ECE 340 # Homework Assignment #1 **Spring 2016**

DUE: FRIDAY, JANUARY 29, 2016

PRINT YOUR **NAME** AND **NETID** LEGIBLY. FOLLOW THE GUIDELINES AND FORMAT GIVEN IN THE SYLLABUS. STAPLE MULTIPLE PAGES. SHOW ALL UNITS. HOMEWORK MUST BE TURNED IN AT THE **BEGINNING** OF CLASS AND ANY LATE HOMEWORK ASSIGNMENTS WILL NOT BE ACCEPTED. PLEASE CONTACT THE COURSE COORDINATOR, PROFESSOR DALLESASSE, SHOULD ANY ISSUES WITH LATE HOMEWORK ARISE.

1. COMMON UNITS OF MEASUREMENT IN SEMICONDUCTORS

A convenient unit of length for the description of solids is the nanometer (nm), which corresponds to the order of magnitude of typical distances between atoms in crystals (actual distances are between 0.1 nm and 1.0 nm). Many older texts use the angstrom (Å), which equals 0.1 nm. A convenient unit of energy is the electronvolt (eV), defined as the energy gained by moving an electron through a potential difference of 1 V. Temperature is also almost always given in units of kelvin (K).

(A). Given the definition of an electronvolt, what is the mathematical relationship between electronvolts and joules?

(B). What is the room temperature (T = 300K) value of $k_B T$ (where $k_B = 1.38 \times 10^{-23}$ J/K is the Boltzmann constant) in units of electronvolts?

(C). Given a solid with an atomic density (atoms per unit volume) of 10 $Å^{-3}$, what is the atomic density in cm^{-3}?

2. LATTICE AND CRYSTAL STRUCTURES

Complete the following questions for the (1) simple cubic (sc) lattice, (2) body-centered cubic (bcc) lattice, (3) facecentered cubic (fcc) lattice, (4) diamond crystal structure, and (5) zinc blende crystal structure:

(A). Calculate the total number of atoms found inside the unit cell lattice. Remember to pay special attention to atoms on the boundary of the unit cell itself.

(B). Calculate the nearest neighbor distance assuming a lattice constant of a.

(C). Calculate the packing fraction (the maximum fractional volume of the unit cell that can be occupied by hard spheres). ***You can ignore zinc blende for this calculation***.

(D). Assuming a lattice constant of a for each lattice or crystal structure, which one has the largest atomic density? The smallest?

3. DENSITY OF CRYSTAL

For the following problems, use lattice constants (Appendix III) , atomic weights (see periodic table), and Avogadro's number (Appendix II).

(A). Calculate the (mass) densities of Si and GaAs (in g/cm^3). Compare the results with the densities given in Appendix III.

(B). What makes a semiconductor special are *impurities* which introduce mobile carriers to the system. Imagine we have a perfect silicon crystal. Let's introduce an imaginary atom which can replace the silicon atom and generate one mobile electron. What is electron density when all silicon atoms are replaced by this imaginary atom (in cm^{-3})? (This will be an upper limit of the carrier density in silicon. In reality, the maximum carrier density that can be obtained is approximately 2 orders of magnitude lower than your answer.)

4. TERNARY ALLOYS

In a III-V semiconductor, the compositions of each interpenetrating fcc lattice in the zinc blende crysal can be varied to form a ternary compound (such as AlGaAs or InGaAs). The fraction of each atom is typically represented by the subscript x, so a ternary compound with a fraction of x Al atoms would be represented as $Al_xGa_{1-x}As$. The value of x is typically called the mole fraction.

(A). Assume the lattice constant of a ternary alloy varies linearly with the mole fraction. What is the lattice constant of $Al_{0.2}In_{0.8}P$ (in Å)?

(B). Determine the density of aluminum atoms (in cm^{-3}) in $Al_{0.2}In_{0.8}P$ (in cm^{-3}).

(C). Assume the band gap of a ternary alloy varies linearly with the mole fraction. What is the band gap of $Al_{0.2}In_{0.8}P$ (in eV)?

(D). As you have seen in (C), the band gap of ternary alloys can be adjusted by mixing III-V semiconductor compounds in certain mole fraction. As you may learn soon, a light can be generated from semiconductor and a wavelength of the light is strongly related with the band gap of material. If the energy of a photon is equal to the band gap of $Al_{0.2}In_{0.8}P$, what is its wavelength (in nm)?