

SEMI E141-0705 (Reapproved 0211) GUIDE FOR SPECIFICATION OF ELLIPSOMETER EQUIPMENT FOR USE IN INTEGRATED METROLOGY

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1 Purpose

1.1 The application of integrated metrology is anticipated to become a key factor for advanced process control in future integrated circuit (IC) manufacturing. Important parameters, which are typically measured for the characterization and qualification of device manufacturing steps, are the thickness and the optical properties of fabricated layers and the critical dimensions (CD) of submicron structures. For the measurement principle of ellipsometry, which is commonly applied in both applications, different equipment and, hence, procedures and notations for data acquisition and modeling exist. If, therefore, ellipsometry is to be applied for integrated metrology equipment, the physical and the software integration into the equipment should be standardized to avoid efforts for specific installations depending on the equipment and fabrication environment.

1.2 The description of the mechanical integration of an ellipsometer into an equipment module (e.g., a front end module or an equipment chamber) comprises the:

- specification of the ellipsometer equipment and the spatial arrangement of the ellipsometer modules and components,
- specification of the relative position of the ellipsometer equipment to the equipment module, and
- specification of the mechanical interfaces to the equipment module.

1.3 A prerequisite for a standardized software integration of an ellipsometer is the standardized notation of the layer counting method, the measurement parameters, the measurement data, and the measurement results. This Standard describes the position of the metrology equipment with respect to the sample. The position of the measurement position (i.e., the position of the measurement spot) refers to the description of the wafer surface coordinate system as described in SEMI M20.

1.4 The purpose of this Standard is to provide a guide for a unique specification of the most commonly applied ellipsometer equipment, the comprised modules and components, and their spatial arrangement. In this Standard, the notation for parameters required in data acquisition and modeling is specified, and a unique notation for remote access on measurement parameters, data, and results is provided. Derived from these definitions, the required parameters to identify the calibration status of an ellipsometer are specified. Additionally, recommendations for preferred physical units are given.

1.5 This Standard is intended for use in integrated metrology, but may also be applicable for stand-alone metrology.

2 Scope

2.1 This Standard covers reflection ellipsometric measurements in integrated metrology.

2.2 This Standard covers the typical applications of ellipsometry, which are the determination of layer thickness and optical properties.

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3 Limitations

3.1 This Standard is limited to the measurement technique of ellipsometry although definitions may be applicable to the measurement technique of polarimetry.

3.2 This Standard is limited to the measurement of isotropic samples. It is limited to the application of Stokes vectors, Jones-, or Muller-matrix formalisms for the mathematical treatment of the sequence of optical components (refer to ¶ 7.6).

3.3 The ellipsometer equipment differs in the capability to measure all elements of the Stokes vector.

3.4 The ellipsometer equipment differs in the capability to measure the number of unknown optical properties of a sample and in their capability to measure critical dimension parameters.

3.5 This Standard does not address the calibration procedures of ellipsometer equipment.

4 Referenced Standards and Documents

4.1 SEMI Standards and Safety Guidelines

SEMI E30.5 — Specification for Metrology Specific Equipment Model (MSEM)

SEMI E89 — Guide for Measurement System Analysis (MSA)

SEMI E127 — Specification for Integrated Measurement Module Communications: Concepts, Behavior, and Services (IMMC)

SEMI M20 — Practice for Establishing a Wafer Coordinate System

SEMI MF576 — Test Method for Measurement of Insulator Thickness and Refractive Index on Silicon Substrates by Ellipsometry

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5 Terminology

5.1 Definitions

5.1.1 *calibration* — set of operations that establish, under specified conditions, the relationship between values of quantities indicated by a measuring instrument or measuring system, or values represented by a material measure or a reference material, and the corresponding values realized by standards.¹

5.1.2 *ellipsometry* — a measurement method based on the principle of measuring the change of the polarization state of light after reflection from the sample surface. Ellipsometry is commonly applied for the measurement of layer thickness, refractive index and extinction coefficient, or critical dimensions.

5.1.3 *in situ measurement* — a measurement performed inside the processing chamber of an equipment. If a wafer is used for this measurement, the wafer typically can be fed back into the process flow. The measurement data is typically available within regular wafer-to-wafer processing time frame or within wafer processing time frame (e.g., when performing layer thickness measurements during plasma etching).

5.1.4 *in situ metrology* — the science of measurement referring to in situ measurements.

5.1.5 *in-line measurement* — a measurement performed inside any portion of an equipment or work cell except the processing chamber. If a wafer is used for this measurement, the wafer typically can be fed back into the process flow.

¹ *International vocabulary of basic and general terms in metrology*, Second Edition, ISBN 92-67-01075-1, International Organization for Standardization 1993.

The measurement data is typically available within regular wafer-to-wafer processing time frame (e.g., layer thickness measurements performed inside a cooling station of a cluster tool).

5.1.6 *in-line metrology* — the science of measurement referring to in-line measurements.

5.1.7 *integrated metrology* — the science of measurement using metrology equipment that is closely connected to an equipment or work cell, characterized by the capability to perform in-line and in situ measurements.

5.1.8 *layer thickness* — the metric distance between two interfaces.

5.1.9 *measurand* — particular quantity subject to measurement.¹

5.1.10 *measurement* — set of operations having the object of determining a value of a quantity.¹

5.1.11 *measuring instrument* — device intended to be used to make measurements, alone or in conjunction with supplementary device(s).¹

5.1.12 *measuring system* — complete set of measuring instruments and other equipment assembled to carry out specified measurements.¹

5.1.13 *metrology* — the science of measurement.¹ In semiconductor manufacturing, metrology denotes the science of measurement to ascertain dimensions, quantity, or capacity; the techniques and procedures for using sensors and measurement equipment to determine physical and electrical properties in wafer processing.²

5.1.14 *metrology equipment* — any equipment that collects and reports information on specific predetermined sites or features on a substrate with consistent data structure, or reports general information about the entire substrate.³

6 Ellipsometer Equipment

6.1 Ellipsometer Equipment Specification

6.1.1 In the reflection ellipsometric measurement, a light beam with known state of polarization is directed towards a specular reflecting sample surface. The change in both the amplitude and phase of the oscillating parallel and perpendicular vector components of the electric field associated with the beam are measured after reflection from the surface as the complex amplitude reflectance ratio (i.e., a change in the polarization of the light beam occurs). There are several possible configurations for ellipsometer equipment, which can be described by the arrangement of modules that comprise the optical components required to perform the ellipsometric measurement. In addition, the optical components also induce changes in the polarization of the light beam.

6.1.2 For specification of the ellipsometer equipment, it is necessary to describe all modules and optical components included both in the measuring and in the reflection process from the sample system and their position within a coordinate system defined by the sample and the light beam. Additionally, information on the number of wavelengths used for measurement and the method of data acquisition must be provided. The following definitions are provided for ellipsometer equipment specification.

6.2 Ellipsometer Module Definition (refer to Figure 1)

6.2.1 *Ellipsometer Modules* — An ellipsometer consists of two modules, the polarizer module and the analyzer module. The modules comprise the components used to establish and analyze the state of polarization of the incident and reflected beam, respectively.

6.2.1.1 *Polarizer Module* — Arrangement of optical devices that generates a light beam of well-defined known state of polarization for interacting with the sample system. The polarizer module includes the polarizer device and the light source and may also include the compensator or modulator.

6.2.1.2 *Analyzer Module* — Arrangement of optical devices that allows measurement of the state of polarization of the light beam after reflection from the sample system. The analyzer module may also include the compensator or modulator, and the detector.

6.2.1.3 *Incident Beam* — The light beam that passes from the light source through the polarizer module on the sample surface.

² SEMATECH Official Dictionary, Rev 5.0, SEMATECH Inc., 2004; <http://www.semtech.org>

³ SEMI International Standards: Compilation of Terms. March 2004; <http://www.semi.org>