Department of Materials Science and Engineering
Massachusetts Institute of Technology
3.14 Physical Metallurgy – Fall 2003

Solutions to Problem Set #3

3.1 Exercise 5.3

The three slip systems on the (111) plane are: a. (111)$[10\bar{1}]$, b. (111)$[1\bar{1}0]$, c. (111)$[01\bar{1}]$.

Their Schmid factors are:

a. $\frac{1}{\sqrt{3}} \cdot \frac{1}{\sqrt{2}} = 0.408$
b. $\frac{1}{\sqrt{3}} \cdot \frac{1}{\sqrt{2}} = 0.408$
c. $\frac{1}{\sqrt{3}} \cdot \frac{0}{\sqrt{2}} = 0$

The resolved shear stress acting on each slip system is:

a. 0.82 MPa
b. 0.82 MPa
c. 0 MPa

Since all of these are less than the critical resolved shear stress, no slip system will be activated.

3.2 Exercise 5.10

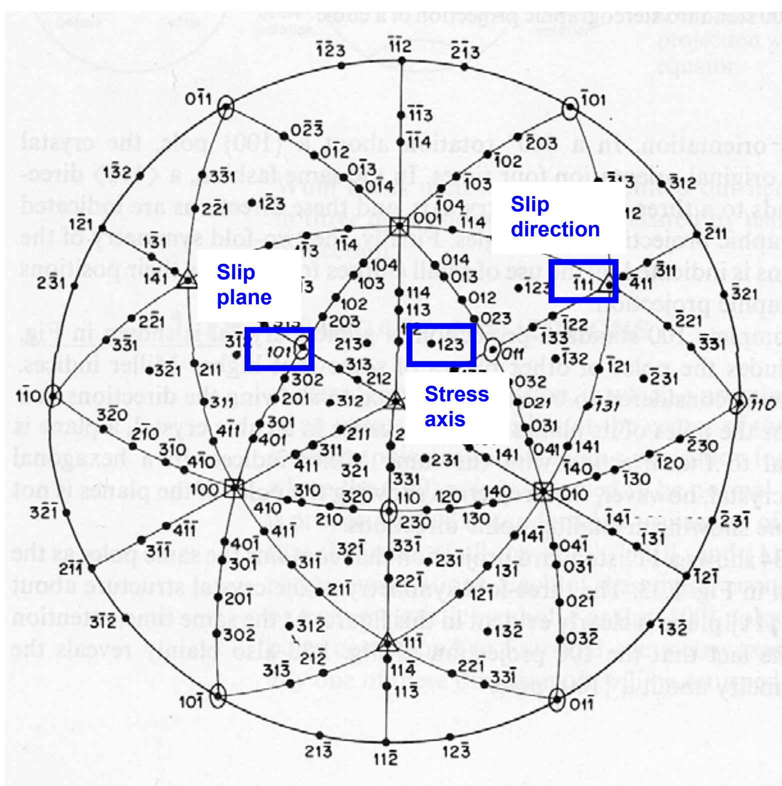
(a) No, the slip planes and directions are all perpendicular to the stress axis, so no slip (or plastic deformation) will occur.

(b) Yes, since the slip system $(11\bar{2}2)[\bar{1}\bar{1}23]$ makes an angle with the basal plane pole [0001], deformation will be possible. (See Fig. 5-19 if you had trouble visualizing this).

3.3 Assume that a bcc crystal slips on {110}<111>. For a tensile axis parallel to the [123] crystal axis, calculate the Schmid factor for all possible slip systems. Discuss the sequence of events that occurs as the stress along [123] is increased to plastic yield.

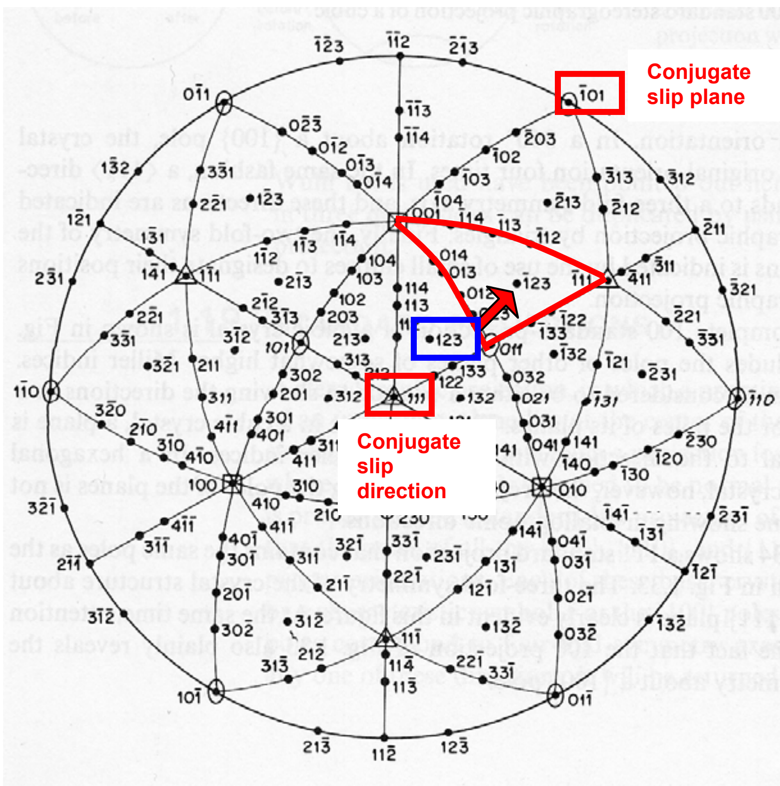
plane			direction			cos θ	cos ϕ	Schmid
1	1	0	-1	1	1	0.5669	0.6172	0.3499
1	1	0	1	-1	1	0.5669	0.3086	0.1750
1	-1	0	1	1	1	-0.1890	0.9258	-0.1750
1	-1	0	-1	-1	1	-0.1890	0.0000	0.0000
1	0	1	1	1	-1	0.7559	0.0000	0.0000
1	**0**	**1**	**-1**	**1**	**1**	**0.7559**	**0.6172**	**0.4666**
1	0	-1	1	1	1	-0.3780	0.9258	-0.3499
1	0	-1	-1	1	-1	-0.3780	-0.3086	0.1166
0	1	1	1	1	-1	0.9449	0.0000	0.0000
0	1	1	1	-1	1	0.9449	0.3086	0.2916
0	1	-1	1	1	1	-0.1890	0.9258	-0.1750
0	1	-1	1	-1	-1	-0.1890	-0.6172	0.1166

Until the stress on the slip plane in the slip plane reaches the critical resolved shear stress, there will only be elastic deformation. When it reaches the critical resolved shear stress, slip on (101)[$\bar{1}11$] will be activated. As the stress increases, other slip systems (like the conjugate system) will be activated.



3.4 What will the conjugate slip system be for the crystal in Problem 3.3?

The primary slip system is (101)[$\bar{1}11$], and under an applied tensile stress, the crystal will tend to rotate so that the slip direction is aligned with the stress axis. We can take two different approaches to find the conjugate slip system. The first involves using the stereographic projection to find the new slip system upon rotation. The arrow on the stereographic projection below shows the rotation, and the red outlined stereographic triangle shows the region of the new stress direction. The conjugate slip system is therefore ($\bar{1}01$)[111].



The second way is to recalculate the Schmid factors for all of the slip systems when the new stress axis is a direction from the new stereographic triangle. If you use [$\bar{1}23$], for example, you can find out that the conjugate slip system is ($\bar{1}01$)[111] (same as before). Its interesting to note that if the crystal rotates so that the stress axis is along [023] (intermediate to [123] and [$\bar{1}23$], the slip systems ($\bar{1}01$)[111] AND (101)[$\bar{1}11$] have the same Schmid factor of 0.4711)