DETERMINATION OF ALL PRINCIPAL INDICES OF REFRACTION ON DIFFICULTLY ORIENTED MINERALS BY DIRECT MEASUREMENT

John L. Rosenfeld, *Missouri School of Mines and Metallurgy, Rolla, Missouri*

Abstract

A device and method of general applicability is described whereby one can determine all principal indices of refraction on a single grain of non-opaque substance by direct measurement. The materials used are easily obtained and cost less than one dollar.

Theory

In the course of examining the optical properties of amphiboles, carbonates, and micas during a recent petrographic investigation, it occurred to the writer that no rapid and, at the same time, rigorous systematic method existed for the accurate determination of all the principal indices of refraction on minerals which are difficult to orient due to perfect cleavage at undesirable angles to the optical directions. In attempting to measure γ and α on a hornblende, the writer experimented with a grain mounted on the end of a needle capable of rotation in the plane of the microscope stage. It soon became apparent that any linear direction within any mineral grain could be turned into the plane of the microscope stage, and that by rotation of the microscope stage this linear direction could be rotated into any azimuthal direction (i.e. parallel to the north-south cross hair). The principal indices of refraction represent linear directions within any non-opaque mineral grain, and therefore can be turned into parallelism with the stage of the microscope parallel to the north-south cross hair, the measuring position. There remains to be be recognized a proper orientation of one of the principal indices when it is attained. It can be stated as a result of the theory of the optical indicatrix that whenever one of the principal indices of refraction is in the measuring position, an interference figure will show, in the general case, an isogyre along the east-west cross hair. This can readily be visualized by studying a skiodrome model. Conversely, whenever a dark bar occurs along the east-west cross hair under conoscopic observation, one of the principal indices of refraction lies in the measuring position parallel to the north-south cross hair.

The Device

The following materials are desirable for the construction and use of the device:

1 object glass (1 inch × 3 inches × .04 inch).
1 scrap object glass (preferably .06 inch thick).

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  waterglass (in small dropper bottle with rod applicator).
1 diamond point or other suitable device for cutting glass (corundum satisfactory).
1 2.5 inch corsage pin with spherical knob on end (a standard size available at almost any floral shop). Pin must be straight.
  Beeswax
1 12 mm. circular or square glass cover slip.

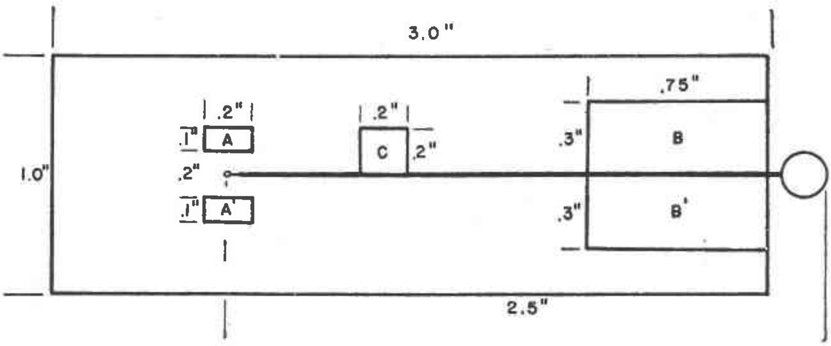

FIG. 1

In Fig. 1 a top view of the device is shown. A and A' represent pieces of the .04 inch object glass cemented with waterglass to the slide. These serve as support for the cover slip. B and B' represent guides for the needle and should be cemented to the slide with the needle in position in order to get a snug fit. They should be made out of .06 inch object glass. C represents a piece of .06 inch object glass beveled so as to overlap the needle with light pressure. It should be installed with the needle in position after A, A', B, and B' have been mounted. Its purpose is to prevent the needle from flying up when the knob is adjusted.

MOUNTING THE GRAIN

One of the more difficult problems in developing the device involved a practicable method of mounting the mineral grain on the end of the needle with a cement which would not be attacked by the immersion media. It was found that a grain could be picked up on the end of the needle by first making the point sticky with a minute amount of beeswax. Inasmuch as the beeswax is attacked by most immersion media, it is necessary to further armour the point of contact between the grain and the needle, being careful not to coat the grain. This is done with waterglass by carefully twirling the point of contact of the needle and grain on the topside of the waterglass rod applicator. A very small amount of waterglass will suffice for a firm connection. Waterglass has the desirable property of drying very rapidly. Mounting is facilitated by the use of a hand lens or binocular microscope. After a little practice it becomes very simple to mount even relatively small grains in this fashion. Another method which is occasionally easier for mounting small grains involves cementing with waterglass a quarter inch segment of fine capillary tubing on the end of the needle. After the cement has hardened, the end is moistened with a small amount of waterglass and immediately touched to the mineral grain, which adheres rather firmly. The capillary tubing helps to eliminate the tendency of the waterglass to "ball up" near the end of the needle. Both methods have been used with success by the writer.

PROCEDURE

After the grain is mounted, the needle is placed on the slide as shown in Fig. 1. The cover slip is placed on the cover slip supports, and an appropriate immersion medium is allowed to be drawn into the immersion chamber by capillarity. Using a 4 mm. objective (preferably of N. A. .65 with longer working distance than the N. A. .85 objective) the grain is viewed under conoscopic conditions. By rotation of either the needle or the stage or both, an isogyre is brought into the field of view and oriented along the east-west cross hair. One of the principal indices of refraction is oriented parallel to the north-south cross hair in the measuring position. Maintaining this orientation and using the spherical knob on the end of the needle as a spherical projection, two ink dots are placed on the knob so that the line between them is parallel to the north-south cross hair. The stage is then rotated 90°. By synchronous rotation of stage and needle, the line between the two ink dots is rotated in a plane perpendicular to the north-south cross hair until a second isogyre lies along the east-west cross hair. A second principal index of refraction lies in the measuring position parallel to the north-south cross hair. Two more ink dots are placed on the knob parallel to the north-south cross hair. The third principal index of refraction lies perpendicular to the plane containing the other two, and can be immediately oriented, by synchronous rotation of stage and needle, into parallelism with the north-south cross hair, in which position a third isogyre will be seen to lie along the east-west cross hair. Ink dots are placed on the knob as before. The purposes of marking the knob are merely to prevent duplication of steps, to give an approximately correct orientation of the indicatrix in the attached mineral grain, and to aid in achieving a rigorous sequence of steps. Accurate orientation in each case is based on the presence of an isogyre along the east-west cross hair.

With the information concerning principal vibration directions recorded on the knob of the needle, it is a relatively simple matter to determine the indices parallel to these directions by immersing the grain in successive media and orienting in accordance with the above method. A medium may be removed by adsorption into some absorbent paper, followed by one flush of the next medium to be used. Dilution effects thus become practically negligible. It also becomes unnecessary to move from a desired orientation. If it is desired to do accurate work, the cell may be flushed with acetone. It is then necessary to wait for the slide to warm to room temperature because of the cooling caused by the evaporation of acetone.

The uniaxial mineral represents a special case of the biaxial mineral where either α and β are equal, or γ and β are equal. The same procedure therefore applies to uniaxial minerals. The uniaxial character will be demonstrated by the fact that either α and β will be found equal (positive mineral) or γ and β will be found equal (negative mineral).

Conclusions

This method has been used by the writer and his students with considerable success. It offers little or no advantage in speed for grains of minerals which tend to assume random orientation in powdered form. However, it has been found to be practicable in the cases of minerals which tend to assume preferred orientations at undesirable angles. For this latter class of minerals the method is believed to have the following advantages:

1. Rigor. No assumptions need be made about cleavage angles, as the method relies entirely on functions of the optical indicatrix.
2. Speed. The writer has found that, by using this method, he is able to determine all the principal indices on a clinoamphibole just about as rapidly as he can on an olivine, using conventional methods.
3. Teaching aid. It has proved a valuable aid in teaching elementary students to visualize the orientation of the indicatrix within crystals.
4. Simplicity. It is unnecessary to carry out any trigonometric calculations.
5. Use of only one grain of mineral. This has an added advantage if impurities are abundant in the source material, as in many sediments.

Acknowledgments

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