ECE 235: Introduction to Solid State Electronics

Discussion

Week 8

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Carrier Statistics

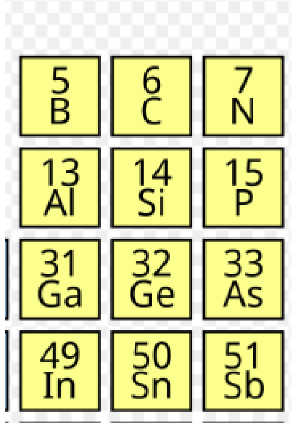
$$n = N_c e^{-(E_c - E_F)/kT} \quad \text{where} \quad N_c = 2\left(\frac{2\pi m^* kT}{h^2}\right)^{3/2}$$

$$p = N_v e^{-(E_F - E_v)/kT} \quad \text{where} \quad N_v = 2\left(\frac{2\pi m^* kT}{h^2}\right)^{3/2}$$

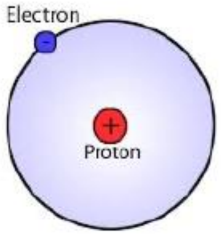
$$E_i = \frac{E_c + E_v}{2} + \frac{3kT}{4}\ln\left(\frac{m_p^*}{m_n^*}\right) \cong \frac{E_c + E_v}{2}$$

$$n_i = \sqrt{N_c N_v}\, e^{-E_G/2kT}$$

Donor Energy

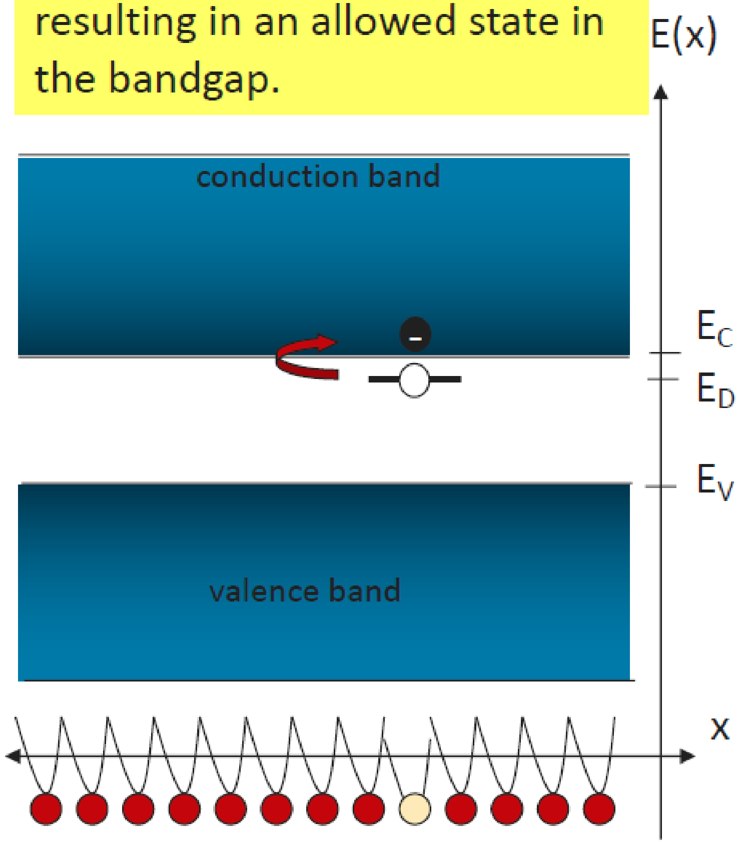


$$E_b = -\frac{m_e e^4}{8\epsilon_0^2 h^2} = -13.6\ eV$$



$$E_b^{As} = E_b \frac{m_e^*}{m_e} \frac{1}{\epsilon_r^2} = -0.032\ eV$$

The donor creates a small variation in the lattice potential resulting in an allowed state in the bandgap.



Electron and Hole Concentration

$$np = n_i^2$$

Intrinsic semiconductor	N-type material	P-type material
$n = p = n_i$	$n \approx N_D$	$p \approx N_A$
	$p \approx \dfrac{n_i^2}{N_D}$	$n \approx \dfrac{n_i^2}{N_A}$

Drift and Diffusion Current

$$J_e(drift) = n\, e\mu_e E$$

$$J_h(drift) = p\, e\mu_h E$$

$$J_{e(diffusion)} = e\, D_e \frac{dn}{dx}$$

$$J_{h(diffusion)} = -e\, D_h \frac{dp}{dx}$$

$$J(diffusion) = J_e(diffusion) + J_h(diffusion)$$

Practice Problem 1

Given that the density of states related effective masses of electrons and holes in Si are approximately 1.08me, and 0.60me, respectively, and the electron and hole drift mobilities at room temperature are 1350 and 450 $cm^2 V^{-1} s^{-1}$, respectively, calculate the intrinsic concentration and intrinsic resistivity of Si. Si bandgap is 1.10 eV.

Practice Problem 2

Find the resistance of a 1 cm × 1 cm × 1 cm pure silicon crystal. What is the resistance when the crystal is doped with arsenic if the doping is 1 part per billion (ppb)? Given data: Atomic concentration in silicon is 5×10^{22} cm^{-3}, $n_i = 1.0 \times 10^{10}$ cm^{-3}, the electron and hole drift mobilities at room temperature are 1350 and 450 cm^2 V^{-1} s^{-1}, respectively.

Practice Problem 3

An n-type Si semiconductor containing 10^{16} phosphorus (donor) atoms cm^{-3} has been doped with 10^{17} boron (acceptor) atoms cm^{-3}. Calculate the electron and hole concentrations in this semiconductor. Given that $n_i = 1.0 \times 10^{10}$ cm^{-3}

Practice Problem 4

An n-type Si wafer has been doped uniformly with 10^{16} antimony (Sb) atoms cm^{-3}. Calculate the position of the Fermi energy with respect to the Fermi energy E_{Fi} in intrinsic Si. The above n-type Si sample is further doped with 2×10^{17} boron atoms cm^{-3}. Calculate the position of the Fermi energy with respect to the Fermi energy E_{Fi} in intrinsic Si. Given that $n_i = 1.0 \times 10^{10}$ cm^{-3} (Assume that T = 300 K).