Single Crystals: Mechanical and Optical Properties

Mechanical properties:

Gypsum can be cleaved along particular crystallographic planes using a razor blade. The bonding perpendicular to these cleavage planes is weaker than that in other directions, and hence the crystal breaks preferentially along these planes. Quartz and diamond do not have such distinct cleavage planes, and so cleaving these crystals requires much more effort and care.

There are distinct planes in the gypsum structure, with no bonding between them. These are the cleavage planes. It is much more difficult to cleave gypsum along planes other than these. In contrast, all of the planes in the quartz structure are interconnected and the material is much more difficult to cleave in any direction. This is a demonstration of a way in which the crystal structure of a material can influence its mechanical properties.

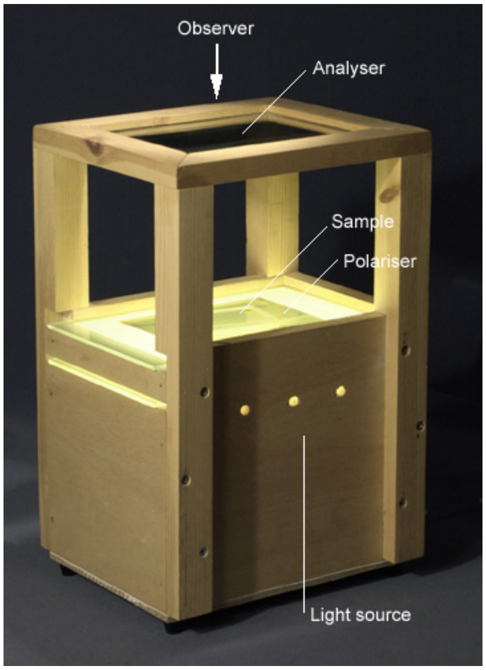
Certain crystals, such as gypsum, can be cleaved with a razor blade along particular crystallographically-determined planes.

Glass is impossible to cleave. As an amorphous substance, glass has no crystallographic planes and therefore can have no easy-cleavage directions. Glassy materials are often found to be mechanically harder than their crystalline equivalents. This is an example of how mechanical properties of crystals and amorphous substances differ.

Optical properties :

Quartz crystals are birefringent , so they exhibit optical anisotropy. Consider plane polarised light passing through a birefringent crystal. Inside the crystal, the light is split into two rays travelling along *permitted vibration directions* (p.v.d.s). The two rays are subject to different refractive indices, so the light travelling along each p.v.d. reaches the opposite side of the crystal at a different time. When the two rays recombine, there is a phase difference between the two rays that causes the *polarisation state* of the transmitted light to be different from that of the incident light.

Optical anisotropy in thin samples can be observed by placing the sample between crossed polarising filters in a light box. The bottom filter, between the light source and the sample, is called the polariser . The top filter, between the sample and the observer, is called the analyser . The polariser and analyser have polarising directions perpendicular to one another.



The apparatus used for examining optical anisotropy consists of a white-light source, two polarising filters and a frame to hold them apart so creating a working space.

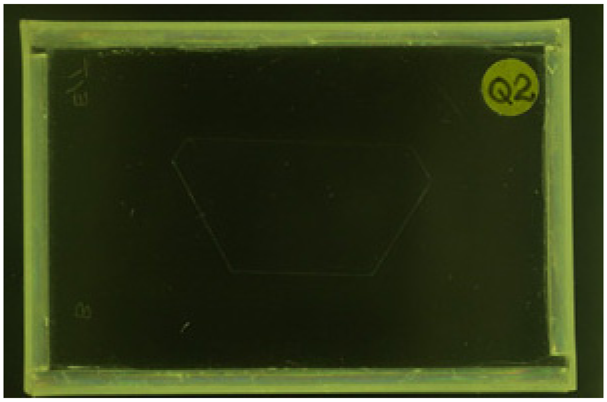
When no sample is in place the light that reaches the analyser is polarised at 90° to the analyser's polarisation direction, so no light is transmitted to the observer. When a quartz sample (with favourable orientation, see later) is placed between the filters, the crystal changes the polarisation state of the light that is transmitted through it. When this light reaches the analyser, some component of it lies parallel to the polarisation direction of the analyser, and therefore some light is transmitted to the observer.

If a quartz slice shows optical anisotropy, the intensity of light transmitted through the analyser varies as a function of the angle of rotation of the quartz sample in the plane of the filters. At certain orientations, no light is transmitted. These 'extinction positions' are found at 90° intervals.

Video animation of anisotropic quartz rotated between crossed polarisers (225 KB) ... in separate window ... video alone

When the same experiment is done using a piece of glass, it is found that light is not transmitted for *any* orientation. This is because the glass is*optically isotropic*, and does not change the polarisation state of the light passing though it.

In quartz, there is one direction of propagation for which no birefringence is observed. If a sample is cut so that the incident light is parallel to this direction, the sample behaves as if it is optically isotropic and no light is transmitted. The crystallographic direction that exhibits this property is known as the *optic axis*.



When the quartz sample is cut so that the incident light is parallel to the optic axis, no light is transmitted in any orientation.

This experiment demonstrates that some single crystals, such as quartz, show anisotropic optical properties. The phenomenon depends on the crystallographic orientation of the crystal with respect to the incident light. Amorphous materials like glass have no 'distinct' crystal directions, so anisotropic properties are generally not observed.

Source : http://www.doitpoms.ac.uk/tlplib/atomic-scale-structure/single3.php