Ejercicios relativos al semiconductor

Soluciones

Soluciones de los problemas del semiconductor

1. EJERCICIO

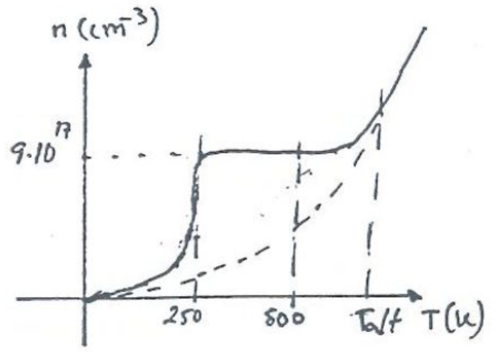
a) $p_0 \sim N_A = 10^{17}$ cm^{-3}; $p_0 = n_i^2 / p_0 = 2250$ cm^{-3}

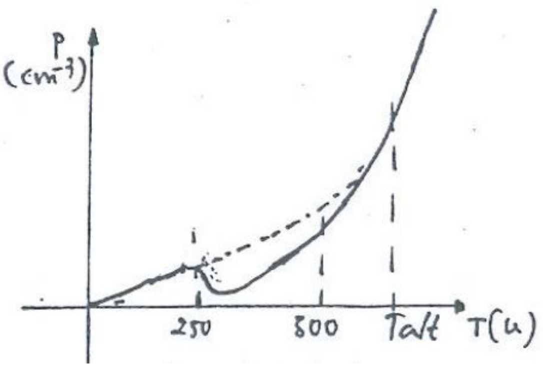
b) $p' = n' = 10^7$ cm^{-3}; $p \sim p_0$; $n \sim n'$

c) $p'(t) = n'(t) = n'(0) \cdot \exp(-t/\tau_m) = 10^7 \cdot \exp(-t/10^{-7}s)$ cm^{-3}

2. EJERCICIO

T(K)	0	200	248	249	250	251	300	400	500	>500
$N_{ioi}/N*100$	0	0	0	1	99	100	100	100	100	100
n_i (cm^{-3})	0	1E5	7E7	7E7	7E7	7E7	1E10	6E12	3E14	1E19
p (cm^{-3})	0	1E5	7E7	9E15	8.9E17	9E17	9E17	9E17	9E17	1.05E19
n (cm^{-3})	0	1E5	7E7	0.54	0.0055	0.0055	111	4E7	1E11	9.5E18
	intrínseco			extrínseco						intrínseco





3. EJERCICIO

a) $n' = p' = 10^8$ cm^{-3};

b) $n' = p' = 4.54 \cdot 10^3$ cm^{-3};

4. EJERCICIO

a) $\mu_p = 460\ cm^2/(V\cdot s)$; $n_0 = N_D = 4.63\cdot10^{14}\ cm^{-3}$; $p_0 = 2.16\cdot10^{5}\ cm^{-3}$

b) $Kte = 2.15\cdot10^{-9}\ cm^3/s$

c) $p' = n' = 1.94\cdot10^{15}\ cm^{-3}$; $p = 1.94\cdot10^{15}\ cm^{-3}$; $n = 2.4\cdot10^{15}\ cm^{-3}$ (alta inyección)

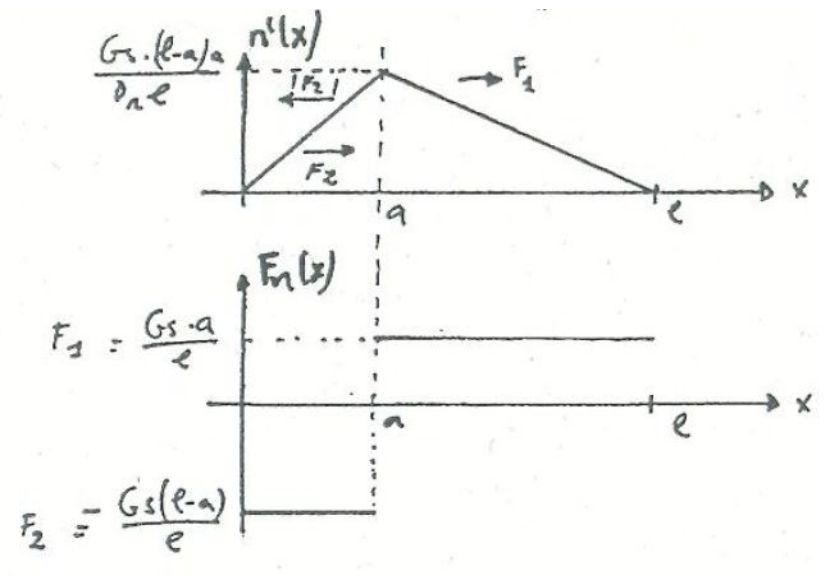
d) $\sigma_{oscuridad} = 0.1$ S/cm; $\sigma_{iluminada} = 0.66$ S/cm; $R_{oscuridad} = 20\ \Omega$; $R_{iluminada} = 3\ \Omega$

(la iluminación aumenta la conductividad de la muestra al generar portadores)

5. EJERCICIO

$$n'_{izquierda}(x) = \frac{G_s}{D_n}\frac{l-a}{l}x \qquad n'_{derecha}(x) = \frac{G_s}{D_n}\frac{a}{l}(l-x)$$

$$F_{n-izquierda}(x) = -G_s\frac{l-a}{l} \qquad F_{n\_derecha}(x) = G_s\frac{a}{l}$$



Recombinación:

contacto izquierdo: $G_s(l-a)/l$ pares/(cm^{2}s)

contacto derecho: $G_s\cdot a/l$ pares/(cm^{2}s)

volumen: 0

total: G_s (todo lo generado)

6. EJERCICIO

a) $\tau_{nuevo} = 2\cdot\tau_0 = 6.36$ μs;

b) $R_{oscuridad} = 45.5$ MΩ

c) $n' = p' = 1.5\cdot10^{13}$ cm^{-3}; $n = p = n' = p'$

d) $R_{iluminación} = 45.5$ kΩ $\qquad R_{iluminación} = R_{oscuridad} / 1000$

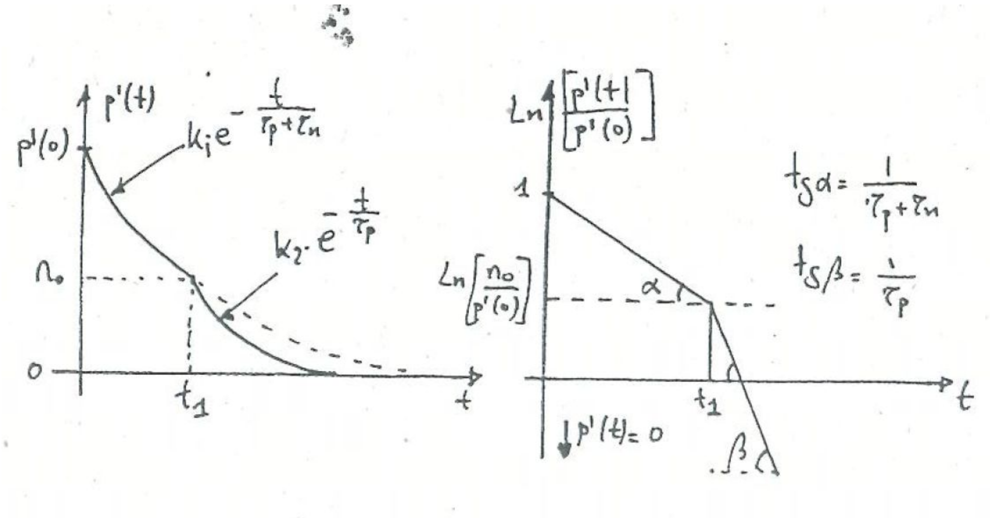
e) R(t = 63.6 μs) = 123 kΩ

7. EJERCICIO

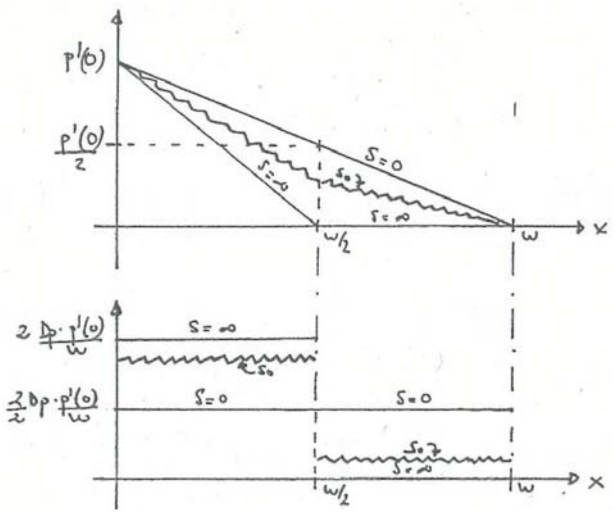
a) $p' = G_L(\tau_p + \tau_n)$ (alta inyección) (si $G_L\cdot\tau_p$ es moderado, $p' = G_L\,\tau_p$ (baja iny)

b) En un principio, nos encontraremos en A.I. $p'(t) = G_L(\tau_p + \tau_n)\cdot\exp[-t/(\tau_p + \tau_n)]$

Posteriormente entraremos en baja inyección y $p'(t) = k\cdot\exp[-t/\tau_p]$



8. EJERCICIO



$$p'_{\text{ezkerrean}}(x) = -\frac{p'(0)/W \cdot \left[1+\frac{SW}{2D_p}\right]}{1+\frac{SW}{4D_p}} \cdot x + p'(0) \longrightarrow \begin{cases} S=0 & p'(x) = p'(0)\frac{W-x}{W} \\ S=\infty & p'(x) = p'(0)\,\frac{W/2-x}{W/2} \end{cases}$$

$$p'_{\text{eskuinean}}(x) = -\frac{p'(0)/W}{1+\frac{SW}{4D_p}} \cdot (x-W) = \frac{p'(0)/W}{1+\frac{SW}{4D_p}} \cdot (W-x) \longrightarrow \begin{cases} S=0 & p'(0)\cdot\frac{W-x}{W} \\ S=\infty & 0 \end{cases}$$

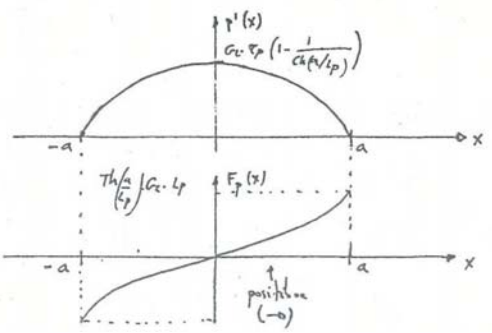
$$p'(W/2) = \frac{p'(0)/W}{1+\frac{SW}{4D_p}} \cdot W/2 = \frac{p'(0)/2}{1+\frac{SW}{4D_p}} \longrightarrow \begin{cases} S=0 & p'(0)/2 \\ S=\infty & 0 \end{cases}$$

$$Fp_{\text{ezkerrean}}(x) = D_p \cdot \frac{p'(0)/W \cdot \left[1+\frac{SW}{2D_p}\right]}{1+\frac{SW}{4D_p}} \longrightarrow \begin{cases} S=0 & D_p\cdot\frac{p'(0)}{W} \\ S=\infty & 2\cdot D_p\cdot\frac{p'(0)}{W} \end{cases}$$

$$Fp_{\text{eskuinean}}(x) = D_p \cdot \frac{p'(0)/W}{1+\frac{SW}{4D_p}} \longrightarrow S = \begin{cases} 0 & D_p\cdot\frac{p'(0)}{W} \\ \infty & 0 \end{cases}$$

$$Fn_{\text{ezkerrean}}(W/2) - Fn_{\text{eskuinean}}(W/2) = D_p \cdot \frac{p'(0)/W}{1+\frac{SW}{4D_p}}\frac{SW}{2D_p} = \frac{p'(0)/2}{1+\frac{SW}{4D_p}} \cdot S \longrightarrow \begin{cases} S=0 & B_G = 0 \\ S=\infty & B_G = \frac{2\cdot D_p\cdot p'(0)}{W} \end{cases}$$

9. EJERCICIO



$$p'(x) = G_L \cdot \tau_p \left[1 - \frac{\exp\left(\frac{x}{L_p}\right) + \exp\left(-\frac{x}{L_p}\right)}{\exp\left(\frac{a}{L_p}\right) + \exp\left(-\frac{a}{L_p}\right)}\right] = G_L \cdot \tau_p \left[1 - \frac{Ch\left(x/L_p\right)}{Ch\left(a/L_p\right)}\right]$$

$$F_p'(x) = \frac{G_L \cdot D_p \cdot \tau_p}{L_p}\left[\frac{\exp\left(\frac{x}{L_p}\right) - \exp\left(-\frac{x}{L_p}\right)}{\exp\left(\frac{a}{L_p}\right) + \exp\left(-\frac{a}{L_p}\right)}\right] = -G_L \cdot L_p \frac{Sh\left(x/L_p\right)}{Ch\left(a/L_p\right)}$$

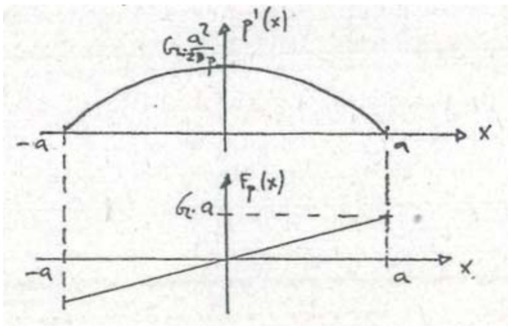
d) Recombinación en volumen y superficies

$$R_{VOL} = \int_{-a}^{a} U \cdot A \cdot dx = 2 \cdot \int_{0}^{a} \frac{p'(x)}{\tau_p} \cdot A \cdot dx = 2G \cdot A \cdot \left[a - L_p Th\left({a}/{L_p} \right) \right] = 4.77 \cdot 10^{11}\ pares/cm^2 s$$

$$R_{SUP} = 2 \cdot F_p(a) \cdot A = \frac{2 \cdot A \cdot G_L}{L_p} \cdot Th\left({a}/{L_p} \right) = 1.52 \cdot 10^{12}\ pares/cm^2 s$$

Observaciones: la suma de recombinaciones anula la generación y la recombinación sucede principalmente en superficie.

e) Despreciando la recombinación en volumen (U ~ 0)



$$p'(x) = \frac{G_L}{2D_p} \cdot \left(a^2 - x^2 \right) \qquad\qquad F_p(x) = G_L \cdot x$$

10. EJERCICIO

$$\log\left(v_n\right) = K_1 + K_2 \cdot \log\left(\varepsilon\right) \Rightarrow v_n = 10^{K_1} \cdot \varepsilon^{K_2}$$

Por lo que para que la relación sea lineal debe cumplirse $K_1 = 0$ y $K_2 = 1$

11. EJERCICIO

$$p_1'(x) = -\frac{G_L \cdot x^2}{2D_p} + \frac{G_L W^2}{2D_p} - \frac{3/8 \cdot G_L \cdot W^2 / D_p}{\frac{2D_p}{S_0 \cdot W} + 1} = \frac{G_L (W^2 - x^2)}{2D_p} - \frac{3/8 \cdot G_L \cdot W^2 / D_p}{\frac{2D_p}{S_0 \cdot W} + 1}$$

$\xrightarrow{S_0 = 0} \frac{G_L}{2D_p} (W^2 - x^2)$

$\xrightarrow{\infty} \frac{G_L}{2D_p} \left[(W^2 - x^2) - \frac{3W^2}{4} \right]$

$$p_2'(x) = \frac{G_L \cdot (W^2 - x^2)}{2D_p} - \frac{3/4 \cdot G_L \cdot W}{\frac{2D_p}{S_0 \cdot W} + 1} \cdot \frac{(W - x)}{D_p}$$

$\xrightarrow{0} \frac{G_L}{2D_p} (W^2 - x^2)$

$\xrightarrow{\infty} \frac{G_L}{2D_p} \left[(W^2 - x^2) - \frac{3}{2} W (W - x) \right]$

$$F_{p_1}'(x) = G_L \cdot x$$

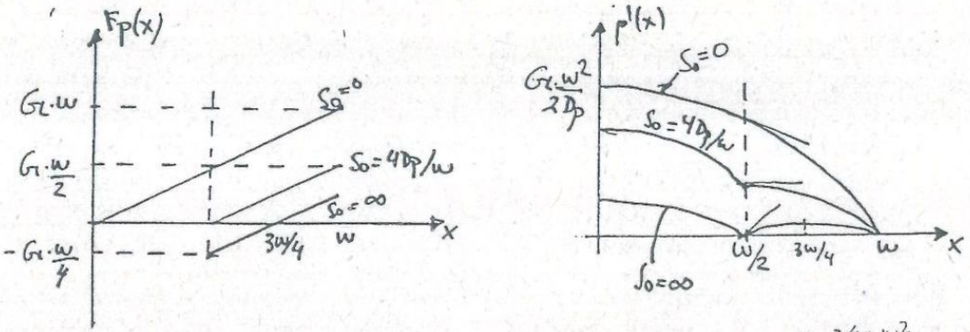
$$F_{p_2}'(x) = G_L \cdot x - \frac{3/4 \cdot G_L \cdot W}{\frac{2D_p}{S_0 \cdot W} + 1}$$

$\xrightarrow{0} G_L\ x$

$\xrightarrow{\infty} G_L \left(x - \frac{3W}{4} \right)$

$$F_{p_2}'(W/2) = 0 \Rightarrow G_L \cdot W/2 = \frac{3/4 \cdot G_L \cdot W}{\frac{2D_p}{S_0 \cdot W}+1} \Rightarrow \frac{2D_p}{S_0 \cdot W}+1 = 3/2 \Rightarrow$$

$$S_0 \cdot W = 4D_p \Rightarrow S_0 = 4D_p / W$$



$$p_2'(3w/4) = \frac{G_L\ 7/16\ w^2}{2D_p} - \frac{G_L\ 5/16\ w^2}{D_p\left(1+\frac{2D_p}{w S_0}\right)} = \begin{cases} \xrightarrow{S_0 \to 0} \frac{G_L\ 7/16\ w^2}{2D_p} \\ \xrightarrow{S_0 \to \infty} \frac{G_L w^2}{2D_p} \cdot 1/16 \end{cases}$$

12. EJERCICIO

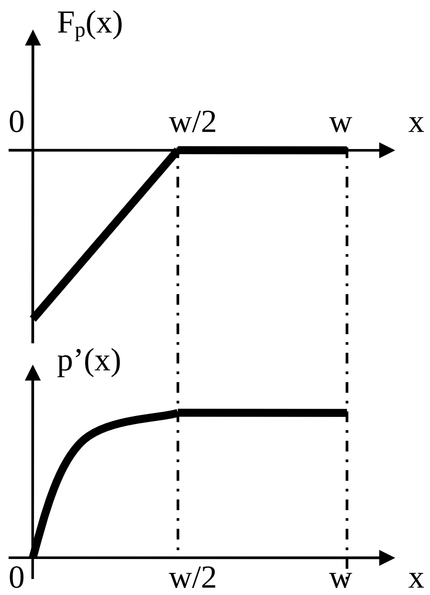
$$F_{pI}(x) = G_L\left(x - \frac{w}{2}\right)$$

$$F_{pII}(x) = 0$$

$$p_I'(x) = -\frac{G_L x^2}{2D_p} + \frac{G_L w}{2D_p}x$$

$$p_{II}'(x) = \frac{G_L w^2}{4D_p}$$

c) $-G_L w/2$ (la generación)



13. EJERCICIO

La solución se encuentra en el propio enunciado

14. EJERCICIO

$$p_1'(x) = p'(0) - \frac{1}{D_p}\cdot\frac{S_0 p'(0)}{1+\frac{W\cdot S_0}{2D_p}}\cdot x = p'(0)\cdot\left(1-\frac{S_0/D_p}{1+\frac{WS_0}{2D_p}}\cdot x\right) \begin{cases} \xrightarrow{0} p'(0) \\ \xrightarrow{\infty} p'(0)\left[1-\frac{x}{w/2}\right] \end{cases}$$

$$F_{dp1} = \frac{S_0 p'(0)}{1+\frac{W\cdot S_0}{2D_p}} \begin{cases} \xrightarrow{0} 0 \\ \xrightarrow{\infty} p'(0)\left(D_p/\frac{w}{2}\right) \end{cases}$$

$$p_2'(x) = \frac{p'(0)}{1+\frac{W\cdot S_0}{2D_p}} \begin{cases} \xrightarrow{0} p'(0) \\ \xrightarrow{\infty} 0 \end{cases} \qquad F_{dp2} = 0$$