Analytical Methods for Materials

Lesson 3

Components in an Optical Microscope

Suggested Reading

- Y. Leng, *Materials Characterization, 2nd Edition*, (2013), Wiley, Hoboken, NJ – Chapter 1.

Reference

- Goodhew, Humphreys and Beanland, Chapter 1
- Brandon and Kaplan, Chapter 3, pp. 123-177
- K. Geels, D.B. Fowler, W-U. Kopp, and M. Rückert, *Metallographic and Materialographic Specimen Preparation, Light Microscopy, Image Analysis and Hardness Testing*, (2007) ASTM International, West Conshohocken, PA.
- G.F. Vander Voort, Metallography Principles and Practice, (1999) ASM International, Materials Park, OH.

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

↓ Intensity and $$$

- 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:

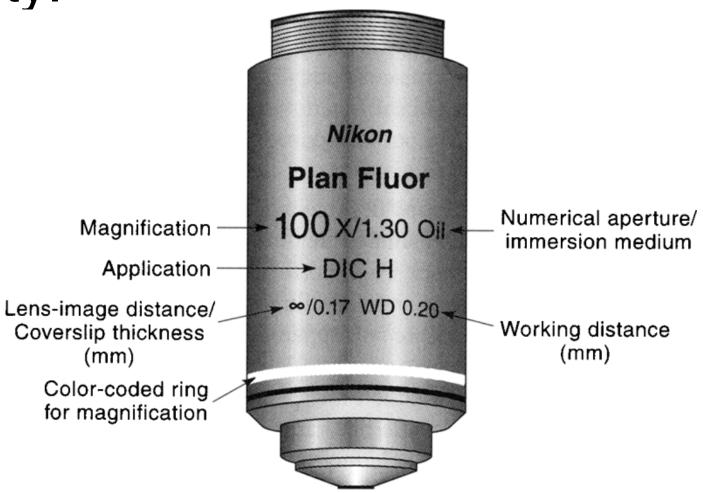
The Optical System

- 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.

$$N.A. = \mu \sin \alpha$$

$\mu =$ index of refraction

$\alpha =$ 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 λ;
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.
9. Adjust brightness for best resolution.

Capabilities of different types of microscopes used to characterize microstructures.

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

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.

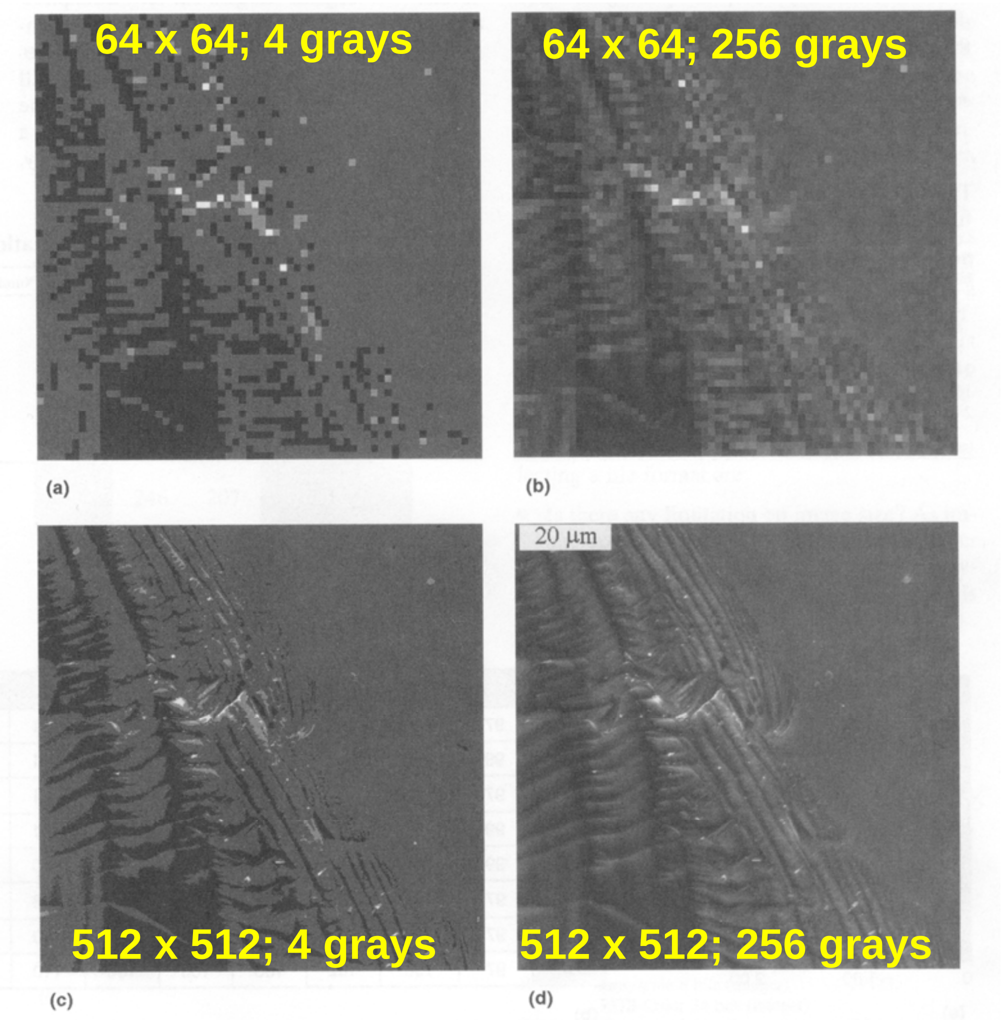
Recording The Image

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.

Recording The Image

Digital



ASM Handbook ,Vol. 9, *Metallography and Microstructures*, ASM International, Materials Park, OH (2004), pg. 369

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.