3.40J / 22.71J
Modern Physical Metallurgy

Problem Set 1
Due 02.24.04

1. Fe is a BCC element at standard temperature and pressure.

(a) Draw the BCC crystal structure and label the salient features that <u>define</u> this crystal structure.

(b) Calculate the atomic packing factor of Fe's crystal structure and compare it quantitatively to that of Mn, which is next to Fe on the periodic table of elements.

(c) Draw and label the Miller indices of one of the slip systems of Fe. How many of this type of slip system exist in the BCC unit cell?

(d) Compare the number of these slip systems in Fe with the number of slip systems in Ni, which is two doors down from Fe on the periodic table. Based on this, how would you rate the ductility of Fe as compared to Ni?

2. Uranium has an orthorhombic unit cell, with a, b and c lattice parameters of 0.286, 0.587 and 0.495 nm, respectively. Below are the physical characteristics of the element.

Density: 19.05 g/cm^3
Atomic Weight: 238.03 amu or g/mol
Atomic radius: 0.1385 nm

(a) Based on this information, calculate the atomic packing factor and compare that APF quantitatively with that of a BCC metal.

(b) Based on this comparison, would you recommend storing U in a pressure vessel fabricated from a BCC metal? Why/why not?

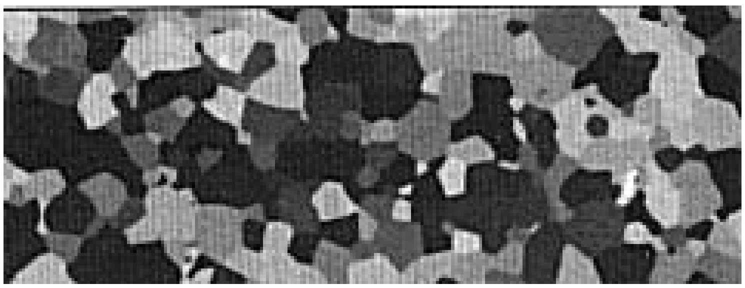
3. Thompson Tetrahedron

The Thompson Tetrahedron is formed from four {111} planes that intersect to form a 3D structure, and is pictured in Problem 1.6 on p. 31 of PMP.

(a) Why, as noted in that problem, is the Thompson Tetrahedron significant to the understanding and discussion of deformation in FCC crystals, as opposed to HCP crystals that also include a close-packed plane?

(b) Construct a 3D Thompson Tetrahedron (from the materials of your choice) in which the indices of every specific plane and specific direction that define this structure are clearly labeled. Please turn this in with your problem set.

4. Certain metals and alloys respond well when viewed with cross-polarized light (i.e., the polarization direction of the polarizer and analyzer are 90 degrees apart to produce extinction). If a metal or alloy such as Mo, Al or a steel is viewed with cross-polarized light, the field of view is uniformly dark. That is, no microstructural detail can be observed. However, if a polished specimen of beryllium, cadmium, magnesium, alpha-titanium, uranium, zinc or zirconium is viewed with crossed-polarized light, the microstructure is revealed vividly, as shown below:



Cross-polarized reflected light image of Zr

1000 μm

Why? What do those metals that exhibit high contrast under cross-polarized light have in common with each other, and why would cross-polarized light show contrast for these but not the other crystals?

5. Should you make a boat out of a crystalline Na?

Elemental sodium, Na, exists at standard temperature and pressure as a crystalline metal. It has a BCC crystal structure, an atomic radius of 0.186 nm and an atomic weight of 22.99 amu.

(a) Based on this information, calculate the density of Na.

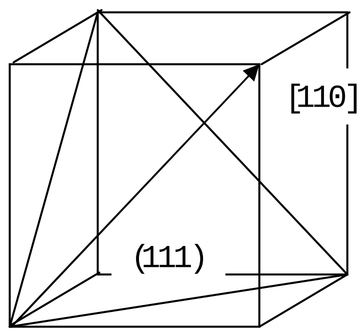
(b) Would you feel safe in a boat constructed from crystalline Na? Why/why not? Your answer should consider both whether the boat will float and how it might react with a given environment.

6. Crystallographic planes and directions

(a) Prove that the indices of a plane and the vector normal to that plane have the same indices in a cubic system, for the particular example of {110}<110>.

(b) Why does this rule not work for noncubic systems such as orthorhombic or monoclinic?

(c) When indicating specific planes and the directions that are contained IN those planes using (hkl) and [xyz] notation, respectively, it is important to make sure that the indices indicate this coplanarity. For example, the (111) plane does not contain the [110] direction, even though it contains <110> directions:



Show mathematically how you can be sure that the specific direction is contained within (ie, lies on) the specific plane.

7. Slip systems and Schmid Factor

You have a single crystal of BCC Fe, for which you've decided to apply a tensile stress of 52 MPa along the [010] direction.

(a) What is the resolved shear stress along the $[\bar{1}11]$ of a (110) plane in this crystal under these conditions?

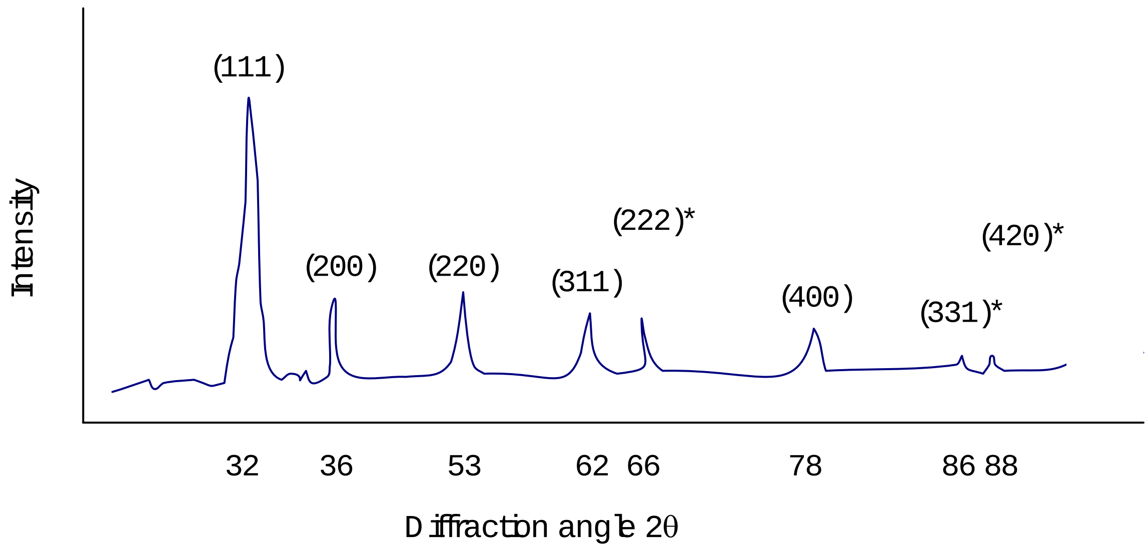
(b) If the critical resolved shear stress required to initiate yielding in this crystal is 30 MPa, will the crystal deform permanently along the $[\bar{1}11]$ of a (110) plane in this crystal under the applied tensile stress you've chosen?

(c) If not, what is the applied tensile stress, or σ_y, required to initiate yielding?

8. Experimental determination of crystal structure via x-ray diffraction

(a) Rhodium is an FCC metal. If the angle of diffraction for the {311} set of planes occurs for a first-order (n = 1) reflection for an X-ray wavelength of 0.0711 nm is used, what is the interplanar spacing and atomic radius of Rh?

(b) Below is an XRD spectrum for powdered Pb using a x-ray wavelength of 0.1542 nm, where the peaks have been indexed. From these data, calculate the interplanar spacing for each set of planes indexed, as well as the lattice parameter(s) of Pb.



(c) Within cubic unit cells, draw those planes indicated with asterisks (*) and indicate any directions in which the Pb atoms are touching.