Háskóli Íslands
Raunvísindadeild
Eðlisfræðiskor

Sumar 2001

09.21.43 Rafeindatækni fastra efna

Lokapróf

25. ágúst 2001, kl. 13:30 - 16:30

1. (25 %) **Potential well**

We consider 3 electrons in a one-dimensional potential well of width $L = 10$ nm, and infinitely high in energy.

(a) Calculate the first 3 energy levels in the well, in units of meV.

(b) Show which levels are occupied by the 3 electrons in the ground state, and calculate the total energy of the system. (Note: Do not forget the electron spin!)

(c) Calculate the minimum energy which must be given to the system such that all electrons can have the spin up.

(d) What is the average position of every electron in the well ?

(e) What is the average velocity of every electron ?

2. (25 %) **Semiconductor statistics**

The concentrations of electrons in the conduction band and of holes in the valence band of a semiconductor are

$$n = N_{\mathrm{c}} \exp\left(\frac{E_{\mathrm{F}} - E_{\mathrm{c}}}{k_{\mathrm{B}}T}\right) \ , \ p = N_{\mathrm{v}} \exp\left(\frac{E_{\mathrm{v}} - E_{\mathrm{F}}}{k_{\mathrm{B}}T}\right) \ , \tag{1}$$

where

$$N_{\mathrm{c}} = 2\left(\frac{2\pi m_n^* k_{\mathrm{B}}T}{h^2}\right)^{3/2} \ , \ \ N_{\mathrm{v}} = 2\left(\frac{2\pi m_p^* k_{\mathrm{B}}T}{h^2}\right)^{3/2} \ , \tag{2}$$

E_{c} is the bottom of the conduction band, E_{v} is the top of the valence band, m_{n}^* is the effective mass of electrons, m_{p}^* is the effective mass of holes.

(a) Derive an expression for the Fermi level, relative to the middle of the energy gap, $(E_{\mathrm{c}} + E_{\mathrm{v}})/2$.

(b) Calculate the Fermi level for Silicon, for which the energy gap is $E_{\mathrm{g}} \equiv E_{\mathrm{c}} - E_{\mathrm{v}} = 1.11$ eV, and the effective masses are $m_{\mathrm{n}}^* = 1.1 m_0$, $m_{\mathrm{p}}^* = 0.56 m_0$, at the room temperature, $T = 300$ K.

(c) Find the concentrations of electrons and holes at $T = 300$ K, in units of cm^{-3}.

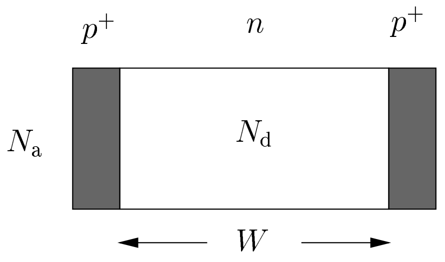
(d) Explain why holes are found at the top of the valence band whereas electrons are found at the bottom of the conduction band.

(e) How the Fermi level changes when the semiconductor is doped with donors and respectively with acceptors ?

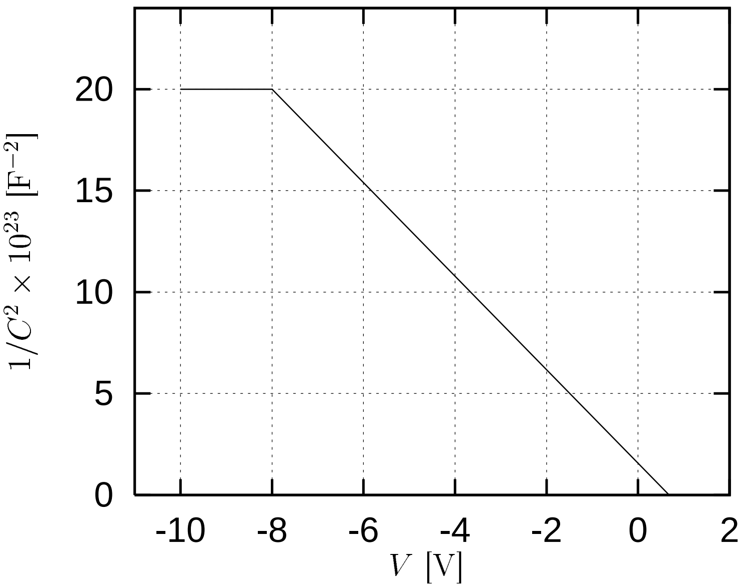
3. (10 %) **Rek í rafsviði**

   Hve langan tíma tekur það meðalrafeind að reka 2 μm í hreinum kísli í rafsviði sem er 120 V/cm. Hvað gerist við hærri rafsviðsstyrk, $> 10^4$ V/cm ?

4. (20 %) $C-V$ **mæling**



   Gefin er ferill sem sýnir $1/C^2$ sem fall af álagðri spennu fyrir kísiltvistinn hér að ofan. Reikna skal þröskuldsspennuna og þéttleikana N_a og N_d í p^+ og n-svæðunum. Þverskurðarflatarmál tvistsins er 10^{-3} cm^2. Einnig skal reikna breidd n-svæðisins, W.



5. (20 %) **Sveimlengd víkjandi bera**

Gerð er tilraun á kísli sem íbættur er með $N_\mathrm{d} = 10^{17}$ cm^{-3} rafgjöfum. Tilraunin fer fram við 300 K. Leiðnin er mæld 10.0 $(\Omega\ \mathrm{cm})^{-1}$.

Þegar lýst er á sýnið við tiltekinn ljósstyrk breytist leiðnin og verður 11 $(\Omega\ \mathrm{cm})^{-1}$. Slökkt er á ljósinu við tímann 0 og 1.0 μs síðar er leiðnin 10.5 $(\Omega\ \mathrm{cm})^{-1}$. Þessi ljósörvaða leiðni fellur eins og

$$\delta\sigma = \delta\sigma(0)\exp\left(-\frac{t}{\tau}\right)$$

þar sem τ er líftími hleðslubera. Reikna skal:

(a) Hve hátt hlutfall rafgjafanna er jónaður ?

(b) Hver er sveimlengd hola í efninu ?