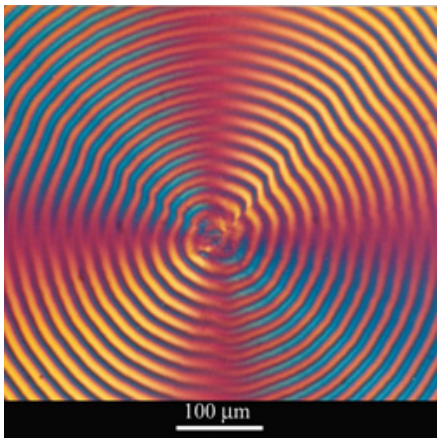
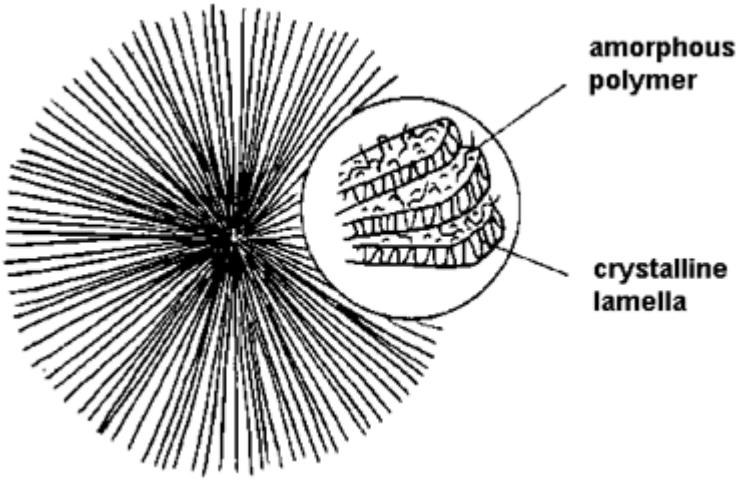
Spherulites and optical properties

Since crystallisation in polymers follows a different process to that in metals - the laying down of successive lamellar layers of polymer chain - it produces a different structure. After nucleation, growth in most polymers is faster in one preferred direction. By convention this is called the b-axis.

The other two axes (the c- and a-axes) grow at the same speed, and have no set direction provided they are orthogonal to the b-axis. Thus they are free to rotate. This means that polymer crystals grow in helical strands radiating from a nucleation point. Such growth leads to the formation of structures called spherulites.





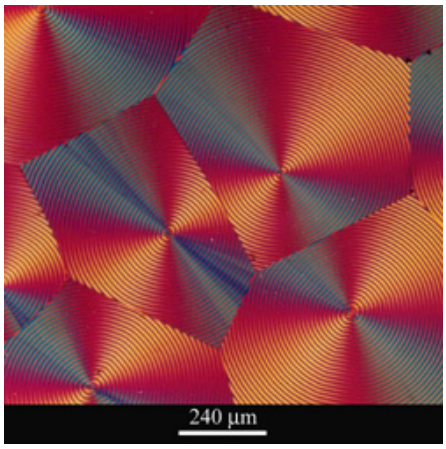
On the left is a transmitted cross-polarised light micrograph of a spherulite in polyhydroxybutyrate (PHB), micrograph no 600 in the DoITPoMS Micrograph Library, where further details of the sample's history can be found.

The photograph displays banding and a Maltese cross pattern. These features are characteristic of polymer spherulites viewed with cross-polarised light. The orientations of the polymer chains within a spherulite are shown schematically on the above right. Note that the lamella are growing radially, interspersed with amorphous material.

The Maltese cross is seen because polymers are birefringent. Polarised light cannot travel through a crystalline polymer if the direction of the polarisation of the light is perpendicular to the direction of carbon chain in the polymer. As a result, when a sample is studied under crossed polars, only those polymer chains perpendicular to neither polariser nor the analyser are visible - these are at approximately 45° to each polaroid. The Introduction to Photoelasticity TLP goes into more depth on the subject of birefringence.

The banded appearance of the image is also a consequence of birefringence. Due to a regular helical twist of the lamellae growing radially there are regions in which the polymer chain will be orthogonal to the polarisation of the light in the x-z plane, even if it is running at 45° to it in the x-y plane.

These positions will occur at periodic intervals, once every full 360° rotation of the polymer chain. This translates to a given length outwards along each strand. This is then observed under crossed polars as alternating dark and light areas.



The image above is micrograph 601 in the DoITPoMS Micrograph Library. It is an image of PHB spherulites viewed with a transmitted cross-polarised light microscope. A Maltese cross can be seen in each spherulite and each one has a banded appearance.

The photograph shows a good example of impingement, which occurs when spherulites growing outwards from single nucleating points meet each other. Due to impingement they are unable to continue growing out radially in all directions. A polygonal microstructure is formed as seen in this photograph.

Source: http://www.doitpoms.ac.uk/tlplib/polymers/spherulites.php