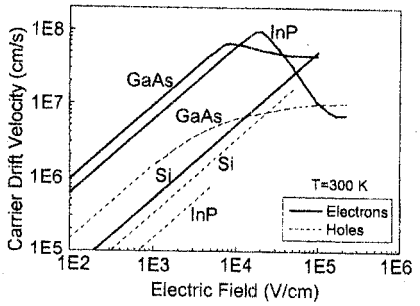
所別：電機工程學系碩士班 乙組(一般生) 科目：半導體元件 (學位在職生)

1. (a) (10%) Explain the direct semiconductor (direct bandgap) and indirect semiconductor (indirect bandgap), and give one example for each semiconductor. (b) (5%) If silicon (Si) is doped with Arsensic (As) atom, what kind of type Silicon will be? n-type or p-type? Why? (c) (5%) If GaAs is doped with silicon (Si), what kind of type GaAs will be? n-type or p-type? Why?
2. (10 %) Note in the following figure that for GaAs, the electron drift velocity reaches a maximum then decreases as the electric field further increases. Explain the reasons for the change in drift velocity.



3. (20%) Explain and deduce equations for the depletion capacitance and diffusion capacitance in a p-n junction (one-sided abrupt junction) diode, respectively.

4. (a) (5%) Explain the conditions of the cutoff, saturation, and inverse-active modes in a bipolar transistor. (b) (5%) Describe what is meant by flat-band voltage in a MOSFET.

5. (10%) Assuming the ideal linear electron contribution in the base of an npn transistor, the collector current in active mode can be written as a diffusion current given by $i_C \propto \frac{dn(x)}{dx}$ and $i_C = I_S \exp(V_{BE}/V_t)$, where V_t is the thermal voltage. Find the expression of I_S in terms of D_n, A_{BE}, x_B, and n_{B0}, where D_n is the electron diffusivity, A_{BE} is the cross-sectional area of the B-E junction, x_B is the neutral base width, and n_{B0} is the thermal equilibrium electron concentration in the base.

6. (10%) Consider an npn bipolar transistor biased in the active mode. Using the Ebers-Moll model, derive the equation for the base current, I_B, in terms of α_F, α_R, I_{ES}, I_{CS}, and V_{BE}. Note that the currents are defined as all entering the terminals so that $I_E + I_B + I_C = 0$.

7. (a) (3%) Sketch the C-V characteristics of an MOS capacitor with an n-type substrate under the low-frequency condition. (b) (3%) How do the characteristics change for the high-frequency condition. (c) (4%) Explain the physical origin for the difference between (a) and (b).

8. (10%) Using superposition, the shift in the flat-band voltage due to a fixed charge distribution $\rho(x)$ in the oxide can be given by $\Delta V_{FB} = a \int_0^{t_{ox}} x\rho(x)dx$. Find the expression of a in terms of ϵ_{ox}, where ϵ_{ox} is the permittivity of the oxide.