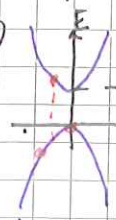
7/2 2013

Rep:

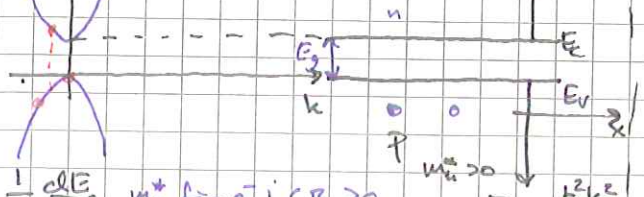
(9)



$v_g = \frac{1}{\hbar}\frac{dE}{dk}$

m_e^* för e^- i CB >0

m_h^* för hål i VB >0

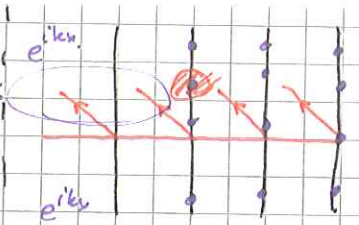


$E_{kin} = \frac{\hbar^2 k^2}{2m_e^*} = \frac{m_e^* v_g^2}{2}$

$m_e^* > 0$

$E_{kin} = \frac{\hbar^2 k^2}{|m_h^*|} = \frac{|m_h^*| v_g^2}{2}$

$m_h^* > 0$



Väteatom $E = -\frac{me^4}{8\varepsilon_0 h^2}$ $\quad -13{,}6\ eV$

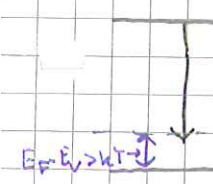
$\frac{m_e^*}{m_0} \times \frac{1}{\varepsilon_r^2}$ $\quad \sim 10^{-2}$ $\quad \sim 10^{-3}$

1) kap 4.) Parabolska band

2) $Z(E)$ per v.e., 3-dim V.E.

$$n = \int_{E_c}^{\infty} Z_e(E) F_e(E) dE = N_c e^{-(E_c - E_F)/kT}$$

$$p = \ldots = N_v e^{-(E_F - E_v)/kT}$$



$F_e(E > E_c) \ll 1$.

klassisk fysik (utan Pauli:)

$F_h(E < E_v) = 1 - F_e(E < E_v) \ll 1$

$E_F - E_v > kT$

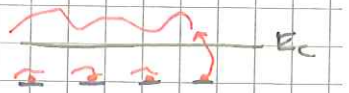
$n \cdot p < N_c N_v e^{-E_g/kT} \ (= n_i^2)$

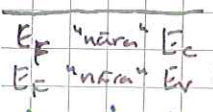
intrinsisk laddningstäthet.

$E_c - E_D = E_d \sim \begin{matrix} 0{,}1\ eV \\ 0{,}01\ eV \end{matrix}$

$a_0 = \frac{4\pi\varepsilon_0\hbar^2}{m_0 e^2} \cdot \varepsilon_r \cdot \frac{m_0}{m_e^*} \sim 10\ nm$

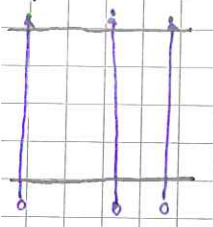
$\sim 0{,}05\ nm$.





E_F "nära" E_c : $n \gg p$

E_F "nära" E_v : $p \gg n$.

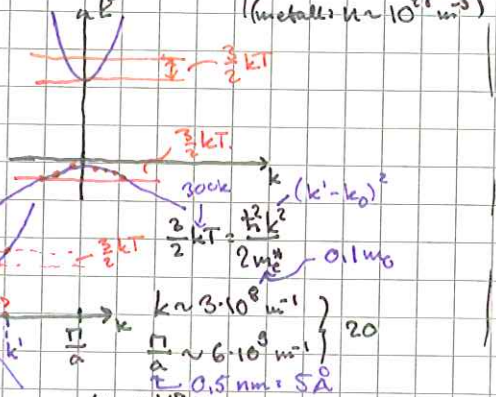


$n = p$

$n \cdot p = n_i^2$ $\Big\} n = p = n_i$

ex) Si: $E_g \sim 1{,}1\ eV$, $T \sim 300K$ } $n_i \sim 10^{16}\ m^{-3}$

(metall: $n \sim 10^{28}\ m^{-3}$)



$\frac{3}{2}kT$

$\frac{3}{2}kT$

300K

$\frac{3}{2}kT = \frac{\hbar^2 k^2}{2m_e^*}$ $\quad (k' - k_0)^2$

$0{,}1\ m_0$

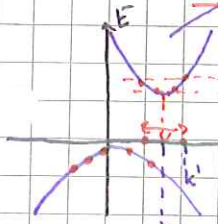
$k \sim 3 \cdot 10^8\ m^{-1}$

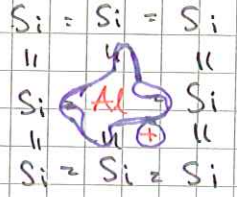
$\frac{\pi}{a} \sim 6 \cdot 10^9\ m^{-1}$

$\frac{\pi}{a} \sim 0{,}5\ nm = 5\ Å$

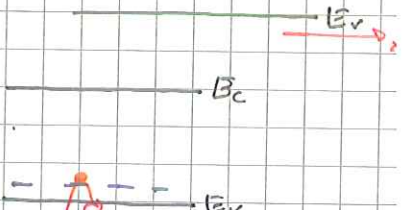
20

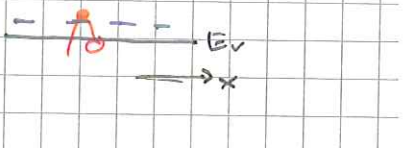
$\Delta k \left(\begin{matrix}\max VB \\ \to \min CB\end{matrix}\right) \sim \frac{\pi}{2a}$





p-dopn:

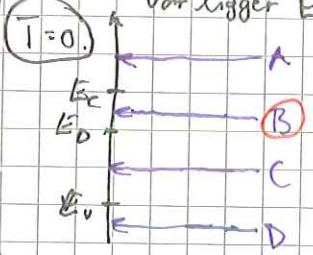




n-dopad halvledare: $T = 0 \to$?

Var ligger E_F?

$T = 0$.



A $\quad F(E_D) = 1$

B $\quad F(E_c) = 0$

C $\quad F(E_v) = 0$

D

T lite större kanc. donatoratomer N_D

laddn. neutralitet: $n = N_D^+ + p$

$p \ll N_D^+$

$n = N_D^+$

$N_D^+ = N_D(1 - F(E_D))$

sätt samt tillstånd vid E_D

$n \cdot p = N_c N_v e^{-E_g/kT}$ $\quad / \cdot$

$p = N_v e^{-(E_F - E_v)/kT}$ $\quad / \cdot$

$n = \sqrt{N_c N_D} e^{-E_d/2kT}$

Doping: extrinsiska eller störledande halvledare

Ersätter några få* värdkristallatomer med andra atomer.

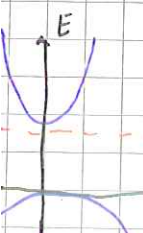
* ~ 1. på 10^6 $\to$ Fortfarande samma ämne.

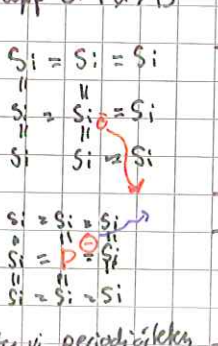
$10^{-6} \cdot 10^{28}\ m^{-3} = 10^{22}\ m^{-3}$.

Atomer ur grupp 5: As, P $\quad$ 5 ve$^-$ n-doping

Atomer ur grupp 3: Al, B $\quad$ 3 ve$^-$ p-doping.

n-doping:





Bryter vi periodicitet:

E_D = Donator

Gäller endast om $n \ll N_D$

$N_D^+ \ll N_D$.

$E_F = \frac{E_c + E_D}{2} - \frac{kT}{2} \ln\left(\frac{N_c}{N_D}\right)$

$n = N_c e^{-(E_c - E_F)/kT}$

vet man $n \to E_F$

T lite större: mättnadsområdet

$n \approx N_D^+ + p$ $\quad N_D^+ \approx N_D$ $\Big\} n = N_D + p$ $\quad p \ll N_D, n$ $\Big\} n \approx N_D$

här vill man helst komp. ska jobba.

$F(E_D) \ll 1 \Rightarrow E_F < E_D$.

ex) $n \cdot p = n_i^2 \Rightarrow p = \frac{n_i}{n} = \frac{n_i^2}{N_D}$ $\quad$ S @ 300K $\Big\}$ $p \geq 10^{10}\ m^{-3}$

$n_i \sim 10^{11}\ m^{-3}$

$N_D \geq 10^{22}\ m^{-3}$

$n = N_D \approx N_c e^{-(E_c - E_F)/kT} \Rightarrow E_F$

T hög: $n = N_D^+ + p$ $\Big\} n = p$ $\quad$ intrinsikt mat

$N_D \ll p, n$ $\quad N_D^+ \to 0$

$n = p = n_i = \sqrt{N_c N_v} e^{-E_g/2kT}$

$E_F \approx$ mitten av bandgap