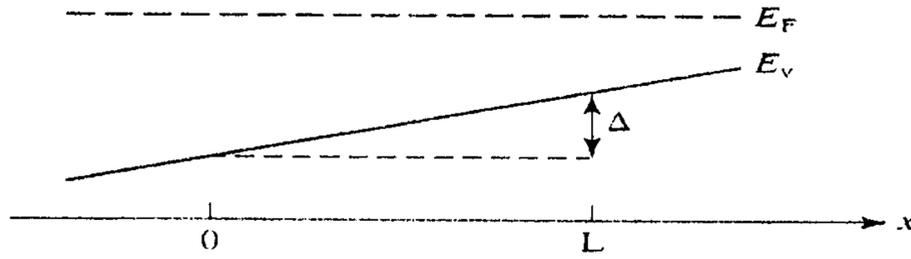


參考用

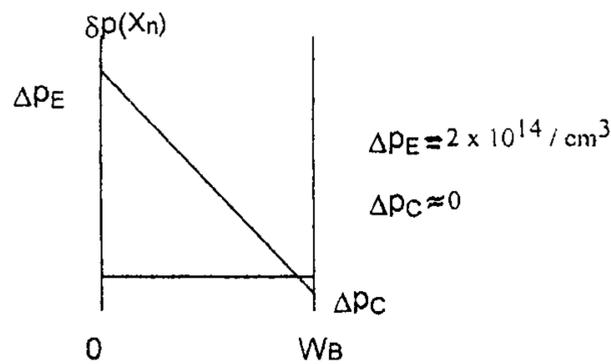
科目：固態電子元件(300H)

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<sup>+</sup>-N junction, with a cross sectional area of  $10^{-4}$  cm<sup>2</sup> 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  $1.5 \times 10^{10}$ /cm<sup>3</sup>, and  $kT = 0.0259$  eV at room temperature.
- On the P-side:  
 $N_A = 5 \times 10^{18}$  cm<sup>-3</sup>,  $D_n = 10$  cm<sup>2</sup>/s,  $\tau_n = 10^{-8}$  s, length of neutral region,  $\ell_p = 200$  μm.  $\mu_p = 50$  cm<sup>2</sup>/V-s
- On the N-side:  
 $N_D = 10^{16}$  cm<sup>-3</sup>,  $D_p = 20$  cm<sup>2</sup>/s,  $\tau_p = 10^{-6}$  s, length of neutral region,  $\ell_n = 2$  μm.  $\mu_n = 1080$  cm<sup>2</sup>/V-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,  $0 \leq x_n \leq \ell_n$ . 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<sup>2</sup> and the relevant parameters for the emitter, base and collector regions are as follows:



Emitter:  $N_A = 1 \times 10^{18}$ /cm<sup>3</sup>,  $\tau_p = \tau_n = 0.5$  μs,  $\mu_n = 360$  cm<sup>2</sup>/V-s,  $\mu_p = 100$  cm<sup>2</sup>/V-s, Neutral emitter width = 100 μm.

Base:  $N_D = 1 \times 10^{17}$ /cm<sup>3</sup>,  $\tau_p = \tau_n = 2$  μs,  $\mu_n = 700$  cm<sup>2</sup>/V-s,  $\mu_p = 210$  cm<sup>2</sup>/V-s, Neutral emitter width,  $W_B = 0.8$  μm.

Collector:  $N_A = 4 \times 10^{16}$ /cm<sup>3</sup>,  $\tau_p = \tau_n = 5$  μs,  $\mu_n = 840$  cm<sup>2</sup>/V-s,  $\mu_p = 320$  cm<sup>2</sup>/V-s, Neutral emitter width = 100 μm

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

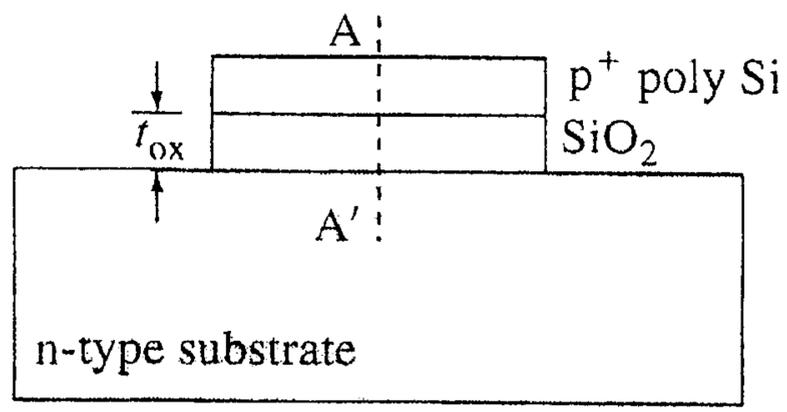
- (a) Calculate the collector current at room temperature. (5%)
- (b) Calculate the base current and the base-to-collector current amplification factor,  $\beta$ , for the present problem. (10%)

注意：背面有試題

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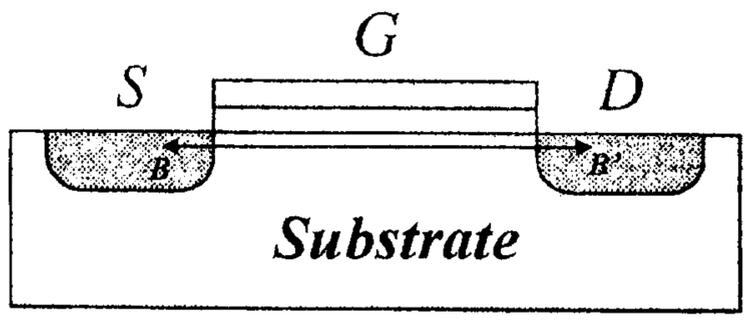
5. Consider a MOS capacitor as shown. Draw the band diagrams below (indicate  $E_c$ ,  $E_v$ ,  $E_i$ , and  $E_F$ ),



參考用

- (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%)