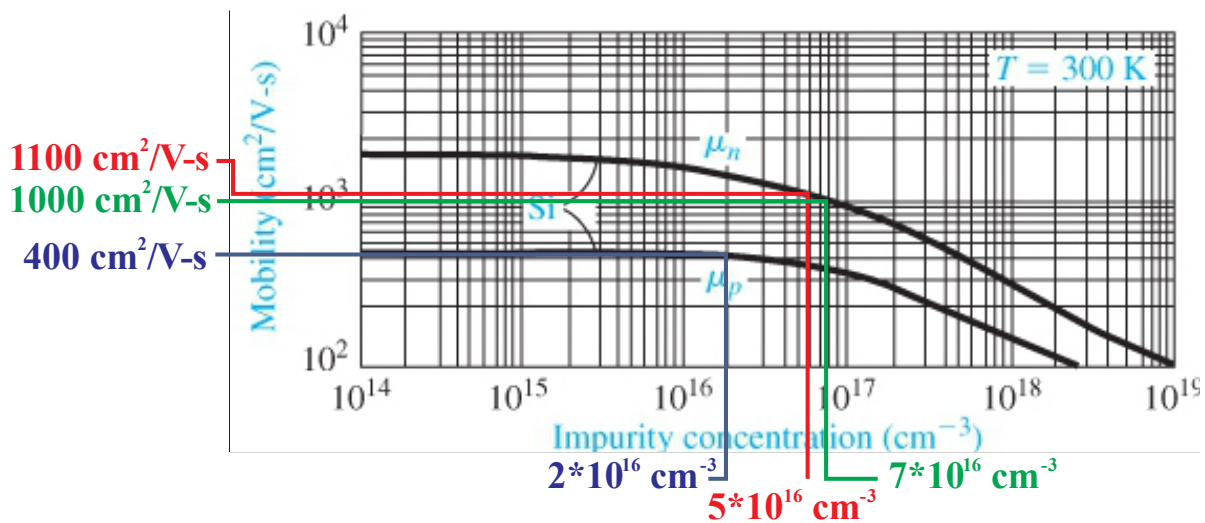


**5.23** Consider three samples of silicon at  $T = 300$  K. The n-type sample is doped with arsenic atoms to a concentration of  $N_d = 5 \times 10^{16} \text{ cm}^{-3}$ . The p-type sample is doped with boron atoms to a concentration of  $N_a = 2 \times 10^{16} \text{ cm}^{-3}$ . The compensated sample is doped with both the donors and acceptors described in the n-type and p-type samples. (a) Find the equilibrium electron and hole concentrations in each sample, (b) determine the majority carrier mobility in each sample, (c) calculate the conductivity of each sample, (d) and determine the electric field required in each sample to induce a drift current density of  $J = 120 \text{ A/cm}^2$ .

a) From Table B.4, the intrinsic charge concentration,  $n_i \approx 1.5 \times 10^{10} \text{ #/cm}^3$ , is negligible compared to the doped samples.

- **n-type sample:**  $n_0 \approx N_d \Rightarrow \underline{n_0 = 5 \times 10^{16} \text{ #/cm}^3}$   
 Use (4.43) to get  $p_0 = n_i^2 / n_0 = (1.5 \times 10^{10})^2 / 5 \times 10^{16} \Rightarrow \underline{p_0 = 4,500 \text{ #/cm}^3}$
- **p-type sample:**  $p_0 \approx N_a \Rightarrow \underline{p_0 = 2 \times 10^{16} \text{ #/cm}^3}$   
 Use (4.43) to get  $n_0 = n_i^2 / p_0 = (1.5 \times 10^{10})^2 / 2 \times 10^{16} \Rightarrow \underline{n_0 = 11,250 \text{ #/cm}^3}$
- **compensated sample:**  $n_0 \approx N_d - N_a = (5-2) \times 10^{16} \text{ #/cm}^3 \Rightarrow \underline{n_0 = 3 \times 10^{16} \text{ #/cm}^3}$   
 Use (4.43) to get  $p_0 = n_i^2 / n_0 = (1.5 \times 10^{10})^2 / 3 \times 10^{16} \Rightarrow \underline{p_0 = 7,500 \text{ #/cm}^3}$

b) Use Figure 5.3 (middle graph for silicon) to get the majority carrier mobilities.



- **n-type sample:** With  $N_i \approx N_d = 5 \times 10^{16} \text{ #/cm}^3 \Rightarrow \underline{\mu_n \approx 1100 \text{ cm}^2/\text{V-s}}$
- **p-type sample:** With  $N_i \approx N_a = 2 \times 10^{16} \text{ #/cm}^3 \Rightarrow \underline{\mu_p \approx 400 \text{ cm}^2/\text{V-s}}$
- **compensated sample:** With  $N_i \approx N_d + N_a = 7 \times 10^{16} \text{ #/cm}^3 \Rightarrow \underline{\mu_n \approx 1000 \text{ cm}^2/\text{V-s}}$

c) Per (5.23),  $\sigma = e(\mu_n n + \mu_p p)$ .

➤ **n-type sample**:  $\sigma \approx e\mu_n N_d = (1.6022 \cdot 10^{-19})(1100)5 \times 10^{16} \Rightarrow \underline{\underline{\sigma \approx 8.81 \text{ S/cm}}}$

➤ **p-type sample**:  $\sigma \approx e\mu_p N_a = (1.6022 \cdot 10^{-19})(400)2 \times 10^{16} \Rightarrow \underline{\underline{\sigma \approx 1.28 \text{ S/cm}}}$

➤ **compensated sample**:  $\sigma \approx e\mu_n N_d = (1.6022 \cdot 10^{-19})(1000)3 \times 10^{16} \Rightarrow \underline{\underline{\sigma \approx 4.81 \text{ S/cm}}}$

d) Per (5.19),  $J = \sigma E \Rightarrow E = J/\sigma$ .

➤ **n-type sample**:  $E = 120/8.81 \Rightarrow \underline{\underline{E \approx 13.62 \text{ V/cm}}}$

➤ **p-type sample**:  $E = 120/1.28 \Rightarrow \underline{\underline{E \approx 93.75 \text{ V/cm}}}$

➤ **compensated sample**:  $E = 120/4.81 \Rightarrow \underline{\underline{E \approx 24.95 \text{ V/cm}}}$