Bridging Length Scales - A constant reminder

#8: Plasticity - Atomistic Features of Plastic Flow

•What we can learn from a zinc single crystal pulled in uniaxial tension

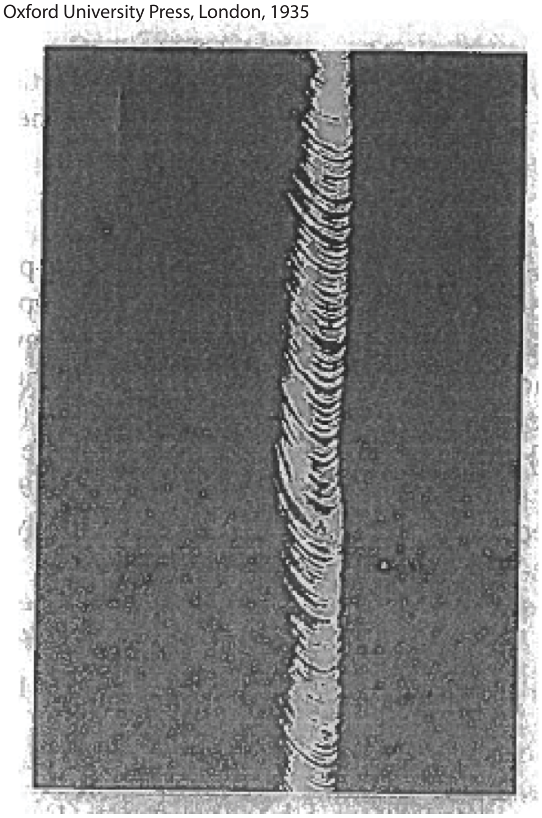
•Crystal structure is preserved despite large deformation

•Plastic deformation is a shear phenomenon which is crystallographic

•Ideal crystal and crystal with defects --> what are the defects?

Zinc single crystal

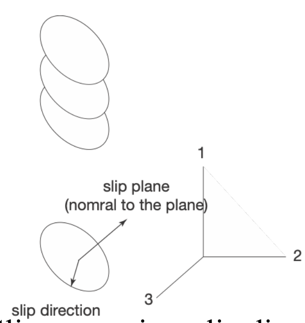
Slip in Zinc Single Crystal (C. F. Elam, the Distortion of Metal Crystals, Oxford University Press, London, 1935



Observations:

•Deformation occurs as if sliding on specific planes. We call is slip on crystal planes. These planes are called slip planes.

•There is a length scale to the microscopic deformation which is characterized by the distance between the planes. In the picture the this distance can be 10 -100 μm. Interatomic spacing is just 0.1 nm.



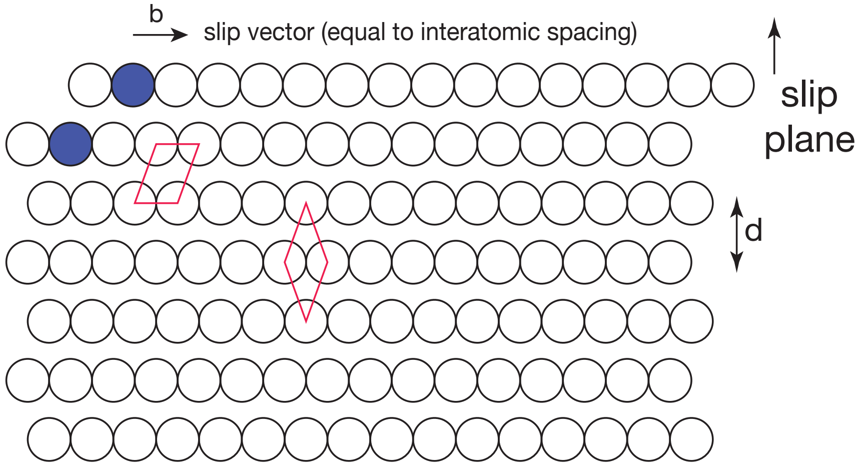
•Slip occurs in a slip direction

How do we know that the structure remains unchanged (X-ray diffraction)

Diffraction allows:

•Determine the symmetry of the crystal.

•Determine the distance between slip planes in the crystal.



Structure has two features that pertain to plastic deformation, that is, the slip between the planes that leads to plastic deformation.

Slip distance = interatomic spacing in the slip plane= b (it is vector)

Distance between the slip planes = d in the direction of the normal to the slip plane.

(it can be measured by X-ray diffraction)

Structure is preserved! No matter how large the plastic strain

•Plastic deformation in crystal occurs in discreet steps.

•Slip is a shear phenomenon

•Shear strain for each quantum of slip = $\frac{b}{d}$

•Since plastic deformation is a shear phenomenon, it is related to the shear modulus, G. This means that the shear stress required to produce plastic strain will scale with "G".

In Summary

(i) The crystal structure remains constant despite large strain experiences in plastic deformation.

(ii) The mechanism of deformation is the sliding of crystal planes one over another by a slip distance.

(iii) The crystal structure is preserved if the slip vector is a lattice translation vector.

(iv) Thus the deformation is described by the slip vector which we call $\vec{b}$, and the slip plane which is defined by the normal to the plane, $\vec{n}$.

(v) The combination of the slip vector and the slip plane, is called a slip system.

(vi) Slip is a shear phenomenon, and therefore is related to shear strains and shear stresses. The shear stress required to produce slip is called the yield stress, and it scales with the shear modulus.

(vii) Recall that we asked for two elastic constants, one related to volumetric deformation called the Bulk Modulus and the other related to shear deformation or change in shape.