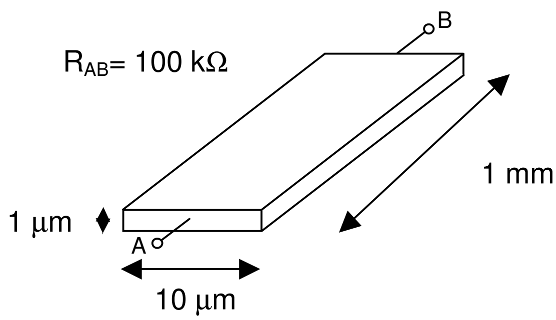
EECS 170A Section B
Homework Solution #2

Fall 2007 – Prof. Burke

1) A thin metal film resistor as shown in the figure below has a resistance of 100 kΩ. It is 1 mm long, 10 µm wide, and 1 µm thick.
   a. Calculate the resistivity (ρ), in units of Ω-m.
   b. Now express the resistivity in units of µΩ-cm, a more common unit.



a) (10 pts) *Resistance, R = 100kΩ*
Length, L = 1mm = 1 x 10^{-3} m
Width, W = 10 µm = 1 x 10^{-5} m
Thickness, H = 1 µm = 1 x 10^{-6} m
∴ *Resistivity,* ρ = R. W. H / L
=(10^5 Ω x 10^{-5} m x 10^{-6} m) / (10^{-3} m)
=10^{-3} Ω-m

b) (10 pts) *Resistivity,* ρ = 10^{-3} Ω-m x (10^2c m/ 1m) x (10^6 µΩ/ 1 Ω)
= 10^5 µΩ-cm

2) For Si at 300 K, do the following: (Use cm^{-3} as your units.)

   a. N_D= 10^{19} cm^{-3}; N_A << N_D. Calculate the equilibrium electron concentration (n) and hole concentration (p).

(7.5 pts) *Since N_A << N_D and n_i <<N_D, the concentration of electrons:*

$$n \approx N_D = 10^{19}\ cm^{-3}$$

(7.5 pts) *And hole concentration:*

$$p = \frac{n_i^2}{n} = \frac{\left(10^{10}\right)^2}{10^{19}} = 10 cm^{-3}$$

b. N_D=2x10^{10} cm^{-3}; N_A << N_D. Calculate the equilibrium electron concentration (n) and hole concentration (p).

(7.5 pts) *Since $N_A << N_D$ and $n_i \approx N_D$, the concentration of electrons:*

$$n = \frac{N_D}{2} + \left[\left(\frac{N_D}{2}\right)^2 + n_i^2\right]^{1/2} = \frac{2\times10^{10}}{2} + \left[\left(\frac{2\times10^{10}}{2}\right)^2 + \left(10^{10}\right)^2\right]^{1/2} = 2.41\times10^{10}\,cm^{-3}$$

(7.5 pts) *And hole concentration:*

$$p = \frac{n_i^2}{n} = \frac{\left(10^{10}\right)^2}{2.41\times10^{10}} = 4.14\times10^{9}\,cm^{-3}$$

c. N_A=2x10^{19} cm^{-3}; N_D <<N_A. Calculate the equilibrium electron concentration (n) and hole concentration (p).

(7.5 pts) *Since $N_D << N_A$ and $n_i << N_A$, the concentration of holes:*

$$p \approx N_A = 2 \text{ x } 10^{19} \text{ cm}^{-3}$$

(7.5 pts) *And electron concentration:*

$$n = \frac{n_i^2}{p} = \frac{\left(10^{10}\right)^2}{2\times10^{19}} = 5cm^{-3}$$

d. N_A=3x10^{10} cm^{-3}; N_D<<N_A. Calculate the equilibrium electron concentration (n) and hole concentration (p).

(7.5 pts) *Since $N_D << N_A$ and $n_i \approx N_A$, the concentration of holes:*

$$p = \frac{N_A}{2} + \left[\left(\frac{N_A}{2}\right)^2 + n_i^2\right]^{1/2} = \frac{3\times10^{10}}{2} + \left[\left(\frac{3\times10^{10}}{2}\right)^2 + \left(10^{10}\right)^2\right]^{1/2} = 3.30\times10^{10}\,cm^{-3}$$

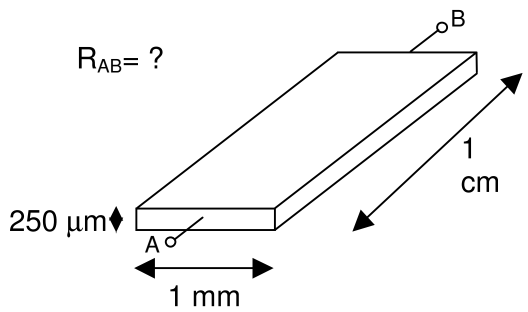
(7.5 pts) *And electron concentration:*

$$n = \frac{n_i^2}{p} = \frac{\left(10^{10}\right)^2}{3.3\times10^{10}} = 3.03\times10^{9}\,cm^{-3}$$

3) For the silicon sample at T= 300 K shown below, given $N_A=10^{16}$ cm^{-3}, $N_D<<N_A$,

a. Find the resistivity ρ of the Si to within 10%. For units, use Ω-cm. (You may use figure 3.8 from the text.)

b. Calculate the resistance R_{AB} in units of Ω, for the following geometry:



(a) **(10 pts)** *Given: T= 300K*

$N_A = 10^{16}$ cm^{-3} *and* $N_D << N_A$

From Figure 3.8 in the text book,

Resistivity, ρ *=1. 3* Ω*-cm*

(b) **(10 pts)** *Resistance, R = 1 k*Ω *= 1000* Ω

Length, L = 1 cm

Width, W = 1 mm = 0.1 cm

Thickness, H = 250 $\mu m = 2.5 \times 10^{-2}$ *cm*

$\therefore$ *Resistance, R = (* ρ*L) / A*

$=(1.3\,\Omega\text{-cm} \times 1\text{ cm})/(0.1\text{cm} \times 2.5\times10^{-2}\text{cm})$

$=520\,\Omega$