Subject: MM-101 5/11/24

Ohm's law: $V = IR$

current

voltage

Resistance

The amount of Voltage flowing across a conductor is directly proportional to the current flowing provided constant conditions

Resistivity: $\rho = \frac{RA}{L}$

surface Area

length

- Resistance per unit length & A_o.
- Independent of geometry & sample size.

Conductivity: $G = \frac{1}{\rho}$

- Reciprocal of resistivity

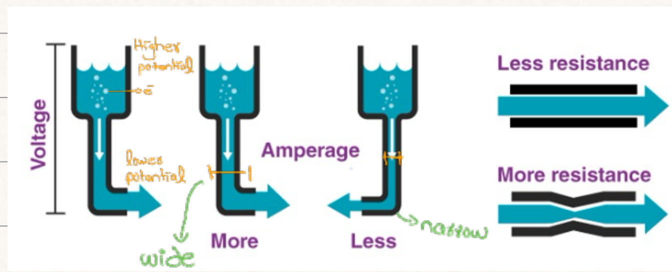
1) Metals
2) Semi-conductors
3) Ceramics
4) Polymers

conductivity

Electrical Resistance:

- Depends on the geometry & size of sample

A & L

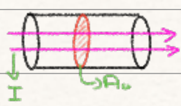


Current density: $J = \sigma E$

Amount of current flowing through A_o.

$\perp$ to I

$= \frac{I}{A_o}$



For constant Electric field,

$V = \frac{Work}{q}$ $V = Ed$

$= \frac{Fd}{q}$ units $= \frac{Nm}{C} = \frac{J}{C} =$ Volts

$= \frac{\cancel{F}d}{\frac{\cancel{F}}{E}}$

Electric field potential: $E = \frac{V}{L}$

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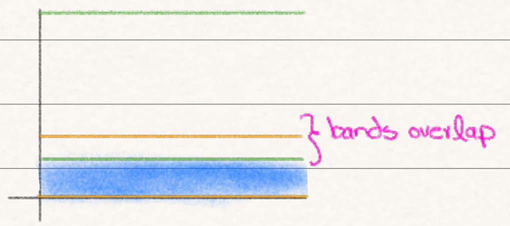
Energy Band Theory:

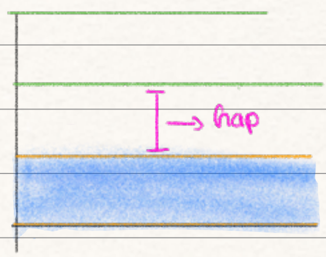
one atom   2 atoms   N atoms

↳ Their energy levels come close

In metals,



In insulator; semi-conductors,

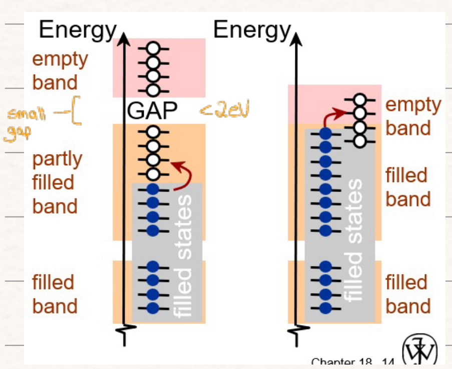


As bands overlap, ēs can freely move without the need for holes.

Due to gap, ēs need to jump & leave behind holes.

Metals:

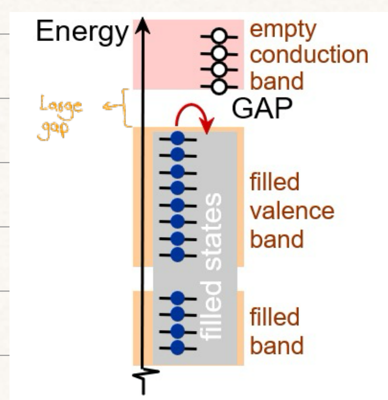
- Thermal energy excites ē into higher empty energy states
- There are two states for metals:



state 1   state 2

Insulators:

- Band gap is large (>2eV)
- Thus, few ēs reach higher empty energy states.



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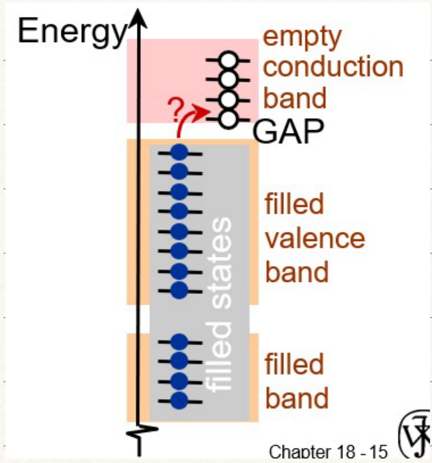
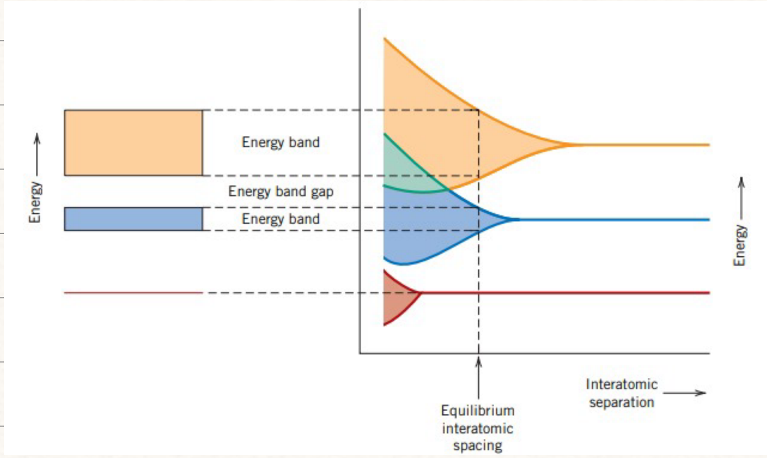
• Semiconductors:

• Narrow band gap

• Thus, ēs able to jump to higher empty energy states





Influence of temp & imperfections on ρ:

→ Resistivity

• Presence of impurities such as grain boundaries, dislocations, impurity atoms, vacancies } These scatter ēs path

$$\rho = \rho_T + \rho_{impurity} + \rho_{deformation}$$

Drift velocity:

• Avg velocity of ē in the direction of the force imposed by applied field.

$$V_d = \mu E$$

↳ electron mobility

Types of electronic charge:

1) Free ē → In conduction band (-ev)

2) Hole → In valence band (+ev)

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Intrinsic Semi-Conductors:

- Pure semi-conductor

Example:

Si, Ge

III–V compounds ⟶ InSb

II–VI compounds ⟶ ZnTe

NOTE: Electronegativity difference ∝ band gap

Conductivity: $\sigma = \underbrace{n}_{\#\bar{e}}\,\underbrace{|e|}_{\text{charge}}\,\underbrace{\mu_e}_{\bar{e}\text{ mobility}} + \underbrace{p}_{\#\text{holes}}\,\underbrace{|e|}_{\text{charge}}\,\underbrace{\mu_h}_{\text{hole mobility}}$

For intrinsic semi-conductor,

$n = p = n_i$ ⟶ intrinsic carrier concentration

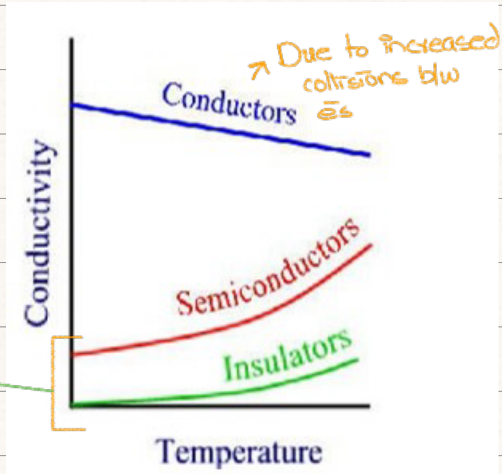
$\sigma = n_i|e|(\mu_e + \mu_h)$

Si:

↳ σ increases with T

↳ At RTP, it acts as insulator. On increasing T, $\bar{e}$s excite & thus Si acts as conductor.

$n_i \propto e^{-E_{gap}/KT}$



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Extrinsic:

- Properties determined by impurities induced holes & ēs.

$n \neq p$

n-type Extrinsic: $(n \gg p)$

$\sigma = n|e|\mu_e$

P-type Extrinsic: $(p \gg n)$

$\sigma = p|e|\mu_h$

- Doping increases conductivity because imperfections lower activation energy levels.
- For T:
  - < 100, Nothing happens — ēs don't move
  - $150 < T < 450$: extrinsic — Doped holes/ēs play crucial role
  - $\gg 450$: intrinsic — Inherent holes/ēs play crucial role

P—N Rectifying region:

- Allows flow of current in only one direction.

No applied potential:

↳ no current flow

Forward bias:

↳ External V applied, ēs from n region move to p region & combine with holes.

↳ Thus, current flows.

Reverse bias:

↳ External V applied in opposite direction, ēs don't move.

↳ Depletion region widens.

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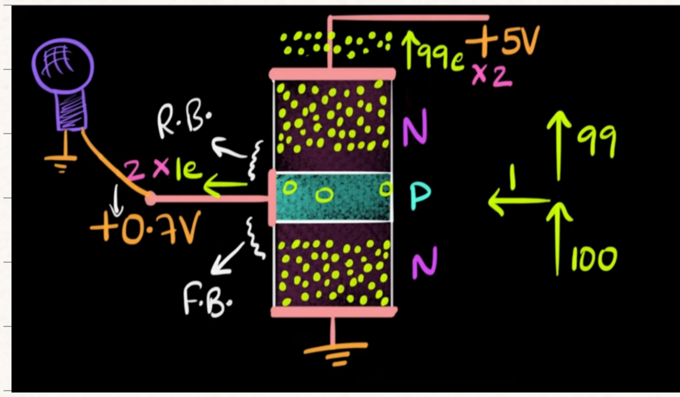
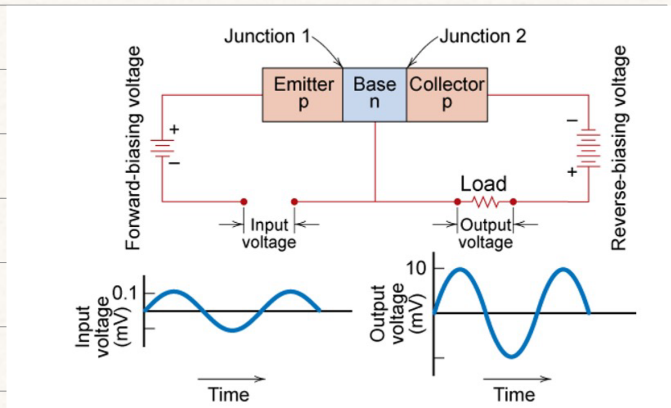
Transistors:

↳ Amplification





Piezoelectric materials:

- Stress induces V

Ferroelectric material:

- exhibit spontaneous polarization
- Re-allign beyond it's curie temp