

科目：固態電子元件(5001)

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- Two impurities, A_1 and A_2 , are uniformly doped in crystal silicon, and the energy states of the two impurities, E_1 and E_2 , are shown in Fig.1. Assume the intrinsic density, $n_i = 1 \times 10^{10} \text{ cm}^{-3}$.
 - Which impurity is acceptor? Which impurity is donor? (5%)
 - Assume the two impurities are fully ionized, A_1 's concentration is $5 \times 10^{17} \text{ cm}^{-3}$ and A_2 is $1 \times 10^{18} \text{ cm}^{-3}$, what are the electron and hole concentrations in the silicon (cm^{-3})? (5%)
 - If without proper annealing process, the ionization rate of A_1 reduces to 50% and that of A_2 reduces to only 10%, what are the electron and hole concentrations (cm^{-3})? (5%)

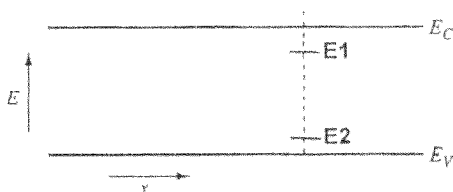


Fig. 1

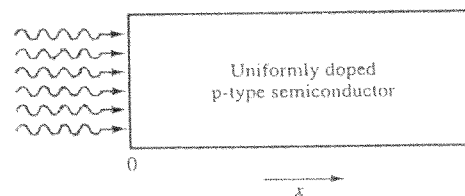


Fig. 2

- For a p-type silicon as shown in Fig.2, and there is a continuous uniform electron current flowing from the left to the right. Answer the following questions.
 - If electron mobility remains constant with temperature, how does the diffusivity, D_n , change with temperature? Any why? (5%)
 - Explain what govern the minority lifetime (τ_n) in a semiconductor material and how does τ_n affect the diffusion process? (5%)
 - Let electron density $n(x=0) = n_0$. Write down the expression of the electron concentration at $x > 0$, where the diffusion lengths are L_n for electrons and L_p for holes. (5%)
- Consider one n-type and one p-type crystal silicon have same doping concentration, 10^{16} cm^{-3} and the impurities are fully ionized at room temperature. ($\mu_n = 1200 \text{ cm}^2/\text{V}\cdot\text{s}$ and $\mu_p = 450 \text{ cm}^2/\text{V}\cdot\text{s}$)
 - Let the p-type silicon with length of 8cm and the cross-sectional area is 1 cm^2 and the n-type silicon has same cross-sectional area and resistance as the p-type silicon, what is the length of the n-type silicon? (5%)
 - There is an extra collision event (μ_x) added and which is affecting the electron conduction only. If the new total mobility of electron become $\mu_n = 600 \text{ cm}^2/\text{V}\cdot\text{s}$. What is the mobility of the extra collision event (μ_x) for electron? (5%)
- For a silicon (bandgap 1.1 eV) one-sided abrupt $P^+ - N$ junction under zero bias and room temperature:
 - (4%) Give an expression for the depletion layer width using the built-in potential V_{bi} and the N-type doping N_D .
 - (4%) If the Fermi level is 0.2 eV higher than the mid-gap in the neutral N-type region, find V_{bi} .
 - (2%) If the $P^+ - N$ junction is reverse-biased, the junction capacitance will become larger, smaller, or unchanged?

注意：背面有試題

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5. A silicon (bandgap 1.1 eV) P-N junction at thermal equilibrium can be separated into three distinct regions: (i) the quasi-neutral region with a constant doping N_A on the p-side; (ii) the depletion region around the junction; and (iii) the quasi-neutral region with an exponential impurity distribution on the n-side: $N_D(x) = N_{D0} \exp(-x/\lambda)$. Here, N_{D0} is constant; λ is constant and is smaller than the length of the n-side; and $x = 0$ represents the depletion edge of the n-side.
 - (a) (5%) Draw the energy band diagram of the junction at thermal equilibrium (quasi-Fermi levels must be included).
 - (b) (5%) The built-in electric field is developed across the quasi-neutral region in n-side. Derive an analytic expression for this field.

6. For a silicon P-N junction at 300K, the typical I-V characteristic at reverse bias is shown in the Fig.3.
 - (a) (5%) Please explain the reason why the leakage current increases with the increase of reverse bias.
 - (b) (5%) Please sketch the I-V characteristics of the same P-N junction at 350K, 400K, and 500K schematically.

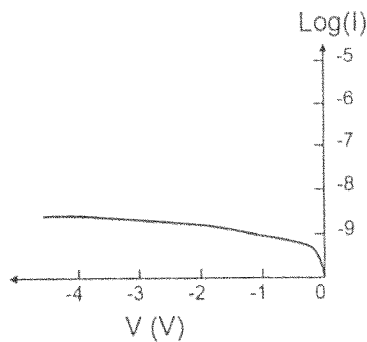


Fig. 3

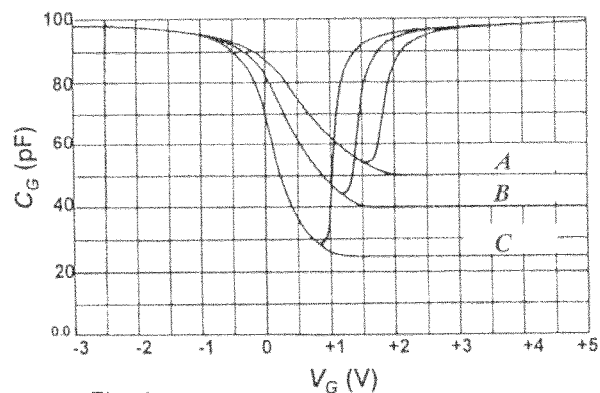


Fig. 4

7. Fig. 4 shows the measured C-V curves of n^+ -poly-Si/SiO₂/Si MOS capacitors. Assume that MOS capacitors A, B, and C have identical fabrication process and layout geometry except for different substrate doping levels, 10^{15} cm^{-3} , 10^{16} cm^{-3} , 10^{17} cm^{-3} , respectively.
 - (a) What is the type (*n* or *p*) of the substrate dopant? (3%)
 - (b) Which curve belongs to device A? why? (6%)
 - (c) What is the surface potential of device B when it is biased at threshold voltage. Plot the corresponding band diagram assuming that *poly-Si* is so heavily doped that it can be taken to be a metal. (6%)

8. Consider an n-MOSFET ($L_g = 0.1 \mu\text{m}$) with a uniformly doped p-substrate (N_a),
 - (a) How will the threshold voltage change with increasing N_a ? Provide qualitative explanation. (5%)
 - (b) How will the subthreshold swing S ($\delta V_{GS} / \delta \log I_D$) change with increasing N_a ? Provide qualitative explanation. (5%)
 - (c) How will the drain-induced barrier lowering (DIBL) change with increasing N_a ? Provide qualitative explanation. (5%)