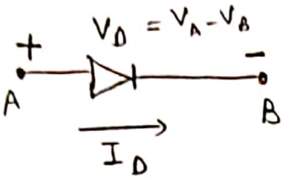
Rayene BECH 18011115

Semiconductor Diodes

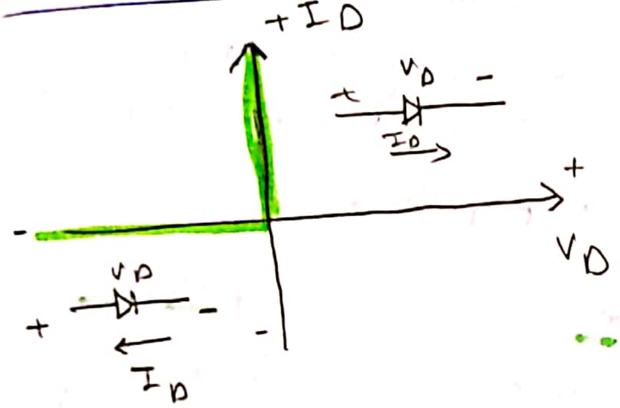
Ideal Diode

An ideal diode is a two-terminal device with the following symbol and characteristics:

Symbol:



Characteristics:



→ An ideal diode can conduct current in only one direction.

→ For forward current with $V_D = 0$

$R_{diode} = \frac{V_D}{I_D} = \frac{0}{I_D} = 0\,\Omega$ so the diode acts like short circuit.

→ If $V_D < 0$ the current $I_D = 0$

so $R_{diode} = \frac{V_D}{I_D} = \frac{V_D}{0} = \infty\,\Omega$

so the diode acts like open circuit

Semiconductor Materials

The conductivity of materials is related to its resistivity $\rho = \frac{RA}{l}$

where
- R is the resistance of a specimen
- A is its cross-sectional area
- l is its length

It differs from material to another

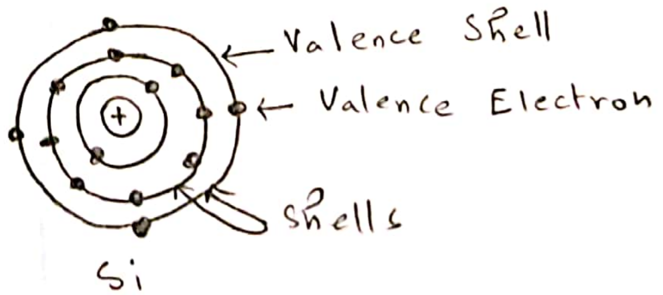
Conductor	Semiconductor	Insulator
$\rho \approx 10^{-6}\,\Omega.cm$	$\rho \approx 50 \times 10^{3}\,\Omega\text{-}cm$ (silicon)	$\rho \approx 10^{12}\,\Omega cm$

For semiconductor materials

Single-Crystal
- → Repetitive crystal structure
- → More available
- → Cheaper
- → Example: Ge, Si

Compound
- → Different atomic structures
- → Faster
- → More expensive
- → Example: GaAs

⇒ A Bohr model for sillcon atom:



⇒ **The valence Shell**: the shell with the lowest potential required to remove an electron from the shell.

⇒ **Covalent Bonding**: how atoms stick together by the sharing of covalent electrons.

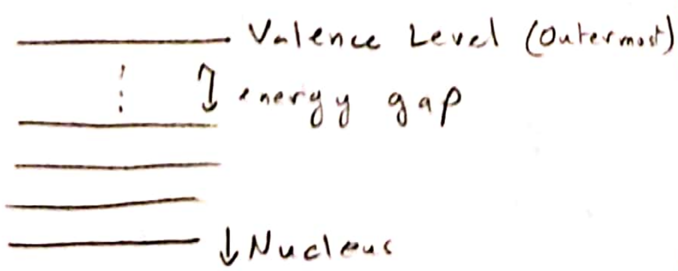
⇒ **Intrinsic Materials**: semi-conductor materials that has been refined to reduce the number of impurities.

⇒ If valence electrons absorb enough energy (Kinetic or temperature) they can be **free**.

⇒ Ge and Si has **negative temperature coefficient**: if temperature increases their resistance decreases.

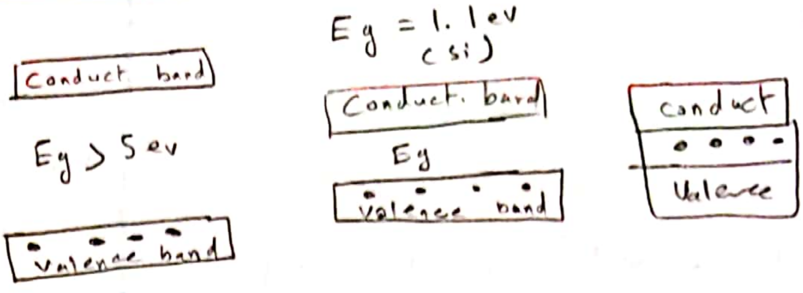
Energy levels

With each orbiting electron there is an associated energy level.



The gap between the conduction band and valence band differs from one type to another as follows:

Insulator — Semiconductor — Conductor



where Eg = Energy gap

Extrinsic Materials

n-type, p-type:

⇒ Extrinsic material = a semi conductor that has been subject to doping in order to enhance its conductivity and electrical propreties.

n-type

→ Pentavalent (5 valence e^-) atoms added

⇒ Results in free electrons

⇒ Added atoms are called "donor"

⇒ e^- is majority carrier

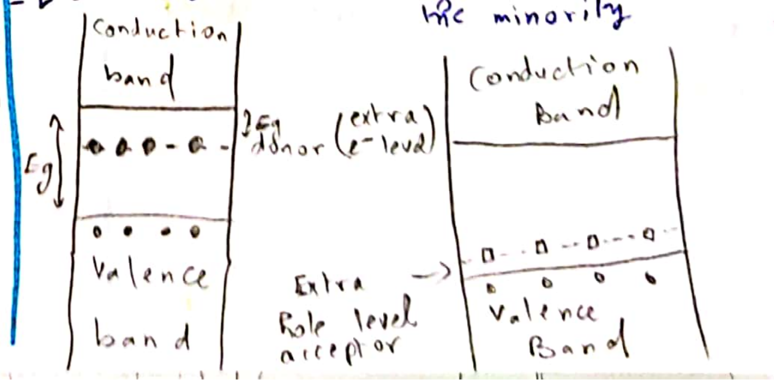
p-type

→ Trivalent (3 valence e^-) atoms added

⇒ Results in holes (e- efficiency)

⇒ Added Atoms are called "acceptor."

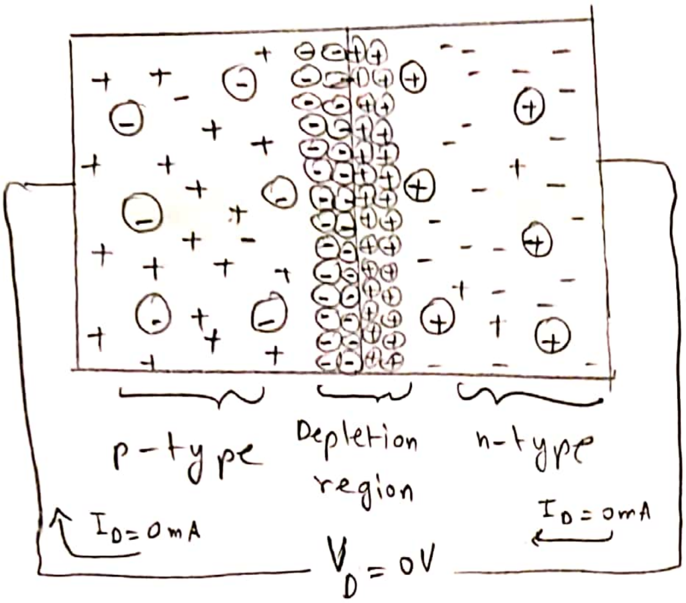
⇒ holes are majority carier, electrons are the minority



Semiconductor Diode

⇒ Combining n-type and p-type materials together results in forming a semiconductor diode.

⇒ The depletion region = the region of uncovered ions (positive and negative)



3 types of voltage can be applied:

$V_D < 0V$

- minority carriers in depletion region will increase due to the reverse bias.
- The depletion region becomes so wide → a hard barrier
- → Reverse saturation current is made

$V_D = 0V$

- minority carriers in both types that are in depletion region move to the opposite type.
- The net flow of charge in any one direction is zero because the flow of minorities from each side is cancelled

$V_D > 0V$

- applied voltage will pressure e⁻ in n-type and holes in p-type to re-combine with ions in the depletion region

⇒ As voltage increases, the depletion region decreases and current flows

The equation for forward and reverse-bias region is:

$$\boxed{I_D = I_s\left(e^{kV_D/T_K} - 1\right)}$$

where: I_s = reverse saturation current

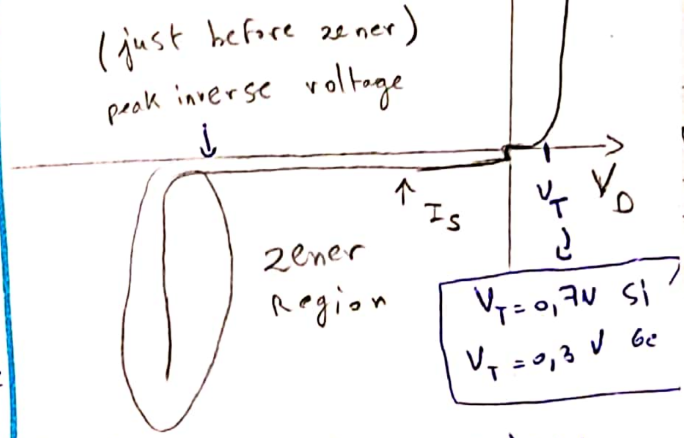
k = constant $(11{,}600/n)$ → Ge: $n=1$, Si: $n=2$

T_K = temperature in kelven $(T_C + 273°)$

⇒ It can be seen from the equation above how the sign of V_D affects I_D: $I_D = I_s e^{kV_D/T_K} - I_s$

Zener Region:

When applying a high negative potential a sharp change happens.



So for reverse-bias region:

$V_D^- \nearrow \rightarrow I_s \nearrow \rightarrow$ velocity of ions $\nearrow$

→ Ionization happens → Avalanche current is established.

Scanned with CamScanner

Temperature Effects

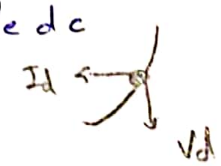
⇒ Increase in taperature results in a faster and more magnitude for the current (both forward and reverse)

⇒ The silicon gets affected by the temperature more than the germanium.

Resistance Levels

⇒ **DC or static Resistance:** This one can be found by $\boxed{R_D = \frac{V_D}{I_D}}$

- The lower is the current through a diode the higher the dc resistance level.



⇒ **AC or dynamic Resistance:**

For a sinusoidal input the AC resistance is $\boxed{r_d = \frac{\Delta V_D}{\Delta I_d}}$

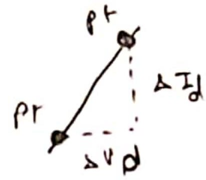
- The lower the Q-point of operation (smaller current or lower voltage) the higher the ac resistance.
- It can be also found by derivating the equaton $\frac{d}{dV_D} I_d = \frac{d}{dV}\left[I_s(e^{kV_D/T_K} - 1)\right]$

by calculations $\boxed{r_d = \frac{26\,mV}{I_D}}$

⇒ **Average AC Resistance:**

It is determined graphically be a line drawn between two points

$$\boxed{r_{av} = \frac{\Delta V_d}{\Delta I_d}\bigg|_{pt.\ to\ pt}}$$



- The lower the level of currents used to determine the average resistance, the higher the resistance level.