Lecture 4

http://courses.washington.edu/mse170/index.shtml

Friday, April 04, 2008
11:06 AM

References Used:

1. B D Cullity, **Elements of X-ray Diffraction, 2nd Edition**, *Addison Wesley*, 1978.

Course Notes

1. Rules of "The Game":
   - I am going to make 3 mistakes in my lecture notes by the end of lecture Friday
   - Those mistakes will be written on the board -- they will not be in my jumbled wording -- if I mispeak because I haven't had my morning coffee.
   - To win you must:
     1) Document all 3 mistakes on paper
     2) Provide corrections for all 3 mistakes on paper
     3) Be the first person in your lab section to turn in the written solutions to your lab section TA
   - You will win 2 extra credit points on your homework grade (which is a 20% kicker on any given homework)

2. Look at the website --The course calendar and homework includes the lecture plan/ the lab plan/ and the course homework problems and when they are due http://courses.washington.edu/mse170/index.shtml
3. 1st homework is due on Friday. It is on the website:
   Homework #1
   Ch. 2: 2, 7, 11, 14, 16, 20
   Ch. 3: 2, 3, 7, 10, 14, 16

4. Is anyone having a difficult time procuring a copy of the text book? Does everybody have a copy of the 7th Edition of Callister?

5. 1st Labs meet this week -- please report to your lab section

Corrections:

Let's clarify some points and sweep some stuff up from last week:

Let's not confuse solidity and crystallization with atomic bonding schemes

- Ionic bonding -- typically between metals and non-metals
- Covalent Bonding -- typically between two non-metals
- Molecule -- sufficiently stable electrically neutral group of at least 2 atoms that are held together by strong chemical bonds
  - Typically term molecule is applied to covalently bonded structures
  - However, not all covalently bonded structures are molecules
- Melting point refers to the stability of a crystal structure -- whether covalently bonded, ionically bonded, or metallically bonded

- Melting point of MgO --
  - A molecule can be defined as a group of atoms joined in a particular structure
  - A compound is a substance made up of more than one element
  - Not all compounds are composed of discrete molecules
- In the case of MgO:
  - This is an ionic crystalline compound with a crystal structure similar to NaCl
  - We are do not talk about a "molecular" structure with an ionic crystalline compound
  - Endless repeating clusters of Mg^{2+} and O^{2-} ions -- not strictly molecules

- Diamond -- Graphite: covered on board

Beginning of Chapter 3:

What is a crystalline solid

- Through metallographic techniques and x-ray diffraction both developed in the late 1800s
  - Materials Scientists began to understand that metals were actually polycrystalline
  - Most solid materials diffracted x-rays -- how was that possible?

- Solid materials can be classified by the way in which the atoms are organized
  - > In crystalline materials:
    - – Crystal may be defined as "*a solid composed of atoms arranged in a pattern periodic in three dimensions"*
    - – we have repetitive 3 dimensional arrays or matrices of atoms over large distances
    - – (long range order)
    - – All metals are crystalline
    - – Many ceramic materials are crystalline
    - – Certain polymers are crystalline or partially crystalline
  - > If solids do not have long-range order -- then they are amorphous
    - – undercooled liquid
    - – metastable state -- will change with time or energy input

Crystallography

- Spend the next several lectures delving into crystallography
  - > Crystallography is the study of crystal structure and geometrical organization
  - > Its critical because many material properties depend on crystal structure
  - > Its one of the science bases that all of materials science is built upon

- Really the fundamental question of crystallography is: How do you describe the atomic arrangement of various solids?
- One way is to ignore the actual atoms
  - > Instead think of an imaginary set of points which
    - – has a fixed relation in space to the atoms of the crystal
    - – Which can be considered a framework or skeleton for the actual crystal
- Build a point lattice: "*an array of points in space so arranged that each point has identical surroundings*"
  - > Space is divided by three sets of planes
  - > The planes in each set are parallel and equally spaced
- Produces a set of cells each
  - > identical in size, shape, and orientation to its neighbors
  - > Each is a parralelepiped --
  - > opposite faces are parallel
  - > each face is a parallelogram
- Identical surroundings means:
  - > "*that the lattice of points, when viewed from a particular direction from one lattice point, has exactly the same appearance when viewed in the same direction from any other lattice point"*

- Unit Cell
  - > Any cell can be a unit cell -- or the defining cell which is repeated to make the lattice
  - > The size and shape of the unit cell can be described by three vectors a, b, c
    - – Vectors are called the crystallographic axes of the cell
    - – Described in terms of their lengths (a, b, c) and the angles between them (α, β, γ)
    - – The lengths and angles are the *lattice constants* or *lattice parameters* of the unit cell
    - – Using the vectors a, b, c and multiples of those vectors (translations) the entire lattice can be described

- Crystal Systems and Bravais Lattices
  - > Can produce unit cells of various shapes depending on how the planes are arranged
  - > If the planes are equally spaced and perpendicular to one another -- then the unit cell is cubic
    - – a, b, c are all equal and at right angles or a = b = c and $\alpha = \beta = \gamma$
  - > Crystal Systems
    - – You might think that there is a infinite number of possible unit cells -- you would be wrong
    - – It turns out that geometry limits us to only 7 different kinds of cells to describe all of the possible point lattices
    - – These correspond to the 7 crystal systems from which all crystals can be classified
    - – These seven can be obtained by putting points at the corners of the unit cells of the seven crystal systems

  - > Bravais Lattices
    - – However, there are other possible arrangements of points which fulfill the requirements of a point lattice, namely that each point have identical surroundings
    - – In 1848 The French crystallographer Bravais demonstrated that there are a total of 14 possible point lattices and only 14
    - – For example, if a point is put in the center of each cell in a cubic lattice, the new array of points also forms a point lattice

  - > Table Below includes all of the Bravais Lattices

System	Axial Lengths and Angles	Bravais Lattice
Cubic	Three equal axes at right angles a= b = c, $\alpha = \beta = \gamma = 90^o$	Simple Body-Centered Face-Centered
Tetragonal	Three axes at right angles, two equal a= b ≠ c, $\alpha = \beta = \gamma = 90^o$	Simple Body-Centered

Orthorhombic	Three unequal axes at right angles $a \neq b \neq c$, $\alpha = \beta = \gamma = 90^o$	Simple Body-Centered Base-Centered
Rhombohedral	Three equal axes, equally inclined $a = b = c$, $\alpha = \beta = \gamma \neq 90^o$	Simple
Hexagonal	Two equal coplanar axes at 120^o, third axis at right angles $a = b \neq c$, $\alpha = \beta = 90^o$, $\gamma = 120^o$	Simple
Monoclinic	Three unequal axes, one pair not at right angles $a \neq b \neq c$, $\alpha = \gamma = 90^o \neq \beta$	Simple Base-centered
Triclinic	Three unequal axes, unequally inclined and none at right angles $a \neq b \neq c$, $\alpha \neq \gamma \neq \beta \neq 90^o$	Simple