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※請在答案卷內作答

1. Consider a silicon sample is doped with $1 \times 10^{16}\ cm^{-3}$ phosphorus. How the following parameters will change (increase, decrease, or does not change) as the temperature of the sample is increases from 25 °C to 100 °C. Give also a brief justification of your choice.
   (a) Electron concentration n. (4%)
   (b) Hole concentration p. (4%)
   (c) Electron mobility μ_n. (4%)
   (d) Location of the Fermi level, i.e. $E_f - E_i$. (5%)

2. Use the energy band diagram to show the event described below:
   (a) The existence of a constant electric field. (4%)
   (b) An electron with kinetic energy = $E_g/2$. (4%)
   (c) Recombination via a mid-gap G-R center. (4%)
   (d) Band-to-Band tunneling. (5%)

3. For an abrupt PN junction made of Si, the acceptor (donor) concentration in the p (n) region is N_A (N_D). The width of neutral n- (p-) region is denoted as W_p (W_n). Assumed both contacts to electrodes are Ohmic and need not be taken into account.
   (a) Assumed that both W_p and W_n are much larger than the diffusion lengths of their respective minority carriers, please plot the band diagram of this PN junction at a small forward bias (say, 0.3V). You must include E_c、E_i、E_v and both quasi-Fermi levels in your band diagram. (4%)
   (b) Continued to (a) and alongside with the band diagram, please plot the distribution of carrier contraction, both of electron and hole, for this forwardly biased PN junction. Repeat plotting again the current density, both of electron and hole, in a separate plot. (6%)
   (c) Without derivation, write down the current density as a function of the applied bias voltage for a PN junction at small and moderate forward bias. You must include both generation/recombination in depletion and neutral regions. (4%)
   (d) Repeat (c), albeit with a forwardly biased PN junction in which both W_p and W_n are much smaller than the diffusion lengths of their respective minority carriers. (3%).

注意：背面有試題

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4. For an npn bipolar junction transistor (BJT) of uniform cross section, denote as N_E, N_B, N_C (W_E, W_B, W_C) for the doping levels (width of neutral region) of the emitter, the base and the collector, respectively. Assumed all contacts to electrodes are Ohmic and need not be taken into account.

   (a) Please plot the band diagram of this BJT at active bias mode, that is, with forwardly biased EB junction and reversely biased BC junction. You must include E_c、E_i、E_v and both quasi-Fermi levels in your band diagram. (4%)

   (b) Explain why such an actively biased BJT exhibits high (>>1) current gain β, which is defined as the ratio of collector current to base current, whereas two head-to-head connected conventional pn diodes do not. (6%)

   (c) Plot the current gain β of an actively biased npn BJT as a function of the collector current and explain the trend, i.e., why β increases/decreases. (6%)

5. For a silicon n-channel MOSFET, assume that the gate-to-substrate work function difference ϕ_{ms} = −1.4 eV, gate oxide thickness =10 nm, N_a=10^{18} cm^{-3}, and fixed oxide charge of $5 \times 10^{10} \times e$ C/cm^2 where $e = 1.6 \times 10^{-19}$ C.

   (a) Calculate the threshold voltage V_T of this MOSFET for the substrate bias of −2.5 V and the source voltage of 0 V. (10%)

   (b) Calculate the threshold voltage V_T of this MOSFET for the substrate bias of 0 V and the source voltage of 0 V. (10%)

6. For an ideal MOSFET, please derive the expressions of transconductance in the linear region and in the saturation region, respectively, and state the dependence of the transconductance on V_{DS} and V_{GS} for both cases. (13%)