ECE 418 / ECE 518 - Semiconductor Processing  
Spring 2020  
Homework 1  
Due at the beginning of class Wednesday April 15th

Question 1 [6 marks]:
Gallium arsenide (GaAs) adopts the Zinc blende crystal structure (see Figure 1). The zinc blende structure is cubic, and similar to the diamond crystal structure (adopted by silicon), but the two interpenetrating face-centered-cubic structures consist of different atoms. The lattice constant in GaAs is a = 5.65 Å. The mass of Ga atoms are 69.72 amu and the mass of As atoms are 74.92 amu. You will need to know that 1 amu = 1.66 × 10⁻²⁷ kg.

a) What is the nearest neighbor distance between gallium and arsenic atoms (in Å)? [2 marks]  
b) What is the atomic density of gallium arsenide (in atoms/cm³)? [2 marks]  
c) What is the mass density of gallium arsenide (in g/cm³)? [2 marks]

Figure 1: Crystal structure of gallium arsenide.

Question 2 [9 marks]:
a) Explain why we require high purity silicon for microelectronics.[2 marks]  
b) Explain why we require single-crystal (rather than polycrystalline or amorphous) silicon for microelectronics.[2 marks]  
c) As part of an industrial process, the top-half a phosphorus-doped silicon ingot is used for some further processing. Using the normal freezing relationship, determine the average phosphorus concentration (in atoms/cm³) throughout the top half of an ingot pulled from a melt containing an impurity concentration of 1×10¹⁶ cm⁻³. Remember, X in the normal freezing relation is the fraction of the melt solidified. So if X = 0.25 for example, 25% of the melt has been solidified and 75% remains as liquid. The segregation coefficient for phosphorus in silicon is 0.35. [5 marks]

Question 3 [10 marks]:
a) For clean Si(111) surfaces it has been determined that the sticking coefficient for O₂ is \( S_c = 0.15 \) for coverages of < 0.7 monolayer, and \( S_c = 0.015 \) for coverages > 0.7 monolayer. How long will it take to for 1 monolayer of O₂ to be adsorbed on the Si(111) surface at an oxygen pressure of 1.0×10⁻³ torr and at 25º C? Use the assumption that an O₂ monolayer will be formed of a square lattice of O₂ molecules on the surface. Assume the diameter of O₂ molecule is 2.96Å. Give your answer in hours. [7 marks]  
b) Provide a reason why a cryogenic pump is designed to adsorb helium and hydrogen atoms rather than condense them.[1 mark]  
c) Very briefly explain why Turbomolecular pumps cannot be run until they are already under a vacuum.[2 marks]