

27-750 HOMEWORK 2, SPRING 2008

Projections, Pole Figures and Inverse Pole Figures

Due: 31st Jan. '08

A. D. Rollett/ v1: 20 i 02/ v2: 21 i 06/ v3: 22 i 08

1. Assume that we are dealing with a cubic material. What are the direction cosines associated with the following Miller indices?
 - (a) the direction [100]?
 - (b) the direction [110]?
 - (c) the direction [111]?
 - (d) the direction [123]?

2. Why do we observe many different types of poles (100, 110, 111, 112...) in a standard projection as found in a textbook, but only one type of pole in a measured (or calculated) pole figure?

3. Draw a circle of radius=1 for the purpose of laying out a stereographic projection. Assume that [100] points to the right, and [010] up (with [001] coming out perpendicularly out of the plane of the paper at the origin). Write down the (Cartesian) coordinates of the following points in your stereographic projection (which you can think of as a pole figure):

- a) (001);
- b) (100);
- c) (101);
- d) (110);
- e) (123);
- f) (111).

In the past I have required you to write a program to answer this question. It is likely that you will find such a program useful to you in subsequent exercises but it is acceptable to do this in an Excel spreadsheet. In fact, it is quite useful to be able to plot instant pole figures of specific orientations. Mathematica or Maple can also accomplish this (automatic graphing of results).

- g) Write out the coordinates to a file, and plot them (as points) in any graphics program you please. Draw a circle of radius=1 to complete the pole figure.

4. You have seen, albeit briefly, the {001}, {111} and {110} pole figures associated with the *cube component* which is written as {001}<100>, i.e. any {001} plane parallel to the rolling plane (whose normal is called *ND*), and any (orthogonal) <100> direction parallel to the rolling direction (whose normal is called *RD*). The Goss texture is famous in the development of electrical steels for use in power transformers because the alignment of the "soft" magnetic direction (<100>) with the direction of magnetization is almost ideal for minimizing power losses. Let's study the *Goss texture component* because it is a particularly simple orientation that can be easily translated between the *plane-and-*

direction notation, pole figures, and Euler angles (to be explained later). The ideal *Goss component* is written as $\{110\}\langle 001\rangle$, i.e. a (110)-type plane parallel to the rolling plane, and a [001]-type direction parallel to the rolling direction.

a) The *Goss component* is often called “cube-on-edge.” Sketch a set of three orthogonal axes, label them 1=*RD*, 2=*TD* & 3=*ND*; then draw a cube sitting with one edge parallel to the first axis (*RD*). The *cube component* is often called “cube-on-face”: make the equivalent sketch for this component.

b) Sketch the $\{100\}$, $\{110\}$ and $\{111\}$ pole figures for the *Goss component*, with the rolling direction (*RD*) pointing to the right (east), and the transverse direction (*TD*) pointing up (north) and the normal direction, *ND*, pointing out of the page. Make sure that you label the axes.

c) Now calculate and plot the same set of pole figures in a computer program or spreadsheet. This involves calculating the position of each symmetry related pole in each pole figure; the recipe (properly speaking, pseudo-code) is given in the slides for “Introduction to X-ray Pole Figures”. One detail that is that there are only 3 $\langle 100\rangle$ poles in one hemisphere, 4 $\langle 111\rangle$ directions and 6 $\langle 110\rangle$ directions, unless the orientation is in a symmetric position with respect to a sample axis. However, to make your method general, you need to perform the calculation for all the poles and then discard those that lie in the lower (or southern, if you prefer) hemisphere. This is simple in most graphing programs: just limit the range of x and y that is plotted (maximum x, minimum x etc.). Again, put the *RD* (sample 1) pointing to the right (east) and *TD* up (north) so as to keep x and y the same as in ordinary mathematical graphing.

d) Why is it not possible to observe all the poles that you have sketched in your theoretical pole figures? Hint: consider what happens in pole figure measurement as you tilt the specimen closer and closer to being parallel to the focal plane.

e) To know more about the experimental basis for obtaining a strong *Goss* texture, download (from the 27-750 website) and read the 1958 paper by May and Turnbull [Secondary recrystallization in silicon iron. *Trans. Met. Soc. AIME*, **212**, 769-781]. Why are their pole figures different from your sketches (see your answer to part c)?

f) Now calculate and plot the inverse pole figure for the **Goss** orientation. In this case, locate all three of *RD*, *TD* and *ND* on a single figure and label which axis is which; you may need to plot the negative of a given direction, depending on which turns out to be in the upper hemisphere. Normally, of course, one would plot the distributions each of these directions in a polycrystal on a separate figure, but this it is more reasonable to combine them for a single orientation.

5. Now for a similar but harder exercise, drawn from the textures of rolled fcc metals. One of the most characteristic texture components of low stacking fault energy fcc metals deformed in rolling (plane strain compression) is the *Brass component*, denoted by $\{110\}\langle 1-12\rangle$. This is closely related to the *Goss component*, as we have discussed in class.

a) Based on this plane-direction definition, calculate and plot the {111}, {110} and {100} pole figures

b) Now calculate and plot the inverse pole figure for the brass orientation. As for the Goss case, locate all three of RD, TD and ND on a single figure and label which axis is which; you may need to plot the negative of a given direction, depending on which turns out to be in the upper hemisphere.

You can always check your work (and get some practice at library work) by looking up the pole figures of rolled copper in the course textbook (Kocks, Tomé & Wenk) in Ch. 5, or in Bunge's book [1982, *Texture Analysis in Materials Science*, Butterworths, London] or Dillamore's article [with W. Roberts (1965), Preferred Orientation in Wrought and Annealed Metals. *Metall. Rev.*, **10**, 271-380.]