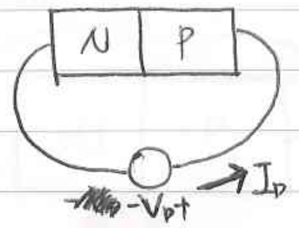
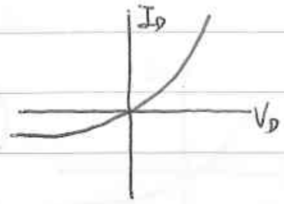
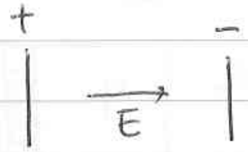
Lect 3

Basics of Si device. PN Junction





진공상태



$\vec{F}=q\vec{E}$ → 힘이 있으므로 $\vec{a}=\frac{\vec{F}}{m}$

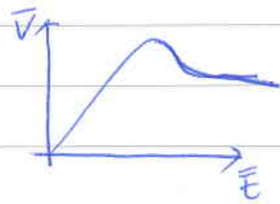
즉 전류가 흐르기 시작.

반도체 안에서는 Si으로 가득 차있으므로 damping force가 有 (가속은 생기지X)

→하지만 전기장 방향으로 움직인다. $\bar{v}=\mu E$. (μ: $cm^2/s\cdot V$)

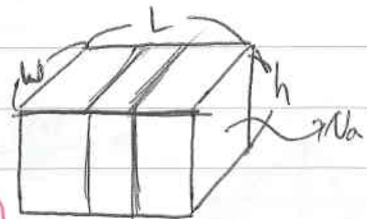
Si 결정 ~ $\mu_p \sim 400$, $\mu_n \sim 1350$

추3



$I=\frac{dQ}{dt}$

$=\frac{V\Delta t\cdot Wh\cdot q\cdot N_a}{\Delta t}$



$J=\frac{I}{Wh}=q\mu_p p E$. → $J=\sigma E$. $[\sigma=\frac{1}{\Omega\cdot cm}]$

$\rho=\frac{1}{\sigma}$ resistivity $[\Omega\cdot cm]$

$R=\frac{V}{I}=\frac{E\cdot L}{J\cdot A}=\frac{\rho\cdot L}{A}$

$V=IR$

$J=\sigma E$ (구조상관X)

⇒ $J_{total}=J_p+J_n=q(\mu_p p+\mu_n n)E$

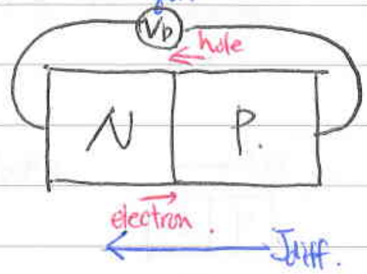
$J_{diffusion}=-qD_p\frac{dp}{dx}+qD_n\frac{dn}{dx}$ ⇒ $\vec{J}=-qD_p\vec{\nabla}p+qD_n\nabla n$

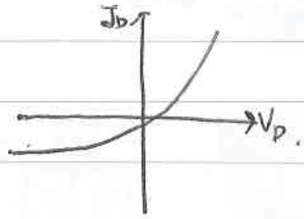
$[D]$: diffusion coefficient : $\frac{C}{sec\cdot cm^2}\cdot\frac{1}{C}\cdot cm^4=\frac{cm^2}{sec}$

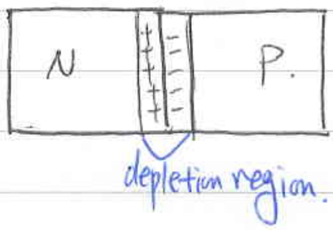
MooKeuk

$\frac{\mu}{D} = \frac{kT}{q}$ → Thermal Energy (주어진 온도에서 Carrier가 가지고 있는 평균 운동E).
$[\frac{eV}{e}]$: Thermal Voltage : 26mV.

Einstein Equ.

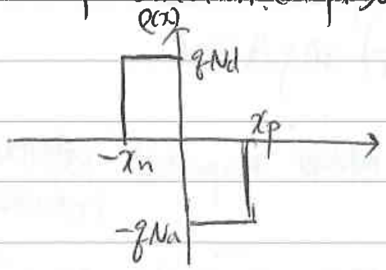






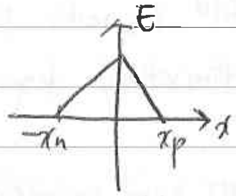
외부 Voltage가 없으면 $J_{drift} + J_{diff} = 0$

Abrupt junction (step junction)



$N_d x_n = N_a x_p$

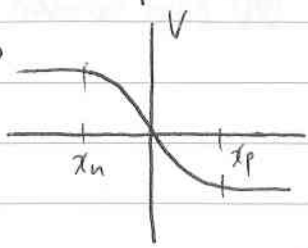
$\varepsilon \nabla E = \rho$, $\frac{dE}{dx} = \frac{\rho(x)}{\varepsilon}$ ⇒



$-x_n < x < 0$, $E(x) = \frac{qN_d}{\varepsilon}(x - x_n)$

$0 < x < x_p$, $E(x) = -\frac{qN_a}{\varepsilon}(x - x_p)$

$E(x) = -\frac{dV}{dx}$ ⇒



부호: potential이 높은(+) → 낮은(−)로 가는것이 E-field이므로

$-x_n < x < 0$,
$\Rightarrow V(x) = V_n - \frac{qN_d}{2\varepsilon}(x + x_n)^2$

$0 < x < x_p$
$\Rightarrow V(x) = V_p + \frac{qN_a}{2\varepsilon}(x_p - x)^2$

$V_n - V_p = \frac{qN_d}{2\varepsilon}x_n + \frac{qN_a}{2\varepsilon}x_p$

$J_{p,drift} + J_{p,diff} = 0$

$-qD_p\frac{dp}{dx} + q\mu_p pE = 0$

$D_p\frac{dp}{dx} = \mu_p \cdot pE$

$np = n_i^2$

$p = \frac{n_i^2}{n}$

$\int_{\frac{n_i^2}{N_d}}^{N_a} D_p\frac{dp}{p} = \int_{-x_n}^{x_p} \mu_p E dx$

$\rightarrow D_n(\ln N_a - \ln\frac{n_i^2}{N_d}) = D_n \ln \cdot \frac{N_a \cdot N_d}{n_i^2} = \mu_p - V(x)\Big]_{-x_n}^{x_p}$

$= \mu_p(V(x = -x_n) - V(x = x_p))$

$V_{bi} = V_n - V_p = \frac{kT}{q}\ln\frac{N_a N_d}{n_i^2}$

MooKeuk

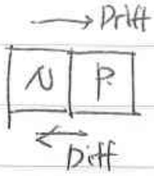
$$x_n + x_p = W_D = \left[\frac{2\varepsilon}{q} V_{bi} \left(\frac{1}{N_a} + \frac{1}{N_d}\right)\right]^{1/2}$$

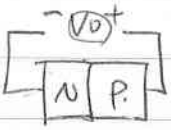
→ 외부전압이 있으면 $(V_{bi} - V_D)$로 쓴다.

$$x_p = W_D \frac{N_d}{N_a + N_d} \qquad x_n = W_D \cdot \frac{N_a}{N_a + N_d}$$

// equilibrium 관계식

$V_D \neq 0.$





$V_D > 0$ 인경우: more diffussion. 급격히증

↳ potential 장벽이 낮아지면 양쪽(p,n)의 농도차이가 매우 크므로 급격하게 흐른다.

$V_D < 0$인 경우: drift가 커져야 되는데 그러기 위해선 왼쪽(n)에 hole이 多, 오른쪽(p)에 electron이 多아야 되지만 도핑이 그렇지 않으므로: 전류 조금흐른

$$I_D = I_s \exp\left(\frac{V_D}{V_T} - 1\right)$$

$$I_s = Aqn_i\left(\frac{D_n}{N_a L_n} + \frac{D_p}{N_d L_p}\right)$$

버렉터 (Varactor): Voltage가 바뀌면 Cap이 바뀌는것

Capacitor: Voltage를 가했을때 charge가 바뀌는지

이건 PN junction은 charge가 uniform하지만 거리가 달라진다.

$C = \frac{\varepsilon \cdot A}{W_D}$. 즉 Reverse bias 걸면 Cap이 작아진다.