Determination of Fermi Levels

RECALL

$$n = N_c e^{-\frac{E_c - E_F}{kT}}$$

$$p = N_v e^{-\frac{E_F - E_v}{kT}}$$

RECALL

$$N_C = 2\left(\frac{m_e^* kT}{2\pi\hbar^2}\right)^{3/2}$$

$$N_V = 2\left(\frac{m_h^* kT}{2\pi\hbar^2}\right)^{3/2}$$

$$n = n_i e^{\frac{E_F - E_{f_i}}{kT}}$$

$$p = n_i e^{\frac{E_{f_i} - E_F}{kT}}$$

For an intrinsic semiconductor, $n = p = n_i$; $E_F = E_{f_i}$

$$N_c e^{-\frac{E_c - E_{f_i}}{kT}} = N_v e^{-\frac{E_{f_i} - E_v}{kT}}$$

$$E_{f_i} = \frac{E_c + E_v}{2} + \frac{kT}{2}\ln\left(\frac{N_v}{N_c}\right)$$

E_{f_i} is at the bandgap center in intrinsic semiconductors when $m_h^* = m_e^*$ or when $T = 0K$.

$$E_{f_i} = \frac{E_c + E_v}{2} + \frac{3}{4}kT\ln\left(\frac{m_h^*}{m_e^*}\right)$$

For extrinsic semiconductors, $n \cong N_D$ in donor-doped & $p \cong N_A$ in acceptor doped semiconductors

$$E_F - E_{f_i} = kTln\left(\frac{n}{n_i}\right) = -kTln\left(\frac{p}{n_i}\right)$$

$$E_F - E_{f_i} = kTln\left(\frac{N_D}{n_i}\right)$$

$$E_{f_i} - E_F = kTln\left(\frac{N_A}{n_i}\right)$$

E_F moves systematically upward in energy from E_{f_i} with increasing donor doping and systematically downward in energy from E_{f_i} with increasing acceptor doping.

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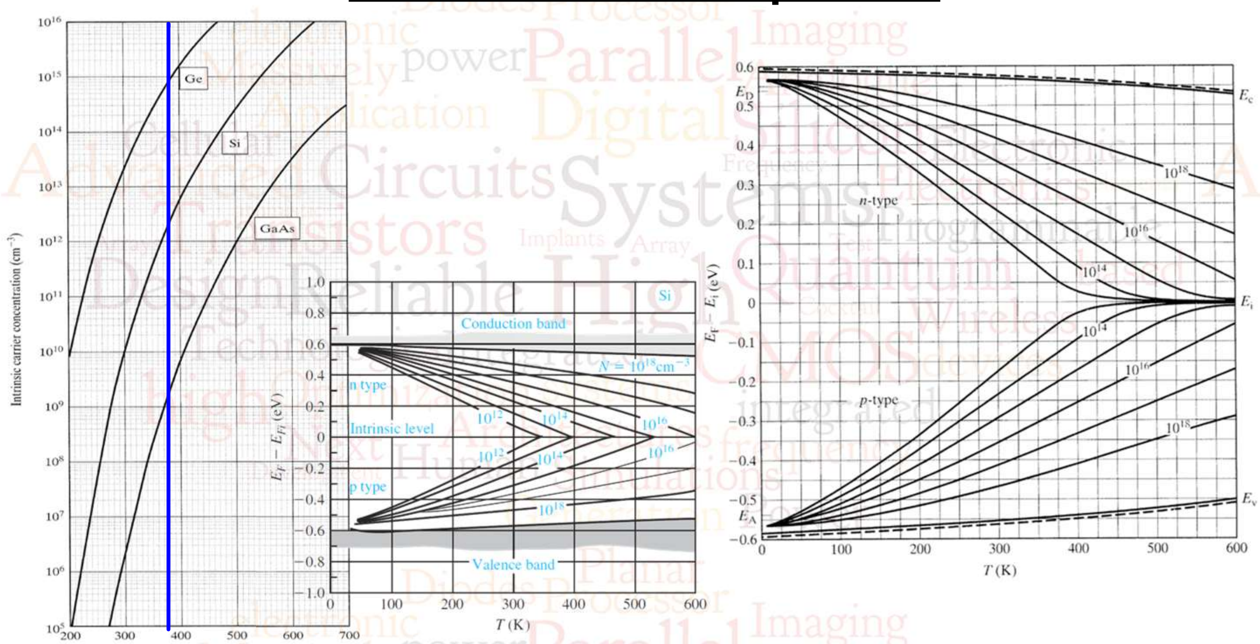
Fermi levels with temperature



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