equipment characteristics of (Table 1), materials to be measured by (Table 2), and metrology specific equipment characteristics of (Table 3) measurement equipment used for verifying the quality parameter localized light scatterer (LLS) counts per wafer in large scale production of bare polished or epitaxial surfaces of silicon wafers, the back surface of which may be polished or acid etched, either bare or covered by an unpatterned, homogeneous layer of polysilicon or low temperature oxide (LTO). Reference materials for calibrating measurement equipment might have different properties.

2.3 The guide also applies to measurement equipment that provides only a subset of the measurement features outlined in Table 3.

2.4 This guide does not apply to measurement equipment used to control intermediate process steps during silicon wafer manufacturing. However, it may be completely or partly used for measurement equipment for those applications provided corresponding constraints are appropriately identified.

2.5 This guide does not apply to measurement equipment for SOI wafers (Silicon on Insulators) or patterned wafers.

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 Referenced Standards and Documents

3.1 SEMI Standards

SEMI E1.9 — Mechanical Specification for Cassettes Used to Transport and Store 300 mm Wafers

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

SEMI E10 — Specification for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM)

SEMI E19 — Standard Mechanical Interface (SMIF)

SEMI E30 — Generic Model for Communications and Control of Manufacturing Equipment (GEM)

¹ International SEMATECH, 2706 Montopolis Drive, Austin, TX 78741-6499, USA Website: www.semtech.org. Updated versions of the ITRS are available from the International SEMATECH website.

SEMI E37 — High Speed SECS Message Services (HSMS) Generic Services

SEMI E47 — Specification for 150 mm/200 mm Pod Handles

SEMI E47.1 — Provisional Mechanical Specification for Boxes and Pods Used to Transport and Store 300 mm Wafers

SEMI E58 — Automated Reliability, Availability, and Maintainability Standard (ARAMS): Concepts, Behavior, and Services

SEMI E89 — Guide for Measurement System Analysis (MSA)

SEMI M1 — Specifications for Polished Monocrystalline Silicon Wafers

SEMI M31 — Provisional Mechanical Specification for Front-Opening Shipping Box Used to Transport and Ship 300 mm Wafers

SEMI M33 — Test Method for the Determination of Residual Surface Contamination on Silicon Wafers by Means of Total Reflection X-Ray Fluorescence Spectroscopy (TXRF)

SEMI M35 — Guide for Developing Specifications for Silicon Wafer Surface Features Detected by Automated Inspection

SEMI M38 — Specification for Polished Reclaimed Silicon Wafers

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

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

SEMI M58 — Test Method for Evaluating DMA Based Particle Deposition Systems and Processes

SEMI M59 — Terminology for Silicon Technology

3.2 ISO Standards²

ISO 8859 — Information technology – 8-bit single-byte coded graphic character sets

ISO 8879 — Information Processing – Text and office systems – Standard Generalized Markup Language (SGML)

ISO 9000 — Quality management systems – Fundamentals and vocabulary

ISO 9001 — Quality management systems – Requirements

ISO 10646-1 — Information technology – Universal multiple-octet character set (UCS) – Part 1: Architecture and basic multilingual plane

ISO 10918 — Information technology – Digital compression and coding of continuous-tone still images

ISO 14644-1 — Cleanroom and associated controlled environments – Part 1: Classification of air cleanliness

ISO 14706 — Surface chemical analysis – Determination of surface elemental contamination on silicon wafers by Total Reflection X-ray fluorescence (TXRF) spectroscopy

3.3 IEEE Standards³

IEEE 754 — IEEE Standard for Binary Floating-Point Arithmetic

IEEE 802 — IEEE Standard for Local and Metropolitan Networks: Overview and Architecture

IEEE 854 — IEEE Standard Radix-Independent Floating-Point Arithmetic

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

4 Terminology

4.1 Terminology for silicon technology can be found in SEMI M59. Other terminology required for use with this standard is given below.

4.2 Abbreviations and Acronyms

4.2.1 ARAMS — Automated Reliability, Availability, and Maintainability Standard

² 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

³ Institute of Electrical and Electronics Engineers, IEEE Operations Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, New Jersey 08855-1331, USA. Telephone: 732.981.0060; Fax: 732.981.1721

- 4.2.2 *ASCII* — American Standard Code for Information Interchange
- 4.2.3 *FTP* — File Transfer Protocol
- 4.2.4 *GEM* — Generic Model for Communications and Control of Manufacturing Equipment
- 4.2.5 *HSMS* — High Speed SECS Message Services
- 4.2.6 *IEEE* — The Institute of Electrical and Electronic Engineers
- 4.2.7 *JPEG* — Joint Photographics Expert Group
- 4.2.8 *LSE* — Latex Sphere Equivalent
- 4.2.9 *PSL* — polystyrene latex, as applied to spheres used for calibration of SSISs
- 4.2.10 *PWP* — particles per wafer pass
- 4.2.11 *SECS II* — SEMI Equipment Communications Standard II
- 4.2.12 *XML* — eXtensible Markup Language

4.3 Definitions

- 4.3.1 *bias* — difference between the population mean of the test results from a measurement process and the true (accepted reference) value of the property being measured [SEMI E89].
- 4.3.2 *calibration* — a measurement process that assigns a value to the property of an artifact or to the response of an instrument relative to reference standards or to a designated measurement process set of operations that establish the relationship between values of quantities indicated by a measurement system (MS) and the corresponding values assigned to reference materials [SEMI E89].
 - 4.3.2.1 *Discussion* — The purpose of calibration is to eliminate or reduce bias in the MS [SEMI E89].
- 4.3.3 *capture rate* — the probability that an SSIS detects an LLS of latex sphere equivalent (LSE) signal value at some specified SSIS operational setting [SEMI M50].
- 4.3.4 *classification accuracy* — the ratio of the total number of machine (SSIS) classified defects for which human and machine classification results agree to the total quantity of human classified defects.
- 4.3.5 *classification purity* — the ratio of the total number of machine (SSIS) classified defects for which human and machine classification results agree to the total quantity of defects classified as a specific class by the machine.
- 4.3.6 *compatibility* — the capability of measurement equipment to emulate the measurement process of other tools. Downward compatibility refers to former generation(s) of the same or similar type of equipment of an equipment supplier.
- 4.3.7 *correlation* — the relation of measurement results obtained by repeated measurements with the same set of test specimen(s) and any two measurement tools expressed in terms of a regression curve.
- 4.3.8 *level 1 variability* (σ_1) — the variation of measurement results obtained by repeated measurements on the same test specimen(s) with the same measurement tool under nominally identical conditions with a single calibration in the shortest possible time interval and without replacing the test specimen between subsequent measurement runs.
- 4.3.9 *level 2 variability* (σ_2) — the variation of measurement results obtained by repeated measurements on the same test specimen(s) with the same measurement tool with a single calibration in the shortest possible time interval under nominally identical conditions except for replacing the test specimen between subsequent measurement runs.
- 4.3.10 *level 3 variability* (σ_3) — the variation of measurement results obtained by repeated measurements on the same test specimen(s) with the same measurement tool over a time period greater than level 2 variability tests under nominally identical conditions without operator induced adjustment and with replacing the test specimen between subsequent measurement runs.
- 4.3.11 *matching tolerance* (Δ_m) — the difference in bias for any two measurement tools of the same kind as determined under the conditions of level 3 variability tests.
- 4.3.12 *slurry ring* — a ring-shaped area, higher than the surrounding wafer surface caused by incomplete cleaning of slurry residue.
- 4.3.13 *spike* — in an epitaxial wafer, a tall thin dendrite of crystalline filament that often occurs at the center of a recess.
- 4.3.14 *sorting* — real and virtual separation of test specimens in different categories specified by one or multiple parameters.

5 Recommended Specifications for SSISs for Use on Silicon Wafers of the 130 nm, 90 nm, 65 nm, and 45 nm Technology Generations

5.1 *The recommended specifications are structured in three sections (Tables 1 through 3):*

- Generic Equipment Characteristics (Table 1)
- Materials to Be Measured (Table 2)
- Metrology-Specific Equipment Characteristics (Table 3)

5.1.1 Tables 1 through 3 contain the recommended specifications, referenced documents, test methods, and comments. Additional explanations and discussions are provided in this section.

5.2 *Generic Equipment Characteristics (Table 1)*

5.2.1 The section “Generic Equipment Characteristics” consists of five subsections:

- Wafer handling
- Reliability
- Procedural
- Documentation
- Computer/User Interface/Connectivity

5.2.2 Subsections covering “Facilities Requirements” and “Safety/Legal/Regulatory” are not included in the present guide as these issues are highly user specific and dependent on national regulations.

5.3 *Materials to Be Measured (Table 2)*

5.3.1 Table 2 specifies the categories and parameters of silicon wafers that the SSIS must be capable to handle and to measure.

5.4 *Metrology Specific Equipment Characteristics (Table 3)*

5.4.1 This section specifies the measurement functions of the SSIS, the setup parameters of the SSIS, and the performance of the SSIS. Specifications in Table 3 apply to wafer front surface inspection only, except where otherwise noted.

5.4.1.1 For back surface inspection, particles, scratches, and haze are required to be detected.

5.4.2 The surface defects to be detected by the SSIS are listed in Table 3, items 1.1.1 to 1.1.14. They are reported as LLS or XLS. The measurement performance of the equipment is verified with PSL sphere depositions on wafers that meet the COP and haze requirements of the appropriate technology generation.

5.4.3 All size units of LLS are given in [length unit] LSE (e.g., nm LSE) and refer to a nominal diameter.

5.4.4 The geometrical size of a defect (LLS) may differ considerably from its size as reported in LSE units, as the cross section for light scattering of a defect depends sensitively on the properties of the LLS.

5.4.5 PSL depositions used as reference materials are required to be CRMs, traceable to a National Standards Laboratory. The characteristics of the deposition system and procedures shall be established in accordance with SEMI M58.

5.4.6 For COPs and particles, classification accuracy and purity are specified.

5.4.7 In this guide, a hierarchy of variability levels is used to describe the performance of measurement equipment that is calibrated and adjusted/aligned according to the supplier's procedures. The various terms are defined in ¶ 4.3.

5.4.7.1 Level 1 variability: standard deviation σ_1 .

5.4.7.2 Level 2 variability: standard deviation σ_2 .

5.4.7.3 Level 3 variability: standard deviation σ_3 .

5.4.7.4 In addition two levels of systematic off-set between different tools are defined:

5.4.7.5 Matching tolerance (difference of means, Δ_m)

5.4.7.6 Correlation (regression curve)

5.4.8 Level 3 variability and matching tolerance are explicitly specified in Table 3.

5.4.9 For the SSIS, downward compatibility is subject to limitations imposed by changes in geometry and number of detectors.