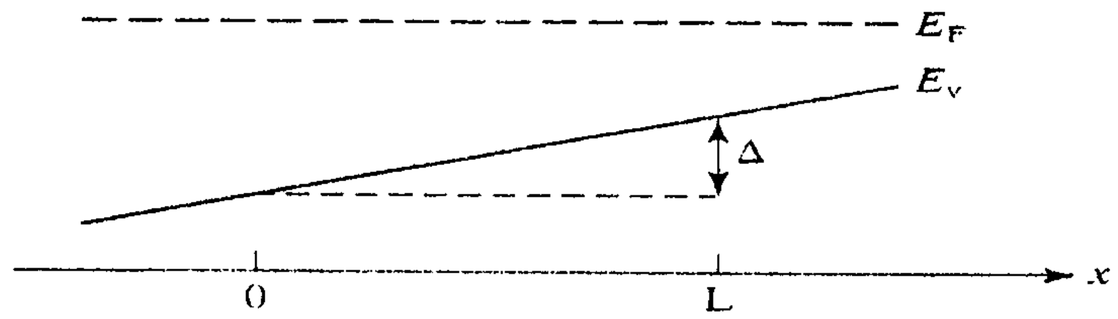
科目：固態電子元件(300H)　　校系所組：清華大學電子工程研究所

1. The energy band diagram of a P-type silicon bar is shown in the following figure.



(a) Find the electric field inside this silicon bar. (5%)

(b) Assuming the Boltzmann approximation is valid, find the electron concentration $n(x)$ assuming $n(0) = n_0$? (5%)

(c) Find the total electron current density. (5%)

2. Use the energy band diagram to show the event described below:

(a) An electron with kinetic energy = $E_g/4$. (5%)

(b) Band-to-band tunneling. (5%)

(c) Auger recombination. (5%)

3. An abrupt Si P^+-N junction, with a cross sectional area of 10^{-4} cm^2 and with the following properties, is forward-biased at 0.6 volts at 300 K. For silicon, the intrinsic carrier concentration at room temperature is $1.5x10^{10}/cm^3$, and $kT = 0.0259$ eV at room temperature.

On the P-side:

$N_A = 5 \times 10^{18}$ cm^{-3}, $D_n = 10$ cm^2/s, $\tau_n = 10^{-8}$ s, length of neutral region, $\ell_p = 200$ μm. $\mu_p = 50$ $cm^2/V\text{-}s$

On the N-side:

$N_D = 10^{16}$ cm^{-3}, $D_p = 20$ cm^2/s, $\tau_p = 10^{-6}$ s, length of neutral region, $\ell_n = 2$ μm. $\mu_n = 1080$ $cm^2/V\text{-}s$

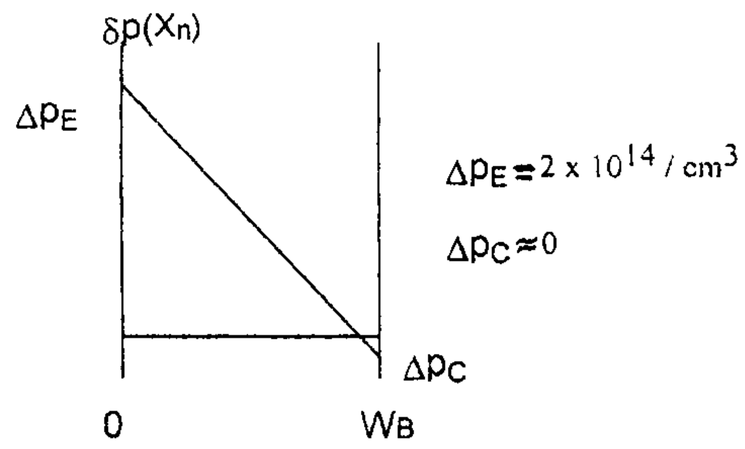
(a) Calculate the maximum and minimum value of the excess hole concentration, $\delta p(x_n)$, in the neutral n-region and indicate where they occur in the x_n-coordinate. (5%)

(b) Calculate the analytic expression of $\delta p(x_n)$ and plot the excess hole distribution for the entire neutral n-region, $0 \le x_n \le \ell_n$. You may use the "Straight-Line Approximation" if you can justify it. (5%)

(c) Determine the current in the diode. (5%)

(d) Estimate the electric field strength near the end of the neutral p-region, which is about 200 μm away from the space charge region. (5%)

4. The minority hole distribution within the base of a Si P-N-P transistor is sketched below. The cross-sectional area of the transistor is constant at 10^{-3} cm^2 and the relevant parameters for the emitter, base and collector regions are as follows:



Emitter: $N_A = 1x10^{18}/cm^3$, $\tau_p = \tau_n = 0.5$ μs, $\mu_n = 360$ $cm^2/V\text{-}s$, $\mu_p = 100$ $cm^2/V\text{-}s$, Neutral emitter width =100 μm.

Base: $N_D = 1x10^{17}/cm^3$, $\tau_p = \tau_n = 2$ μs, $\mu_n = 700$ $cm^2/V\text{-}s$, $\mu_p = 210$ $cm^2/V\text{-}s$, Neutral emitter width, $W_B = 0.8$ μm.

Collector: $N_A = 4x10^{16}/cm^3$, $\tau_p = \tau_n = 5$ μs, $\mu_n = 840$ $cm^2/V\text{-}s$, $\mu_p = 320$ $cm^2/V\text{-}s$, Neutral emitter width = 100 μm

For silicon, the intrinsic carrier concentration at room temperature is $1.5x10^{10}/cm^3$, and $kT = 0.0259$ eV at room temperature.

(a) Calculate the collector current at room temperature. (5%)

(b) Calculate the base current and the base-to-collector current amplification factor, β, for the present problem. (10%)

注意：背面有試題

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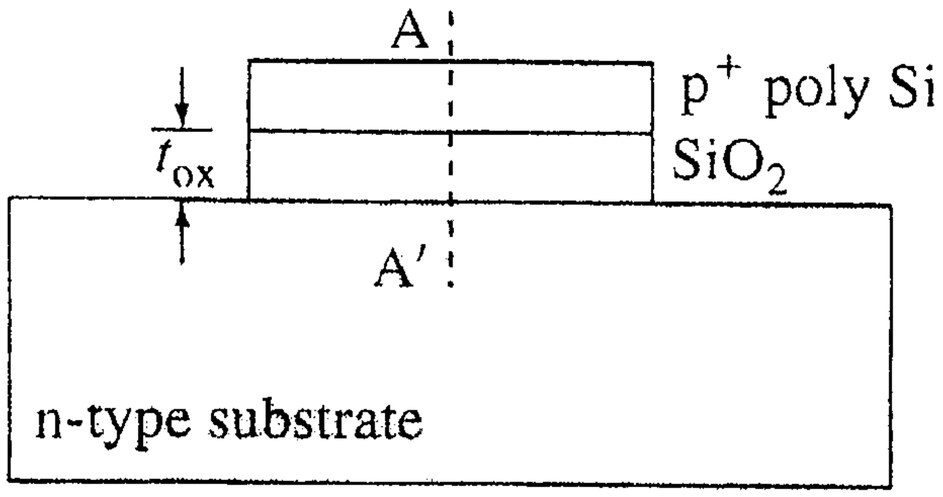
5. Consider a MOS capacitor as shown. Draw the band diagrams below (indicate E_c, E_v, E_i, and E_F),

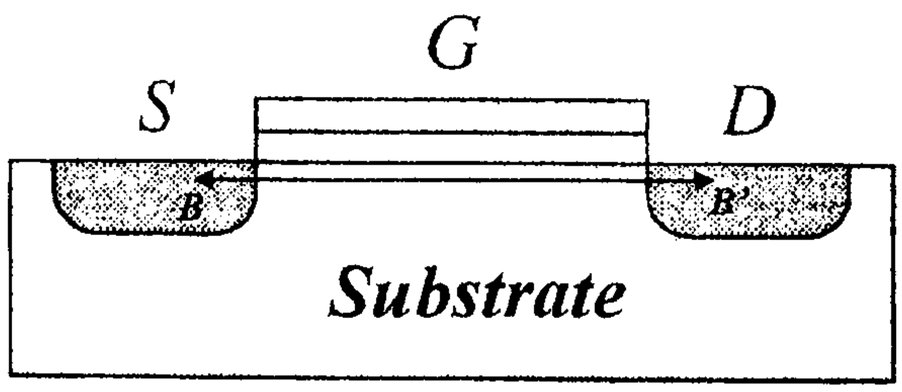


(a) Draw the band diagram at cross-section A-A'. (5%)

(b) Following (a), draw the band diagram with a **negative** voltage on n-type substrate. (5%)

(c) Following (b), Use n+ poly instead of p+ poly gate, draw the new band diagram at cross-section A-A'. (5%)

6. Consider an n-channel enhancement MOSFET as shown. Please answer the questions below:



(a) All terminals are grounded, draw the band diagram (E_c, E_i, and E_F) along the cross-section BB'. (5%)

(b) When the channel is formed ($V_{GS} = V_{TH}$, $V_D = V_S = V_{SUB} = 0$), draw the band diagram (E_c, E_i, and E_F) along the cross-section BB'. (5%)

(c) When $V_{GS} = V_{TH}$ and $V_D > (V_{GS} - V_{TH})$, indicate the region of maximum electrical field and the effective channel length. (5%)

(d) Explain output conductance and early voltage by the modulated effective channel length of (c). (5%)