“The instrument”

Lecture 4
Review of imaging modes

System overview

Review of imaging modes

- Condenser system
- Objective lens & sample stage
- Forming images and diffraction patterns
  - TEM mode
  - STEM mode

Microscope alignment

- Philosophy
- Step-by-step

Calibrations

- Magnification, camera length, rotation (if needed), convergence angle
TEM overview
TEM cross section
(simplified - somewhat)

Electron Gun
- Electron gun 1st beam deflector coil
- Electron gun 2nd beam deflector coil
- 1st condenser lens coil
- 2nd condenser lens coil
- 3rd condenser lens coil
- Condenser lens stigmator coil
- Spot alignment coil
- Condenser lens 1st beam deflector
- Condenser lens 2nd beam deflector
- Condenser mini-lens (CM lens) coil
- Objective lens stigmator coil
- Objective lens coil
- Objective mini-lens (OM lens) coil
- 1st image shift coil
- 2nd image shift coil
- Intermediate lens stigmator coil
- 1st intermediate lens coil
- 2nd intermediate lens coil
- 3rd intermediate lens coil
- Projector lens beam deflector coil
- Projector lens coil

Condenser System

Objective System

Projector System
TEM cross section

- Electron gun
- Condenser system
  - C1 "Spot Size"
  - C2 "Brightness"
  - C3 "Convergence"
  - C Aperture
  - C Stigmators
  - Beam deflectors / scan coils
- Objective system
  - Objective lens
  - Sample
  - Obj aperture
  - Obj stigmator
  - Selected Area apt.
- Intermediate system
- Projector
Condenser system

Goal: place the beam on the sample

Variables:
- Probe size
- Convergence angle
- Intensity (brightness)

Imaging modes & uses:
- Parallel illumination
  - Approximately - routine
  - Perfectly (Köhler)
- Focused illumination
  - Microdiffraction / EDS / EELS
  - Convergent beam diffraction
- Translating / tilting the beam
  - Bright field / dark field
  - Scanning TEM imaging
Condenser system
“parallel beam”

Gun crossover

C1 Lens

C1 crossover

C2 Lens (underfocused)

Specimen

α
Condenser system effect of C1 strength - “spot size”

Gun crossover
C1 Lens
C1 crossover
Weak C1 crossover
C2 Lens
Specimen
Condenser system

effect of C1 strength - "spot size"

Graphical representation of the condenser system showing the effect of C1 strength on the "spot size". The diagram includes lenses (C1 and C2) and crossover points, indicating the movement of light paths through the system.
Condenser system
parallel illumination (Köhler)

Gun crossover

C1 Lens

C1 crossover

C2 Lens (focused)

Upper pole of objective lens
or dedicated C3 (Köhler)

Front focal point of objective lens / C3 lens

Specimen
Condenser system
aperture effect

Gun crossover

C1 Lens

C1 crossover

C2 Lens

Does change convergence angle

Specimen
Condenser system
‘convergent beam’ focused probe

Gun crossover
C1 Lens
C1 crossover
C2 Lens (off)
C aperture
Upper pole of objective lens
or dedicated C3
Specimen
Condenser system
scanning / tilting & translating

Apparent source
Real source

Apparent source
Real source

Upper scan coils

Lower scan coils

Translating

Tilting
Actual ray diagrams are always available in the operation manual of the microscope.

L mode: Fine Probe mode. For TEM observation.
S mode: Super Focus mode. For analysis and convergent beam electron diffraction.
S mode TEM: For TEM observation in the S mode.
Objective & Imaging system

Relationship between sample & object plane

TEM mode
- Forming images
  - Bright field
  - Dark field
  - HREM
- Forming diffraction patterns

STEM mode
- Scanning
- Bright field STEM
- Dark field STEM
- Annular dark field STEM
Eucentric position

Optimum position of sample

- Where it does not translate when you tilt

This defines the ‘object’ plane

In older systems, you then set the microscope’s lens strength to make it coincide with the object

In newer systems, the physical location is known, yielding a fixed objective lens current

- This is better
  - No need to change lens current during imaging
  - Greater stability
Recall ...

Object plane

Convex lens

Back focal plane

Image plane
TEM imaging

Sample

Objective lens

Back focal plane

Image plane
TEM diffraction

Location of diffraction pattern

Sample

Objective lens

Back focal plane

Image plane
TEM diffraction

Sample

Objective lens

Back focal plane

Image plane

Selected area aperture (SAD)

Intermediate

Location of diffraction pattern

Projector
Selected area diffraction aperture

Object plane

Back focal plane

Image plane

SAD
Bright field image

Reflecting planes

Incident beam

Direct beam

Diffraction beam

θ

2θ
“Dirty” dark field

Reflecting planes

Direct beam

Incident beam

Diffracted beam

\[ \theta \]

\[ 2\theta \]