ECSE-2210 Microelectronics Technology
Class Activity 1 – Solution

Problem 1

a. Name one elemental semiconductor and one compound semiconductor.

Si and Ge are elemental semiconductors. GaAs, GaSb, AlSb, SiC, ZnSe are examples of compound semiconductors.

b. What is the difference between a crystalline and polycrystalline material?

In a *crystalline* material the atoms are arranged in an orderly three dimensional array – its just one "single crystal". Every part of the crystal is oriented exactly the same. A *polycrystalline* material consists of many small crystalline subsections (called "crystallites"), which may be oriented differently with respect to each other.

c. Give a word definition of the term "unit cell".

Unit cell is a small portion of any given crystal, on repeating results in a full crystal. Unit cells are not unique. You can have different unit cells, each giving the full crystal when repeated.

d. How many atoms are in a unit cell of the simple cubic/bcc/fcc/diamond lattice?

SC = 1: 1/8 from each corner atom, 8 corner atoms. Only 1/8 belongs to the unit cell.

BCC = 2: In addition to the 1 atom from 8 corner atoms similar to the SC, we have now one atom at the center of the cube. So, there are a total of 2 atoms per unit cell.

FCC = 4: Here, we have 1 atom from the 8 corner atoms. In addition, we have 3 atoms from the face atoms. Since each face atom is shared between two unit cells, only ½ belongs to the unit cell in question. Since there are 6 faces, we have a total of (½ × 6) = 3 atoms. So, there are 4 atoms in the unit cell.

Diamond = 8: This comprises of 2 interpenetrating fcc lattices. 1 atom is contributed from the 8 corners, 3 atoms from the six faces, and 4 whole atoms from inside the unit cell. As a result, there are 8 atoms per unit cell.

e. 1 Å =? cm; 1 nm =? Å.

1 Å = 10^{-8} cm; 1 nm = 10 Å
1 Å = 1 Angstroms = 10^{-10} meters
1 nm = 1 nanometer = 10^{-9} meters

f. In terms of the lattice constant *a*, what is the distance between nearest-neighbor atoms in a simple cubic lattice?

It is the lattice constant a. The nearest neighbors for any given atom are the ones along the cube edge.

g. How many nearest-neighbor atoms are there in the diamond and zincblende lattices?

There are 4 atoms surrounding each atom or in other words, each atom is "bonded" to 4 other atoms. This fact has important implications, as you will see in the next class when we describe band and bond models of Si and Ge crystals.

h. Classify materials based on their resistivity (Hint: Build three groups of materials). What is unique about semiconductors?

Insulators	$10^{10} - 10^{18}$ Ω cm
Semiconductors	$10^{-4} - 10^{8}$ Ω cm
Conductors	$10^{-6} - 10^{-4}$ Ω cm

The uniqueness of semiconductors is that their conductivity can be varied **by us over** a wide range,

- by adding minute quantities of impurities
- by applying electric field
- illumination

Problem 2

The lattice constant of Ge at room temperature is a = 5.65 Å. Determine the number of Ge atoms per cm^3. Determine the mass density of Ge in g cm^{-3} if Ge has an atomic weight of 72.6 atomic units.

Ge crystallizes in diamond lattice structure, which means there are 8 atoms in one unit cell. Since the lattice constant is 5.65×10^{-8} cm, we can calculate the volume occupied by these 8 Ge atoms or we can calculate the number of Ge atoms in 1 cm^3 of the Ge crystal.

Number of the Ge atoms per cm^3 = $8 / (5.65 \times 10^{-8}\ \text{cm})^3 = 4.4 \times 10^{22}\ \text{cm}^{-3}$

Mass density = 4.4×10^{22} (atoms/cm^3) × 72.6 (g / mole) / (6.02×10^{23} (atoms/mole))

= 5.34 g cm^{-3}

Problem 3

In terms of the lattice constant a, what is the distance between nearest-neighbor atoms in:

a. The bcc lattice?

Here, nearest neighbor atoms are lined up along the body diagonal. The distance from corner to corner is $a\sqrt{3}$. So, the distance between two nearest neighbors will be $a\sqrt{3}/2$.

b. In an fcc lattice?

This is the distance between any two atoms along the face diagonal of this cubic lattice.

Length of the face diagonal is $a\sqrt{2}$ and therefore the nearest-neighbor distance is given by $a\sqrt{2}\,/\,2$

Problem 4

The cubic unit cell pictured below characterizes a crystalline lattice. The cell has a single atom positioned at the center of the cube

a. What is the name of the lattice generated by the given unit cell?
The name is "simple cubic structure". Imagine that the unit cell is repeated; this ends up in a SC lattice (and not in the bcc structure!)

b. Determine the number of atoms per cm^3 in the crystal if the lattice constant a is 0.5 nm.
The number of atoms in 1 cm^3 of the crystal will be:
$1 / (0.5 \times 10^{-7}\ cm)^3 = 8 \times 10^{21}$ atoms/cm^3