A Review on The Electrical Properties of Silicon Semiconductors

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***Abstract*—Semiconductor materials are fundamental to modern electronic systems due to their tunable electrical properties and broad scope of application. Their conductivity lies between that of a conductor and an insulator, making them suitable for devices in computing and communication. This review analyses key electrical characteristics of commonly used semiconductors, focusing on carrier concentration, mobility, and the Hall effect in silicon and germanium.**
The paper outlines the behaviour of intrinsic semiconductors and explains how n-type and p-type materials are formed through controlled impurity doping. Experimental data show that semiconductor conductivity rises with temperature, and the addition of dopants significantly alters carrier density and device performance. The impact of impurities on electrical response and thermal efficiency is also examined.

***Index Terms*—Semiconductor Materials**
- **Types of semiconductors**
- **Electrical Properties**
- **Conductivity**
- **Charge Carrier Mobility**
- **Hall effect**

I. INTRODUCTION

Semiconductor materials have become one of the most important components in the development of modern science and technology. These materials exhibit electrical conductivity that falls between that of a metallic conductor and a dielectric insulator. Because of this intermediate conductivity, semiconductors find extensive application in electronic devices such as transistors, diodes, integrated circuits, and solar cells.
The electrical response of semiconductors is primarily governed by temperature and impurity concentration, and external electrical fields. Silicon and germanium have characteristics and thermal stability. In recent years, semiconductor materials, due to their excellent electrical properties, have played a critical role in communication systems, computing engineering, medical instruments, and renewable energy applications.

II. LITERATURE REVIEW

Several researchers have contributed to the understanding and advancement of semiconductor technology. Early studies focused on the conductivity and charge transport in semiconductor materials is primarily controlled by carrier drift and diffusive processes. Later development introduced semiconductor devices capable of performing complex electronic operations.

William Shockley and his colleagues introduced transistor technology, which transformed the electronics industry. Research presented in Physics of Semiconductor Devices explains the theoretical and practical aspects of semiconductor behaviour.
Modern research is mainly focused on nanoscale semiconductors, high- speed electronic devices, and energy-efficient semiconductor systems. Scientists are also developing flexible semiconductor materials for wearable electronics and advanced medical devices.

III. SEMICONDUCTOR THEORY

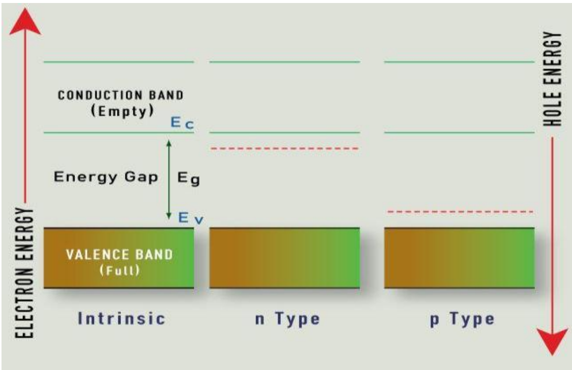
The theory of semiconductors is based on the movements of electrons and holes within a material. In semiconductor atoms, electrons occupy different energy levels known as energy bands. The two important bands are the valence band and the conduction band gap. These bands are separated by a small energy gap called the forbidden band gap.
When thermal energy is supplied, electrons move from the valence band to the conduction band, resulting in electrical conduction. conductivity of semiconductors, therefore, increases with temperature.

The electrical conductivity of a semiconductor can be expressed as:

$\sigma = nq\mu$

Where:

- σrepresents conductivity,
- $n$represents carrier concentration,
- $q$is the electronic charge,
- μrepresents mobility



Types of Semiconductors:
They are mainly classified into two major types based on their purity and electrical behaviour.

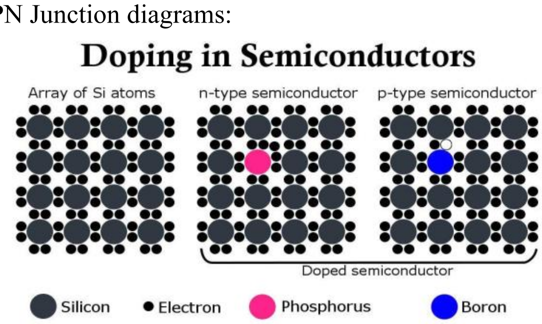
1. Intrinsic Semiconductor
2. Extrinsic Semiconductor

1. Intrinsic Semiconductor:
An intrinsic semiconductor is a pure semiconductor material without any impurity atoms. Silicon and germanium.

2. Extrinsic Semiconductor:
Extrinsic semiconductors are produced by adding impurities to improve conductivity.

a. N-Type Semiconductor: N-Type semiconductorsare formed by adding pentavalent impurities such as phosphorus.
b. P-Type Semiconductor: P-Type semiconductors are formed by adding trivalent Impurities such as boron.

PN Junction diagrams:



IV. ELECTRICAL PROPERTIES:

Electrical Conductivity:
Electrical conductivity is one of the most significant properties of semiconductor materials. Unlike materials, semiconductor conductivity changes with temperature and impurity concentration.

Resistivity:
Resistivity measures the opposition offered by a material to the flow of electric current. Semiconductors possess moderate resistivity compared to conductors and insulators

Mobility of charge Carriers:
Carrier mobility describes how rapidly electrons or holes move under the influences or an electric field.Higher mobility improves the performance of semiconductor devices.

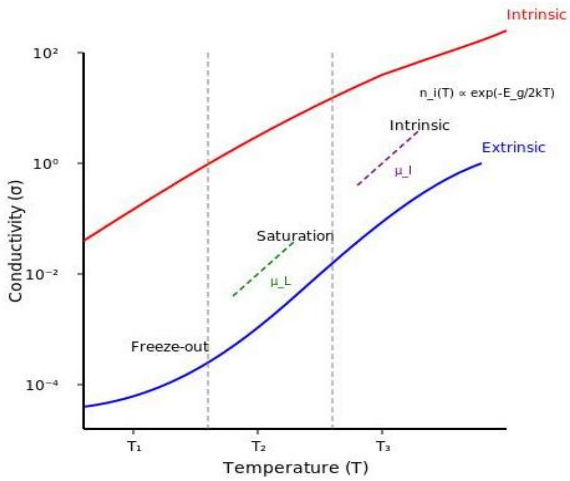
Hall Effect:
The Hall Effect is used to determine carrier type, carrier concentration, and mobility in semiconductor materials

Hall effect experiments:

Hall Effect Experiment

Experimental Analysis: -
The experimental study of semiconductor materials involves measuring conductivity, resistivity and carrier concentration under different temperature conditions.
The experiment begins by preparing semiconductor samples and connecting them to an electrical measurement setup. Voltage and current values are recorded at different temperatures. The collected data show that conductivity increases with rising temperature due to the increase in free charge carriers.

Experimental graphs:



The experimental analysis also indicates that doping significantly enhances the electrical conductivity of semiconductor materials.

Applications

Semiconductors are essential in modern electronic technology. Their electrical properties make them suitable for various industrial and scientific applications.

Major Applications

- Transistors
- Solar Cells
- Integrated Circuits
- LEDs
- Sensors
- Communication Devices
- Computer Processors

Application examples:

Important semiconductor companies:

- Intel
- Samsung Semiconductor
- Texas Instruments

V. CONCLUSION

The study of the electrical properties of semiconductor materials demonstrates their importance in modern electronic systems. Semiconductor materials possess unique characteristics such as variable conductivity, high efficiency, and excellent thermal response. Silicon and germanium continue to be widely used in electronic devices due to their reliable performance.

Advancements in semiconductor research are contributing to the development of high-speed communication systems, renewable energy technologies, and intelligent electronic devices. Future innovations in semiconductor materials are expected to improve the efficiency and performance of modern electronics.

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