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Since 2

$$\boxed{\text{Updated value for } m_i(\text{Si}) = \cancel{1.65}^{9.65 \times 10^9} \text{ cm}^{-3}}$$

1.- At 300K we assume complete ionization of impurity atoms.

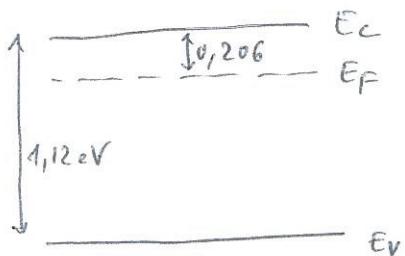
$$\text{Therefore } n \approx N_d = 10^{16} \text{ cm}^{-3}$$

$$\text{Since } p_n = n^2 \rightarrow p = nN_D = n^2 \Rightarrow p = 2.1 \times 10^4 \text{ cm}^{-3}$$

$$\text{For the Fermi level we know } n = N_D = N_c \exp\left(\frac{E_F - E_c}{kT}\right)$$

$$\text{we find } E_c - E_F = 0.1206 \text{ eV}$$

Graphically



$$2. \text{ Because of doping } n \approx N_d = 10^{15} \text{ cm}^{-3}$$

the dependence of m_i (intrinsic carrier concentration) on temperature is given by the figure 1.

$$\text{The temperature for which } m_i = n \text{ is } 1000/T(K) = 1.8 \Rightarrow 282^\circ\text{C}$$

3. For an acceptor impurity of 10^{16} cm^{-3} means that the semiconductor is p-type.

If we want to make/transform it into a n-type semiconductor we must add donor impurities in larger quantities than acceptor impurities.

If we have both acceptor and donor impurities then the Fermi level comes from the balance of these opposite impurities

$$N_D - N_A = N_c \exp\left(\frac{E_F - E_c}{kT}\right)$$

So in our case we want to get $E_c - E_F = kT \ln(N_c / (N_D - N_A))$

$$\text{or } N_D - N_A = 2,86 \times 10^{19} \exp(-0,2/0,0259) = 1,26 \times 10^{16} \text{ cm}^{-3}$$

$$\Rightarrow N_D = 2,26 \times 10^{16} \text{ cm}^{-3}$$

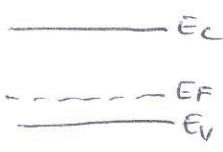
A semiconductor that has both acceptor and donor impurities is called a compensated semiconductor

4. a) $n = \frac{n_i^2}{N_A}$ where $p \approx N_A$ (impurities completely ionized)

$$n = 9,3 \times 10^4 \text{ cm}^{-3}$$

Like we did for electrons we can write for holes $p = N_V \exp\left(\frac{E_V - E_F}{kT}\right)$

$$\Rightarrow E_F - E_V = 0,267 \text{ eV}$$



where E_V is the valence band and N_V the concentration of available hole states in the valence band

b) we have both types of impurities so the net doping (a dopagem effective)

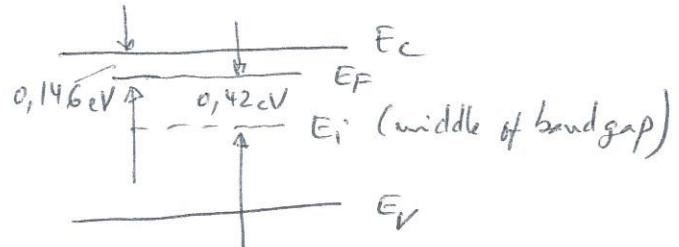
is $N_A - N_D = 10^{15} \text{ cm}^{-3}$ so the Fermi level is at the same position as in a)

5. If all impurities are ionized, then $n_D \gg n_i$

$$\Rightarrow n \approx N_D \Rightarrow p = \frac{n_i^2}{N_D} = 9,3 \times 10^2 \text{ cm}^{-3} \text{ holes}$$

E_i = intrinsic Fermi level

$$n = n_i \exp\left(\frac{E_F - E_i}{kT}\right) \Rightarrow E_F - E_i = 0,42 \text{ eV}$$



We can also obtain by

$$n = N_c \exp\left(\frac{E_F - E_c}{kT}\right) \Rightarrow E_c - E_F = 0,146 \text{ eV}$$

6. a) the net doping is $N_D - N_A = \underbrace{2 \times 10^{16} - 1 \times 10^{16}}_{N_L}$ and is a n-type semiconductor

$$\text{so } p = \frac{n_i^2}{N_L} = 2,25 \times 10^4 \text{ cm}^{-3}$$

this material has 1×10^{16} electrons/cm³ and $2,25 \times 10^4$ holes/cm³

b) $N_a > N_D \Rightarrow p\text{-type semiconductor}$

$$P_L = N_A - N_D = 2,8 \times 10^{16} \text{ cm}^{-3} \Rightarrow n = \frac{n_i^2}{P_L} = 8,04 \times 10^3 \text{ cm}^{-3}$$

This material has $2,8 \times 10^{16}$ holes/cm³ and $8,04 \times 10^3$ electrons/cm³