

SEMI M39-0999

TEST METHOD FOR MEASURING RESISTIVITY AND HALL COEFFICIENT AND DETERMINING HALL MOBILITY IN SEMI-INSULATING GaAs SINGLE CRYSTALS

This test method was technically approved by the Global Compound Semiconductor Committee and is the direct responsibility of the Japanese Compound Semiconductor Committee. Current edition approved by the Japanese Regional Standards Committee on June 1, 1999. Initially available at www.semi.org August 1999; to be published September 1999.

1 Purpose

1.1 The purpose of this document is to specify a method to measure resistivity and determine Hall mobility of semi-insulating GaAs single crystals by the Van der Pauw method. Especially, this document specifies a simple and practical method for commercial semi-insulating GaAs single crystals.

2 Scope

2.1 This test method covers a procedure for measuring the resistivity and determining Hall mobility of semi-insulating GaAs single crystals by the van der Pauw method. This method requires a singly connected test specimen without any isolated holes, of homogeneous thickness and with a square shape. In this method, contacts must be sufficiently small and located at the corners of the specimen.

2.2 This standard may involve hazardous materials, operation, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Referenced Standards

3.1 ASTM Standards

F 76-73 — Standard Method for Measuring Hall Mobility and Hall Coefficient in Extrinsic Semiconductor Single Crystals

F 76-86 — Standard Test Methods for Measuring Resistivity and Hall Coefficient and Determining Hall Mobility in Single-Crystal Semiconductors

F 43-93 — Standard Test Methods for Resistivity of Semiconductor Materials

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

4 Terminology

NOTE 2: Many of the terms associated with this test method can be found in ASTM Definitions F 76-86.

hall mobility — the ratio of the magnitude of the Hall coefficient to the resistivity; it is readily interpreted only in a system with carriers of one charge type.

resistivity — the ratio of the potential gradient parallel to the current in the material to the current density. For the purpose of this method, the resistivity shall always be determined for the case of zero magnetic flux.

5 Summary of Test Method

5.1 In this method, the thickness of a specimen cut from a semi-insulating GaAs single crystal is measured.

5.2 Ohmic contacts are formed on the specimen.

5.3 The temperature near the specimen is measured.

5.4 Hall-effect measurement is performed and data are taken.

5.5 From the measured data, the resistivity and Hall mobility are calculated and corrected for temperature.

6 Interferences

6.1 Light could cause an error due to photoconductivity, so the specimen must be placed in a dark environment.

6.2 Temperature fluctuation gives significant error. Specimen itself could be at higher temperature than the environment if one does not take sufficient time after soldering the contacts.

6.3 The current-voltage conditions must be ohmic.

6.4 The damaged layer due to the sawing must be removed by etching the specimen, for example by using mixture of sulfuric acid (H_2SO_4), hydrogen peroxide (H_2O_2) and water ($\text{H}_2\text{SO}_4:\text{H}_2\text{O}_2:\text{H}_2\text{O} = 3:1:1$).

7 Apparatus

7.1 *Measurement of Specimen Thickness* — Dial gauge, micrometer, or electronic thickness gauge

capable of measuring the specimen thickness within $\pm 1\%$ must be used.

7.2 Magnet — A calibrated magnet capable of providing a magnetic flux density uniform within $\pm 1\%$ over the area in which the test specimen is to be located. Flux densities must be between 3,000–10,000 gauss (0.3T–1.0T).

7.3 Instrumentation

7.3.1 Current Source — Capable of maintaining current through the specimen constant to $\pm 1\%$ during the measurement. The current source is accurate to $\pm 1\%$ on all ranges used in the measurement.

7.3.2 Electrometer or Voltmeter — With which voltage measurements can be made to an accuracy of $\pm 1\%$. The input resistance of the electrometer (or voltmeter) must be greater than $1\text{E}13\ \Omega$. In addition to the Electrometer, the input resistance greater than $1\text{E}13\ \Omega$ must be kept in the Hall measurement system.

7.4 Specimen Holder

7.4.1 Container — Used to hold the specimen, to isolate it from surroundings and shield it from light.

7.4.2 Thermometer — Located in close proximity to the test specimen and associated instruments for monitoring temperature to an accuracy of $\pm 0.1^\circ\text{C}$ during the measurement. This may include, for example, a thermocouple.

8 Reagents and Materials

8.1 Purity of Reagents — All chemicals for which such specifications exist shall conform to SEMI C1.

8.2 Purity of Water — When water is used, it is either distilled water or deionized water having a resistivity greater than $2\text{M}\Omega\text{cm}$ at 25°C as determined by the Non-Referee Test of Test Methods D 1125.

9 Test Specimen Preparation

9.1 Regardless of the specimen preparation process used, high-purity reagents and water are required.

9.2 Material — The test specimen is prepared from a sliced wafer of a GaAs single crystal.

9.3 Specimen Cutting

9.3.1 Cut wafers which have a thickness ranging from 0.3 to 1.0 mm from a GaAs single crystal.

9.3.2 Clean and etch them, for example by a sulfuric acid/peroxide solution ($\text{H}_2\text{SO}_4:\text{H}_2\text{O}_2:\text{H}_2\text{O} = 3:1:1$), in order to remove surface damage and to obtain smoother surfaces. Polishing can be used instead of etching.

9.3.3 Cleave or dice the test specimen into a square shape with each side length from 3 mm to 10 mm. The thickness variation over the specimen should be in $\pm 1\%$.

9.4 Contact Formation

9.4.1 Ohmic contact materials can be In, AuGe/Au or AuGe/Ni.

9.4.2 Place the contacts on four corners of the specimen.

9.4.3 Maintain the contact dimensions as small as possible relative to the peripheral length of the specimen. Recommended dimension of the contact is not greater than $1/10$ of the side length of the specimen.

10 Measurement Procedure

10.1 Thickness Measurement — Measure the specimen thickness, $t[\text{cm}]$ with a precision of $\pm 1\%$.

10.2 Contact Evaluation — Verify that all combinations of contact pairs in both polarities have linear current-voltage characteristics, without noticeable curvature, about the actual value of current to be used and at the measurement temperature.

10.3 Specimen Placement — Place the clean and contacted specimen in its container. If a permanent magnet is used to provide the magnetic flux, keep the magnet and the specimen separate during the measurement of resistivity. If an electromagnet is used, be certain that the residual flux density is small enough not to affect the resistivity measurement.

10.4 Resistivity Measurement (see Figure 1) — Measure the temperature, T_1 , of the specimen. Set the current magnitude, I , to the desired value in a linear region. Measure the voltages V_1 at I_1 and V_2 at I_2 . T_1 shall be $25 \pm 5^\circ\text{C}$ and the fluctuation of T_1 shall be maintained to $\pm 1^\circ\text{C}$ during the resistivity measurement.

10.5 Hall Mobility Measurement (see Figure 2)

10.5.1 Position the specimen between the magnet-pole pieces so that the magnetic flux is perpendicular to the two flat faces of the specimen.

10.5.2 Measure the temperature, T_2 , of the specimen. Set the current magnitude, I , to the desired value. Measure the voltage V_3 with the magnetic flux and V_4 without the magnetic flux.

10.5.3 T_2 shall be $25 \pm 5^\circ\text{C}$ and the fluctuation of T_2 shall be maintained to $\pm 1^\circ\text{C}$ during Hall mobility measurement.