Microstructure Development

1. Draw the following microstructures by hand (computer drawings are not acceptable):
(a) a dendritic solidification front;
   *The main feature to capture here is the branched nature of the structure. To be able to image this structure there must be some segregation or a second phase present.*
(b) a eutectic structure;
   *The main feature to capture here is the lamellar structure. It would also be acceptable to draw a rod morphology eutectic. Including dendrites of a primary phase is not wrong but is not required here.*
(c) a Widmanstätten structure;
   *The main feature to capture is the crystallographic relationship between the parent and daughter phases based on matching of planes, hence a plate morphology.*
(d) a partially recrystallized, single phase metal.
   *The main feature to draw is the contrast between the deformed structure (variable contrast within a grain and rough boundaries) and the recrystallized grains (no contrast within the grain, smooth boundaries). Be careful here to not confuse recrystallization with crystallization (from an amorphous phase).*

Describe the features of each of these four microstructures that you regard as being distinctive.
2. For the example shown below of a Cu-1%Bi sample annealed at a temperature where the Bi is liquid, analyze the probable thermal history of the microstructure. You should copy or sketch the phase diagram and indicate temperatures and times on the diagram. Discuss the microstructure in terms of the volume fractions of the two phases and the relative interfacial energies, i.e. compare Cu-Cu and Cu-Bi boundaries.

The target microstructure was 2.13 (outlined by a box) the other two micrographs were from different alloys altogether. The likely history was casting from fully liquid followed by holding at a temperature just above the eutectic at 270C. The interesting feature of the structure is the way in which the Bi is distributed along the grain boundaries between the Cu grains. This suggests that the energy of the Cu-Bi interface is less than one half of the (typical) Cu-Cu grain boundary so that the Bi is able to wet the Cu grain boundaries. It is also interesting to note that not all the grain boundaries are wet, suggesting a variation in grain boundary energy (as expected).
3. For the example shown below of an Al-10%Cu sample etched in cold 10% ferric nitrate, analyze the probable thermal history of the microstructure. Identify the phases that are visible in the micrograph. You should copy or sketch the phase diagram and indicate temperatures and times on the diagram.

This is very straightforward: the alloy was solidified at a slow enough rate that primary aluminum formed first (the large near-spherical white phase) followed by solidification of the Al-Cu eutectic at 648°C as segregation occurred (rejection of Cu from the primary Al). Be careful of describing this structure in relation to equilibrium: there would have been LOCAL equilibrium only at the solidification front. The segregation that has obviously occurred demonstrates deviations from equilibrium!

4. For the example shown below of a Fe-1.4 (wt.%)C sample etched in 2% nital, analyze the probable thermal history of the microstructure. Identify the phases present in the microstructure and where the grain boundaries lie. You should copy or sketch the phase diagram and indicate temperatures and times on the diagram.

The steel has been slowly cooled (normalized) from the austenite region, allowing cementite to form on the prior grain boundaries (white lines delineating grains) and as a
Widmanstätten precipitate within the grains. The remaining austenite has transformed to a fine pearlite. This latter feature is not possible to resolve in the micrograph provided because one really needs another micrograph at a higher magnification in order to see the pearlite.
5. For the example shown below of an electro-slag weld in a 3-inch thick mild-steel plate, analyze the probable thermal history of the microstructure. Where do you think the limits of the molten region lie? Why do you suppose there are large grains at either side of the region shown by the blue (shorter) arrow? What consequence for the mechanical properties of the weld might these large grains have? What do you think is microstructural significance of the dark streaks at the ends of the orange (longer) arrow?

The fusion zone (where the metal was molten) is marked by the large grain band at either end of the blue arrow. The large grains are often a source of weakness in such welds. They have grown epitaxially into the melt from the unmelted grains in the base metal. The dark streaks at either end of the orange arrow represent the heat affected zone (HAZ); within this region, the temperature went high enough for the ferrite to transform to austenite and back again to ferrite. The word ‘slag’ refers to the oxide mixture that is used to protect the molten metal from the atmosphere; the oxide mixture is itself molten but sits on top of the molten metal.

Just in case you are worried by this question, you are not expected to know detailed answers to these questions but it is useful to get you thinking about more complicated thermal histories in materials.