國立中央大學94學年度碩士班考試入學試題卷　共 1 頁 第 1 頁

所別：電機工程學系碩士班 乙組　科目：半導體元件

1. (a) (4%) 畫出 energy band diagram (E_C, E_V, E_F) for a Si p-n junction in thermal equilibrium。

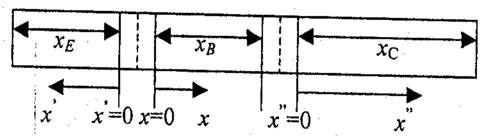
   (b) (8%) 請指出 Depletion (transition) region 與 neutral region. 並在 energy band diagram 上之適當位置用"電子及電洞"繪出其 Diffusion 的方向。

   (c) (4%) 最後說明原因在 thermal equilibrium 時 p-端的電洞不會因擴散原理(高濃度的往低濃度擴散)往 n-端擴散。

2. (16%) To measure the carrier concentration directly, the most common used method is the Hall Effect. Consider a *p*-type semiconductor sample (size is L×H×W), try to set up the measurement (畫出測量的接法與外加電壓電場磁場的方向等) and write the equations to obtain carrier concentration.

3. (18%) From Poisson's equation to derive (推導) electric-field distribution and find the maximum field in an abrupt *p-n* junction. Assumed the metallurgical junction is located at $x = 0$, the depletion region in *p*-side and *n*-side are $-x_p$ and x_n, respectively. Dielectric constant is ε_s.

4. (a) (10%) A silicon npn bipolar transistor is uniformly doped and biased in the forward-active region. The ~~neutral base width is $x_B = 0.8$ μm. The transistor doping concentrations are $N_E = 5\times10^{17}$ cm^{-3}, N_B =~~ 10^{16} cm^{-3}, and $N_C = 10^{15}$ cm^{-3}. For $V_{BE} = 0.625$ V, determine n_B at $x = 0$ and p_E at $x' = 0$. Note that $n_i = 1.5\times10^{10}$ cm^{-3}, $V_t = kT/q = 0.0259$ V, and $e^{24.131} = 3.02\times10^{10}$.



   (b) (10%) Consider a uniformly doped silicon bipolar transistor with a metallurgical base width of 0.5 μm and a base doping of $N_B = 10^{16}$ cm^{-3}. The punch-through voltage is to be $V_{pt} = 25$ V. Determine the collector doping and collector width to meet the punch-through voltage specification. Note that $\varepsilon_{Si} = 11.7 \times 8.85 \times 10^{-14}$ F/cm.

5. (a) (10%) Consider an n^+ polysilicon gate and a p-type silicon substrate doped to $N_a = 3 \times 10^{16}$ cm^{-3}. Assume the fixed charge at the oxide-semiconductor interface is $Q_{ss}' = 10^{11}$ cm^{-2}. Determine the work function difference ϕ_{ms}. Note that $n_i = 1.5\times10^{10}$ cm^{-3}, the bandgap energy $E_g = 1.12$ eV, and the electron affinity $\chi = 4.01$ V.

   (b) (10%) Follow (a). Determine the oxide thickness such thate the threshold voltage $V_{TN} = +0.6$ V. Note that $V_t = kT/q = 0.0259$ V, and $\ln(N_a/n_i) = 14.5086$.

6. (10%) Using superposition, the shift in the flat-band voltage ΔV_{FB} due to a fixed charge distribution $\rho(x) = (a \times x)$ C/cm^3 in the oxide can be given by $\Delta V_{FB} = f(\varepsilon_{ox}, t_{ox}, a)$. Please find the function $f(\varepsilon_{ox}, t_{ox}, a)$, which is a function of the oxide permittivity ε_{ox}, the oxide thickness t_{ox}, and the charge distribution coefficient a.