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INTRODUCTION TO MICROSCOPY



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MICROSCOPE

Compound microscope = enormous magnification range. Can reveal detail at the cellular level. "What do I want to observe?" This determines the type of microscope you need. Very small subjects - cells and microorganisms - require a lot of magnification and you will need to prepare a glass slide to observe them. The slide is then used with a compound light microscope at magnifications anywhere from 40x all the way up to a maximum of 1500x, depending on the subject-

HEADS

There are 4 main types of heads or tube-lens

- Monocular : for 1 eye
- Binocular: for 2 eyes
- Trinocular: for 2 eyes + a vertical tube to insert a camera: reflex, digital or compact digital.
- Multi-head: for 2, 3 or 5 observers. Optika offers a model up to 10 observers.

EYEPIECES

The tube-lens contains the eyepieces (oculars). The eyepieces work in combination with microscope objectives to magnify the image of specimen so that specimen details can be clearly observed.

Types of eyepieces:

Huyghens (H), cheap and simple eyepiece.

Widefield (WF), bigger field of view

High eyepoint widefield, for those users who use eyeglasses, no need to remove it.

WF = means "Widefield"

10x = magnification of the eyepiece

18 mm = field of view (could be also 20mm / 22mm / 23mm most of the stereos)

The tube-lens in binocular and trinocular heads includes a diopter adjustment, this allow the focusing characteristics of each ocular to match the users own eyes. The diopter adjustment can be found on the left tube or in both tubes depending on microscope model.

Finally, there's a comfort adjustment to bring the two eyepieces in line with distance between the user's pupils, this is the interpupillary distance.

STAND

Stand is the microscope body where on the top holds the head and the bottom the light. Also, focusing system, stage and nosepiece.

NOSEPIECE

It is the part of microscope that holds the objectives. There're many types of nosepieces:

3: to hold 3 objectives

4: to hold 4 objectives

5: to hold 5 objectives

Professional microscopes can hold up to 6 or 7 objectives.

Design: **inward** where the objectives are “faced” inside the stand or **outward** where objectives are “faced” outside the stand. We recommend inward for protection of lens. Usually the less expensive microscopes have the objectives mounted on an outward nosepiece.

OBJECTIVES



Code by colors

Objective 4x: RED

Objective 10x: YELLOW

Objective 20x: GREEN

Objective 40x: LIGHT BLUE

Objective 60x: DARK BLUE

Objective 100x: WHITE

Objectives: The objectives are the most important component of an optical microscope because they determine the quality of images. There're many types of objectives, achromatic, semi-plan, plan-achromatic and apochromatic are the most popular.

Most microscope objectives are designed to be used with a cover glass that has a standard thickness of 0.17 millimeters and a refractive index of 1.515.

"DIN" is an abbreviation of "Deutsche Industrial Normen." This is a German standard that has been adopted internationally as an optical standard used in most quality microscopes. The focal tube length of a DIN standard microscope objective is 160mm. A typical DIN standard microscope objective lens has 20.1mm diameter threads.

RMS ("Royal Microscope Society"), which had a longer tube length 170mm and 20.32mm thread. Most DIN optics are interchangeable. However, DIN and RMS objectives are not interchangeable. If you have RMS objectives and want to use them on a DIN objective nosepiece you would need to use an adapter, and even with this adapter the microscope would not be parfocaled.

The properties of each objective's lens refer to aberrations or defects.

Chromatic aberration: color defect.

Spherical aberration: shape defect on the image produced by the curve of lens.

Achromatic: the lens only correct the chromatic aberration, colors red and blue, but still give spherical aberration. It is the cheapest type lens most used in microscope construction. Field of view types: 16mm / 18mm / 20mm

Semi-plan: the lens corrects the chromatic aberration (red & blue) and spherical aberration. It is made of 2 lens, one concave and one convex. Field of view: 20mm/22mm

E-Plan: the lens corrects the chromatic aberration (red & blue) and spherical aberration. Deliver long working distances, high numerical aperture and flat images over the entire field of view with virtually no curvature of field. (E-Plan, Nikon nomenclature).

Plan-Achromatic: the lens corrects the chromatic aberration as well as provide excellent plan images without spherical aberration. It is usually made of 1 len without curve. Field of view: 20mm / 22mm / 23mm

Plan-Apochromatic: is the best type of lens, corrects all chromatic aberrations from 4 colors and more, as well as spherical aberration, provides a plan image and wider visual field of view. It is used on lens of 25mm field view or superior. This is the best for research in fluorescence (Plan-apo FL).

Infinity Optical System: In modern and research microscopes the objective is designed to focuses an image to infinity. A lens is inserted between the objective and the eyepiece to create a real intermediate image through the combination of objective and tube lens, therefore the resulting light path is parallel.

Numerical Aperture (N.A.): This number is imprinted on the objective lens. It is a measure of the resolving power of the objective (how fine a detail can be seen). The condenser aperture diaphragm should be adjusted to the same value of the N.A. of the objective, to obtain the best results.

Mechanical Tube Length: The mechanical tube length of an optical microscope is defined as the distance from the nosepiece opening to the top edge of the observation tubes. Most microscopes had a fixed tube length ranging from 160 to 210 millimeters. Modern microscopes are equipped with infinity-corrected objectives that utilize a tube lens in the microscope body to form a parallel region of light waves into which optical accessories can be inserted without seriously affecting image quality.

LWD or ULWD: These abbreviations stand for “long working distance” or “ultra-long working distance”. These objectives are able to work with a large specimen-objective distance and are used for specific applications. Mainly on inverted microscopes but also other applications like metallurgical.

Parcentered: As the user turns the nosepiece to bring another objective over the specimen, each image should be right in the center of the view through the eyepieces, with no change from one objective to another.

Parfocal: When rotating a new objective into position, there should be only minor adjustment to bring the specimen into the same sharp focus as the previous magnification. This is parafocality.

Magnification: Is the mathematical product of multiplying the power of the eyepiece, times the power of the objective. It is always referred with the signal “X”. Therefore 10x eyepiece by 4x objective, total magnification is 40x.

STAGE

Is the part where the user puts the specimen slide. It is always square shape, although in some models are circular like polarizing microscopes which uses a 360° rotating stage.

Mechanical stage: is a stage made with a mechanical movement and a vertical knob usually located on the right side of the microscope, (in some professional models can be ordered on the left side for left-hand users). The stage has a movable clip and a fixed clip to hold the slide and provides X-Y movement to find another section of the specimen. The manufacturers provide information about the X-Y range like for example 76x55 mm.

X range = horizontal translation movement

Y range = vertical translation movement

CONDENSER

It is located below the stage of microscope. It is one of the most important elements of a microscope. The condenser is made of lens and diaphragms which allow to improve the resolution and contrast of an image, also reduce brightness and guarantee optimum results in all objectives combinations.

The condenser is also named: sub-stage condenser.

The condenser concentrates the light source into a cone light that illuminates the specimen with uniform intensity over the entire viewfield.

The iris diaphragm is a part of the condenser. The user may open or close to control contrast and sharpness. The condenser set can be height adjusted to change the light cone point to optimize the intensity and angle of light entering the objective front lens. Its best height position is closer to the objective lens.

Numerical Aperture (N.A.) of a condenser determines the resolving power of an objective. The objective gives information of what is the maximum N.A. to work with.

Objective 4x / 0.10 = 4x magnification / N.A. 0.10 (numerical aperture of condenser or superior)

10x / 0.25

20x / 0.40

40x / 0.65 / S (S = spring)

60x / 0.85 / S

100x / 1.25 / S – oil

The **ABBE condenser** is the most simple type of a condenser lens which is located below the stage, it good to gather light but it does not correct any of both aberrations: chromatic and spherical.

ILLUMINATION

Koehler illumination: the property to adjust and align the light path.

Pre-centered illumination: the alignment system of the light is not available.

Halogen: best light, clear and longer time of life. It has intensity control to change brightness. Needs blue or white filters in the condenser.

LED: A new high-efficiency single chip LED.

X-LED: Same as above, the X-LED lamp works in combination with a special optical lens, which allows to double the intensity of the light generated by the LED itself.

The result is a quantity of light equivalent to the light generated by a normal 30-35W halogen bulb, but with a color temperature of 6300°K. It means white light instead of the yellow one produced by halogen bulbs. The electrical consumption (3.6W only) shows the high efficiency of the system: same light intensity with less than 10% of the consumption of a normal halogen bulb.

Last but not least, the lifetime of our LED: 50.000 hours, instead of 1.500 hours!. (approximately 6 years if never turned off)

Benefits of the LED light:

- 1) Provides true white Light, without alteration of the natural sample's colors. pleasing natural light color (instead of yellow incandescent or halogen bulbs)
- 2) Longer life-time of the lamp.
- 3) Cold light, avoid higher temperatures. No or very little heat production (Wasted energy)
- 4) Light intensity of an equivalent 30W halogen.
- 5) Electrical consumption 10% less than normal halogen lamp. an average of 0.030A (very low power)
- 6) zero bulb replacement
- 7) state of the art LED (Light Emitting Diode)
- 8) earth friendly microscopes

LED with batteries: same as before but with a rechargeable battery. The microscope can work in the field, outdoor or any place where does not exists power supply. Batteries can be re-charged during night. Only for small microscopes.

ALC system exclusive from Optika: Automatic Light Control function: the level of light is adjusted by the microscope in order to maintain the same level as the one the user has chosen, no matter if the aperture of the diaphragm changes, another objective is inserted, opacity of the sample changes, etc.

FOCUSING

The focusing knobs are located in both sides of the microscope's stand. The knobs can be mounted on 2 separated focusing knobs or mounted in the same axis, also named "coaxial".

Macro or coarse: for rapid focusing of the specimen. It is use to locate the section of specimen the user wants to observe. The macro knob moves up & down the stage.

Micro or fine: for a slow focusing of the specimen, when user has already found the section of specimen and now wants to obtain an image in detail. As a general measure, one complete rotation of the fine knob correspond to 0.02 mm.

For security reasons all microscopes have an "upper stop" mechanism to prevent the objective will not break the slide when working at little distance. Also, includes an adjustable tension of coarse focusing.

STEREOMICROSCOPES

Dissecting or "Stereo" Microscopes. If you are working with larger specimens, or if you wish to use a microscope to inspect parts, plants, stamps, coins, insects, rocks, fossils or archaeological specimens, or to guide you during fine dissection, you need a "stereo" or dissecting microscope.

Stereo microscopes have the unique ability to see the third dimension 3D – depth. This makes stereo microscopes the instruments of choice for surgeons, gemologists, electronic assemblers, denture makers and fine engravers, to name a few examples.

HEAD

Always binocular or trinocular if the user wants to fit a camera or digital camera.

EYEPIECES

Same as in microscopes, however the 18mm FOV does not exist in stereomicroscopes. Field of view usually 23mm

STAND

Stand is the stereomicroscope body to hold the head with focusing system, light system and macro focus knobs.

A stage plate is a glass or plastic platform the subject rests upon when you observe. Stage plates black or white, to improve contrast between the subject and the background. Clear glass stage plates are also supplied on models that offer illumination from below the subject.

OBJECTIVES

Stereo microscopes have "*long working distance*" objectives to enable larger specimens to be examined. Magnification in the stereo microscope in the same manner as it does in the "*compound microscope*." For technical reasons, the magnification capabilities of standard stereo microscopes are usually limited to much less than 200x.

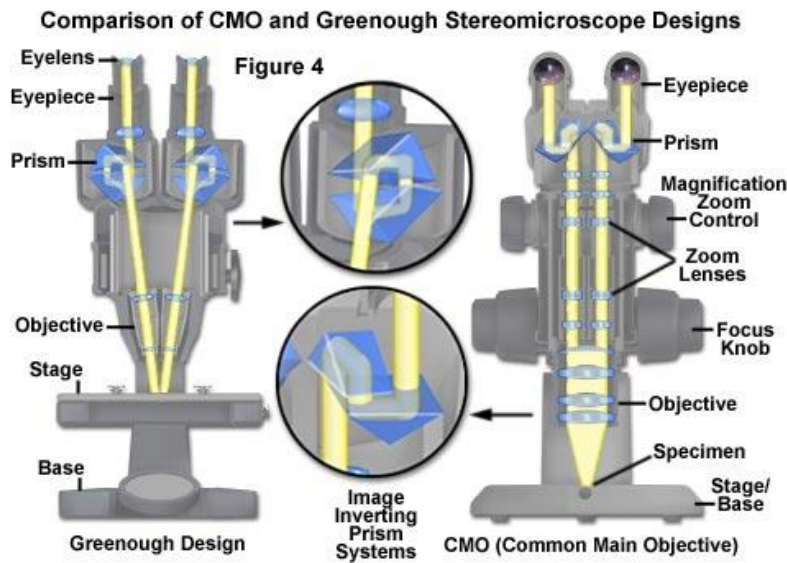
Two types of objectives, fixed paired objective set mounted in turret type usually only 2 objectives 2x, 4x) or zoom (0,7x to 4,5x)

Two types of objectives construction:

Parallel optics or Galilean (most of the time are also infinity corrected) allow to insert some attachment without affecting the final quality of the image. As an example: our modular series SZP can add the ST-170, the coaxial illuminator or the fluorescence attachment without any problem, while the series SZM, SZR cannot do the same.

In general parallel stereo microscopes have a greater light-gathering power than the Greenough type design and are often more highly corrected for optical aberration, though in most circumstances, the choice between Greenough or parallel is usually based on the application, rather than whether one design is superior to the other.

Greenough stereo microscopes are typically employed for "workhorse" applications, such as printed circuit board inspection, dissecting biological specimens, or similar routine tasks. These microscopes are relatively small, inexpensive, very rugged, simple to use, and easy to maintain.



(Source: Nikon)

Other objectives type: PLAN or PLAN-APO

A PLAN objective is one that makes a flat field correction, one of the possible optical corrections that allow us to observe a "realistic" image with the stereo microscope.

A PLAN-APO objective is one that makes a flat field correction and chromatic correction. This correction compensates the small difference in refractive index between the different color light passing through the lens and gives us an image without halos as well as optimum contrast and definition.

The disadvantage with PLAN-APO in stereomicroscope objectives have a less working distance.

A PLAN objective is good for manipulation under the stereo, while a PLAN-APO objective with greater numerical aperture is good for photos, if you're going to make microphotography use PLAN-APO.

PLAN-APO:

- is expensive
- greater numerical aperture
- less working distance
- better optical correction, flat images and true color. The best for photography



PLAN



PLAN-APO

ILLUMINATION

Dissecting microscope illuminator design commonly provides for “*incident*” light -- light *falling on* the specimen -- and “*transillumination*” – light *passing through* the specimen from a light source inside the base.

Some models does not have illumination system. That is for professional use, they required an external light system like fiber optic or a LED ring.

FOCUSING

The fine (micro) focusing knobs are located in both sides of the stereo head.

In some models the coarse (macro) focusing is located on the back side of the head support bar. It is a big screw when unscrew head moves up & down along the bar in order to get a fast focusing.

How to calculate zoom range of a stereo zoom microscope?

To get the zoom range of a stereo zoom microscope, only divide the higher magnification objective by the lower magnification. As an example SZM series with (0,7x.....4,5x)

4,5x /0, 7x = 6,428 ----- range 6,428:1

How to calculate FOV of samples in a stereo microscope?

The FOV *is* the diameter of the sample plane that you see.

The general formula is:

$$\text{FOV} = ((\text{Field Number of Eyepiece}) / (\text{Zoom magnification, if stereo has zoom})) / \text{Additional lens magnification (if any)}$$

See example #1 for a ST-40B-2L

This model is featured with 1x & 3x objectives and WF10x/20mm eyepieces. Therefore formula will be:

FOV with 1x objective = 20mm/1x = 20mm,

FOV with 3x objective = 20mm/3x = 6,6mm

See example #2 for a Stereo zoom microscope with additional lens

Standard Eyepiece: WF10x/FN20mm

Zoom magnification: 0.7x...4.5x

Without additional lens:

FOV = $(20\text{mm} / 4.5\text{x}) = 4.4\text{mm}$ at higher magnification

FOV = $(20\text{mm}/0.7\text{x}) = 28.57\text{mm}$ at lower magnification

With Additional lens: 0,5x

FOV = $(20\text{mm} / 4.5\text{x}) / 0.5\text{x} = 8.8\text{mm}$ at higher magnification

FOV = $(20\text{mm}/0.7\text{x}) / 0.5\text{x} = 57.14\text{mm}$ at lower magnification

Standard Eyepiece: WF15x/FN15mm

Zoom magnification: 0.7x...4.5x

Without additional lens:

FOV = $(15\text{mm} / 4.5\text{x}) = 3.3\text{mm}$ at higher magnification

FOC = $(15\text{mm}/0.7\text{x}) = 21.42\text{mm}$ at lower magnification

With additional lens: 0,5x

FOV = $(15\text{mm} / 4.5\text{x}) / 0.5\text{x} = 6.6\text{mm}$ at higher magnification

FOV = $(15\text{mm} / 0.7\text{x}) / 0.5\text{x} = 20.92\text{mm}$ at lower magnification

TYPES OF MICROSCOPESBrightfield microscope

Brightfield microscopy is the most elementary form of microscope illumination techniques and is generally used with compound microscopes. The name "brightfield" is derived from the fact that the specimen is dark and contrasted by the surrounding bright viewing field. Simple light microscopes are sometimes referred to as brightfield microscopes. Samples must be stained.

Life Science Applications: Pathology, biology, microbiology, haematology, oncology, botany, parasitology, urine analysis, veterinary, food, dermatology.

Darkfield microscopy

Dark field microscope is arranged so that the light source is blocked off, causing light to scatter as it hits the specimen. In darkfield microscopy, the objective lens sits in the dark hollow of this cone and light travels around the objective lens, but does not enter the cone shaped area. The entire field of view appears dark when there is no sample on the microscope stage. However, when a sample is placed on the stage it appears bright against a dark background. Dark Field illumination is a technique used to observe unstained samples causing them to appear brightly lit against a dark, almost purely black, background.

Application: haematology, pathology

Phase contrast

Also called Zernike microscope thanks to Mr. Zernike who discovered this technique.

Is a contrast-enhancing optical technique that is only useful on specimens that are colorless and transparent and usually difficult to distinguish from their surroundings, living cells can be examined in their natural state without being stained and make details in the image appearing darker against a light background. Zernike developed a system of rings located both in the objective lens and in the condenser system. When aligned properly, light waves emitted from the illuminator arrive at your eye $1/2$ wavelength out of phase. The image of the specimen then becomes greatly enhanced.

Phase Contrast POSITIVE: dark samples on brightfield background. Phase Contrast NEGATIVE: Bright signs on darkfield (dark gray) background (Optika option). This is the same technique, but it depends on customer preference.

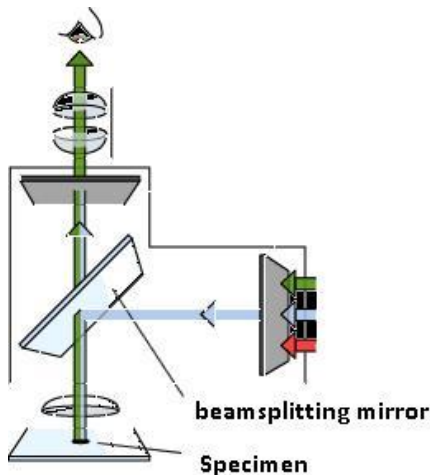
Application: Cell parts in protozoans, bacteria, sperm tails and other types of unstained cells, microorganisms, asbestos, food, water, pathology, microbiology.

Fluorescence: HBO, LED

The fluorescence microscope is based on the phenomenon that certain material emits energy detectable as visible light when irradiated with the light of a specific wavelength.

The basic task of the fluorescence microscope is to let excitation light radiate the specimen and the sort out the much weaker emitted light to make up the image. First, the microscope has a filter that only lets through radiation with the desired wavelength that matches your fluorescing material. The radiation collides with the atoms in your specimen and electrons are excited to a higher energy level. When they relax to a lower level, they emit light. To become visible, the emitted light is separated from the much brighter excitation light in a second filter. Here, the fact that the emitted light is of lower energy and has a longer wavelength is used. The fluorescing areas can be observed in the microscope and shine out against a dark background with high contrast.

The technique has made it possible to identify cells and cellular components with a high degree of specificity. For example, certain antibodies and disease conditions or impurities in inorganic material can be studied with the fluorescence microscopy.



HBO fluorescence microscope uses a mercury lamp. This is a traditional technique as the lamp is 100W which offer needed power for certain fluorochromes to excite at high power. It is accompanied with an external power source that controls the lamp intensity and time life (between 250-300 hours).

Disadvantage of working with mercury lamp: very delicate, once it has been switched off cannot be switched on again until it is completely cold. The advantage is that with HBO light a wide range of fluorochromes can be used. Optika offers 4 type like blue, green, violet and ultraviolet. If other fluorochrome should be needed, Chroma Technologies manufactures and supply many of them at high quality.

LED fluorescence microscope uses a white LED lamp. This new technique however, is not fully developed. Optika model for fluorescence with LED lamp can only use blue and green fluorochromes under certain wavelength values. The advantage is a cold light hence no need to wait for switching on again, it doesn't use either an external electrical source.

Filters are usually built up inside a cube or block. It can be sold separately or together.

Blue filter for Acridine yellow, Acridine orange, Auramine, DiO, DTAF, FITC, GFP, YFP

Green filter for Cy3, DiL, Blu evans, Feulgen, Rhodamine, Texas red, TRITC.

UV filter for AMCA, auto fluorescence, BAO, BFP, Blu cascade, DANS, DAPI, Hoechst, Indo-1, SITA

V filter for ANS, Fluorescamine, Catecholamine

Applications: Oncology, pathology

Polarizing microscope

Petrographic or polarizing microscope is the best choice for birefringent (material having a refractive index) material which have measurable refracting differences determined by observation direction. Polarizing allow researchers to obtain information on color absorption, structure, composition, light refraction and other properties of materials. Polarizing microscope contains the following components:

- A polarizer and analyzer
- A circular rotating stage
- Special plates or filters placed between the object and analyser. (compensator or retardator plates: Lambda or first order red, $\frac{1}{4}$ Lambda, quartz wedge)
- Bertrand lens

A polarizer (placed below the stage or on the base of light) only allows certain light waves or vibrations to pass through it. An analyser (slides into position in between objective and ocular lenses), often a second polarizer located above the sample, determines the amount and direction of light that illuminates a sample. The relationship of the polarizer and analyser, in addition to other filters to be added, determines the amount of light absorbed, reflected and refracted through the microscope. When polarizing filter is aligned 90° over the illumination it is able to pass through different angles of light allowing to see different aspects of the specimen.

A polarizing microscope can employ transmitted and reflected light. Reflected light, referred to as epi- or incident light, is best suited for opaque samples, such as metals, alloys, composites and mineral oxides and sulphides.

The type of light used in polarizing microscopy to improve image quality when examining birefringent (doubly-refracting) anisotropic material. An anisotropic substances are “direction-dependent”, that is they do not behave the same way in all directions. One example is wood, which break more easily in a direction along its grain than against it. Steel, on the other hand, is isotropic and behaves the same way in all directions. In general most liquids and gases are isotropic and have same optical properties in all directions, they have one refractive index. By contrast, most solid material are anisotropic. Their optical properties vary depending on the orientation of incident light (that fall on a surface) and they have numerous refractive indices.

Bertrand Lens - The lens is designed to enable easy examination of the objective rear focal plane, to allow accurate adjustment of the illuminating aperture diaphragm and to view interference figures,

Compensator and Retardation Plates - Many polarized light microscopes contain a slot to allow the insertion of compensators and/or retardation plates between the crossed polarizers, which are used to enhance optical path differences in the specimen.

Applications: Geology, petrography for the study of rocks and minerals although other materials like ceramic, polymers, wood, urine crystals, gout crystals, amyloid.

With conoscopic light we can distinguish: shape, color, size, inclusions, relief, and alterations.

With orthoscopic light we can distinguish mainly colors. (table of Michel Levy)

Metallurgical microscope

A metallurgical microscope can illuminate solid specimens to identify, inspect and measure them. Metallography microscope allow the user to view opaque items at high magnification.

The light orientation is different from conventional microscopes. A conventional microscope illuminates a transparent specimen from below the stage, making it visible through the eyepiece. Since light cannot penetrate opaque or solid objects this is not suitable for observing these samples under magnification. Metallurgical microscopes illuminate objects from above. The light travels through the magnification objectives using beam splitters. This lighting technique illuminates the entire object without creating unnecessary reflections. The illumination technology may include color filters or filters designed to change polarisation and light intensity.

Some industries use inverted metallurgical microscopes which observe the specimen from below the stage.

Application: measuring thin films, electroplating coatings, grain size, surface inclusions and defects. For the inverted type microscope: Electronic parts manufacturers, metal foundries.

Inverted Microscopes

The inverted microscope is designed with the light source and the "condenser" lens above the specimen. The objectives and turret of the microscope is on the bottom. Basically, in an upright microscope, you look down to see the image, and with an inverted model, you look up. This microscope model is a very good choice if your sample to be viewed is in suspension or is very large and heavy.

Application: This type is commonly used in metallurgy, cell culture and for viewing aquatic specimens.

Stereo Microscopes

This type of equipment is used for opaque objects.

Applications: coins, stamps, forensic, gemology, jewellery, metallography, mineralogy, odontology, petrology, quality control in industry, restoration and conservation, textile, botany, water, dermatology, graphology.

APPLICATIONS

Urine: brightfield, polarizing, phase contrast.

Leptospira: (bacteria in animals living in tropical environments) brightfield, fluorescence.

Textile: brightfield with polarizing filters, polarizing

Textile stained with resin: metallurgical

Tuberculosis: brightfield, fluorescence

Fungi: brightfield with objective 40x and 60x

Malaria: brightfield, fluorescence only with blue filter

Sperm: phase contrast with heating stage

Honey particles: brightfield

Trichinosis: brightfield with darkfield condenser

Water: phase contrast, stereomicroscope

Water sediment: inverted

Entomology: stereomicroscope

Phytopathology: stereomicroscope

Hair: polarizing

Tree rings: stereomicroscope

Cytology: brightfield

Pathology: brightfield, phase contrast, fluorescence

Histology: brightfield

Haematology (blood): brightfield, darkfield

Parasites in blood: phase contrast, darkfield

Powders/Crystals: polarizing, stereomicroscope

Chromosomes: fluorescence

PCB materials (printed circuit boards): stereomicroscope, metallurgical (upright or inverted)

Yeast and fungi: brightfield

Wine yeast: phase contrast

Diatoms: phase contrast

Pigments, paint: polarizing

Emulsion in water: brightfield with polarizing filters

Lactose crystals: polarizing, brightfield with polarizing filters

Polystyrene XPL: stereomicroscope

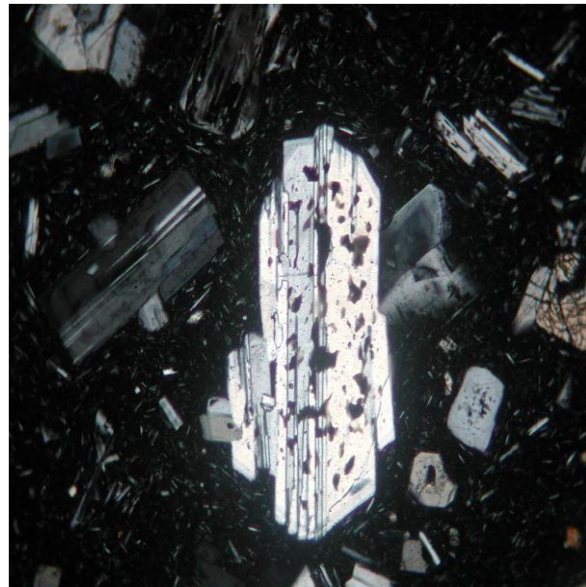
C. Elegans: stereomicroscope, fluorescence

MINIERALS FROM VOLCANIC ROCKS

PLAGIOCLASI WITH GLASS INCLUSIONS



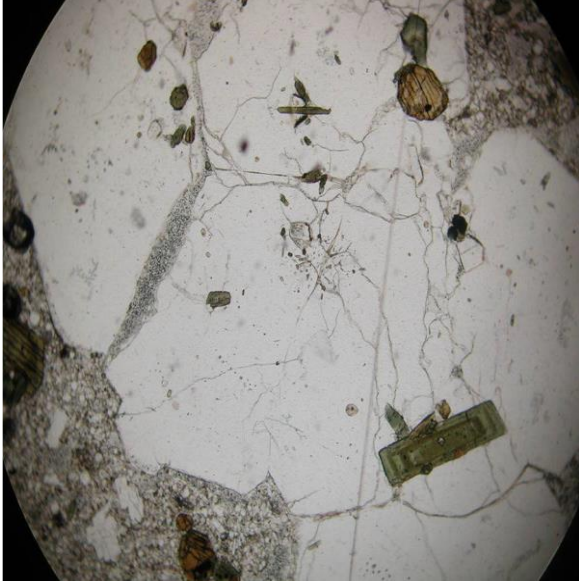
Polarizer



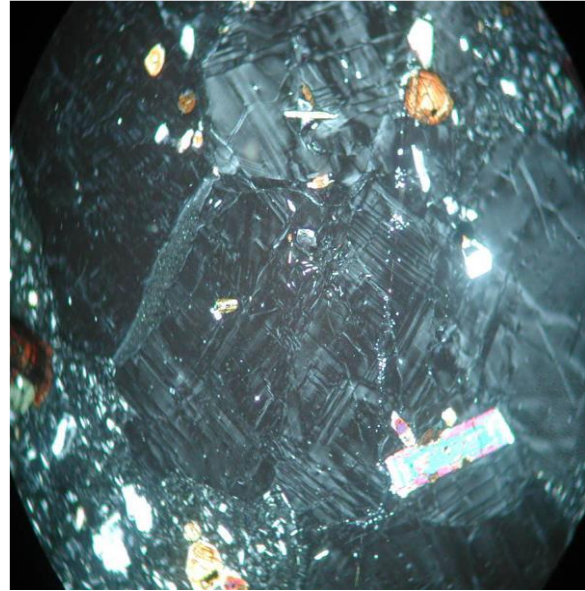
Polarizer + Analyser

Source: Univeristy of Barcelona (UB), Geology Engineerying, Professors: E. Tauler, N. Otero and A. Soler

ANORTOCLAS

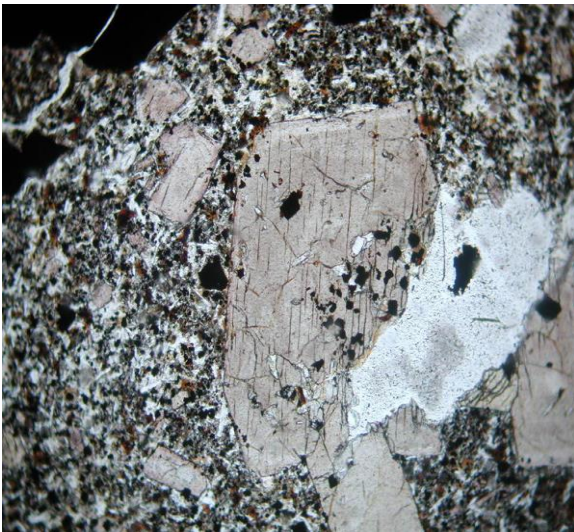


Polarizer

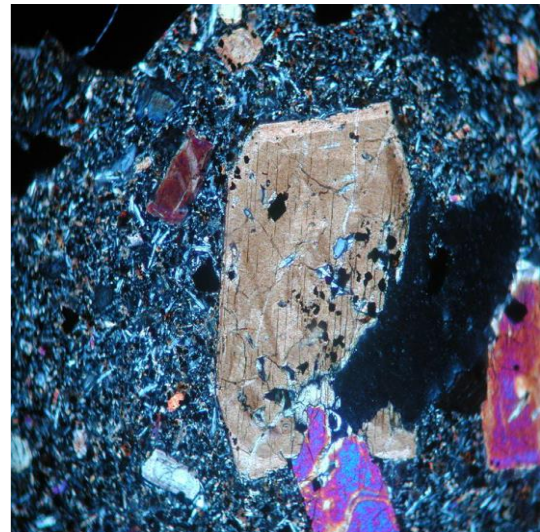


Polarizer + Analyser

AUGITA



Polarizer



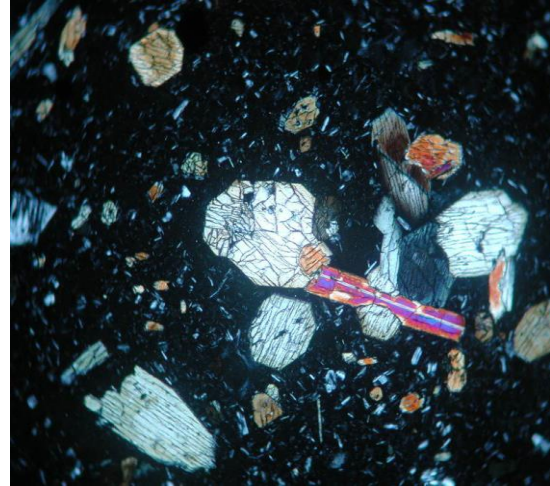
Polarizer + Analyser

Source: Univeristy of Barcelona (UB), Geology Engineerying, Professors: E. Tauler, N. Otero and A. Soler

AUGITA EGIRNICA

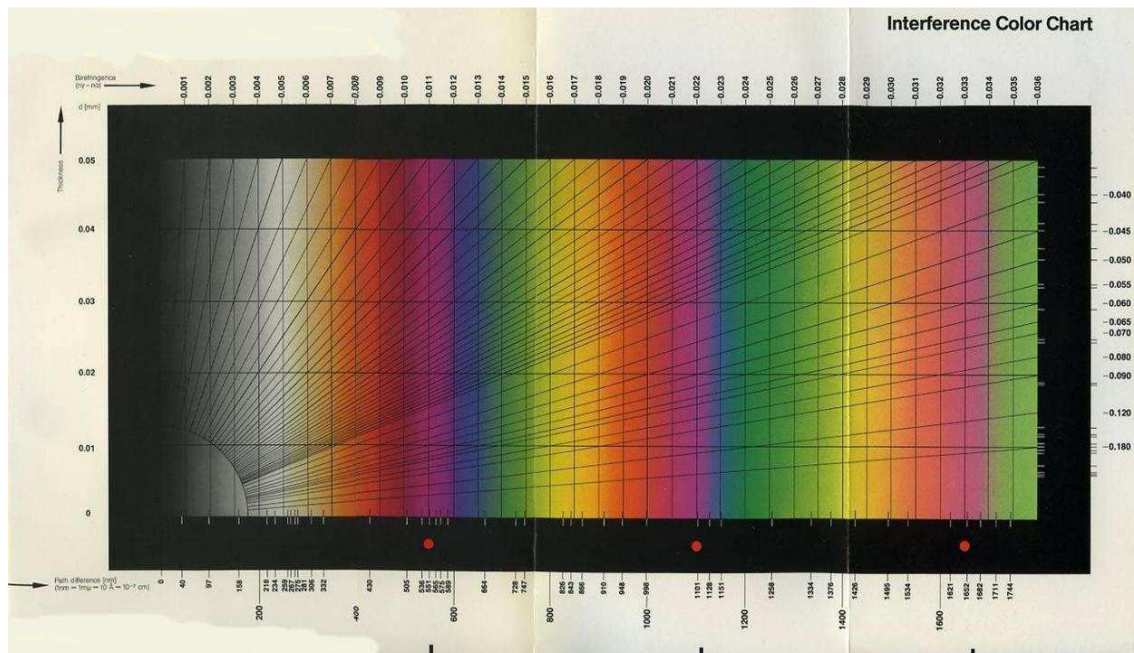


Polarizer



Polarizer + Analyser

Michel Levy table



Source: Univeristy of Barcelona (UB), Geology Engineering, Professors: E. Tauler, N. Otero and A. Soler