

類組：電機類 科目：固態電子元件(300G)

※請在答案卷內作答

1. For the material of Figure 1, there are two different effective masses (heavy / light) for electrons. Which effective mass will be the one displayed by most electrons in the conduction band? Explain why? (10%)

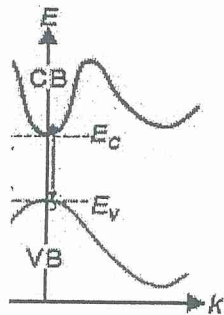


Figure 1

2. For a medium doped semiconductor with saturation velocity,  $v_{sat}=10^7$ cm/sec, and critical field (when drift velocity reaches  $v_{sat}$ ) equals  $10^4$ V/cm,
- Find its low-field mobility and sketch the plot of drift velocity vs. electric field. (10%)
  - Plot qualitatively its mobility as a function of temperature and explain why it increase or decrease with temperature. (10%)
3. Consider one side P+/N junction where  $N_D$  is  $10^{17}$  cm<sup>-3</sup>, this junction has the built-in voltage,  $V_{bi} = 1$ V and the depletion width is  $2\mu$ m for  $V_A=-2$ V external reverse bias. Please answer the problems as below, (15%)
- No external bias, what is the maximum electric field (V/cm)? (5%)
  - For  $V_A=-5$ V reverse bias, what is the depletion width ( $\mu$ m)? (5%)
  - Assume junction breakdown field is  $1$ MV/cm, what is the maximum reverse voltage (V) drop? (5%)
4. For a PN junction at forward operation, the total forward current is contributed by diffusion current  $J_{diff}$  and generation/recombination current  $J_{GR}$ , where  $J_{GR0} = 1000 \times J_{0(diff)}$ , please answer the problem below, (10%)
- For external bias  $V_A$ , write down the total forward current equation. (5%)
  - Plot  $I/V$  curve of the forward current, where  $V_A$  is as X-axis and  $J$  is as Y-axis. (5%)
5. Draw the energy band diagram ( $E_C$ ,  $E_V$ ,  $E_i$ ,  $E_F$ , the depletion region) for a PNP transistor in Figure 2 at following conditions, (10%)
- Active mode (5%)
  - Base Push-out effect (5%)

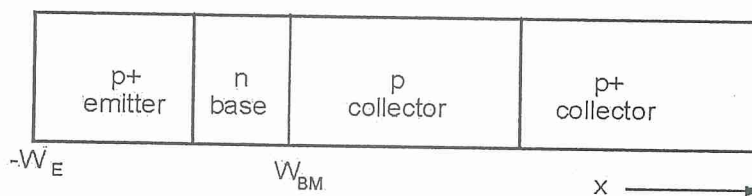


Figure 2

注意：背面有試題

參考用

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## 6. MOS capacitor (20%)

Assumed that there is an  $n^+ - poly - Si / SiO_2 / n - Si$  metal-oxide-semiconductor (MOS) capacitor; it is given that the thickness of  $SiO_2$  is  $t_{ox}$ , the doping level of the  $n - Si$  is  $N_D$  and the total area of the MOS capacitor is

A. Assumed futhermore that the work function of the  $n^+ - Poly - Si$  equals  $\chi_{Si}$ , which is the electron affinity of  $Si$ .

- Please plot the band diagrams of the MOS capacitor when the MOS capacitor is biased at equilibrium, depletion, threshold, flatband and accumulation, respectively. (10%)
- Supposed that there is no charge in the oxide and at the  $SiO_2 / Si$  interface and that the  $SiO_2$  is perfect insulator. Without derivation, please write down the threshold voltage  $V_{th}$  of this MOS capacitor. Other than those given above, please define the symbols you used. (5%)
- Describe how the fixed charges, interface traps, mobile ions in the MOS capacitor affect the  $V_{th}$  of this MOS capacitor. (5%)

## 7. MOSFET (15%)

- Please explain how enhancement-mode and depletion-mode MOSFETs are defined and their relationship to the threshold voltage in the case of an n-channel MOSFET. (5%)
- Please explain the sub-threshold slope of an n-channel MOSFET and how it affects the threshold voltage  $V_{th}$ . (5%)
- Please explain drain-induced barrier lowering in a short-channel n-channel MOSFET.? (5%)

參考用

注意：背面有試題