Example 2.6c 4H-SiC is doped with 2 x 10^{17} cm^{-3} nitrogen donor atoms ($E_c - E_d$ = 90 meV). Use N_c = 4 x 10^{20} cm^{-3}.

a) Calculate the electron density at 300 K.

b) Calculate the hole density at 300 K after adding 2 x 10^{18} cm^{-3} aluminum acceptor atoms ($E_a - E_v$ = 220 meV) Use N_v = 1.6 x 10^{20} cm^{-3}.

Solution

a) First we calculate N^*

$$N^* = \frac{N_c}{2}\exp\frac{E_d - E_c}{kT} = 6.16 \text{ x } 10^{18} \text{ cm}^{-3}$$

The free electron density is then obtained from:

$$n_o = -\frac{N^*}{2} + \sqrt{\frac{(N^*)^2}{4} + N^* N_d} = 1.94 \text{ x } 10^{17} \text{ cm}^{-3}$$

As a result 97.0 % of the donors are ionized

b) Since we are now dealing with *p*-type material we have to recalculate N^*

$$N^* = \frac{N_v}{4}\exp\frac{E_v - E_a}{kT} = 8.08 \text{ x } 10^{15} \text{ cm}^{-3}$$

where the factor 4 is due to the doubly degenerate valence band. The free hole density is then obtained from:

$$p_o = -\frac{N^* + N_d}{2} + \sqrt{\frac{(N^* + N_d)^2}{4} + N^*(N_a - N_d)}$$
$$= 5.52 \text{ x } 10^{16} \text{ cm}^{-3}$$

which is identical to (2.6.42) except that the donor and acceptor densities have been exchanged. Only 2.76 % of the acceptors are ionized while all donors are ionized.