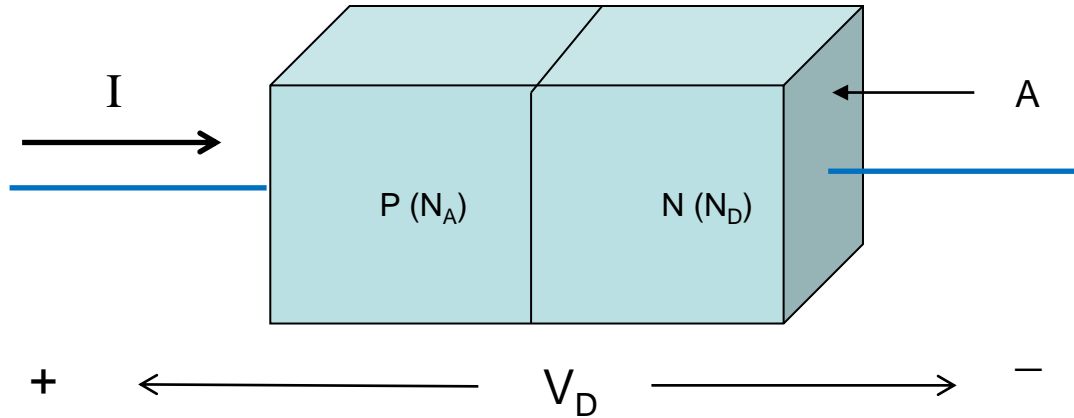


Ecuación de la Juntura P - N



Depende de la polarización

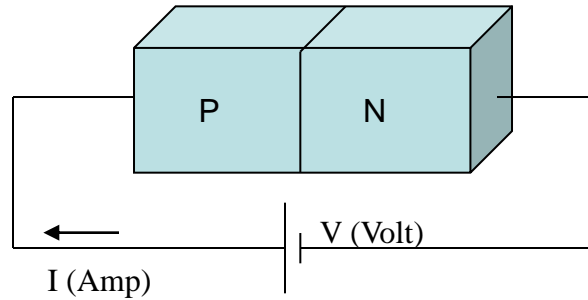
$$I = I_S \left[e^{(V_D/U_T)} - 1 \right]$$

Depende de la fabricación

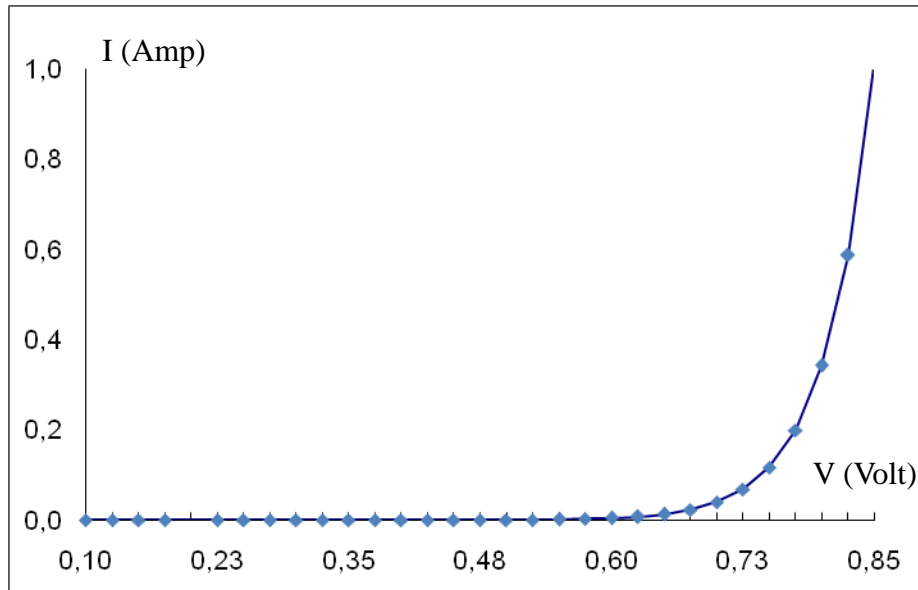
$$I_S = qn_i^2 A \left[\frac{D_p}{L_p N_D} + \frac{D_n}{L_n N_A} \right]$$

CARACTERISTICA V- I JUNTURA P-N

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

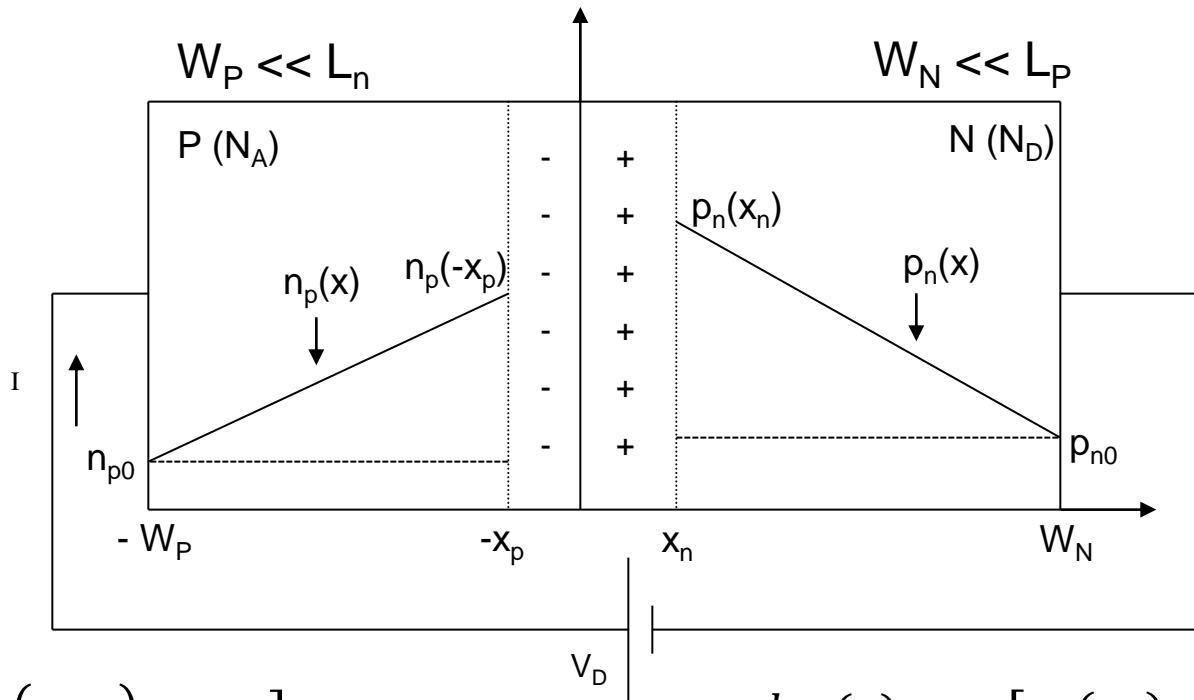


$$I = I_s [\exp (V_D/U_T) - 1]$$



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



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

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

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

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

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

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

$$\frac{dn_p(x)}{dx} = \frac{n_{p0}}{W_P} [e^{(V_D/U_T)} - 1]$$

$$\frac{dp_n(x)}{dx} = - \frac{p_{n0}}{W_N} [e^{(V_D/U_T)} - 1]$$

$$J_{Dn}(x) = q D_n \frac{dn_p(x)}{dx}$$

$$J_{Dp}(x) = -q D_p \frac{dp_n(x)}{dx}$$

$$J_{Dn}(x) = \frac{q D_n n_{p0}}{W_P} [e^{(V_D/U_T)} - 1]$$

$$J_{Dp}(x) = \frac{q D_p p_{n0}}{W_N} [e^{(V_D/U_T)} - 1]$$

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

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

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

$$I_S = qA \left[\frac{D_n n_{p0}}{W_P} + \frac{D_p p_{n0}}{W_N} \right]$$

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

I_S Para Juntura Corta

JUNTURA ASIMETRICA

• Cuando una de las zonas (N o P) tiene muchas mas impurezas que la otra

• N⁺ P $N_D \gg N_A$

• P⁺ N $N_A \gg N_D$

• 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

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

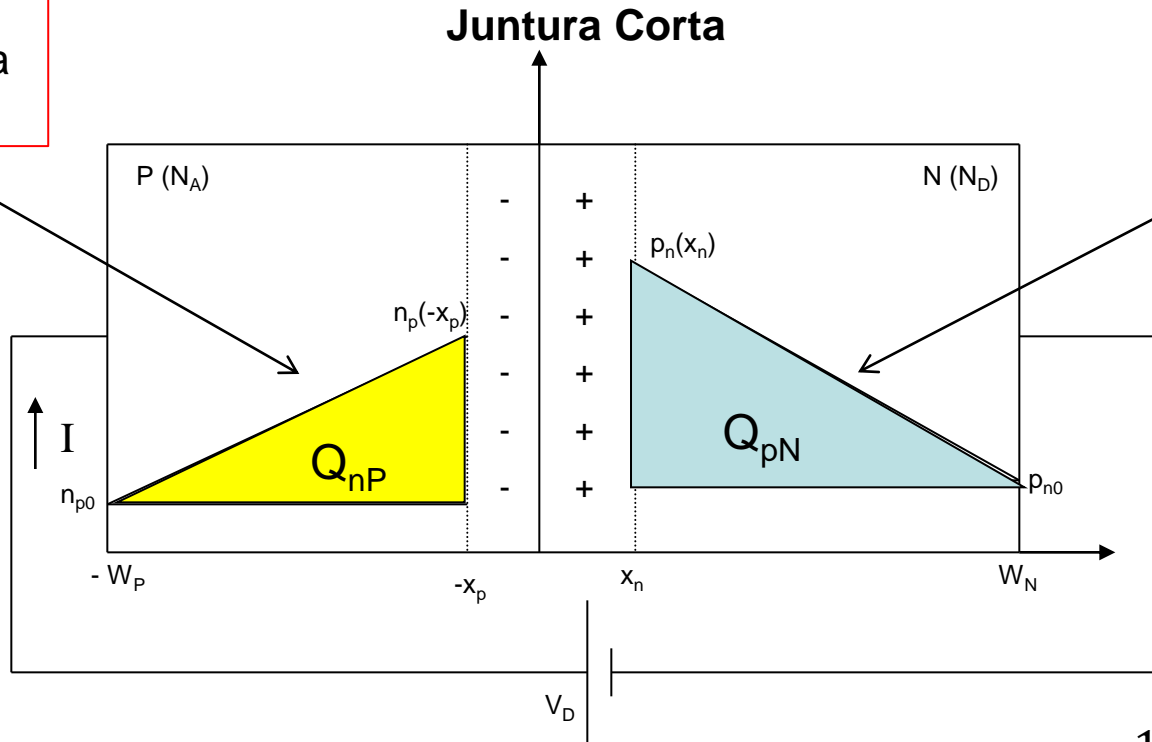
$$I_S = qAn_i^2 \left[\frac{D_p}{W_N N_D} \right] \rightarrow P^+N$$

JUNTURA CORTA

CAPACIDAD DE DIFUSION

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

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



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

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

$$Q_{nP} = \frac{1}{2} q A W_P n_{p0} [e^{(V_D/U_T)} - 1]$$

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

Carga almacenada de electrones en la zona P

Carga almacenada de huecos en la zona N

Suponiendo una Juntura P+N \longrightarrow

$$Q_{nP} \ll Q_{pN}$$

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

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

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

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

$T_T \rightarrow$ Tiempo de transito

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

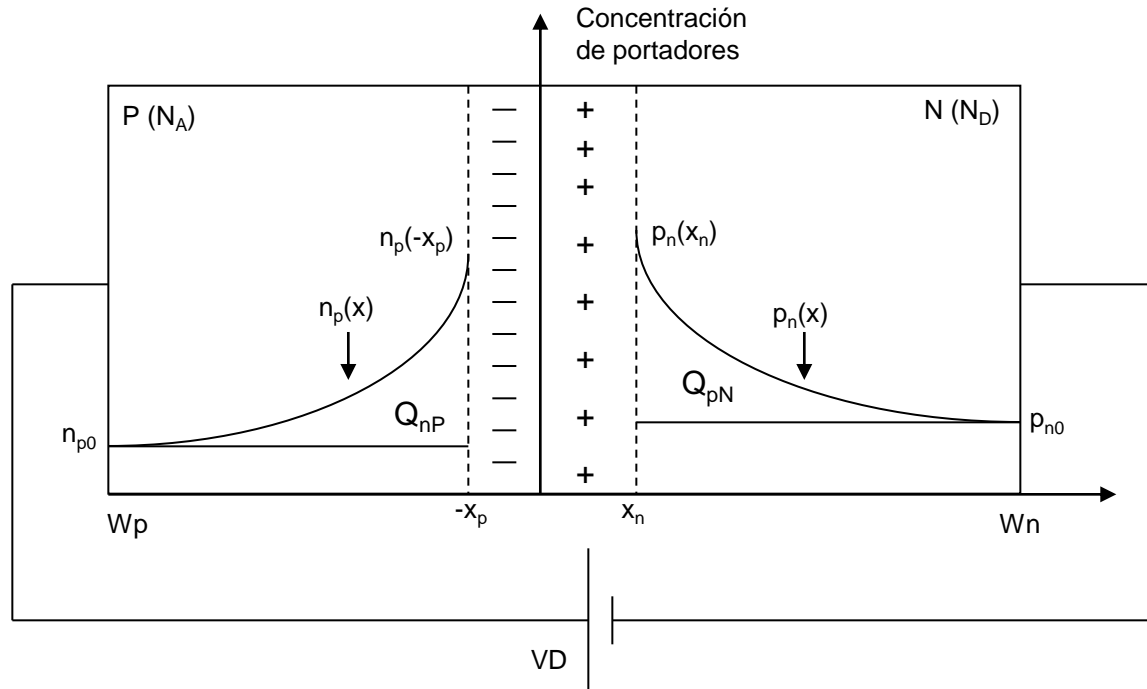
$$Q = T_T I \quad \text{Capacidad [C]} \longrightarrow C = \frac{dQ}{dV} \longrightarrow \frac{dQ}{dV} = T_T \frac{dI}{dV} \longrightarrow \frac{dI}{dV} = \frac{I}{U_T}$$

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

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

CAPACIDAD DE DIFUSION

Juntura Larga



- Carga almacenada en las zonas neutras con polarización directa

Q_{pN} → Carga de huecos en la zona N

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

$$Q_{Pn} = qA \int_{x_n}^{W_N} p'_n(x) dx$$

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

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

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

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

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

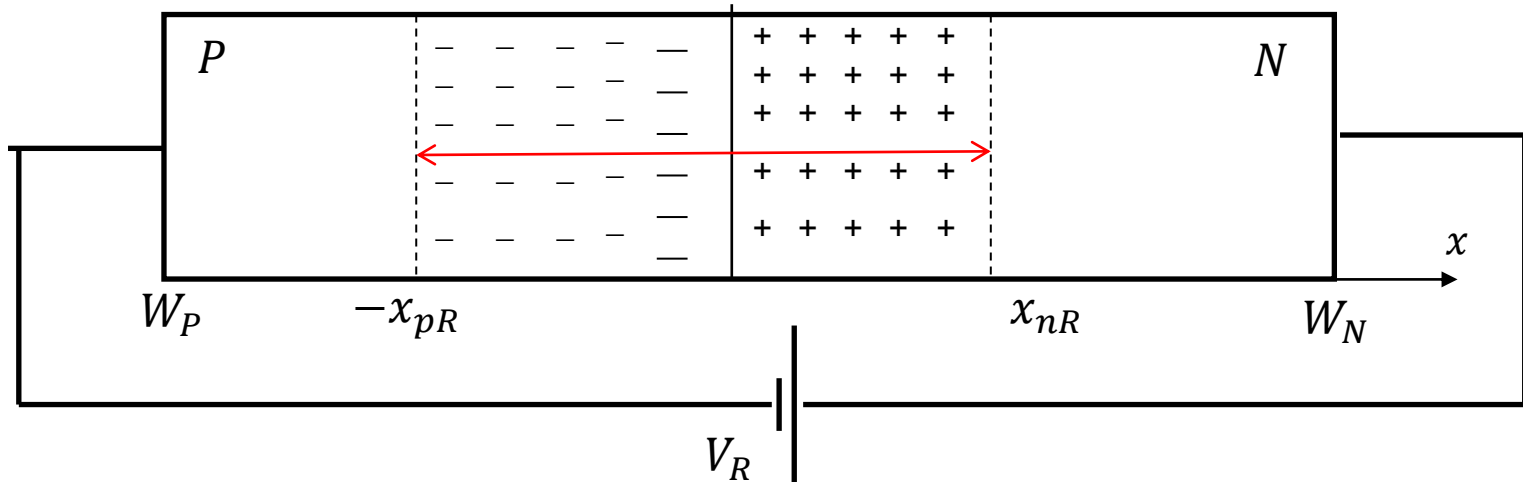
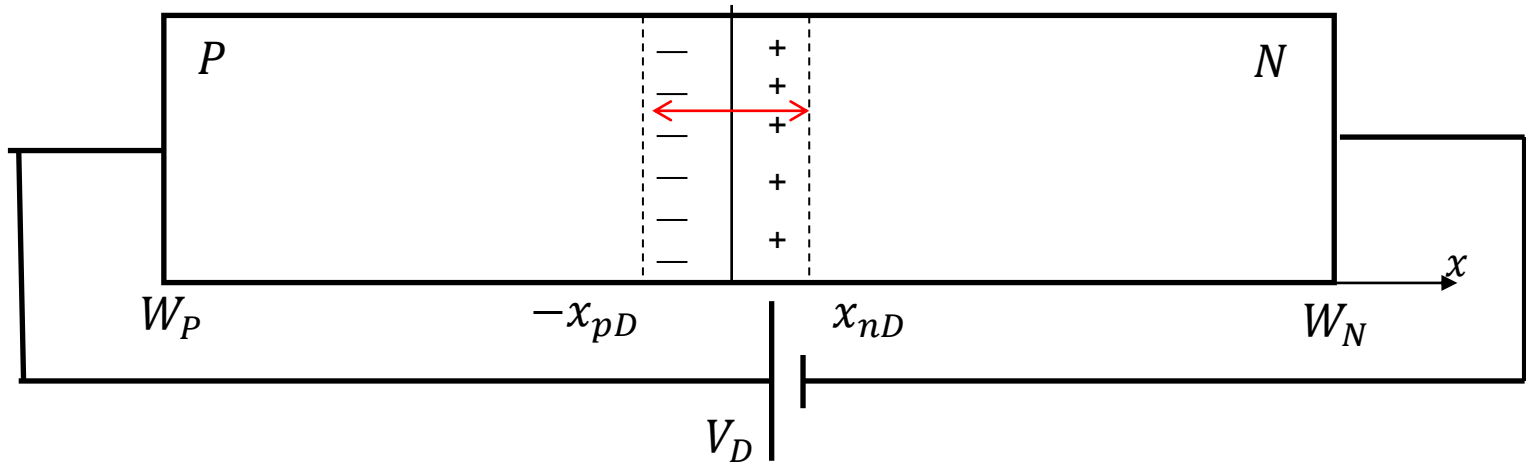
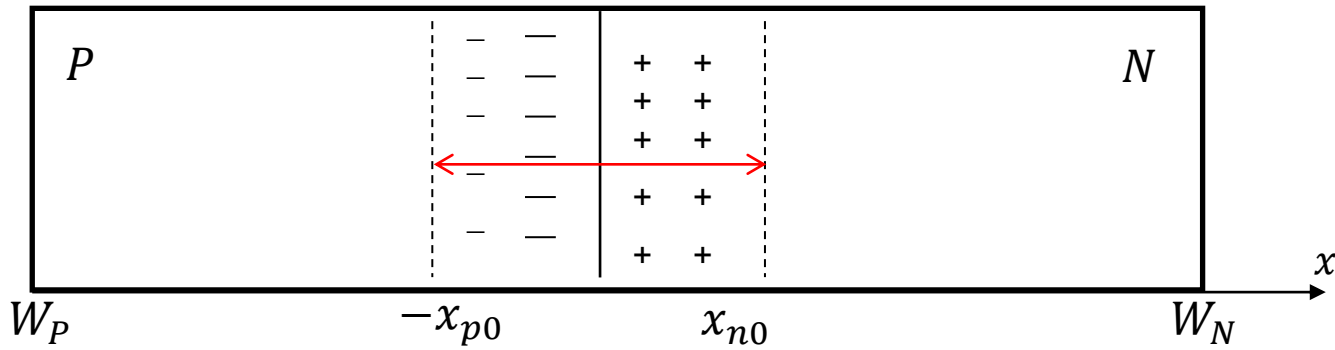
$$Q = \tau_p I$$

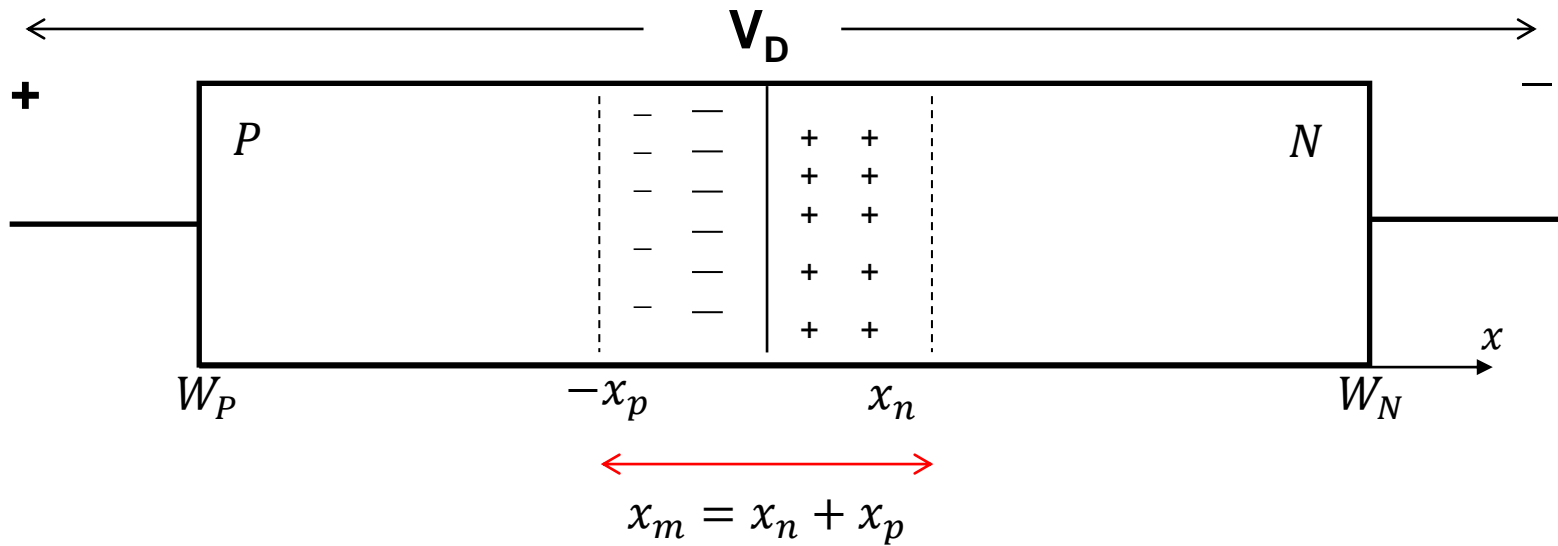
$$I = I_S [e^{(V_D/U_T)} - 1]$$

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

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

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





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

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

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

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

$$C_j = \varepsilon \frac{A}{x_m}$$



Capacidad de la zona de deplexion

$$\varepsilon = 1,04 \times 10^{-12} \left[\frac{F}{cm} \right]$$

$$C_j \rightarrow f(x_m)$$

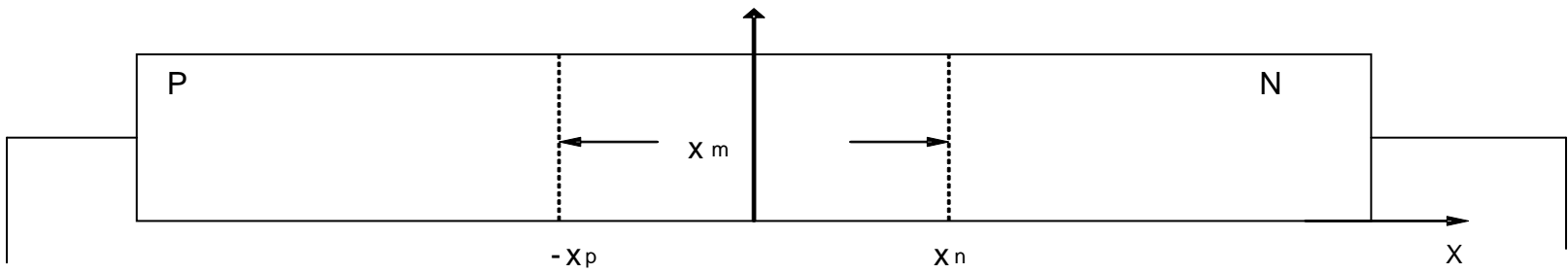


$$x_m \rightarrow f(V_D)$$



$C_j \rightarrow$ Capacitor variable con tensión

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

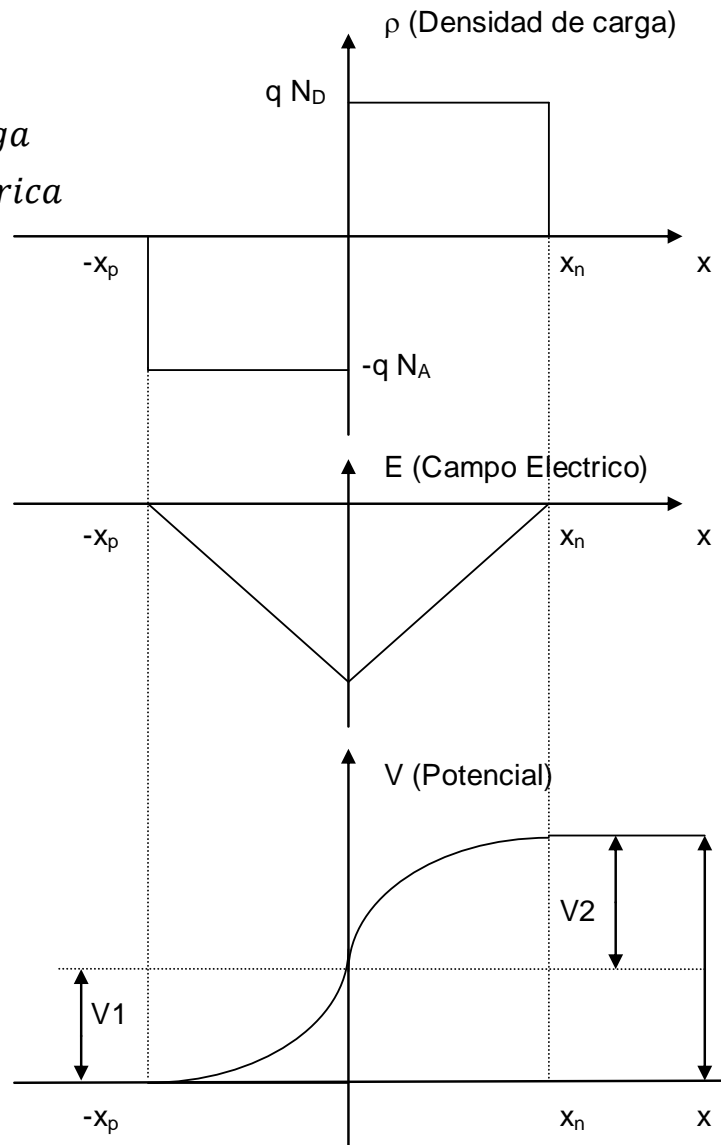


$$\frac{d^2V}{dx^2} = -\frac{\rho}{\epsilon}$$

$\rho \rightarrow$ densidad de carga
 $\epsilon \rightarrow$ constante dielectrica del silicio

Ecuación de Poisson

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



$$x_p N_A = x_n N_D$$

Ecuación de Poisson para una dimensión $\longrightarrow \frac{d^2V}{dx^2} = -\frac{\rho}{\epsilon}$ $\rho \rightarrow$ densidad de carga
 $\epsilon \rightarrow$ constante dielectrica del silicio

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

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

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

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

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

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

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

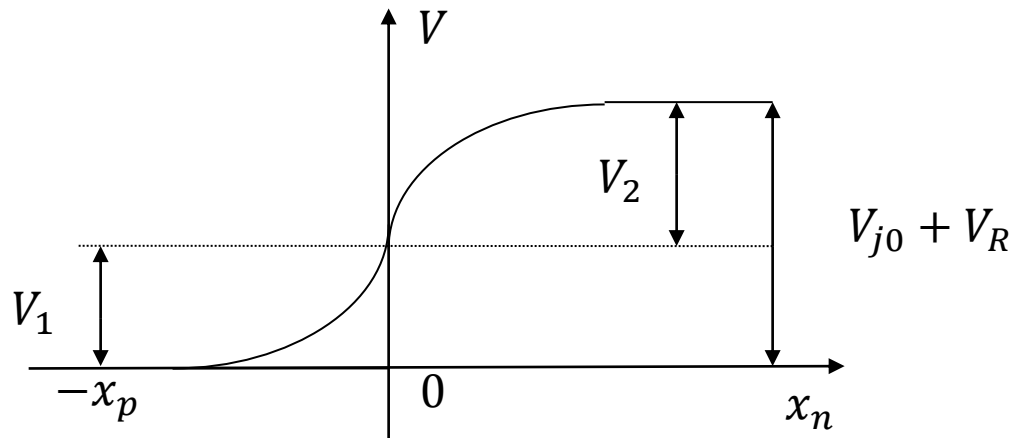
Condición de borde $V(-x_p) = 0 \longrightarrow C_2 = \frac{qN_A x_p^2}{2\epsilon}$

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

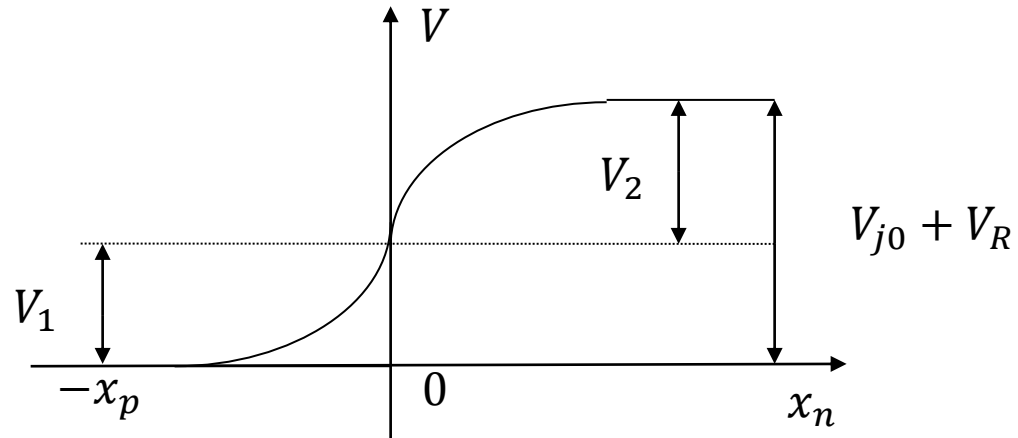
$$V_1 = V(0) = \frac{qN_A x_p^2}{2\epsilon}$$

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

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



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



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

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

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

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

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

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

Para juntas asimétricas:

$$P^+N \longrightarrow x_m = x_n = \left[\frac{2\varepsilon}{qN_D} \right]^{1/2} (V_{j0} + V_R)^{1/2}$$

$$N^+P \longrightarrow x_m = x_p = \left[\frac{2\varepsilon}{qN_A} \right]^{1/2} (V_{j0} + V_R)^{1/2}$$

$$|E_{\max}| = \left[\frac{2q}{\varepsilon} \frac{N_D N_A}{(N_D + N_A)} (V_{j0} + V_R) \right]^{1/2}$$

Capacidad de Juntura

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

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

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

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