國立清華大學命題紙

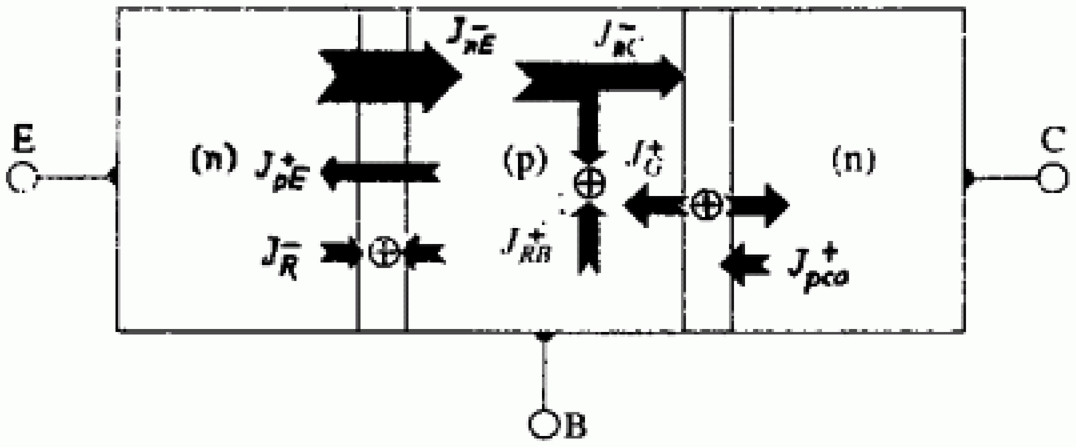
九十一學年度 電子工程 研究所 ______ 組 碩士班研究生入學考試
科目 固態電子元件 科號 2605 共 2 頁第 1 頁 *請在試卷(答案卷)內作答

1. Sketch the energy band diagram for the following situations:

   (a) Existence of a constant electric field of 1 MV/cm in positive x direction. (4%)
   (b) An electron with zero kinetic energy. (4%)
   (c) A hole with kinetic energy equals to E_g. (4%)
   (d) Direct thermal generation. (4%)
   (e) Recombination via a mid-gap GR center. (4%)
   (f) Impact ionization by an electron with kinetic energy equals to $1.5E_g$. (4%)
   (g) Band-to-band direct tunneling for a 1V reversed biased silicon p^+n^+ diode. (4%)
   (h) An indirect band semiconductor. (4%)
   (i) Silicon doped with Boron. (3%)

2. The current components of a BJT under forward active mode are shown below. If $I_{nE} = 1.20$ mA, $I_{pE} = 0.10$ mA, $I_{nC} = 1.18$ mA, neglect I_R, I_G and I_{pc0}, Determine

   (a) Emitter injection efficiency γ. (3%)
   (b) The base transport factor α_T. (3%)
   (c) The current gain β. (4%)



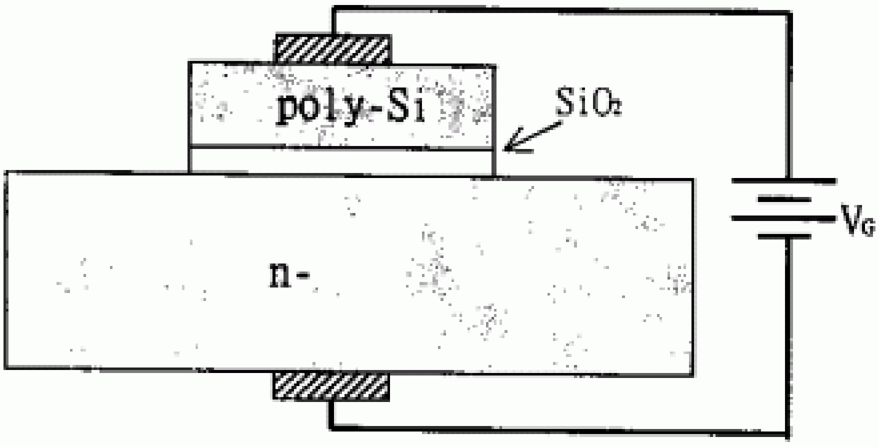
3. Plot the energy-band diagram of a metal and an n-type semiconductor with $\phi_m > \phi_s$, (a) before contact, (b) after contact, (c) under reverse bias, and (d) under forward bias. (e) What kind of contact is this? Label all of important physical parameters. (10%)

4. Which of the following doping concentrations of 10^{19} cm^{-3}, 10^{17} cm^{-3}, 10^{15} cm^{-3}, is suitable for collector, base, and emitter, respectively? (3%) Explain why? (7%)

國立清華大學命題紙

九十一學年度 電子工程 研究所 ______ 組 碩士班研究生入學考試
科目 固態電子元件 科號 2605 共 2 頁第 2 頁 ＊請在試卷(答案卷)內作答

5. The electron affinity and bandgap of SiO_2 is 0.95 eV and 8 eV respectively. The electron affinity and bandgap of Si is 4.05 eV and 1.2 eV respectively. The gate oxide thickness T_{ox} is 2nm, V_T is the threshold voltage. Let $n_i = 1 \times 10^{10}\ \text{cm}^{-3}$, $\varepsilon_{Si}/\varepsilon_{ox} = 3$, $(\ln 10)kT/q = 60$ mV. The poly-silicon gate is doped with Boron of density $1 \times 10^{20}\ \text{cm}^{-3}$ and the doping level of the n-substrate is $1 \times 10^{15}\ \text{cm}^{-3}$.



(a) Plot the energy-band diagram at thermal equilibrium for this MOS system. Label the position of the Fermi level. (5%)

(b) What is the flatband voltage? (5%)

(c) Assume at $V_G = V_T$, the voltage across the gate oxide from top to bottom interface is -0.6 V. Using the charge-sheet model, find the threshold voltage, V_T. (5%)

(d) Sketch the quasi-static C-V curve of this MOS-C and label the key turning points in the plot. (5%)

(e) In reality, the charge-sheet model causes certain error in calculating the threshold voltage. Assuming the inversion charge is uniformly distributed in a 1.5 nm-layer below the SiO_2/Si interface, estimate the threshold voltage considering finite inversion charge thickness. (5%)

6. Assume an n-MOSFET with uniformity p-substrate with doping level, N_a.

(a) How will the sub-threshold swing change with increased N_a? Provide qualitative explanations. (5%)

(b) How will the body effect coefficient change with increased N_a? Provide qualitative explanations. (5%)