SEMICONDUCTOR

INTRODUCTION

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TOPIC OUTLINE

Atomic Structure

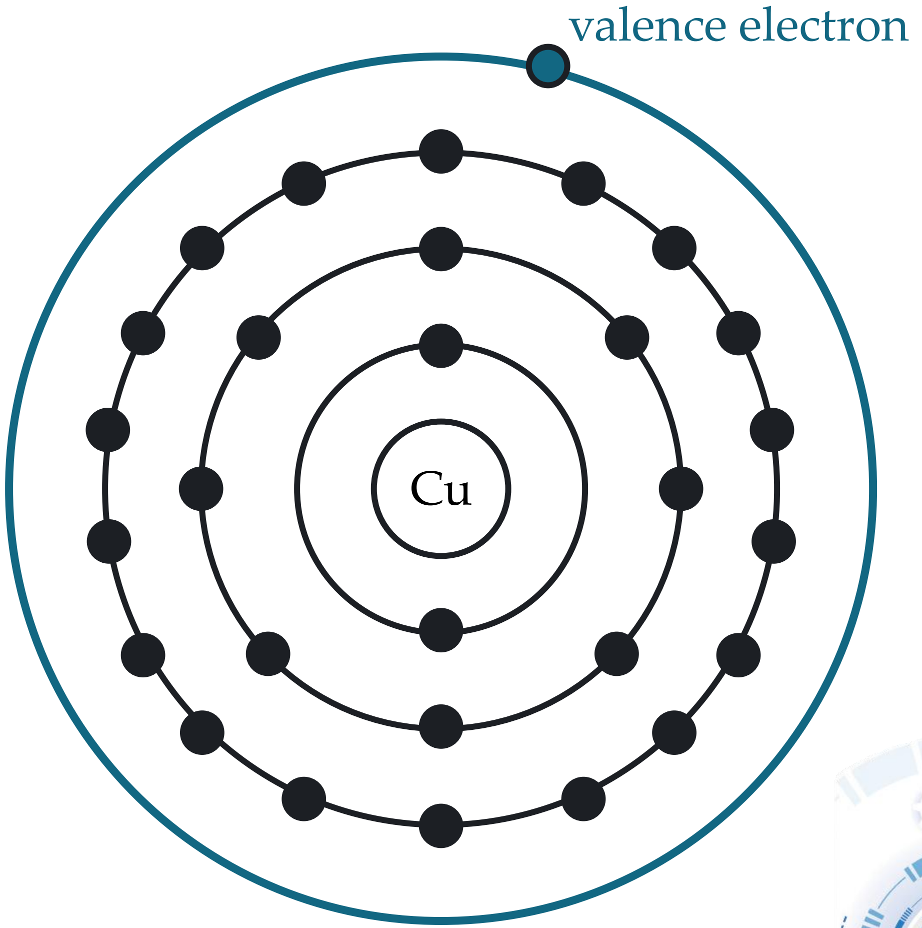
Properties of Semiconductor

Two Types of Extrinsic Semiconductor

ATOMIC STRUCTURE

VALENCE ORBIT

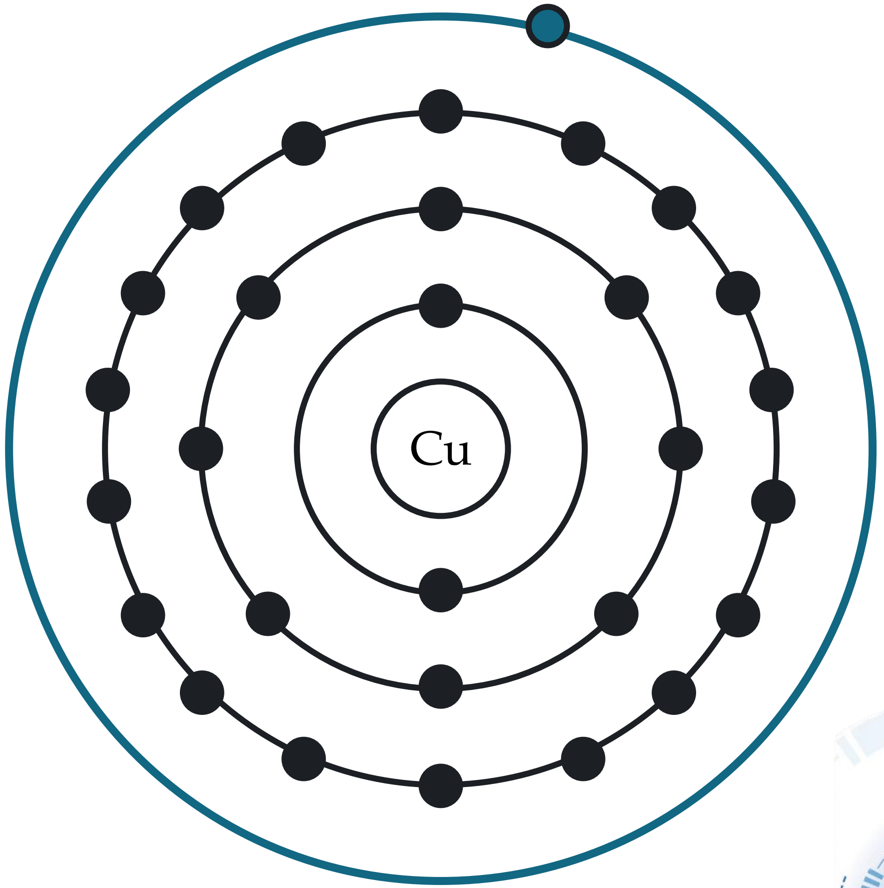
Copper Atom



The **valence orbit** (or valence shell) is the outermost electron shell of an atom. It contains the valence electron(s), which control the **electrical properties** of the atom.

CONDUCTOR

Copper Atom



Conductors are materials that allow the electric current to flow through them.

valence electrons

Less than 4 electrons

example

Copper

Silver

Gold

INSULATOR

Insulators are materials that do not conduct electricity.

valence electrons

More than 4 electrons

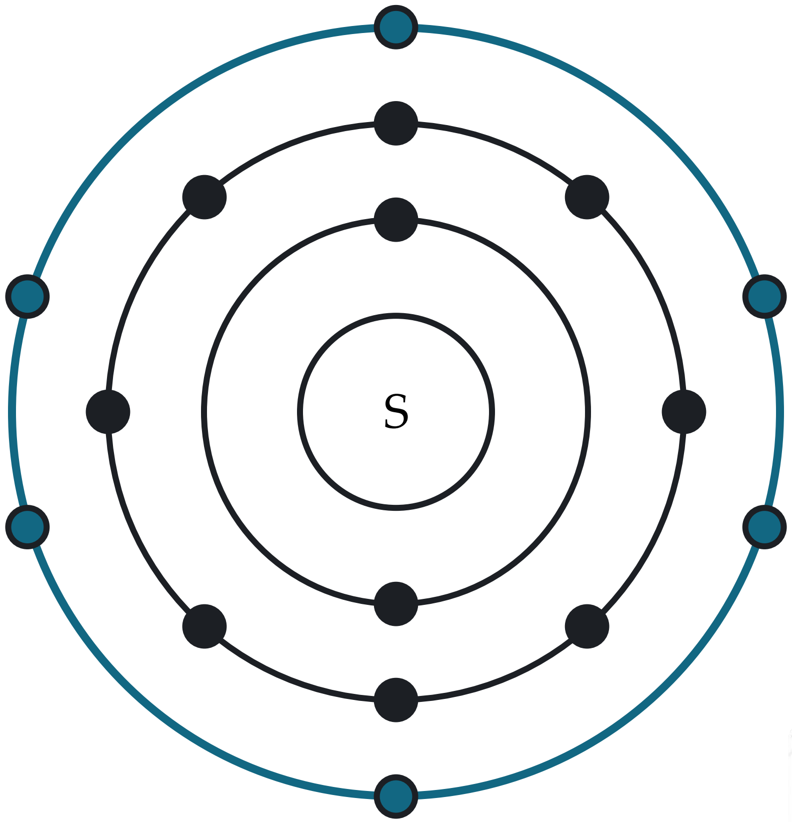
example

Rubber

Plastic

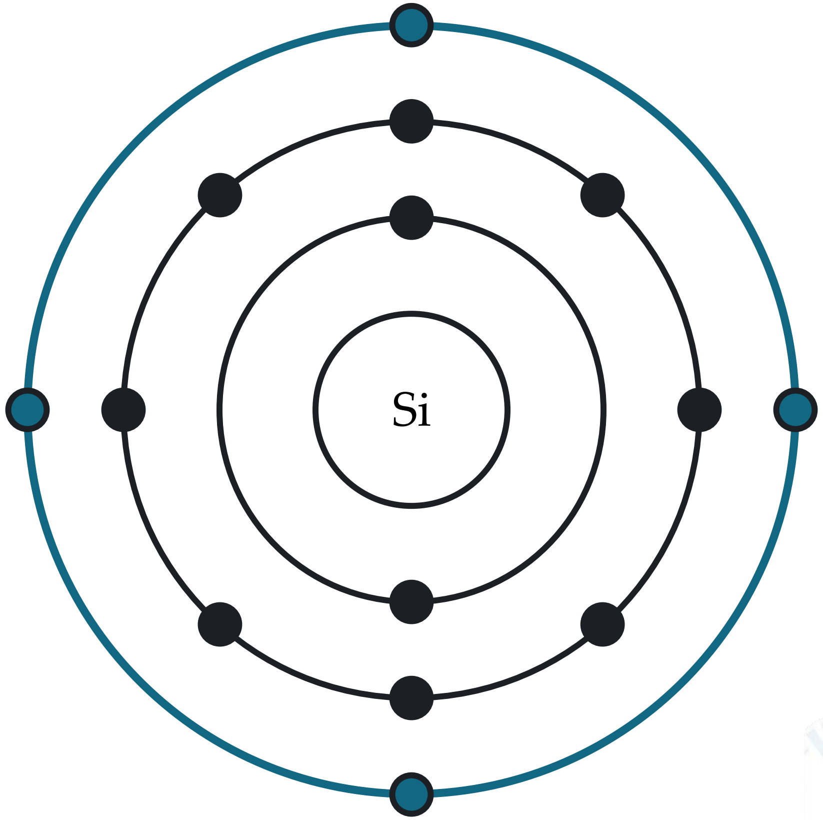
Sulfur

Sulfur Atom



SEMICONDUCTOR

Silicon Atom



Semiconductors are materials that have an electrical conductivity between that of a conductor and an insulator.

valence electrons

Exactly 4 electrons

example

Silicon

Carbon

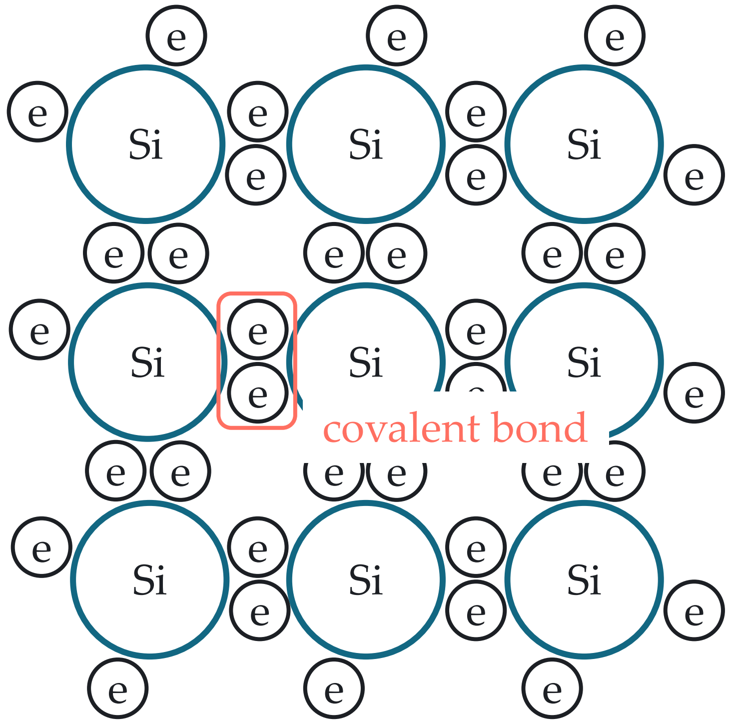
Germanium

PROPERTIES OF SEMICONDUTOR

THE SILICON ATOM

A **valence saturation** occurs when an atom's outermost electron shell (valence orbit) reaches its maximum capacity of **8 electrons**.

Silicon Crystal

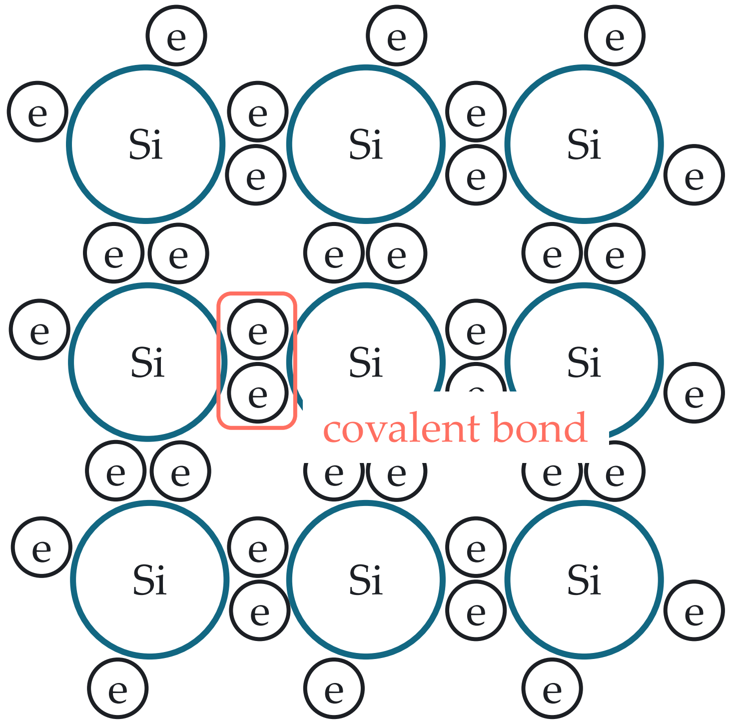


INTRINSIC SEMICONDUCTOR

Silicon Crystal

An **intrinsic semiconductor** is a pure semiconductor.

At room temperature, it acts like an **insulator**.



EXTRINSIC SEMICONDUCTOR

Doping is the process of **adding impurity atoms** to an intrinsic crystal to alter its electrical conductivity.

Group III Elements

B	Al	Ga	In
Boron	Aluminum	Gallium	Indium

Group V Elements

P	As	Sb
Phosphorus	Arsenic	Antimony

TWO TYPES OF EXTRINSIC SEMICONDUCTOR

TWO TYPES OF FLOW

Electron flow is the movement of **free electrons** in a semiconductor (or conductor).

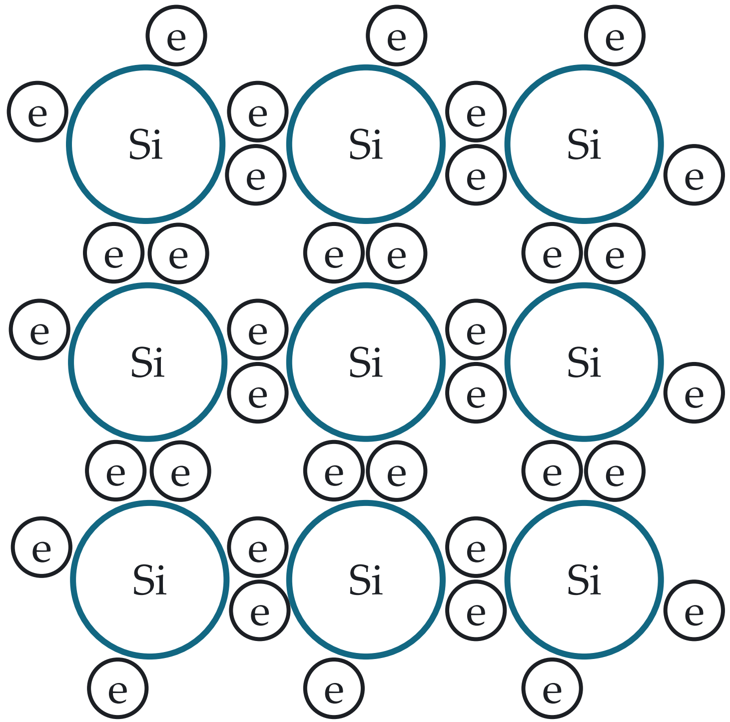
Hole flow is the movement of "**empty spaces**" (holes) left behind when electrons jump in the valence band.

Electron Flow

Hole Flow

N-TYPE SEMICONDUCTOR

Silicon Crystal



An **n-type** semiconductor is created by doping intrinsic semiconductor with a **pentavalent** impurity.

example

Arsenic (As)

Antimony (Sb)

Phosphorus (P)

N-TYPE SEMICONDUCTOR

An **n-type** semiconductor is created by doping intrinsic semiconductor with a **pentavalent** impurity.

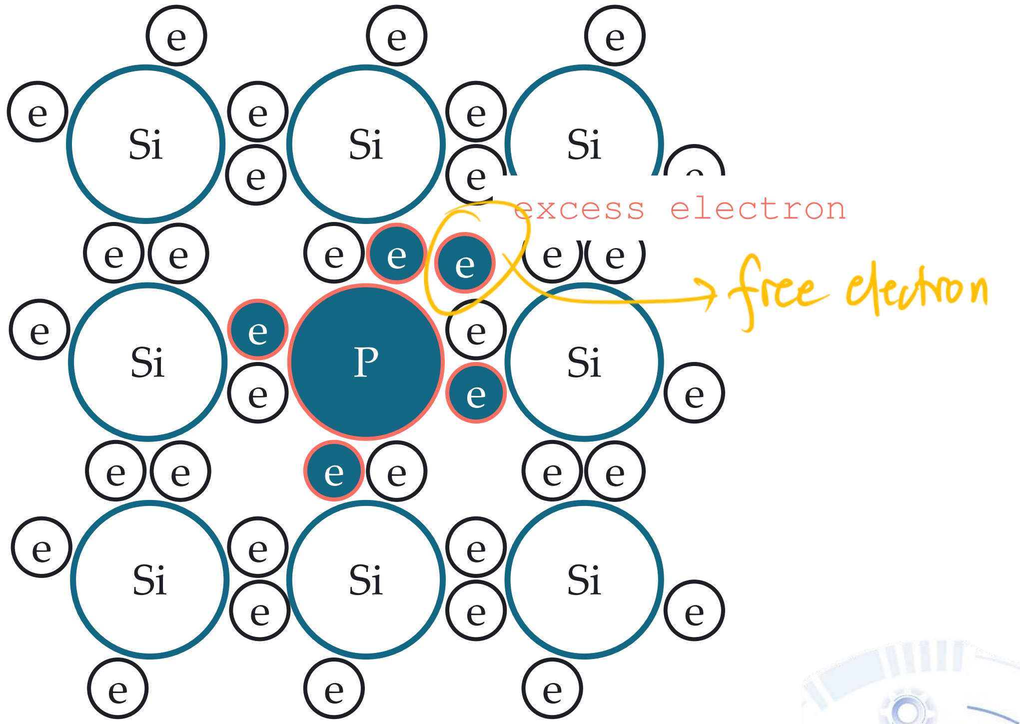
example

Arsenic (As)

Antimony (Sb)

Phosphorus (P)

Doped with Phosphorus



N-TYPE SEMICONDUCTOR

Doped with Phosphorus

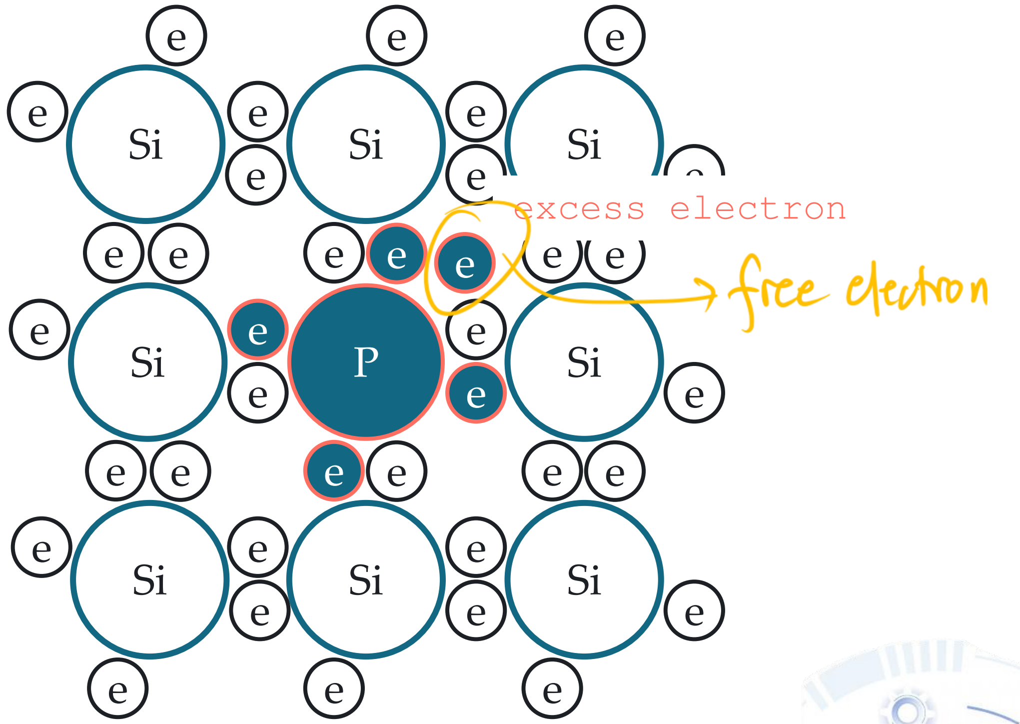
An **n-type** semiconductor is created by doping intrinsic semiconductor with a **pentavalent** impurity.

majority carriers

Electrons

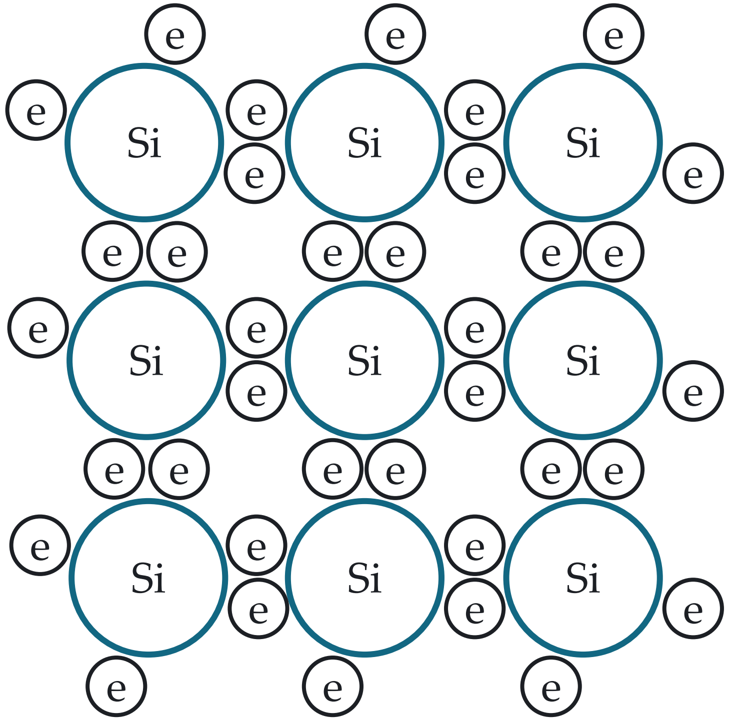
minority carriers

Holes



P-TYPE SEMICONDUCTOR

Silicon Crystal



A p-type semiconductor is created by doping intrinsic semiconductor with a **trivalent** impurity.

example

Aluminum (Al)

Boron (B)

Gallium (Ga)

Indium (In)

P-TYPE SEMICONDUCTOR

A **p-type** semiconductor is created by doping intrinsic semiconductor with a **trivalent** impurity.

example

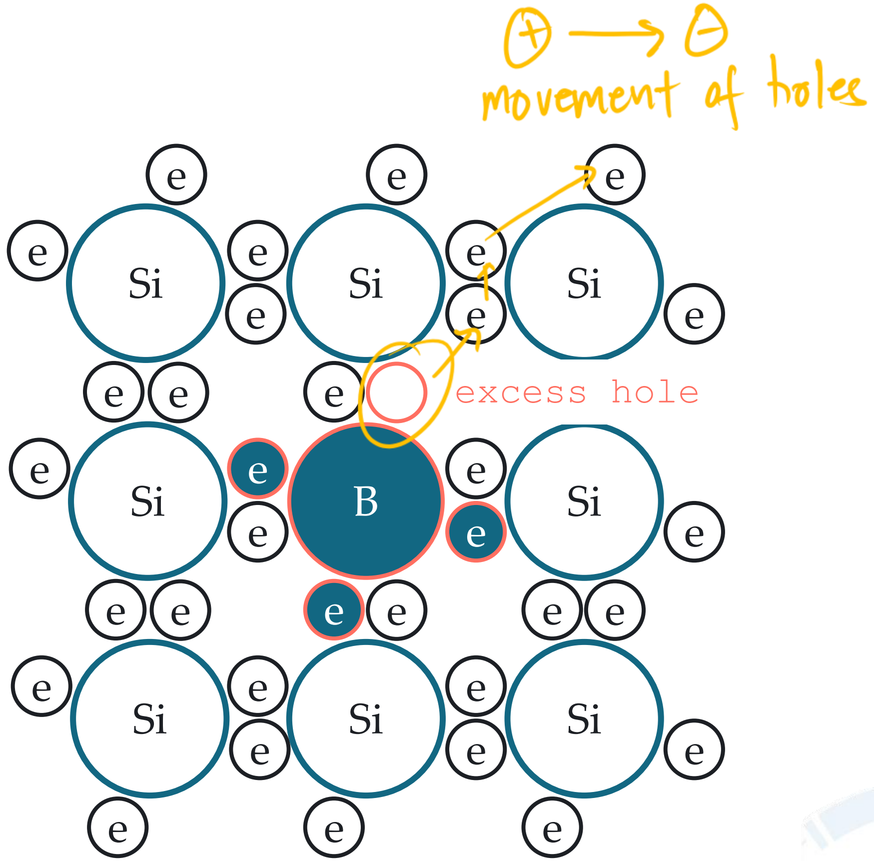
Aluminum (Al)

Boron (B)

Gallium (Ga)

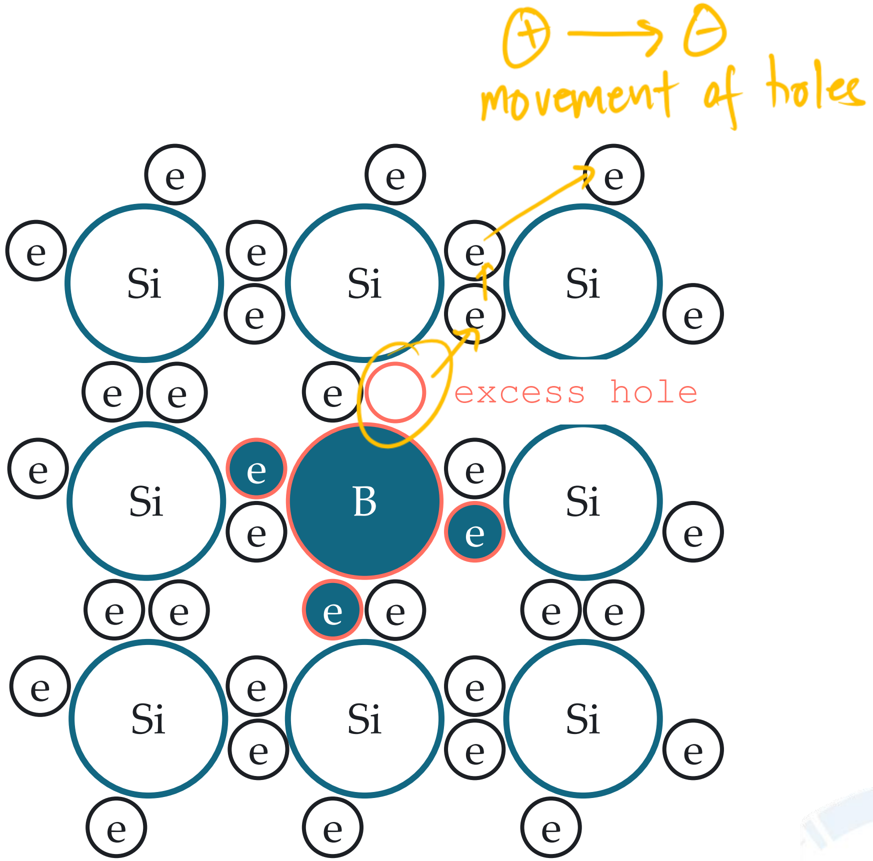
Indium (In)

Doped with Boron



P-TYPE SEMICONDUCTOR

Doped with Boron



A **p-type** semiconductor is created by doping intrinsic semiconductor with a **trivalent** impurity.

majority carriers

Holes

minority carriers

Electrons

EXERCISE

A doped semiconductor has 10 billion silicon atoms and 15 million pentavalent atoms. If the ambient temperature is 25º C, how many free electrons and holes are there inside the semiconductor?

Solution

1 pentavalent = 1 excess electron

$$\text{free electrons} = 15M\ \cancel{\text{pentavalent}} \cdot \frac{1\ \text{electron}}{1\ \cancel{\text{pentavalent}}}$$

$$\boxed{\text{free electrons} = 15M\ \text{electron}}$$

ans

$$\boxed{\text{holes} = 0}$$

ans

EXERCISE

In reference to the previous example, if 5 million trivalent atoms are added instead of pentavalent atoms, how many holes are there inside the semiconductor?

Solution

$$1 \text{ trivalent} = 1 \text{ hole}$$

$$\text{no. of holes} = 5\text{M}\ \text{tri}\cancel{\text{valent}}\ \frac{1 \text{ hole}}{1\ \text{tri}\cancel{\text{valent}}}$$

$$\boxed{\text{no. of holes} = 5\text{M holes}}$$

ans

$$\boxed{\text{free electron} = 0}$$

ans

ENERGY LEVELS

Electronvolt (eV) is the energy needed to move one electron through a potential difference of 1 volt.

Conductor

Conduction Band

Energy Gap = 0 eV

Valence Band

Insulator

Conduction Band

Energy Gap > 5 eV

Valence Band

Semiconductor

Conduction Band

Energy Gap = 1.1 eV (Si)

Energy Gap = 0.67 eV (Ge)

Energy Gap = 1.41 eV (GaAs)

Valence Band

LABORATORY