SEMI M49-1102
GUIDE FOR SPECIFYING GEOMETRY MEASUREMENT EQUIPMENT FOR SILICON WAFERS FOR 130 nm TECHNOLOGY GENERATION

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1 Purpose

1.1 This document provides a guide for specifying measurement equipment for geometry and flatness of silicon wafers of the 130 nm technology generation as anticipated by the International Technology Roadmap for Semiconductors (ITRS), 1999 edition and in the forecasts of the major manufacturers of semiconductor devices. Wafer parameters as defined by SEMI M1, M24 or M38 are specified by customers of Si wafer suppliers and are usually part of Certificates of Compliance. Suppliers of Si wafers and their customers might measure these parameters using equipment provided by different manufacturers of such equipment or using different generations of equipment of one supplier. Agreement on basic features and capability of such measurement equipment improves data exchange and interpretation of data as well as procurement of appropriate tools.

2 Scope

2.1 This guide outlines and recommends basic specifications for equipment for measuring geometry and flatness of Si wafers of 130 nm technology generation.

NOTE 1: Future revisions of this guide are expected to reflect changed requirements for the 130 nm node as well as requirements of other nodes.

2.2 The guide applies to measurement equipment used for verifying the quality parameters geometry and flatness in large scale production of bare polished or epitaxial Si wafers the backside of which may be acid etched and/or covered by unpatterned, homogeneous layers of e.g. poly-Si or LTO (low temperature oxide). Artifacts (e.g., 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 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 health practices and determine the applicability or regulatory limitations prior to use.

3 Limitations

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

3.2 The document also does not apply to measurement equipment for SOI wafers or patterned wafers.

4 Referenced Standards

4.1 *SEMI Standards*

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

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

SEMI E14 — Measurement of Particle Contamination Contributed to the Product from the Process or Support Tool

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

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

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

SEMI E89 — Guide for Measurement System Capability Analysis

SEMI M1 — Specification for Polished Monocrystalline Silicon Wafers

SEMI M1.15 — Standard for 300 mm Polished Monocrystalline Silicon Wafers (Notched)

SEMI M8 — Specification for Polished Monocrystalline Test Wafers

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SEMI M11 — Specifications for Silicon Epitaxial Wafers for Integrated Circuit (IC) Applications

SEMI M12 — Specification for Serial Alphanumeric Marking of the Front Surface of Wafers

SEMI M13 — Specification for Alphanumeric Marking of Silicon Wafers

SEMI M24 — Specification for Polished Monocrystalline Silicon Premium Wafers

SEMI M27 — Practice for Determining the Precision Over Tolerance (P/T) Ratio of Test Equipment

SEMI M38 — Specification for Polished Reclaimed Silicon Wafers

SEMI M43 — Guide for Reporting Wafer Nanotopography

SEMI T7 — Specification for Back Surface Marking of Double-Side Polished Wafers with a Two-Dimensional Matrix Code Symbol

4.2 *ASTM Standards*[1]

F 42 — Standard Test Methods for Conductivity Type of Extrinsic Semiconducting Materials

F 84 — Standard Test Method for Measuring Resistivity of Silicon Wafers with an In-Line Four-Point Probe

F 534 — Standard Test Method for Bow of Silicon Wafers

F 657 — Standard Test Method for Measuring Warp and Total Thickness Variation on Silicon Wafers by Non-contact Scanning

F 671 — Standard Test Method for Measuring Flat Length on Wafers of Silicon and Other Electronic Materials

F 673 — Standard Test Methods for Measuring Resistivity of Semiconductor Slices or Sheet Resistance of Semiconductor Films with a Non-contact Eddy-Current Gage

F 928 — Standard Test Methods for Edge Contour of Circular Semiconductor Wafers and Rigid Disk Substrates

F 1152 — Standard Test Method for Dimensions of Notches on Silicon Wafers

F 1390 — Standard Test Method for Measuring Warp on Silicon Wafers by Automated Non-contact Scanning

F 1451 — Standard Test Method for Measuring Sori on Silicon Wafers by Automated Non-contact Scanning

F 1530 — Standard Test Method for Measuring Flatness, Thickness, and Thickness Variation on Silicon Wafers by Automated Non-contact Scanning

F 2074 — Standard Guide for Measuring Diameter of Silicon and Other Semiconductor Wafers

4.3 *ISO Standards*[2]

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

ISO/IEC 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

4.4 *JEITA Standards*[3]

JEIDA 43 — Terminology of silicon wafer flatness

4.5 *DIN Standards*[4]

50431 — Measurement of the electrical resistivity of silicon or germanium single crystals by means of the four-point-probe direct current method with collinear probe array

50432 — Determination of the conductivity type of silicon or germanium by means of rectification test or hot-probe

50441-1 — Determination of the geometric dimensions of semiconductor slices; measurement of thickness

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555 Website: www.astm.org

2 International Organization for Standardization, ISO Central Secretariat, 1, rue de Varembé, 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 Japanese Electronic and Information Technology Industries Association, Tokyo Chamber of Commerce and Industry Bldg. 2-2, Marunouchi 3-chome, Chiyoda-ku, Tokyo 100-0005, Japan. Website: www.jeita.or.jp

4 Available from Deutches Institut für Normung e.V., Beuth Verlag GmbH, Burggrafenstrasse 4-10, D-10787 Berlin, Germany. Website: www.din.de

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50441-2 — Determination of the geometric dimensions of semiconductor slices; testing of edge rounding

50441-4 — Determination of the geometric dimensions of semiconductor slices; diameter and flat depth of slices

50441-5 — Determination of the geometric dimensions of semiconductor wafers; terms of shape and flatness deviation

50445 — Contactless determination of the electrical resistivity of semiconductor wafers with the eddy current method

NOTE 2: Unless otherwise indicated, all documents cited shall be the latest published versions.

4.6 *IEEE Standards*[5]

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

4.7 *Other Standards*

FED-STD 209E —Airborne Particulate Cleanliness Classes in Clean Rooms and Clean Zones[6]

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *ARAMS* — Automated Reliability, Availability, and Maintainability Standard

5.1.2 *ASCII* — American Standard Code for Information Interchange

5.1.3 *FTP* — File Transfer Protocol

5.1.4 *GEM* — Generic Equipment Model

5.1.5 *HSMS* — High Speed SECS Messaging Service

5.1.6 *IEEE* — The Institute of Electrical and Electronics Engineers, Inc.

5.1.7 *JPEG* — Joint Photographics Expert Group

5.1.8 *SECS* — SEMI Equipment Communications Standard

5.1.9 *XML* — Extensible Markup Language

5 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

6 General Services Administration, Federal Supply Service, FSS Acquisition Management Center, Environmental Programs and Engineering Policy Division (FCOE), Washington, D.C. 20406

5.2 *Definitions*

5.2.1 *bias* — the difference between the average of measurements made on the same object and its true value. Sufficient measurements are needed to mitigate the effects of variability. (SEMI E89)

5.2.2 *calibration* — calibration is a measurement process that assigns value to the property of an artifact or to the response of an instrument relative to reference standards or to a designated measurement process.

NOTE 3: The purpose of calibration is to eliminate or reduce bias in the user's measurement system relative to the reference base. The calibration process compares an unknown or test item or instrument with reference standards according to a specific algorithm, often in the form of a specific calibration curve. (SEMI E89)

5.2.3 *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.

NOTE 4: Compatibility can be provided by a measurement mode in which filtering, spatial resolution, etc. of another, older, tool is imitated.

5.2.4 *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.

5.2.5 *matching tolerance* (Δ_m) — the difference in bias for any two measurement tools of the same kind. Otherwise matching tolerance tests are performed under the conditions of σ_3 tests.

NOTE 5: In the absence of certified or standard reference materials matching may be tested by using appropriate wafers complying with 130 nm technology node specifications. It is recommended to test for matching with a set of samples covering the parameter range of interest.

5.2.6 *precision over tolerance (P/T) ratio* — the ratio of the precision of measurement equipment and a product's tolerance. (SEMI M27)

5.2.7 *level 1 variability* (σ_1) — the variation (standard deviation) of measurement results obtained by repeated measurements with the same test specimen(s) and the same measurement tool under nominally identical conditions without replacing the test specimen between subsequent measurement runs. σ_1 tests are performed with a single calibration in the shortest possible time interval.

5.2.8 *level 2 variability* (σ_2) — the variation (standard deviation) of measurement results obtained by repeated measurements with the same test specimen(s) and the same measurement tool with replacing the test specimen between subsequent measurement runs but

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otherwise under nominally identical conditions. σ_2 tests are performed with a single calibration in the shortest possible time interval.

5.2.9 *level 3 variability* (σ_3) — the variation (standard deviation) of measurement results obtained by repeated measurements with the same test specimen(s) and the same measurement tool with replacing the test specimen between subsequent measurement runs but otherwise under nominally identical conditions. σ_3 tests are performed over a time period greater than σ_2 tests without operator induced adjustment.

5.2.10 *sorting* — real and virtual separation of test specimens in different categories specified by one or multiple parameters.

5.2.11 *tolerance* — the absolute magnitude of the range of the product specification. (SEMI M27)

6 Specification for Measurement Equipment for Silicon Wafers of 130 nm Technology Generation

6.1 The specification is structured in three sections (Tables 1–3):

- Generic Equipment Characteristics (Table 1)
- Materials to be measured (Table 2)
- Metrology Specific Equipment Characteristics (Table 3)

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

6.3 Generic Equipment Characteristics (Table 1)

6.3.1 The section "Generic Equipment Characteristics" consists of five subsections:

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

6.3.2 Subsections covering "Facilities Requirements" and "Safety/Legal/Regulatory" are not included in the present document as these issues are highly user specific and dependent on national regulations.

6.4 *Materials to be measured (Table 2)*

6.4.1 Table 2 specifies the parameters of Si wafers that the measurement equipment must be capable to handle and to measure.

6.5 *Metrology Specific Equipment Characteristics (Table 3)*

6.5.1 This section specifies the dimensional parameters of Si wafers to be measured and to be reported by equipment for measuring the geometry and flatness of wafers as well as the required spatial resolution, precision and accuracy of the measurement equipment.

6.5.2 The ability of a metrology tool to properly measure surface features of different spatial wavelengths is affected by the spatial bandwidth of the tool's response function. Spatial bandwidth can be defined in many ways and is influenced by many factors beyond the scope of this document. Some of these need to be standardized.

6.5.3 Spatial resolution is defined by the high spatial frequency limit of the bandwidth of the tool's response function.

6.5.4 Low and high cut-off frequency f_{min} and f_{max} define the bandwidth of the response function of measurement equipment. The cut-off frequencies correspond to an attenuation of 0.5 for the amplitude of a sinusoidal surface feature with the exception of a low pass filter ($f_{min} = 0$) for which the attenuation remains 1 at f_{min}.

6.5.5 The rate of change of the attenuation approaching the cut-off frequencies has to be larger than the rate of a Gaussian filter with the corresponding cut-off frequency.

6.5.6 The present document recommends f_{max} and f_{min} that must be measured by the instrument.

6.5.7 Any variations in filtering procedures applied near the FQA boundary must be described by the supplier of the equipment.

6.5.8 The bandwidth as specified in Table 3 is a nominal value.

6.5.9 In the present document a hierarchy of variability levels is used to describe the performance of measurement equipment which is calibrated and adjusted/aligned according to the supplier's procedures. The various terms are defined in section 5. These variability levels are consistent with terms defined in SEMI E89 but not fully interchangeable. Their relation is indicated in parentheses.

6.5.9.1 Level 1 variability: standard deviation σ_1 (SEMI E89 static repeatability)

6.5.9.2 Level 2 variability: standard deviation σ_2 (SEMI E89 dynamic repeatability)

6.5.9.3 Level 3 variability: standard deviation σ_3 (SEMI E89 reproducibility)

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