Intrinsic and Extrinsic Semiconductors

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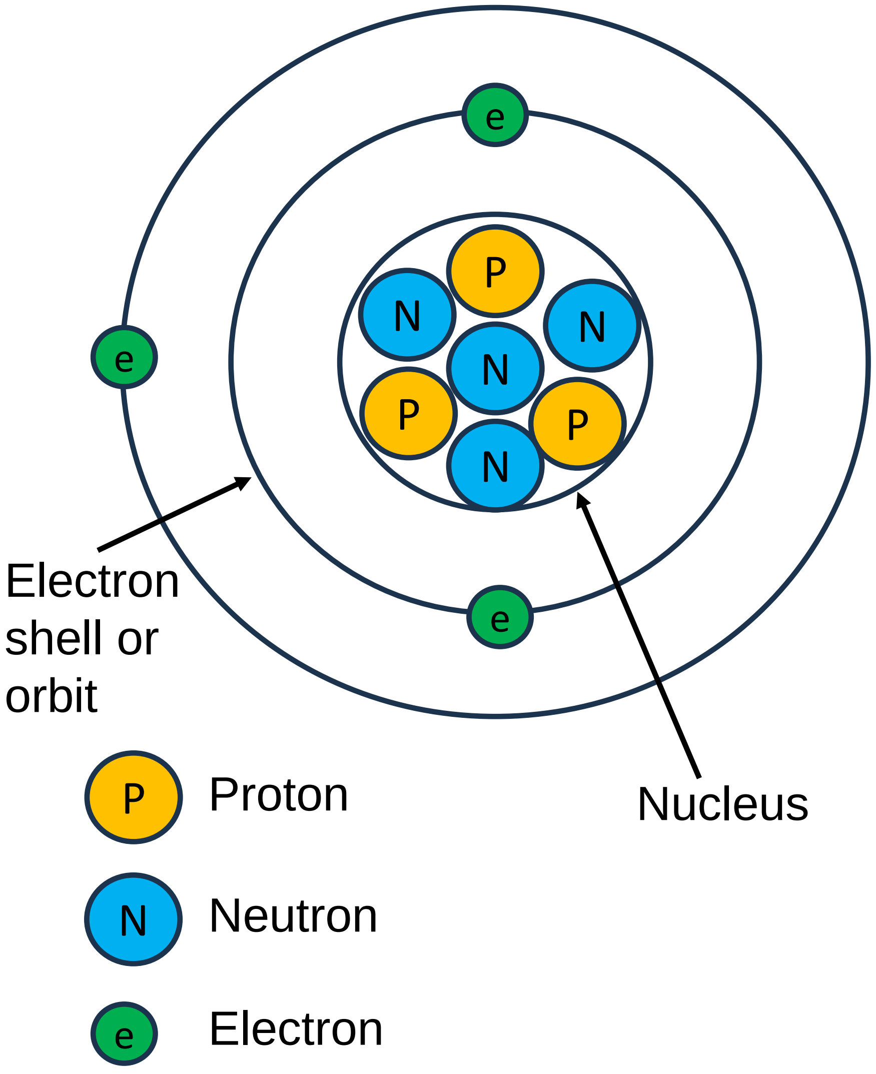
REVIEW OF ATOMIC THEORY:



An atom of any material consists of a central core called nucleus.

The nucleus contains protons and neutrons.

Electrons are orbiting in different shells or orbits around the nucleus.

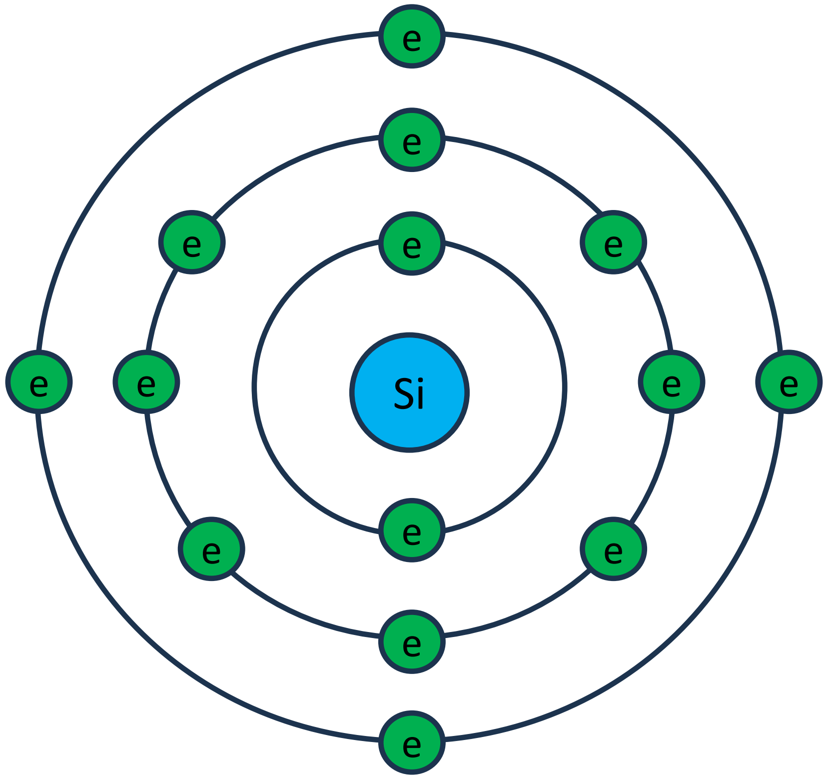
An atom is electrically neutral because the number of protons with positive charge and orbiting electrons with negative charge are equal.

The number of electrons present in the outermost shell are called valence electrons.

The outermost orbit must have eight electrons.

If the outermost orbit has less than eight electrons, we call them vacancies or holes (i.e., empty spaces).

SEMICONDUCTING MATERIALS:



Silicon atom

Germanium (Ge) and silicon (Si) are examples of semi conductors.

Silicon has 14 electrons orbiting in three orbits and they are distributed as 2, 8 and 4.

The atom is electrically neutral because the nucleus has 14 protons which are positively charged.

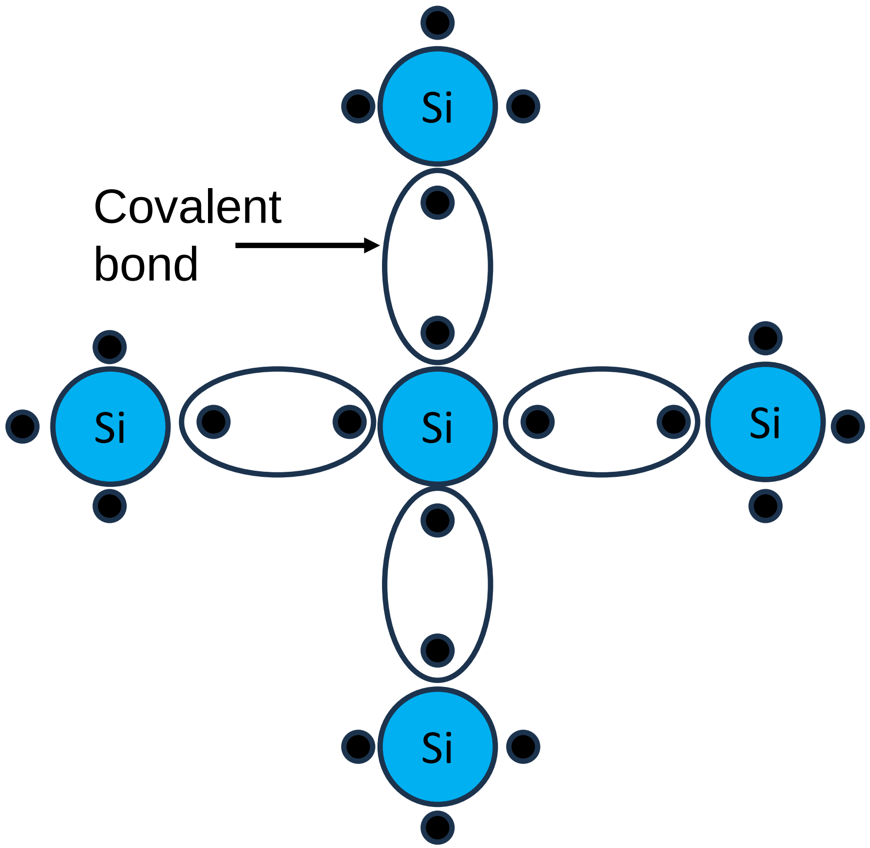
Both silicon and germanium have four valance electrons in their outermost orbits.

Electrons in the outermost orbit are comparatively loosely bound with the nucleus.

A small amount of energy will be required to take out an electron from the outermost orbit.

When an electron leaves its orbit, it becomes a free electron.

INTRINSIC SEMICONDUCTOR:



Crystalline structure of silicon

A semiconductor item with four valance electrons require four more electrons so as to make the outermost orbit completely filled (i.e., eight electrons in the outermost orbit).

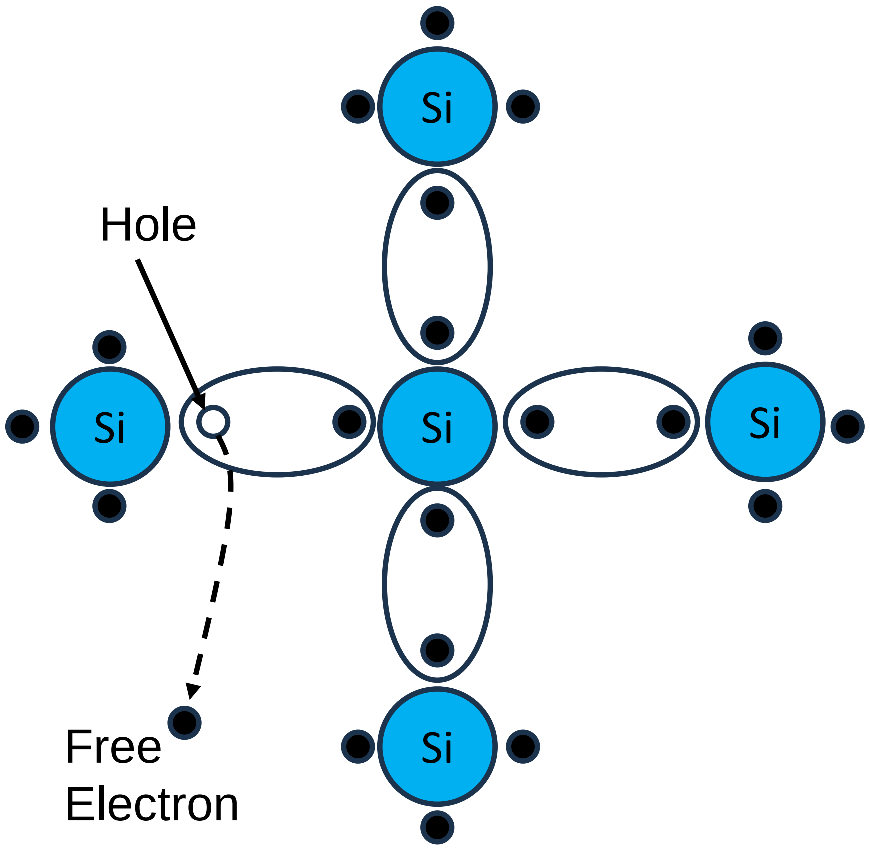
Sharing of electrons of the neighbouring atoms is called covalent bonding.

Because of covalent bonding, each atom have a full outer shell with eight electrons.

At absolute zero temperature there will be no free electrons in the crystal.

A semiconductor material, silicon or germanium where the electrons are bound to their respective atoms and are not free to conduct electric current, are called intrinsic, or pure semiconductors.

INTRINSIC SEMICONDUCTOR:



Crystalline structure of silicon

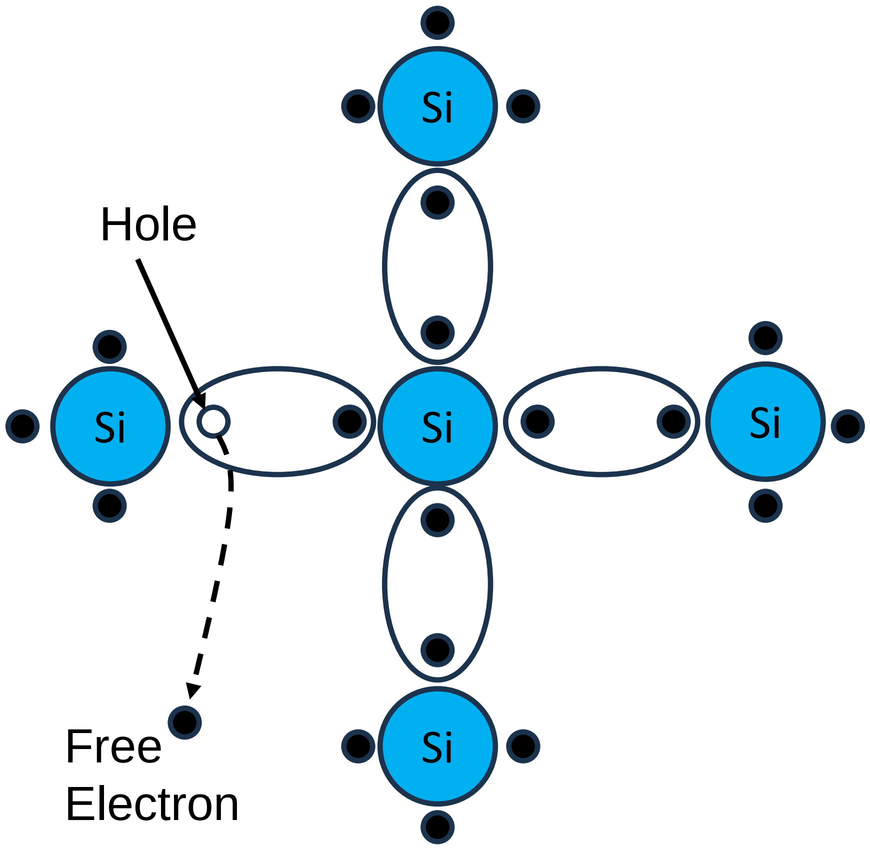
If the temperature of the crystal is increased, external energy in the form of heat gets applied to the semiconductor material.

The heat energy at room temperature is sufficient to move the valance electron to move away from the covalent bond and it becomes a free electron.

When an electron leaves to become free, it leaves a vacant space called a hole.

For every free electron there will be a corresponding hole produced, which is called an electron–hole pair.

INTRINSIC SEMICONDUCTOR:



Crystalline structure of silicon

A large number of such electron–hole pairs are formed due to rise in temperature of the semiconductor.

When electrons become free, they get attracted and fall into a hole created by another electron.

This merging of free electrons and holes is called recombination.

Thus, pure silicon or germanium is not of much use in electronics.

However, it is used for the manufacturing of heat or light-sensitive resistance.

EXTRINSIC SEMICONDUCTOR:

The conductivity of a semiconductor can be increased by adding some amount of another material having eighter three or five valance electrons.

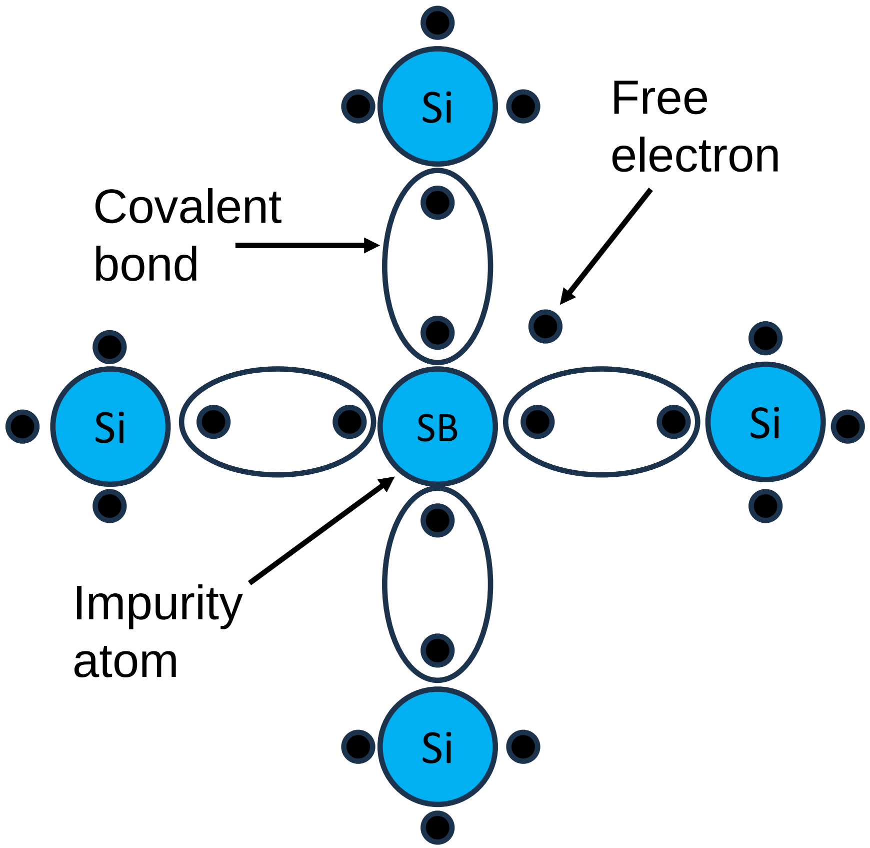
Adding such material with the pure semiconductor is called ‘doping’.

The doped semi-conductor is known as an extrinsic semiconductor.

If a pentavalent impurity is added, extrinsic semiconductors are called as ‘N’ type semiconductors.

If a trivalent impurity is added, extrinsic semiconductors are called as ‘P’ type semiconductors.

N-TYPE SEMICONDUCTOR:



N-type extrinsic semiconductor

N-Type semiconductor is formed by doping a pure silicon or germanium crystal with a material having five valence electrons.

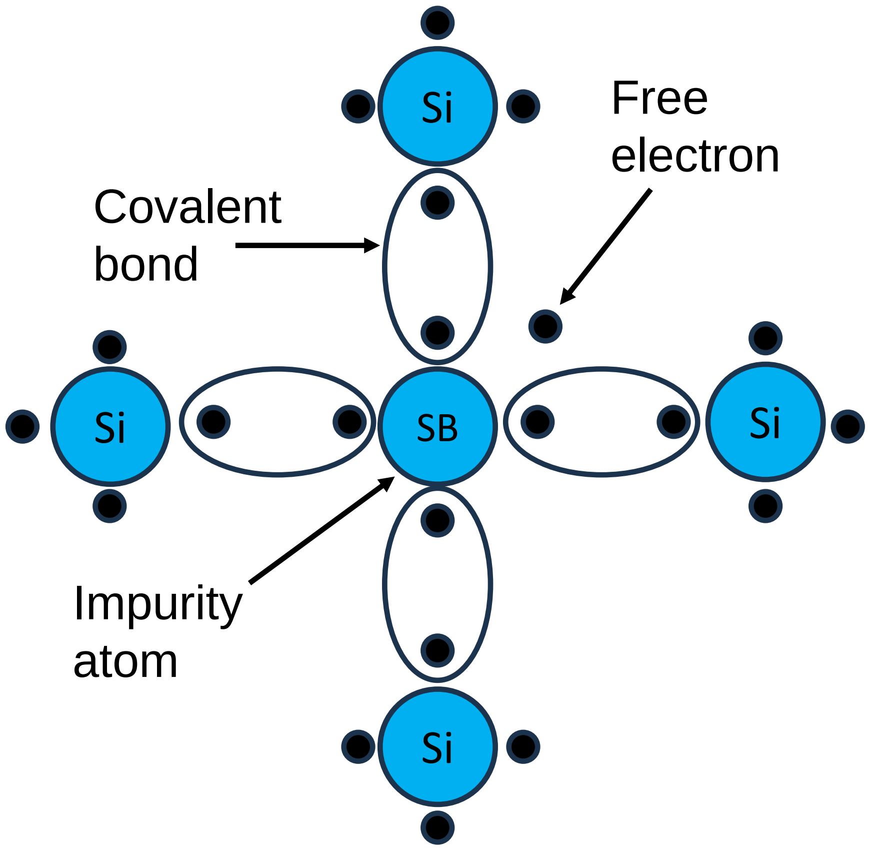
Antimony, arsenic, and phosphorous are examples of pentavalent materials.

If arsenic in very small quantity is added to a silicon crystal, four out of five valence electrons will form covalent bonds with silicon atoms.

There is one extra electron for each impurity atom added.

This extra electron is not a part of any covalent bond and called as free electron.

N-TYPE SEMICONDUCTOR:



N-type extrinsic semiconductor

The added impurity material donates one free electron per atom and hence called as donor impurity.

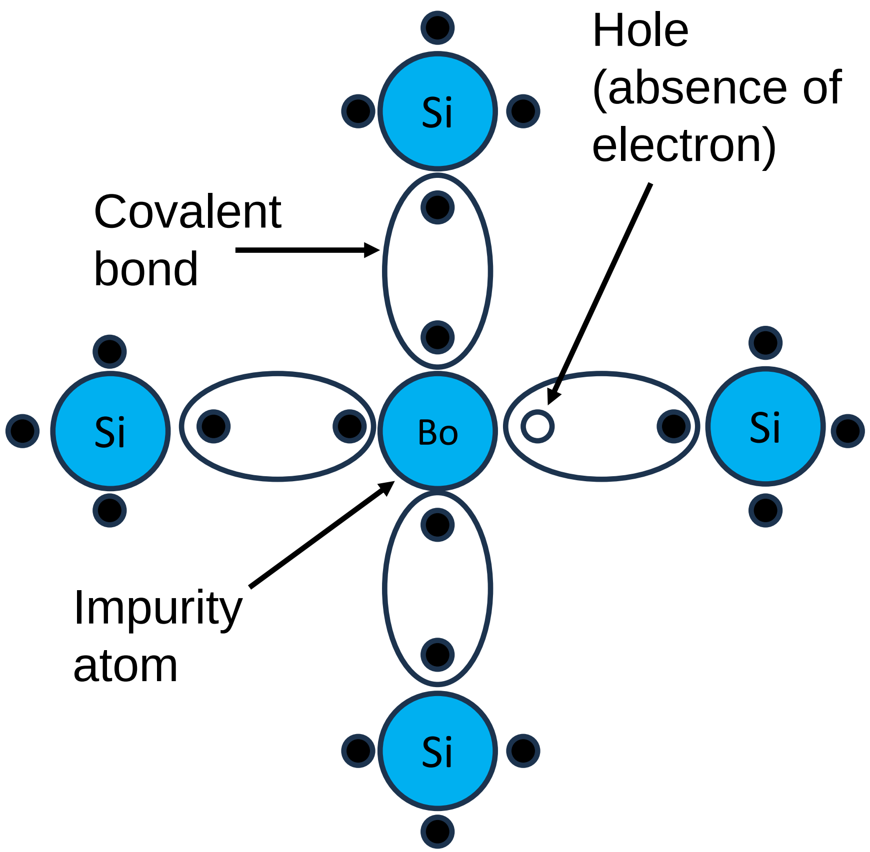
Donor atoms create free electrons which form the majority charge carrier in an N-type material.

Temperature rise above absolute zero also creates free electrons and holes due to breaking of covalent bonds.

These holes are called minority charge carriers in the N-type semiconductor.

Thus, in an N-type semiconductor the majority charge carriers are the electrons, and the minority charge carriers are thermally generated holes.

P-TYPE SEMICONDUCTOR:



P-type extrinsic semiconductor

P-Type material is formed when silicon or germanium crystal is doped with a small amount of trivalent impurity material like boron, gallium or indium.

The trivalent impurities are called accepter impurities.

When covalent bonds are formed between boron having three valence electrons with silicon having four valence electrons, there will be shortage of one electron in the covalent bonds.

This is represented by an empty space in the covalent bonds and is called a hole.

In a P-type material the holes are the majority charge carriers.

Thermally generated electrons are the minority charge carriers.

Thank You