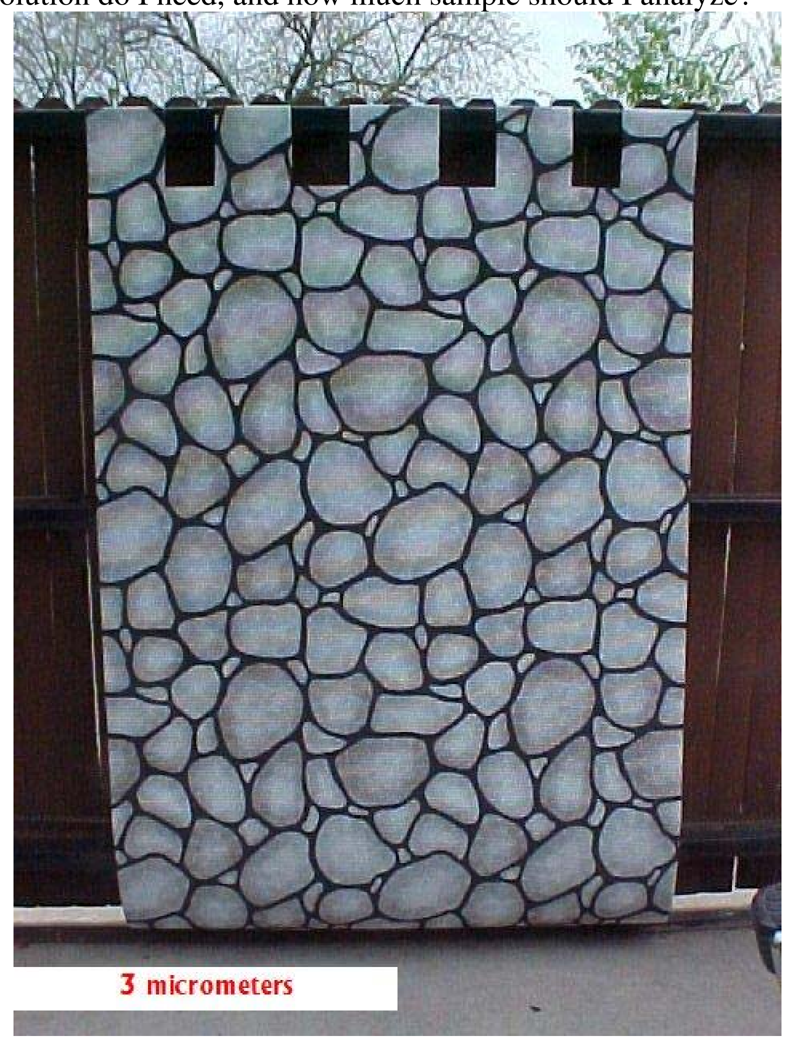
MMAT 5322 – Fall 2009
Homework 1– Microstructural Principles
Due Friday, Sep 18, at the start of class

Question 1

For the image below (NOTE: **download** the .jpg file directly from the web site) solve the following. ImageJ is strongly recommended. You may assume that the image, and each pixel, are the same dimensions in x and y:

a. Crop the image to just the grains (throw out the extra info at the edges).
b. What is the average grain size for the entire image (note scale bar)?
c. Make 3 histograms of the grain sizes, using 10, 50, and 100 bins. Are these bimodal, trimodal, etc? How does bin size matter?
d. How does the average grain size vary as the image size is cropped (plot average grain size as a function of image area, and separately number of grains vs image area). Consider at least 5 areas?
e. What do (c) and (d) tell you about feature analysis for this sample? In other words, how fine of resolution do I need, and how much sample should I analyze?



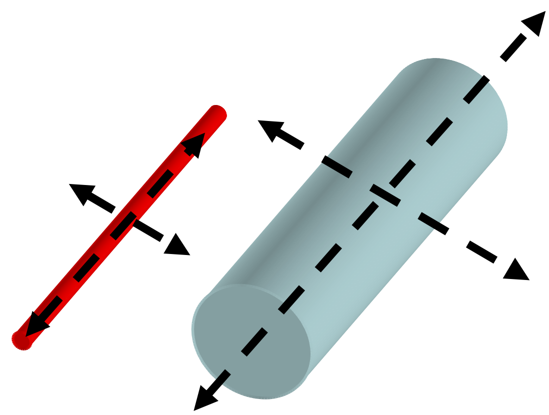
Question 2

You need to study a sample with features that are roughly 500 nm tall. You have access to an optical microscope with a 60x oilr objective, which has an NA of 1.3 and uses 532 nm light.

a. What is the lateral limit of optical resolution for this setup?
b. You decide to buy a camera for the microscope and want to be able to record images at the optical resolution limit or better. Given the 60x magnification and a standard camera chip size of 1 cm (square), show whether
    i. you need to spend lots of money for a camera with 1024 pixels on a side, or
    ii. you can get away with a 512x512 pixel camera.
c. The 532 nm light source breaks one day. The only thing you have available is a violet-ish source (422 nm) Do you get better or worse lateral resolution?
d. Can you ***simultaneously*** focus on the top of the 500nm features, and the substrate beneath, with either source (or both)? (You may assume a collection angle of 60 degrees for each case)?

Question 3

You have an optical microscope with a 100x air lens with a numeric aperture of 0.90, and you are using **680 nm light**.



You use this scope to image nanotubes and microtubes. The nanotubes have a diameter of 10 nm, are straight, and have a length of 100 um. The microtubes have a diameter of 5 um, are straight, and have a length of 100 um.

a. Assuming your tubes are isolated from each other, draw a single plot showing the cross section (as sketched) of the intensity as a function of position:
    a. along the microtubes
    b. along the nanotubes.
b. Draw another single plot sketching the intensity as a f(position) for:
    a. perpendicular to the microtubes
    b. perpendicular to the nanotubes

NOTE: Each diagram should be drawn with respect to the intensity you would detect for an infinitely large sample (ie do you reach this intensity or not?).

Question 4

a. Calculate the deBroglie wavelength for a 500 keV TEM experiment and a 50 keV SEM. Account for relativistic effects in both cases—do they matter?

Now, for the TEM case only:

b. Determine the ideal alpha angle in degrees, assuming Cs=6 mm. What is the error caused by spherical aberration, and the error due to diffraction effects (i.e. diffraction limited resolution)? What is the overall total error in this IDEAL case?
c. Now, alpha is actually 1 degree (i.e. NONIDEAL). In this case, what is the error caused by spherical aberration, the error due to diffraction effects (i.e. diffraction limited resolution), and the total error?
d. What is the depth of field for the ideal case, and for the 1 degree (nonideal) case?
e. For a magnification of 100,000, what is the depth of focus for the ideal case (only).

Question 5

What optical microscopy method would you use to study the following and why:

a. Porous alumina substrates.
b. Distributed tin-oxide nanorods.
c. Transparent polymers with embedded rods of transparent (but different n) second phases.
d. Light-sensitive cells stained with fluorescent dyes.
e. Identifying x, y, and z positions of fluorescing 2^{nd} phases in glass.
f. Grain distribution in ceramics with an anisotropic index of refraction.
g. Surface roughness on highly porous titanium.
h. the orientation of a lithographic step on a surface (stepping up, or stepping down).