LECTURE 4

4.0 INTRODUCTION TO THE MICROSCOPIC STUDY OF MINERALS

4.1 LECTURE OUTLINE

Welcome to the fourth Lecture of this unit. You should now be familiar with the concepts of optical mineralogy covered in Lecture 3. In this lecture, we are going to learn firstly about the important components of the petrographic microscope itself. Technologically, microscopes vary in their design, not only in their appearance but also in the positioning and operation of the various essential components. These components are present in all microscopes and will be described briefly in this lecture. Although dual purpose microscopes incorporating both transmitted and reflected light options are now available in the market, it is more convenient for the purpose of this unit and for your ease of understanding, to describe the two techniques separately. Secondly, in learning about the microscopic study of minerals, we shall give a systematic description of the characteristic optical properties observed under plane- and crossed-polarized light. Finally we shall review the general procedures used in the making of thin- and polished sections.

At the end of this lecture, you should be able to:

- Describe and illustrate the use of all the major components of the transmitted light polarizing microscope
- Give a systematic description of minerals in thin sections using transmitted light.
- Explain the optical properties observed under plane-polarized light and crossed polars.
- Give examples of minerals with distinctive optical properties
- Describe the use of the Reflecting Microscope.
- Describe the general procedures of making thin- and polished-sections.
4.2 THE TRANSMITTED-LIGHT MICROSCOPE

The polarizing transmitted-light microscope, commonly known as petrographic microscope, consists essentially of a light source, a sub-stage condenser and a stage to hold the specimen, an objective, and an eyepiece (Figure 4.1). In addition to these, there is a device for producing polarized light, termed the polarizer, a graduated rotating stage as opposed to a fixed stage, and a second polarizing device termed the analyser. A brief description of these major components is discussed here below.

4.2.1 The light source

In transmitted-light studies a lamp is commonly built into the microscope base (Figure 4.1). The typical bulb used has a tungsten filament, which gives the field view a yellowish tint. A blue filter can be inserted immediately above the light source to change the light colour to that of daylight.

Figure 4.1. The transmitted-light polarizing microscope
In older microscopes the light source is quite separate from the microscope and is usually contained in a hooded metal box to which can be added a blue glass screen for daylight colored light. A small movable circular mirror, one side of which is flat and the other concave, is attached to the base of the microscope barrel. The mirror is used to direct the light through the rock thin section on the microscope stage, and the flat side of the mirror should be used when a condenser (described below) is present.

4.2.2 The polariser

The assumption is that light consists of electromagnetic vibrations. These vibrations move outwards in every direction from a point source of white light, such as a microscope bulb. A polarizing film (the polariser) is held within a lens system located below the stage of the microscope and this is usually inserted into the path. On passing through the polariser, the light is polarized and now vibrates in a single plane. This is called plane-polarized light (PPL). In most UK microscopes the polariser is oriented to give an E-W vibrating incident light.

4.2.3 Substage diaphragms

One or two diaphragms may be located below the stage. The field diaphragm, often omitted on simple student microscopes, is used to reduce the area of light entering the thin section, and should be in focus at the same position as the thin section: it should be opened until it just disappears from view. The aperture diaphragm is closed to increase resolution, it can be seen when the Bertrand’s lens is inserted.

4.2.4 The condenser or convergent lens

A small circular lens (the condenser) is attached to a swivel bar, so that it can be inserted into the optical train when required. It serves to direct a cone of light on the thin section and give optimum resolution for the objectives (described below) used. The entire lens system below the microscope stage, including polarizer, aperture diaphragm and condenser, can often be racked upwards or downward in order to optimize the quality of illumination.
4.2.5 Stage

The microscope stage is flat and can be rotated. It is marked in degree units, and a side vernier enables angles of rotation to be accurately measured. The stage can usually be locked in place at any position. The rock thin section is attached to the centre of the stage by metal spring clips.

4.2.6 Objectives

Objectives are magnifying lenses with the power of magnification inscribed on each lens (e.g. x5, x30). An objective of very high power (e.g. x100) usually requires immersion oil between the objective lens and the thin section.

4.2.7 Eyepiece

The eyepiece (or ocular) contains crosswires, which can be independently focused by rotating its uppermost lens. Eyepieces of different magnification are available. Monocular heads are standard on student microscopes. Binocular heads may be used and, if correctly adjusted, reduce eye fatigue.

4.2.8 The analyzer

The analyzer is similar to the polariser; it is also made of polarizing film but oriented in a N-S direction, i.e. at right angles to the polariser. When the analyzer is inserted into the optical train, it receives light vibrating in an E-W direction from the polariser and cannot transmit this; thus the field of view is dark and the microscope is said to have crossed polars (CP, XPOLS or XP). With the analyzer out, the polariser only is in position; plane polarized light is being used and the field of view appears bright.

4.2.9 The Bertrand lens

This lens is used to examine interference figures (see section 4.3.2). When it is inserted into the upper microscope tube an interference figure can be produced which fills the field of view, provided that the convergent lens (condenser) is also inserted into the optical path train.
4.2.10 The accessory slot

Below the analyzer is a slot into which accessory plates, e.g. a quartz wedge, or first order red (gypsum plate), can be inserted. The slot is oriented so that accessory plates are inserted at 45° to the cross wires. In some microscopes the slot may be rotatable.

4.2.11 Focusing

The microscope is focused either by moving the microscope stage up or down (newer models) or by moving the upper microscope tube up or down (older models). Both coarse and fine adjusting knobs are present.

4.3 SYSTEMATIC DESCRIPTION OF MINERALS IN THIN SECTION USING TRANSMITTED LIGHT

Description of the optical properties of each mineral includes those that are determined in plane-polarized light (PPL) and those that are determined with crossed polars. For most properties, a low power objective is usually used (up to x 10).

4.3.1 Properties in plane polarized light

The analyzer (see above in section 4.2.8) is taken out of the optical path to give a bright image.

4.3.1.1 Colour

Minerals show a wide range of colour (i.e. the natural or body colour of a mineral), ranging from colorless minerals (e.g. quartz and feldspars) to colored minerals (e.g. brown biotite, yellow staurolite and green hornblende). Colour is related to the wavelength of visible light, which ranges from violet (wavelength $\lambda = 0.00039$ mm or 390 nm) to red ($\lambda = 760$ nm). White light consists of all the wavelengths between these two extremes. With colorless minerals in thin section (e.g. quartz), white light passes unaffected through the mineral and none of its wavelengths is absorbed, whereas with opaque minerals (such as metallic ores) all wavelengths are absorbed, and the minerals appear black. With colored minerals, selective absorption of wavelengths takes place and the colour seen represents a combination of wavelengths of light transmitted by the mineral.
4.3.1.2 Pleochroism

Some colored minerals change colour between two extremes when the microscope stage is rotated. The two extremes in colour are each seen twice during a complete (360°) rotation. Such minerals are said to be pleochroic, and ferromagnesian minerals such as the amphiboles, biotite and staurolite of the common rock–forming silicates possess this property.

Pleochroism is due to the unequal absorption of light by the mineral in different orientations. For example, in a longitudinal section of biotite, when plane polarized light from the polariser enters the mineral which has its cleavages (see here below) parallel to the vibration direction of the light, considerable absorption of light occurs and the biotite appears dark brown. If the mineral section is then rotated through 90° so that the plane polarized light from the polarizer enters the mineral with its cleavages now at right angles to the vibration direction, much less absorption of light occurs and the biotite appears pale yellow.

4.3.1.3 Habit

This refers to the shape that a particular mineral exhibits in different rock types. A mineral may appear euhedral, with well defined crystal faces, or anhedral, where the crystal has no crystal faces present, such as when it crystallizes into gaps left between crystals formed earlier. Other descriptive terms include prismatic, when the crystal is elongate in one direction, or acicular, when the crystal is needle like, or fibrous, when the crystal resembles fibers. Flat, thin crystals are termed tabular or platy. Figure 4.2 illustrates a contrast shown between well-formed tabular grains of biotite and well-formed prismatic grains of apatite as they appear in thin section.

Figure 4.2 Shape in thin section of (a) tabular biotite contrasted with (b) prismatic apatite.
4.3.1.4 **Cleavage**

Most minerals can be cleaved along certain specific crystallographic directions, which are related to planes of weakness in the minerals atomic structure. These planes or cleavages, which are straight, parallel and evenly spaced in the mineral, are denoted by miller indices, which indicate their crystallographic orientation.

Some minerals such as quartz and garnet possess no cleavages, whereas others may have one, two, three or four cleavages. When a cleavage is poorly developed it is called a *parting*. Partings are usually straight and parallel but not evenly spaced. The number of cleavages seen depends upon the orientation of the mineral section. Thus, for example, a prismatic mineral with a square cross section may have two prismatic cleavages. These cleavages are seen to intersect in the mineral section cut at right angles to the prism zone, but in a section cut parallel to the prism zone the traces of the two cleavages are parallel to each other and the mineral appears to possess only one cleavage (e.g. pyroxenes, andalusite).

Measurement of angles between cleavages can be a useful identification technique, particularly in the distinction between amphiboles e.g., hornblende (two cleavages at 124 degrees) and pyroxenes e.g., augite (two cleavages at nearly 90 degrees). Figure 4.3 illustrates the two characteristic cleavages.

![Figure 4.3](image)

**Figure 4.3.** (a). Sections normal to c-axis in augite, showing the two cleavages nearly at right angles to each other; (b) a similar section of hornblende showing cleavages at 124 degrees.
4.3.1.5 **Relief**

All rock thin sections are trapped between two thin layers of resin (or cementing material) to which the glass slide and the cover slip are attached. The refractive index (RI) (see lecture 3, section 3.2) of the resin is 1.54. The surface relief of a mineral is essentially constant (except for carbonate minerals), and depends on the difference between the RI of the mineral and the RI of the enclosing resin. The greater the difference between the RI of the mineral and the resin, the rougher the appearance of the surface of mineral. This is because the surfaces of the mineral in thin section are made up of tiny elevations and depressions, which reflect and refract the light.

If the RI’s of the mineral and resin are similar the surface appears smooth. Thus, for example, the surfaces of garnet and olivine, which have much higher RI than the resin, appear rough whereas the surface of quartz, which has the same RI as the resin (1.54), is smooth and virtually impossible to detect (Figure 4.4).

Figure 4.4. Illustration of relief in thin sections. The diamond shaped section of sphene shows very high relief. Beside it is biotite, which shows high relief, and a conspicuous cleavage while the remainder of the photograph is occupied by quartz and feldspar, both of which have low relief. X 100. Plane polarized light.
To obtain a more accurate estimate of the RI of a mineral (compared to 1.54), a mineral grain should be found at the edge of the thin section, where its edge is against the cementing material (resin). The diaphragm of the microscope should be adjusted until the edge of the mineral is clearly defined by a thin, bright band of light, which is exactly parallel to mineral boundary. The microscope tube is then carefully racked upwards (or the stage lowered), and this thin band of light - the Becke line - will appear to move towards the medium with the higher RI (see Becke test on Lecture 3 on section 3.4.2). For example, if RI [mineral] is greater than RI [cement] the Becke line will appear to move into the mineral when the microscope tube is slowly racked upwards. If the RI of a mineral is close to that of the cement then the mineral surface will appear smooth and dispersion of the refractive index may result in slightly coloured becke lines appearing in both media. The greater the differences between a mineral’s RI and that of the enclosing cement, the rougher the surface of the mineral appears. An arbitrary scheme used for describing relief in minerals is presented in Table 4.1 here below:

Table 4.1. Descriptive scheme for relief of minerals with reference to their refractive indices.

<table>
<thead>
<tr>
<th>Refractive Index (RI)</th>
<th>Description of relief</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.40 – 1.50</td>
<td>Very low</td>
</tr>
<tr>
<td>1.50 – 1.58</td>
<td>Low</td>
</tr>
<tr>
<td>1.58 – 1.67</td>
<td>Moderate</td>
</tr>
<tr>
<td>1.67 – 1.76</td>
<td>High</td>
</tr>
<tr>
<td>&gt; 1.76</td>
<td>Very high</td>
</tr>
</tbody>
</table>

The refractive indices of adjacent minerals in thin section may be compared using the Becke line test as explained in the text.
4.3.1.6 Alteration

The most common cause of alteration is by water or CO$_2$ coming into contact with a mineral, chemically reacting with some of its elements, and producing a new, stable mineral phase(s). For example, water reacts with the feldspars and produces clay minerals. In thin section this alteration appears as an area of cloudiness within the transparent feldspar grain. The alteration may be so advanced that the mineral is completely replaced by a new mineral phase. For example, crystals of olivine may have completely altered to serpentine, but the area occupied by the serpentine still has the configuration of the original olivine crystal. The olivine is said to be pseudomorphed by serpentine (NB. more on the topic of pseudomorph will be given at lecture 5 section 5.6).

4.3.2 PROPERTIES UNDER CROSSED POLARS

The analyzer is inserted into the optical path to give a dark, colorful image.

4.3.2.1 Isotropism

Minerals belonging to the cubic system are isotropic and remain dark under crossed polars whatever their optical orientation. All other minerals are anisotropic and usually appear coloured and go into extinction (that is, go dark) four times during a complete rotation of the mineral section. This property, however, varies with crystallographic orientation, and each mineral possesses at least one orientation, which will make the crystal appear to be isotropic. For example, in tetragonal, trigonal and hexagonal minerals, sections cut perpendicular to the c axes are always isotropic.

4.3.2.2 Birefringence and interference colour

The colour of most anisotropic minerals under crossed polars varies, the same mineral showing different colours depending on its crystallographic orientation. Thus quartz may vary from grey to white, and olivine may show a whole range of colours from grey to red or
blue or green. These are colours on Newton’s scale, which is divided into several orders as indicated in Table 4.2.

Table 4.2 Colors observed in the Newton’s scale.

<table>
<thead>
<tr>
<th>Order</th>
<th>Colours</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>Grey, white, yellow, red</td>
</tr>
<tr>
<td>Second</td>
<td>Violet, blue, green, yellow, orange, red</td>
</tr>
<tr>
<td>Third</td>
<td>Indigo, green, blue, yellow, red, violet</td>
</tr>
<tr>
<td>Fourth and above</td>
<td>Pale, pinks, and green</td>
</tr>
</tbody>
</table>

A Newton’s scale of colours can be found in many mineralogy textbooks. These orders represent interference colours; they depend on the thickness of the thin section mineral and the birefringence, which is defined as the difference between the two refractive indices (i.e., the least and the greatest refractive indices) of the anisotropic mineral grain. The principle of using the Newton’s color chart to determine the birefringence value is indicated in Figure 4.5 her below.

Figure 4.5 Principle of using the Newton’s colour chart in the determination of birefringence or thickness.

The thin section thickness is constant (normally 30 microns) and so interference colours depend on birefringence: the greater the birefringence, the higher the order of the interference colours. Since the maximum and minimum refractive indices of any mineral are oriented along precise crystallographic directions, the highest interference colours will be shown by a mineral section, which has both maximum and minimum RI’s in the plane of the section.
This section will have the maximum birefringence (denoted $\delta$) of the mineral. Any differently oriented section will have a smaller birefringence and show lower colours. The descriptive terms used for birefringence are as shown in Table 4.3 as follows:

Table 4.3. Descriptive terms for birefringence in minerals.

<table>
<thead>
<tr>
<th>Maximum Birefringence $\delta$</th>
<th>Interference colour range</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00-0.018</td>
<td>first order</td>
<td>Low</td>
</tr>
<tr>
<td>0.018-0.036</td>
<td>second order</td>
<td>Moderate</td>
</tr>
<tr>
<td>0.036-0.055</td>
<td>third order</td>
<td>High</td>
</tr>
<tr>
<td>&gt;0.055</td>
<td>fourth order or higher</td>
<td>Very high</td>
</tr>
</tbody>
</table>

NB. Very low may be used if the birefringence is close to zero and the mineral shows anomalous blue colours.

What do you understand by the term “birefringence” in a mineral?

### 4.3.2.3 Interference figures

All minerals except cubic minerals show interference figures. There are two types of interference figures: uniaxial and biaxial (see Figure 4.6 (a) & (b)).

![Figure 4.6](image)

Figure 4.6 (A) - Uniaxial interference figure; (B) – Biaxial interference figure
Suitably orientated sections from tetragonal, trigonal and hexagonal minerals may produce uniaxial figures. An isotropic section (or near isotropic section) of a mineral is first selected under crossed polars, and then a high power objective (X 40 or more) is used with the substage convergent lens in position and the aperture diaphragm open. When the Bertrand lens is inserted into the optical train a black cross will appear in the field of view. If the cross is off center, the lens is rotated so that the center of the cross occurs in the SW (lower left hand) segment of the field of view.

The first order red accessory plate (i.e., the gypsum plate – refer to section 3.4.1 in the previous lecture 3) is then inserted into the optical train in such a way that the length slow direction marked on it points towards the center of the black cross, and the colour in the NE quadrant of the cross is noted:

- Blue means that the mineral is positive (denoted +ve)
- Yellow means that the mineral is negative (denoted – ve)

**4.3.2.4 Extinction Angle**

Anisotropic minerals go into extinction four times during a complete 360° rotation of a mineral section. If the analyzer is removed from the optical train while the mineral grain is in extinction, the orientation of some physical property of the mineral, such as a cleavage or trace of a crystal face edge, can be related to the microscope cross wires.

All uniaxial minerals posses *straight or parallel* extinction since a prism face or edge, or a prismatic cleavage, or a basal cleavage, is parallel to one of the crosswires when the mineral is in extinction.
Biaxial minerals possess either *straight* or *oblique* extinction. Orthorhombic minerals (olivine, sillimanite, andalusite, orthopyroxenes) show straight extinction against either a prismatic cleavage or a prism face edge. All other biaxial minerals possess oblique extinction, although in some minerals the angular displacement may be extremely small: for example, an elongate section of biotite showing a basal cleavage goes into extinction when these cleavages are almost parallel to one of the microscope crosswires. The angle through which the mineral has then to be rotated to bring the cleavage parallel to the crosswires will vary from nearly 0° to 9° depending on the biotite composition, and this angle is called the *extinction angle*.

Extinction angle, a characteristic of monoclinic and triclinic minerals, is often a diagnostic property. If the mineral shows an identifiable crystallographic direction, measure the angle between that direction and the nearest extinction position – which is the extinction angle. Properly used, this parameter can be used for such things as distinguishing between monoclinic pyroxenes; the common amphiboles have maximum extinction angles of less than 25°, whereas most pyroxenes have maximum extinction angles near 40° (see Figure 4.5).

Figure 4.5. Maximum extinction angles of elongated sections of (a) biotite, (b) hornblende, (c) augite. Vibration directions shown by arrows. Note that in the correct orientation to show the maximum extinction, hornblende and augite show only slight traces of cleavage because the cleavage planes are not normal to the slide.
The maximum extinction angle of many biaxial minerals is an important optical property and has to be precisely determined. This is done as follows. A mineral grain is rotated into extinction, and the angular position of the microscope stage is noted. The polars are uncrossed (by removing the upper analyzer from the optical train and the mineral grain rotated until a cleavage trace or crystal trace edge or twin plane (see section 1.5.9 in lecture 1) is parallel to the crosswires in the field of view. The position of the microscope stage is again noted and the difference between this reading and the former one gives the extinction angle of the mineral grain. Several grains are tested since the crystallographic orientation may vary and the maximum extinction angle obtained is noted for that mineral. The results of measurements from several grains should not be averaged.

How do you measure the extinction angle of an anisotropic mineral?

**4.3.2.5 TWINNING**

This property is present when areas with differing extinction orientations within the same mineral grain have planar contacts. Often only a single twin plane is seen, but in some minerals (particularly plagioclase feldspars) multiple or lamellar twinning occurs with parallel twin planes (Figure 4.7).

You are advised to make a quick review on the subject of twinning that you covered in lecture 1, section 1.5.9)
4.3.2.6 ZONING

Compositional variation (zoning) within a single mineral may be expressed in terms of changes of “natural” colour from one zone to an adjoining one; or by changes in birefringence; or by changes in extinction orientation (Figure 4.8). These changes may be abrupt or gradational, and commonly occur as a sequence from the core of a mineral grain (the early-formed part) to its edge (the last-formed). Zoning is generally a growth phenomenon and is therefore related to the crystal shape.
4.3.2.7 DISPERSION

Refractive index increases as the wavelength of light decreases. Thus the refractive index of a mineral for red light is less than for blue light (since the wavelength of red light is longer than the wavelength of blue light). White light entering a mineral section is split into the colours of the spectrum, with blue nearest to normal (i.e. the straight through path) and red the furthest away. This breaking up of the white light is called dispersion.

In most minerals the amount of dispersion is very small and will not affect the minerals’ optical properties. However, the Na-rich clinopyroxenes, the Na-rich amphiboles, sphene, chloritoid, zircon and brookite posses very strong dispersion. With many of these minerals, interference figures may be difficult to obtain and the use of accessory plates (to determine mineral sign, e.g., as explained in section 4.3.2.3 etc.) may not be possible.

4.4 THE REFLECTING MICROSCOPE

4.4.1 Study of opaque minerals

The study of opaque minerals by the use of vertically incident polarized light is generally termed ore microscopy because most ore minerals are opaque. The microscopic setup used is often referred to as a metallographic microscope because it also finds wide use in investigations of metals and alloys. A commonly used ore microscope is the Vickers M73 reflected light microscope (Figure 4.9).

High quality polished surfaces are required for reflected-light studies. Mineral differentiation is made on the basis of properties such as color, reflectivity, isotropic or anisotropic character, and hardness. Colors are, for the most part, shades of grey, so color contrasts between coexisting minerals are generally more useful than the colors themselves.

In some essential opaque minerals, the incident light may penetrate the surface and be reflected from cleavages and fractures, thus giving a characteristic internal reflection, the color of which rather commonly resembles the individual mineral’s streak. When the stage is rotated, the color and reflectivity of isotropic minerals are unchanged, whereas either or both tend to change for anisotropic minerals. Also, when the analyzer is inserted, isotropic
minerals remain dark or nearly dark on rotation, whereas anisotropic minerals display *bireflectance* (which is analogous to *birefringence* in transparent minerals) with four positions of extinction during a 360° rotation.

**Figure 4.9. The Vickers M73 reflected light microscope**

Distinguish the difference between bireflectance and birefringence optical properties.

Hardness is revealed by slight differences in relief produced during polishing, by employing a micro-hardness indentation apparatus, or by observing a phenomenon that closely resembles the Becke line in transparent minerals.
4.4.2 The Appearance of Polished Sections Under the Reflected-light Microscope

Experience has shown that students who have been accustomed to the use of transmitted light microscopes for several years before being introduced to reflected light microscopes usually find the interpretation of polished sections of a rock or ore sample rather difficult. One reason for this is because in transmitted light, they have been conditioned into interpreting bright areas as being transparent and dark areas as being opaque; for polished sections the opposite is the case! It is recommended to begin examination of a polished section such as that illustrated in Figure 4.10.

Figure 4.10. Diagrammatic representation of a polished section of a sample of lead ore. Transparent phases, e.g. fluorite (A), barite (B), and the mounting resin (D) appear dark grey. Their brightness depends on their refractive index. The fluorite is almost black. Absorbing phases (opaque), e.g. galena (C), appear white. Holes, pits and cracks appear black. Scratches appear as long straight or curving lines. They are quite abundant in the galena, which is soft, and scratches easily.
By using low power magnification and plane-polarized light, most of the following features can be observed:

- Transparent phases appear dark grey. This is because they reflect only a small proportion of the incident light, typically 3 to 15%. Occasionally bright patches are seen within areas of transparent minerals, and are due to reflection from surfaces under the polished surface.
- Absorbing phases (opaque or ore minerals) appear grey to bright white as they reflect much more of the incident light, typically 15 to 95%. Some absorbing minerals appear coloured, but usually colour tints are very slight.
- Holes, pits, crack and specks of dust appear black. Reflection from crystal faces in holes may give peculiar effects such as very bright patches of light.
- Scratches on the polished surface of minerals appear as long straight or curving lines, often terminating at grain boundaries or pits. Severe fine scratching can cause a change in the appearance of minerals. Scratches on native metals, for example, tend to scatter light and cause colour effects.
- Patches of moisture or oil tend to cause circular dark or iridescent patches (or play of light) and indicate a need for cleaning of the polished surface.
- Tarnishing (or low reflectance) of minerals is indicated by an increase in colour intensity, which tends to be rather variable. Sulphides, for example bornite, tend to tarnish rapidly. Removal of tarnishing usually requires a few minutes of buffing or repolishing.
- Polishing relief, due to the differing hardness of adjacent minerals, causes dark or light lines along grain contacts. Small soft bright grains may appear to glow, and holes may have indistinct dark margins because of polishing relief.

4.4.3 Thin- and Polished-Section Preparation

Thin sections are prepared by cementing thin slices of rock to glass and carefully grinding using carborundum grit to produce a paper-thin layer of rock. The standard thickness of 30
microns is estimated using the interference colours of known minerals in the section. A cover slip is finally cemented on top of the layer of rock (Figure 4.11).

![Figure 4.11. Thin- and polished sections.](image)

The three common types of polished section are shown in Figure 4.11. Preparation of a polished surface of a rock or ore sample is a rather involved process that involves usually five stages, namely:

- **Cutting** the sample with a diamond saw
- **Mounting** the sample on glass or in a cold-setting resin
- **Grinding** the surface flat using carborundum grit and water on a glass or a metal surface
• **Polishing** the surface using diamond grit and an oily lubricant on a relatively hard “paper” lap.

• **Buffing** the surface using gamma alumina powder and water as lubricant on a relatively soft “cloth” lap.

There are many variants of the procedure described for thin- and polished section preparation, and the details usually depend on the nature of the samples and the polishing materials, and equipment that happen to be available. Whatever the method used, the objective is a flat, relief-free, scratch-free polished surface.

4.5 SUMMARY

In this lecture we have learned that the major components of the transmitted polarizing microscope include the light source, the polarizer, substage diaphragm, the condenser or convergent lens, the stage, objectives, eyepiece, the analyzer, the Bertrand lens, the accessory slot and the focusing knobs. We learned that the major optical properties to be observed under plane-polarized light are colour, pleochroism, habit, cleavage, relief and alteration features of the mineral grains. Under crossed polars, the optical properties to describe include isotropism, birefringence and interference colour, interference figures, extinction angle, twinning, zoning and dispersion.

We further learned that the petrographic study of opaque minerals is done by the assistance of the reflecting microscope. Under reflected light, mineral differentiation is made on the basis of properties such as color, reflectivity, isotropic or anisotropic character, and hardness.
Colors under reflected light are, for the most part, shades of grey, so color contrasts between coexisting minerals are generally more useful than the colors themselves.

Finally we learnt that thin sections are prepared by cementing thin slices of rock to glass and carefully grinding them using carborundum grit to produce a paper-thin layer of rock. The standard thickness of 30 microns is estimated using the interference colours of known minerals. On the other hand, preparation of a polished surface of a rock or ore sample is a rather involved process that involves usually cutting, mounting, grinding, polishing and buffing. Whatever the method of preparation used, the objective is to produce a flat, relief-free, and a scratch-free polished surface.

REFERENCES


