
Example 4.3

An abrupt silicon p-n junction ($N_a = 10^{16} \text{ cm}^{-3}$ and $N_d = 4 \times 10^{16} \text{ cm}^{-3}$) is biased with $V_a = 0.6 \text{ V}$. Calculate the ideal diode current assuming that the n-type region is much smaller than the diffusion length with $w_n' = 1 \text{ }\mu\text{m}$ and assuming a "long" p-type region. Use $m_n = 1000 \text{ cm}^2/\text{V}\cdot\text{s}$ and $m_p = 300 \text{ cm}^2/\text{V}\cdot\text{s}$. The minority carrier lifetime is $10 \text{ }\mu\text{s}$ and the diode area is $100 \text{ }\mu\text{m}$ by $100 \text{ }\mu\text{m}$.

The current is calculated from:

$$I = qA \left[\frac{D_n n_{p0}}{L_n} + \frac{D_p p_{n0}}{w_n'} \right] (e^{V_a/V_t} - 1)$$

with

$$D_n = m_n V_t = 1000 \times 0.0258 = 25.8 \text{ cm}^2/\text{V}\cdot\text{s}$$

$$D_p = m_p V_t = 300 \times 0.0258 = 7.75 \text{ cm}^2/\text{V}\cdot\text{s}$$

$$n_{p0} = n_i^2/N_a = 10^{20}/10^{16} = 10^4 \text{ cm}^{-3}$$

$$p_{n0} = n_i^2/N_d = 10^{20}/4 \times 10^{16} = 2.5 \times 10^3 \text{ cm}^{-3}$$

$$L_n = \sqrt{D_n \tau_n} = \sqrt{25.8 \times 10^{-5}} = 161 \text{ }\mu\text{m}$$

yielding $I = 40.7 \text{ }\mu\text{A}$

Note that the hole diffusion current occurs in the "short" n-type region and therefore depends on the quasi-neutral width in that region. The electron diffusion current occurs in the "long" p-type region and therefore depends on the electron diffusion length in that region.
