POLARIZED LIGHT MICROSCOPY

Polarized Light Microscopy (PLM) is a traditional, transmitted light microscopy technique dating back to the 19th century. Polarizing filters in microscopy force the refracting light waves to pass through the study materials to the eyepieces in such a way that characteristic properties can be observed. PLM is uniquely suited for the study of minerals and rocks, so the PLM microscope is commonly referred to as the "petrographic" microscope. However, any translucent to transparent material can be examined using PLM, provided it meets the sample requirements.

The PLM used in ASG is a Nikon Optiphot2-POL, and it is equipped with a Diagnostic Instruments SPOT-RT digital camera and associated software. The light source for the PLM is a halogen lamp (12V, 100W) which is positioned at the bottom of the microscope. The microscope has four objectives, resulting in the following approximate magnifications: 40x, 100x, 200x, and 400x.

Sample requirements depend on the type of investigation, but every investigation involves mounting a sample on a glass microscope slide. Sample types analyzed include limestone, dolomite, talc, mica, PCC, GCC, glasses, polymers, and refractories.

- The most common procedure is to use a powder mount and specialized immersion oil. In this case, the samples must be in powdered form or be capable of being rendered into a powder. The ideal particle size is -50 to +100 mesh. (If the particle size is below 25 microns, the results may be qualified.) The ideal sample size is a few grams, but smaller amounts of sample can be evaluated.
- Polymer samples such as low density polyethylene (LDPE), linear low density polyethylene (LLDPE), or polypropylene (PP) can be analyzed using the immersion method, but the form of the samples should be discussed with ASG prior to submission
- Thin sections are another way of mounting a sample on the glass microscope slide. This method requires a hand sample of rock or other well indurated material, from which a slice is cut with a rock saw and is mounted on the slide. The mounted sample is ground down to a thickness of approximately 0.3 mm. One hand sample of the material is needed for 1 to 2 thin sections.

In ASG, PLM is most often used for two types of investigations:

- **Refractive Index (RI) Evaluation.** ASG has developed a draft Test Method for RI Evaluation using PLM. This test method is an immersion method of determining RI in powders, and can be used for samples comprised of one or more components, such as the Optibloc products or glasses. This test method is also used for polymer materials such as LDPE, LLDPE, and PP.
  Accuracy: +/- 0.005 RI units over the RI range 1.490-1.670.

- **Regulatory Mineral Identification.** PLM is one of several analytical techniques used for identifying regulated minerals such as chrysotile asbestos and asbestiform amphiboles. Samples are usually powders, but can be evaluated as thin sections. The important role of PLM in these investigations is documenting the morphology of the minerals. Morphology is a defining characteristic of asbestos and it cannot be characterized using X-ray diffraction or elemental analyses alone. Numerous optical properties are evaluated during this type of investigation, and they are summarized in the table below.

PLM has multiple observation modes, depending on the configuration of the components in the optical path. In addition, the PLM has a rotating stage that is used in all observation modes. The stage has a goniometer marked in degrees on the edge of the stage, providing for accurate measurement of angular properties in all observation modes. The observation modes are as follows:

- **Plane light:** One polarizing filter is included in the substage assembly of the microscope, and the light always passes through this filter, called the "polarizer". The polarizer makes the light waves vibrate in one plane before passing through the sample.
- **Crossed polars:** Above the microscope stage, a second polarizing filter can be inserted into the optical path. This second filter is called the "analyzer", and it confines the vibration of the light waves in a plane that is perpendicular to the plane of light waves exiting the first polarizer. This configuration is also called "crossed nicols".

- **Crossed polars with compensator plate:** The PLM in ASG has a compensator plate, also known as a "quartz plate".
- **Conoscopic mode:** This mode is for minerals only. The PLM in ASG is equipped with a substage condenser and a Bertrand lens located above the analyzer. When these components are inserted into the optical path and the polars are crossed, the interference figure of a mineral can be evaluated. Interference figures are patterns formed by the interference colors of a mineral, and they are very informative when they can be clearly observed.

The following table summarizes the optical properties used for the two types of investigations most commonly performed using PLM in ASG. The table is organized with respect to the different observation modes used to evaluate each property.

Table 1. Optical Properties Evaluated using PLM, organized by Investigation Type and Observation Mode.

Investigation Type	**Plane Light**	**Crossed Polars**	**Crossed Polars with Quartz Plate**	**Conoscopic Mode**
Refractive Index Evaluation	Refractive Index Becke Line	Birefringence	None	None
Regulatory Mineral Identification	Refractive Index Becke Line Color Pleochroism Cleavage Morphology Relief Texture	Birefringence Extinction Extinction Angle	Sign of Elongation	Interference Figure Uniaxial or Biaxial Optic Sign

Turnaround time for PLM analysis is 2 weeks under normal circumstances. However, the turnaround time could vary with the number of samples submitted and whether other priority samples are in the queue.

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