

SEMI MF43-0316

TEST METHOD FOR RESISTIVITY OF SEMICONDUCTOR MATERIALS

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1 Purpose

1.1 The resistivity of a semiconductor material is an important materials acceptance requirement. Resistivity determinations made during device fabrication are also widely used for quality control purposes.

1.2 This Test Method covers two procedures which are widely used for making routine measurements.

2 Scope

2.1 The two test methods in this Standard are as follows:

2.1.1 *Method A, Two-Probe* — This test method requires a bar specimen of measurable cross section and with cross-sectional dimensions small in comparison with the length of the bar. For materials for which no specific referee method has been developed, this test method is recommended for materials acceptance purposes.

2.1.2 *Method B, Four-Probe* — This test method is rapid and does not require a specimen of regular cross section. This test method may be used on irregularly shaped specimens, provided a flat region is available for the contacting probes. As described in this Standard, this test method is applicable only to specimens such that the thickness of the specimen and the distance from any probe point to the nearest edge are both at least four times the probe spacing. For the special case of specimens of circular cross section with thickness more than one, but less than four, times the probe spacing, measurements by this test method are possible; the required application of approximate geometric corrections results in improved accuracy (see ¶ 10.1.3).

2.2 In general, resistivity measurements are most reliable when made on single crystals, since with such material local variations in impurity which affect the resistivity are less severe. Localized impurity segregation at grain boundaries in polycrystalline material may result in large resistivity variations. Such effects are common to either of the measurement test methods but are more severe with the four-probe test method, and its use, therefore, is not recommended for polycrystalline material.

2.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

NOTE 1: DIN 50430 is an equivalent method to Method A and DIN 50431 is an equivalent method to Method B.

NOTE 2: Other standardized test methods are preferred for use in various special circumstances. For measurements on thin wafers, use SEMI MF84; this method is preferred for referee measurements on silicon wafers. For measurements on specimens for which point contacts are unsatisfactory, use a procedure in ASTM F76 based either on Van der Pauw or bridge specimens. For two-probe referee measurements on cylindrical single crystal bars, use SEMI MF397. For four-probe referee measurements of sheet resistance on epitaxial layers deposited on or diffused or implanted into opposite conductivity-type substrates, use SEMI MF374.

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 In making resistivity measurements, spurious results can arise from a number of sources. The following must be guarded against:

3.1.1 Photoconductive and photovoltaic effects can seriously influence the observed resistivity, particularly with nearly intrinsic material. Therefore make all determinations in a dark chamber unless experience has shown that the material is insensitive to ambient illumination.

3.1.2 Spurious currents can be introduced in the testing circuit when the equipment is located near high-frequency generators. If equipment is located near such sources, adequate shielding must be provided.

3.1.3 Minority carrier injection during the measurement can occur due to the electric field in the specimen. With material possessing high minority carrier lifetime and high resistivity, such injection can result in a lowering of the resistivity for distance of several centimeters. Carrier injection can be detected by repeating the measurements at lower current. In the absence of injection no increase in resistivity should be observed. It is recommended that the current used in a resistivity measurement be as low as possible, consistent with the required precision.

3.1.4 Semiconductors have a significant temperature coefficient of resistivity. Consequently, the temperature of the specimen should be known at the time of the measurement and the current used should be small to avoid resistive heating. If resistive heating is suspected, it can be detected by a change in readings as a function of time starting immediately after the current is applied. Temperature coefficients for extrinsic germanium and silicon near room temperature are available in the literature.¹ For referee purposes, it is recommended that the test be performed at $23 \pm 0.5^\circ\text{C}$.

NOTE 3: Temperature correction factors for silicon are given in tabular form in SEMI MF84 together with equations for generating the factors.

3.1.5 Vibration of the probes sometimes causes troublesome changes in the contact resistance. If difficulty is encountered, shock mount the apparatus.

4 Referenced Standards and Documents

4.1 SEMI Standards and Safety Guidelines

SEMI M1 — Specification for Polished Single Crystal Silicon Wafers

SEMI M59 — Terminology for Silicon Technology

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 MF397 — Test Method for Resistivity of Silicon Bars Using a Two-Point Probe

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

SEMI MF2074 — Guide for Measuring Diameter of Silicon and Other Semiconductor Wafers

4.2 ANSI Standard²

ANSI B74.10 — Specifications for Grading of Abrasive Microgrits

4.3 ASTM Standard³

ASTM F76 — Test Methods for Measuring Resistivity and Hall Coefficient and Determining Hall Mobility in Single-Crystal Semiconductors

4.4 DIN Standards⁴

DIN 50430 — Testing of Semi-Conducting Inorganic Materials; Measurement of the Electrical Resistivity of Silicon or Germanium Single Crystals in Bars by Means of the Two-Point-Probe Direct Current Method (Withdrawn)

DIN 50431 — Testing of Semi-Conducting Inorganic Materials; Measurement of the Electrical Resistivity of Silicon or Germanium Single Crystals by Means of the Four-Point-Probe Direct Current Method with Collinear Four-Probe Array

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

¹ Bullis, W. M., Brewer, F. H., Kolstad, C. D., and Swartzendruber, L. I. "Temperature Coefficient of Resistivity of Silicon and Germanium near Room Temperature." *Solid State Electronics*, Volume 11 (1968): pp. 639–646.

² American National Standards Institute, 25 West 43rd Street, New York, NY 10036, USA; Telephone: +1.212.642.4900, Fax: +1.212.398.0023, <http://www.ansi.org>

³ ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA; Telephone: +1.610.832.9585, Fax: +1.610.832.9555, <http://www.astm.org>

⁴ Deutsches Institut für Normung e.V., Available from Beuth Verlag GmbH, Burggrafenstrasse 4-10, D-10787 Berlin, Germany; <http://www.din.de>

5 Terminology

5.1 Definitions

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

6 Summary of Test Methods

6.1 *Two-Probe Method* — A direct current, I , is passed through ohmic contacts at the ends of a bar specimen and the potential difference, V , is determined between two probes placed along the current direction (see Figure 1). The resistivity, ρ , is calculated from the current and potential values and factors appropriate to the geometry.

6.2 *Four-Probe Method* — An in-line four-point probe is placed on a flat surface of a solid specimen which can be approximated as semi-infinite. A direct current, I , is passed through the specimen between the outer probes and the resulting potential difference, V , is measured between the inner probes (see Figure 2). The resistivity, ρ , is calculated from the current and potential values and factors appropriate to the geometry.

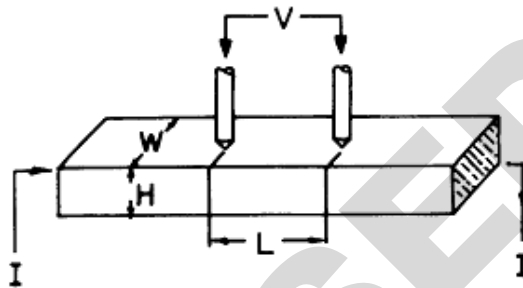


Figure 1

Specimen and Probe Arrangement for Two-Probe Measurements on a Rectangular Bar

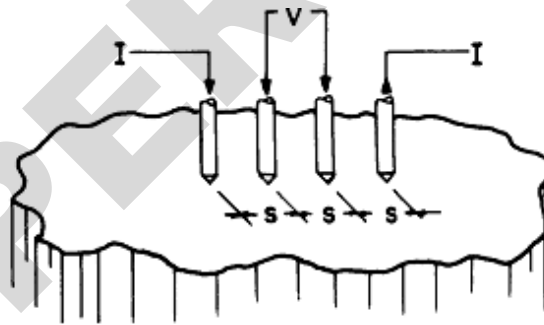


Figure 2

Specimen and Probe Arrangement for Four-Probe Measurements on a Semi-Infinite Solid Specimen

7 Apparatus

7.1 *Jigs* — Suitable for mounting the specimens and contacting them with either two or four probes as required.

7.1.1 *Probes* — Shall be individually spring mounted and shall be loaded with a force of 1.5 ± 0.5 N. The probes may be made from hardened tool steel, tungsten carbide, or other conducting metal and may be chisel shaped for measurement of curved surfaces or pointed for measurement on flat sections. In the case of point probes, the nominal radius of the tips shall be initially 25 to 50 μm . With all probing devices, frequent checking of the probe spacing with a calibrating microscope is desirable. Probes shall be replaced or resharpened when necessary to maintain the required spacing tolerance. Isolation resistance between the probes shall be at least $10^9 \Omega$.

NOTE 4: Detailed procedures for in situ determination of the spacing between adjacent probes of an in-line four-point probe are given in the Probe Assembly paragraph of the Suitability of Test Equipment section of SEMI MF84. These procedures, for which