**Problem Set #1**

Due Monday, September 28

Problem #1:

In class we briefly discussed the standard (0001) stereographic projection for a hexagonal crystal. For the same crystal, draw a schematic of the stereographic projection along a $[10\bar{1}0]$ axis. Please label the symmetry elements (rotation axes and mirrors).

Problem #2:

The 'standard stereographic projection' we discussed in class in represented in the crystal frame of reference. In other words, the axes of the crystal are used as the reference frame, and we can represent directions in the laboratory within that frame. For example, consider the following, relatively common, geometry that might apply to a metal crystal:
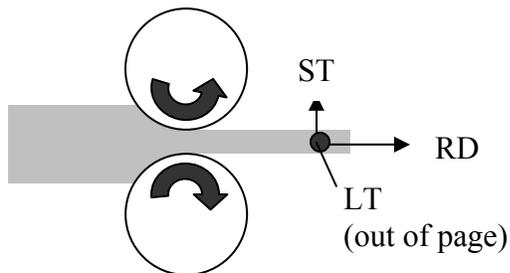

Here the crystal (in grey) is being rolled between two rollers, and the laboratory reference frame is defined by the rolling direction (RD), as well as the short-transverse (ST) and long-transverse (LT) directions.

The crystal in the above image is being rolled such that the [111] direction is along RD, and the $[\bar{1}01]$ direction is along ST. In a standard stereographic projection, label the RD, ST, and LT (yes, you have to calculate the latter).

Problem #3:

Another complementary type of stereographic projection is also common in materials science—one in which the laboratory reference frame is used to define the axes. For example, below is a stereographic projection, onto which are plotted the <100> directions defining the principal axes of four cubic grains, with respect to a laboratory reference frame. Each grain produces three spots on this projection. Identify which spots belong together, being from the same grain. In total, you should identify four sets of three spots each, corresponding to each of the four different grains. Hint: think about the symmetry of <100> axes in cubic crystals.
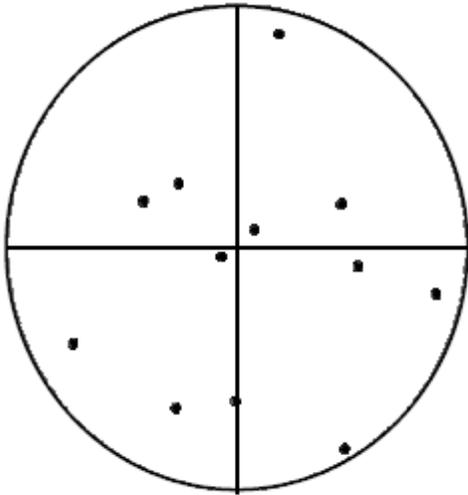
Problem #4:

Imagine a plane containing two parallel screw dislocations. Viewed edge-on, the plane is a line and the dislocations are normal to the page

The one on the right is just sitting there, and does not feel compelled to move until it experiences a shear stress on the order of 2 MPa.

If the dislocation at the left is moving in slowly, at what point will the one on the right move? You will need some materials parameters to complete the calculation; use those for (a) aluminum and (b) gold.

(This problem should give you a rough idea of the distance over which dislocations "see" each other and react to one another, and how variable it is from one metal to the next)

Problem #5:

(a) In Problem #3 we said nothing about the Burger's vectors of the SCREW dislocations. Keeping the magnitude of the Burger's vector the same, consider what happens if the screws have parallel or antiparallel Burger's vectors. Does your calculation from Problem #3 change?

(b) Repeat part (a) if we allow these to be parallel edge dislocations lying in the same plane. What differences do you see between edge and screw?

(c) Finally, what would happen if the moving dislocation were a screw and the stationary one were an edge? If you require assumptions to complete the problem, state them clearly.

Problem #6:

Calculate the energy of a dislocation loop which is a circle of radius r, and where the Burger's vector lies in the plane. Assume that the loop is large enough that there is no significant interaction of the loop with itself (i.e., opposites sides do not feel each other). Your answer should be a general formula for the loop energy (don't plug in numbers).

Hint: remember that the dislocation character is a function of position around the loop; i.e., if you use cylindrical coordinates, then as θ ranges from 0 to 2π the character changes continuously.

Problem #7:

For a small loop of, say, 1 nm radius, let's plug in the numbers into the equation you derived in Problem #6. Do so for copper. Then, compare this energy to the energy required to form a vacancy in copper (in your prior classes you discussed vacancy formation enthalpies, etc; you may have to revisit your notes/book from those classes).

Vacancies are called "equilibrium defects" because thermal energy (kT) is enough to make them appear in crystals. Based on your calculations, would you say that dislocation loops are "equilibrium defects"? Discuss please.

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