



# Analytical Methods for Materials

## Lesson 3

### Components in an Optical Microscope

#### Suggested Reading

- Y. Leng, *Materials Characterization*, (2008), 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

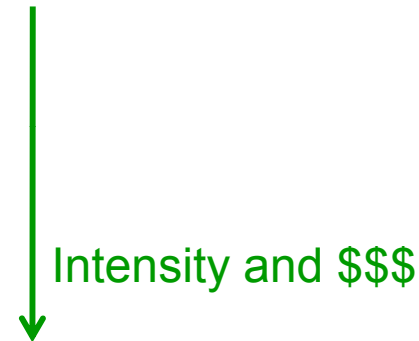
# Microscope Components:

## The Illumination System

- Lamps

- Light source

- Tungsten-filament
- Quartz/tungsten-halogen bulbs
- Xenon lamp
- D.C. carbon arc



- 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

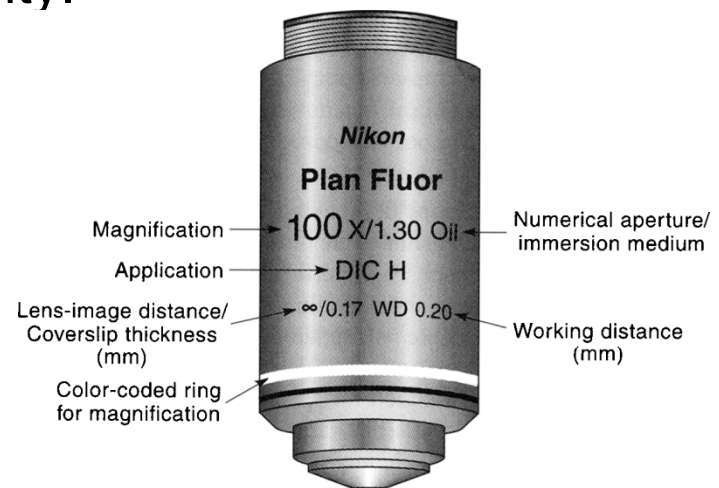
- Objective Lens

- 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.

$$\text{N.A.} = \mu \sin \alpha$$

$\mu$  = 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*

# 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 identify different features 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.
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
<b>Illumination source</b>	Visible light	X-rays	Electrons	Electrons	Ions
<b>Maximum useful magnification</b>	1000 – 2000×	>5000 – 100,000×+	~100,000×	500,000 – 1,000,000×	>1,000,000×
<b>Resolution limit (<math>r_l</math>)</b>	~200 nm	~1 -- 10 nm	1 – 2.5 nm	~0.2 – 0.3 nm	Atomic
<b>Information obtained</b>	Phases Reflectivity	3-D imaging of internal structures	Topography Composition Crystal orientation	Crystal structure Crystal orientation Defects Composition	Microstructure Composition
<b>Depth of field</b>	<0.5 $\mu$ m	High	5 – 500 $\mu$ m	---	---

# 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.

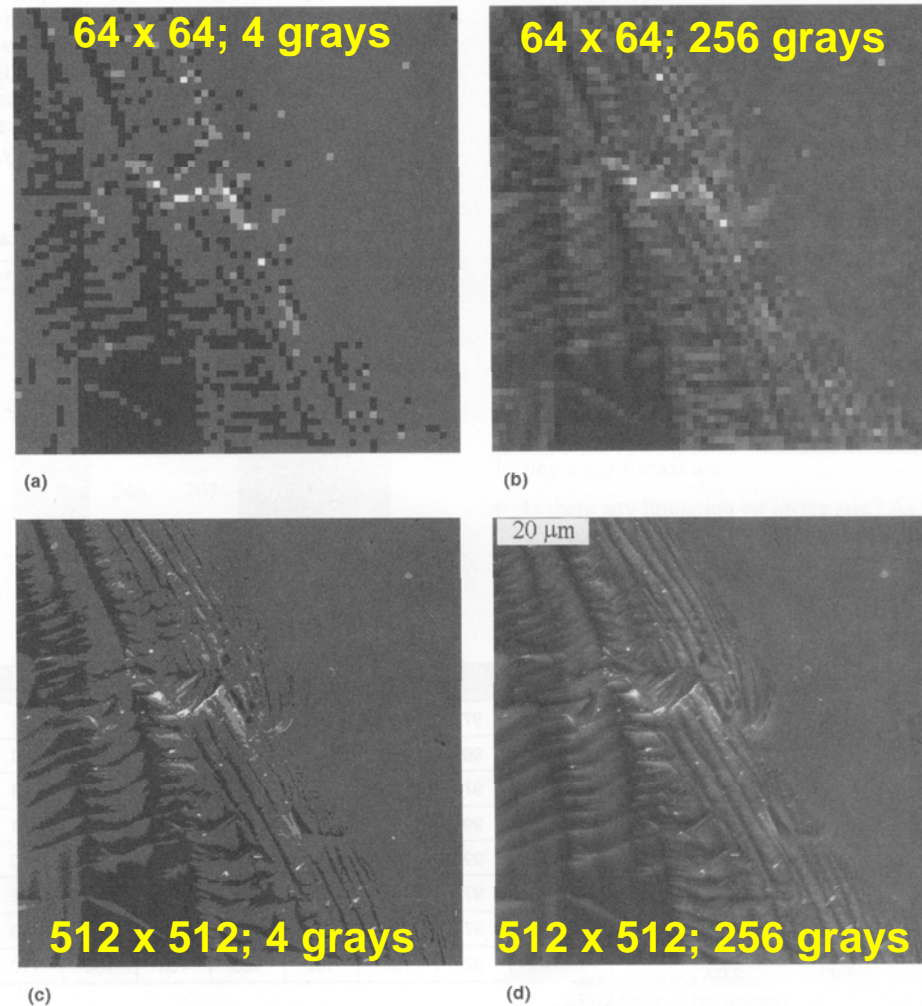
# Recording The Image

## 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.