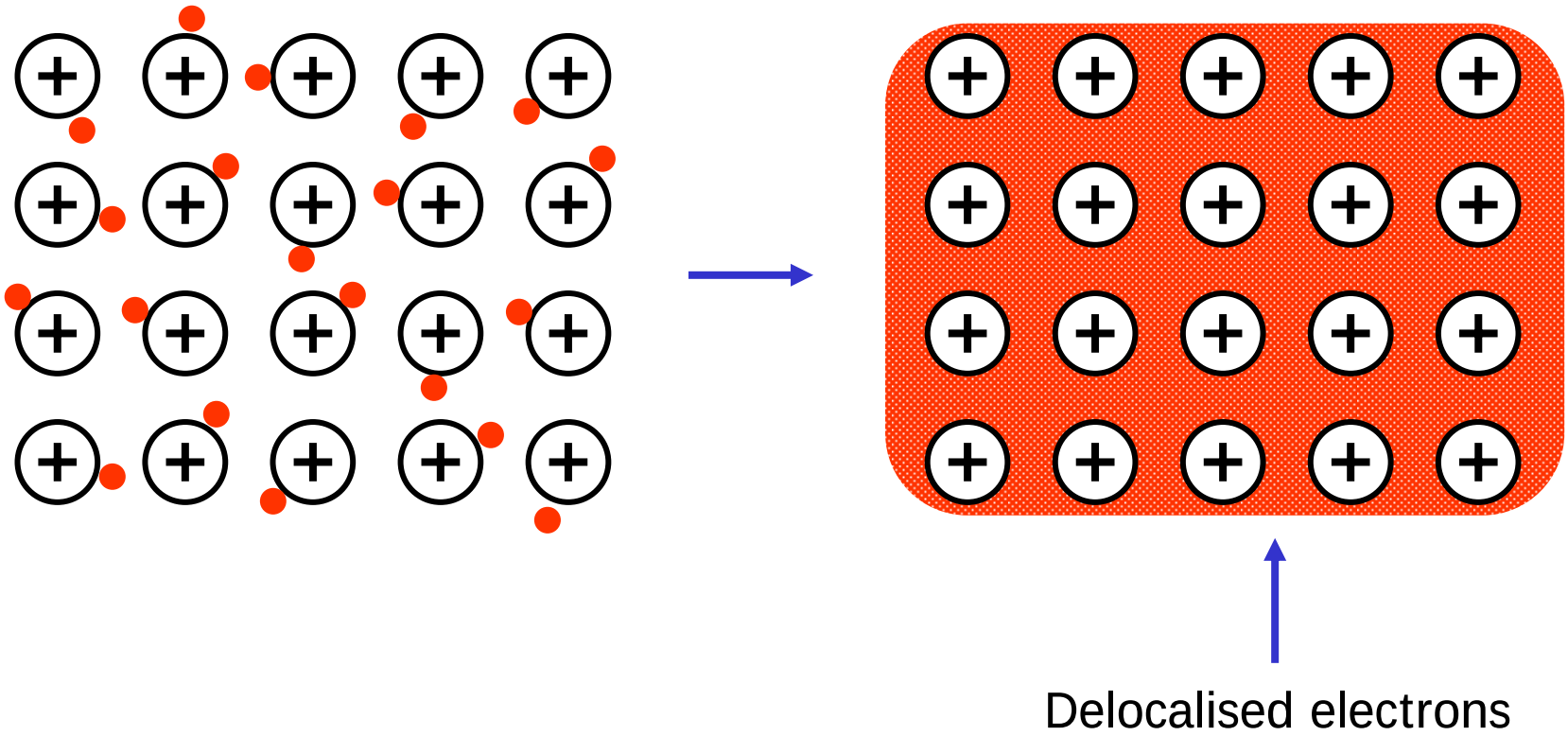
Metallic Bonding

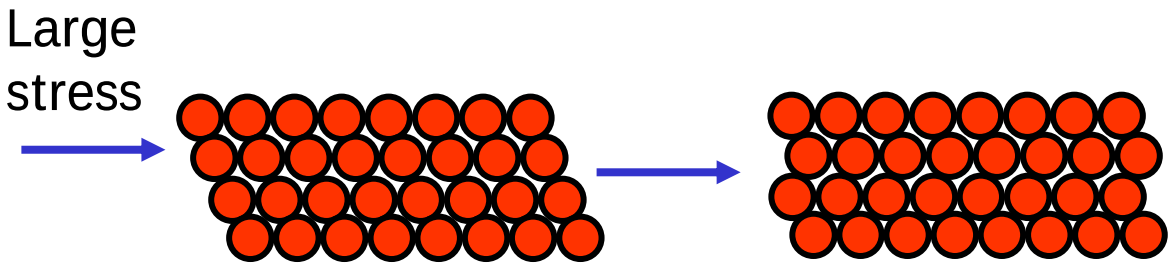


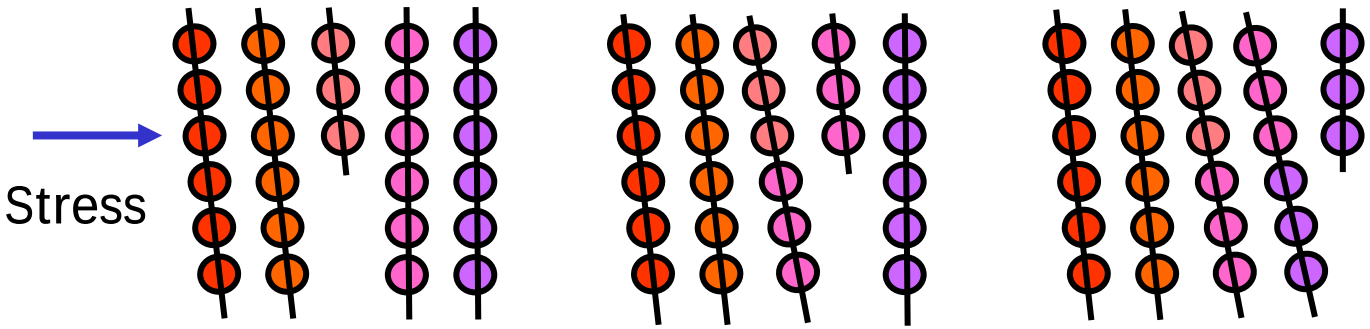
Metallic bonds are non-directional and do not break on deformation: metals are ductile and malleable

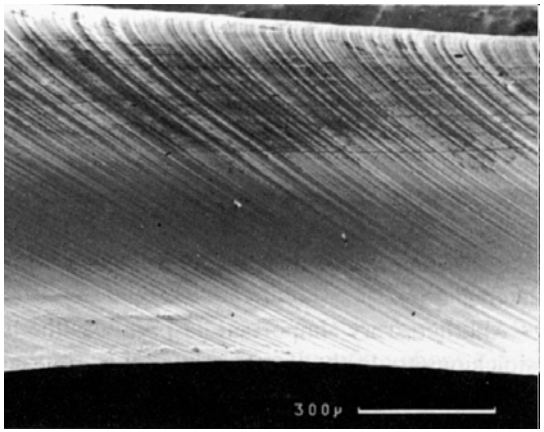
Electrons can move through the metal: metals conduct heat and electricity

Atoms pack closely together: metals are dense

Dislocations

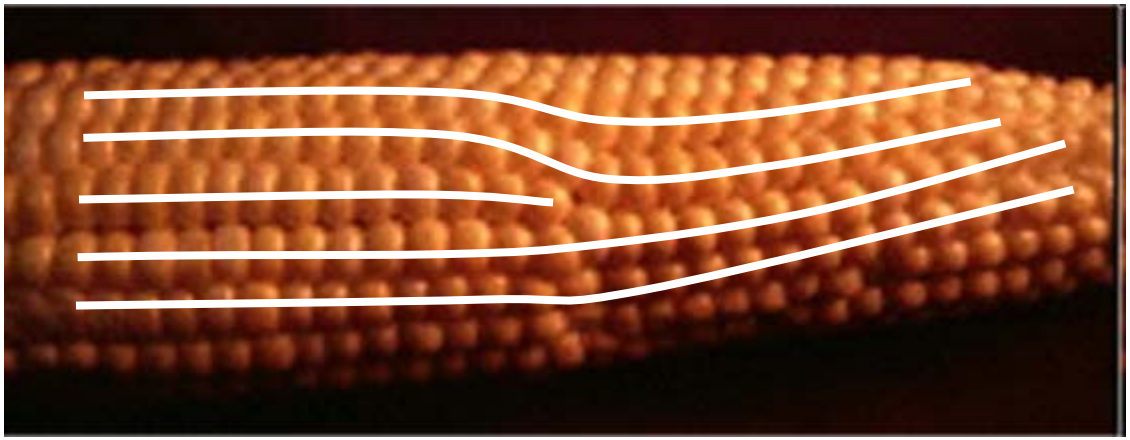






SEM of cadmium deforming by dislocation, forming steps on the surface

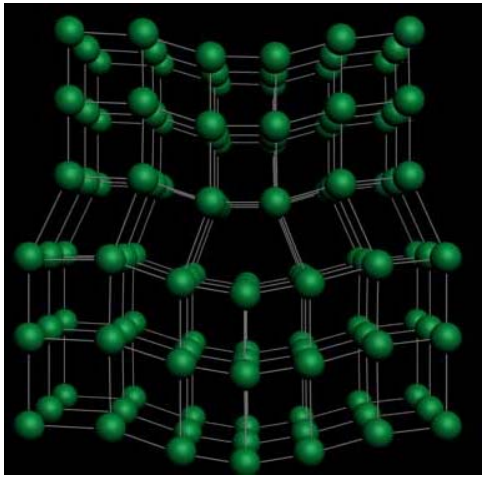
http://www.msm.cam.ac.uk/doitpoms/tlplib/miller_indices



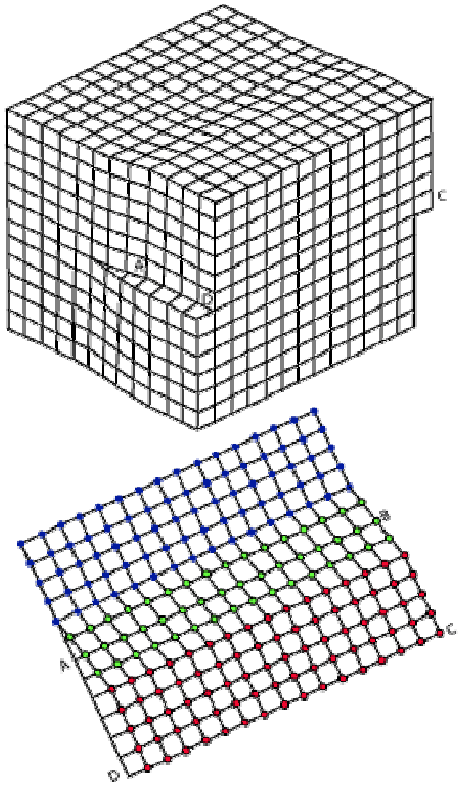
http://mrsec.wisc.edu/Edetc/background/amorphous/images/CORN.jpg

Slip dislocation in a corn cob

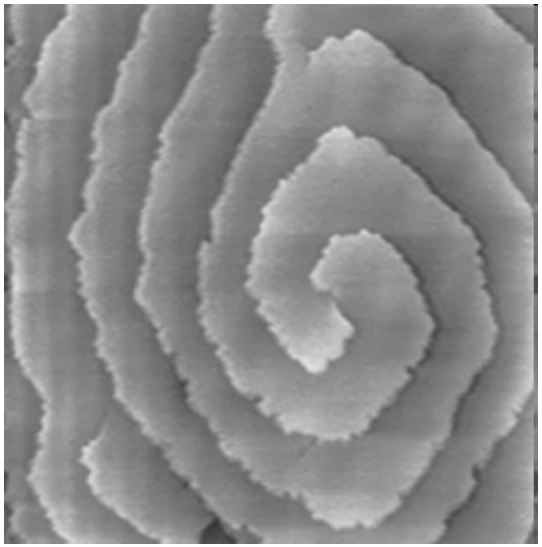
Dislocations



Edge Dislocations



Screw Dislocations

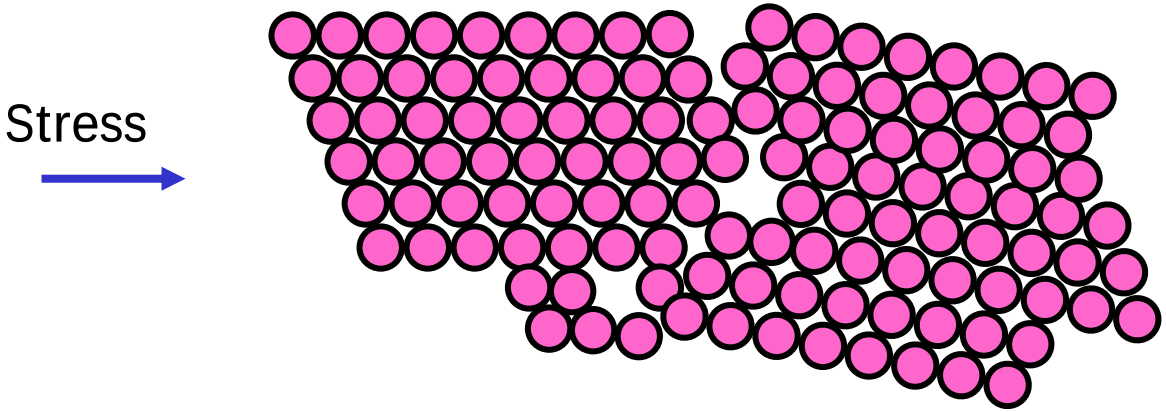


Double-screw dislocation, on the surface of a crystal of the protein canavalin

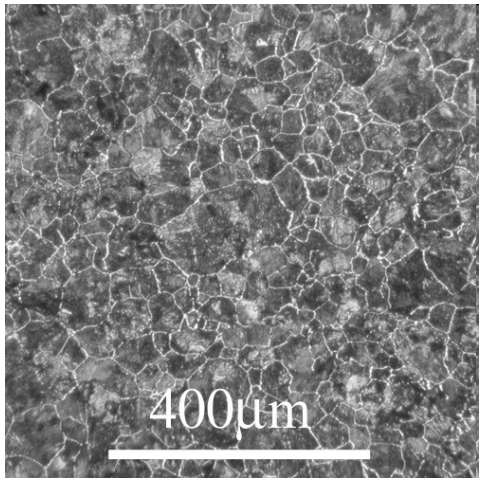
http://mm04.nasaimages.org/MediaManager/srvr?mediafile=/Size4/nasaNAS-9-NA/60066/0101744.jpg

www.ndt-ed.org/.../Structure/linear_defects.htm

Polycrystalline Materials



galvanised steel, the grains are big enough to be seen unaided. The plate measures 5 cm across

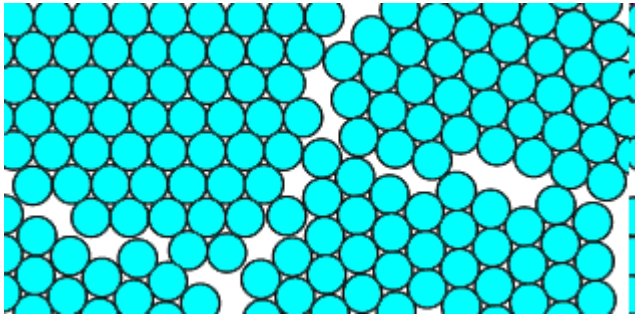


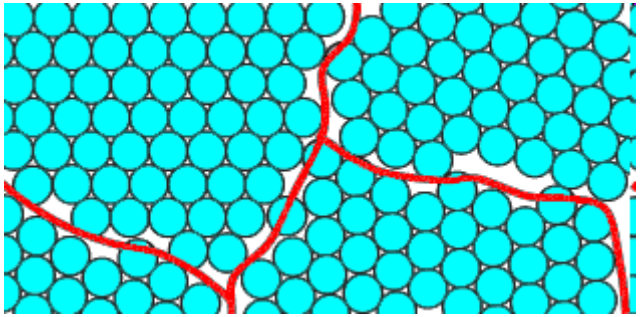
iron-carbon alloy, the grains may only be seen under a microscope

The packing of soap bubbles is somewhat similar to the packing of crystals - minimum surface area

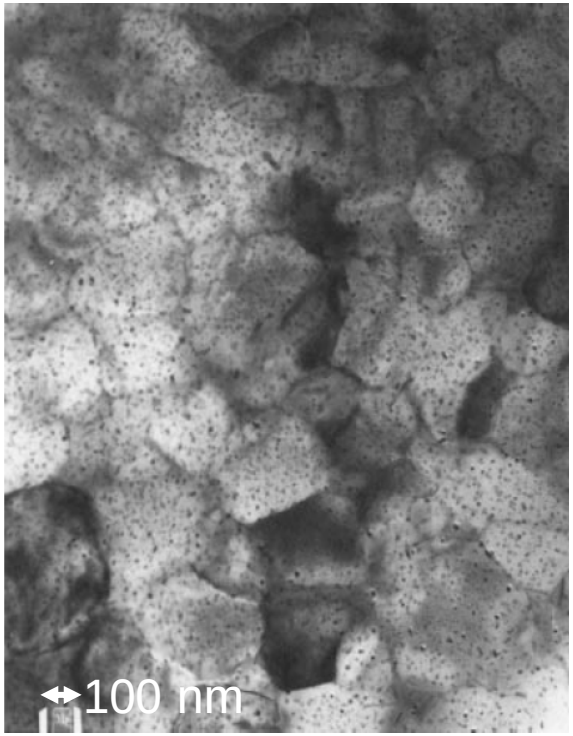
http://www.doitpoms.ac.uk/tlplib/atomic-scale-structure

Glass Ceramics





www.corelle.com



Microstructure of a β-quartz solid solution glass ceramic

L. R. Pinckney, "Glass Ceramics" in Kirk-Othmer Encyclopedia of Chemical Technology, Vol 12, p 626

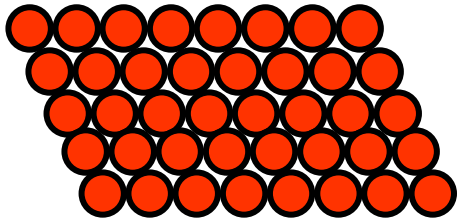
Glass Ceramics

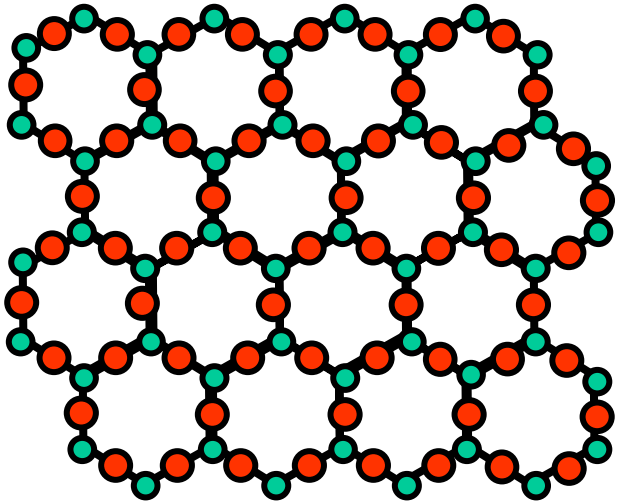
http://farm3.static.flickr.com/2347/2155854135_69656906c9.jpg?v=0

http://en.wikipedia.org/wiki/Glass

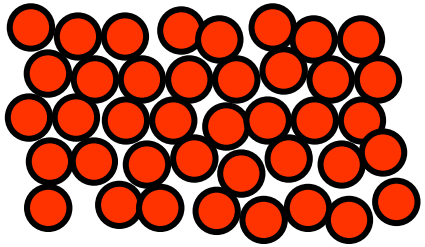
Glass

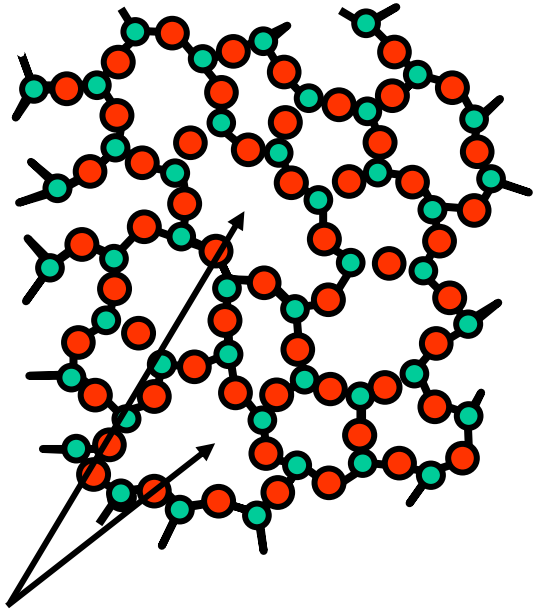
Crystalline Silica





Silica Glass



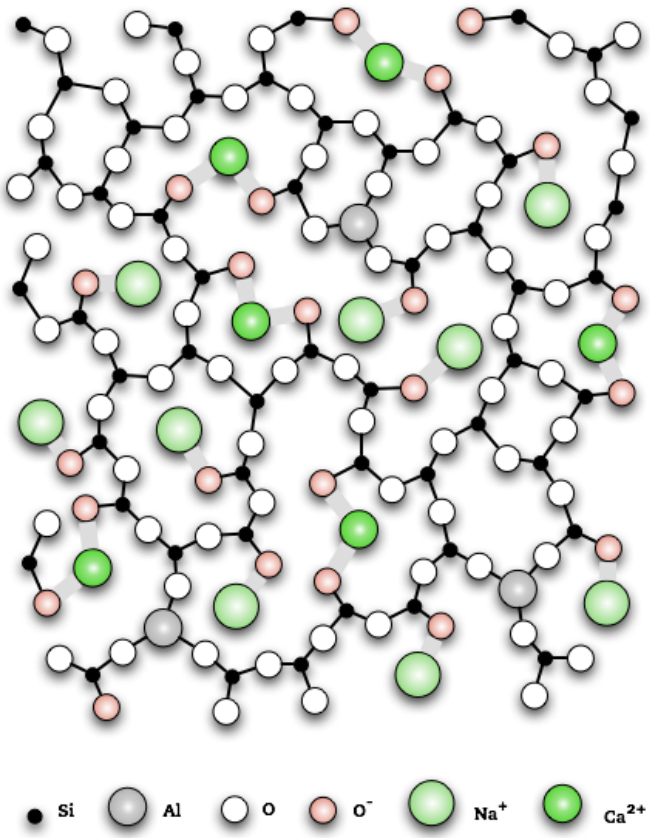


Glass has a very random molecular structure with loosely spaced molecules. This allows much of the visible and ultra-violet spectrum of light to pass through.

oxygen

silicon

“Window” Glass (Soda-Lime Glass)



- SiO_2 (sand, ~74%)
- Na_2O (soda, ~15%) lower viscosity and melting point (from 1723˚ to 850˚) CaO (lime, ~10%) to make insoluble in water
- Al_2O_3 (~1%) to increase durability

  Both Na_2O and CaO also alter the network structure making the mixture more fluid and more likely to form a glass.

- MgO slows down the rate at which the glass crystallizes.
- B_2O_3 (instead of Na_2O) produces a borosilicate glass that expands less on heating (pyrex).
- PbO produces lead glasses that are ideally suited for high-quality optical glass (“crystal”).

http://upload.wikimedia.org/wikipedia/commons/8/83/Kalk-Natron-Glas_%28ohne_Stabilisator%29_2D.png

Breaking Glass

There are no slip planes to let the atoms slide over each other – no way to relieve a large stress. A crack forms at a surface flaw. Particles in the crack become separated so they can't distribute the stress to neighbouring particles causing a larger crack... until the glass breaks. [If you want to cut a piece of glass, start by scoring the glass with a file to produce a scratch along which it will break when stressed.]

http://greytdragons.tripod.com/images_glass/

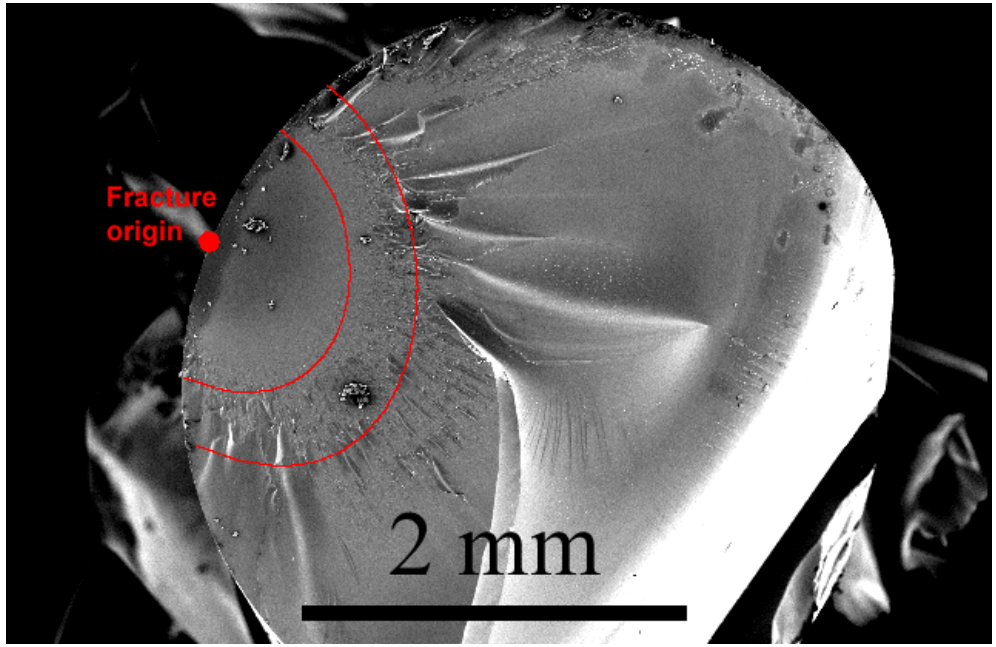
http://i22.ebayimg.com/03/i/001/0a/c1/9c60_1.JPG

Applying a temperature change to one side of the glass causes expansion or contraction. Because glass is not a good conductor, the glass does not expand or contract evenly across its width. [Don't pour boiling water into a "normal" glass]

Making a sound at the natural frequency of the glass causes it to vibrate. The louder the sound the larger the vibrations. Eventually they will be big enough to break the bonds and cause the glass to shatter (>100dB). [still need a flaw in the glass]

http://www.topnews.in/files/breaking-glass.jpg

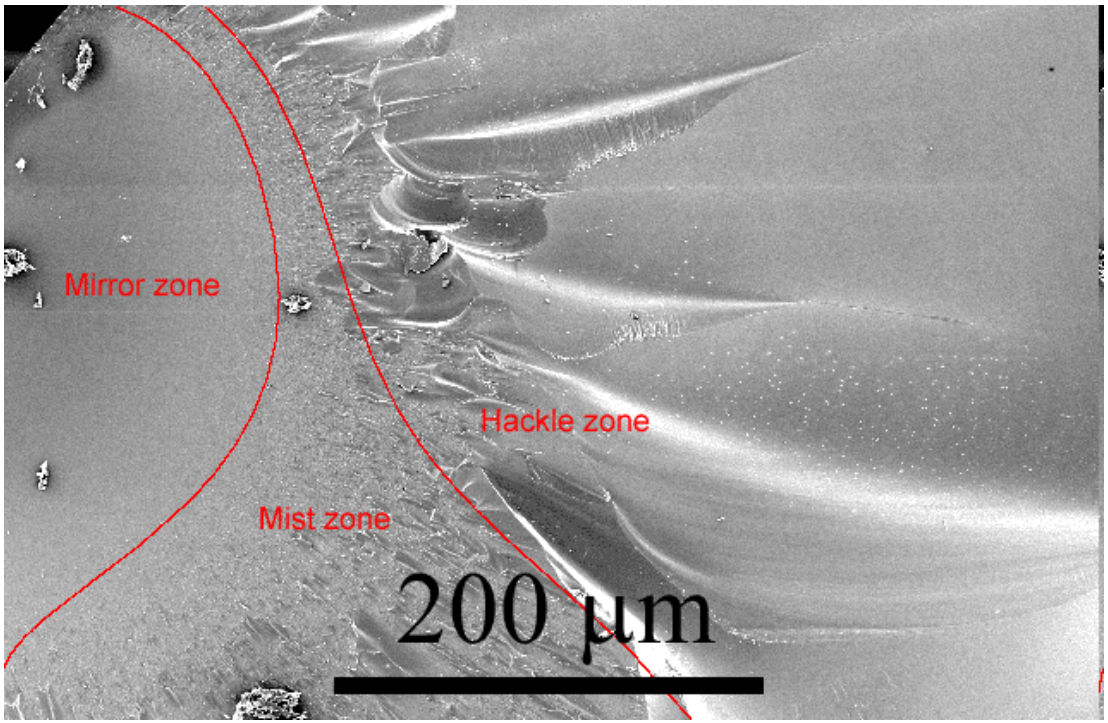
Breaking Glass



http://www.doitpoms.ac.uk/tlplib/fracture/

Three distinct regions can be seen on the fracture surface:

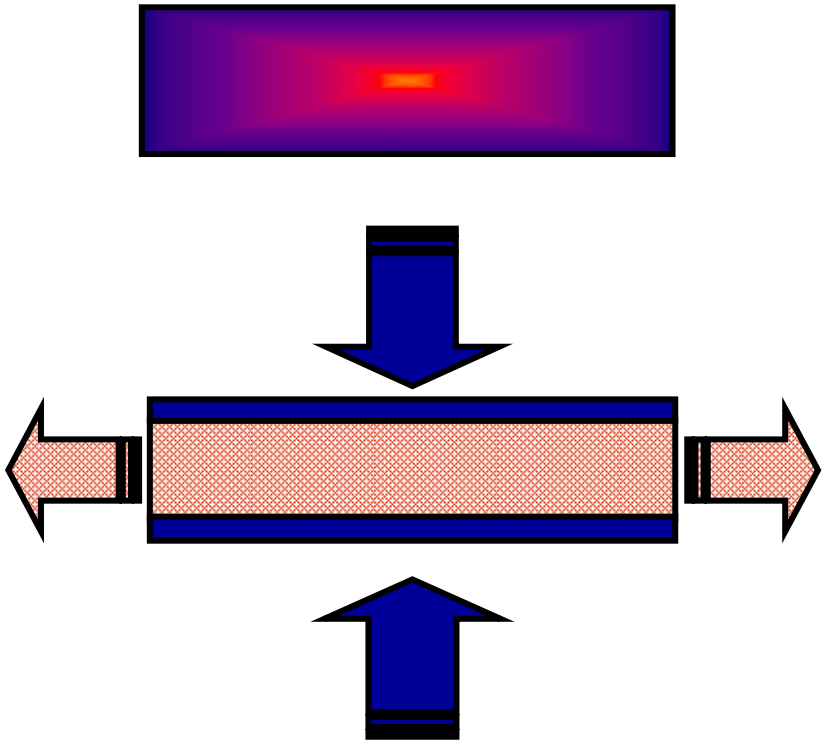
- A smooth region surrounding the fracture origin called the mirror zone.
- A small band of rougher surface surrounding the mirror region, known as the mist zone.
- An area beyond this known as the hackle zone, composed of large irregularly oriented facets.



Tempered Glass

Tempered glass is a “stressed skin sandwich”: both glass surfaces are in compression and the glass core is in tension.

- Thermally: by rapid heating and cooling – the outer surface freezes while the middle is still molten
- Chemically: by replacing some of the sodium atoms on the surface with larger potassium atoms



Tempered glass is four to five times stronger than standard glass

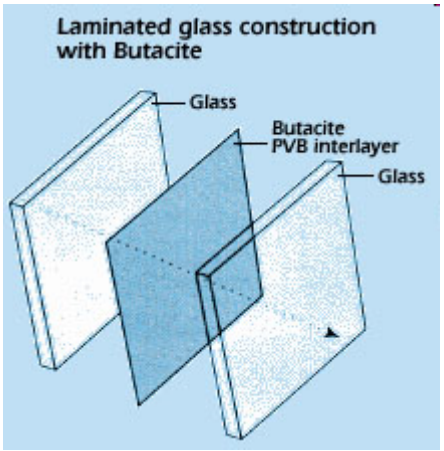
The weakness of tempered glass is its edges: a light impact with a sharp object can cause its failure, or it can fail when you punch through the stressed skin of the glass. It also has to be cut to size before being tempered because cutting after tempering results in shattering of the sheet.

Because the glass core is under tension, when it breaks it breaks everywhere.

http://www.tintworks.net/

“Bullet-Proof” Glass

Polyvinyl butyral (PVB) sheets are sandwiched between sheets of standard glass, and bonded together by heat. Alternating layers of plastic and glass are then built up. The more layers, the better the bullet-stopping power.



http://www.tintworks.net/

http://www.tintworks.net/

http://4engr.com/images/thumb/6e7d831c1672d9e21efadd39008f31c9.jpg

Ceramics

keramikos, which means “pottery” (“burnt stuff”)

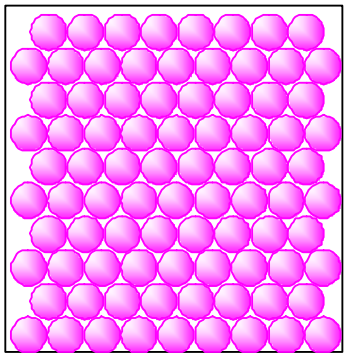
- Ceramics are all solid materials except metals and alloys.
- crystalline or glass-like (most ceramics are polycrystalline materials)
- pure, single-phase materials or mixtures of two or more discrete substances.
- Network covalent solids (SiO_2) or ionic solids (salt)
- Brittle

Eg Clay is kaolinite: $Al_4Si_4O_{10}(OH)_8$

Ceramics can be:

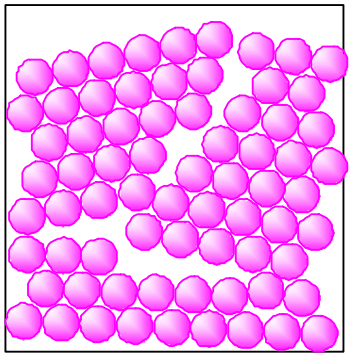
- conductors eg ReO_3 and CrO_2
- insulators eg the glass-ceramics used in spark plugs
- semiconductors eg GaAs
- capacitors eg $BaTiO_3$
- magnets eg SrO/Fe_2O_3

http://www.digdorchester.net/IMAGES/roman_pottery.jpg

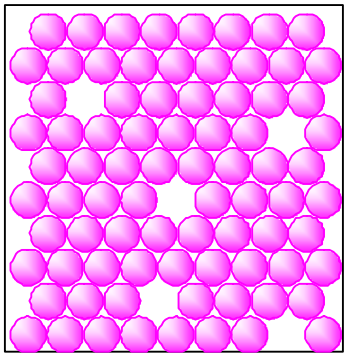


Perfect – “ideal” crystal, no defects

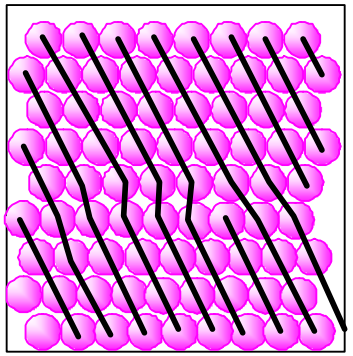
Melting Points:
Diamond ~ 3550 ˚C; Silica (SiO_2) ~ 1723 ˚C;
NaCl ~ 801 ˚C; MgO – 2800 ˚C
Tin ~ 450 ˚C; Silver ~ 962 ˚C; Gold ~ 1064 ˚C



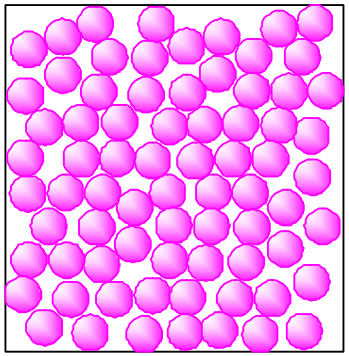
Polycrystalline



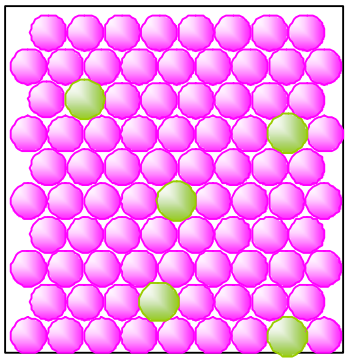
Vacancy



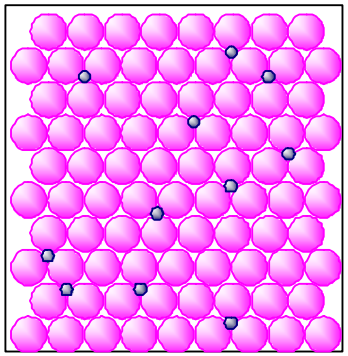
Slip dislocation



glass



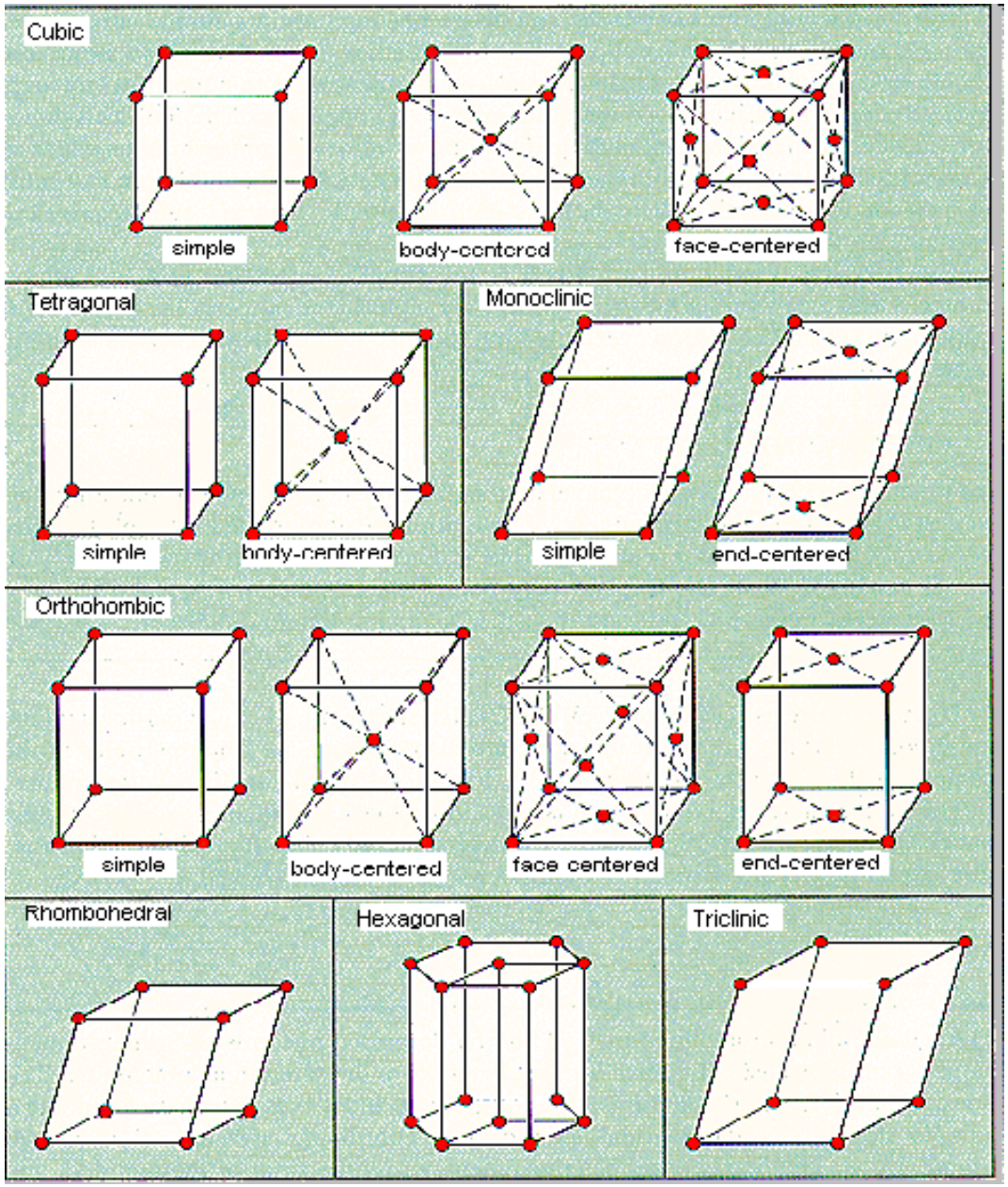
Substitutional



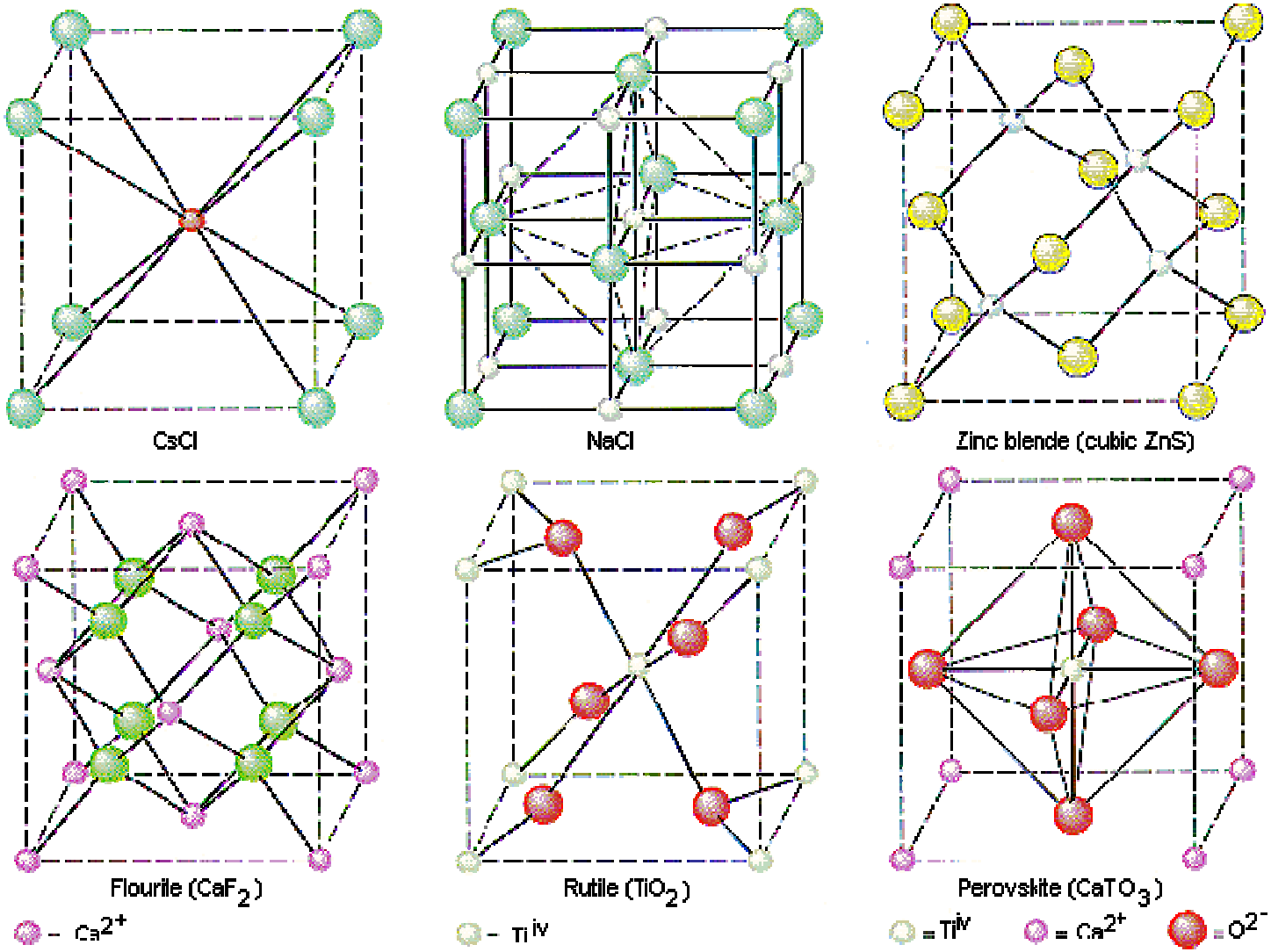
Interstitial

Defects Can impede progress of a dislocation (ie make the material stronger) by:

- controlling the grain size (reducing continuity of atomic planes)
- strain hardening (creating and tangling dislocations)
- alloying (point defects pin dislocation)



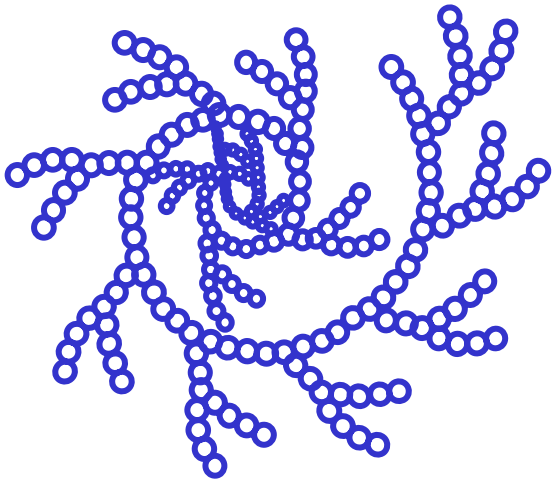
http://chemed.chem.purdue.edu/genchem/topicreview/bp/ch13/graphics/13_16.gif



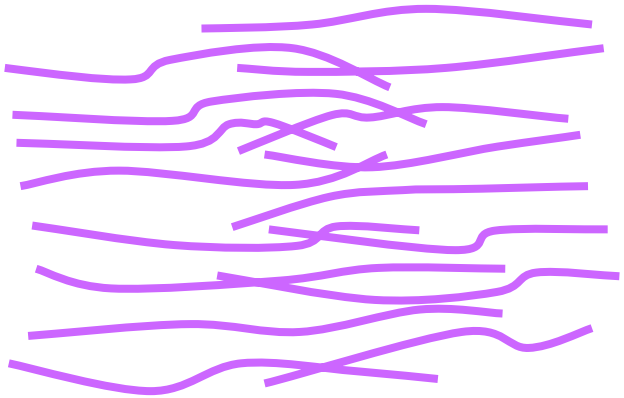
http://chemed.chem.purdue.edu/genchem/topicreview/bp/ch13/graphics/13_19.gif

Polymers

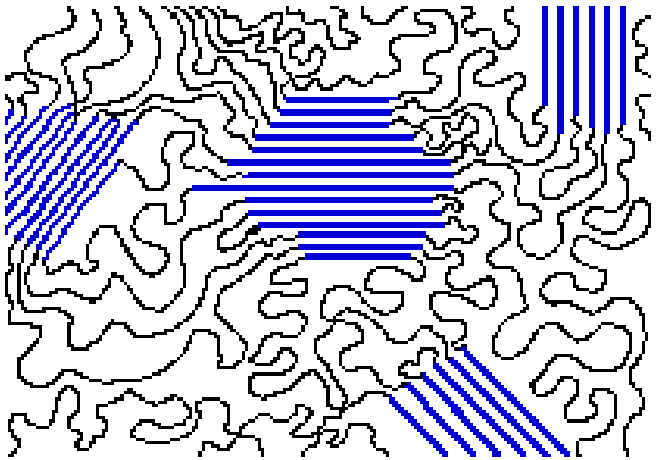
Thermoplastic



Starch

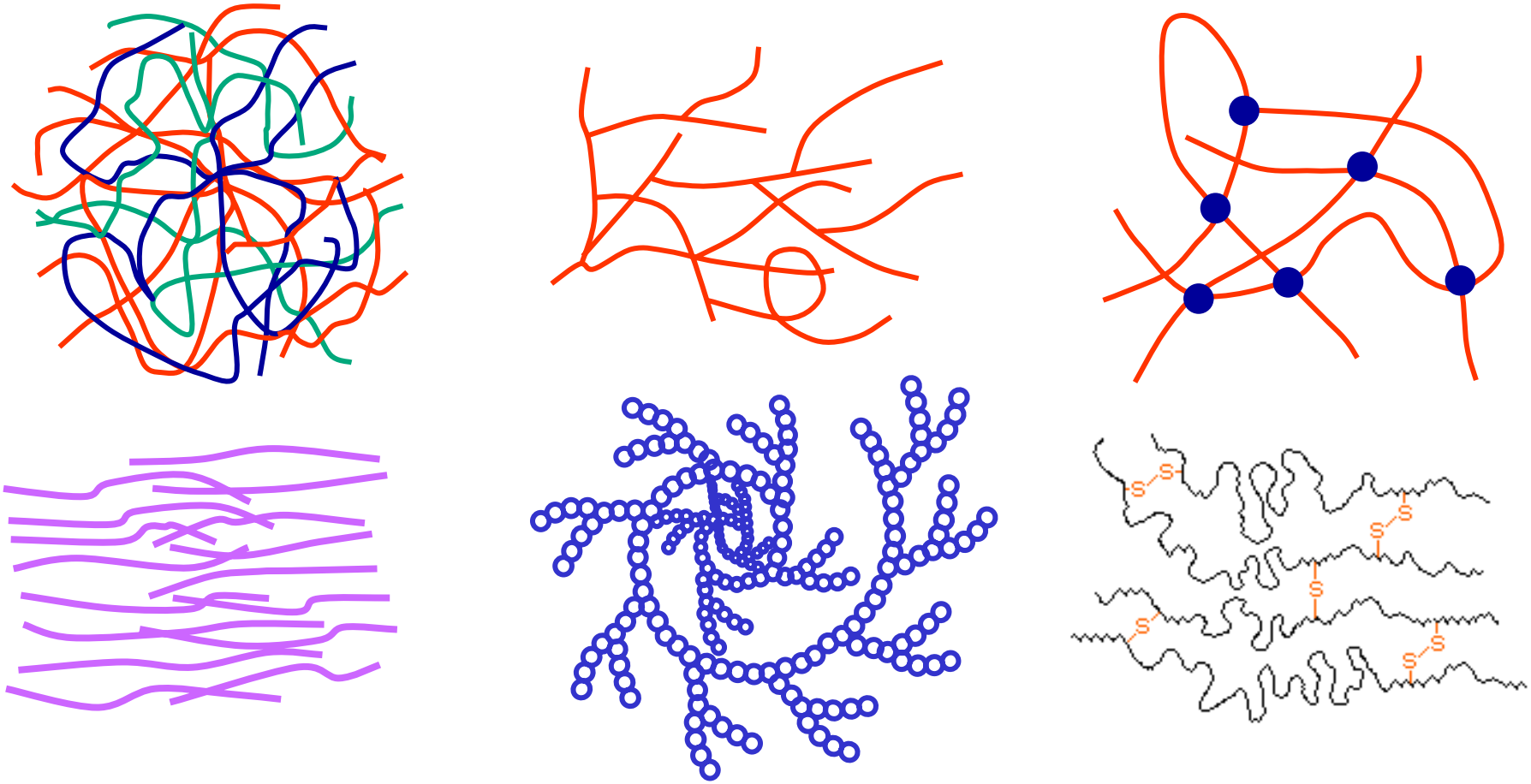


Fibre



Crystalline regions

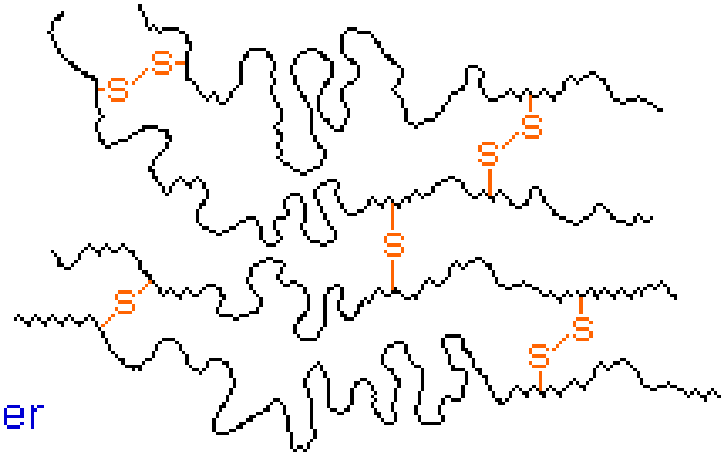
Polymer Backbones



Linear

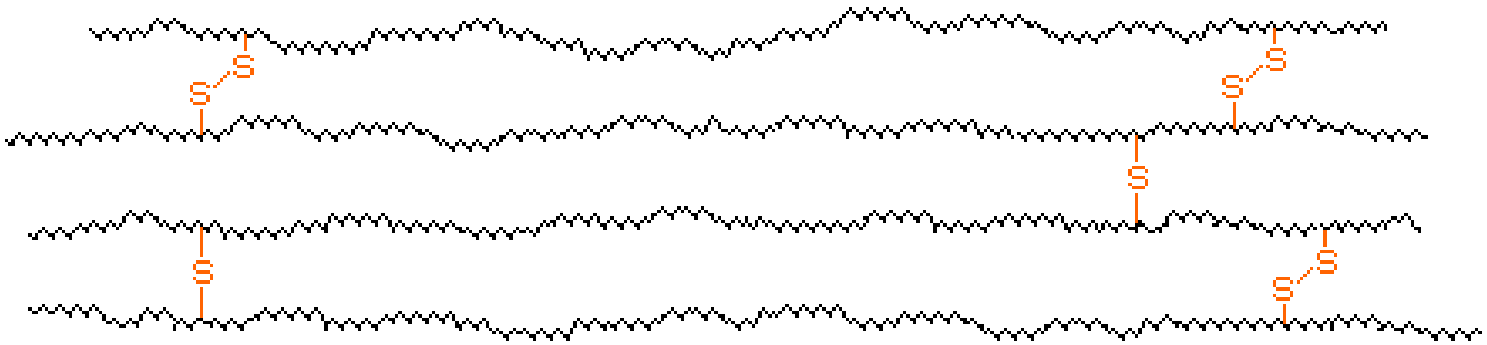
Branched

Cross-linked



Unstretched Rubber

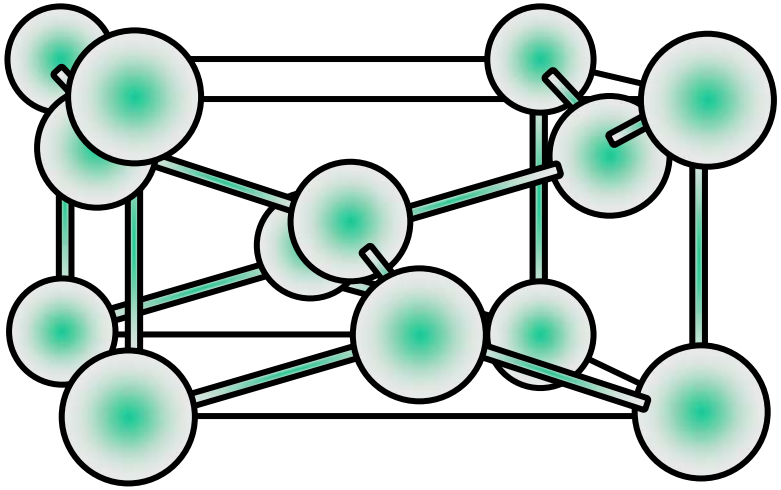
http://www.cem.msu.edu/~reusch/VirtTxtJml/polymers.htm

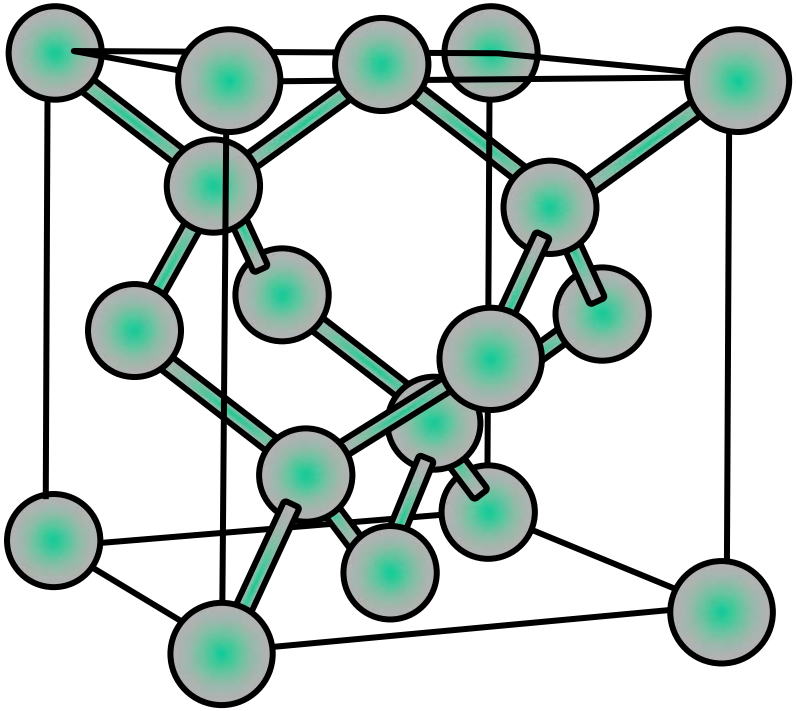


Stretched Rubber

http://www.cem.msu.edu/~reusch/VirtTxtJml/polymers.htm

Tin



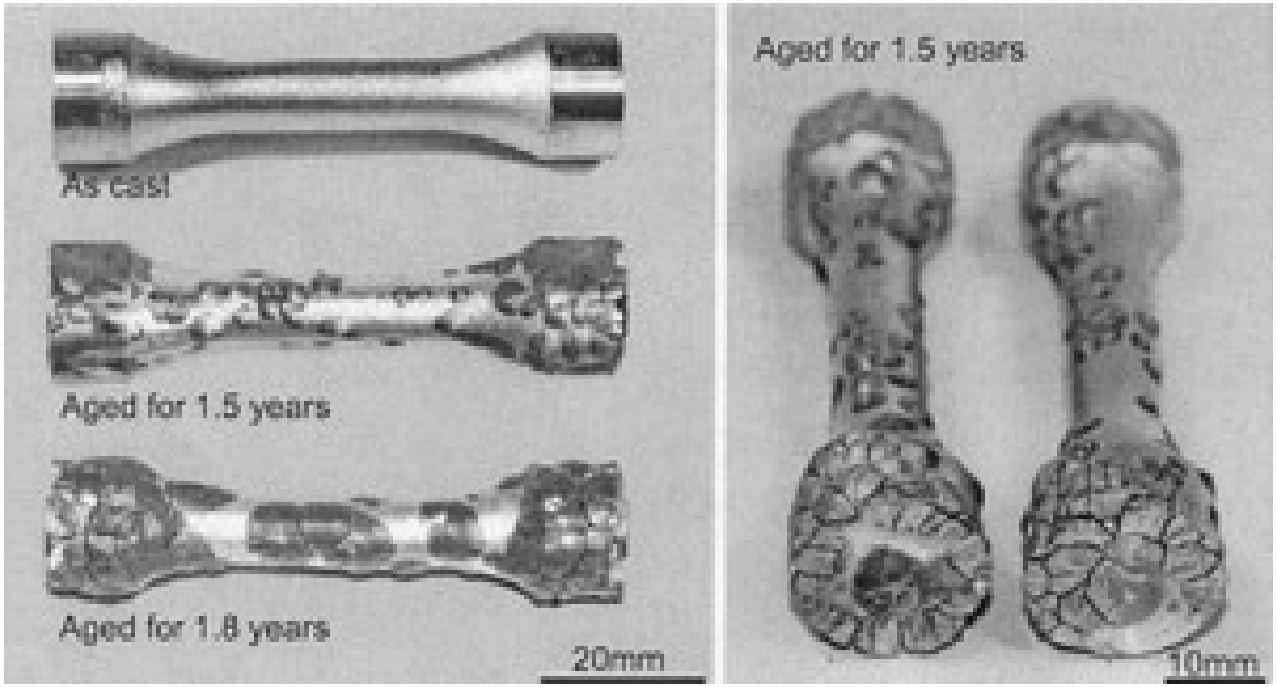


Normal or white β tin is a metal
tetragonal crystal structure
density of 7.31g/cm^3

Below about 13.2 °C,
grey α tin is a semiconductor
diamond structure
density of 5.77g/cm^3

The expansion of tin from white to grey causes most tin objects to crumble.

Tin ‘Pest’



•Y. Karlya, C. Gagg, and W.J. Plumbridge, "Tin pest in lead-free solders", in *Soldering and Surface Mount Technology*, 13/1 [2000] 39-40

Tin ‘Pest’

http://materials.open.ac.uk/solder/images/TinPest2.jpg

Tin ‘Pest’

- The tin buttons on Napoleon's soldiers' coats disintegrated while on their retreat from Moscow.

- Since tin pest looks like the tin has become diseased, many in the middle-ages attributed it to Satan as many tin organ pipes fell victim.

- In 1910 Scott was beaten to the South Pole by Amundsen. Scott’s expedition returned on foot towards caches of food and kerosene they had left on the way in but there was no kerosene, the cans, soldered with tin, were empty. The members of the expedition died only 11 miles from a massive depot of supplies

http://www.powellhistory.com/art/Painting/Albert_Northern%20-%20Napoleons_retreat_from_moscow.jpg

http://www.spri.cam.ac.uk/about/http://www.spri.cam.ac.uk/about/legacy/legacy.jpg