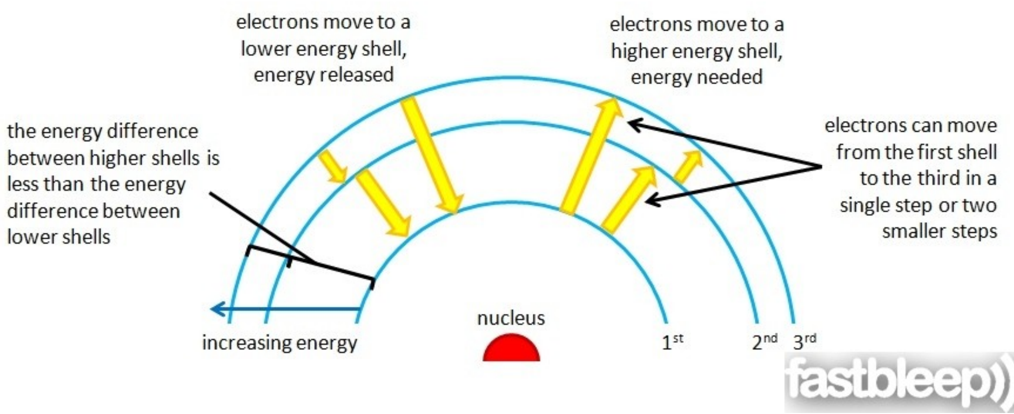
Semiconductors

Vladan Bernard

Atomic model

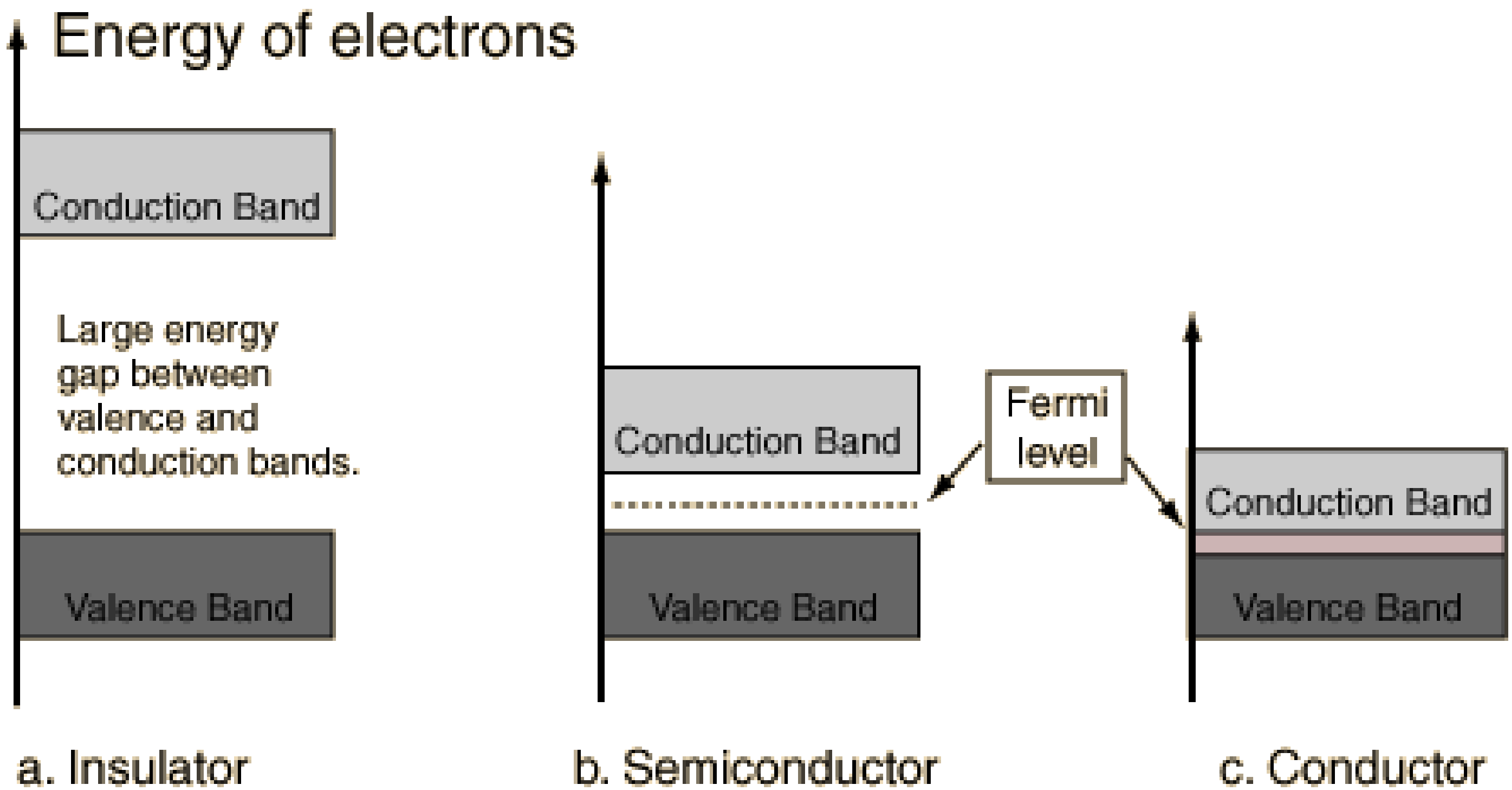
- Atanoms are comprised of electrons, protons and neutrons
- Electrons are found orbiting the nucleus of an atom at specific intervals, based upon their energy levels
- The outermost orbits is the valence orbit



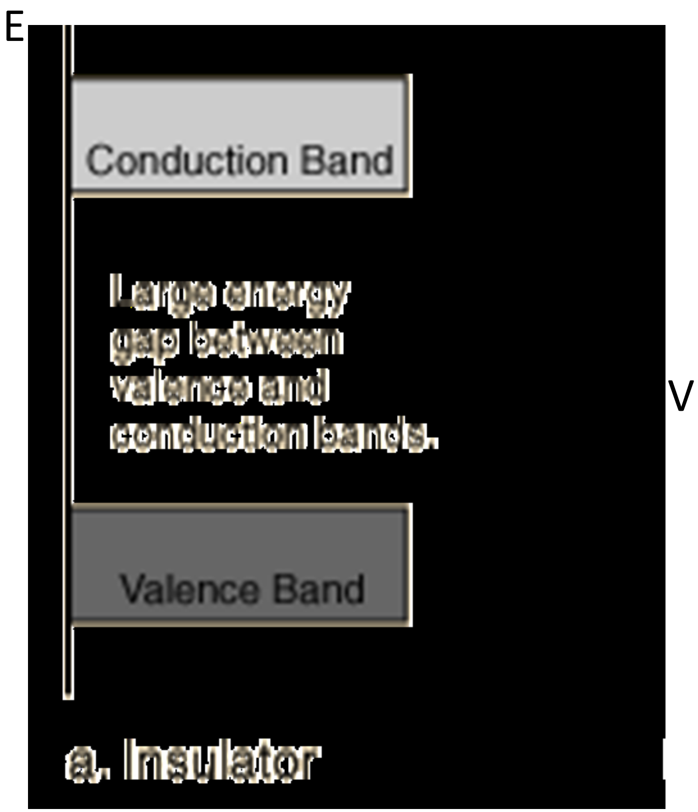
Orbitals - energy

- Valence band electron are the furthest from the nucleus
- Have higher energy levels than electron in lower orbits
- The region beyond the valence band is called the conduction band
- Electrons in the conduction band are easily made to be free electrons

Conduction band

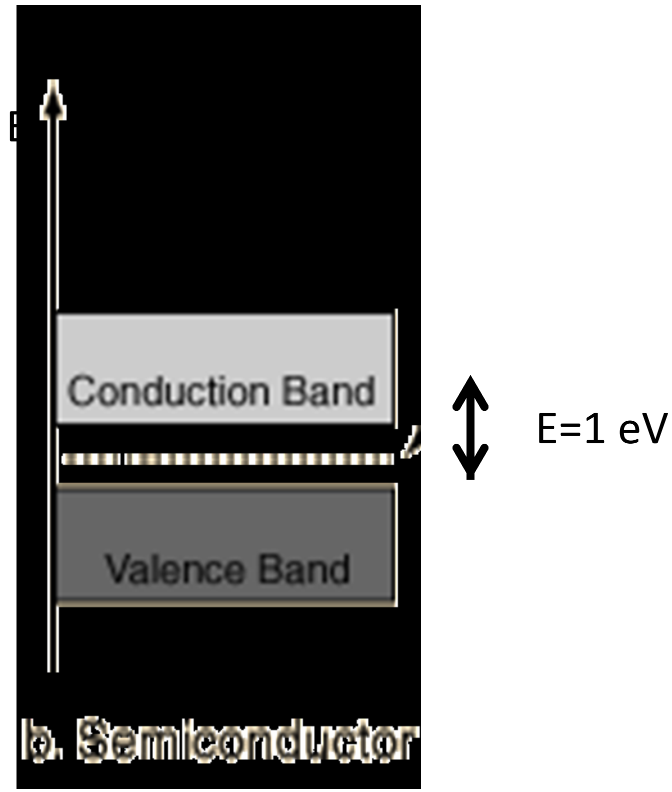


Insulator



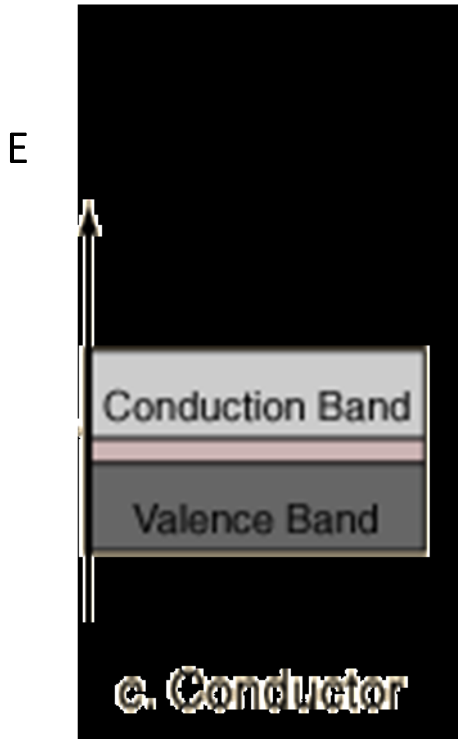
The energy gap in an insulator is large enough that few, if any, electrons have enough thermal energy to reach the conduction band

Semiconductor



In a semiconductor, the energy gap is small enough that same electrons have enough thermal energy to enter the conduction band

Conductor



In conductor, same electrons are in the conduction band. These electrons are free to move between atoms. The electrons move randomly in a conductor, but if a electric field is applied across the wire, the electrons drift toward one end.

Semiconductors

„Semiconductors are crystalline or amorphous solids with distinct electrical characteristics. They are of high electrical resistance — higher than typical resistance materials, but still of much lower resistance than insulators. Their resistance decreases as their temperature increases, which is behavior opposite to that of a metal. Finally, their conducting properties may be altered in useful ways by the deliberate, controlled introduction of impurities ("doping") into the crystal structure, which lowers its resistance but also permits the creation of semiconductor junctions between differently-doped regions of the extrinsic semiconductor crystal. The behavior of charge carriers which include electrons, ions and electron holes at these junctions is the basis of diodes, transistors and all modern electronics.“ …wiki

Semiconductors

- Semiconductors are materials whose electrical properties lie between Conductors and Insulators.
- Examples : Silicon and Germanium
- Their resistance decreases as their temperature increases
- The semiconductor materials are used in electronic devices

- Becouse of cristalline structure of semiconductor materials, valence electrons are shared between atoms

- This sharing of valence electrons is called covalent bonding. Covalent bonding makes it more difficult for materials to move their electron into the conduction band
- Atoms as silicon SI, gallium Ga, arsenide As

$\uparrow$ temperature $\Longrightarrow$ $\uparrow$ el. current

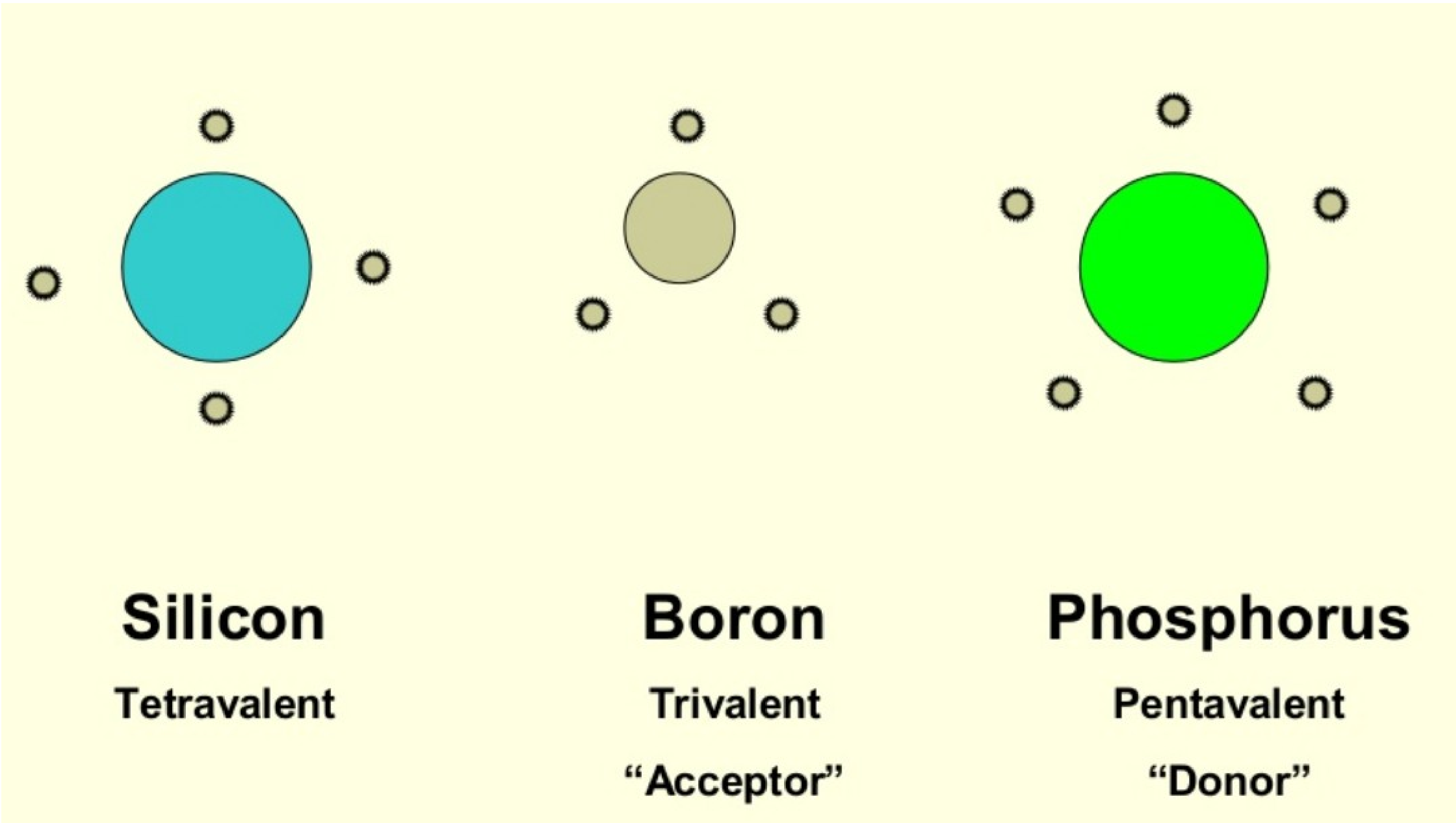
- When energy is applied to a semiconductor, more electron will move into the conduction band and current flow more easily through the material
- The resistance of semiconductor materials decrease with increasing temperature
- It is described as a negative temperature coefficient

Semiconductor doping

- Intrinsic semiconductor X doped semiconductor
- Doped semiconductor = impurities are added to intrinsic semiconductor materials to improve the electrical properties of the material

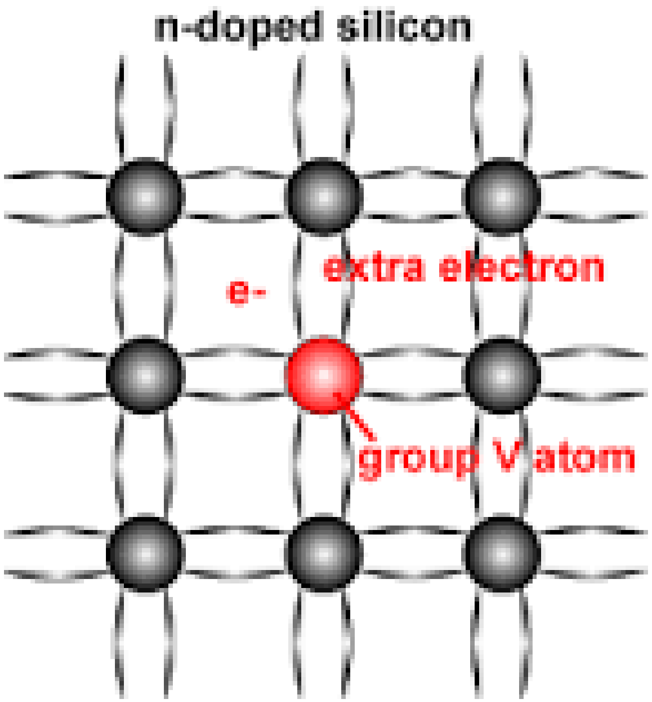
- Two major classifications of dopin materials (when major atoms are tetravalent)
  - **trivalent** – aluminium, gallium, boron -**acceptor**
  - **pentavalent** – arsenic, phosphorous - **donor**

Doped semiconductor

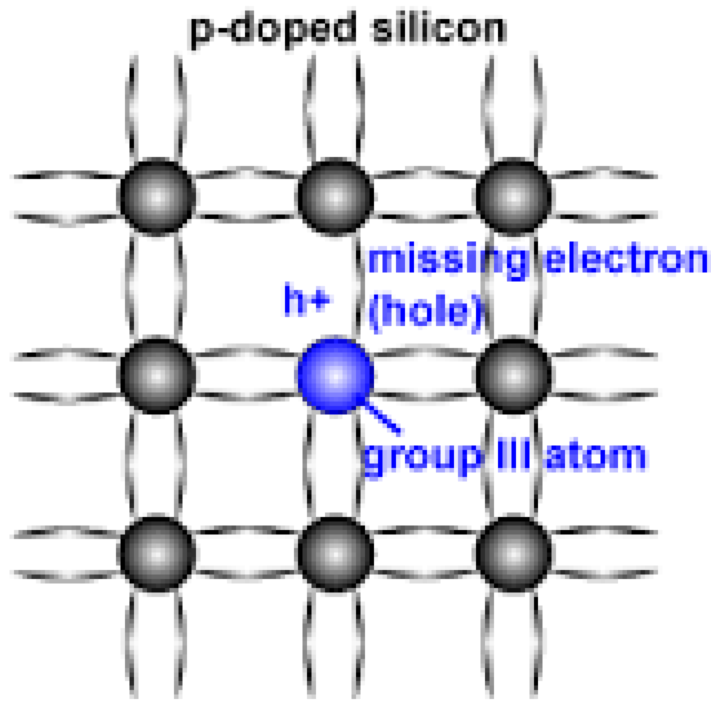


Doped semiconductors

- Doped semiconductors are classified in to P-type and N-type semiconductor
- P-type: A P-type material is one in which holes are majority carriers i.e. they are positively charged materials (++++)
- N-type: A N-type material is one in which electrons are majority charge carriers i.e. they are negatively charged materials (-----)

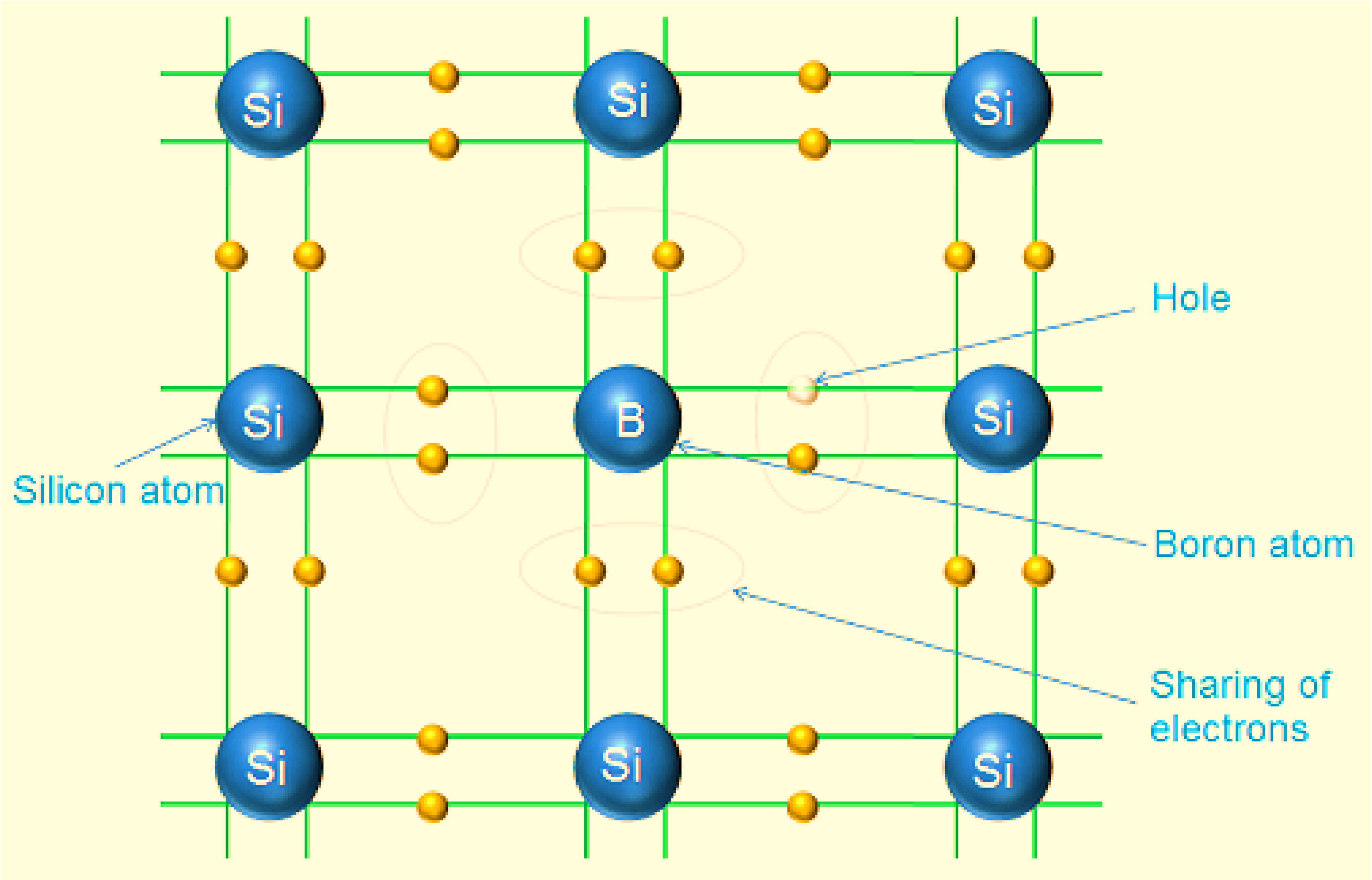


pentavalent

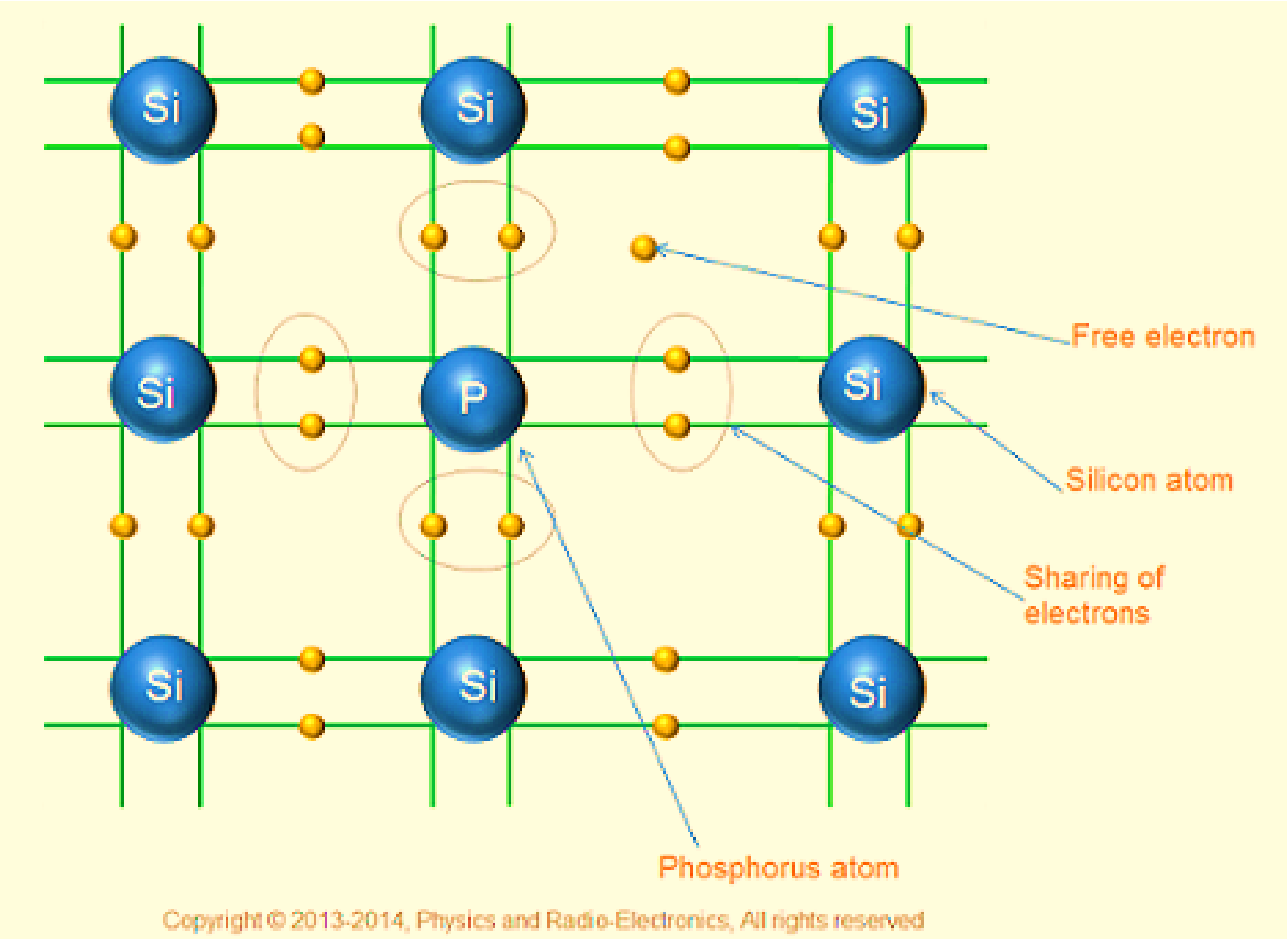


trivalent

P-type semiconductor



N-type semiconductor



???

- The free electron density of a conductor.
- Haw many free electrons exist in a cubic centimeter of copper? Each atom contributes one electron. The density $\rho=8.92\ g/cm^3$, atomic mass $M=63.55\ g/mol$, $N_A=6.02\times10^{23}$ atoms/mol.

- free e^-/cm^3 = ???

???

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- free e$^-$/cm^3 = ???

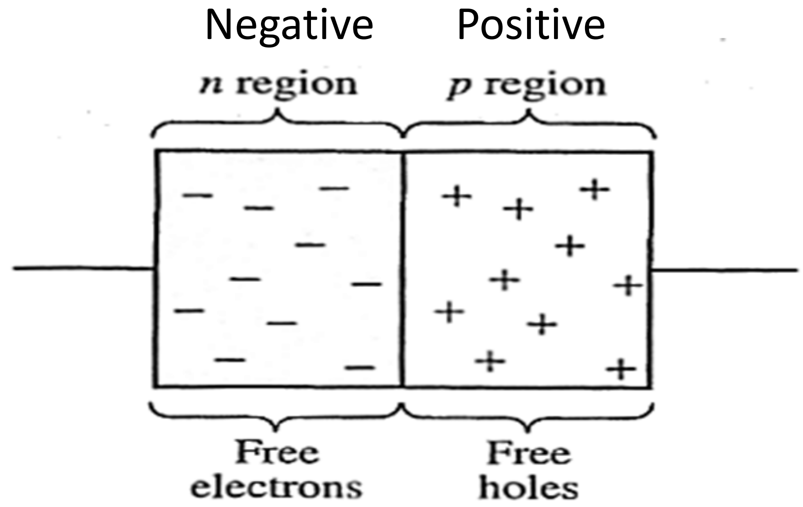
$$\frac{free\ e-}{cm^3} = \frac{free\ e-}{atom}(N_A)\frac{1}{M}(\rho)$$

$$\frac{free\ e-}{cm^3} = \frac{1 free\ e-}{1 atom}\left(\frac{6.02x10^{23}}{1\ mol}\right)\frac{1\ mol}{63.55\ g}\left(\frac{8.92\ g}{1\ cm3}\right)$$

8.45 x 10^{22} free e-/cm ^{3} in copper

Diodes

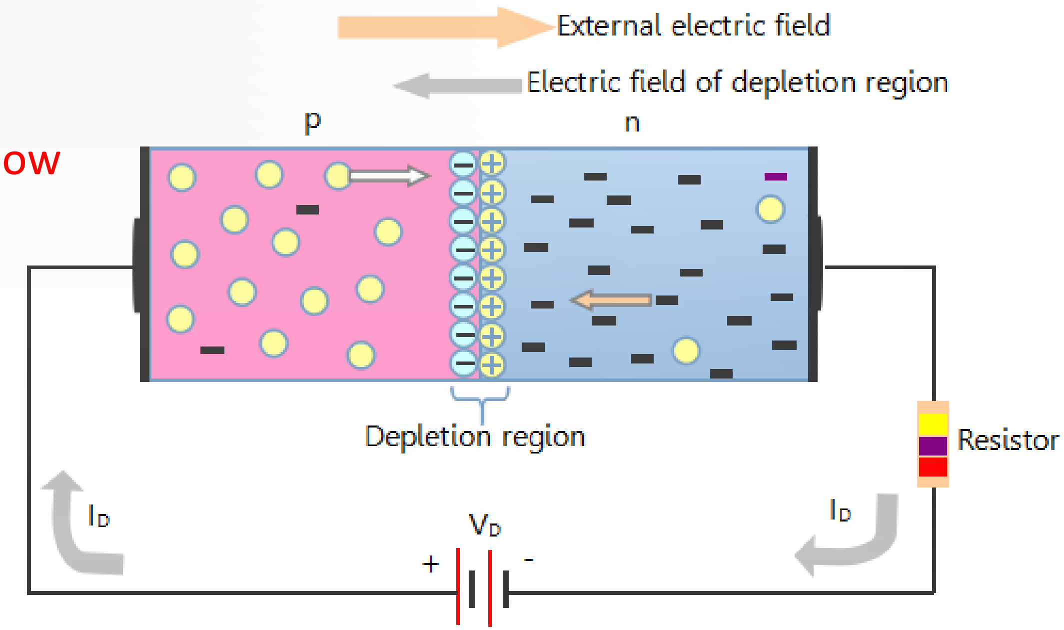
- Electronic devices created by bringing together a p-type and n-type region within the same semiconductor lattice. Used for rectifiers, LED etc



Forward biase junction

- An external source can either opposite or aid the barrier potential
- If the positive side of voltage source is connected to the p-type material, and the negative side to the n-type material, then the junction is said to be **forward biased.**

The maximum current flow

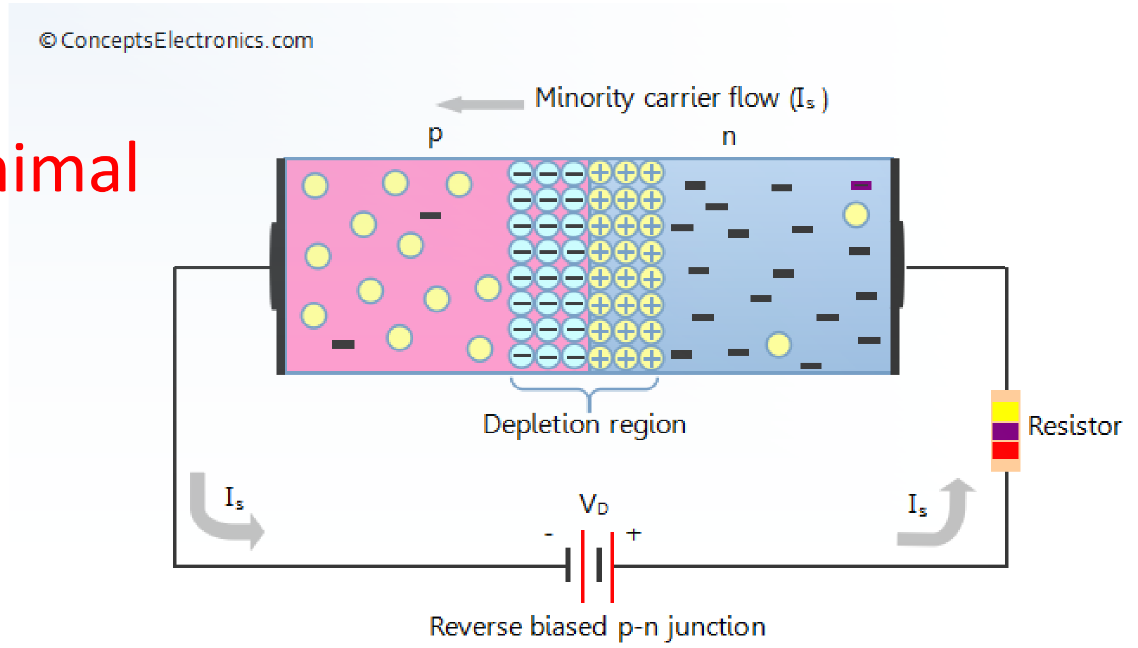


Forward biased p-n junction

Reverse biase junction

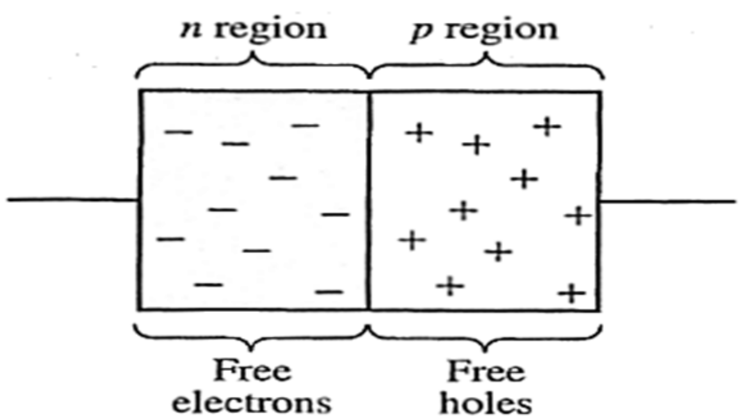
- Reverse bias occurs when the negative source is connected to the p-type material
- Reverse bias strengthens the barrier potential

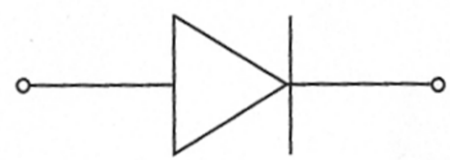
Current flow is minimal



Diodes

- It is represented by the following symbol, where the arrow indicates the direction of positive current flow.

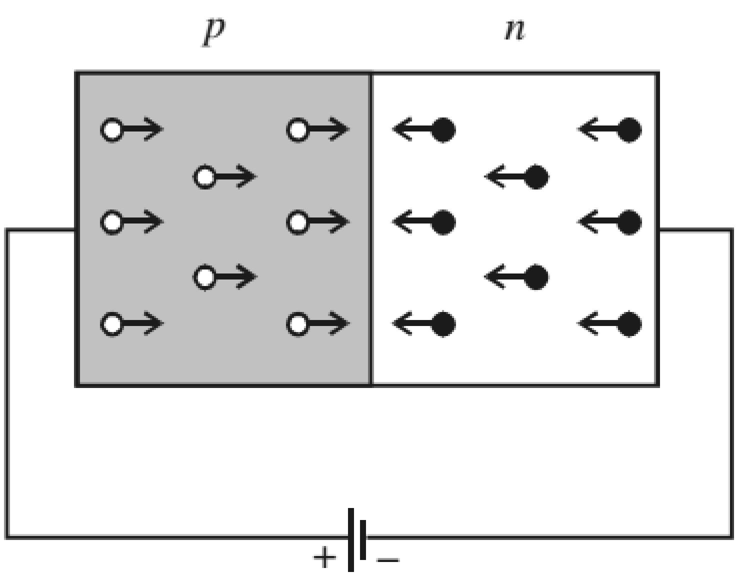




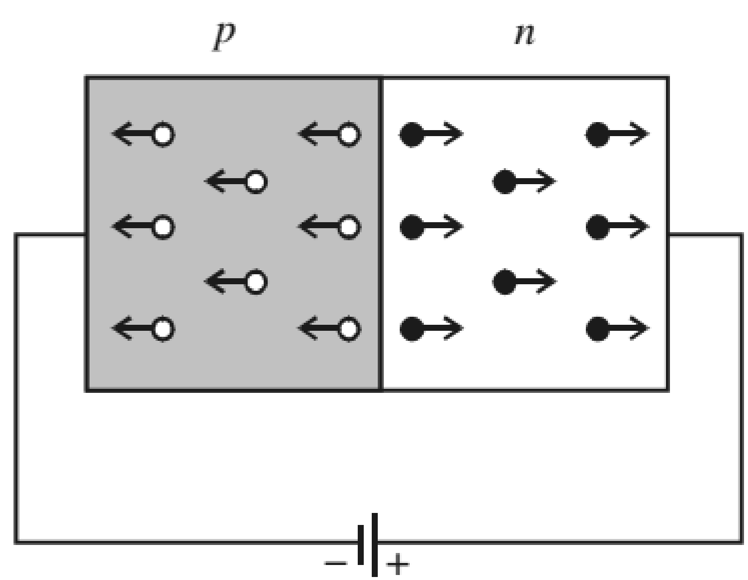
Diode

- Forward Bias : Connect positive of the Diode to positive of supply…negative of Diode to negative of supply
- Reverse Bias: Connect positive of the Diode to negative of supply…negative of diode to positive of supply.

Forward



Reverse



Diode

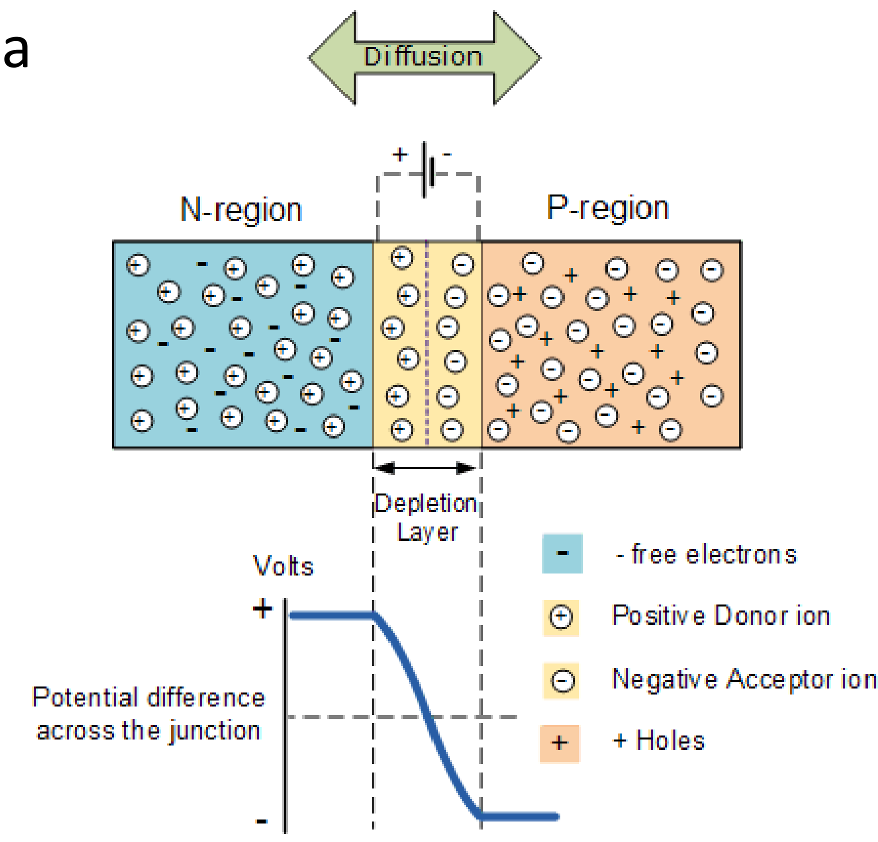
Characteristic:

- Diode always conducts in one direction.
- Diodes always conduct current when “Forward Biased” (Zero resistance)
- Diodes do not conduct when Reverse Biased
- (Infinite resistance)

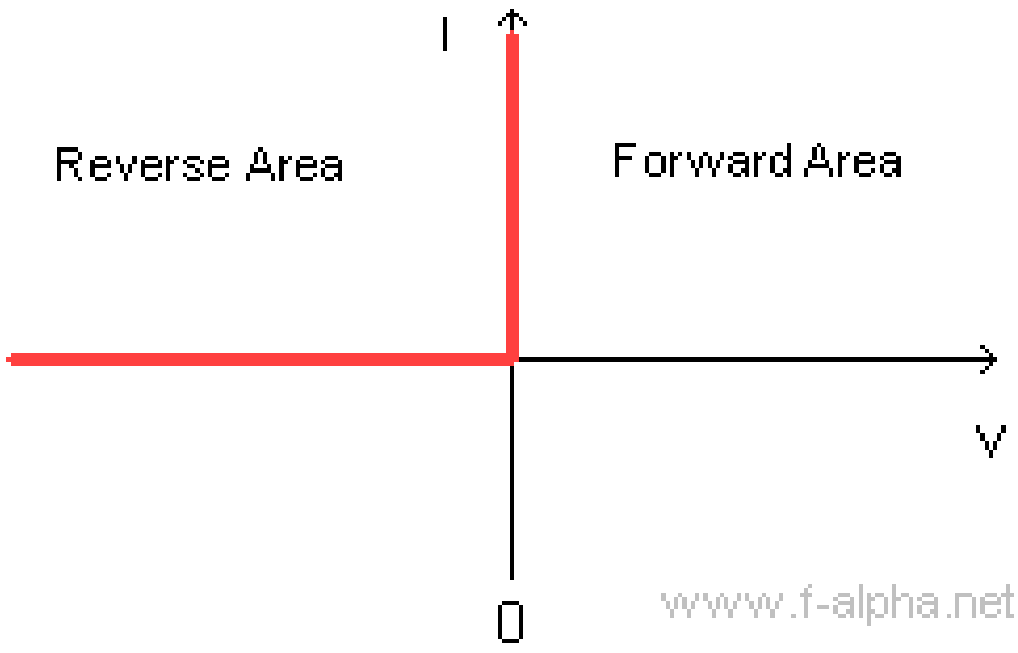
Depletion zone

When no voltage is applied, to the diode, electron from the N-type material fill holes from the P-materia along the junction between the layers, forming a depletion zone.

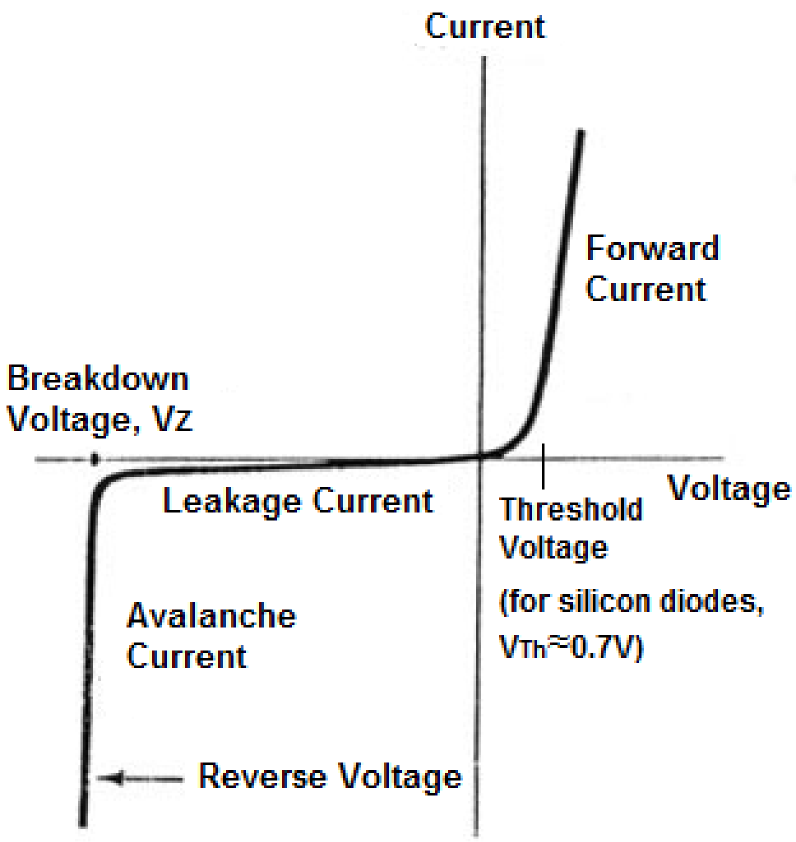
In a depletion zone, the semiconductor material is returned to its original insulating state -- all of the holes are filled, so there are no free electrons or empty spaces for electrons, and charge can't flow.

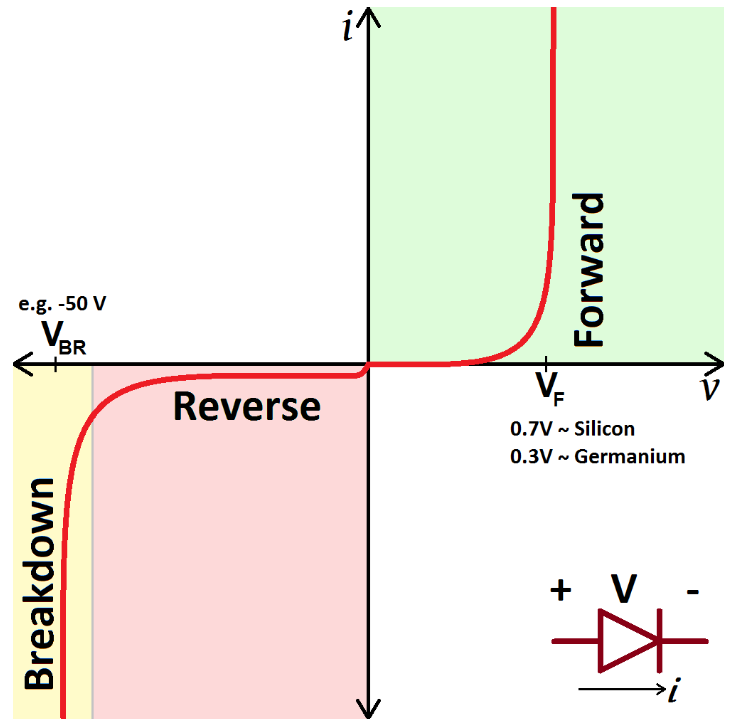


I-U characteristics of Ideal diode



I-U Characteristics of Realistic Diode





Light Emitting Diode

- LEDs are made from combination of gallium or aluminium with arsenic and phosporus
- LEDs emit light when they are forward-biased (during process of recombination of electrons and holes)
- LEDs can detect light (reverse action) – light fall on the PN junction produce electrons and holes – resulting in a electric current