Exercises for lesson 4

Febr. 22, 2024

Diffraction

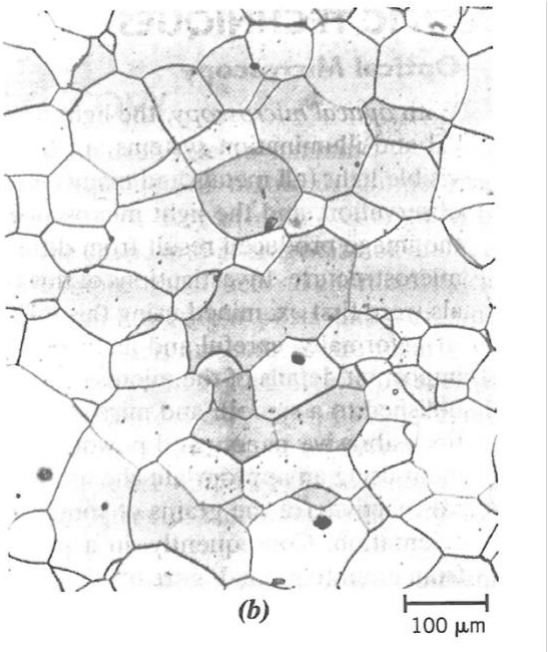
Callister version NINE numbers 4.61, 4.62, 4.63, 4.64, 4.65, 4.66, 4.68. The relevant two pages from the old version are attached below.

Please note that atomic radii for some atomic radii can be found in Table 3.1 in your version of the book, version 10.

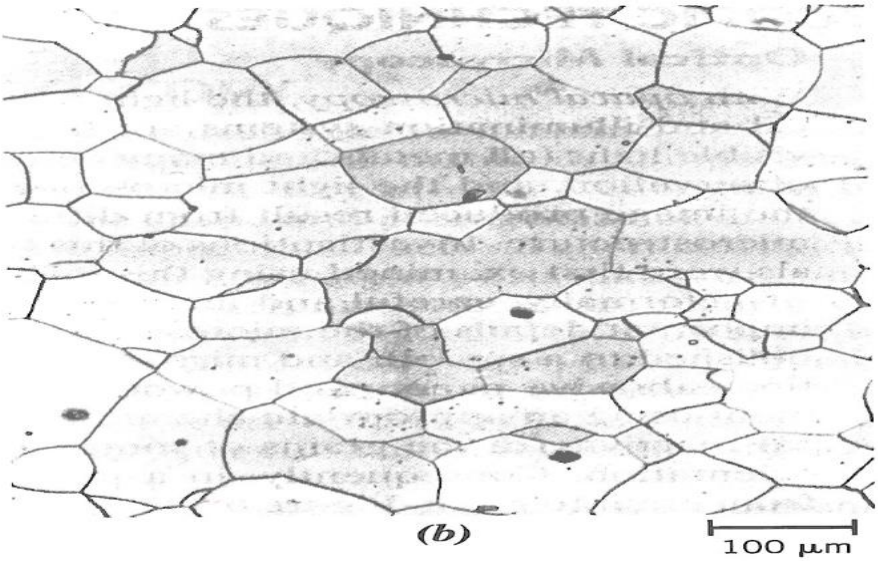
Microscopy

- Assume a simple light microscope has a focal length of 10 μm and a distance from lens to sample plane of 100 μm. What is the distance from lens to the image plane? What is the magnification?
- Assume we have an x-ray lens with a focal length of 0.2 m and that we want a magnification by a factor 100. What is the distance from sample plane to lens and from lens to image plane?
- Given an optical lens with a focal length of 12 mm operating in vacuum. How large does the diameter of the lens need to be to reach a spatial resolution of 900 nm at a wavelength of 550 nm? Same question, but now assume the focal length is 24 mm?

Grain size determination



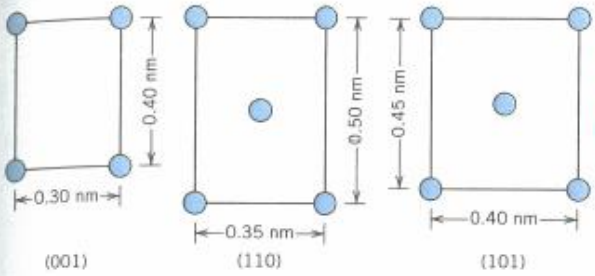
A. For above figure, determine the average grain size using the linear intercept method (use at least 7 lines).



B. For this strethced version of A): Determine the average grains size using the linear intercept method (use at least 7 lines).
C. Are the results for A and B consistent? What error sources are there?

Exercises from Callister version NINE

4.53 The accompanying figure shows three different crystallographic planes for a unit cell of a hypothetical metal. The circles represent atoms.



(a) To what crystal system does the unit cell belong?

(b) What would this crystal structure be called?

(c) If the density of this metal is 8.90 g/cm^3, determine its atomic weight.

4.54 For each of the following crystal structures, represent the indicated plane in the manner of Figures 4.20 and 4.21, showing both anions and cations:

(a) (100) plane for the rock salt crystal structure

(b) (110) plane for the cesium chloride crystal structure

(c) (111) plane for the zinc blende crystal structure

(d) (110) plane for the perovskite crystal structure

Linear and Planar Densities

4.55 **(a)** Derive linear density expressions for FCC [100] and [111] directions in terms of the atomic radius R.

(b) Compute and compare linear density values for these same two directions for silver.

4.56 **(a)** Derive linear density expressions for BCC [110] and [111] directions in terms of the atomic radius R.

(b) Compute and compare linear density values for these same two direction for tungsten.

4.57 **(a)** Derive planar density expressions for FCC (100) and (111) planes in terms of the atomic radius R.

(b) Compute and compare planar density values for these same two planes for nickel.

4.58 **(a)** Derive planar density expressions for BCC (100) and (110) planes in terms of the atomic radius R.

(b) Compute and compare planar density values for these same two planes for vanadium.

4.59 **(a)** Derive the planar density expression for the HCP (0001) plane in terms of the atomic radius R.

(b) Compute the planar density value for this same plane for magnesium.

The Diffraction Phenomenon

X-Ray Diffraction and Bragg's Law

Diffraction Techniques

4.60 Using the data for molybdenum in Table 4.1, compute the interplanar spacing for the (111) set of planes.

4.61 Determine the expected diffraction angle for the first-order reflection from the (113) set of planes for FCC platinum when monochromatic radiation of wavelength 0.154 nm is used.

4.62 Using the data for aluminum in Table 4.1, compute the interplanar spacings for the (110) and (221) sets of planes.

4.63 The metal iridium has an FCC crystal structure. If the angle of diffraction for the (220) set of planes occurs at 69.20° (first-order reflection) when monochromatic x-radiation having a wavelength of 0.154 nm is used, compute **(a)** the interplanar spacing for this set of planes and **(b)** the atomic radius for an iridium atom.

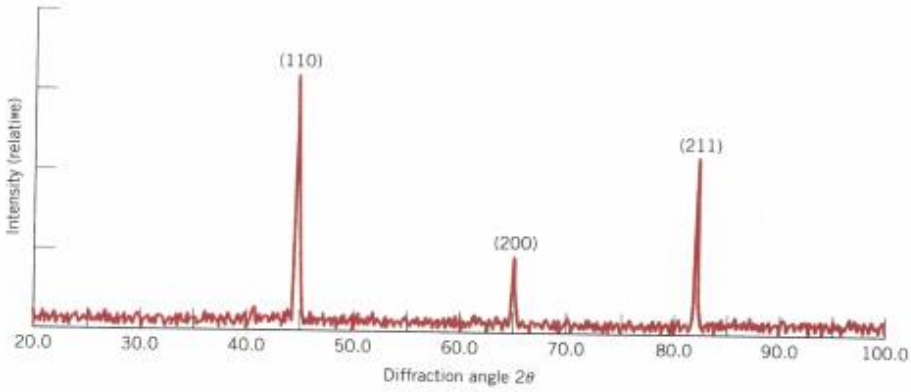
4.64 The metal rubidium has a BCC crystal structure. If the angle of diffraction for the (321) set of planes occurs at 27.00° (first-order reflection) when monochromatic x-radiation having a wavelength of 0.071 nm is used, compute **(a)** the interplanar spacing for this set of planes and **(b)** the atomic radius for the rubidium atom.

4.65 For which set of crystallographic planes will a first-order diffraction peak occur at a diffraction angle of 46.21° for BCC iron when monochromatic radiation having a wavelength of 0.071 nm is used?

4.66 Figure 4.32 shows an x-ray diffraction pattern for α-iron taken using a diffractometer and monochromatic x-radiation having a wavelength of 0.154 nm; each diffraction peak on the pattern has been indexed. Compute the interplanar spacing for each set of planes indexed; also determine the lattice parameter of Fe for each of the peaks.

4.67 The diffraction peaks shown in Figure 4.32 are indexed according to the reflection rules for BCC (i.e., the sum $h + k + l$ must be even). Cite the h, k, and l indices for the first four diffraction peaks for FCC crystals consistent with h, k, and l all being either odd or even.

Figure 4.32
Diffraction pattern for polycrystalline α-iron.



4.68 Figure 4.33 shows the first four peaks of the x-ray diffraction pattern for copper, which has an FCC crystal structure; monochromatic x-radiation having a wavelength of 0.154 nm was used.

(a) Index (i.e., give h, k, and l indices for) each of these peaks.

(b) Determine the interplanar spacing for each of the peaks.

(c) For each peak, determine the atomic radius for Cu and compare these with the value presented in Table 4.1.

Spreadsheet Problems

4.1SS For an x-ray diffraction pattern (having all peaks plane-indexed) of a metal that has a unit cell of cubic symmetry, generate a spreadsheet that allows the user to input the x-ray wavelength, and then determine, for each plane, **(a)** d_{hkl} and **(b)** the lattice parameter, a.

4.2SS For a specific polymer, given at least two density values and their corresponding percents crystallinity, develop a spreadsheet that allows the user to determine the following: **(a)** the density of the totally crystalline polymer, **(b)** the density of the totally amorphous polymer, **(c)** the percent crystallinity of a specified density, and **(d)** the density for a specified percent crystallinity.

Figure 4.33
Diffraction pattern for polycrystalline copper.