Solid State Devices Problems

Problems

1. The mobility of free electrons and holes in pure germanium are 3800 and 1800 $cm^2/V\text{-}s$ respectively. The corresponding values for pure silicon are 1300 and 500 $cm^2/V\text{-}s$, respectively. Assuming $n_i = 2.5 \times 10^{13}\ cm^{-3}$ for germanium and $n_i = 1.5 \times 10^{10}\ cm^{-3}$ for silicon at room temperature, the values of intrinsic conductivity for germanium and silicon are respectively given by

a)

4.32×10^{-6} S/cm and 0.0224 S/cm

b)

4.32×10^{-6} S/cm and 0.325 S/cm

c)

0.0224 S/cm and 4.32×10^{-6} S/cm

d)

0.325 S/cm and 4.32×10^{-6} S/cm

Correct answer is option 'C'. Can you explain this answer?

Given information:

Mobility of free electrons (μ_n) in pure germanium = 3800 cm^2/V-s
Mobility of holes (μ_p) in pure germanium = 1800 cm^2/V-s
Mobility of free electrons (μ_n) in pure silicon = 1300 cm^2/V-s
Mobility of holes (μ_p) in pure silicon = 500 cm^2/V-s
Intrinsic carrier concentration (ni) at room temperature for germanium = 2.5 x 10^13cm^{-3}
Intrinsic carrier concentration (ni) at room temperature for silicon = 1.5 x 10^10 cm^{-3}

Solution

The intrinsic conductivity for germanium is

$$\sigma_i = qn_i(\mu_n + \mu_p)$$
$$= (1.6 \times 10^{-19})(2.5 \times 10^{13})(3800 + 1800)$$
$$= 0.0224 \text{ S/cm}$$

The intrinsic conductivity for silicon is

$$\sigma_i = qn_i(\mu_n + \mu_p)$$
$$= (1.6 \times 10^{-19})(1.5 \times 10^{10})(1300 + 500)$$
$$= 4.32 \times 10^{-6} \text{ S/cm}$$

2. Use Fermi distribution function to obtain the value of F(E) for $E-E_F=0.01ev$ at 200k

Given data:

$E-E_F=0.01ev$

$=0.01 \times 1.6 \times 10^{-19}$

$= 1.6 \times 10^{-21}$ J

T=200k

Boltzmann's constant

$k = 1.38 \times 10^{-23}$ J/K

Solution

$F(E) = 1/\ (1+ e^{(E-Ef)/kt})$

Substituting the given values, we have

$F(E) = 1/(1+ e^{(1.6 \times 10^{\wedge}-21)/(1.38 \times 10^{\wedge}-23 \times 200)})$

$= 1/(1+e^{0.5797)}$

$=1/(1+1.7855)$

$=1/2.7855$

$F(E) = 0.359$

Fermi Level

- Fermi level in an intrinsic semicondutor

  $E_{f\,=}\,(E_c + E_v)/2$

- Fermi level in a extrinsic semicondutor

  N type semiconductor

  $E_{f\,=}\,E_c – kT \ln (N_c/N_d)$

  P type semicondutor

  $E_{f\,=}\,E_v + kT \ln (N_v/N_a)$

3. In an n–type semi-conductor, the Fermi level lies 0.3 eV below the conduction band at 300 k. If the temperature is increased to 360 K, where does the new position of the Fermi level?

Given:

At T=300k, $(E_c\text{-}E_f) = 0.3$

At T=360k, $(E_c\text{-}E_{f1}) = ?$

- Fermi level in a extrinsic semicondutor

N type semiconductor

$E_f = E_c – kT \ln (N_c/N_d)$

At T= 300

$E_c - E_f = kT \ln (N_c/N_d)$

$0.3 = 300\, k \ln (N_c/N_d)$ (1)

At T = 360

$(E_c – E_{f1}) = kT \ln (N_c/N_d)$

$(E_c - E_{f1}) = 360\, k \ln (N_c/N_d)$ (2)

$$\frac{0.3 = 300\, k \ln (N_c/N_d)}{(E_c - E_{f1}) = 360\, k \ln (N_c/N}$$

equ. 2 divided by equ.1

0.3/(Ec-Ef1)= 300/360

(Ec-Ef1) = (360/300)*0.3

ans = 0.36ev

- Hence, the new position of the fermi level lies 0.36ev below the conduction level

4. In a p–type semi-conductor, the Fermi level lies 0.3 eV above the valence band at 300 k. If the temperature is increased to 350 K and 400 K, where does the new position of the Fermi level