

Four Probe Method



Resistivity of Semiconductor by Four Probe Method at different temperatures and determination of the Band-gap:

The Four Probe Method is one of the standard and most widely used method for the measurement of resistivity of semiconductors. The experimental arrangement is illustrated. In its useful form, the four probes are collinear. The error due to contact resistance, which is specially serious in the electrical measurement on semiconductors, is avoided by the use of two extra contacts (probes) between the current contacts. In this arrangement the contact resistance may all be high compare to the sample resistance, but as long as the resistance of the sample and contact resistances are small compared with the effective resistance of the voltage measuring device (potentiometer, electrometer or electronic voltmeter), the measured value will remain unaffected. Because of pressure contacts, the arrangement is also specially useful for quick measurement on different samples or sampling different parts of the same sample.

Description of the experimental set-up:

1. Probes Arrangement

It has four individually spring loaded probes. The probes are collinear and equally spaced. The probes are mounted in a teflon bush, which ensure a good electrical insulation between the probes. A teflon spacer near the tips is also provided to keep the probes at equal distance. The whole –arrangement is mounted on a suitable stand and leads are provided for the voltage measurement.

2. Sample

Germanium crystal in the form of a chip

3. Oven

It is a small oven for the variation of temperature of the crystal from the room temperature to about 200°C (max.)

Salicon Nano Technology Pvt. Ltd.

111, 1st Floor, Laxmi Deep Tower, Laxmi Nagar District Center, Delhi - 110092, INDIA,
Tel: 91-11-22525940, 40618940; Fax; 91-11-22525941; E-mail: info@salicontech.com; Web: www.salicontech.com

4. Four Probe Set-up, DFP-02

The set-up consists of three units in the same cabinet.

(i) Multirange Digital Voltmeter

In this unit, intersil 3½ digit single chip A/D Converter ICL 7107 has been used. It has high accuracy like auto zero to less than 10µV, zero drift of less than 1µV/ °C, input bias current of 10pA max. and roll-over error of less than one count. Since the use of internal reference causes the degradation in performance due to internal heating, an external reference has been used.

SPECIFICATIONS:

Range

X1 (0-200mV) & X10 (0-2V)

Resolution

100µV at X1 range

Accuracy

±0.1% of reading ±1 digit

Impedance

1MΩ

Display

3½ digit, 7 segment LED (12.5mm height) with auto polarity and decimal indication

Overload Indicator

Sign of 1 on the left & blanking of other digits

(ii) Constant Current Generator

It is an IC regulated current generator to provide a constant current to the outer probes irrespective of the changing resistance of the sample due to change in temperatures. The basic scheme is to use the feedback principle to limit the load current of the supply to preset maximum value. Variations in the current are achieved by a potentiometer included for that purpose. The supply is a highly regulated and practically ripple free d.c. source. The current is measured by the digital panel meter.

SPECIFICATIONS:

Open Circuit Voltage : 18V

Current range : 0-20mA

Resolution : 10µA

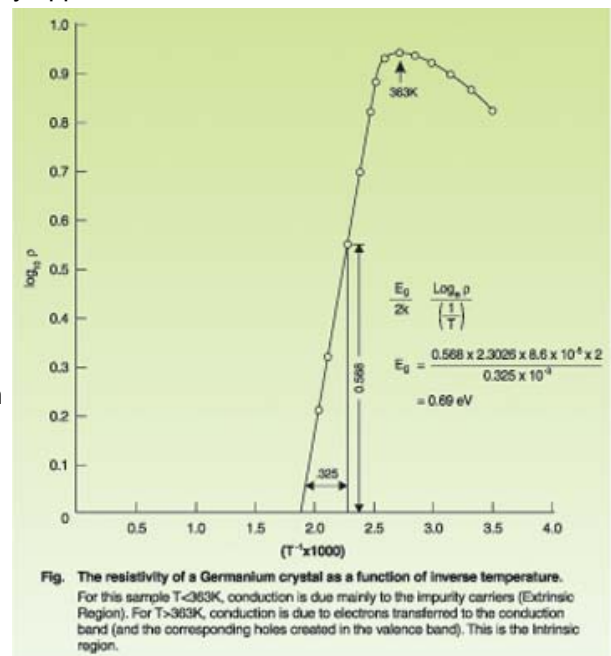
Accuracy: ±0.25% of the reading, ±1 digit

Load regulation: 0.03% for 0 to full load

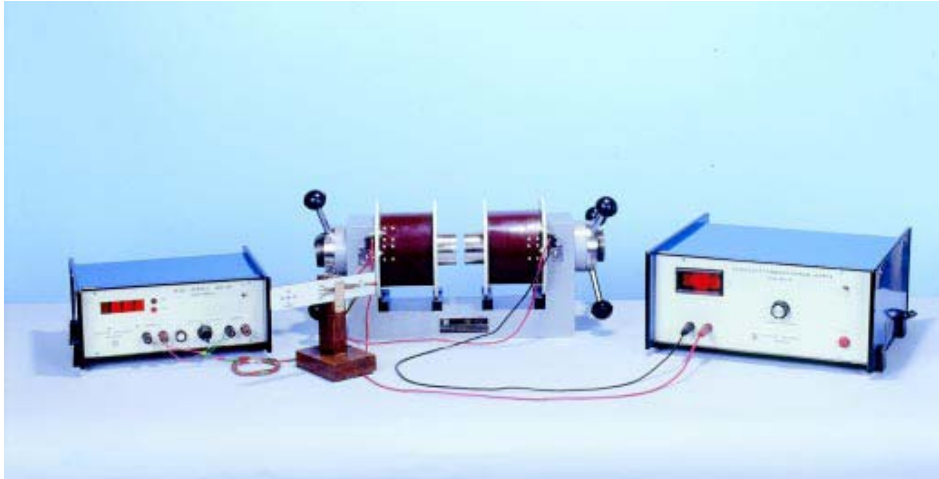
Line Regulation: 0.05% for 10% changes

iii) Oven Power Supply

Suitable voltage for the oven is obtained through a step down transformer with a provision for low and high rates of heating. A glowing LED indicates, when the oven power supply is 'ON' The experimental set-up is complete in all respect Typical results obtained from this set-up are shown in the figure.



Hall Effect Experiment



Introduction:

The resistivity measurements of semiconductors can not reveal whether one or two types of carriers are present; nor distinguish between them. However, this information can be obtained from Hall Coefficient measurements, which are also basic tools for the determination of carrier density and mobilities in conjunction with resistivity measurement.

Theory:

As you are undoubtedly aware, a static magnetic field has no effect on charges unless they are in motion. When the charges flow, a magnetic field directed perpendicular to the direction of flow produces a mutually perpendicular force on the charges. When this happens, electrons and holes will be separated by opposite forces. They will in turn produce an electric field (E_h) which depends on the cross product of the magnetic intensity, H , and the current density, J

$$E_h = RJ \times H$$

Where R is called the Hall Coefficient

Now, let us consider a bar of semiconductor, having dimension, x , y and z . Let J is directed along X and H along Z then E_h will be along Y . Then we could write

$$R = \frac{V_h/y}{JH} = \frac{V_h \cdot z}{IH}$$

Where V_h is the Hall voltage appearing between the two surfaces perpendicular to y and $I = Jyz$

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Hall Effect experiment consists of the following:

1. (a) Hall Probe (Ge Crystal); (b) Hall Probe (InAs)
2. Hall Effect Set-up (Digital), DHE-21
3. Electromagnet, EMU-75 or EMU-50V
4. Constant Current Power Supply, DPS-175 or DPS-50
5. Digital Gaussmeter, DGM-102

Hall Probes:**(a) Hall Probe (Ge Crystal)**

Ge single crystal with four spring-type pressure contacts is mounted on a sunmica decorated bakelite strip. Four leads are provided for connections with measuring devices.

TECHNICAL DETAILS

- > Material: Ge single crystal n or p-type as desired
 - > Resistivity: 8-10 Ω .cm
 - > Contacts: Spring type (solid silver)
 - > Zero-field potential: <1mV (adjustable)
 - > Hall Voltage: 25-35mV/10mA/KG
- It is designed to give a clear idea to the students about Hall Probe and is recommended for class room experiment. A minor drawback of this probe is that it may require zero adjustment

(b) Hall Probe (InAs)

Indium Arsenide crystal with 4 soldered contacts is mounted on a PCB strip and covered with a protective layer. The Hall Element is mounted in a pen-type case and a 4-core cable is provided for connections with the measuring device and current source.

TECHNICAL DETAILS

- > Contacts: Soldered
- > Rated Control Current: 4mA
- > Zero Field Potential: <4mV
- > Linearity (0-20KG): $\pm 0.5\%$ or better
- > Hall Voltage: 60-70mV/4mA/KG

The crystal alongwith its four contacts is visible through the protective layer. This is mainly used as a transducer for the measurement of magnetic field.

Hall Effect Set-up (Digital), DHE-21

DHE-21 is a high performance instrument of outstanding flexibility. The set-up consists of a digital millivoltmeter and a constant current power supply. The Hall voltage and probe current can be read on the same digital panel meter through a selector switch.

(i) Digital Millivoltmeter

Intersil 3 $\frac{1}{2}$ digit single chip A/D Converter ICL7107 have been used. It has high accuracy like, auto zero to less than 10 μ V, zero drift of less than 1 μ V/ $^{\circ}$ C, input bias current of 10pA max. and roll over error of less than one count. Since the use of internal reference causes the degradation in performance due to internal heating, an external reference has been used. Digital voltmeter is much more convenient to use in Hall experiment, because the input voltage of either polarity can be measured.

SPECIFICATIONS

- > Range: 0-200mV (100 μ V minimum)
- > Accuracy: $\pm 0.1\%$ of reading ± 1 digit

(ii) Constant Current Power Supply

This power supply, specially designed for Hall Probe, provides 100% protection against crystal burn-out due to excessive current. The supply is a highly regulated and practically ripple free dc source.

SPECIFICATIONS

- > Current: 0-20mA
- > Resolution: 10 μ A
- > Accuracy: $\pm 0.2\%$ of the reading ± 1 digit
- > Load regulation: 0.03% for 0 to full load
- > Line regulation: 0.05% for 10% variation

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