Solve the following problems:

1. A silicon ingot that should contain $10^{16}$ phosphorus atoms/cm$^3$ is to be grown by the Czochralski method.

   (a) Determine the concentration of phosphorus atoms in the melt to give the required concentration in the ingot.

   (b) The crucible initially contains 50 kg of molten silicon. Determine how many grams of phosphorus should be added:

   Given: for phosphorus the segregation coefficient, defined as the ratio of the concentrations of the impurity in the solid to that in the liquid, is 0.35, density of Si = 2.53 g/cm$^3$, atomic weight of phosphorus = 30.98 g/mole, and Avogadro's number = $6.023 \times 10^{23}$ atoms/mole.

2. Silicon crystallizes in the diamond structure as shown below. The dimension of the unit cell of this basically cubic structure is 5.43 Å (1 Å = $10^{-8}$ cm). The atomic weight of silicon is 28.1. Find (a) the nearest-neighbor distance between atoms (the bond length); (b) the atomic radius of a silicon atom in this structure; and (c) the density of silicon using the above data.

3. Determine the thickness of silicon that is consumed when a silicon dioxide layer of thickness $x_o$ is grown on the surface by thermal oxidation.

4. Semiconductor material A has an energy gap of 0.36 eV, while semiconductor material B has an energy gap of 0.72 eV. Compare the intrinsic density of carriers in
these two semiconductor materials at 300 K. Assume that the effective masses of all the electrons and holes are equal to the free electron mass.

(5) Given the n-type semiconductor silicon at 300 K with an energy gap of 1.12 eV. The material contains only donor-type impurities, all of which are ionized. The donor density is $1.0 \times 10^{16}$ cm$^{-3}$. Calculate the Fermi energy.

(6) At 300 K the conductivity of intrinsic silicon is $5 \times 10^{-4}$ $\Omega^{-1}$cm$^{-1}$. If the electron and hole mobilities are 0.14 and 0.05 m$^2$/Vs, respectively, what is the density of electron-hole pairs? If the crystal is doped with $10^{22}$ m$^{-3}$ phosphorus atoms calculate the new conductivity; repeat for the case of boron doping at the same impurity level. Assume all of the impurities are ionized in both cases.

For further reading on semiconductors/electronic materials and their processing see:


* Solutions are due on ?????