1. properties of semiconductors (30%)

(a) Derive the Einstein relationship between carrier mobility and carrier diffusion constant (diffusion coefficient).

(b) Supposed now we have a high-quality Si sample held at room temperature, write down the typical value and unit for electron diffusion constant. Only order of magnitude is important.

(c) It is usually found that the carrier mobilities in MOS channel are significantly smaller than the typical values of carrier mobilities in bulk Si. Explain why.

(d) For an epitaxial Si film doped with As to doping level $N_D = 1 \times 10^{17} \, cm^{-3}$ and of 1 μm in thickness, calculate the resistivity and sheet resistance. Supposed the sample is kept at room temperature.

(e) Explain what dielectric relaxation time is and calculate the dielectric relaxation time for the Si film in (d).

2. Plot the major current components and terminal currents in the cross sectional area of an active-biased prototype pnp BJT. (7%) Define the emitter injection efficiency. (3%)

3. Plot the doping profile of a real vertical pnp BJT from emitter to the epitaxially grown collector. (5%) What is the effect of the graded-base on the transistor properties? (5%)

4. Explain the following terms:

(a) Interdigitated contact (5%),

(b) Kirk effect (5%),

(c) HBT (5%).

5. A semiconductor is in contact with a metal. The work function of the semiconductor is Φ_s and the work function of the metal is Φ_m. Assuming that the effect of the surface states can be neglected, plot the ideal energy band diagrams between the metal and the semiconductor under the following conditions: (a) n-type semiconductor with $\Phi_s \langle \Phi_m$, (b) n-type semiconductor with $\Phi_s \rangle \Phi_m$, (c) p-type semiconductor with $\Phi_s \langle \Phi_m$, (d) p-type semiconductor with $\Phi_s \rangle \Phi_m$. (15%)

6. A metal-oxide-semiconductor (MOS) capacitor with p-type semiconductor is biased under the condition of surface inversion. A large enough positive voltage V is applied to the metal gate. Draw the following diagrams: (a) the energy band diagram of the MOS capacitor. (b) the charge distribution in the MOS capacitor structure. (c) the electric field distribution in the MOS capacitor structure, (d) the electric potential distribution in the MOS capacitor structure.
There are normally four types of charges distributed in the oxide layer. List the four types of charges and briefly explain the origin of these charges.
(20%)