

EE128 Homework Set 1

Question 1:

1. An intrinsic semiconductor has an electron concentration of $1 \times 10^9 \text{ cm}^{-3}$, what is the hole concentration?
 - a. The hole concentration in an intrinsic semiconductor equals the electron concentration, in this case, $1 \times 10^9 \text{ cm}^{-3}$.
2. If a Si wafer is doped with $10^8 \text{ As atoms/cm}^3$. Will the Si be n-type, p-type or intrinsic at room temperature, if $n_i = 1.5 \times 10^{10} \text{ cm}^{-3}$ at room temperature?
 - a. The Si will still be intrinsic because the doping concentration is less than two orders of magnitude than the intrinsic concentration.
3. Which semiconductor would be better suited for high temperature (Pick a Temp between 400K and 500K) operation, GaAs or SiC? Justify your answer by comparing the approximate ratios of $n_{i\text{GaAs}}:n_{i\text{SiC}}$.
 - a. SiC because its bandgap is much larger than that of GaAs, and its intrinsic range of temperature will be higher than that of GaAs. SiC is also more tightly bound than GaAs so that it can physically withstand the increased temperature. The equation for the intrinsic semiconductor density is:

$$n_i = 2 \left(\frac{2\pi kT}{h^2} \right)^{3/2} (m_n^* m_p^*)^{3/4} e^{-\frac{E_g}{2kT}}$$

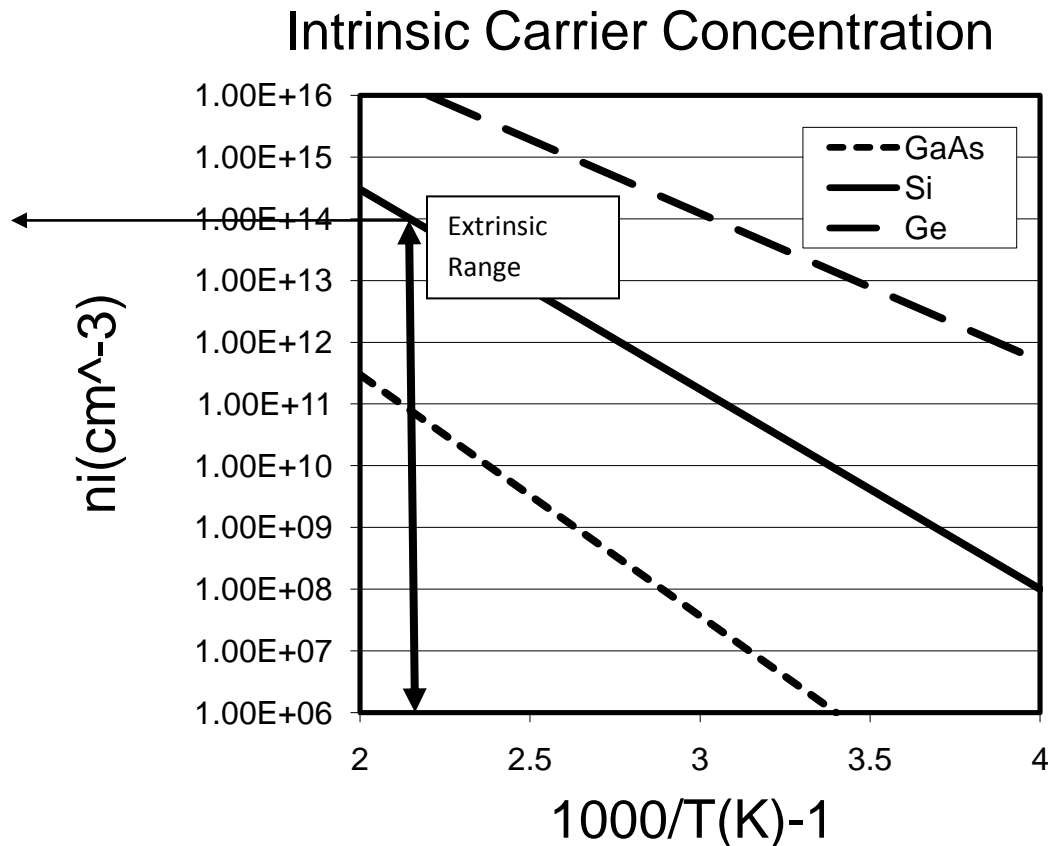
Type equation here.

If we assume that the effective mass difference in GaAs and SiC is insignificant, then the ratio of the respective n_i 's is:

$$\frac{n_{i\text{SiC}}}{n_{i\text{GaAs}}} = \frac{e^{-\frac{E_{g\text{SiC}}}{2kT}}}{e^{-\frac{E_{g\text{GaAs}}}{2kT}}} = e^{-\frac{E_{g\text{SiC}} - E_{g\text{GaAs}}}{2kT}}$$

4. SiC is a compound semiconductor made up of elements from group IV of the periodic table. Which group of elements should behave as acceptors (make p-type SiC) and which should behave as donors (make n-type SiC)?
 - a. Elements from column three of the periodic table should behave as acceptors with Al and B being the most commonly used elements for this purpose. Elements from column five of the periodic table should behave as donors with As and P being the most commonly used elements for this purpose.

5. Indicate on the chart below which temperature range Si doped with 10^{14} B atoms/cm³ will be intrinsic.



6. In the non-intrinsic temperature range, Si doped with 10^{14} P atoms/cm³ will be either (choose one) n-type p-type or amphoteric?
- If it is in the extrinsic range, then P being in column 5 of the period table, the Si will be n-type.
7. Label which energy band diagrams below are p-type, which are n-type, and which are intrinsic.
- P-type, A
 - N-type, C
 - Intrinsic B
8. Label which energy band diagrams are under thermal equilibrium.
- All are under TE given that the slope of the Fermi level is zero.
9. Label which energy band diagram represents a semiconductor with the highest intrinsic carrier concentration compared with the other three. (All are at same temperature.)
- A, it has the smallest bandgap and therefore the largest n_i for a given temperature.

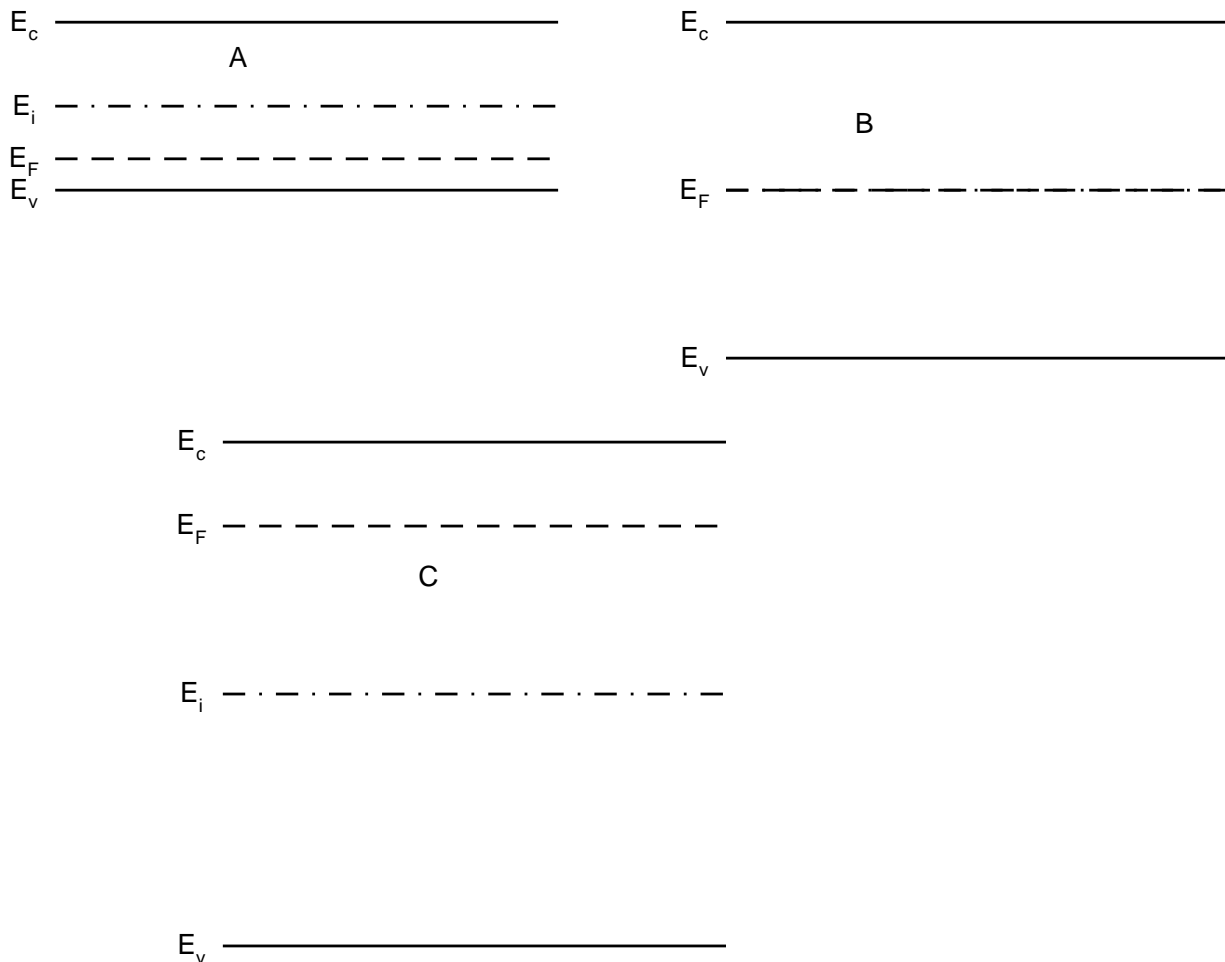


Figure 1: Figures for questions 7, 8, and 9.

10. Since the effective mass of electrons in a conduction band decreases with increasing curvature of the band according to Equation 3-3 in the text, comment on the electron effective mass in the Γ valley of GaAs compared to the indirect valley or L valleys (fig 3-10).
 - a. The electron effective mass will be larger in the L valleys.
11. How is the effective mass difference reflected in the electron mobility for GaAs and GaP as shown in Appendix III?
 - a. A semiconductor's effective mass shows up in mobility. The larger effective mass for electrons in GaP shows up as a smaller mobility, when compared to GaAs.
12. From figure 3-10 what would you expect to happen to the conductivity of GaAs if the Γ valley electrons drifting in an electric field were suddenly promoted to the L valley?

a. I would expect the mobility to decrease giving rise to negative differential resistance.

13. How long does it take an average electron to drift 1 micron in pure Si at an electric field of 100V/cm? Repeat for 10^5 V/cm.

$$\mu_n := 1350 \frac{\text{cm}^2}{\text{V}\cdot\text{s}}$$

$$\text{Distance} := 1 \cdot 10^{-4} \text{ cm}$$

$$\text{Efield} := 100 \frac{\text{V}}{\text{cm}}$$

$$\text{Velocity} := \mu_n \cdot \text{Efield}$$

$$\text{Velocity} = 1.35 \times 10^5 \frac{1}{\text{s}} \text{ cm}$$

$$\text{Time} := \frac{\text{Distance}}{\text{Velocity}}$$

$$\text{Time} = 7.407 \times 10^{-10} \text{ s}$$

We have to use the saturation velocity from figure 3-24 page 106.

$$\text{Velocity} := 10^7 \frac{\text{cm}}{\text{s}}$$

$$\text{Time} := \frac{\text{Distance}}{\text{Velocity}} \quad \text{Time} = 1 \times 10^{-11} \text{ s}$$