Module 2 Unit 1

SEMICONDUCTORS - FORMULAS

(As per Revised Curriculum SVU R-2023)

1. Number of atoms per unit volume	$\mathbf{N} = \frac{\mathbf{D\times N_0}}{\mathbf{M}}$
2. Intrinsic carrier concentration	$n = p = n_i = \sqrt{N_C N_V}\exp\left(-\frac{E_g}{2kT}\right)$
3. Extrinsic carrier concentration	N-type: • Majority carriers: $n_n \approx N_D$ at RT • Minority carriers: $p_n \approx \frac{n_i^2}{N_D}$ at RT • $n = N_C\exp\left(-\frac{E_C-E_F}{kT}\right)$ at moderate temperatures P-type: • Majority carriers: $p_p \approx N_A$ at RT • Minority carriers: $n_p \approx \frac{n_i^2}{N_A}$ at RT • $p = N_V\exp\left(-\frac{E_F-E_V}{kT}\right)$ at moderate temperatures
4. Conductivity and resistivity	Conductivity: Intrinsic: $\sigma_i = qn_i(\mu_n + \mu_p)$ N-type: $\sigma_n = qn\mu_n$ P-type: $\sigma_p = qp\mu_p$ Resistivity: $\rho = \frac{1}{\sigma}$
5. Drift velocity and mobility	Drift velocity: $v_d = \mu\varepsilon$ Mobility: $\mu = \frac{q\langle\tau\rangle}{m^*}$; $\langle\tau\rangle$: average charge carrier lifetime
6. Drift current density	Electrons: $J_n(\text{drift}) = qn\mu_n\varepsilon = \sigma_n\varepsilon$ Holes: $J_p(\text{drift}) = qp\mu_p\varepsilon = \sigma_p\varepsilon$
7. Diffusion current density	Electrons: $J_n(\text{diffusion}) = qD_n\frac{dn}{dx}$

	Holes: $J_p(\text{diffusion}) = -qD_p\frac{dp}{dx}$
8. Einstein's relation	$\frac{D}{\mu} = \frac{kT}{q} = \text{constant at a given temperature}$
9. Probability factor for occupation of energy level E (Fermi-Dirac function)	Electrons: $F(E) = \frac{1}{1+\exp\left(\frac{E-E_F}{kT}\right)}$ Holes: $1 - F(E) = \frac{\exp\left(\frac{E-E_F}{kT}\right)}{1+\exp\left(\frac{E-E_F}{kT}\right)}$
10. Position of Fermi level in intrinsic semiconductors	$E_F = E_i = \frac{E_C+E_V}{2} + \frac{3}{4}kT\ln\frac{m_h^*}{m_e^*}$ $\approx \frac{E_C+E_V}{2} = \frac{E_g}{2}$
11. Fermi level shift due to doping	N-type: $E_F - E_i = kT\ln\left(\frac{n}{n_i}\right)$; $n \approx N_D$ at RT P-type: $E_F - E_i = -kT\ln\left(\frac{p}{n_i}\right)$; $p \approx N_A$ at RT Alternatively, $E_i - E_F = kT\ln\left(\frac{p}{n_i}\right)$

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