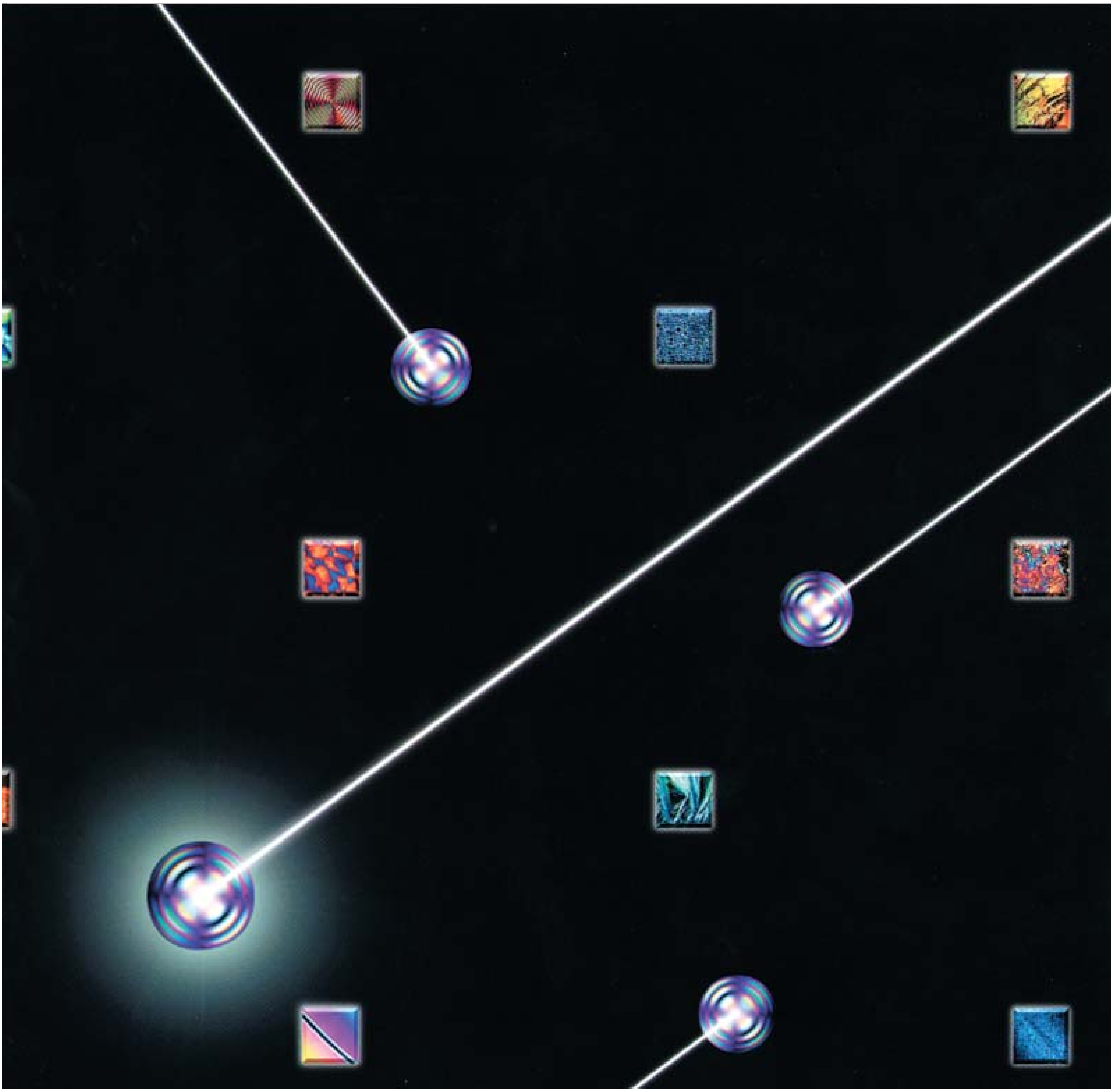
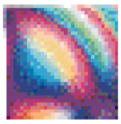
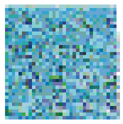
Applications of Polarising Microscopy





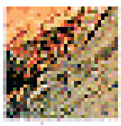


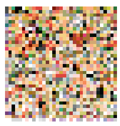
Preface

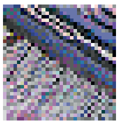
The polarising microscope is basically a regular microscope combined with a pair of polarising filters and other accessories. This combination is made in order to observe the optical properties of double refracting materials such as crystals.

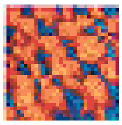
The polarising microscope was originally developed for investigating crystalline structures within rocks and minerals. However, this microscope has now come to be used for research and examinations in medical and biological fields, as well as in such industrial fields as abestos identification chemicals, fibres, materials, electronics, and forensics Improved performance of the polarising microscope combined with a full line of accessories has made it possible to perform operations such as detecting minute double refracting materials and measuring retardation. These operations were previously not possible with simple polarising microscopes.

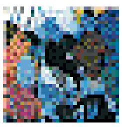
The Applications of Polarising Microscopy explains and provides many examples of how polarising microscopes are currently being used in various fields. In order for the polarising microscope to be easily comprehended by all users, explanations have been made as simple as possible. We hope that this manual will be a valuable source of information both for first-time users, as well as those already using the polarising microscope.











Applications of Polarising Microscopy

C O N T E N T S

Medical/Biological

Polarising microscopes are used in medical fields to perform various examinations. In biological fields, these microscopes are used to observe double refracting structures in living organisms.

1-1 Medical applications

Urinalysis, gout and amyloid examinations[1] are the typical medical examinations using polarising microscopes.

Gout examinations

Polarising microscopes are employed in gout examinations using synovial fluid[2]. Because urates crystals that cause gout have negative elongated optical characteristics, while pseudo-gout pyrophosphoric acids have positive elongated optical characteristics, the two can be differentiated by using a polarising microscope combined with a sensitive tint plate.

Preparing specimens

Place several drops of fresh synovial fluid onto a slide, cover with a cover glass and observe. When observations cannot be made soon after making the specimen, drying can be prevented by sealing the edges around the cover glass with clear manicure polish.

Observation method

In the cross polarisers state, rotate the stage to a position where needle, rod, or diamond shaped crystals can be seen under the brightest condition (the diagonal position) and insert a sensitive tint plate into the light path. At this time, based on the relationship between the crystal direction and the interference colour (explained below), gout urates crystals and pyrophosphoric acid calcium crystals can be differentiated.

(1)Gout urates crystals

Urates have a strongly negative elongation optical characteristic. For this reason, when a sensitive tint plate is inserted into the light path, the direction of longer parts of needle or rod crystals can be seen as yellow (subtraction) when the needles are parallel to the Z'direction (γ direction) of the tint plate, and blue (addition) when perpendicular to Z' direction.

(2)Pseudo-gout pyrophosphate crystals

Pyrophosphate has a positive elongation optical characteristic. As in the above example, observations are made by inserting a sensitive tint plate into the light path, but here the image appears in the opposite fashion. In other words, the direction of longer parts of needle or rod crystals is seen as blue when parallel to the Z'direction of the sensitive tint plate and yellow when perpendicular to Z'direction.

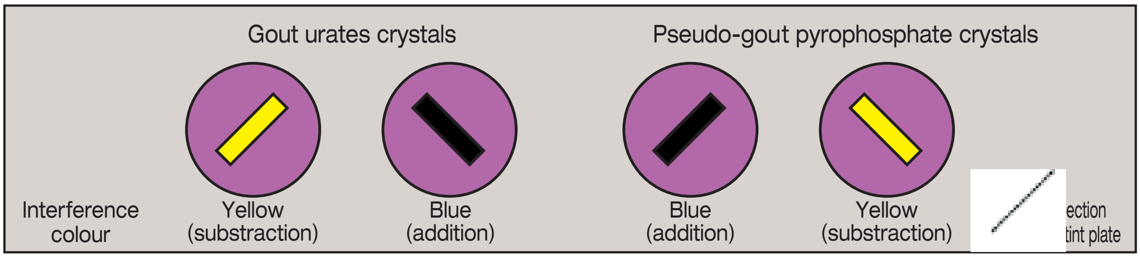
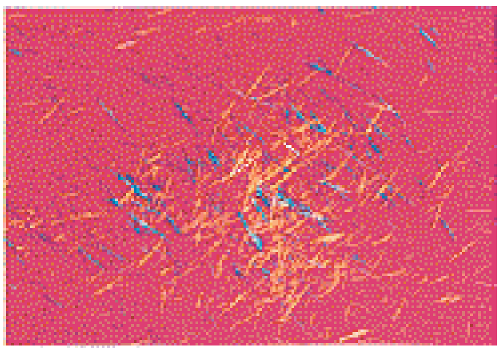
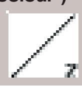


Figure1-1 Using a sensitive tint plate to differentiate between urates and pyrophosphoric acid calcium

1-1 Gout urates crystals (sensitive tint colour)

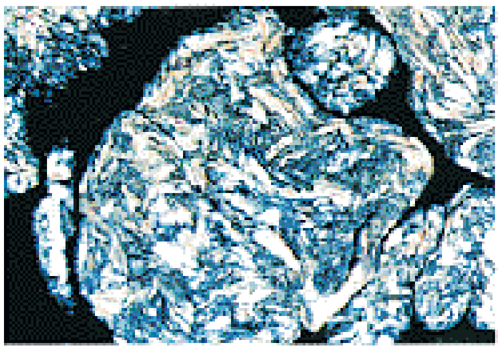


Transmitted polarisation (sensitive tint colour)
Objective UPLFL40XP
Photo eyepiece PE2.5X
Sensitive tint plate U-TP530



Z' direction of the tint plate

1-2 Urates crystals in a toe joint



Transmitted polarisation
Objective UPLFL4XP
Photo eyepiece PE2.5X

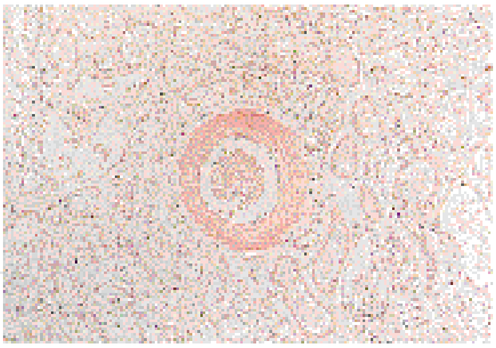
Bright objects within the tissue are urates crystals.

Amyloids

Amyloid is a protein substance created by obstructions to protein metabolism, and is deposited in various body organs (spleen, liver, kidneys, brain, etc.). Amyloid is not observed in normal tissue.

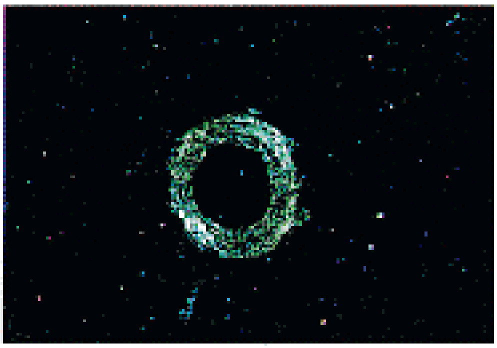
Amyloid determinations are possible by polarised light observations of a sample using Congo Red dye or direct first scarlet dye 3) . If amyloid is present , a bright green colour will be visible.

1-3 Renal vein with deposited amyloid (brightfield image)



Transmitted brightfield
Objective UPLFL10xP
Photo eyepiece PE3.3x
Congo red dye

1-4 Renal vein with deposited amyloids (polarised light image)

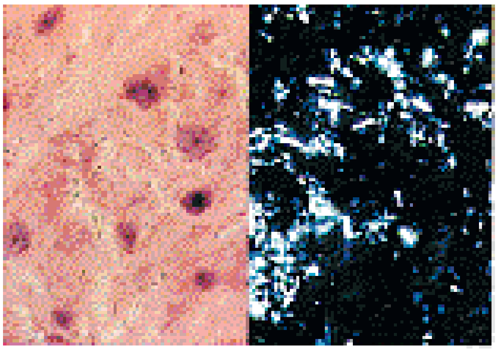


Transmitted polarisation
Objective UPLFL10XP
Photo eyepiece PE3.3X
Congo Red dye

1-2 Biology

Polarised light is often used to observe double refracting structures in teeth, bone striated, muscle tissue and nerve tissue, as well as spindles and actomyosin fibres. When these structures are dyed, they can be easily seen in brightfield, however, applying dye to living specimens will cause the tissues and cells to die. On the other hand, polarised light observations do not require dye, and so structures can be observed between crossed polarisers while they are still alive. Retardation (amount of wave delay) of teeth and bone is comparatively large, however, retardation of actomyosin fibres and spindles is extremely small and these specimens become dark with normal polarised light observations. With such specimens, a Brace-Koehler compensator is often used to enhance contrast. (1-6, 1-7, and 1-8 are all examples of observations using a Brace-Koehler compensator.) Also, it is possible to measure the retardation of double refracting structures.

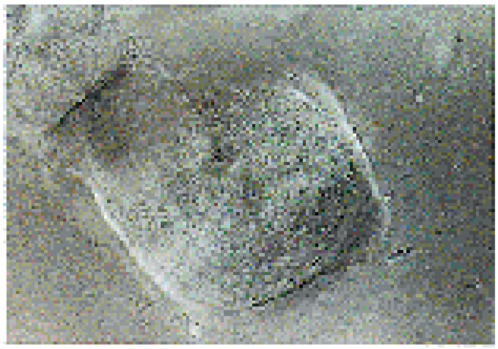
1-5 Fibre cartilage



Left: Transmitted brightfield
Right: Transmitted polarisation
Objective UPLFL20XP
Photo eyepiece PE3.3X

Cartilage structures with strong double refracting properties can be clearly observed by using polarised light.

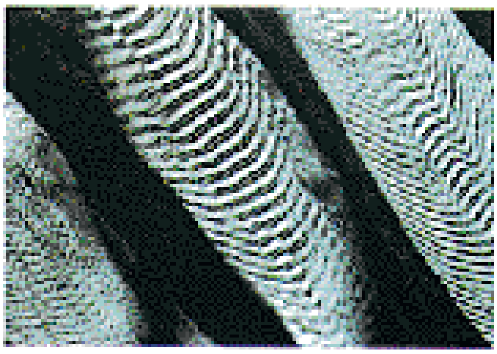
1-6 Epidermal cells



Transmitted polarisation
Objective PLAPO60XO
Photo eyepiece PE5X
Compensator U-CBR2 (λ/30)

Ribbed structures on the surface of cells can be clearly observed.

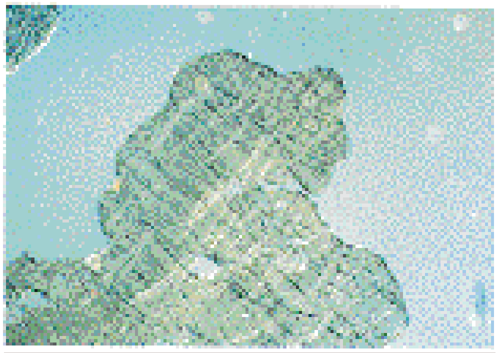
1-7 Skeletal muscle (rabbit)



Transmitted polarisation
Objective PLAPO60XO
Photo eyepiece PE5X
Compensator U-CBR2 (λ/30)

Polarised light image of a very thin slice of rabbit skeletal muscle.
The white stripe is the A band, the black stripe is the I band, and the thin white muscle between these is the Z band.

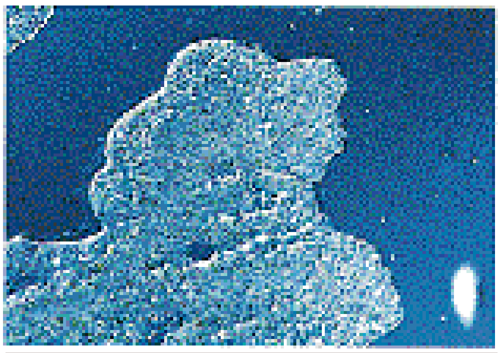
1-8 Mucus plasmodium



Transmitted polarisation
Objective UPLFL10XP
Photo eyepiece PE2.5X
Compensator U-CBR2 (λ/30)

Black or white muscle in the mucus is the actomyosin fibres that are the cause of plasma streaming.

1-9 Mucus plasmodium



Transmitted DIC
Objective UPLFL10XP
Photo eyepiece PE2.5X

Actomyosin fibres can not be observed in the DIC image.

2 Rock Minerals

Rocks are constructed primarily of optically anisotropic minerals and mineral structures can be seen with a polarising microscope. Conoscopic observations are frequently used to identify minerals.

Orthoscopic observations

Orthoscopic observations of thin rock sections are used to examine rock structures, the optical characteristics of crystals, such as twin crystals, and to identify minerals. Opaque minerals can be observed by using incident polarised light.

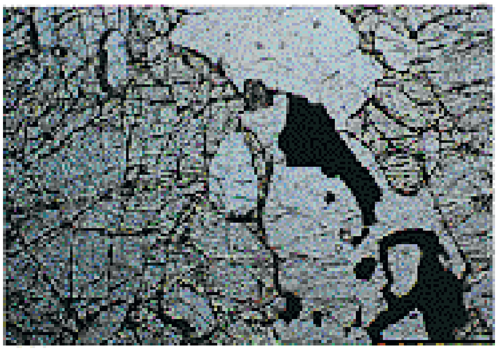
Preparing samples

In order to observe rock minerals with a transmitted polarising microscope, first, use a rock cutter or other device to cut a thin rock slice. Finely polish one side of this rock slice and then affix the polished side to a slide glass with adhesive. Next, polish the opposite side to a 30 micron thickness and affix to a cover glass with balsam (1) . Another method is to grind the rock into a powder, sprinkle the powder onto a slide, surround the powder with an immersion liquid and then cover with a cover glass. This is called the immersion method. With this method the structure of the mineral is destroyed, but there is the advantage that observations can easily be performed without having to first prepare the thin rock section. With the immersion method, there is also a way to measure the refractive index by using the Beck line. However, this method is omitted here.

Observation of thin rock sections

With only a polariser inserted into the light path (polariser only observation), the shape, size and colour of crystals inside a rock mineral can be observed. By crossed polarisers observations with an analyser additionally inserted into the light path, the interference colour corresponding to the crystals double refraction can be seen. The crystals double refraction can be estimated from an interference colour chart. With these observations, rock minerals can be identified based on shape, size, colour , and double refraction of the crystals.

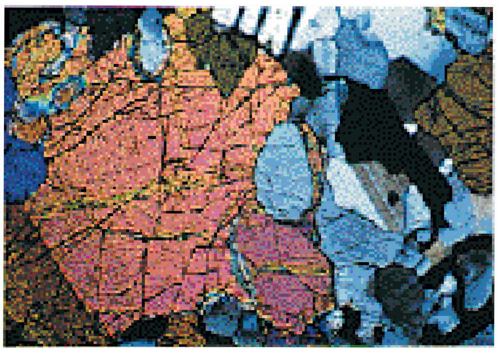
2-1 Peridotite (Single polariser)



Transmitted polarisation
Objective UPLFL40XP
Photo eyepiece PE2.5X

In the rock, the roughness on the surface of the crystals on the left side shows the large difference in the refractive index compared to the mounting adhesive.

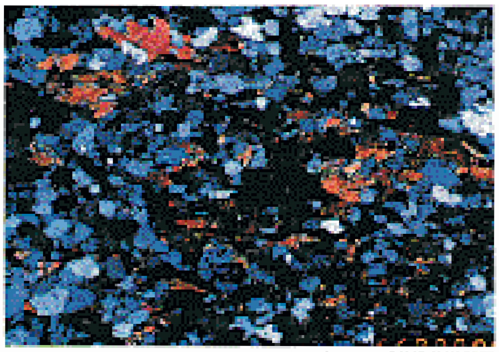
2-2 Peridotite (crossed polarisers)



Transmitted polarisation
Objective UPLFL40XP
Photo eyepiece PE2.5X

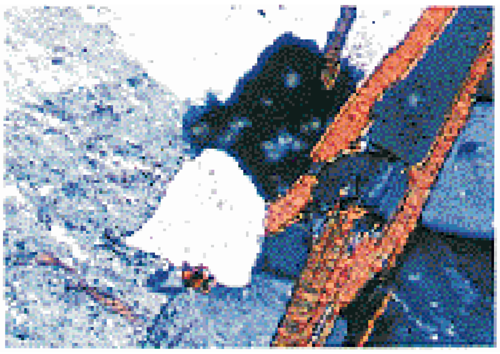
The clear interference colour of the crystal shows the large refractive index. This crystal can be identified as a peridotite based on the refractive index, double refraction, and cleavage characteristics.

2-3 Biotite gneiss



Transmitted polarisation
Objective UPLFL40XP
Photo eyepiece PE2.5X

2-4 Biotite granite

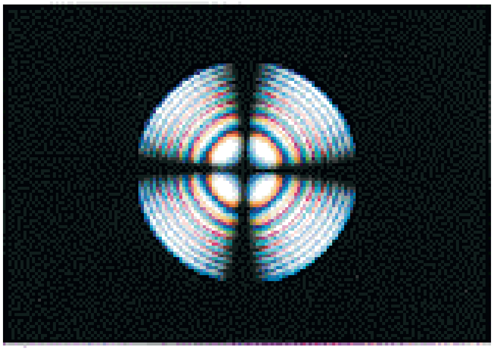


Transmitted polarisation
Objective UPLFL40XP
Photo eyepiece PE2.5X

Conoscopic observations (observation of the back folcal plan of the objective)

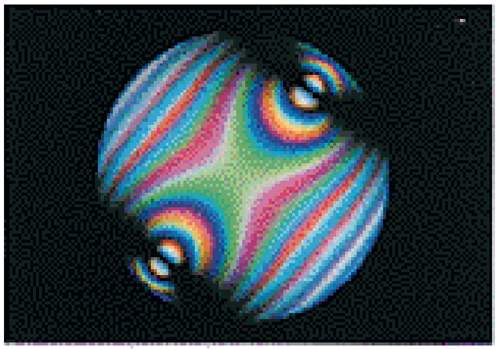
By using a Bertrand lens to observe the effect of crystals inside of rock minerals at high magnifications (40x or 100x objectives), it can be determined whether a crystal is optically uniaxial or biaxial and also whether a crystal is an optically positive or negative crystal. The direction and angle of the optical axis can also be determined. Conoscopic images of uniaxial and biaxial crystals are shown below.

2-5 Conoscopic image of a uniaxial crystal (calcite)



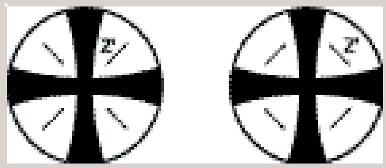
Transmitted polarisation
Objective UPLFL 40XP
Photo eyepiece PE2.5X

2-6 Conoscopic image of a biaxial crystal (topaz)



Transmitted polarisation
Objective UMPLFL100XOP
Photo eyepiece PE2.5X

By using a Bertrand lens with a test plate, it can be determined whether a crystal is optically positive or negative. For uniaxial crystals, the extraordinary ray vibrates in the direction that is in the plane with the progressing direction and the optical axis of the crystal. The ordinary ray vibrates perpendicular to this. For this reason, the Z'direction (vibration direction of the delayed ray) of the conoscopic images of both optically positive and negative uniaxial crystals becomes as shown in Fig. 2-1.

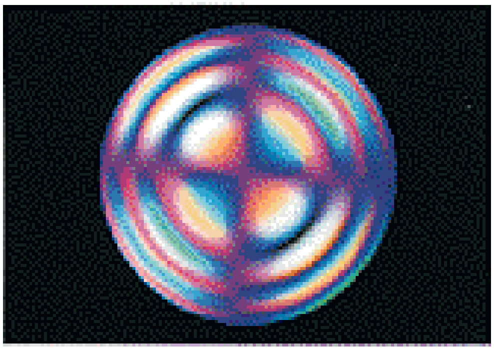


Positive crystal　Negative crystal

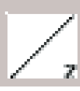
Fig. 2-1 Z'direction of a uniaxial crystal

For this reason, optical characteristics (positive or negative) of a crystal can be detected by inserting a test plate into the light path. If the 1st and 3rd quadrants of the conoscopic image add to the interference colour , the crystal has a positive characteristic. Likewise, the crystal has a negative characteristic if the 2nd and 4th quadrants add to the interference colour. The pictures below show conoscopic images, taken while using an inserted test plate, of a magnesium fluoride crystal as a positive crystal, and a calcite as a negative crystal. Z'direction in the figures is the sensitive tint plate Z'direction (g direction). Whether a crystal is positive or negative can be determined based on changes in the interference colour near the optical axis.

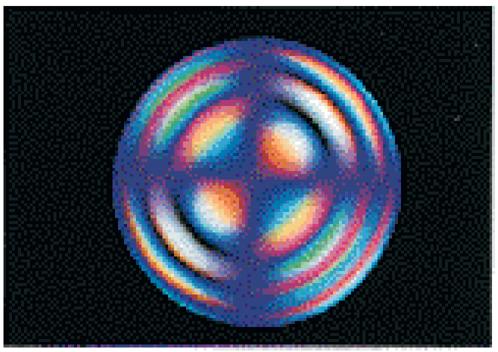
2-7 Conoscopic image of a magnesium fluoride crystal (positive crystal)



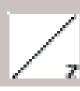
Transmitted polarisation
Objective UPLFL 20XP
Photo lens PE2.5X
Tint plate U-TP530



2-8 Conoscopic image of a calcite (negative crystal)



Transmitted polarisation
Objective UPLFL 20XP
Photo eyepiece PE2.5X
Tint plate U-TP530



3 Industrial Applications

3-1 Liquid crystals

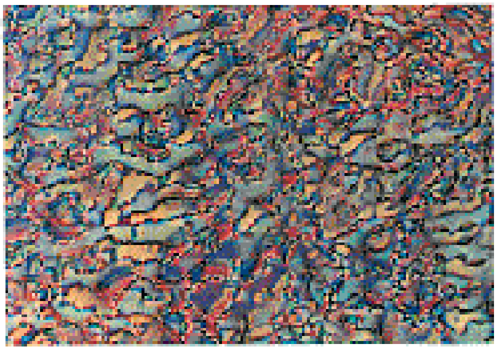
Liquid crystals, which have physical properties in between those of liquids and solids, are often observed by polarising microscopes because they exhibit optical anisotropy. These microscopes are popular for thermotropic liquid crystal applications (crystals in which crystallization occurs due to changes in the temperature of the crystal). Presently, heating stages have been added to these microscopes to observe crystals as their temperature changes. Liquid crystal observations by a polarising microscope can be divided into the following main groups:

- observation of peculiar optical patterns in phase and defects of liquid crystals
- measurement of liquid crystal retardation
- judgement of whether a liquid crystal is optically positive or negative by conoscopic observation of their orientation pattern.

Optical Pattern Observations

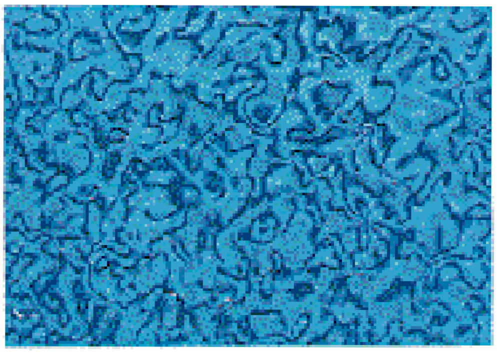
Peculiar optical patterns within a liquid crystal can be observed by using a polarising microscope. By observing this optical pattern, the phase and defects in the liquid crystal can be investigated. A book of photographs (e.g.see bibliography), showing the standard optical patterns seen by the polarising microscope, can be purchased. Transmitted polarised light observations are frequently performed. Reflecting type crystals are observed using incident polarised light. Liquid crystals and retardation of their orientation patterns can be measured with a compensator. It is necessary to select compensators in accordance with the size and retardation of each liquid crystal and orientation pattern.
The following pictures are of liquid crystal optical patterns seen by a polarising microscope.

3-1 MBBA liquid crystal



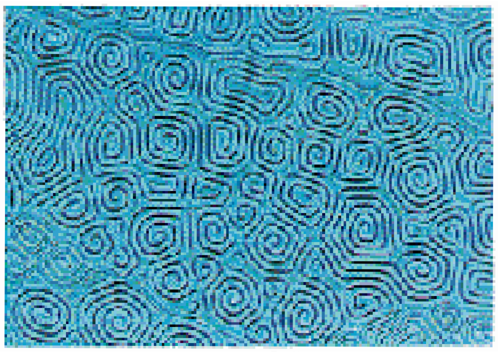
Transmitted polarisation
Objective UPLFL40XP
Photo eyepiece PE2.5X

3-2 Amorphous TN liquid crystal



Transmitted polarisation
Objective UPLFL10XP
Photo eyepiece PE2.5X

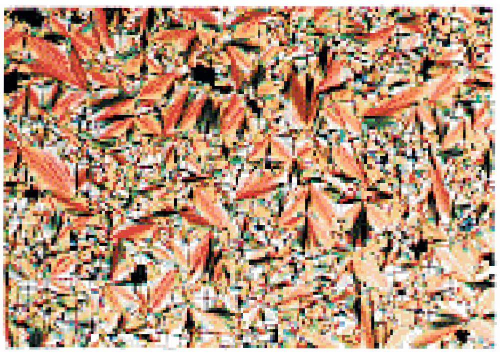
3-3 Chiralnematic liquid crystal



Transmitted polarisation
Objective UPLFL20XP
Photo eyepiece PE2.5X

This pattern is called a scroll defect.

3-4 Macromolecular liquid crystal



Transmitted polarisation
Objective UMPLFL10X
Photo eyepiece PE5X

Observation of a liquid crystals fan-shaped pattern when using a heating stage.

Industrial Applications

3-2 Macromolecular materials

Fibre and film retardation measurements

Uniaxial and biaxial enlargement are done for both fibre and film; their properties are often the result of molecular orientation.
Because fibre and film retardation is dependent on the molecular orientation, this molecular orientation can be estimated by measuring retardation.

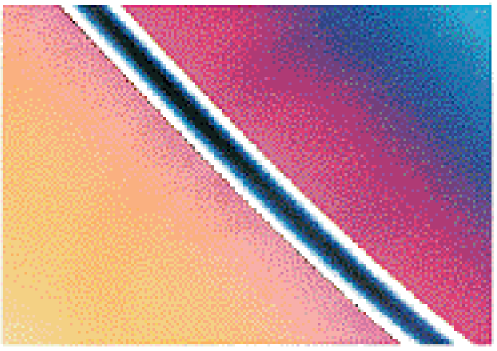
Preparing samples

Place the fibre or film onto the slide glass, cover with the cover glass and seal. When viewing thick fibres, only one fibre may cause the cover glass to tilt. For this reason, separately place two or more fibres to level the cover glass. This is also the same for film. However, in low magnifications, viewing without a cover glass is possible.

Retardation measurements

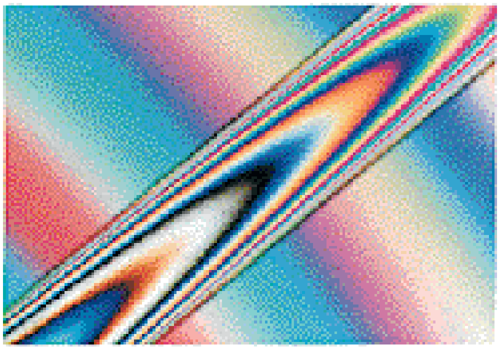
Retardation measurements are performed by orientating the fibre or film in a diagonal position and inserting a compensator (see 4.2) into the light path. Retardation R has the following relationship to double refraction (n e - n o).
R=d (n e - n o) (d=thickness of the fibre)
Assuming that a cross section of the fibre is circular, then the fibre thickness d can be determined by an ocular micrometer, etc., and double refraction related to the molecular orientation can also be determined.
Also, by using a compensator, it can be determined whether a fibres double refraction is negative or positive. Double refraction of the fibre is often positive ($n_e - n_o > 0$). In such cases, the interference fringe by U-CBE and U-CTB appear like the examples shown below in 3-5 and 3-6.
When double refraction is negative, the interference fringe is reversed as shown in 3-6 for the case of U-CBE and in 3-5 in the case of U-CTB. This is due to differences in the optical characteristics of crystals used with U-CBE and U-CTB.

3-5 Positive double refraction and retardation measurement of a fibre



Transmitted polarisation (retardation measurement)
Objective UPLFL40XP
Photo eyepiece PE3.3X
Compensator U-CBE

3-6 Positive double refraction and retardation measurement of a fibre



Transmitted polarisation (retardation measurement)
Objective UPLFL4XP
Photo eyepiece PE2.5X
Compensator U-CTB

In 3-5 and 3-6, double refraction is the interference fringe of the positive fibre.

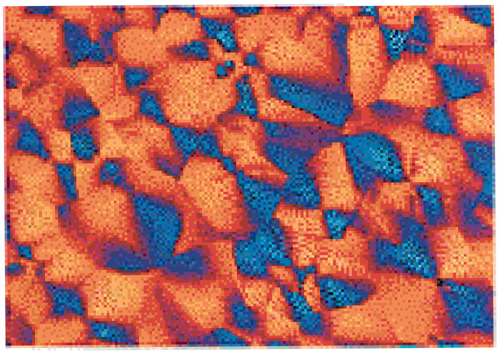
Observation of Spherical crystals

Spherulite are spherically formed macromolecular crystals. Their density and size influences the strength and transparency of macromolecular materials. Although spherulites are transparent, they have double refraction and so the spherulites of such items as plastics and fibres can be observed by using a polarising microscope.

Heating stage combinations

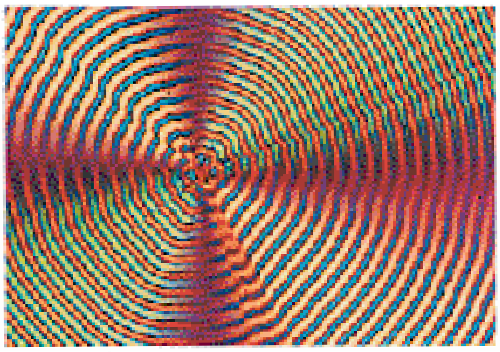
By combining a heating stage with a polarising microscope, macromolecular materials can be identified by observing different spherulite growth conditions (speed of growth and density) caused by heat and by measuring the melting point of the plastic.

3-7 High density polyethylene spherulite (sensitive colour)



Transmitted polarisation
Objective UPLFL40XP
Photo eyepiece PE 3.3X
Sensitive tint plate U-TP530

3-8 Macromolecular spherulite



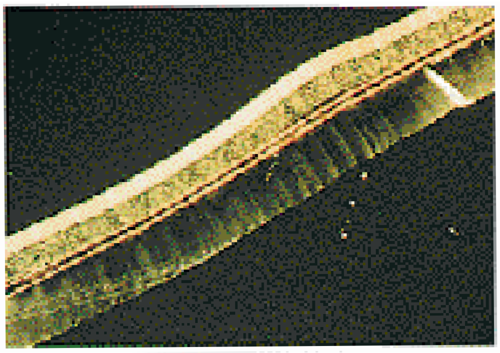
Transmitted polarisation
Objective UPLFL4XP
Photo eyepiece PE5X

Photo of a biodegradable spherulite which has undergone biosynthesis by hydrogen bacteria.
A heating stage was used to develop the spherulite. Processablity and degradability characteristics of macromolecules can be controlled by the size and weight of the spherulite.

Observation of cross sections of plastic

Plastics processed into such items as containers are injection molded one time and then, after heating, are stretched and molded. During the stretching process, double refraction occurs due to the molecular orientation. For this reason, by using polarised light to observe a cross section of the plastic, the construction of cross sections that are different depending on processing and the process method, can be observed.

3-9 Cross section of a plastic with multilayers



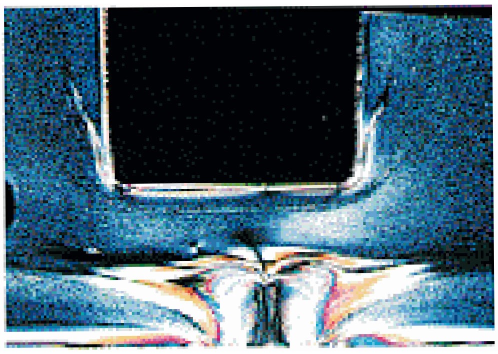
Transmitted polarisation
Objective UPLFL10XP
Photo eyepiece PE5X

The multilayer structure of the cross section of plastic, film thickness and others can be observed.

Observations of optical strain

When stress is added, even to the isotropic properties of such things as plastics, optical strain occurs and the double refraction phenomenon appears (photo-elasticity).
Stress distribution of such materials can be seen through polarised light observations.

3-10 Cross section of a plastic connector



Transmitted polarisation
Objective UPLFL4XP
Photo eyepiece PE2.5X

An insert into the plastic from the center of the connectors bottom portion. Since this is a molded part, the stress distribution can be seen.

Industrial Applications

3-3 Food chemicals

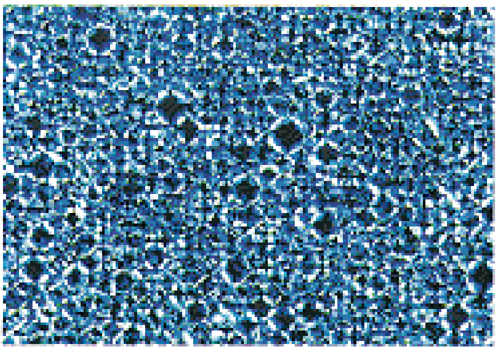
Fat Observations

The emulsion and emulsifiers of such things as butter and cream have optical anisotropy. For this reason, polarising microscopes have been used for such purposes as inspecting water/oil mixture conditions, etc.

Preparing samples

Place the emulsion or emulsifier onto a slide glass, cover with a cover glass and observe.

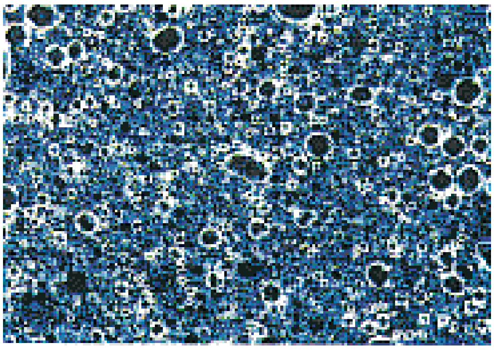
3-11 Emulsion



Transmitted polarisation
Objective UPLFL40XP
Photo eyepiece PE3.3X

The polarisation portion (bright portion) shows liquid crystal emulsification.

3-12 Butter and cream



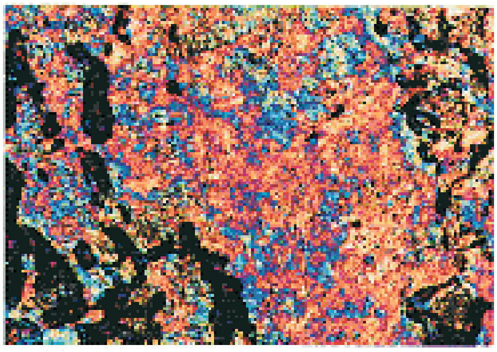
Transmitted polarisation
Objective UPLFL10XP
Photo eyepiece PE3.3X

Butter and cream are emulsions mixed with air. The black holes in the picture show the air that has been mixed into the emulsion.

Observation of food crystals

Polarising microscopes have been used for the investigation of food crystals with optical anisotropy.

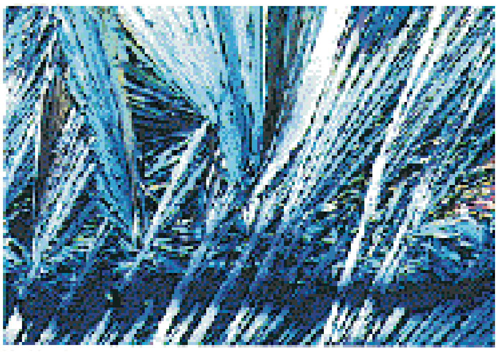
3-13 Fat crystals (sensitive colour)



Transmitted polarisation
Objective UPLFL4XP
Photo eyepiece PE5X
Tint plate U-TP530

The above photograph shows fat crystals forming on chocolate.

3-14 Vitamin B1 Crystals



Transmitted polarisation
Objective UPLFL10XP
Photo eyepiece PE2.5X

3-4 Glass

Observations of defects in glass

Polarising microscopes can be used for quality inspections during the glass manufacturing process.
These microscopes can identify (by crystal colour, shape, diffraction index, double diffraction, etc.) defects with only a single defect (crystal impurity), and can analyse the cause (by the crystal habit, combination, etc.).

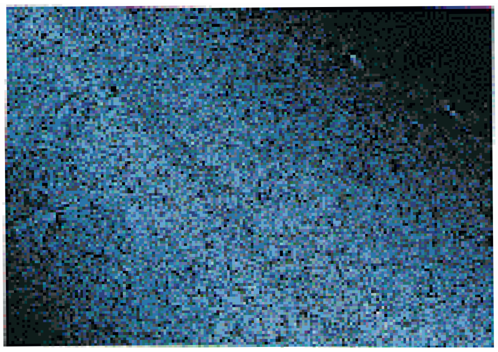
Preparing samples

In the same manner used for preparing rock samples, glass samples are prepared by the method of polishing a thin glass slice and then observing, or by the method of grinding the glass into a powder, surrounding it with an immersion fluid and observing.

Measuring glass strain [retardation]

Although glass is primarily an isotropic material, if stress is applied to the glass, the resulting optical strain will cause double refraction to occur. This double refraction corresponds to the applied stress.
The glass stress can be analysed based on retardation measured using a compensator.
There is also a method of obtaining the coefficient of thermal expansion through measuring glass strain.5) With this method, glass in which the coefficient of thermal expansion is already known, and the glass to be measured are both heated and adhered to each other. At this point, optical stress occurs due to the stress applied to the point of adhesion. Because retardation at the point of adhesion is in proportion to the difference in the coefficient of thermal expansion for both pieces of glass, the coefficient of thermal expansion for the glass can now be estimated by measuring this retardation.

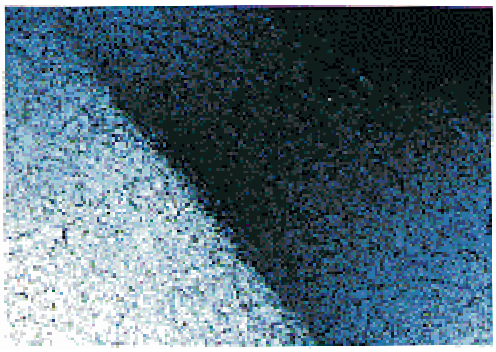
3-15 Strain of adhered glass



Transmitted polarisation
Objective UPLFL4XP
Photo eyepiece PE2.5X

The adhesion surface can be seen from the upper left corner to the lower right corner of the photograph. The area near the adhesion surface becomes bright due to the optical strain.

3-16 Strain of adhered glass



Transmitted polarisation (Retardation measurement)
Objective UPLFL4XP
Photo eyepiece PE2.5X
Compensator U-CBE

Retardation near the upper left section of the adhesion surface is measured using a Bereks compensator.

3-5 Ceramics

Ceramics are aggregates of various crystals and amorphous materials. Their characteristics are determined by the type and size of these crystals and amorphous materials.
Polarising microscopes are used to identify crystals within ceramics and to observe their structures.
The firing conditions and temperatures can also be estimated. 6) When the refractive index of the crystals that make up the ceramic is high, since the sample will have a large reflection, reflected polarised light observations can be more easily made. Also, crystals can be identified by conoscopic observtions.

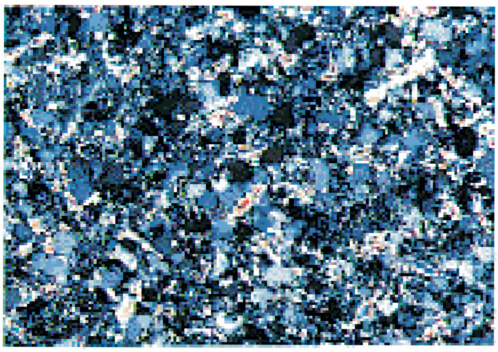
Preparing samples

The same methods used for preparing rock samples are also used for preparing ceramic samples.
One such method is to polish the sample and then affix it to a slide, and the other method is the immersion method in which the sample is ground into a powder, sprinkled onto the slide, completely surrounded by an immersion liquid and then covered with a cover glass.
The photographs below are polarised light photographs of ceramics (brick, porcelain, and alumina ceramics).

3-17 Brick

Transmitted polarisation
Objective UPLFL4XP
Photo eyepiece PE2.5X

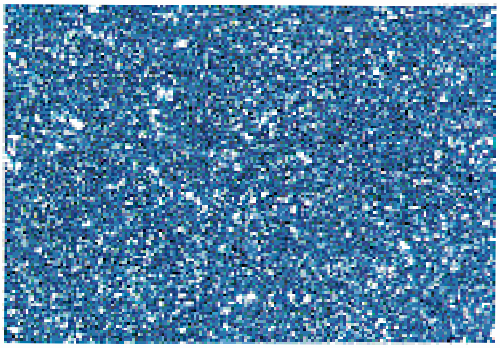
3-18 Porcelain



Transmitted polarisation
Objective UPLFL10XP
Photo eyepiece PE2.5X

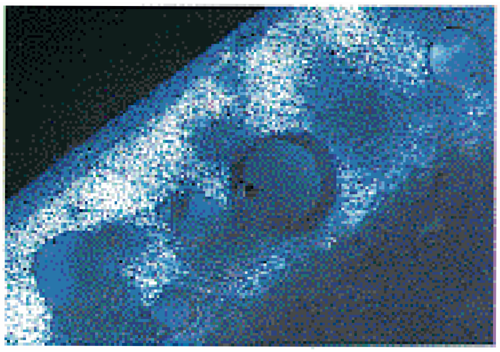
Optical strain in ceramics can also be observed.

3-19 Alumina ceramics



Transmitted polarisation
Objective UPLFL20XP
Photo eyepiece PE3.3X

3-20 Porcelain (stress distribution of a coffee cup)



Transmitted polarisation
Objective UPLFL20XP
Photo eyepiece PE3.3X

Strain has be seen on the porcelain surface (bright white portion). This strain is necessary so that stress can be added to the surface in order to improve the strength of the porcelain.

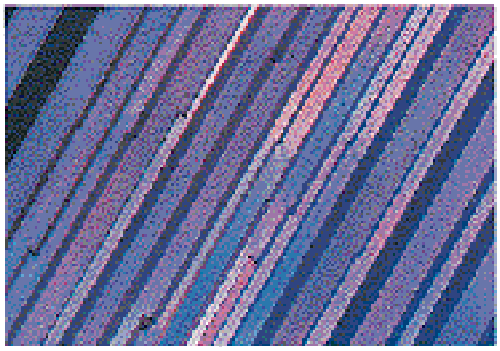
3-6 Other crystals

There are many crystals, such as strong elastic crystals, which often have optical anisotropy. A polarising microscope can be used to observe the shapes, structures (twin crystals, etc.), and uniformity of crystals, and can be used for crystal identification. Crystal identification and uniformity inspections can be performed using X-ray analysis, but the same observations can be more easily performed with a polarising microscope.

Preparing samples

When the crystal is transparent, polish both sides to produce a thin sample. If the sample is opaque, polish only one side, or leave the sample untreated, and then observe using incident polarised light.

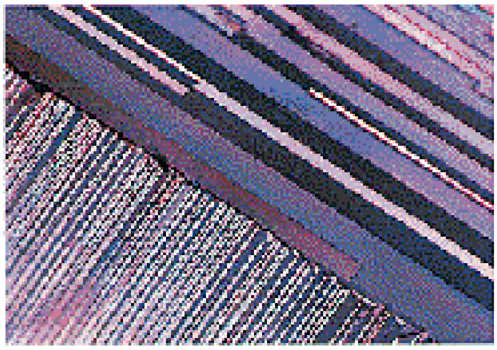
3-21 Strong elastic crystal ($LaNbO_4$) structure



Transmitted polarisation
Objective UMPLFL100XBDP
Photo eyepiece PE2.5X

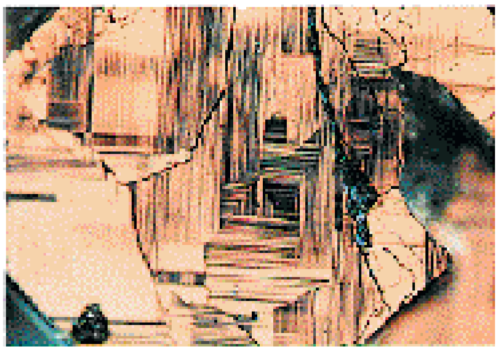
Polarised light image of an elastic crystal. The minute structure of a twin crystal (thin stripes shown in the photo) can be observed.

3-22 Elastic crystal ($LaNbO_4$) structure



Transmitted polarisation
Objective UMPLFL100XBDP
Photo eyepiece PE2.5X

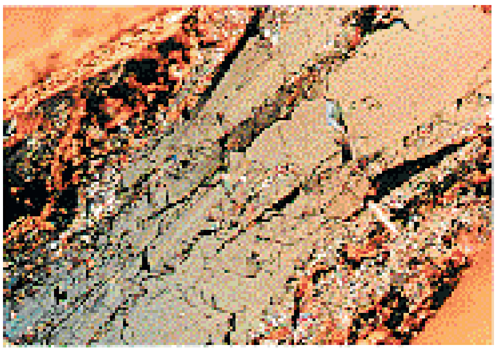
3-23 Super conductor crystal ($YBa_2 Cu_3 O_{7-x}$)



Incidence polarisation
Objective UMPLFL20XBDP
Photo eyepiece PE2.5X

In investigations of YBCO of super conductor crystals, incident polarised light observations have been used to determine the crystal orientation and whether or not YBCO was made. The creation of YBCO can be determined by twin-crystal confirmation.

3-24 Super conductor crystal (bismuth base)



Incident polarisation
Objective UMPLFL20XBDP
Photo eyepiece PE2.5X

3-7 Metals

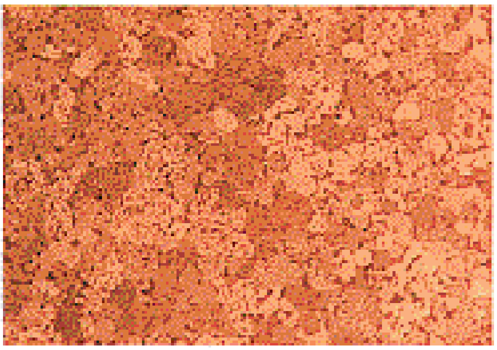
Incident polarised light observations of metal materials

By observing the minute structures of metal materials, it is possible to inspect composition, chemical properties, and surface conditions.

Preparing samples

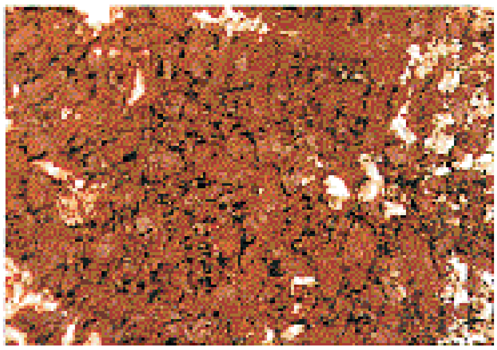
Evenly polish the metal material to be observed until it becomes a mirror-like surface, and then observe using incident polarised light. In this case, rotate the analyser, and observations can also be made with the brightness of the background slightly increased compared to the cross-polarised position (extinction). The following pictures are polarised light images of metallic structures (3-25~27).

3-25 Metallic structure (PbSnAg alloy)



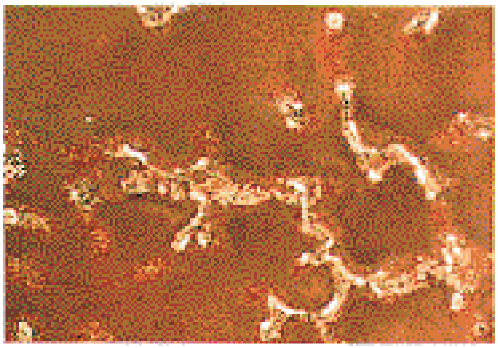
Incident polarisation
Objective UMPLFL20X
Photo eyepiece PE3.3X

3-26 Metallic structure (iron alloy)



Incident polarisation
Objective UMPLFL20X
Photo eyepiece PE3.3X

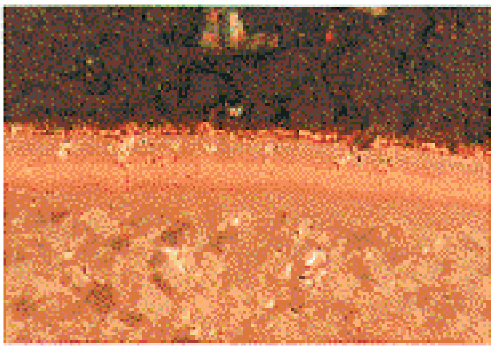
3-27 Metallic Structure (magnesium alloy)



Incident polarisation
Objective UMPFL50X
Photo eyepiece PE3.3X

An eutectic reaction (red particle portion) can be seen around the magnesium (bright, shiny portion).

3-28 Coating over TiN based materials



Incident polarisation
Objective UMPLFL50X
Photo eyepiece PE5X

A thin layer of coating can be seen between the TiN based material (bottom half of the picture) and the resin.

4 Appendix

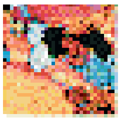
4-1 Major Fields Using Polarising Microscopes

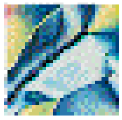
Field	Observation Method	Object of Observation	Can be determined by polarising microscope	Page
Medical	Transmitted polarisation Sensitive tint plate	Gout crystals in synovial fluid Amyloid in sections of tissues Egg-shaped fat particles in urine	Gout diagnosis Amyloidosis diagnosis Nephrotic syndrome diagnosis	3 4
Biology	Transmitted polarisation Brace-Koehler compensator	Double-refracting structures Actomyosin fibre, Muscle, Teeth, Nerve tissue, etc.	Observation of double refraction structures Retardation of double refraction structures	4 5
Rock Minerals	Transmitted (incident) polarisation Sensitive tint plate Conoscope	Mineral crystals in rocks interference colours Conoscopic images of crystals	Rock structures Crystal identification(by shape, interference) Crystal identification (by optical positive/negative, uniaxial and biaxial judgement)	6 7
Liquid Crystals	Transmitted (incident) polarisation Heating stage Compensator Conoscope	Optical patterns Phase change, Phase change temperature Liquid crystals, Orientation film Conoscopic images of crystals	Liquid crystal judgement Defects Measurement of phase change temperature, Liquid crystals, orientation film retardation Liquid crystal optical characteristics judgement	8
Macromolecules	Transmitted polarisation Compensator Heating stage Sensitive tint plate	Fibres, macromolecular sheets Spherulites Observing the section of molded products Optical strain	Retardation of fibre and macromolecular sheets Judgement of macromolecular materials based on phase change temperature Number and size of spherulites Observation of spherulite growth Direction of refractive index ellipsoid Multilayer construction of molded objects Layer thickness Stress distribution	9 10
Food Chemicals	Transmitted polarisation Sensitive tint plate	Fats (butter, cream, etc.) Food crystals	Mixture of water and oil Existence of crystals	11
Glass	Transmitted polarisation	Glass defects (crystals) Optical strain	Identification of defects in glass Glass stress (coefficient of thermal expansion)	12
Ceramics	Transmitted polarisation (incident polarisation) Conoscope	Crystals within ceramics Shape, double refraction Optical strain Conoscopic image of crystals	Structure of ceramics Crystal identification Stress distribution Crystal identification (based on whether the crystal is optically positive or negative, uniaxial or biaxial, etc.)	13
Crystals	Transmitted polarisation (incident polarisation) Conoscope	Shape, double refraction Crystal structures Optical strain Conoscopic image of crystals	Crystal identification Crystal uniformity Twin crystal, transference Stress distribution Crystal identification (based on whether the crystal is optically + / -, judging whether it is opti-cally uniaxial or biaxial, etc.)	14
Metals	Incident polarisation	Metallic structures	Composition of metals Surface conditions	15

4-2 Compensator types and measurement ranges

Unit Name *)	Measurement Range **)	Main Applications
Berek U-CTB U-CBE	0 ~ 11000nm (0~20 λ ... (lambda)) 0 ~ 1640nm (0~3 λ ... lambda))	* Retardation of large-retardation materials in crystals, liquid crystals, fibres ,or plastics including teeth, bone, hair, etc. * Measuring retardation of optical strain * Determining the anisotropy Z'direction
de Sénarmont U-CSE	0 ~ 546nm (0~1 λ ... lambda))	* Measuring retardation of crystals, fibres, living organisms, etc. * Measuring retardation of optical strain * Enhancing contrast when observing organisms with minute retardation * Determining the anisotropy Z'direction
Brace-Kohler U-CBR1 U-CBR2	0 ~ 55nm (0~ λ ... lambda)/10) 0 ~ 20nm (0~ λ ... lambda)/30)	* Measuring retardation of thin film, glass, etc. * Enhancing contrast for observing organisms with minute retardation * Determining the anisotropy Z'direction
Quartz wedge U-CWE	500 ~ 2000nm (1~4 λ ... lambda))	* Measuring the general retardation principles of quartz crystals, etc. * Determining the anisotropy Z'direction

*) Compensator names are Olympus brand names.
**) This compensator measurement range is for Olympus compensators.
(Compensator measurement ranges are different for each manufacturer.)





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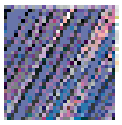
Acknowledgme

Drafting of this Polarising Microscope Applications would not have been possible without the valuable contributions made by teachers and people from various industries. These people took time from their busy schedules to assist in creating samples, and to offer instruction on the use of polarising microscopes. Thanks to their efforts, we were able to produce this manual and include a wide range of fields using the polarising microscope.
We would again like to express our gratitude to everyone involved in producing this manual.



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