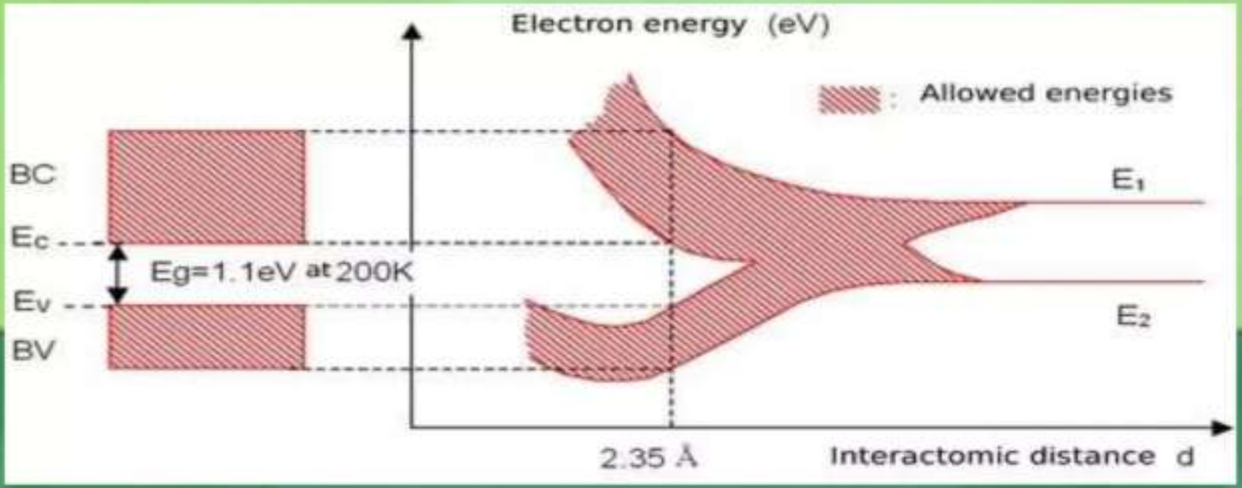
Determination of band gap

Out Line

- Introduction
- Energy band
- Classification of materials

INTRODUCTION

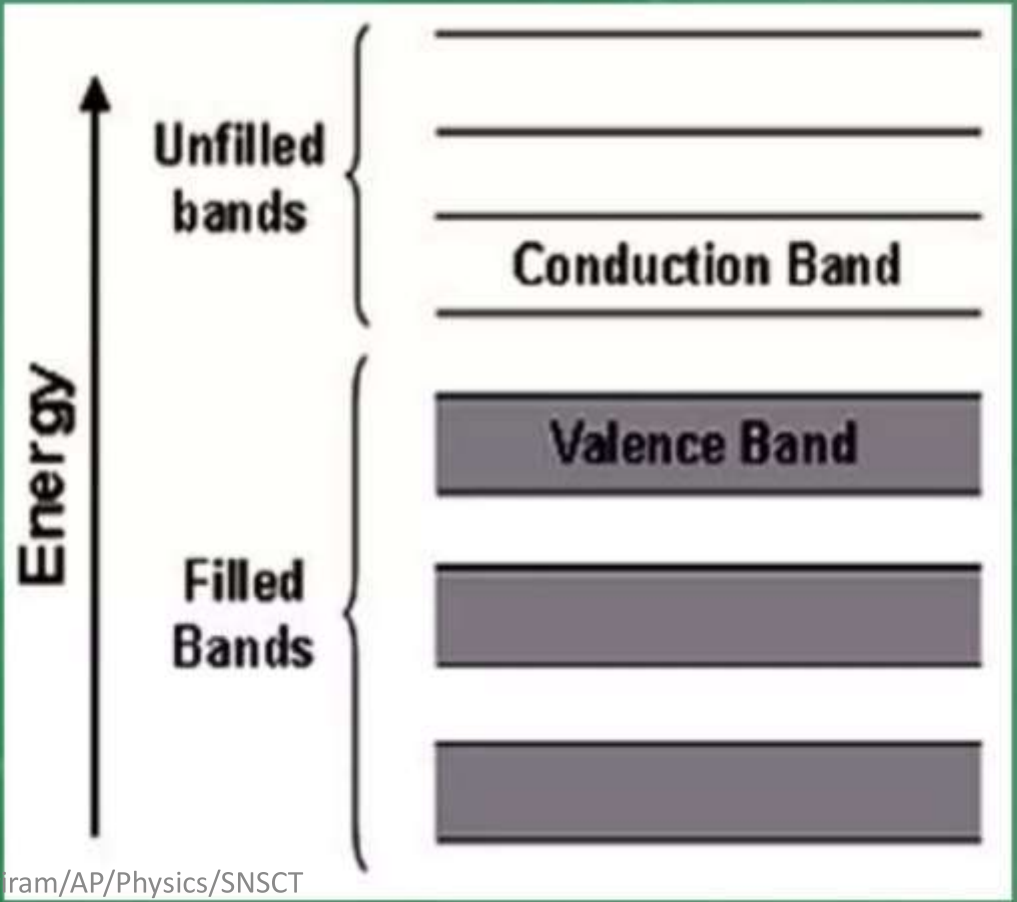
- Si= 14 electrons $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$
- 4 valence electrons
- Electrons present in the outermost orbit are called valence e- and their behavior decide electrical characteristics of a materials.
- For Si 2 e^- are present in 3s and 2 e^- are in 3p orbital's
- Consider n Si atoms, which are for apart from each other so that the interaction b/w them is negligible.
- In this 2N e^- occupy the 3s level and 2N e^- in 3p level.
- When the atoms are brought to closer, the interaction b/w increases and they now form a electronic system.



- The electronic system should obey Paulie's exclusion principal , which states that no 2 e^- are in the system can have same amount of energy.
- To obey this 3s and 3p level spilt into multiple levels so that each e^- can occupy a district energy level.
- When inter atomic distance is further reduced. The 2N 's' levels and 6N 'p' levels combined into a single band.
- At lattice spacing, single band is split into 2 bands with upper band containing 4N and lower band with 4N levels.
- At 00 k e^- possess lowest energy , they fill up valence band and conduction band remaining empty.

Energy Bands theory

- There Important energy bands are,
- Valence Band
- Conduction Band
- Forbidden Band



Valence Band

- Band of energy level which are closer to nucleolus.
- An e- in valence band, expenses strong force of attraction from nucleolus.
- And it can’t move freely when extrenal electric field is applied.
- It is called bounded electron.

Conduction Band

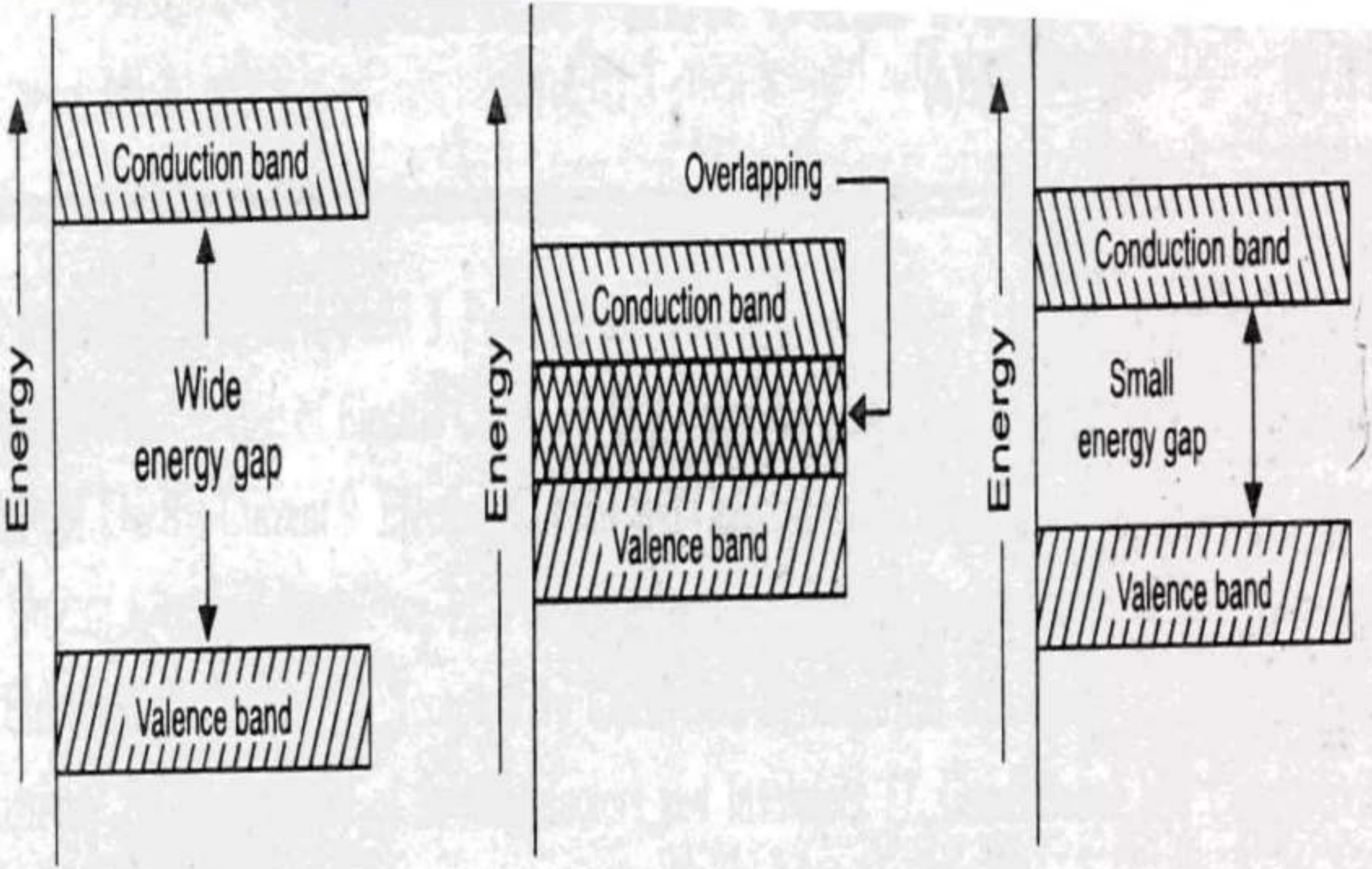
- Bond of energy levels which are far away from the nucleolus.
- The conduction band is the band of orbitals that are high in energy and are generally empty.
- An e- in Conduction band has weak influence of nucleolus and hence it can move free under the effect of applied electric field and thus it produces current, it is called free electrons

Forbidden Band / Energy Gap

- In solid-state physics, an **energy gap** or **bandgap**, is an energy range in a solid where no electron states can exist.
- It generally refers to the energy difference (in electron volts) between the top of the valence band and the bottom of the conduction band in insulators and semiconductors.

Types of Materials

- Materials can be divided into 3 types based on the values of energy gap
- Insulator
- Conductor
- Semi Conductor



(a) Insulators (b) Conductors (c) Semiconductors

INSULATORS

- It is a material with large energy gap
  - Eg= several ev
  - ev= $1.6*10^{-19}$ joules
- Due to large energy gap an e^- from valence band can't move into conduction band remains complete fill.
- Conduction band completly empty.
- Ex: glass, Diamond, Silicon di oxide
- Energy gap of diamond is ~6ev.

CONDUCTORS

- It is a material having zero energy gap. The materials in which conduction and valence bands.
- Valence electrons can move valence to conduction band without requiring thermal energy.
- The overlapping indicates a large number of electrons available for conduction.
- Hence the application of a small amount of voltage results a large amount of current.
- Ex: All metals.
- Best conducting materials are
  - Silver is best, cupper is second best

SEMICONDCUTOR

- The materials, in which the conduction and valence bands are separeated by a small energy gap (1eV) are called semiconductors.
- Silicon and germanium are the commonly used semiconductors.
- A small energy gap means that a small amount of energy is required to free the electrons by moving them from the valence band in to the conduction band.
- The semiconductors behave like insulators at 0K, because no electrons are available in the conduction band.
- If the temperature is further increased, more valence elctrons will acquire energy to jump into the conduction band.

- If a valence receives sufficient thermal energy, it can move into conduction band leaving a vacancy in valence band, which is called hole and therefore, if one e^- is sufficiently thermally energized it creates a pair of free e^- and hole, this process is called carrier generation
- Carrier generation can happen due to
  - Thermal excitation
  - Photo excitation
  - Electrical excitation
  - Impact ionization

$E_g(T) = 1.21 - 3.6*10^{-4}\,T$ for si
$E_g(T) = 0.785 - 2.23*10^{-4}\,T$ for Ge

- When external electric field is applied free electron travels with in conduction band producing electron current.
- Where as hole travels in valence, producing hole current.
- The total current will be sum of free & hole current.
- $I_{total} = I_{free\ e^-} + I_{hole}$
- As temp increase free e^- & holes will increase and conductivity increases.