EE 203. HW2 Due Monday, 5/5 Use App H of Sze for material parameters.

1. Calculate the exact position of the Fermi level of intrinsic Si at T=300K. (Use values from App. H of Sze)

2. Consider a GaAs sample doped to 2 x 10^{15} / cm^3 with Si.

(a) If the Si all goes in substitutionally for Ga atoms, do the Si atoms act as donors or acceptors?

(b) Using Fig. 13 of Sze, determine the energy level of the Si state relative to E_c or E_v.

(c) If the Si goes in substitutionally for the As atoms, determine the energy level of the Si state relative to E_c or E_v.

3. Show that the electronic conduction in Si due to the motion of electrons in the conduction band is isotropic. (Hint: Compute the average value of the acceleration (in the absence of scattering) including the response of electrons in all 6 conduction band valleys. Generate the effective mass matrix for each valley and average. If the acceleration is colinear with the force, then isotropic).

4. For an applied force, the average acceleration (in the absence of scattering) of a conduction band electron obeys

$$\mathbf{a} = \frac{1}{m_{ce}^*}\mathbf{F}$$

where m_{ce}^* is the conductivity effective mass. As a result of (3) above, (a) show that the conductivity effective mass for electrons in Si is given by

$$\frac{1}{m_{ce}^*} = \frac{1}{3}\left(\frac{1}{m_l} + \frac{2}{m_t}\right)$$

(b) In terms of m_0, calculate both the conductivity and density-of-states effective mass for the conduction band of Si using values from App. H of Sze. (Give the answer as αm_0. I do not want an answer in kg. I want α.)

5. What is the electron conductivity and density-of-states effective mass of GaAs? Ge?

6. Calculate scattering time τ corresponding to a mobility of 200 cm^2/Vs in n-type Si (which effective mass should you use?).

7. What would be the resulting mobility in n-type GaAs and Ge for that same scattering time?

8. Consider a GaAs sample with an acceptor concentration of 2×10^{16} / cm^3.

(a) Calculate the density of holes in the light hole band at T=300K.

(b) Calculate the Fermi level at T=300K.

9. A Si sample with a uniform donor density of 2×10^{6}/cm^3 is uniformly illuminated such that 10^{22} electron-hole pairs are created per cm^3 per second. Due to the action of midgap R-G centers, $\tau_n = \tau_p = 1$ µs. Calculate the electron and hole concentrations at T=300K in steady-state. (Note: this is **NOT** low level injection. You **cannot** use the minority carrier diffusion equations).

10. One of the standard metal contact alloys for GaAs is Ni/Au/Ge applied by electron beam evaporation. Do you want to use the same GaAs e-beam evaporation equiment for your Si devices? Why? (Hint, think R-G centers and Fig. 13 of Sze).

11. Si wafers are specified by their doping type and their resistivity in Ω-cm.
(a) If you need an n-type wafer doped 10^{18} / cm^3, what resistivity should you ask for?
(b) A lightly doped p-type wafer for a CMOS process might be 5 Ω-cm. What is the doping?
(Hint. People simply refer to plots such as Fig. 2.8 of Taur or Fig. 21 of Sze).