<u>Experimental Study of the Hall Effect in Semiconductor Materials</u>

PROJECT REPORT

Submitted by

GOURI NANDA DILEEP(AB23PHY014)

Under the guidance of

Dr. MARY VINAYA

Assistant Professor

Department of Physics, and Center for Research

St. Teresa's College (Autonomous), Ernakulam

In partial fulfillment of the requirements of award of

Bachelor degree of science in Physics

ST. TERESA'S COLLEGE (AUTONOMOUS) ERNAKULAM

2025-26

Experimental Study of the Hall Effect in Semiconductor Materials

PROJECT REPORT

Submitted by

GOURI NANDA DILEEP(AB23PHY014)

Under the guidance of

Dr. MARY VINAYA

Assistant Professor

Department of Physics, and Center for Research

St. Teresa's College (Autonomous), Ernakulam

In partial fulfillment of the requirements of award of

Bachelor degree of science in Physics

ST. TERESA'S COLLEGE (AUTONOMOUS) ERNAKULAM

2025-26

ST. TERESA'S COLLEGE(AUTONOMOUS) ERNAKULAM

CERTIFICATE

This is to certify that the project report entitled "**EXPERIMENTAL STUDY OF THE HALL EFFECT IN SEMICONDUCTOR MATERIALS** " is an authentic work done by GOURI NANDA DILEEP St Teresa's College, Ernakulam, under my supervision at Department of Physics And Center For Research, St Teresa's college ,Ernakulam, for the partial requirements for the award of Degree of Bachelor of Science in Physics during the academic year 2025-26. The work Presented in this dissertation has not been submitted for any other degree by any other university.

13.04.26

Supervising Guide
Dr. MARY VINAYA
Assistant professor

St. Teresa's College (Autonomous) Ernakulam * Department of Physics *

13.04.26

Head of the Department
Dr. MARY VINAYA
Assistant professor

ST. TERESA'S COLLEGE(AUTONOMOUS), ERNAKULAM

B.Sc. PHYSICS

PROJECT REPORT

Name: GOURI NANDA DILEEP

Register number: AB23PHY014

Year of Work: 2025-2026

This is to certify that this project work entitled, 'EXPERIMENTAL STUDY OF THE HALL EFFECT IN SEMICONDUCTOR MATERIALS' is an authentic work done by GOURI NANDA DILEEP.

Staff member in-charge

Dr. Mary Vinaya 13.04.26

Head of the Department

Dr. Mary Vinaya 13.04.26

Submitted for the University examination held at St. Teresa's College, Ernakulam.

DATE: 16.04.26

EXAMINER:

1. ATHIRA PRAKASH

2.

DECLARATION

I, **Gouri Nanda Dileep** final year B.Sc. Physics student, Department of Physics and Center for Research, St. Teresa's College (Autonomous), Ernakulam, do hereby declare that the project work entitled **"EXPERIMENTAL STUDY OF THE HALL EFFECT IN SEMICONDUCTOR MATERIALS** has been originally carried out under the guidance and supervision of **Smt. Dr.MARY VINAYA**, Assistant Professor, Department Of Physics, and Center for Research, St. Teresa's College (Autonomous), Ernakulam, in partial fulfilment for the award of the degree of Bachelor of Physics. I further declare that this project is not partially or wholly submitted for any other purpose and the data included in the project is collected from various sources and are true to be the best of my knowledge.

PLACE: ERNAKULAM

DATE:

ACKNOWLEDGEMENT

First and foremost, I would like to thank God almighty for showering his blessing on me in this endeavor. I wish to express my sincere gratitude to Dr. Mary Vinaya, Department of Physics and Center for Research, St. Teresa's College (Autonomous), Ernakulam, for her guidance, timely help, expert advice, support and persistent encouragement given to me throughout the duration of my project work.

I express my deep sense of gratitude to the Department of Physics, St. Teresa's College (Autonomous), Ernakulam, for extending the facilities and cooperation required from time to time. I take this opportunity to thank once again Dr. Mary Vinaya, Head of the Department of Physics for generous concern and support.

Last but not the least I express my thanks to all teaching and nonteaching staff of the department of Physics Center for Research, for their kind co-operation

CONTENTS

ABSTRACT

The Hall Effect experiment is performed to study the electrical behavior of a semiconductor by measuring the Hall voltage developed when a current-carrying sample is placed in a magnetic field. In this project, a semiconductor sample is used, and a constant current is passed through it while a perpendicular magnetic field is applied. Due to the motion of charge carriers, a transverse voltage called the Hall voltage is produced.

By measuring this Hall voltage, important semiconductor properties such as the Hall coefficient, type of charge carriers (n-type or p-type), carrier concentration, and mobility are determined. The experimentally obtained values are compared with standard reference values to check the accuracy of the results.

This experiment provides a simple and effective method to analyze the electrical characteristics of semiconductors and helps in understanding their practical applications in electronic devices.

CHAPTER-1

INTRODUCTION

HALL EFFECT

Henry A. Rowland and Hall were investigating whether the electrical resistance of a current-carrying conductor changes when it is placed in a magnetic field. During his experiments, he observed that when a magnetic field is applied perpendicular to the direction of current in a conductor, the equipotential lines become distorted, producing a measurable voltage across the conductor. This voltage, developed in a direction perpendicular to both the current and the magnetic field, is known as the Hall voltage (V_h).

In his original experiment, The Hall effect was discovered in 1879 by Edwin Herbert Hall during his doctoral research in Physics under the guidance of Professor Henry A. Rowland used a thin gold leaf mounted on a glass plate and connected electrical contacts at various points along its length. By passing current through the gold leaf and applying a magnetic field, he detected a transverse voltage across the sample. He later repeated the experiment using different materials and different contact arrangements, confirming that the observed voltage was a fundamental electromagnetic effect and not an experimental error.

In 1880, Hall published the complete details of this phenomenon as part of his doctoral thesis in scientific journals such as the American Journal of Science and the Philosophical Magazine. The discovery was highly praised by the famous scientist Lord Kelvin, who compared its importance to some of the greatest discoveries made by Michael Faraday. At the time of Hall's discovery, very little was known about the nature of electricity; for example, the electron had not yet been identified. For many years, the Hall effect remained mainly a laboratory curiosity because the materials available produced only very small Hall voltages. However, with the development of semiconductor technology and the introduction of compound semiconductors such as III–V materials, much larger Hall voltages became possible, making the Hall effect extremely useful for practical applications.

The Hall effect occurs when charge carriers, such as electrons in n-type semiconductors or holes in p-type semiconductors, are deflected by a magnetic field while moving through a material carrying an electric current. This deflection causes the accumulation of charge on opposite sides of the material, creating a transverse electric field and producing a measurable Hall voltage. The polarity of this voltage depends on the type of charge carriers present in the material. The magnitude of the Hall voltage depends on the strength of the applied magnetic field, the current flowing through the sample, and the concentration of charge carriers. By combining Hall voltage measurements with resistivity data, important semiconductor parameters such as carrier type, carrier concentration, and carrier mobility can be accurately determined. Therefore, the Hall effect is widely used for characterizing semiconductor materials and studying their electrical properties.

SEMICONDUCTORS

Semiconductors are materials whose electrical conductivity lies between that of good conductors like metals and insulators such as glass. These materials have a crystalline structure and contain only a small number of free electrons at room temperature. Therefore, under normal conditions, a semiconductor behaves almost like an insulator. However, when small amounts of suitable impurity atoms are added to it, its electrical conductivity can be controlled as required. Some common examples of semiconductor materials are silicon, germanium, and carbon.

Semiconductors are the backbone of modern electronics. Devices such as transistors, solar cells, light-emitting diodes (LEDs), and integrated circuits all work based on semiconductor materials. The motion of electrons and holes inside a semiconductor is explained using quantum physics and crystal lattice theory. Unlike metals, the electrical conductivity of a semiconductor increases when its temperature rises. Semiconductor devices show many useful properties such as allowing current to flow more easily in one direction, having variable resistance, and being sensitive to heat and light. Because their electrical properties can be changed by adding impurities or by applying electric fields or light, semiconductors are widely used in amplification, switching, and energy conversion.

Electric current in a semiconductor flows due to the movement of charge carriers, which are free electrons and holes. The process of adding a small amount of impurity to a semiconductor to increase its conductivity is called doping. If a doped semiconductor contains more holes, it is known as a p- type semiconductor, while if it contains more free electrons, it is called an n-type semiconductor. In electronic devices, the position and amount of p-type and n-type regions are carefully controlled. A single semiconductor crystal can contain several such regions, and the junctions formed between them, called p-n junctions, are responsible for the useful electrical behavior of semiconductor devices.

The basic properties of semiconductors were studied during the late nineteenth and early twentieth centuries. Later, the development of quantum physics made it possible to fully understand these materials, which led to the invention of the transistor in 1948. Although many elements and compounds show semiconducting behavior, silicon, germanium, and gallium-based compounds are the most widely used. Silicon and germanium belong to Group XIV of the periodic table and have four valence electrons in their outermost shell. This allows them to easily gain or lose electrons, making them ideal for semiconductor applications. Many important compound semiconductors are also formed from elements of Groups III and V or Groups II and VI, and these materials play an important role in modern electronic devices.

Apart from elemental semiconductors, many compound materials also show semiconducting behavior. These include ternary compounds, oxides, alloys, and organic semiconductors. Organic semiconductors are made from organic compounds and are increasingly used in modern electronic and optoelectronic applications.

Most commonly used semiconductor materials are crystalline solids. However, amorphous and liquid semiconductors are also important. Examples include hydrogenated amorphous silicon and mixtures of elements such as arsenic, selenium, and tellurium in different proportions. These materials have properties that lie between those of good conductors and insulators. They show intermediate electrical conductivity and their conductivity changes rapidly with temperature. In some cases, they even show negative resistance. Since these materials do not have a rigid crystal structure like conventional semiconductors such as silicon, they are generally used in thin-film form. These thin films do not require very high electronic quality and are relatively insensitive to impurities and radiation damage.

In present-day technology, semiconductor materials are used in almost every field. High-temperature semiconductors are widely used in technical applications. Because the electrical properties of semiconductors strongly depend on temperature, it is important to control and improve their temperature stability. For this reason, understanding how different semiconductor materials behave with temperature is essential for their effective use in electronic devices.

TYPES OF SEMICONDUCTOR

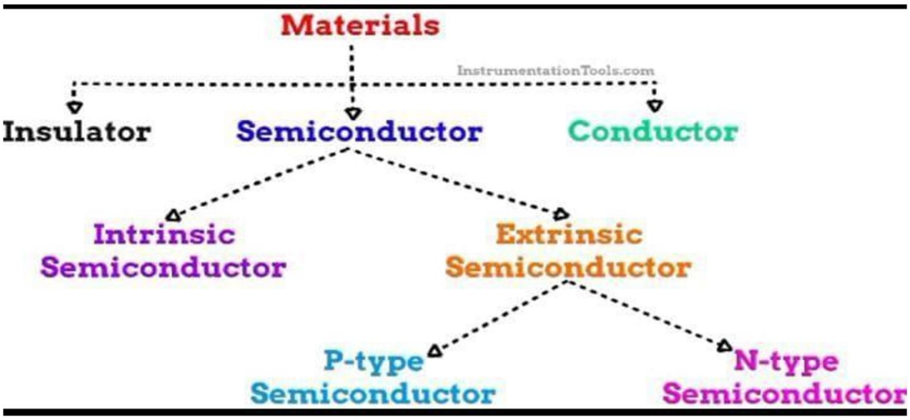


Fig 1-Classification of semiconductors

INTRINSIC SEMICONDUCTOR

An intrinsic semiconductor is one which is made of the semiconductor material in its extremely pure form.

Examples of such semiconductors are: pure germanium and silicon which have forbidden energy gaps of 0.72 eV and 1.1 eV respectively. The energy gap is so small that even at ordinary room temperature; there are many electrons which possess sufficient energy to jump across the small energy gap between the valence and the conduction bands.

Alternatively, an intrinsic semiconductor may be defined as one in which the number of conduction electrons are equal to the number of holes.

Schematic energy band diagram of an intrinsic semiconductor at room temperature is shown in fig 2.

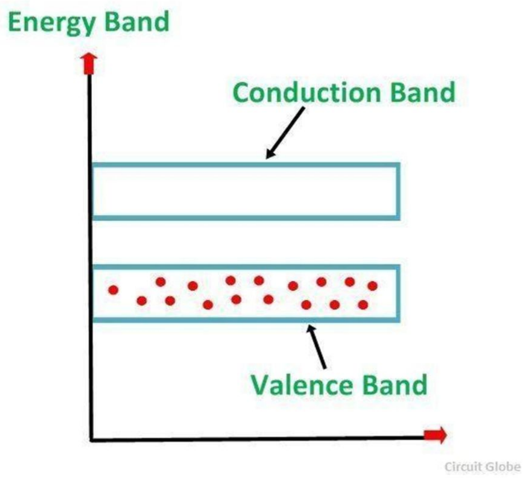


Fig 2: Energy band gap diagram (intrinsic)

EXTRINSIC SEMICONDUCTOR

Those intrinsic semiconductors to which some suitable impurity or doping agent or doping has been added in extremely small amounts are called extrinsic or impurity semiconductors, depending on the type of doping material used, extrinsic semiconductors can be subdivided into two classes.

i. N-type semiconductors

ii. P-type semiconductors

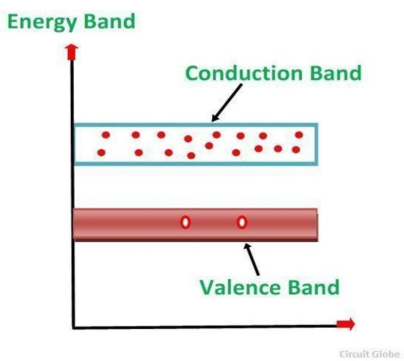


Fig 3-Energy bandgap diagram (extrinsic)

N-TYPE SEMICONDUCTOR

This type of semiconductor is obtained when a pentavalent material like phosphorus is added to pure silicon crystal. As shown in Fig. Below. Each phosphorus atom forms covalent bonds with the surrounding four silicon atoms with the help of four of its five electrons. The fifth electron is superfluous and is loosely bound to the phosphorus atom.

Hence, it can be easily excited from the valence band to the conduction band by the application of electric field or increase in thermal energy. It is seen from the above description that in N-type semiconductors, electrons are the majority carriers while holes constitute the minority carriers.

P-TYPE SEMICONDUCTOR

This type of semiconductor is obtained when traces of a trivalent like boron (B) are added to a pure silicon crystal. In this case, the three valence electrons of a boron atom form covalent bonds with four surrounding silicon atoms but one bond is left incomplete and gives rise to a hole.

Thus, the boron which is called an acceptor impurity causes as many positive holes in a silicon crystal as there are boron atoms thereby producing a P-type extrinsic semiconductor.
In this type of Semiconductor conduction is by the movement of holes in the valence band.

MAJORITY AND MINORITY CARRIERS

In semiconductors, electrical conduction is due to the movement of charge carriers, namely electrons and holes. Depending on the type of semiconductor and the method of doping, one type of charge carrier becomes more abundant than the other. These are classified as majority carriers and minority carriers. Understanding these carriers is essential for explaining the working of semiconductor devices such as diodes, transistors, and integrated circuits.
A majority carrier is the type of charge carrier that exists in a larger concentration in a semiconductor. Conversely, a minority carrier is present in a smaller concentration. The nature of majority and minority carriers depends on whether the semiconductor is intrinsic (pure) or extrinsic (doped).
To increase conductivity, semiconductors are intentionally doped with impurities, resulting in extrinsic semiconductors. These are classified into two types: n-type and p-type semiconductors.

In an n-type semiconductor, a pure semiconductor like silicon is doped with a pentavalent impurity such as phosphorus, arsenic, or antimony. These impurity atoms have five valence electrons. Four of these electrons form covalent bonds with neighbouring silicon atoms, while the fifth electron remains loosely bound and becomes a free electron. This increases the number of free electrons available for conduction. As a result, electrons become the majority carriers, and holes become the minority carriers. Since electrons are negatively charged, n-type semiconductors mainly conduct electricity through electron movement.

The concept of majority and minority carriers is very important in semiconductor physics because it determines the electrical behaviour of the material. Even though minority carriers are fewer in number, they play a crucial role in certain phenomena such as recombination, generation, and the operation of devices like p-n junction diodes and transistors. For example, in a p-n junction, the flow of minority carriers across the junction is responsible for current under reverse bias conditions.

In conclusion, majority and minority carriers are fundamental concepts in understanding semiconductor behaviour. In n-type semiconductors, electrons are the majority carriers and holes are the minority carriers, while in p-type semiconductors, holes are the majority carriers and electrons are the minority carriers. Their behaviour under different conditions determines the functioning of various electronic devices, making them a key topic in modern electronics and solid-state physics.

BAND GAP OF GERMANIUM

A semiconductor (either doped or intrinsic) always possesses an energy gap between its valence and conduction bands. For the conduction of electricity, a certain amount of energy is to be given to the electron so that it can jump from the valence band to the conduction band. The energy needed is the measure of the energy gap (E) between the top and bottom of valence and conduction bands respectively. In case of insulators, the value of Eg varies from 3 to 7 eV. However, for semiconductors, it is quite small. For example, in case of germanium, Eg=0.72 eV and in case of silicon, Eg=1.1 eV.

In semiconductors at low temperatures, there are few charge carriers to move, so conductivity is quite low. However, with increase in temperature, more charge carriers get sufficient energy to be excited to the conduction band. This led to increase in the number of free charge carriers and hence increase in conductivity. In addition to the dependence of the electrical conductivity on the number of free charges, it also depends on their mobility.

The mobility of the charge carriers, however, decreases with increasing temperature. But on the average the conductivity of the semiconductors rises with rise in temperature. To determine the energy band gap of a semiconducting material, we study the variation of its conductance with temperature. In reverse bias, the current flowing through the PN junction is quite small and internal heating of the junction does not take place.

CHAPTER-2

THEORY

HALL EFFECT

The Hall Effect is a phenomenon observed when a current-carrying conductor or semiconductor is placed in a magnetic field. The Hall effect is used to determine important properties such as electrical conductivity, carrier concentration, and mobility. It is also used in non-contact sensors and probes for measuring magnetic fields and other physical quantities.

When no magnetic field is present, electric current flows through the conductor in a straight path between the terminals. However, when a magnetic field is applied perpendicular to the direction of current, the moving charge carriers (electrons or holes) experience a force. This force, called the Lorentz force, causes the charge carriers to move sideways, making their path curved instead of straight.

Because of this sideways movement, negative and positive charges start to collect on opposite sides of the conductor. This charge separation creates an electric field across the conductor. The charges continue to build up until this electric field balances the magnetic force. At this stage, the charge carriers move in a straight line again, and a voltage is produced across the conductor. This voltage is known as the Hall voltage.

When a charged particle moves in a magnetic field, it experiences the
Lorentz force. The magnitude of this force is given by F_B=q $(v \times B) - (1)$

where
q is the charge of the particle.
v is the velocity of the moving charge.
B is the magnetic field.

DETERMINATION OF HALL COEFFICIENT AND CURRENT DENSITY

Let us consider a current 1A passing through a semiconductor slab of breadth 'b', length 'l' and thickness 't' along its length and magnetic field BX applied along its thickness. Consider a free electron associated with the n-type Germanium slab moving in the upward direction which will be acted upon by the Lorentz force. The force acting on the electron is given by:

$$Fe = -eVyBx$$

Where:
Fe is the Lorentz force acting on an electron moving in the upward direction.
Vy is the velocity of the electron in the Y direction.
By is the applied magnetic field in the X direction.

The velocity Vy of the electron cannot be determined experimentally. Hence, it is replaced by a measurable quantity. The current density in the Y direction,
Jy is given by:

$$Jy = -enVy$$

n is the carrier concentration.
Jy Is the current density given by:

$$Jy = \frac{Iy}{bt}$$

Equating Equations (2) and (3) we get the electron velocity as:

$$Vy = \frac{Iy}{-nebt}$$

The terms on the right-hand side of Equation (4) indicate that the velocity of the electrons can be measured by knowing the current and physical dimensions of the semiconductor sample. Hence the force acting on the electron is given by:

$$F_e = -e \cdot \left(\frac{I_y}{nebt}\right) B_x$$

This force acts in the +Z direction, and electrons inside the slab will drift towards it as indicated. The accumulation of electrons along the length of the slab on the left-hand side results in a negative potential. Similarly, accumulation of holes along the length of the slab on the right-hand side of the p-type semiconductor results in a positive electric field which is also called the Hall electric field.
Without the applied magnetic field, the charges will move randomly in all possible directions inside the lattice. Application of a magnetic field provides a definite direction for the charge of carriers for their movement inside the lattice. Equilibrium will be established when all the charges have taken their respective positions at the edges of the slab, and current will flow in the circuit. At this point the Lorentz force equals the force exerted by the Hall electric field that comes into play; hence we can write:

$$F_e = F_H$$

$$E_z = V_y B_x$$

Substituting for V_y(which is not a directly measurable quantity) from equations:

$$E_z = \frac{I_y B_x}{-nebt}$$

This electric field produced by an n-type semiconductor is negative, whereas the field produced in the case of a p-type semiconductor is positive.

$$BE_z = \frac{I_y B_x}{t \cdot ne}$$

In this equation n, e and t are constants for a given sample, hence it is replaced by a new constant

$$R_H$$

given by:

$$R_H = \frac{1}{ne}$$

Where $R_H$is called the Hall coefficient. With this substitution the above equation reduces to:

$$BE_z = \frac{-R_H(I_y B_x)}{t}$$

V_H It is called the Hall voltage, which can be measured along with the Ohmic voltage using a milli voltmeter. Hence, the unknown Hall coefficient R_H can be determined by studying the variation of the Hall voltage with magnetic field for a fixed value of current

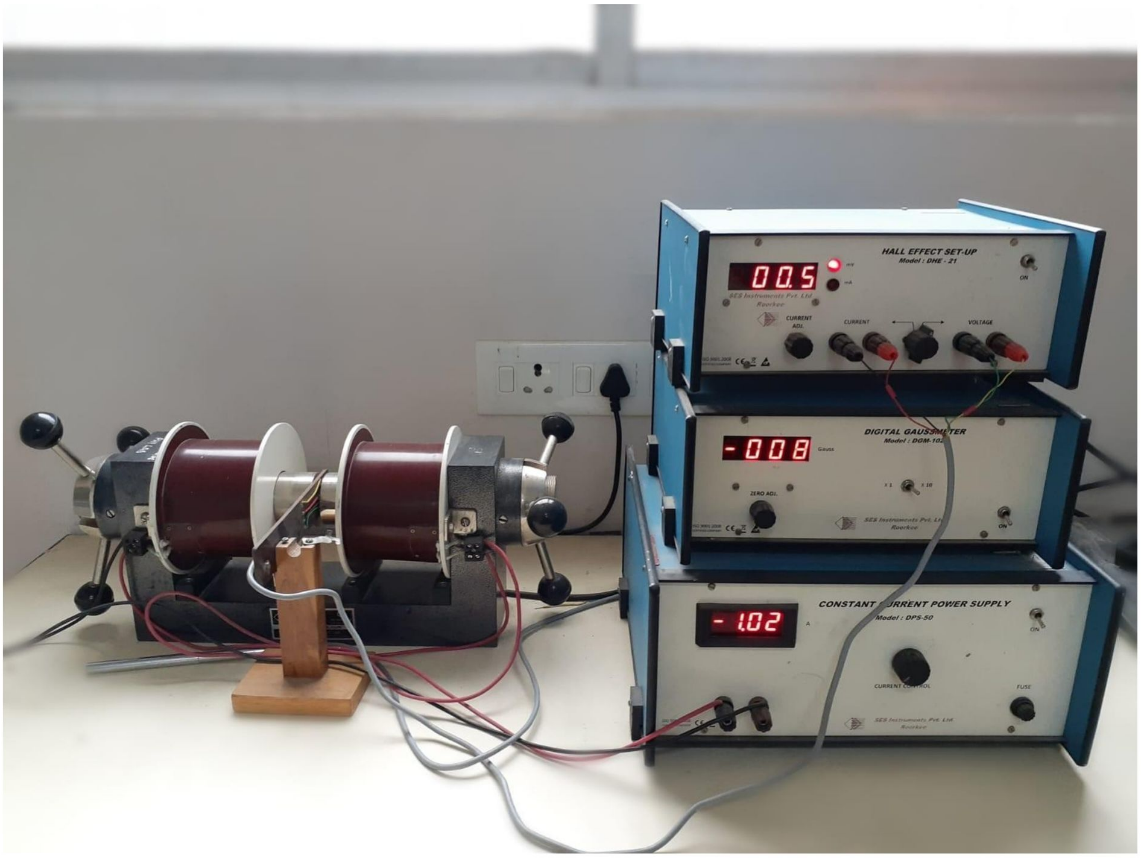
$$\text{Slope} = \frac{-R_H I_x}{t}$$

Passing a known current through the sample and knowing thickness, one can determine its Hall coefficient. With the knowledge of$R_H$the carrier concentration can be determined using the relation:

$$n = \frac{1}{eR_H}$$

CHAPTER-3

APPARATUS



1. Hall Effect Setup (Digital), DHE-21

It is a high-performance and flexible instrument consisting of a digital millivoltmeter and a constant current power supply. The Hall voltage and probe current are measured using the same digital panel meter with the help of a selector switch.

2. Digital Gaussmeter (Model DGM-102)

It is used to measure the magnetic field. The Hall probe detects the magnetic field at its tip. For measuring residual magnetic fields, the probe should be placed perpendicular to the direction of the magnetic field along the surface.

3. Constant Current Power Supply (DPS-50)

It is a stable and high-performance current source suitable for electromagnets. It can be used with electromagnets having coil resistance up to 6 Ω. The current regulation is IC-controlled, ensuring stable output. Matched power transistors share the load current, and the system is protected against transients caused by inductive loads.

4. Electromagnet
It produces the magnetic field required for the Hall effect experiment. The air gap between the pole pieces can be varied using a screw adjustment mechanism, which helps in controlling the magnetic field strength.

5. Hall Probe (Indium Arsenide)
It consists of a thin semiconductor material. When current flows through it in the presence of a magnetic field, a voltage is developed perpendicular to both the current and the magnetic field. This Hall voltage is directly proportional to the magnetic field when the current is kept constant.

6. Samples
These are unknown semiconductor materials used in the experiment. By studying the Hall effect, properties such as carrier concentration, mobility, and type of charge carriers can be determined.

EXPERIMENTAL SET UP

Sample in the form of a thin rectangular slab is mounted on a Hall probe with four spring type pressure contacts. A pair of green color leads is provided for current and another pair of red for Hall voltage. Note the direction of current and voltage measurement carefully. Do not exceed current beyond 8 mA. The unit marked "Hall Effect Set-up" consists of a constant current source (CCS) for supplying current to the sample and a digital milli voltmeter to measure the Hall voltage. The unit has a single digital display used for both current and Hall voltage measurement. For applying the magnetic field, an electromagnet with a constant current supply is provided with a toggle switch to choose either. It is capable of generating a magnetic field of up to 0.75 Tesla for a 10 mm gap between its pole pieces. The magnetic field can be measured using the gauss meter along with the given Hall probe.

PROCEDURE

1 Connect the leads from the sample to the "Hall effect Set-up" unit. Connect the electromagnet to constant current supply.
2 Switch on the electromagnet and check whether zero magnetic field is obtained for zero current, if not then adjust it accordingly. Then, set suitable magnetic field density by varying the current supplied to the electro-magnet.
3 Insert the sample between the pole pieces of the electromagnet such that I, B and V are in the proper direction.
4 From the direction of current and magnetic field, determine the direction of accumulation of majority carriers. Connect the one of the Hall voltage probes into which charge carriers

are expected to accumulate to the positive side of the milli voltmeter. Connect the other Hall voltage probe to the negative side of the milli voltmeter. Don't change this voltmeter connection throughout your experiment.

5 The magnetic field was then switched on and the Hall voltage was noted by varying the current flowing through the electromagnet slowly. We record Hall voltage as a function of the magnetic field. Note that field direction can be changed by changing the direction of current through the electron.

6 Above was repeated for 2 different probes and for 2 values of probe current for each of the two probes.

7 Plot Voltage vs Magnetic field graph by least squares fitting. Calculate R and majority charge carrier's density from this graph.

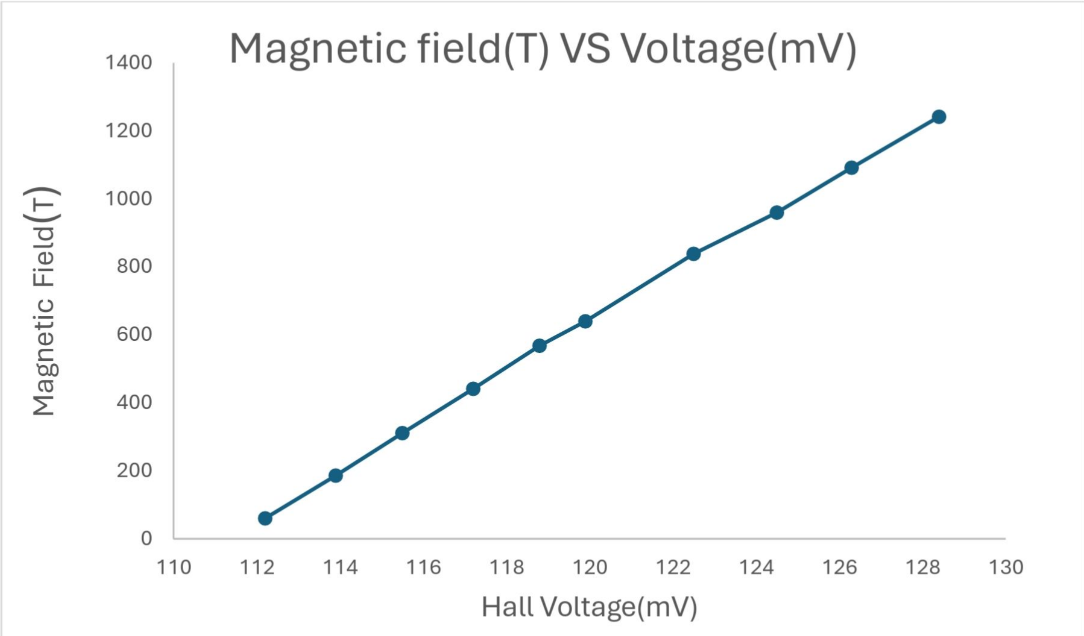
CHAPTER-4

EXPERIMENTAL OBSERVATION

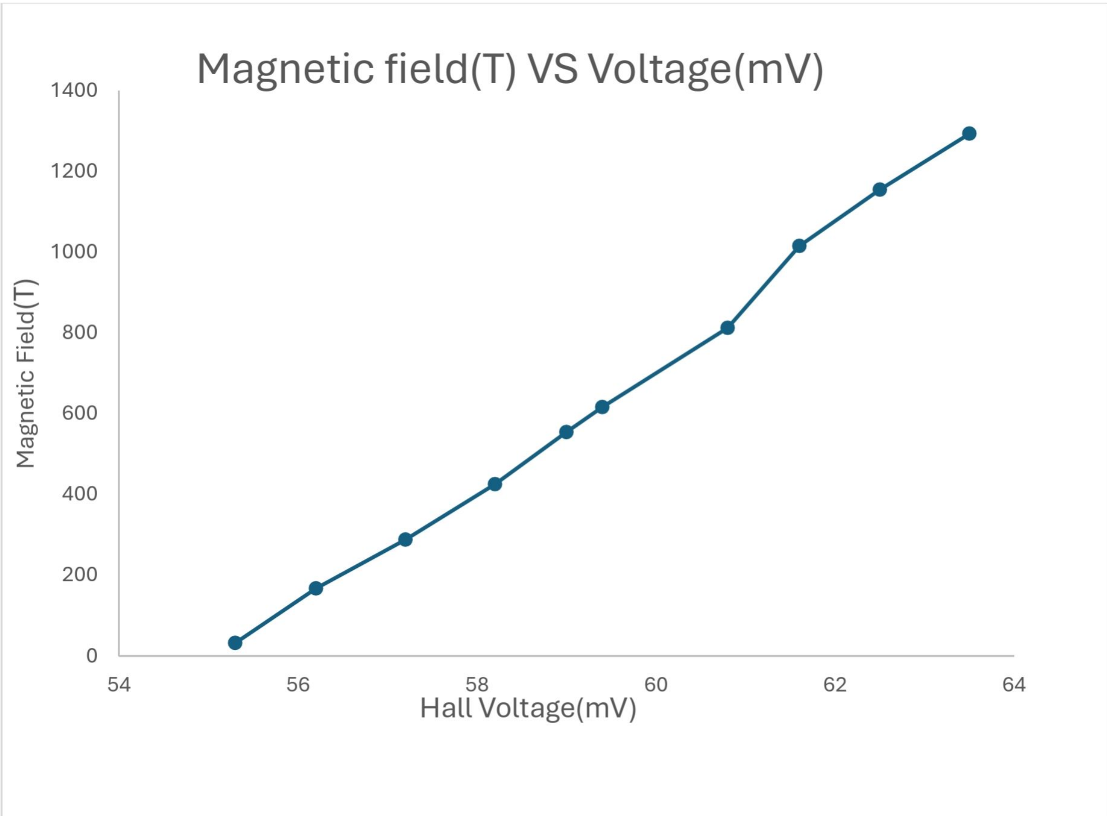
HALL EFFECT EXPERIMENT OBSERVATION

Current (mA)	Magnetic Field (T)	Voltage (mV)	Reverse Magnetic Field (T)	Reverse Voltage (mV)
0.1	32	55.3	-104	54.3
0.3	167	56.2	-231	53.4
0.5	288	57.2	-346	52.6
0.7	425	58.2	-470	51.8
0.9	554	59.0	-599	51.0
1.0	616	59.4	-658	50.6
1.3	812	60.8	-855	49.4
1.5	1015	61.6	-982	48.5
1.7	1155	62.5	-1111	47.8
1.9	1293	63.5	-1250	46.9

Constant (mA)	Magnetic Field (T)	Voltage (mV)	Reverse Magnetic Field (T)	Reverse Voltage (mV)
0.1	60	112.2	-115	109.9
0.3	186	113.9	-229	108.3
0.5	311	115.5	-349	106.7
0.7	441	117.2	-505	105.5
0.9	568	118.8	-633	104.0
1.0	640	119.9	-701	103.1
1.3	838	122.5	-900	100.7
1.5	960	124.5	-1036	99.1
1.7	1092	126.3	-1172	97.5
1.9	1242	128.4	-1306	96.1


Magnetic field(T) VS Voltage(mV)
Magnetic Field(T)
Hall Voltage(mV)
0
200
400
600
800
1000
1200
1400
110
112
114
116
118
120
122
124
126
128
130

I=2mA


Magnetic field(T) VS Voltage(mV)
Magnetic Field(T)
Hall Voltage(mV)
0
200
400
600
800
1000
1200
1400
54
56
58
60
62
64

I=4mA

When I=2mA,

Slope = $221\times10^3\times10^{-4}$ T/V

=22.13 T/V

Thickness = 5×10^{-4} m

$R_H = slope \frac{I_c}{t}$

= $(5\times10^{-4})/((2\times10^{-3})\times0.0451)$

= 0.0225 m^3C^{-1}

When I=4mA,

Slope = $70.4\times10^3\times10^{-4}$ T/V

=7.04 T/V

Thickness = 5×10^{-4} m

$R_H = slope \frac{I_c}{t}$

= $(5\times10^{-4})/((4\times10^{-3})\times7.04)$

= 0.01775568 m^3C^{-1}

Mean, R_H=0.0201 m^3C^{-1}

Current density, $n = \frac{1}{R_H q}$

= $1/(0.0201\times1.6\times10^{-19})$

= 3.472×10^{19} m^{-3}

conductivity(given) σ = 0.16672Ω^{-1}m

$Resistivity = 1/ conductivity$ = .5998 Ωm^{-1}

Therefore, mobility of charge carriers, $\mu = R_H\sigma$ = (0.00181m^3C^{-1}) ×(0.1667Ω^{-1}m)

= 0.00307

CHAPTER-5

RESULT AND CONCLUSION

ERROR ANALYSIS TABLE

Parameter	Experimental Value	Standard Value	Absolute Error	Percentage Error%
Hall Coefficient	0.0181	1.5×10^{-2}	0.0031	20.6 %
Carrier Concentration $\boldsymbol{n}$	3.472×10^{19}	2.5×10^{19}	0.972×10^{19}	38.8 %
Conductivity $\boldsymbol{\sigma}$	0.1667	0.220	0.53	24.22 %
Resistivity $\boldsymbol{\rho}$ (Ωm^{-1})	5.99	4.5	0.149	33.11 %
Mobility $\boldsymbol{\mu}$ (m^2/ Vs)	0.00307	0.001-0.005	In range	-

Although small and moderate percentage errors are observed in some parameters such as the Hall coefficient and carrier concentration, all the experimentally obtained values lie within the standard range for P-type Germanium. The smaller errors in mobility and resistivity indicate good experimental accuracy. Hence, the Hall Effect experiment is considered successful and the measured electrical properties of the semiconductor are in good agreement with standard values.

CHAPTER-6

APPLICATION

SCOPE

- High precision and good measurement accuracy. Certain sensors provide switching thresholds as low as a few milli-tesla.
- Capability to detect very small magnetic fields.
- Good mechanical durability and tolerance.
- Wide bandwidth for detecting fast-changing magnetic fields.
- Designed for low power consumption and low sampling requirements.
- Wide output voltage range suitable for low-power systems.
- Hall effect sensors provide real-time system benefits and are widely used in battery-operated portable electronics and industrial automation systems.
- Common advantages include Low-cost position sensing, High-speed magnetic switching, Flexible and contactless mechanical placement

APPLICATION

- **CURRENT REGULATION**

The Hall effect can be applied to control and stabilize electric current in electronic circuits. By using a Hall sensor to continuously monitor the current and applying a feedback mechanism, the circuit can automatically adjust and maintain a steady current level. This method is widely used in power supplies and control systems where constant current is required. The band gap is an important characteristic of semiconductors that determines their electrical behavior. Depending on the size of the band gap, a material may act as a conductor, an insulator, or a semiconductor. The value of the band gap plays a key role in many practical applications, some of which are given below.

- **OPTOELECTRONICS**

Semiconductors with narrow band gaps are commonly used in optoelectronic devices such as light-emitting diodes (LEDs), laser diodes, and solar cells. In these devices, the band gap determines the energy required for electrons to move from the valence band to the conduction band. This directly affects the wavelength of the emitted light and also influences the performance of solar cells.

- **TRANSISTOR**

Semiconductors having wider band gaps are used in high-power electronic components like transistors. These materials can tolerate higher voltages and temperatures, which makes them suitable for power electronic applications and heavy-duty circuits.

- **QUANTUM COMPUTING**

Materials with small band gaps are being explored for use in quantum computing technologies. In such systems, the band gap helps define the energy levels of qubits, which serve as the fundamental units for storing and processing quantum information.

- **SENSING**

Semiconductors with suitable band gap values are widely used in sensing devices such as gas sensors and temperature sensors. For instance, materials with a wide band gap are preferred for sensors that operate at high temperatures because of their stability and reliability.

- **PHOTOVOLTAICS**

The band gap of a semiconductor determines the minimum energy needed to excite electrons from the valence band to the conduction band. This property is utilized in photovoltaic devices like solar cells, where absorbed light energy is converted into electrical energy.

- **PROXIMITY SENSING**

Hall effect sensors can detect the presence or absence of a magnet near the sensing element. Because of this feature, they are widely used in proximity detection systems such as automotive speedometers, door switches, and safety interlock systems.

- **POSITION SENSING**

By using multiple Hall sensors arranged in an array, the position and orientation of magnetic field can be determined accurately. This method is applied in robotics, automation equipment, and control mechanisms where precise positioning is required.

- **MAGNETIC IMAGING**

The Hall effect can also be utilized to generate images of magnetic field distributions. One important medical application is Magnetic Resonance Imaging (MRI), where magnetic field mapping is essential.

CHAPTER-7

REFERENCES

1. Bradley Armen, Hall Effect Experiment, Department of Physics and Astronomy, University of Tennessee.
2. Hall Effect Theory and Applications, ElPro Cos Engineering Portal.
3. Hall Effect Measurement of Semiconductor Properties, Indian Institute of Technology Guwahati, Department of Physics Laboratory Manual.
4. Rishabh Ghotge, The Hall Effect and its Application in the Measurement of Semiconductor Properties, Northumbria University, UK (2015–16).
5. Md. Atikur Rahman, Measurement of Hall Effect in Semiconductors, Pabna University of Science and Technology, Bangladesh.