SEMI MF673-1105 (Reapproved 0611)
TEST METHODS FOR MEASURING RESISTIVITY OF SEMICONDUCTOR WAFERS OR SHEET RESISTANCE OF SEMICONDUCTOR FILMS WITH A NONCONTACT EDDY-CURRENT GAUGE

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NOTICE: This document was reapproved with minor editorial changes.

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1 Purpose

1.1 Resistivity is a primary quantity for characterization and specification of material used for semiconductor electronic devices. Sheet resistance is a primary quantity for characterization, specification, and monitoring of thin film fabrication processes.

1.2 These test methods outline the principles of eddy-current measurements as they relate to semiconductor substrates and certain thin films fabricated on such substrates as well as requirements for setting up and calibrating such instruments for use particularly at a buyer-seller interface.

1.3 An eddy-current instrument directly measures conductance of a specimen. Values of sheet resistance and resistivity are calculated from the measured conductance, with the resistivity values also requiring a measurement of specimen thickness.

2 Scope

2.1 These test methods cover the nondestructive measurement of bulk resistivity of silicon and certain gallium-arsenide wafers and of the sheet resistance of thin films of silicon or gallium-arsenide fabricated on a limited range of substrates at the wafer center point using a noncontact eddy-current gauge.

2.2 These test methods are presently limited to single-crystal and polycrystalline silicon and extrinsically conducting gallium-arsenide bulk specimens or to thin films of silicon or gallium-arsenide fabricated on relatively high resistivity substrates but in principle can be extended to cover other semiconductor materials.

2.2.1 The bulk silicon or gallium-arsenide specimens may be single crystal or polycrystalline and of either conductivity type (*p* or *n*) in the form of wafers (round or other shape) that are free of diffusions or other conducting layers that are fabricated thereon, that are free of cracks, voids or other structural discontinuities, and that have (1) an edge-to-edge dimension, measured through the center point of the wafer, not less than 25 mm; (2) thickness in the range 0.1 to 1.0 mm, inclusive, and (3) resistivity in the range 0.001 to 200 Ω·cm, inclusive. Not all combinations of thickness and resistivity may be measurable. The instrument is fundamentally limited to a fixed sheet resistance range, such as that given in ¶ 2.2.2.

2.2.2 The thin films of silicon or gallium-arsenide may be fabricated by diffusion, epitaxial or ion implant processes. The sheet resistance of the layer shall be in the nominal range from 2 to 3000 Ω per square. The substrate on which the thin film is fabricated shall have a minimum edge to edge dimension of 25 mm, measured through the center point and an effective sheet resistance at least 1000 times that of the thin film.

NOTE 1: The effective sheet resistance of a bulk substrate is its bulk resistivity (in Ω·cm) divided by its thickness in cm.

2.3 These test methods require no specimen preparation. Measurements are not affected by specimen surface finish.

2.4 These test methods require the use of resistivity standards to calibrate the apparatus (see ¶ 7.1), and a set of reference specimens for qualifying the apparatus (see ¶ 7.1.1).

2.5 Two test methods are covered by this standard.

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2.5.1 Method I ascertains the conformance of the apparatus to linearity and slope limits (±1 digit) over a broad range (2 decades) of calibration standard values. It qualifies apparatus for use over a wide range of sample values.

2.5.2 Method II assumes instrument linearity between calibration standards whose values are narrowly separated (typically ±25% of the anticipated sample range median point). Method II is particularly well suited to computer-based systems where all measurements can be quickly and automatically corrected for value offset and for temperature coefficient of resistivity.

2.5.3 These methods differ in calibration technique, sample measurement value range, data correction techniques, and suitability of instrumentation as indicated in Table 1. Either method may be applied to sheet or bulk specimens.

Table 1 Characteristics of Eddy-Current Methods

Factors	*Method I*	*Method II*
Calibration	Ascertains linearity with five samples	Ascertains slope with two samples
Application range	Broad: 2 decades	Narrow: ±25%
Sample data	Direct reading, then correct for temperature.	Direct reading, then correct for slope.
Suitable instruments	Manual/Automatic	Automatic: computer-controlled

2.6 Method I has been evaluated by interlaboratory experiment (see § 12). Until Method II has been evaluated by interlaboratory comparison, it is not recommended that the test method be used in connection with decisions between buyers and sellers.

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 Because eddy-current measurements for semiconductor materials are made almost exclusively with commercial instrumentation from one of several suppliers, some details included in this test method, such as specific range limits and manner of entering wafer thickness values to obtain resistivity values may not apply strictly to all instruments. In all such cases, the owner's manual for the particular instrument shall be considered to contain the correct information for that instrument.

3.2 Radial resistivity variations or other resistivity non-uniformity under the transducer are averaged by this test method in a manner which may be different from that of other types of resistivity or sheet resistance techniques which are responsive to a finite lateral area. The results may therefore differ from those of four-probe measurements depending on dopant density fluctuation and the four-probe spacing used.

NOTE 2: SEMI MF81 provides a means for measuring radial resistivity variation of silicon wafers.

3.3 Uncertainty of thickness values for the reference (bulk) wafers can introduce, in Method I, an uncertainty in the linearity plot; in Method II it can introduce a corresponding uncertainty in the reference line connecting the two reference wafer values, if calibration is performed in resistivity values.

3.4 Uncertainty of thickness value of sample (bulk) wafers can introduce an error in both measured and reported values for both Methods I and II. These uncertainties can be eliminated by executing the procedure using sheet resistance values for both reference and sample wafers.

3.5 Spurious currents can be introduced in the test equipment when it is located near high-frequency generators. If equipment is located near such sources, adequate shielding must be provided. Power line filtering may also be required.

3.6 Semiconductors have a significant temperature coefficient of resistivity. Temperature-correction factors for extrinsic silicon specimens are given in SEMI MF84. Temperature differences between any of the reference or sample wafers, during calibration or measurement, or both, introduce a measurement error in Method II.

3.7 High levels of humidity may affect the indicated value.

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4 Referenced Standards and Documents

4.1 *SEMI Standards and Safety Guidelines*

SEMI M59 — Terminology for Silicon Technology

SEMI MF81 — Test Method for Measuring Radial Resistivity Variation on Silicon Wafers

SEMI MF84 — Test Method for Measuring Resistivity of Silicon Wafers with an In-Line Four-Point Probe

SEMI MF374 — Test Method for Sheet Resistance of Silicon Epitaxial, Diffused, Polysilicon, and Ion-Implanted Layers Using an In-Line Four-Point Probe with the Single-Configuration Procedure

SEMI MF533 — Test Method for Thickness and Thickness Variation of Silicon Wafers

SEMI MF1527 — Guide for Application of Certified Reference Materials and Reference Wafers for Calibration and Control of Instruments for Measuring Resistivity of Silicon

4.2 *ASTM Standards*[1]

ASTM E691 — Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

ASTM E2251 — Specification for Liquid-in-Glass ASTM Thermometers with Low-Hazard Precision Liquids

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

5 Terminology

5.1 *Definitions*

5.1.1 Terms relating to silicon technology are defined in SEMI M59.

6 Summary of Test Methods

6.1 *Method I*

6.1.1 The temperature of the apparatus during the measurement is determined.

6.1.2 The apparatus is first calibrated using standards of known resistivity or sheet resistance. Then the apparatus is subjected to a test for linearity that involves measuring a set of five reference specimens. As a part of the linearity test, a plot is made of the indicated values as a function of the known values; two limiting curves are also plotted on the same graph. If all the plotted points fall within the limit curves, the apparatus is regarded as satisfactory.

6.1.3 For subsequent measurements of bulk samples, the thickness of the sample (wafer) is measured and entered directly, or by the operator, according to the design of the instrument. The conductance of the specimen is then measured by the apparatus and converted to a resistivity value that is displayed. The resistivity is subsequently corrected to its 23°C equivalent.

6.1.4 For subsequent measurement of thin film specimens, the sheet conductance is measured, converted to sheet resistance, and displayed.

6.2 *Method II*

6.2.1 The apparatus is first calibrated using two standards of known resistivity or sheet resistance. These standards may be of either known bulk resistivity or sheet resistance; their material must be the same electrical type as the samples to be measured (Note 3). The apparatus is then subjected to a test that quantifies apparatus slope at two points, and provides a means of correcting subsequent sample measurements, for values between these two points, to a calibration line established between the two standards employed.

NOTE 3: The maximum error derived from calibrating on one conductivity type and measuring the other is less than or equal to 0.12%/°C in the resistivity range 0.01 Ω·cm to 1000 Ω·cm.

6.2.2 For subsequent measurements of bulk samples, the thickness of each sample (wafer) is measured and entered directly, or by the operator, according to the design of the instrument. These measurements are subsequently referred

[1] American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA; Telephone: 610.832.9585, Fax: 610.832.9555, http://www.astm.org

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