Dislocations

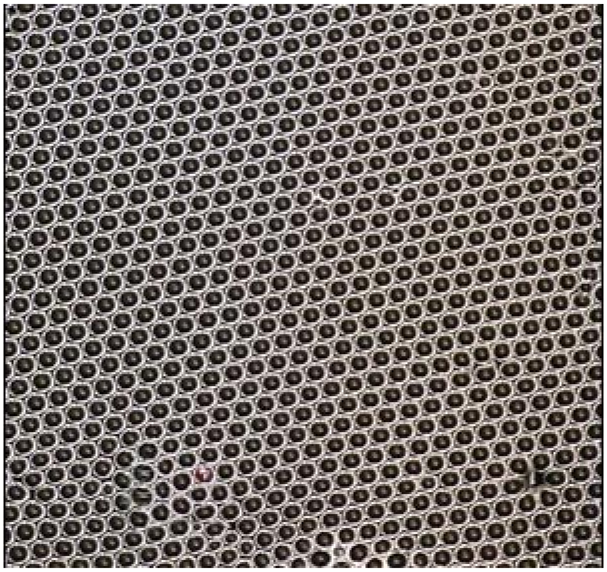
Introduction

The concept of the dislocation was *invented* independently by Orowan, Taylor and Polanyi in 1934 as a way of explaining two key observations about the plastic deformation of crystalline material:

- The stress required to plastically deform a crystal is much less than the stress one calculates from considering a defect-free crystal structure
- Materials *work-harden*: when a material has been plastically deformed it subsequently requires a greater stress to deform further.

Not until 1947 was the existence of dislocations experimentally verified. It took another ten years before electron microscopy techniques were advanced enough to show dislocations moving through a material.

The first section of this package deals with dislocations in the simplest way - in two dimensions. Much of the early work on dislocations was done using simple models such as bubble rafts. These can be tremendously instructive, and we use video clips and still pictures to demonstrate how plastic deformation occurs via dislocation motion.



A bubble raft. (Click on image to view a larger version.)

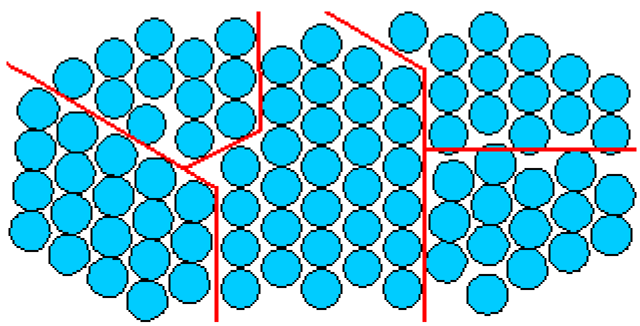
In real crystals, dislocations are three-dimensional. The structure of a dislocation in 3D can be more difficult to visualise. We look briefly at these structures.

In the final part of this package, we consider some of the observations one can make that were first used to verify the presence of dislocations in real crystals.

Dislocations in 2D

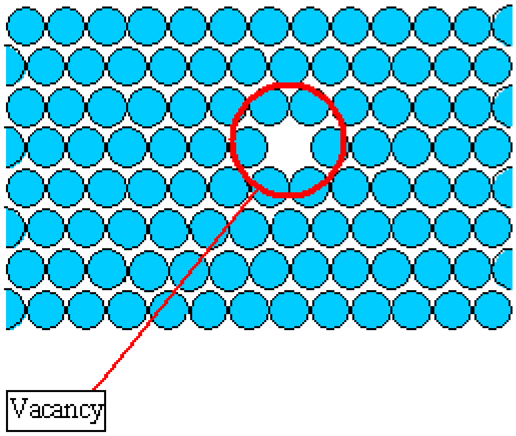
A 'raft' of equally sized bubbles floating on the surface of a liquid is a good large-scale model of a single plane of atoms in a crystal structure. The forces between the bubbles mimic the forces between atoms in a crystal. The bubbles pack to form a close-packed plane. If the raft is made carefully, it is possible to see a variety of structural features in the raft that also occur in real crystal structures, such as *grain boundaries*,*vacancies*, *dislocations* and *solute 'atoms'*.

A grain boundary in a 2D lattice is the interface between two regions of crystalline order. Each region or 'grain' has a different orientation with respect to some arbitrary axis perpendicular to the plane of the lattice.



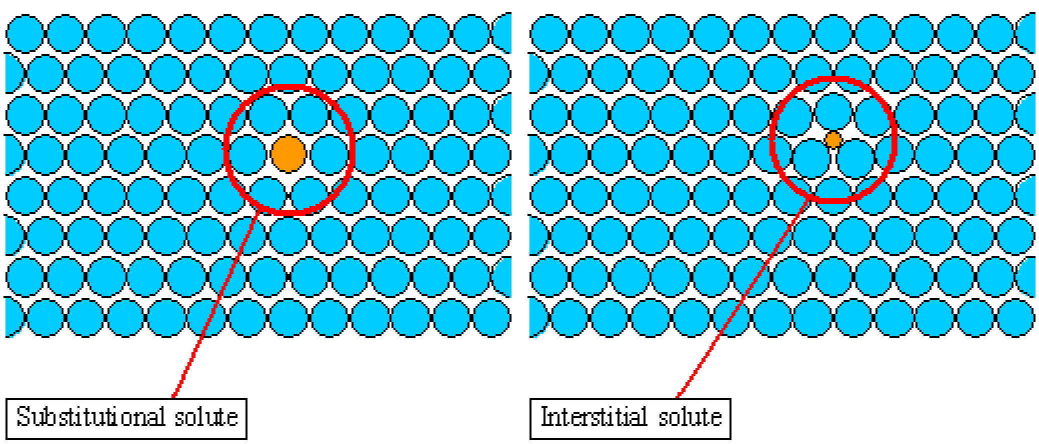
Grain boundaries

A *vacancy* is a point defect that arises when an atom is 'missing' from the ideal crystal structure.



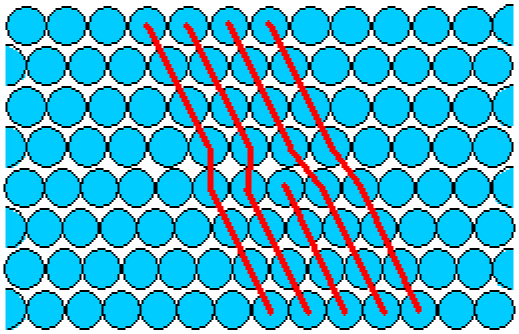
A vacancy

A *solute atom* in a crystal structure is an atomic species that is different from the majority of atoms that form the structure. Solute atoms of similar size to those in the host lattice may substitute for host atoms - these are known as *substitutional solutes*. Solute atoms that are much smaller than the host atoms may exist within normally empty regions (*interstices*) in the host lattice, where they are called *interstitial solutes*.



Substitutional and interstitial solutes. Note that some distortion of the host lattice occurs around the solutes.

A dislocation in a 2D close-packed plane can be described as an extra 'half-row' of atoms in the structure. Dislocations can be characterised by the Burgers vector which gives information about the *orientation* and *magnitude* of the dislocation.

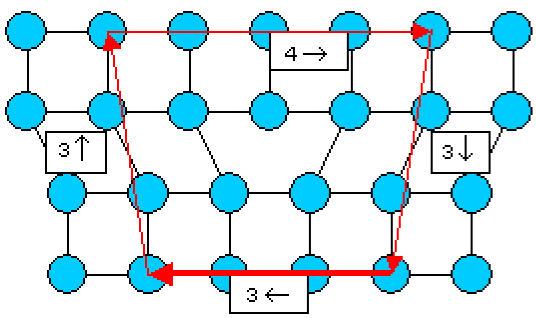


Burgers vector

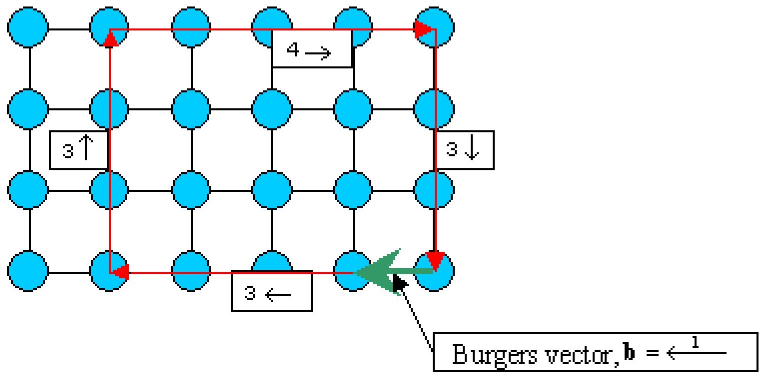
The Burgers vector of a dislocation is a crystal vector, specified by Miller indices, that quantifies the difference between the distorted lattice around the dislocation and the perfect lattice. Equivalently, the Burgers vector denotes the direction and magnitude of the atomic displacement that occurs when a dislocation moves.

To determine the Burgers vector of a dislocation in a two-dimensional primitive square lattice, proceed as follows:

Trace around the end of the dislocation plane to form a closed loop. Record the number of lattice vectors travelled along each side of the loop (shown here by the numbers in the boxes):



In a perfect lattice, trace out the same path, moving the same number of lattice vectors along each direction as before. This loop will not be complete, and the closure failure is the Burgers vector:



Source : http://www.doitpoms.ac.uk/tlplib/dislocations/dislocations_in_2D.php