國立中山大學114學年度
碩士班考試入學招生考試試題

科目名稱：半導體概論【電機系碩士班甲組】

—作答注意事項—

考試時間：100分鐘

- **考試開始鈴響前不得翻閱試題，並不得書寫、劃記、作答。**請先檢查答案卷（卡）之應考證號碼、桌角號碼、應試科目是否正確，如有不同立即請監試人員處理。
- **答案卷限用藍、黑色筆(含鉛筆)書寫、繪圖或標示**，可攜帶橡皮擦、無色透明無文字墊板、尺規、修正液（帶）、手錶(未附計算器者)。每人每節限使用一份答案卷，請衡酌作答。
- 答案卡請以2B鉛筆劃記，不可使用修正液（帶）塗改，未使用2B鉛筆、劃記太輕或污損致光學閱讀機無法辨識答案者，後果由考生自負。
- 答案卷（卡）應保持清潔完整，不得折疊、破壞或塗改應考證號碼及條碼，亦不得書寫考生姓名、應考證號碼或與答案無關之任何文字或符號。
- 可否使用計算機請依試題資訊內標註為準，如「可以」使用，廠牌、功能不拘，唯不得攜帶書籍、紙張（應考證不得做計算紙書寫）、具有通訊、記憶、傳輸或收發等功能之相關電子產品或其他有礙試場安寧、考試公平之各類器材入場。
- **試題及答案卷（卡）請務必繳回，未繳回者該科成績以零分計算。**
- **試題採雙面列印，考生應注意試題頁數確實作答。**
- **違規者依本校招生考試試場規則及違規處理辦法處理。**

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科目名稱：半導體概論【電機系碩士班甲組】　　題號：431007

※本科目依簡章規定「可以」使用計算機（廠牌、功能不拘）（問答申論題）　

The dielectric constants of silicon and silicon dioxide (SiO_2) are 11.7 and 3.9, respectively.
The permittivity of vacuum is 8.85×10^{-14} F/cm.
Energy bandgap of Si: $E_g = 1.12$ eV, charge $q = 1.6 \times 10^{-19}$ C, kT = 25.9 meV at T = 300 K
Electron affinity of Si: $q\chi = 4.01$ eV. Intrinsic concentration of Si at T = 300 K: $n_i = 1.5 \times 10^{10}$ cm^{-3}.
Please note that all calculation answers must include the unit and calculation process.

1. (25%) A silicon pn junction in thermal equilibrium at $T = 300$ K is doped such that $E_F - E_{Fi} = 0.407$ eV in the n region and $E_{Fi} - E_F = 0.3474$ eV in the p region. In the p-type semiconductor, the diffusion coefficient of excess minority carriers is 25 cm^2/s, and the carrier lifetime is 0.5 μs. In the n-type semiconductor, the diffusion coefficient of excess minority carriers is 10 cm^2/s, and the carrier lifetime is 0.1 μs.
   (a) (15%) Calculate the total potential difference across the depletion region and the maximum electric field (E_{max}) for a pn junction under a reverse bias of 8 V.
   (b) (10%) Calculate the current density of holes (J_p) and electrons (J_n) at the edges of the depletion region when a forward bias of 0.72 V is applied.

2. (10%) For a silicon-based n^+-p one-side junction, the relationship between the capacitance density and the reverse bias voltage at T = 300 K is shown in Figure 1. Please calculate the doping concentrations of the p-type and n-type semiconductors (N_a and N_d, respectively).

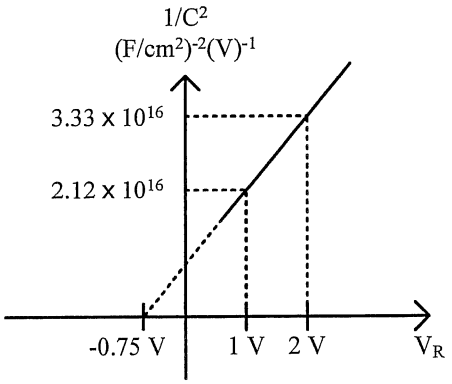

Figure 1

3. (10%) The I-V relationship of a diode can generally be expressed as $I = Is[\exp(qV_a/\mathbf{n}kT) - 1]$, where the parameter **n** is referred to as the ideality factor. What are the possible reasons for **n** = 2? Please provide two examples.

4. (15%) For a silicon-based p-i-n junction, the width of the intrinsic semiconductor is 1 μm, and the doping concentrations of the p-type and n-type semiconductors are 10^{16} cm^{-3} and 10^{17} cm^{-3}, respectively. At T = 300 K, calculate the following when a reverse bias of 8 V is applied:
   (a) (5%) The total depletion region width (W_{pin}).
   (b) (10%) The maximum electric field (E_{max}).

5. (20%) Consider an ideal tungsten-to-p-type silicon Schottky diode at a temperature of 300 K. The work function of tungsten is 4.55 eV, the doping concentration of the semiconductor is 3×10^{15} cm^{-3}, and the effective density of states in the conduction band and valence band for silicon are 2.8×10^{19} cm^{-3} and 1.04×10^{19} cm^{-3} respectively.
   (a) (10%) Calculate the ideal Schottky barrier height and the built-in potential of the semiconductor.
   (b) (10%) Calculate the depletion region width and the maximum electric field when a reverse bias of 8 V is applied.

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6. (20%) Consider a MOS capacitor with an n-type silicon substrate doped to $N_d = 10^{16}$ cm^{-3}, a silicon dioxide (SiO_2) insulator with a thickness of $t_{ox} = 20$ nm, and an n^+ polysilicon gate (assuming $E_F \approx E_C$). The threshold voltage (V_{th}) is defined as the gate voltage required to achieve strong inversion at the silicon surface, where the surface potential $|\psi_s| = 2\phi_F$.
   (a) (10%) Calculate the threshold voltage (V_{th}).
   (b) (10%) Calculate the capacitance density at flat-band (C_{FB}) and the minimum capacitance density (C_{min}) in the high-frequency C-V curve.