MATRL 100A: Structure and Properties I, Problem Set 7

This problem set is due in lecture on **Wednesday, Dec 5** in hard copy. Write neatly, show your work clearly, and include units in all answers. While you are free to discuss this problem set with your classmates, the product that you turn in must be your own work. Do not copy or paraphrase each other's work or copy solutions from the internet.

Chapter 19, Thermal properties

1. To what temperature would 12 kg of a 1025 steel specimen at 25°C be raised if 170 kJ of heat is supplied?

2. To what temperature must a cylindrical rod of tungsten 10.000 mm in diameter and a plate of 316 stainless steel having a circular hole 9.988 mm in diameter have to be heated for the rod to just fit into the hole? Assume that the initial temperature is 25°C.

3. Briefly explain thermal expansion using the potential energy-versus-interatomic spacing curve.

4. For each of the following pairs of materials, decide which has the larger thermal conductivity. Justify your choices.

   (a) Pure copper; aluminum bronze (95 wt% Cu-5 wt% Al)

   (b) Fused silica; quartz

   (c) Linear polyethylene; branched polyethylene

   (d) Random poly(styrene-butadiene) copolymer; alternating poly(styrene-butadiene) copolymer

Chapter 18, Electrical Properties

1. (a) Compute the electrical conductivity of a 6 mm diameter cylindrical silicon specimen 50 mm long in which a current of 0.15 A passes in an axial direction. A voltage of 8.9 V is measured across two probes that are separated by 40 mm.

   (b) Compute the resistance over the entire length of the specimen.

2. Draw the electron band structure of an insulator, a semiconductor, and a conductor. Briefly, how does this difference lead to differences in electrical conductivity?

3. (a) Using the data presented in Figure 1, determine the number of free electrons per atom for intrinsic germanium and silicon at 400 K. The densities for Ge and Si are 5.32 and 2.33 g/cm^3, respectively.

   (b) Now explain the difference in these free-electron-per-atom values.

4. For intrinsic semiconductors, the intrinsic carrier concentration n_i depends on temperature as follows:

$$n_i \propto \exp\left(-\frac{E_g}{2kT}\right)$$

   or, taking natural logarithms,

$$\ln n_i \propto -\frac{E_g}{2kT}$$

Thus, a plot of $\ln n_i$ versus 1/T (K^{-1}) should be linear and yield a slope of $-E_g/2k$. Using this information and the data presented in Figure 1, determine the band gap energies for Si and Ge, and compare these values with those given in Table 18.3 in your book. Using the graphing software of your choice (Excel, MATLAB, Mathematica, etc.) plot at least six values of $\ln n$ vs 1/T to calculate the slope. Attach a computer printout of your plot.

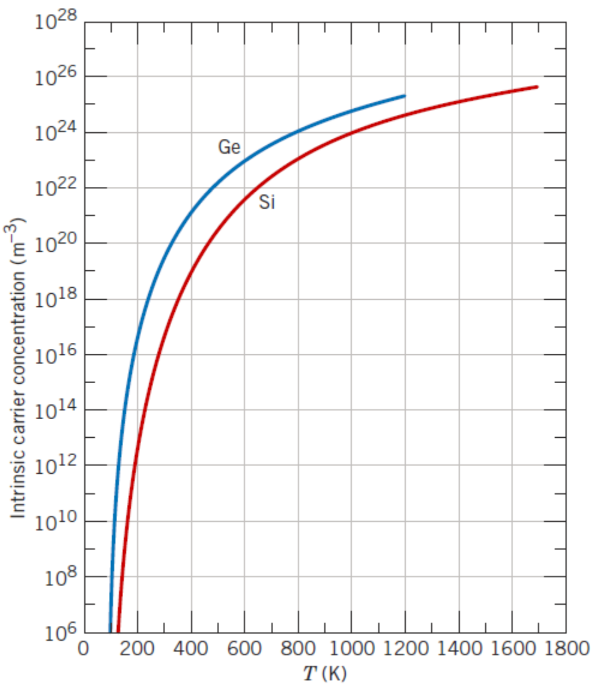

Figure 1: Intrinsic Carrier Concentration vs T

5. Table 1 gives possible substitutional impurities for 5 semiconductors. For each system, write down which atom in the semiconductor the impurity will substitute for and whether the impurity will act as a donor or an acceptor on that site.

Table 1: Dopants in Semiconductors

Impurity	Semiconductor
N	Si
B	Ge
S	InSb
In	CdSe
As	ZnTe