look at problem. 3.108 نفس فكرة سؤال

Q1 p-type silicon of $L = 20\ \mu m$

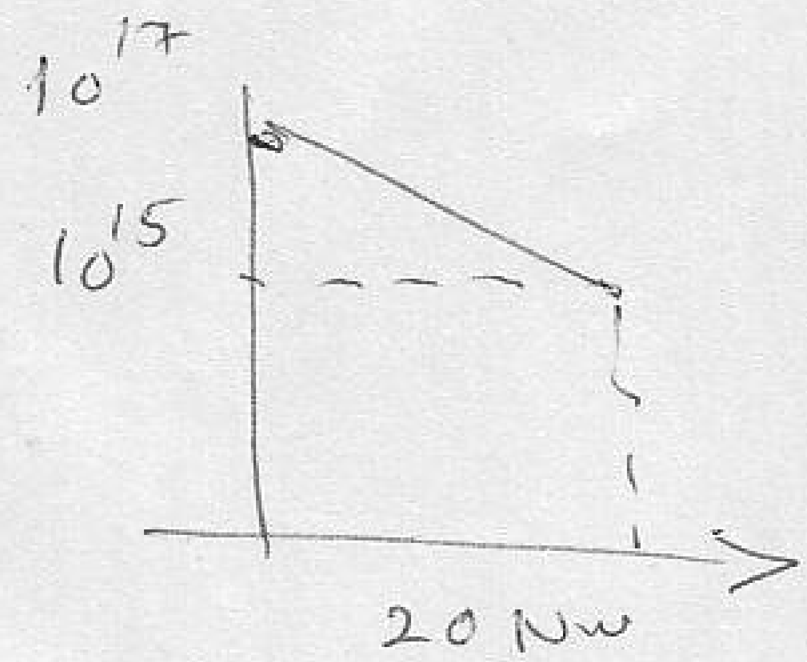
doping decreased from 10^{17} at $x=0$

to 10^{15} at $x=L$

$\mu_p = 500\ cm^2/V.s$

what is diffusion
Current density ?

* diffusion current direction = with holes
* drift " " = " E



$J = (+)\, q D_p \dfrac{dp}{dx}$

$\dfrac{D_p}{\mu_p} = V_T \quad , V_T = \dfrac{KT}{q}$

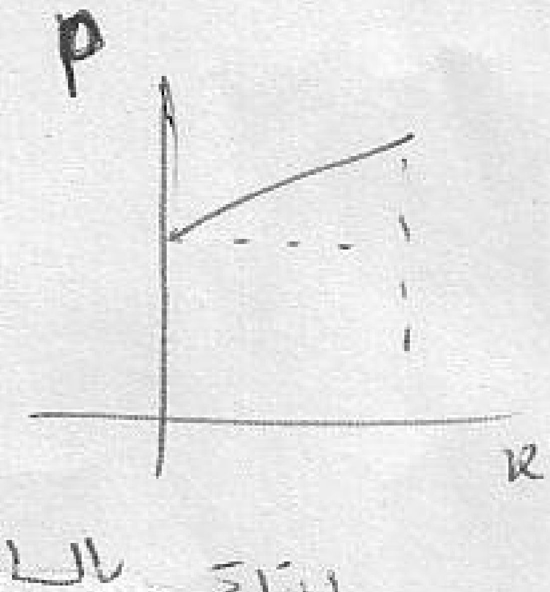
$V_T = 8.62 \times 10^{-5} \times 300 = \boxed{0.025\ V}$ V_T for silicon at room temp

$\Rightarrow D_p = \mu_p \times V_T = 500 \times 0.025 = 12.5\ cm^2/s$

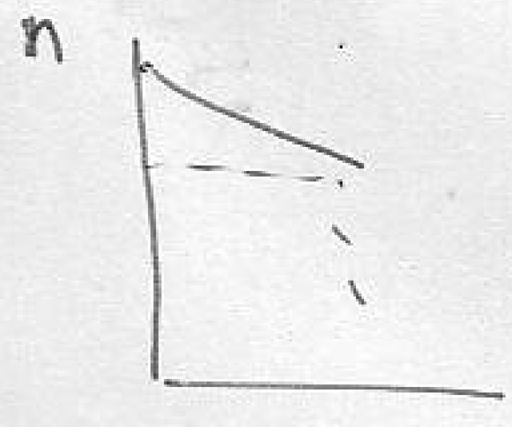
$J_p = (+)\, 1.6 \times 10^{-19} \times 12.5 \times \left| \dfrac{10^{17} - 10^{15}}{20\mu} \right|$

$\hookrightarrow 20\,\mu = 20 \times 10^{-6} = 20 \times 10^{-4}\ cm$

$\simeq 99\ A/cm^2$



انتاج بالسالب



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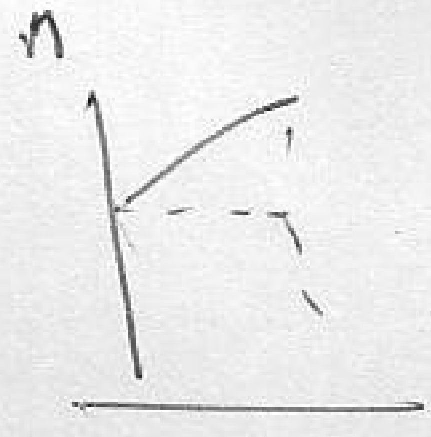

انتاج بالموجب

what is I_{drift} ? $\Rightarrow$ = $I_{diffusion}$
in open cct.

3.110 Find the current flow in a silicon bar of 10-μm length having a 5-μm $\times$ 4-μm cross-section and having free-electron and hole densities of $10^5/\text{cm}^3$ and $10^{15}/\text{cm}^3$, respectively, with 1 V applied end-to-end. Use $\mu_n = 1200\ \text{cm}^2/\text{V}\cdot\text{s}$ and $\mu_p = 500\ \text{cm}^2/\text{V}\cdot\text{s}$.

3.110

$10\mu m = 10 \times 10^{-6} = 10^{-3}$ cm

$5\mu \times 4\mu = 5 \times 10^{-4} \times 4 \times 10^{-4} = 5 \times 4 \times 10^{-8}$

$J_{drift} = q(n\mu_n + p\mu_p)E$ A/cm^2

$I_{drift} = q(n\mu_n + p\mu_p)E \cdot A$

$= 1.6 \times 10^{-19} \times (10^5 \cdot 1200 + 10^{15} \cdot 500) \times \frac{1}{10^{-3}} \times (5 \times 4 \times 10^{-8})$

$= 16\ \mu A$

look at Exercise 3.32, 3.33, Problem 3.114
Problem 3.115

PN Junction, $N_A = 10^{17}/cm^3$, $N_D = 10^{16}/cm^3$, $T = 300K$

1) $V_0 = ?!$, $x_p = ?$, $x_n = ?$

2) if Area is $100\,\mu m^2$, what is the charge stored in each side?

3) find C_{j0} and C_j if $m = 1/2$

4) if a reverse bias voltage of 2V was applied, repeat 1,2,3

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1) $V_T|_{300K} = 0.025$ ← مبادئ من سؤال سابق

$$V_0 = V_T \ln\left(\frac{N_A N_D}{n_i^2}\right) = 0.025 \times \ln\left(\frac{10^{17} \times 10^{16}}{(1.5\times10^{10})^2}\right)$$

300K $n_i = 1.5\times10^{10}$

$= 728\,mV \simeq 0.73V$

$$W = \sqrt{\frac{2\varepsilon_s}{q}\left(\frac{1}{N_A}+\frac{1}{N_D}\right)(V_0 + \underbrace{V_R}_{=0})} = \sqrt{\frac{2\times 11.7\times 8.8\times10^{-14}}{1.6\times10^{-19}}\left(\frac{1}{10^{17}}+\frac{1}{10^{16}}\right)(728m)}$$

cm 1×10^{-12}

$= \sqrt{1.00\times10^{-9}} = 31.6\times10^{-6}\,cm$

الناتج يكون بوحدة cm

$\Rightarrow x_n N_D = x_p N_A$, $W = x_n + x_p \Rightarrow x_p = 31.6\times10^{-6} - x_n$

$$x_n = \frac{10^{17}}{10^{16}}(31.6\times10^{-6} - x_n) \Rightarrow x_n + \frac{10^{17}}{10^{16}}x_n = \frac{10^{17}}{10^{16}}(31.6\times10^{-6})$$

$x_n = 28.7\times10^{-6}\,cm$

$x_p = W - x_n = 31.6\times10^{-6} - 28.7\times10^{-6} = 2.87\times10^{-6}\,cm$

يجب التحويل إلى Cm

(2) Charge in each side

$A = 100\,Nm^2 = 100 \times 10^{-8}\ Cm^2 =$

* n-side

$Volume = A \times x_n = 100\,Nm^2 \times 28.7 \times 10^{-8}\ m$

$= 100 \times 10^{-8}\ Cm^2 \times 28.7 \times 10^{-6}\ Cm$

$\simeq 28.7 \times 10^{-12}\ Cm^3$

$Charge = N_D \times Volume$

$Charge = 10^{16} \times 28.7 \times 10^{-12} = 28.7 \times 10^{4}$ Calumb

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* P-side;

$Volume = 100 \times 10^{-8}\ Cm^2 \times 2.87 \times 10^{-6}\ Cm$

$= 2.87 \times 10^{-12}\ Cm^3$

$Charge = N_A \times Volume = 10^{17} \times 2.87 \times 10^{-12} = 2.87 \times 10^{5}$ Calumb.

$= 28.7 \times 10^{4}\ C$ = n-side.

$\Rightarrow$ n-side = p-side for open CCT.

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(3) $C_{j_0} = \dfrac{\varepsilon_s A}{W_{dep}} = \dfrac{11.7 \times 8.8 \times 10^{-14} \times 1\ Cm^2}{31.6 \times 10^{-6}} = 32.58\ nF/Cm^2$

Per unit area $A = 1\,Cm^2$

$C_j = C_{j_0} \Big|_{V=0} = 32.58\ nF/Cm^2$

$C_{j_0\,total} = 32.58\ nF \times (100 \times 10^{-8}) = 32.58\ fF$

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(4) (i) $V_0 = 728\,mV$

$$w = \sqrt{\frac{2\varepsilon_s}{q}\left(\frac{1}{N_A}+\frac{1}{N_D}\right)(V_0 + \overset{2V}{V_R})} = \sqrt{1.41\times10^{-9}(728m+2)}$$

$$= \sqrt{3.86\times10^{-9}} = 62.1\times10^{-6}\ Cm$$

$x_n N_D = x_p N_A \Rightarrow \quad w = x_p + x_n$

$\Rightarrow x_p = 62.1\times10^{-6}\ Cm - x_n$

$$x_n = \frac{\overset{10^{17}}{N_A}}{\underset{10^{16}}{N_D}}\left[62.1\times10^{-6} - x_n\right] \Rightarrow 11 x_n = 6.21\times10^{-5}$$

$$\boxed{x_n = 5.64\times10^{-6}\ Cm}$$

$$x_p = 6.21\times10^{-6} - 5.64\times10^{-6} = \boxed{0.57\times10^{-6}\ Cm}$$

(ii) Charge = N x Value. $\quad A = 100\,Nm^2 = 1\,Cm^2$

$V_n = 100\times10^{-8} \times 5.64\times10^{-6}\ Cm = 5.64\times10^{-12}\ Cm^3$

$V_p = 100\times10^{-8} \times 0.57\times10^{-6} = 0.57\times10^{-12}\ Cm^3$

$C_n = 10^{16} \times 5.64\times10^{-12} = 5.64\times10^{4}$ Columb

$C_p = 10^{17} \times 0.57\times10^{-12} = 0.57\times10^{4}$ Columb

$= 5.7\times10^{4}$ Columb = n-side.

$C_n = C_p$

(iii) $$C_j = \frac{C_{j0}}{\left(1+\frac{V_R}{V_0}\right)^{\overset{m}{\downarrow 0.5}}} = \frac{32.58\ nF/Cm^2}{\sqrt{1+\frac{2}{0.728}}} = 16.83\ nF/Cm^2$$

ترکیب ناگهانی