#10: Plasticity - Multiplicity of Slip Systems

•A crystal can have several equivalent slip systems. The number of such systems depends on the crystal structure, e.g. simple cubic, body centered cubic, face centered cubic, hexagonal etc.

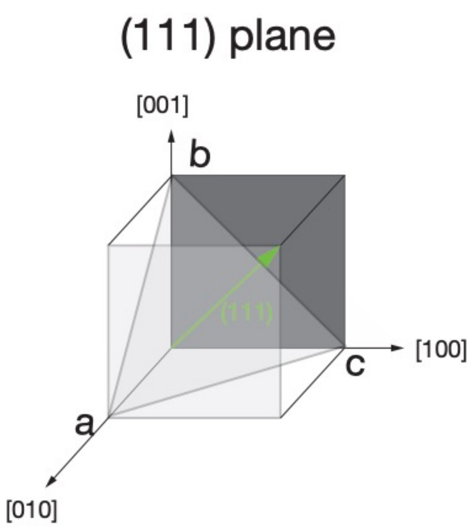
•A metal become more pliable (more ductile) if the number of equivalent slip systems with the lowest yield strength increases. For this reason, fcc crystals which have 12 equivalent slip systems is more malleable. Hexagonal crystals (like zinc) which has only three such systems, is essentially brittle.

•We will develop a method for estimating the number of equivalent slip systems that have the same value of b and the same value of the spacing between the slip planes, d.

•First we need to develop method for describing vectors in a simple notation.

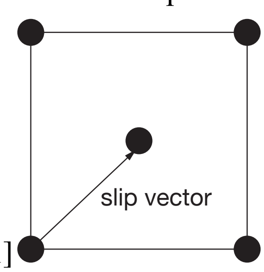
Vector notation to describe the slip direction and the slip plane

First we learn to define the vector and a plane in crystallographic coordinates



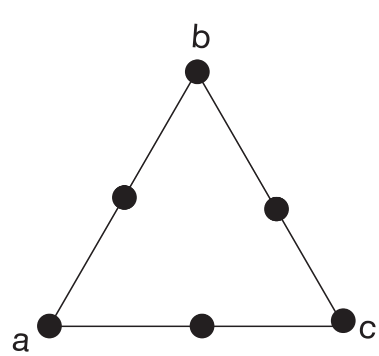
•The vectors are defined in the notation with curly brackets: (n1,n2,n3) etc.

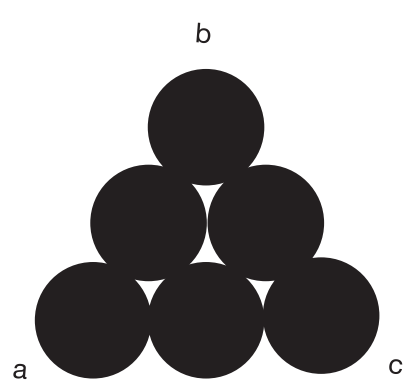
•Therefore, the slip vectors are also defined in this way. For example, consider a slip vector in the face diagonal,



$\vec{b} = \frac{1}{2}[011]$

but more carefully, it is $\frac{1}{2}[01\bar{1}]$.





Now consider the body diagonal plane as the slip plane as shown on the right. The plane is now given by [111] since it has intercepts of unit vectors along the three Cartesian axes.

The combination of the slip vector and the slip plane defines the slip system given by:

$\frac{1}{2}[01\bar{1}],(111)$, the first is the slip vector (it has a magnitude) and the other the slip plane, which is simply a vector. Often, we simply write is as $[01\bar{1}],(111)$

Note that since the slip vector lies in the slip plane it is perpendicular to the plane vector. Therefore, the dot product: $[01\bar{1}].(111) = 0 + 1 - 1 = 0$.

Counting the Number of equivalent (but independent) slip systems for a given combination of slip vector and slip plane.

Example consider a fcc structure where the

slip planes are in the family <111>, (111), etc.

slip vectors are in the family <110>, [110] [101], etc.

Independent slip systems:

4 slip planes and three slip directions in each plane

Therefore, 12 independent slip systems all together

$[\bar{1}11],(110).(101),(0\bar{1}1),(\bar{1}0\bar{1})$

$[111]$

$[1\bar{1}1]$

$[11\bar{1}]$

BCC structure

also 12 independent slip systems

Hexagonal structure

3 independent slip systems

•Multiplicity of slip systems enable malleability in polycrystal.

For example, single crystal of Zn, with a hexagonal structure, is highly malleable but a polycrystal is "brittle": it disintegrates into small crystallites when hit with a hammer.

To remember from this section:

•Description of directions and planes.

•Identification of most favorable slip system

•Number of equivalent slip systems in simple cubic, face centered cubic, body centered cubic and hexagonal structure.