SSP Exercise 7

To be handed in by 4pm, Thursday 15th March.

1. How does the reverse current $J_e^{drift}(p\text{-}n)$ of a Si *p-n* junction change if the temperature raises from 20 to 50 ^{0}C? Find the same for a Ge *p-n* junction. Band gaps of Si and Ge are 1.12 and 0.66 eV, respectively. Hint: Express the change as a ratio of reverse currents $J_e^{drift}(T_2)/\, J_e^{drift}(T_1)$.

[10 marks]

Solution:

Since $J_e^{drift}(p-n) \sim n_i^2 \sim T^3 exp\left(-\frac{\varepsilon_g}{kT}\right)$

we get

$$\frac{J_e^{drift}(T_2)}{J_e^{drift}(T_1)} = \left(\frac{T_2}{T_1}\right)^3 exp\left(-\frac{\varepsilon_g}{kT_2} + \frac{\varepsilon_g}{kT_1}\right) = \left(\frac{T_2}{T_1}\right)^3 exp\left(-\frac{\varepsilon_g(T_1 - T_2)}{kT_2 T_1}\right)$$

For Ge we have:

$$\frac{J_e^{drift}(T_2)}{J_e^{drift}(T_1)} = \left(\frac{323K}{293K}\right)^3 exp\left(\frac{0.66 * 1.6 * 10^{-19} * 30}{94639 * 1.4 * 10^{-23}}\right) \approx 1.34 * exp(2.4) \approx 14.5$$

While for Si:

$$\frac{J_e^{drift}(T_2)}{J_e^{drift}(T_1)} = \left(\frac{323K}{293K}\right)^3 exp\left(\frac{1.12 * 1.6 * 10^{-19} * 30}{94639 * 1.4 * 10^{-23}}\right) \approx 1.34 * exp(4) \approx 71$$

2. Find the height of the potential barrier for a Au-n-Ge metal-semiconductor (Schottky) contact at room temperature (T = 300 K) if $\rho = 1\Omega$ cm, work function $\Phi_{Au} = 5.1$ eV, and $\chi_{Ge} = 4.0$ eV. Electron mobility in Ge is 3900 cm^2 V^{-1} s^{-1}, density of the states in the conduction band is $N_C = 1.98 \times 10^{15} \times T^{3/2}$ cm^{-3}.

[10 marks]

Solution:

The potential barrier is

$$eV_D = e\Phi_B - (\varepsilon_C - \varepsilon_F)$$

where $e\Phi_B = e\Phi_{Au} - e\chi_{Ge}$ hence we need to find $-(\varepsilon_C - \varepsilon_F)$.

From $n = N_c \exp\left(-\frac{\varepsilon_C - \varepsilon_F}{kT}\right)$ we have $-(\varepsilon_C - \varepsilon_F) = kTln\left(\frac{n}{N_C}\right)$

And from $\sigma = \frac{1}{\rho} = ne\mu_n$ we have $n = \frac{1}{\rho e\mu_n}$

Hence – $(\varepsilon_C - \varepsilon_F) = kTln\left(\frac{1}{\rho e\mu_n N_C}\right)$,

and in SI units we have

$$ln(\rho e\mu_n N_C) \approx ln(10^{-2} * 1.6 * 10^{-19} * 3900 * 10^{-4} * 2 * 10^{21} * 5196) \approx -8.8$$

$$-(\varepsilon_C - \varepsilon_F) = -1.4 * 10^{-23} * 300 * 8.8 = 3.7 * 10^{-20}\, J\ or\ \approx -0.23\ eV$$

Hence $eV_D = e(5.1 - 4 - 0.23) = 0.87\ eV$