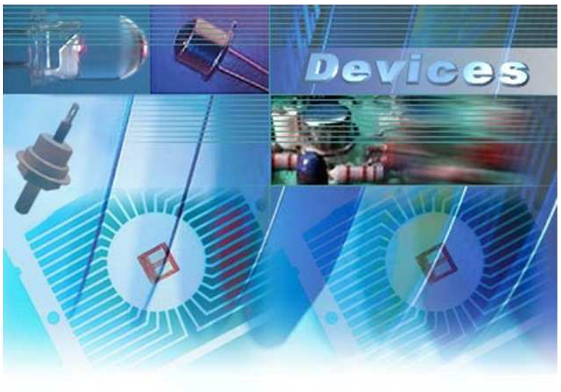
Semiconductors

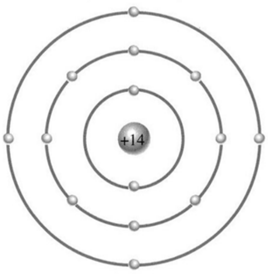


Semiconductor Elements

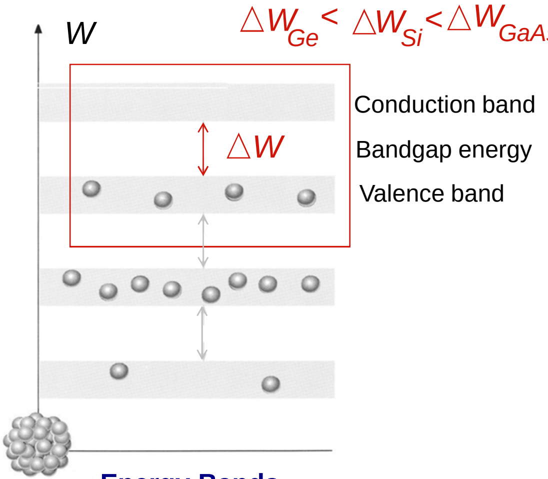
Silicon Atom Structure

$\triangle W_{Ge} < \triangle W_{Si} < \triangle W_{GaAs}$

Nucleus and electrons

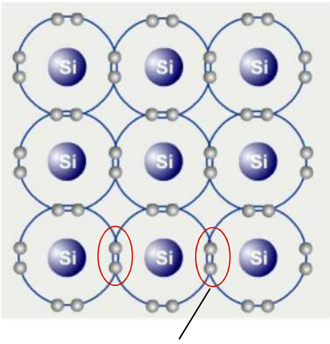


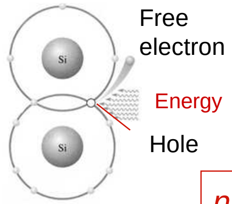
As a whole the atom is ***neutral.***



Energy Bands

Intrinsic Semiconductors

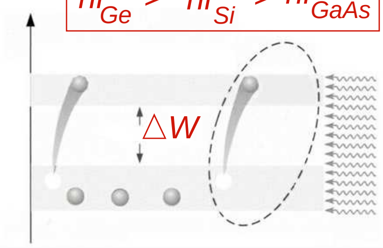




$n_i = p_i$

$n_i . p_i = n_i^2$

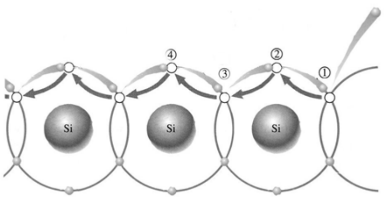
$ni_{Ge} > ni_{Si} > ni_{GaAs}$



Exitation of an electron from the valence to the conductive band.

Equal numbers of free electrons and holes are created in the covalent bonds breaking up. Heat from the surrounding air is the primary source for the required energy.

Electron and Hole Currents



Holes move slower than electrons by drifting from one covalent bond to another.

The movement of one hole requires the movement of many more valence electrons.

J_p ←

J_n ←

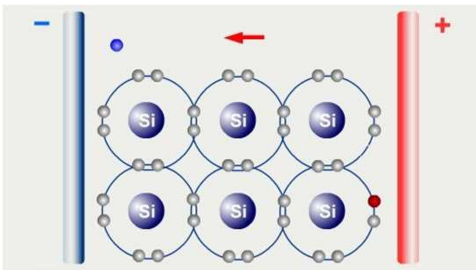
$J = J_n + J_p$

Free electrons and holes are referred to as mobile carriers.

Drift movement

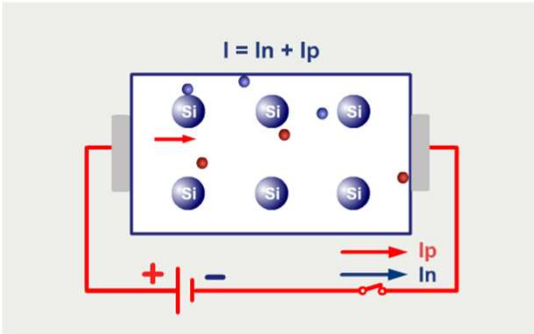
$v_E = \mu E$

$\mu_n > \mu_p$



Carriers flow

Current Direction



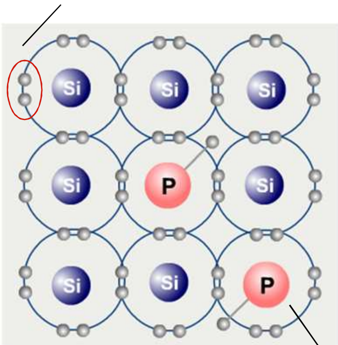
The direction of the hole's flow is opposite to that of the free electrons.

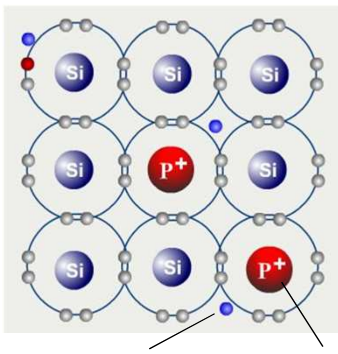
The electric current is **conventionally** represented by the flow of positive charges.

Impure Semiconductors – n-Type

Covalent bonds

Majority carriers | *n >> p* | Minority carriers





Neutral phosphorus (P) atom

Free electron

Positively charged ion

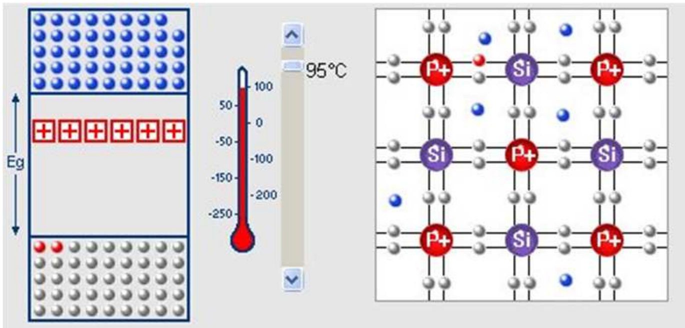
Donor atom – V valence electrons

A donor atom will easily donate an extra electron to the silicon crystal.

Carriers in n-Type Semiconductor

Majority carriers are formed in **donor ionisation** process. One **free electron** will be created, but **without a hole.**

$$n_{no} = N_D$$



Minority carriers are created by breaking covalent bonds.

Whenever a neutral donor atom looses one electron, it will become a positively charged ion.

Carriers Concentration

T = const

$$n_{no} \cdot p_{no} = n_i^2$$

Carrier type — Semiconductor type — Intrinsic concentration

Relation between majority/minority carriers' concentrations

$$n_{no} = N_D$$

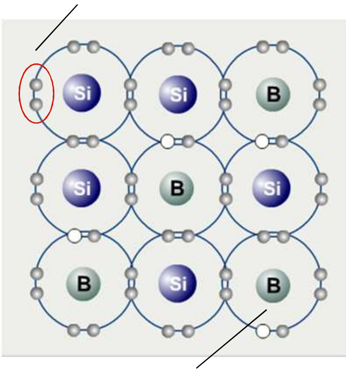
$n_{no} = const\ (T)$

$$p_{no} = \frac{n_i^2}{n_{no}}$$

$p_{no} = f\ (T)$

p-Type Semiconductors

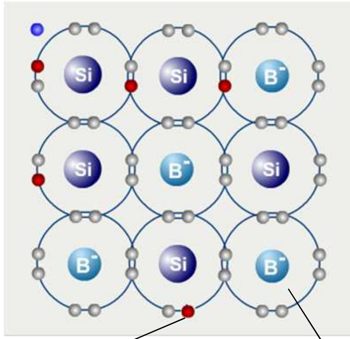
Covalent bonds



Neutral boron (B) atom

Acceptor atom – III valence electrons

Majority carriers | $p >> n$ | Minority carriers



Hole

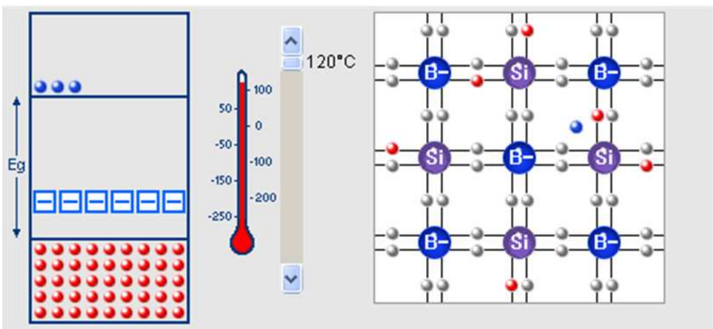
Negatively charged ion

When a neutrally charged acceptor gains an extra electron it will become a fixed *negatively charged ion*.

Carriers in p-Type Semiconductor

Majority carriers are formed in **acceppror ionisation** process. One **hole** will be created, but **without an electron.**

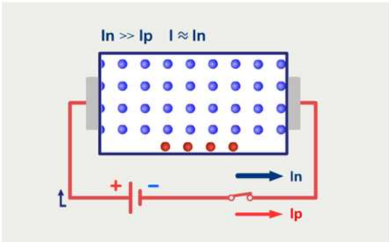
$p_{po} = N_A$

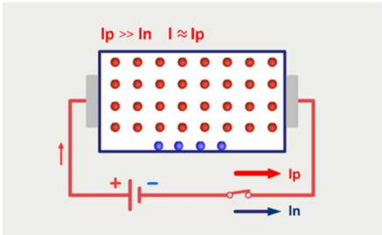


Minority carriers are created by breaking covalent bonds.

Whenever a neutral boron atom gains an extra electron, it will become a negatively charged ion.

Currents in Impurity Semiconductors





In *n*-type semiconductors, electrons are the majority carriers.

The value of the electron current I_n will far exceed the value of the hole current I_p.

In *p*-type semiconductors, holes are the majority carriers.

In *p*-type semiconductors the hole current I_p will far exceed the electron current I_n.