Analytical Methods for Materials

Lesson 3
Components in an Optical Microscope

Suggested Reading


Reference

• Goodhew, Humphreys and Beanland, Chapter 1
• Brandon and Kaplan, Chapter 3, pp. 123-177
Components in an optical microscope

• Primary components:

1. Illumination system
2. Objective: single or multiple lenses close to specimen.
3. Eyepiece: single or multiple lenses closest to eye.
4. Data collection system: camera, eyepiece, etc...
5. Specimen stage

6. Also has various diaphragms, reflectors, prisms
Microscope Components:
The Illumination System

- **Lamps**
  - Light source
    - Tungsten-filament
    - Quartz/tungsten-halogen bulbs
    - Xenon lamp
    - D.C. carbon arc

- **Lenses**
  - Focus light at the desired point in the optical path (details will come in a moment)
Microscope Components:
The Illumination System

• **Filters**
  – Used to modify light for ease of observation, improved photos, and/or to alter contrast
  • **Green filter*** – used in black and white photography to reduce the effect of lens defects on image quality
  • **Polarizing filters** – used to examine non-cubic materials and materials that are optically anisotropic.

• **Diaphragm**
  – Used to minimize internal glare and reflections or to alter the amount of light and the angle of the light cone.
Microscope Components:
The Optical System

- Objective Lens (the most important part of microscope)
  - Collects reflected light and forms the first/primary image of the sample.
  - It is the closest lens to the sample and the lens that is changed to switch magnifications.
  - It is rated by a value called the numerical aperture (N.A.) which is a measure of the light collecting ability.

\[ \text{N.A.} = \mu \sin \alpha \]

\[ \mu = \text{index of refraction} \]

\[ \alpha = \text{half angle of the light cone entering the lens} \]
Microscope Components:
The Optical System

• Projector Lens
  – Converges the beam of light to form the final magnified image.

• Eyepiece (ocular)
  – Further magnifies the primary image produced by the objective lens. Transmits image to eye.

Our eyepieces provide 10× magnification

http://biology.clc.uc.edu/fankhauser/Labs/Microscope/adjustable_ocular_P7030359.JPG
Contrast and Imaging

• We want to reveal microstructural features.

• We want an optimum balance between resolution, contrast and brightness.

• We must have contrast and brightness to see and identify features (e.g., phases, defects, etc.) in a material.
Some ways to increase contrast

1. Staining,
2. Use of color filters,
3. Oblique illumination,
4. Dark-field illumination,
5. Phase contrast illumination,
6. Polarized light microscopy,
7. Interference contrast,
8. Fluorescence microscopy,
9. Heat tinting,
10. Use of a hot stage.

There are other ways
Practical steps to optimize OM resolution

1. Use objective lens with highest $N.A.$;
2. Use higher magnifications;
3. Use eyepiece compatible with the selected objective lens;
4. Use the shortest possible wavelength $\lambda$;
5. Keep the light system properly aligned;
6. Use an oil immersion lens if available (*WHY?*);
7. Adjust the field diaphragm for maximum contrast and the aperture diaphragm for maximum resolution and contrast.
8. Use dark-field or interference-contrast to get additional contrast.
Capabilities of different types of microscopes used to characterize microstructures.

<table>
<thead>
<tr>
<th></th>
<th>Light optical microscopy</th>
<th>X-ray diffraction microscopy / tomography</th>
<th>Scanning electron microscopy</th>
<th>Transmission electron microscopy</th>
<th>Field ion microscopy</th>
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</thead>
<tbody>
<tr>
<td><strong>Illumination source</strong></td>
<td>Visible light</td>
<td>X-rays</td>
<td>Electrons</td>
<td>Electrons</td>
<td>Ions</td>
</tr>
<tr>
<td><strong>Maximum useful magnification</strong></td>
<td>1000 – 2000×</td>
<td>&gt;5000 – 100,000×+</td>
<td>~100,000×</td>
<td>500,000 – 1,000,000×</td>
<td>&gt;1,000,000×</td>
</tr>
<tr>
<td><strong>Resolution limit ( (r_1) )</strong></td>
<td>~200 nm</td>
<td>~1 -- 10 nm</td>
<td>1 – 2.5 nm</td>
<td>~0.2 – 0.3 nm</td>
<td>Atomic</td>
</tr>
<tr>
<td><strong>Information obtained</strong></td>
<td>Phases Reflectivity</td>
<td>3-D imaging of internal structures</td>
<td>Topography</td>
<td>Crystal structure</td>
<td>Microstructure</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Composition</td>
<td>Crystal orientation</td>
<td>Composition</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Defects</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Composition</td>
<td></td>
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<tr>
<td><strong>Depth of field</strong></td>
<td>&lt;0.5 μm</td>
<td>High</td>
<td>5 – 500 μm</td>
<td>- - -</td>
<td>- - -</td>
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Recording The Image

Film

• The best method for capturing an image is film.

• Fine grain film yields the best resolution although they require longer exposure time.

• Detail are preserved upon enlarging.

• Does require a steady stage to eliminate vibrations.
Recording The Image

Digital

• The use of digital photography has become a popular choice because it saves a lot of time.

• Even so digital imaging if done improperly can ruin the quality of an image.

• Care must be taken to ensure the resolution and quantization of a digital image is high enough that it adequately show all of the features of the sample.
Fig. 3 The effect of resolution and quantization on a digital image. The same image as Fig. 2 in different levels of resolution and quantization. (a) 64 x 64 pixels and four gray levels. (b) 64 x 64 pixels and 256 gray levels. (c) 512 x 512 pixels and four gray levels. (d) 512 x 512 pixels and 256 gray levels.