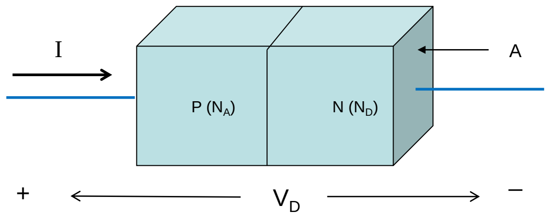
Ecuación de la Juntura P - N



Depende de la polarización

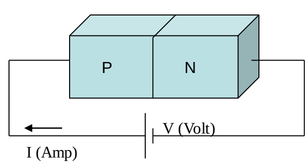
$$I = I_s \left[e^{\left(V_D / U_T \right)} - 1 \right]$$

Depende de la fabricación

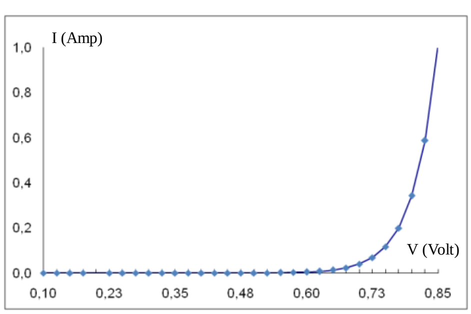
$$I_s = q n_i^2 A \left[\frac{D_p}{L_p N_D} + \frac{D_n}{L_n N_A} \right]$$

CARACTERISTICA V- I JUNTURA P-N

$Is = 1{,}1 \times 10^{-8}$

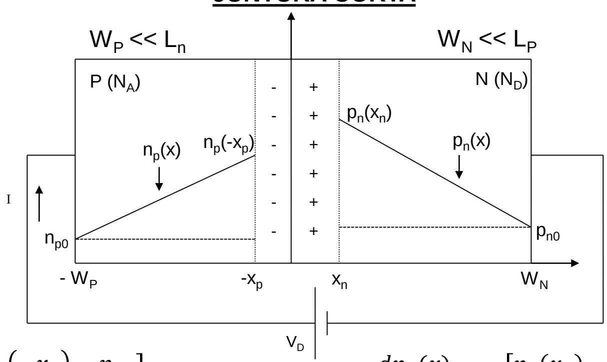


$I = Is\ [\ \exp\ (V_D/U_T) - 1]$



V	I
0,1	8,39E-08
0,125	1,52E-07
0,15	2,68E-07
0,175	4,68E-07
0,2	8,09E-07
0,225	1,40E-06
0,25	2,40E-06
0,275	4,13E-06
0,3	7,08E-06
0,325	1,22E-05
0,35	2,08E-05
0,375	3,58E-05
0,4	6,13E-05
0,425	1,05E-04
0,45	1,80E-04
0,475	3,09E-04
0,5	5,30E-04
0,525	9,09E-04
0,55	1,56E-03
0,575	2,67E-03
0,6	4,58E-03
0,625	7,86E-03
0,65	1,35E-02
0,675	2,31E-02
0,7	3,96E-02
0,725	6,79E-02
0,75	1,17E-01
0,775	2,00E-01
0,8	3,43E-01
0,825	5,87E-01
0,85	1,01E+00

JUNTURA CORTA



$$\frac{dn_p(x)}{dx} = \left[\frac{n_p(-x_p) - n_{p0}}{W_P}\right]$$

$$n_p(-x_p) = n_{p0}e^{\left(V_D/U_T\right)}$$

$$\frac{dp_n(x)}{dx} = -\left[\frac{p_n(x_n) - p_{n0}}{W_N}\right]$$

$$p_n(x_n) = p_{n0}e^{\left(V_D/U_T\right)}$$

$$\frac{dn_p(x)}{dx} = \left[\frac{n_{p0}e^{\left(V_D/U_T\right)} - n_{p0}}{W_P}\right]$$

$$\frac{dp_n(x)}{dx} = -\left[\frac{p_{n0}e^{\left(V_D/U_T\right)} - p_{n0}}{W_N}\right]$$

$$\frac{dn_p(x)}{dx} = \frac{n_{p0}}{W_P}\left[e^{\left(V_D/U_T\right)} - 1\right] \qquad \frac{dp_n(x)}{dx} = -\frac{p_{n0}}{W_N}\left[e^{\left(V_D/U_T\right)} - 1\right]$$

$$J_{Dn}(x) = q\,D_n\frac{dn_p(x)}{dx} \qquad J_{Dp}(x) = -q\,D_p\frac{dp_n(x)}{dx}$$

$$J_{Dn}(x) = \frac{q\,D_n n_{p0}}{W_P}\left[e^{\left(V_D/U_T\right)} - 1\right] \qquad J_{Dp}(x) = \frac{qD_p\,p_{n0}}{W_N}\left[e^{\left(V_D/U_T\right)} - 1\right]$$

$$J_T = \left[\frac{q\,D_n n_{p0}}{W_P} + \frac{qD_p\,p_{n0}}{W_N}\right]\left[e^{\left(V_D/U_T\right)} - 1\right]$$

$$I_T = qA\left[\frac{D_n n_{p0}}{W_P} + \frac{D_p\,p_{n0}}{W_N}\right]\left[e^{\left(V_D/U_T\right)} - 1\right]$$

$$I_T = I_S\left[e^{\left(V_D/U_T\right)} - 1\right]$$

$$\boxed{I_S = qA\left[\frac{D_n n_{p0}}{W_P} + \frac{D_p\,p_{n0}}{W_N}\right]} \qquad \boxed{I_S = qAn_i^2\left[\frac{D_n}{W_P N_A} + \frac{D_p}{W_N N_D}\right]}$$

I_S Para Juntura Corta

JUNTURA ASIMETRICA

- Cuando una de las zonas (N o P) tiene muchas mas impurezas que la otra
  - N^+ P $\quad N_D >> N_A$
  - P^+ N $\quad N_A >> N_D$
- En estas condiciones el parámetro IS esta determinado por la zona menos contaminada

$$I_s = qn_i^2 A\left[\frac{D_p}{L_p N_D} + \frac{D_n}{L_n N_A}\right]$$

$$I_S = qAn_i^2\left[\frac{D_n}{W_P N_A} + \frac{D_p}{W_N N_D}\right]$$

$$I_s = qn_i^2 A\left[\frac{D_n}{L_n N_A}\right] \rightarrow N^+P$$

$$I_s = qn_i^2 A\left[\frac{D_p}{L_p N_D}\right] \rightarrow P^+N$$

JUNTURA LARGA

$$I_S = qAn_i^2\left[\frac{D_n}{W_P N_A}\right] \rightarrow N^+P$$

$$I_S = qAn_i^2\left[\frac{D_p}{W_N N_D}\right] \rightarrow P^+N$$

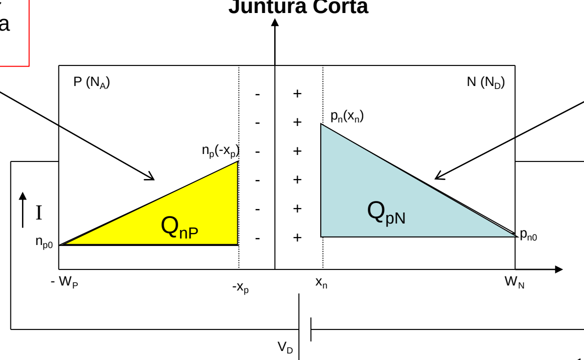
JUNTURA CORTA

CAPACIDAD DE DIFUSION

Q_{nP}: Carga de electrones en la zona P

Juntura Corta

Q_{pN}: Carga de huecos en la zona N



$$Q_{nP} = \frac{1}{2} qAW_P n'_p(-x_p)$$

$$Q_{pN} = \frac{1}{2} qAW_N p'_n(x_n)$$

$$Q_{nP} = \frac{1}{2} qAW_P n_{p0}\left[e^{\left(V_D/U_T\right)} - 1\right]$$

$$Q_{pN} = \frac{1}{2} qAW_N p_{n0}\left[e^{\left(V_D/U_T\right)} - 1\right]$$

Carga almacenada de electrones en la zona P

Carga almacenada de huecos en la zona N

Suponiendo una Juntura P^+N $\longrightarrow$ $\boxed{Q_{nP} \ll Q_{pN}}$

$$\boxed{Q_{pN} = \frac{1}{2} q A W_N p_{n0} \left[e^{\left(V_D/U_T\right)} - 1 \right]}$$

$$\boxed{I = \frac{q A D_p p_{n0}}{W_N} \left[e^{\left(V_D/U_T\right)} - 1 \right]}$$

$$\boxed{\frac{Q_{pN}}{I} = \frac{W_N^2}{2 D_p}}$$

$$\boxed{\frac{Q_{pN}}{I} = T_T}$$

$T_T \rightarrow$ Tiempo de transito

Tiempo de Transito: Tiempo que demora un hueco en atravesar la zona P

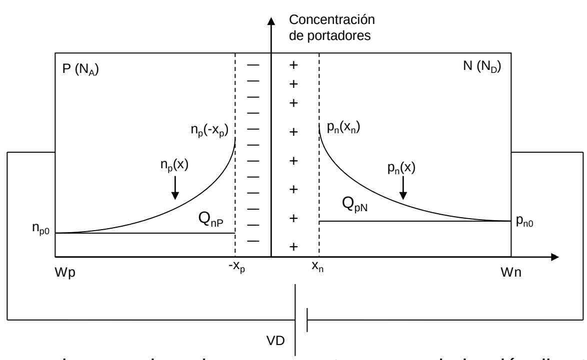
$Q = T_T I$ Capacidad $[C]$ $\longrightarrow$ $C = \dfrac{dQ}{dV} \longrightarrow \dfrac{dQ}{dV} = T_T \dfrac{dI}{dV} \longrightarrow \dfrac{dI}{dV} = \dfrac{I}{U_T}$

$$\boxed{C_D = T_T \frac{I}{U_T}}$$

$$I = I_S \left[e^{\left(V_D/U_T\right)} - 1 \right]$$

CAPACIDAD DE DIFUSION

Juntura Larga



- Carga almacenada en las zonas neutras con polarización directa

$Q_{pN} \rightarrow$ Carga de huecos en la zona N

Para una juntura P^+N $\quad Q_{pN} \gg Q_{nP}$

$$Q_{Pn} = qA \int_{x_n}^{W_N} p'_n(x) dx \qquad Q_{Pn} = qA \int_{x_n}^{W_N} (p_n(x_n) - p_{n0}) e^{\left(\frac{-x+x_n}{L_p}\right)} dx$$

$$Q_{pN} = q\ A\ L_p\ [p_n(x_n) - p_{n0}]$$

$$Q_{pN} = q\ A\ L_p\ p_{n0}\left[e^{\left({V_D}/{U_T}\right)} - 1\right]$$

$$I = \frac{q\ A\ D_p p_{n0}}{L_p}\left[e^{\left({V_D}/{U_T}\right)} - 1\right]$$

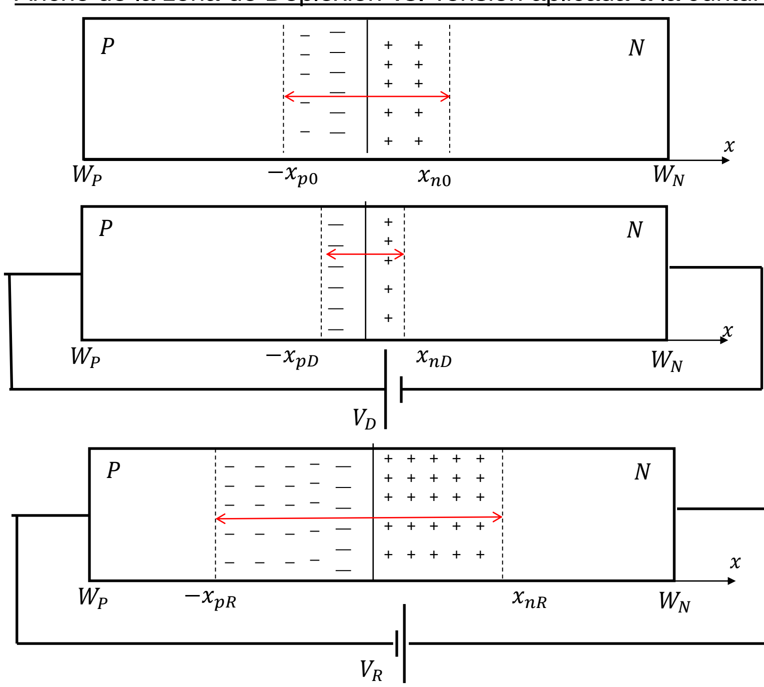
$$\frac{Q_{pN}}{I} = \frac{L_p^2}{D_p} = \tau_p \rightarrow tiempo\ de\ vida\ medio\ de\ los\ huecos$$

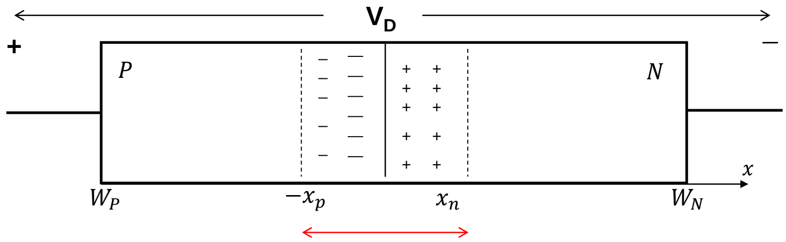
$$Q = \tau_p I \qquad I = I_S\left[e^{\left({V_D}/{U_T}\right)} - 1\right]$$

Capacidad $[C]$ $\quad C = \frac{dQ}{dV} \longrightarrow \frac{dQ}{dV} = T_T\frac{dI}{dV} \longrightarrow \frac{dI}{dV} = \frac{I}{U_T}$

$$\boxed{C_D = \tau_p \frac{I}{U_T}}$$

Ancho de la zona de Deplexion vs. Tensión aplicada a la Juntura





$x_m = x_n + x_p$

x_{m0} → ancho de la zona de deplexion sin polarización $V_D = 0$

$x_m < x_{m0}$ → para polarización directa $V_D > 0$

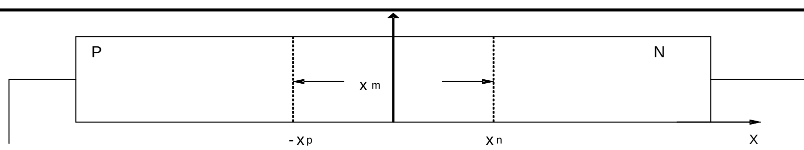
$x_m > x_{m0}$ → para polarización inversa $V_D < 0$

El ancho de la zona de deplexion varia con la tensión aplicada a la juntura

$\boxed{C_j = \varepsilon \frac{A}{x_m}}$ ⟶ Capacidad de la zona de deplexion $\qquad \varepsilon = 1{,}04 \times 10^{-12} \left[\frac{F}{cm}\right]$

$C_j \to f(x_m)$ ⟶ $x_m \to f(V_D)$ ⟶ C_j →Capacitor variable con tensión

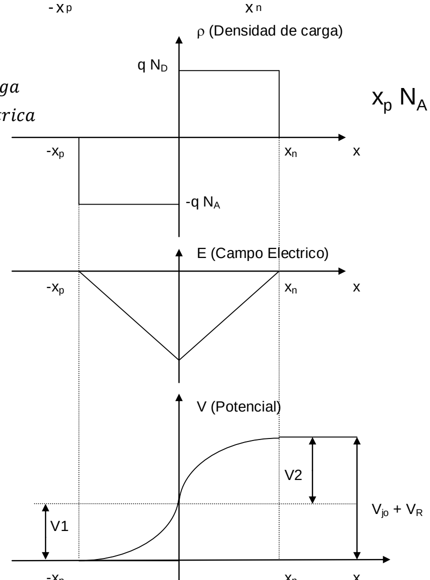
Buscamos la función $x_m(V_D)$ para obtener $C_j(V_D)$



$$\frac{d^2V}{dx^2} = -\frac{\rho}{\varepsilon} \qquad \begin{array}{l} \rho \to densidad\ de\ carga \\ \varepsilon \to constante\ dielectrica \\ \quad del\ silicio \end{array}$$

Ecuación de Poisson

$$E(x) = -\frac{dV}{dx}$$



$x_p N_A = x_n N_D$

Ecuación de Poisson para una dimensión $\longrightarrow$ $\frac{d^2V}{dx^2} = -\frac{\rho}{\varepsilon}$

$\rho \rightarrow densidad\ de\ carga$

$\varepsilon \rightarrow constante\ dielectrica\ del\ silicio$

$$\frac{d^2V}{dx^2} = \frac{qN_A}{\varepsilon} \rightarrow -x_p < x < 0$$

Integrando $\frac{d^2V}{dx^2}$ respecto de x obtengo $\frac{dV}{dx}$ $\longrightarrow$ $\frac{dV}{dx} = \frac{qN_A x}{\varepsilon} + C_1$

Condicion de borde $\frac{dV}{dx} = 0 \rightarrow x = -x_p$ $\longrightarrow$ $C_1 = \frac{qN_A x_p}{\varepsilon}$

$$\frac{dV}{dx} = \frac{qN_A(x + x_p)}{\varepsilon} \longrightarrow -x_p < x < 0$$

$$E(x) = -\frac{dV}{dx} = -\frac{qN_A(x + x_p)}{\varepsilon} \longrightarrow -x_p < x < 0$$

$$|E_{max}| = |E(0)| = \frac{qN_A x_p}{\varepsilon}$$

Integrando $\frac{dV}{dx}$ obtengo $\longrightarrow$ $V(x) = \frac{qN_A}{\varepsilon}\left(\frac{x^2}{2} + x \times x_p\right) + C_2 \rightarrow -x_p < x < 0$

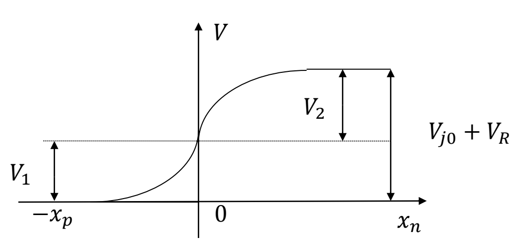
Condicion de borde $V(-x_p) = 0$ $\longrightarrow$ $C_2 = \frac{qN_A x_p^2}{2\varepsilon}$

$$V(x) = \frac{qN_A}{2\varepsilon}\left(x + x_p\right)^2 \rightarrow -x_p < x < 0$$

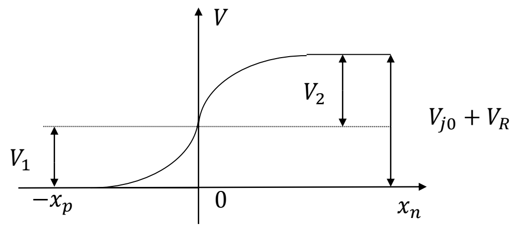
$$V_1 = V(0) = \frac{qN_A x_p^2}{2\varepsilon}$$

Analizando entre $0 < x < x_n$ $\longrightarrow$ $V_2 = V(x_n) = \frac{qN_D x_n^2}{2\varepsilon}$

$$V_1 + V_2 = V_{j0} + V_R = -V_{j0} + V_D$$



$$V_1 + V_2 = V_{j0} + V_R = -V_{j0} + V_D$$



$$V_{j0} + V_R = \frac{q}{2\varepsilon}\left(N_D x_n^2 + N_A x_p^2\right)$$

$$V_{j0} + V_R = \frac{q x_p^2 N_A}{2\varepsilon}\left(\frac{N_A}{N_D} + 1\right) = \frac{q x_n^2 N_D}{2\varepsilon}\left(\frac{N_D}{N_A} + 1\right)$$

$$x_p^2 = \frac{2\varepsilon\left(V_{j0} + V_R\right)}{q N_A \left(\frac{N_A}{N_D} + 1\right)} \qquad x_n^2 = \frac{2\varepsilon\left(V_{j0} + V_R\right)}{q N_D \left(\frac{N_D}{N_A} + 1\right)}$$

$$x_p^2 = \frac{2\varepsilon\left(V_{j0} + V_R\right)}{q N_A \left(\frac{N_A}{N_D} + 1\right)} \qquad x_n^2 = \frac{2\varepsilon\left(V_{j0} + V_R\right)}{q N_D \left(\frac{N_D}{N_A} + 1\right)}$$

Para junturas asimetricas:

$$P^+N \longrightarrow x_m = x_n = \left[\frac{2\,\varepsilon}{q\,N_D}\right]^{½} (V_{jo} + V_R)^{½}$$

$$N^+P \longrightarrow x_m = x_p = \left[\frac{2\,\varepsilon}{q\,N_A}\right]^{½} (V_{jo} + V_R)^{½}$$

$$|E_{max}| = \left[\frac{2\,q}{\varepsilon} \; \frac{N_D\,N_A}{(N_D + N_A)} \; (V_{jo} + V_R)\right]^{½}$$

Capacidad de Juntura

$$C_j = \varepsilon \frac{A}{x_m} \qquad \varepsilon = 1.04 \times 10^{-12} \frac{F}{cm}$$

$$C_j = A\sqrt{\frac{q\,\varepsilon\,N_A N_D}{2(N_A+N_D)V_{j0}}}\,\frac{1}{\sqrt{1+\frac{V_R}{V_{j0}}}}$$

Para $V_R = 0$ $\quad C_j = C_{j0}$ $\quad C_{j0} = A\sqrt{\frac{q\,\varepsilon\,N_A N_D}{2(N_A+N_D)V_{j0}}}$

$$C_j = \frac{C_{j0}}{\sqrt{1+\frac{V_R}{V_{j0}}}}$$

Capacidad de Juntura

Para calcular Cj supongo una juntura asimetrica P^+N $\longrightarrow$ $x_m = x_n$

$$Cj = \frac{\varepsilon A_E}{\left[\frac{2\varepsilon}{q N_D}\right]^{1/2}} \frac{1}{(V_{jo}+V_R)^{1/2}} = \frac{A_E}{2}\left[\frac{2\varepsilon q N_D}{V_{jo}}\right]^{1/2} \frac{1}{\left(1+\frac{V_R}{V_{jo}}\right)^{1/2}}$$

Para $V_R = 0$ $\longrightarrow$ $Cj = Cjo = \frac{A_E}{2}\left[\frac{2\varepsilon q N_D}{V_{jo}}\right]^{1/2}$ p/ juntura P^+N

Para $V_R = 0$ $\longrightarrow$ $Cj = Cjo = \frac{A_E}{2}\left[\frac{2\varepsilon q N_A}{V_{jo}}\right]^{1/2}$ p/ juntura N^+P

$$Cj = \frac{Cjo}{\left(1+\frac{V_R}{V_{jo}}\right)^{1/2}}$$