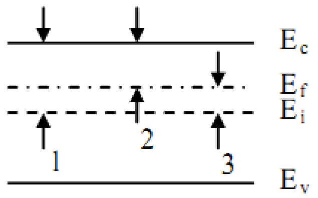
Name:

1- In a silicon sample at T = 300 K, the Fermi level is located at 0.26 eV (10 kT) above the intrinsic Fermi level. What are the hole and electron concentrations? $\boldsymbol{N_c} = 2.8 \times 10^{19}$ cm $^{-3}$, $k = 1.38 \times 10^{-23}$ J.K $^{-1}$, q=1.6x10^{-19} C, $n_i = 10^{10}$ cm^{-3}.

Solution:

Since the Fermi level is located 0.26 eV above E_i and closer to E_c, the sample is n-type. If we assume that E_i is located at the mid-bandgap (~ 0.55 eV), then E_c -E_f = 0.29 eV.



1: E_c-E_i =0.55 eV
2: E_c-E_f =0.29 eV
3: E_f-E_i =0.26 eV

$$n = N_C\, e^{-(E_C - E_F)/kT} \quad \Longrightarrow \quad n = \frac{N_C}{e^{(E_C - E_F)/kT}}$$

$$n = \frac{2.8 \times 10^{19}\ \text{cm}^{-3}}{2.718^{(0.29\, ev\, *\, 1.6\times10^{-19} C)/(1.38\times10^{-23} J.K^{-1} * 300\, K)}}$$

$$n = \frac{2.8 \times 10^{19}\ \text{cm}^{-3}}{2.718^{(4.64\times10^{-20})/(4.14\times10^{-21})}}$$

$$n = \frac{2.8 \times 10^{19}\ \text{cm}^{-3}}{2.718^{11.2}}$$

$$n = \frac{2.8 \times 10^{19}\ \text{cm}^{-3}}{7.3 \times 10^{4}} = 0.38 \times 10^{15}\text{cm}^{-3} = 3.8 \times 10^{14}\text{cm}^{-3}$$

$$p = \frac{n_i^2}{n}$$

$$p = \frac{n_i^2}{n} = \frac{(10^{10})^2}{3.8 \times 10^{14}\text{cm}^{-3}} = \frac{10^{20}}{3.8 \times 10^{14}} = 2.63 \times 10^{5}\text{cm}^{-3}$$

2- Boron atoms are added to a Si film resulting in an impurity density of 4×10^{16} cm^{-3}.

(a) What is the conductivity type (N-type or P-type) of this film?

(b) Why does the mobile carrier concentration increase at high temperatures?

Solution:

a) B is a group III element. When added to Si (which belongs to Group IV), it acts as an acceptor producing a large number of holes. Hence, this becomes a P-type Si film.

b) At high temperatures, there is enough thermal energy to free more electrons from silicon-silicon bonds, and consequently, the number of intrinsic carriers increases.