ECE 340 Homework VI Spring 2003

Due: Monday, February 24, 2003

1. *In soldering wires to a sample such as that shown in Fig. 3-25, it is difficult to align the Hall probes A and B precisely. If B is displaced slightly down the length of the bar from A, an erroneous Hall voltage results. Show that the true Hall voltage V_H can be obtained from two measurements of V_{AB}, with the magnetic field first in the +Z direction and then in the –Z direction.*

Solutions

When misaligned, the V_{AB} is composed of two parts, the Hall voltage (V_H) and an ohmic voltage drop V_d. i.e.,

$V_{AB} = V_H + V_d$

Suppose the first measurement with magnetic field in the +Z direction gives V_{AB1}: $V_{AB1} = V_{H1} + V_{d1}$

The second measurement with magnetic field in the -Z direction gives V_{AB2}: $V_{AB2} = V_{H2} + V_{d2}$

Then, $V_{H1} = -V_{H2} = V_H$, $V_{d1} = V_{d2}$

Therefore, $V_H = \frac{1}{2}(V_{AB1} - V_{AB2})$

2. Consider a silicon sample at 300 K. Assume that the hole concentration varies linearly with distance. At x=0, the hole concentration is p(0). At x=10 μ m, the hole concentration is p(10 μ m)= $5 \times 10^{14}/cm^3$. If the hole diffusion coefficient, assumed constant, is D_p =14 cm^2/sec, determine the hole concentration at x=0 for the following two diffusion current densities: (a) the diffusion current density is found to be J_p^{diff} = + 0.19 A/cm^2 and (b) J_p^{diff} = - 0.19 A/cm^2.

Solution:

(a), From $J_p^{diff}(x) = -qD_p \frac{dp(x)}{dx}$, we have $\frac{dp(x)}{dx} = -\frac{J_p^{diff}(x)}{qD_p}$

$$\frac{dp(x)}{dx} = -\frac{0.19}{1.6 \times 10^{-19} \times 14} = -8.482 \times 10^{16} cm^{-4}$$

Because hole concentration varies linearly with distance, $p(x) = p(0) + x\frac{dp(x)}{dx}$, therefore,

$p(0) = p(x) - x\frac{dp(x)}{dx}$, for $x = 10 mm$

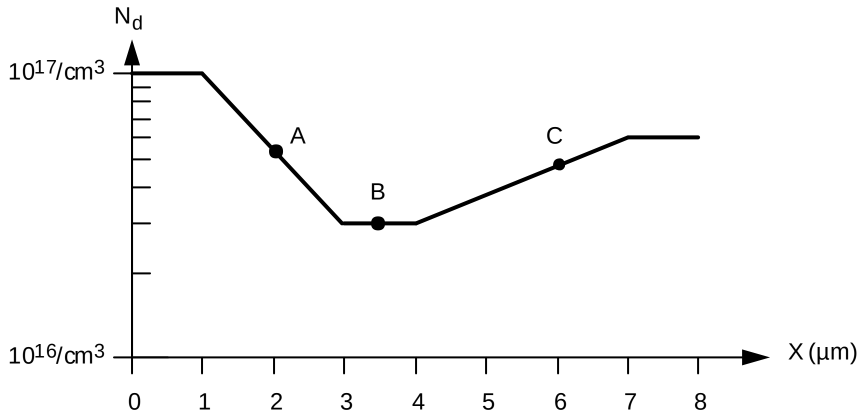
$$p(0) = 5 \times 10^{14} cm^{-3} - 10^{-3} cm \times (-8.482 \times 10^{16} cm^{-4}) = 5.8482 \times 10^{14} cm^{-3}$$

(b) Similarly,

$$\frac{dp(x)}{dx} = -\frac{-0.19}{1.6 \times 10^{-19} \times 14} = 8.482 \times 10^{16} cm^{-4}$$

$$p(0) = 5 \times 10^{14} cm^{-3} - 10^{-3} cm \times (8.482 \times 10^{16} cm^{-4}) = 4.1518 \times 10^{14} cm^{-3}$$

3. The donor profile of a silicon sample is shown below. Assume that the majority carrier mobility can be obtained from Fig. 3-23 (or the enlarged graph shown in HW V), and the sample is at thermal equilibrium at 300 K.



(a) Determine the diffusion coefficients for majority carriers at points A, B and C, respectively.
(b) Find the majority carrier diffusion current densities along the cross sections at points A, B and C, respectively. Indicate not only the magnitude but also the direction.
*(c) Find an expression for the built-in electric field **E**(x) at equilibrium over the range from x= 1μ m to x=3 μm.*
*(d) Sketch a band diagram such as in Fig. 4-15 over the range from x= 1μ m to x=3 μm and indicate the direction of **E**.*

Solutions:

(a) Notice the y-axis was given in log scale, $N_d(x)$ from x= 1μ m to x=3 μ m can be written as:

$N_d(x) = 10^{17} e^{-a(x-1)} cm^{-3}$

$N_d(3mm) = 3\times10^{16} cm^{-3}, \qquad a = 0.602mm^{-1}$

From Einstein Equation, we have $D_n = \frac{KT}{q} m_n$

Point A: x = 2, $N_d(x) = 5.48\times10^{16} cm^{-3}$ (you can also read the y-axis directly), from graph in the back of the HW5, $m_n = 820cm^2/Vs$, $D_n = 21.2cm^2/s$

Point B: $N_d(x) = 3\times10^{16} cm^{-3}$, from Fig 3-23, $m_n = 900cm^2/Vs$, $D_n = 23.31cm^2/s$

The $N_d(x)$ over the range from x= 4μm to x=7 μm can be written as:

$N_d(x) = 3\times10^{16} e^{a(x-4)} cm^{-3}$, because $N_d(7mm) = 6\times10^{16} cm^{-3}$, $a = 0.231mm^{-1}$

Point C: x = 6, $N_d(x) = 4.76\times10^{16} cm^{-3}$, from Fig 3-23, $m_n = 830cm^2/Vs$, $D_n = 21.5cm^2/s$

(b) $J_n = qD_n \frac{dn(x)}{dx}$, assuming quasi-neutrality, then n (x) = $N_d(x)$

Point A:

$$J_n = qD_n \frac{d10^{17} e^{-a(x-1)}}{dx} = -qD_n 10^{17} a e^{-a(x-1)} = -1.6\times10^{-19} \times 21.1\times 10^{17} \times 0.602\times10^4 \times e^{-0.602\times1} = -1120 A/cm^2$$

The current goes to the left

Point B: $\frac{dn(x)}{dx} = 0$, $J_n = 0$

Point C:

$$J_n = qD_n \frac{d3\times10^{16} e^{a(x-4)}}{dx} = qD_n 3\times10^{16} a\, e^{a(x-4)} = 1.6\times10^{-19}\times 21.5\times3\times10^{16}\times 0.231\times10^{4}\times e^{0.231\times2} = 378 A/cm^2$$

The current goes to the right

(c) From 4-23, $\mathbf{E} = -\frac{D_n}{m_n}\frac{dn/dx}{n} = -\frac{kT}{q}\frac{d10^{17} e^{-a(x-1)}/dx}{10^{17} e^{-a(x-1)}} = \frac{kT}{q} a = 0.0259\times 0.602\times10^{4} = 156 V/cm$

(d)