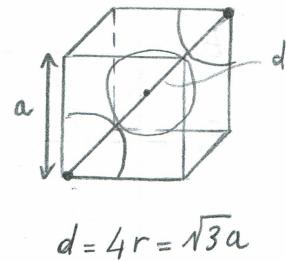


ES1

APF \triangleq atomic packing factor = rapporto di volume delle celle unitarie (c.u.) effettivamente occupate dagli atomi
 $= \frac{N_{\text{atomi, c.u.}} \cdot V_{\text{atomi}}}{V_{\text{c.u.}}}$

$$\text{APF}_{\text{BCC}} = \frac{(8 \times \frac{1}{8} + 1) \cdot \frac{4}{3} \pi r^3}{a^3} = \frac{2 \cdot \frac{4}{3} \pi \left(\frac{\sqrt{3}}{4} a\right)^3}{a^3} = \frac{\sqrt{3} \pi}{8} = 0,68$$

$$r = \frac{\sqrt{3}}{4} a$$



ES2

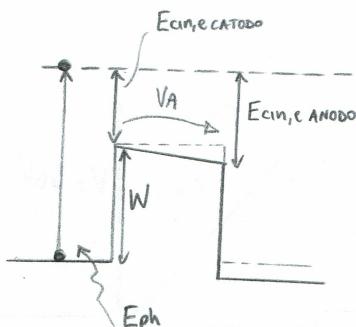
$$W = 4.2 \text{ eV}$$

$$\lambda_{\text{ph}} = 180 \text{ nm}$$

$$V_A = 0.2 \text{ V}$$

i) V_0

ii) $\lambda_{DB, \text{ANODO}}$

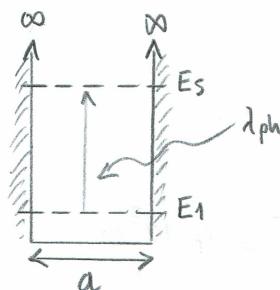


$$E_{\text{ph}} = \frac{hc}{\lambda_{\text{ph}}} = 6.9 \text{ eV}$$

$$E_{\text{cin}, e^- \text{CATHODE}} = E_{\text{ph}} - W = 2.7 \text{ eV} \Rightarrow V_0 = - \frac{E_{\text{cin}, e^- \text{CATHODE}}}{q} = - 2.7 \text{ V}$$

$$E_{\text{cin}, e^- \text{ANODO}} = E_{\text{cin}, e^- \text{CATHODE}} + qV_A = 2.9 \text{ eV} = \frac{h^2}{2m\lambda_{DB}^2} \rightarrow \lambda_{DB} = \frac{h}{\sqrt{2m E_{\text{cin}, e^- \text{ANODO}}}} = 7.21 \text{ \AA}$$

ES3

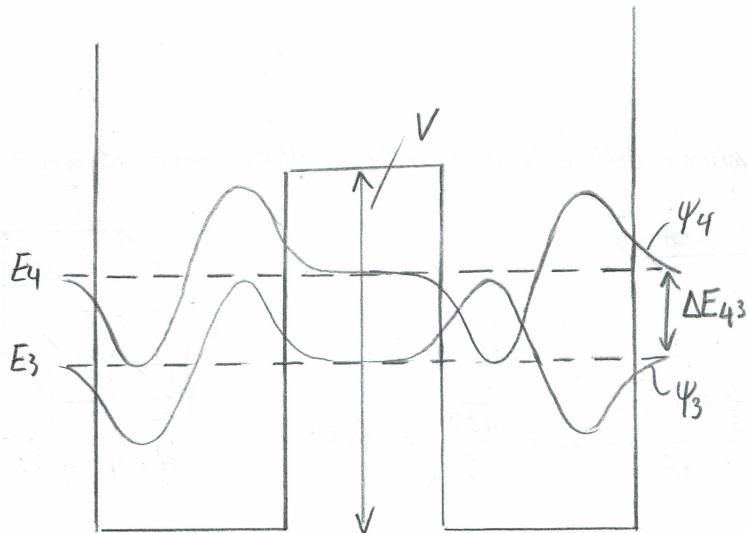


$$\lambda_{\text{ph}} = 1.32 \mu\text{m}$$

$$\Delta E_{S1} = \frac{h^2}{8ma^2} (25-1) = \frac{h^2}{8ma^2} 24 = \frac{3h^2}{ma^2}$$

$$\Delta E_{S1} = E_{\text{ph}} \Rightarrow \frac{3h^2}{ma^2} = \frac{hc}{\lambda_{\text{ph}}} \rightarrow a = \sqrt{\frac{3\lambda_{\text{ph}} h}{mc}} \sim 3.1 \text{ nm}$$

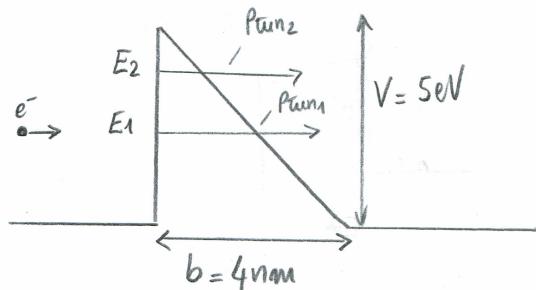
ES4



- * Secondo doppietto di livelli
→ 2 case x uscire buco
- * ψ_3 pari / ψ_4 dispari

All'incrementare dell'altezza di barriera V , le buche sono sempre meno accoppiate
→ ΔE_{43} diminuisce → $\Delta E_{43} = h\nu_{34}$ diminuisce

ES5



BARRIERA TRIANGOLARE → tunneling Fowler-Nordheim

$$P_{\text{tun}}^{\text{FN}} = e^{-\frac{4}{3} \frac{\sqrt{2m}}{\hbar q V} b (V-E)^{3/2}}$$

$$\frac{P_{\text{tun}2}}{P_{\text{tun}1}} = e^{-\frac{4}{3} \frac{\sqrt{2m}}{\hbar q V} b [(V-E_1)^{3/2} - (V-E_2)^{3/2}]} = 10^5$$

ES6

metallo 1D

$$M^* = Mo$$

$$E_F = 1.5 \text{ eV}$$

i) n

$$g_{1D}(E) = \frac{1}{\pi \hbar} \sqrt{\frac{2M^*}{E - E_c}}, \quad E_c = 0$$

$$n = \int_0^\infty g_{1D}(E) f_{FD}(E) dE = \int_0^{E_F} \frac{\sqrt{2M^*}}{\pi \hbar} \frac{1}{\sqrt{E}} dE = \frac{\sqrt{2M^*}}{\pi \hbar} \int_0^{E_F} \frac{1}{\sqrt{E}} dE = \frac{2\sqrt{2M^*}}{\pi \hbar} \sqrt{E_F} = 4 \cdot 10^7 \text{ cm}^{-1}$$

$T=0K$

ES7

InP : semiconduttore e gap diretto \rightarrow dal diagramma a bande si osserva che il minimo della banda di conduzione è allineato al minimo della banda di valenza in Γ

$$M_i(300\text{ K}) = 1.3 \cdot 10^7 \text{ cm}^{-3}$$

$$M_m^{*005} = M_e^* = 0.073 \text{ m} \Omega$$

$$M_p^{*005} = (M_{lh}^{*3/2} + M_{hh}^{*3/2})^{2/3} = 0.623 \text{ m} \Omega$$

$$N_c(300\text{ K}) = \frac{1}{4\pi^3} \left(\frac{2M_m^{*005} kT}{\pi} \right)^{3/2} = 4.94 \cdot 10^{17} \text{ cm}^{-3}$$

$$N_v(300\text{ K}) = \frac{1}{4\pi^3} \left(\frac{2M_p^{*005} kT}{\pi} \right)^{3/2} = 1.23 \cdot 10^{19} \text{ cm}^{-3}$$

$$M_i = \sqrt{N_c N_v} e^{-\frac{E_g}{2kT}} \rightarrow E_{g_{InP}} = 1.344 \text{ eV}$$

$$\lambda = 800 \text{ nm} \rightarrow E_{ph} = \frac{hc}{\lambda} = 1.55 \text{ eV} > E_g \rightarrow \text{non è trasparente}$$

ES8

$$N_D = 10^{17} \text{ cm}^{-3}$$

$$L = 5 \mu\text{m}$$

$$T = 300 \text{ K}$$

$$t_{cm} = 400 \text{ fs}$$

$$J_m = 2.7 \cdot 10^{-4} \text{ A}/\mu\text{m}^2$$

i) V

$$\mu_n = \frac{q t_{cm}}{M_0} = 703 \text{ cm}^2/\text{Vs}$$

$$J_m = q \mu \frac{V}{L} N_D \rightarrow V = \frac{J_m L}{q \mu N_D} = 1.2 \text{ V}$$

ES9

Silicio

$$L = 1 \mu\text{m}$$

$$\Delta V = 1 \text{ V}$$

$$\mu(300\text{ K}) = 1500 \text{ cm}^2/\text{Vs}$$

$$\hbar \omega_{LO} = 63 \text{ meV}$$

i) $t_{\text{TRAVEL}}(300\text{ K})$

ii) $t_{\text{TRAVEL}}(600\text{ K})$

$$v_1 = \mu \frac{\Delta V}{L} = 1.5 \cdot 10^5 \text{ m/s} \quad > \quad v_1 > v_{\text{SAT}} \rightarrow t_{\text{TRAVEL}}(300\text{ K}) = \frac{L}{v_{\text{SAT}}} \sim 13.4 \text{ ps}$$

$$v_{\text{SAT}} = \sqrt{\frac{\hbar \omega_{LO}}{2m}} = 7.5 \cdot 10^4 \text{ m/s}$$

$$T_2 = 600 \text{ K}$$

$$M_2 = 1500 \frac{\text{cm}^2}{\text{Vs}} \left(\frac{600}{300} \right)^{-3/2} \sim 530 \frac{\text{cm}^2}{\text{Vs}}$$

$$V_2 = M_2 \frac{\Delta V}{L} = 5.3 \cdot 10^4 \text{ m/s} < V_{\text{SAT}} \rightarrow t_{\text{TRAVEL}}(600 \text{ K}) = \frac{L}{V_2} \sim 19 \text{ ps}$$

All'aumentare delle temperature aumentano gli eventi di scattering con i fonni e di conseguenza il tempo di transito attraverso il semiconduttore

ES 10

$T = 300 \text{ K} \rightarrow$ regione di funzionamento estunseca (ionizzazione sostanzialmente completa) $\rightarrow N_A^- = N_A = 10^{13} \text{ cm}^{-3}$

Poiché N_D/N_A è solo di un fattore 10, dobbiamo partire dalla condizione di neutralità di carica

$$n - p + N_A^- - N_D^+ = n - \frac{M_i^2}{m} + N_A - N_D = 0 \rightarrow n^2 - (N_D - N_A)n - M_i^2 = 0$$

$$n = \frac{N_D - N_A}{2} + \sqrt{\left(\frac{N_D - N_A}{2} \right)^2 + M_i^2} = 9.6 \cdot 10^{13} \text{ cm}^{-3}$$

$$p = \frac{M_i^2}{m} = 6 \cdot 10^{12} \text{ cm}^{-3} \quad \left. M_i \right|_{\text{Ge}} = 2.4 \cdot 10^{13} \text{ cm}^{-3}$$