The use of a slit in determining refractive indices with the microscope.

By JOHN WILLIAM EVANS, LL.B., D.Sc., F.G.S.,
Lecturer in Petrology, Imperial College of Science and Technology, and Birkbeck College.

[Read March 21, 1916.]

CERTAIN optical properties of crystals, and more particularly the refractive index, may be determined either in the directions-image, often referred to as the 'image in convergent light', or in the ordinary object-image in which the object itself is seen. In the former case, in which the index of refraction is usually determined by means of the critical angle of total-reflection, every point in the image corresponds to a single direction of propagation of the wave-front through the crystal-structure and to the two corresponding directions of vibration. One of these can, however, be eliminated by the insertion of a nicol in an approximate position, and thus all ambiguity in the determination of the refractive index is removed.

In the object-image, however, the wave-fronts of the light by which any point is illuminated have traversed the crystal-structure in an infinite number of different directions, and to each of these correspond two directions of vibration, so that there is no definite refractive index which can be determined and only approximate results can be obtained whatever the method employed.

This difficulty may be overcome to a considerable extent by placing a diaphragm with a minute aperture in a position on the microscope axis where a directions-image is formed, or in a focus conjugate to such a position, so that the image of the aperture is seen in focus simultaneously with the directions-image, thus allowing only a small well-defined portion of the latter to be visible or to be illuminated.

By moving the diaphragm laterally, that is to say, at right angles to the axis of the microscope, any point of the directions-image may be rendered visible or illuminated to the exclusion of the rest, so that the light which passes is limited to that which has traversed the crystal-structure in what is practically one direction only, and with the help of a nicol it may be restricted to that vibrating in one only of the two corresponding directions of vibration. Then by an alteration of the optical system between the diaphragm and the observer, an object-image may be formed and observed, which is illuminated only by this special light.

The simplest method of applying these principles is to insert the diaphragm below the stage in the position in which the iris-diaphragm is usually placed, so that when the Bertrand or Beck lens is inserted or the eyepiece removed it is seen in focus in the directions-image. After the diaphragm has been adjusted as desired, the Bertrand or Beck lens is removed or the eyepiece replaced, and the object-image is seen illuminated only by the vibrations which it is desired to investigate.

If the Bertrand lens be employed to form a directions-image in the focus of the eyepiece, the diaphragm may be placed in that position, and the object-image, formed above the eyepiece, may then be observed with a suitable lens. This image is, however, in the ordinary microscope too high above the eyepiece to be seen with a fixed lens such as the Beck lens without an extra tube, and it is small and ill-defined.[1]

The chief objection to these methods of isolating a particular direction of vibration is the great loss of light which they involve, causing the illumination to be comparatively feeble even with a powerful source of light.

Where, however, a thin section is cut at right angles to a plane of optical symmetry or, what comes to the same thing, a grain is so orientated that a plane of optical symmetry is at right angles to the microscope stage, the direction of vibration at right angles to the plane of optical symmetry may be isolated by means of a diaphragm with a fine slit instead of a small perforation. The slit may be adjustable in the same manner as that of a spectroscope, or the diaphragm may be formed by a metal slide with slits of different widths, which can be used as desired.

The slit is placed in a position of parallelism with the plane of optical symmetry, with the result that all the paths of the light which passes it and illuminates the portion of the object in the axis of the microscope are approximately in that plane. It must therefore, whatever path it follows, *have one of its directions of vibration practically normal to the plane in* question, and the other in the plane and at right angles to its path. If

[1] J. W. Evans, 'The isolation of the directions-image of small objects', Mineralogical Magazine, 1916, this vol., p. 45.

now a Nicol's prism be inserted in the microscope in such a position that the vibrations of the light which traverses it are at right angles to the plane of optical symmetry, the vibrations in that plane will be eliminated, and the image will be illuminated only by vibrations at right angles to it, which have, of course, all the same refractive index, so that definite results will be obtained.

If the section is at right angles to two planes of optical symmetry, or, what comes to the same thing, if two such planes are parallel to the axis of the microscope, each may in turn be placed parallel to the slit, and thus two indices of refraction may be determined. These will be two out of the three principal indices of refraction, that is to say, those of the three lines or axes of optical symmetry.

In the case of uniaxial crystals, the index of refraction of the ordinary or basal vibrations may be observed in any section, while in a section parallel to the axis of optical symmetry, those of both the ordinary and the extraordinary axial vibrations may be determined.

These methods are applicable to the Chaulnes procedure for determining the refractive index, and they eliminate the bifocal effects described by Sorby.[1] If they are employed with the Schröder van der Kolk method, the finger or other screen must be introduced along the direction of the length of the slit.

If the slit is employed in the Beck method, it must be parallel to the boundary along which the effects are to be obtained. The result is that it is only occasionally that the principles described above can be applied. The slit has, however, in this case another important recommendation. When parallel to the boundary of the minerals to be compared, it gives as definite results as a circular aperture with a diameter equal to its width, and at the same time the field is much better illuminated.

Dr. Tutton pointed out at the reading of the paper that the slit could also be employed to obtain monochromatic light for microscope studies of crystals, if the spectrum from a prism were thrown upon it in such a manner that the individual colours were parallel to the slit and the length of the spectrum at right angles to it.

[1] H. C. Sorby, Mineralogical Magazine, 1877, vol. i, p. 97; 1909, vol. xv, p. 189.