Háskóli Íslands
Raunvísindadeild
Eðlisfræðiskor

Haust 2000

09.21.43 Rafeindatækni fastra efna

Lokapróf

13. desember 2000, kl. 9:00 - 12:00

1. (25 %) **Semiconductor statistics**

The concentrations of electrons in the conduction band and of holes in the valence band of a semiconductor (either doped or undoped), are

$$n = N_{\rm c} \exp\left(\frac{E_{\rm F} - E_{\rm c}}{k_B T}\right) \, , \, p = N_{\rm v} \exp\left(\frac{E_{\rm v} - E_{\rm F}}{k_B T}\right) \, , \qquad (1)$$

where

$$N_{\rm c} = 2\left(\frac{2\pi m_{\rm n}^* k_B T}{h^2}\right)^{3/2} \, , \quad N_{\rm v} = 2\left(\frac{2\pi m_{\rm p}^* k_B T}{h^2}\right)^{3/2} \, , \qquad (2)$$

$E_{\rm c}$ is the bottom of the conduction band, $E_{\rm v}$ is the top of the valence band, $m_{\rm n}^*$ is the effective mass of electrons, $m_{\rm p}^*$ is the effective mass of holes. We consider the parameters of silicon: $m_{\rm n}^* = 0.19 m_0$, $m_{\rm p}^* = 0.49 m_0$, $E_g \equiv E_{\rm c} - E_{\rm v} = 1.11$ eV.

(a) For the intrinsic material, find the position of $E_{\rm F}$ relatively to the middle of the energy gap, $E_{\rm i} \equiv (E_{\rm v} + E_{\rm c})/2$, at room temperature, $T = 300$ K.

(b) Find $n_{\rm i}$ and $p_{\rm i}$, the intrinsic electron/hole concentrations at $T = 300$ K.

(c) Show that $np = n_{\rm i}^2$, independent of doping.

(d) Consider the material doped with $N_{\rm d} = 10^{15}$ cm^{-3} donors, and suppose every donor injects one electron into the conduction band. Find p, by assuming $N_{\rm d} \gg n_{\rm i}$.

(e) Find $E_{\rm F}$ for the doped material, at $T = 300$ K, also relatively to $E_{\rm i}$.

2. (25 %) **Electrons in a potential well**

   We put 5 electrons in a one-dimensional potential well of width $L = 10$ nm, and infinitely high in energy.

   (a) Plot the localization probability $|\psi(x)|^2$, versus the position x within the potential well, for the completely occupied states.

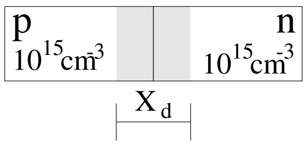
   (b) Calculate the total energy of the 5 electrons at temperature $T = 0$ K. Use units of meV.

   (c) Calculate the minimum energy of an incident photon, $h\nu$, necessary to excite one electron.

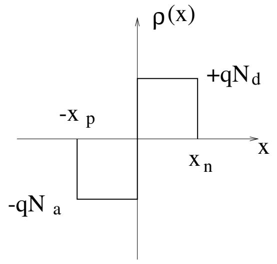
   (d) What is the value of the Fermi level E_F at $T = 0$ K ?

   (e) Calculate the probability to find an electron on the next level above E_F, at temperature $T = 50$ K.

3. (20 %) **Samhverf p-n skeyti**



   (a) Rissa skal rafsviðið $E(x)$ og mættið $\phi(x)$ í varmajafnvægi fyrir p-n-skeytin að ofan fyrir hleðsluþéttleikann $\rho(x)$ sem er sýndur hér að neðan ($N_\mathrm{a} = N_\mathrm{d} = 10^{15}$ cm^{-3}).



   Athuga ber að víddirnar x_n og x_p eru ekki tilgreindar. Mættin í n og p bolsvæðunum (ϕ_n og ϕ_p) eiga að vera tölulega rétt.

   (b) Finna skal tölugildi á $X_\mathrm{d} = x_\mathrm{n} + x_\mathrm{p}$ með því að gera ráð fyrir að þröskuldurinn sé jafnhár summu mættisbreytingarinnar yfir rúmhleðslusvæðin.

   (c) Finna tölugildi rafsviðsins við $x = 0$.

4. (10 %) **Zener hrif**

   Hvernig eru Zener hrif ?

5. (20 %) **Gleypni ljóss**

   Lýst er á einkristallað kísilsýni, sem er 0.25 μm á þykkt, með einlitu ljósi af orku $h\nu = 2.5$ eV. Afl ljóssins er 10 mW.

   (a) Finna skal heildar orkuna sem sýnið gleypir á hverri sekúndu.

   (b) Finna skal umfram varmaorku sem tapast til grindar á hverri sekúndu

   (c) Finna skal fjölda ljóseinda sem er útgeislað við innri samruna hleðslubera á sekúndu hverri