Lec 8 - Semiconductor Physics

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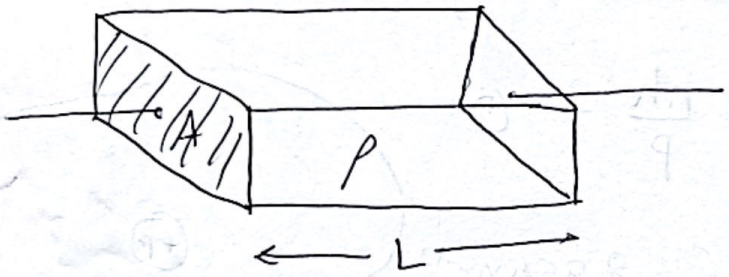
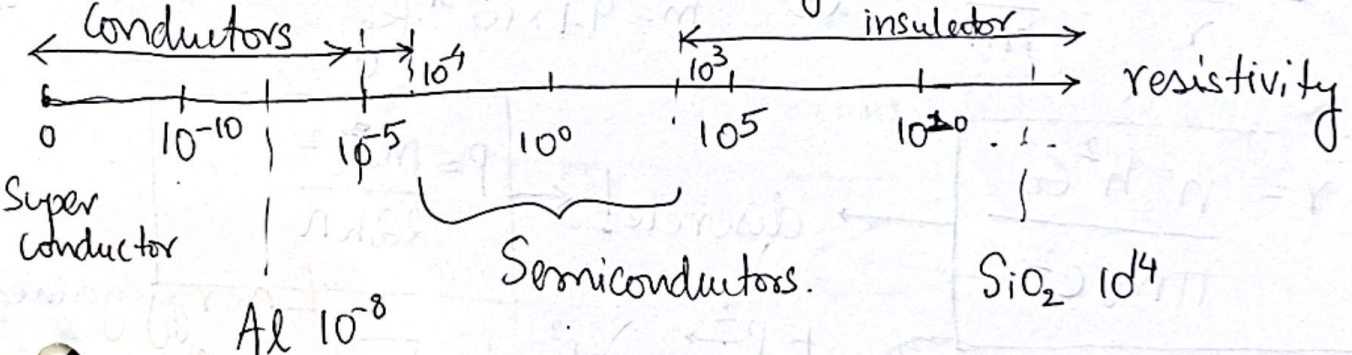
Circuits & Systems (RLC) : Device Physics (Diodes Transistors) : Integrated Electronics Op Amps, ...

Semiconductors (Macroscopic view).



$R = \frac{\rho L}{A}$ $\rho =$ Ωm → resistivity (material property).

$\sigma = 1/\rho$ conductivity



Semiconductors (Microscopic)

wave ⟷ particle (QM).

$\lambda = \frac{h}{p}$ → de Broglie wavelength.

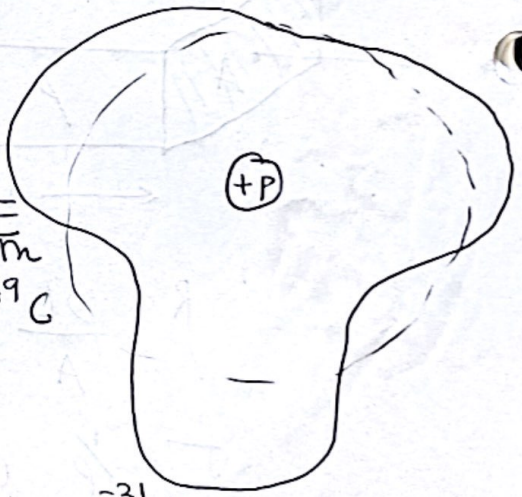
h → Planck's constant. $(6.62 \times 10^{-34}\ m^2 kg/s)$

p → momentum

Wave

> Hydrogen atom } Electron "wave" forms a standing wave around the nucleus → Simplest model (Bohr).

$$\Rightarrow 2\pi r = n\lambda = \frac{nh}{p} \quad \text{—①}$$



Particle

> $F = \frac{1}{4\pi\epsilon_0}\frac{e^2}{r^2}$ $\quad \epsilon_0 = 8.854 \times 10^{-12}\ \frac{F}{m}$

$e = -1.6 \times 10^{-19}\ C$

$$= \frac{mv^2}{r} = \frac{p^2}{m_0 r} \quad \text{—②} \qquad m = 9.1 \times 10^{-31}\ kg$$

Solve ① & ② for r & p ⇒

$$r = \frac{n^2 h^2 \epsilon_0}{\pi m_0 e^2} \rightarrow \text{discrete!} \leftarrow p = \frac{m_0 e^2}{2\epsilon_0 h n}$$

$$E_{total} = E_p + E_K = -\frac{1}{4\pi\epsilon_0}\frac{e^2}{r} + \frac{1}{2}mv^2 = \frac{-p^2}{2m_0} + \frac{p^2}{2m_0}$$

$-p^2/m_0$

$$= \frac{-13.6\ eV}{n^2} \rightarrow \text{discrete!}$$

Energy gained by e when accelerated by 1V.

$1.6 \times 10^{-19}\ C \times 1V = 1.6 \times 10^{-19}\ J$

$E > 0$ } Free electrons. → $|E_k| > |E_p|$

$E_\infty = 0 \longrightarrow |E_p| = |E_k|$

$E_3 = -1.5\,eV$

$E_2 = -3.4\,eV$ $\quad n = 2$ $\quad 2s^2\ 2p^6$ $(l = l, q = -1, 0, 1)$

$l = 0$

$E_1 = -13.6\,eV$ $\quad n = 1$ $\quad 1s^2$

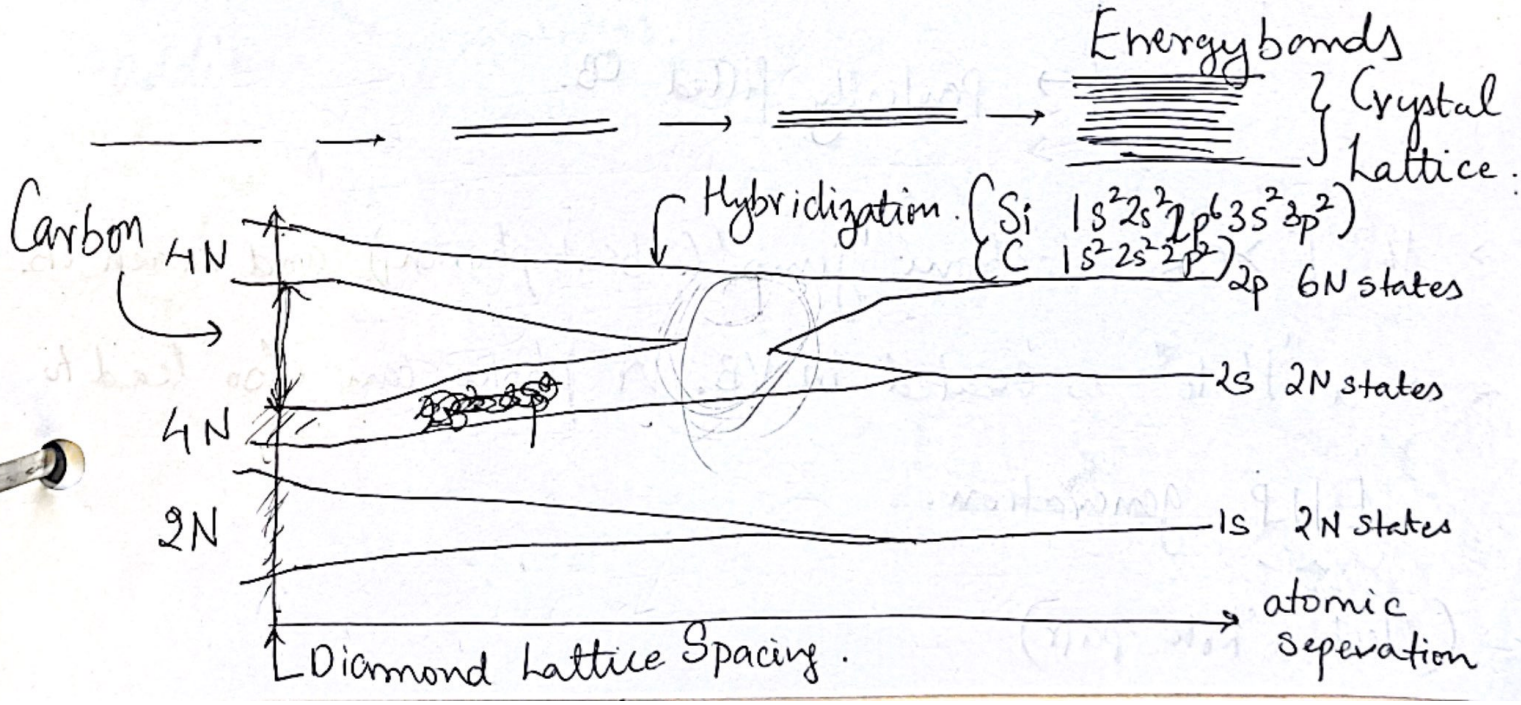
=> n → principal quantum number

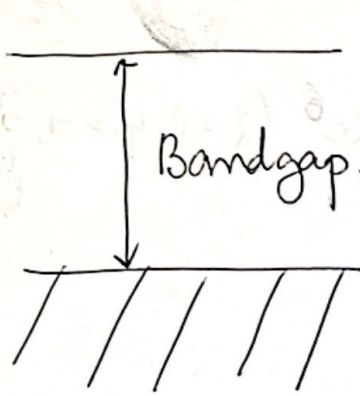
l → orbital angular momentum q.n $\quad (0, 1, 2 \ldots, n-1)$

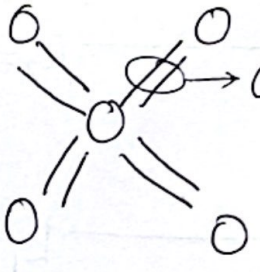
q → magnetic qn $\quad (-l, \ldots, +l)$

s → Spin qn. $\quad (+\frac{1}{2}, -\frac{1}{2})$

> When 2 hydrogen atoms come close energy levels split. (Pauli's Exclusion Principle).







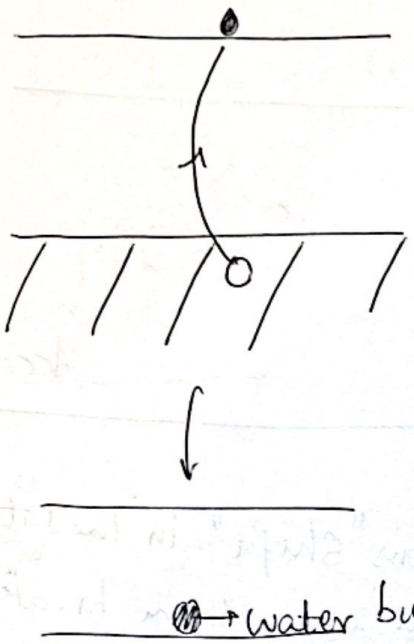
2-D representation of lattice Structure C, Si, Ge.

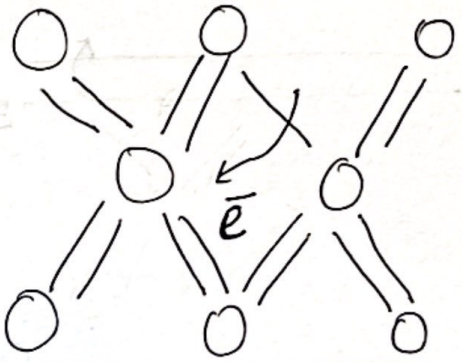
At OK · VB filled
CB empty.
⇒ insulator

> Insulators ⇒ High bandgap (almost no electrons in CB even at $t > 0K$)

> Conductors → Overlapping VB & CB
→ Partially filled CB.

> At $T > 0K$ electrons "jump" (absorb phonon) and reach CB.
⇒ a "Hole" is created in VB. A photon can also lead to EHP generation.
(Electron hole pair)





→ water bubble.

→ air bubble

water

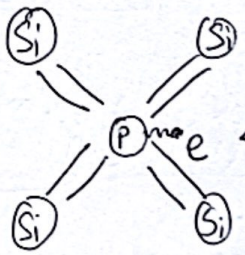
> At T > 0k in pure (intrinsic) Sc #holes = # electrons.

We want to control these quantities ⇒ Doping → careful addition of impurities.

Acceptors III	S-C. IV	Donors V
B	C	N
Al	Si	P
Ga	Ge	As

3 electrons in outer shell

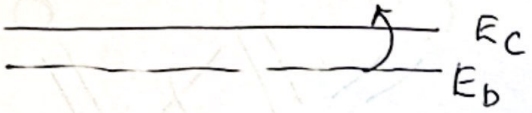
5 electrons in outershell

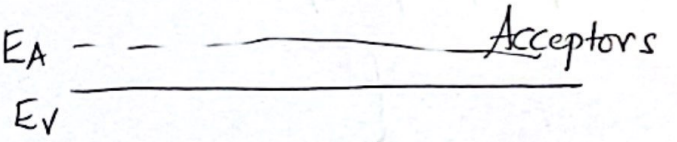


⇔ Si + H (loosely speaking)

⇒ $E_{\substack{total \\ n=1}} = -\frac{13.6}{\epsilon_r^2} = -0.1\,eV$ Very low bonding energy.

Donors ⇒ extra electron + ion (no hole).





electrons "shift" in the lattice (much easier than breaking free).