TEM
(Transmit ion Electron Microscope)

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The TEM system and components:

Vacuum Subsystem

Electron Gun Subsystem

Electron Lens Subsystem

Sample Stage

More Electron Lenses

Viewing Screen w/scintillator

Camera Chamber

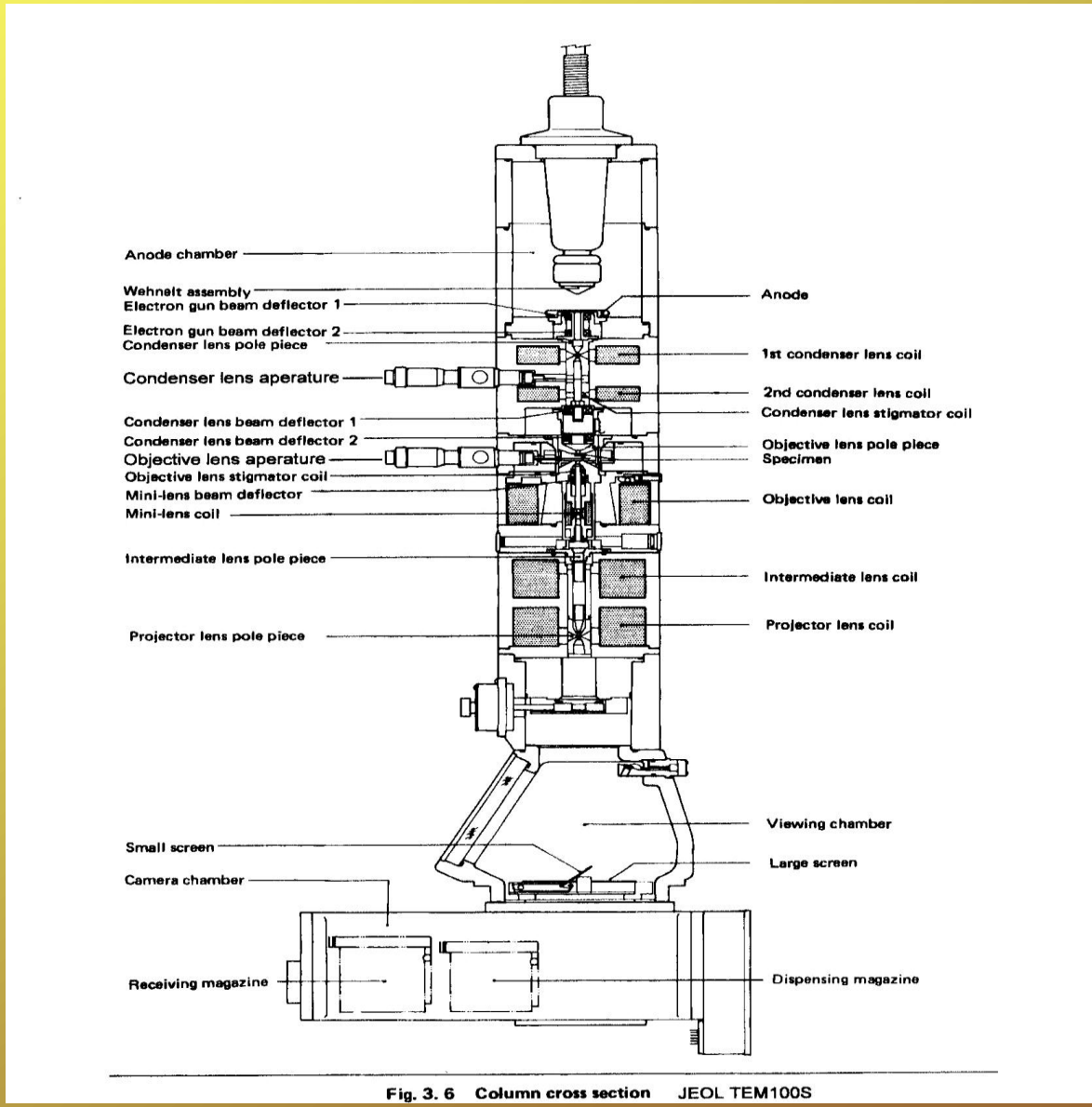
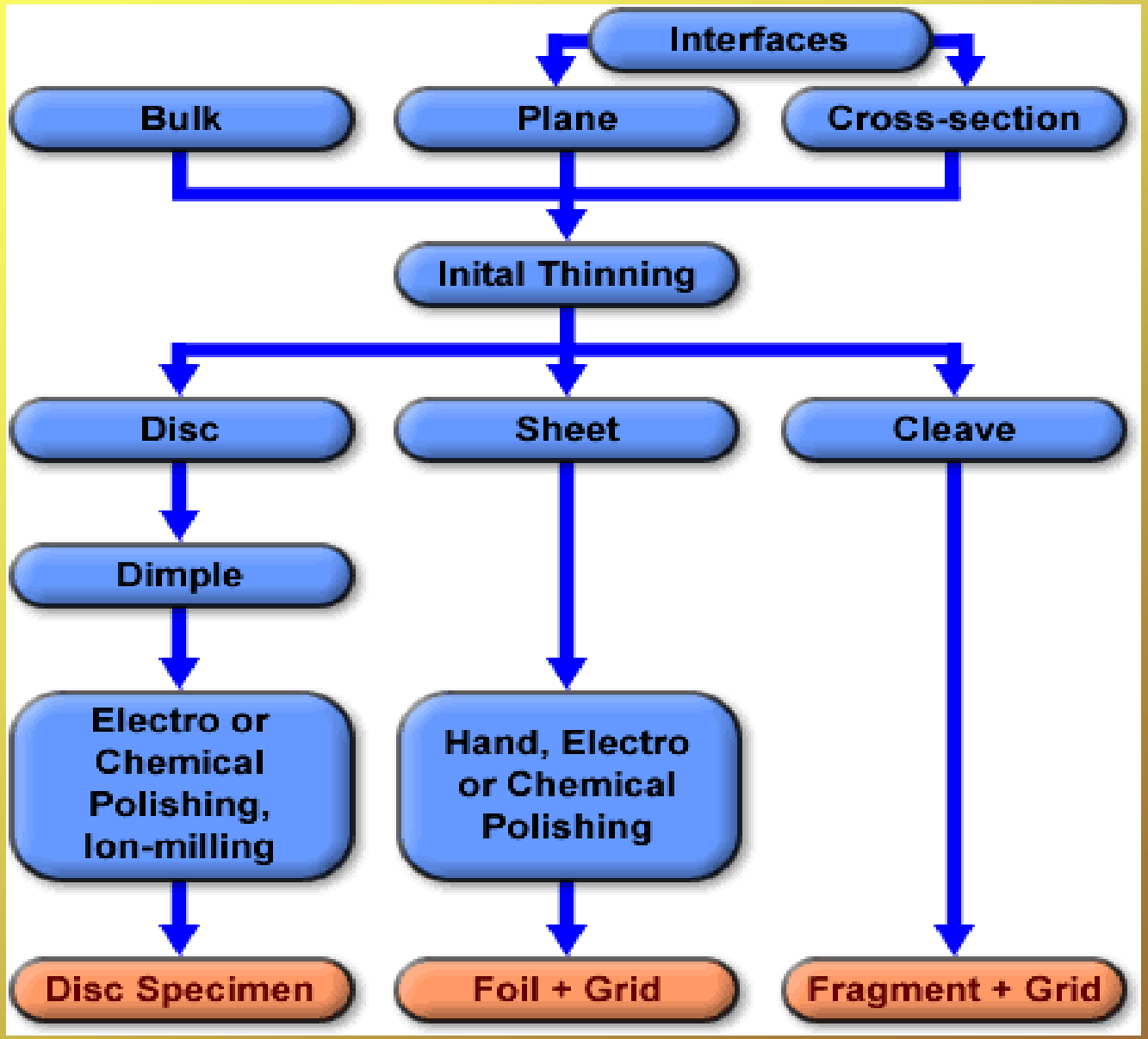


Fig. 3. 6 Column cross section JEOL TEM100S

Most photographic emulsions used in electron microscopy can resolve image details of ~20µm, thus the resolution of object details will depend on the image magnification as shown in the table (resolution = 20µm/magnification):

Magnification	**Resolution at Object (nm)**
2,000	10.0
20,000	1.0
50,000	0.4
100,000	0.2

TEM Sample Prep for Materials



Imaging Modes in the TEM

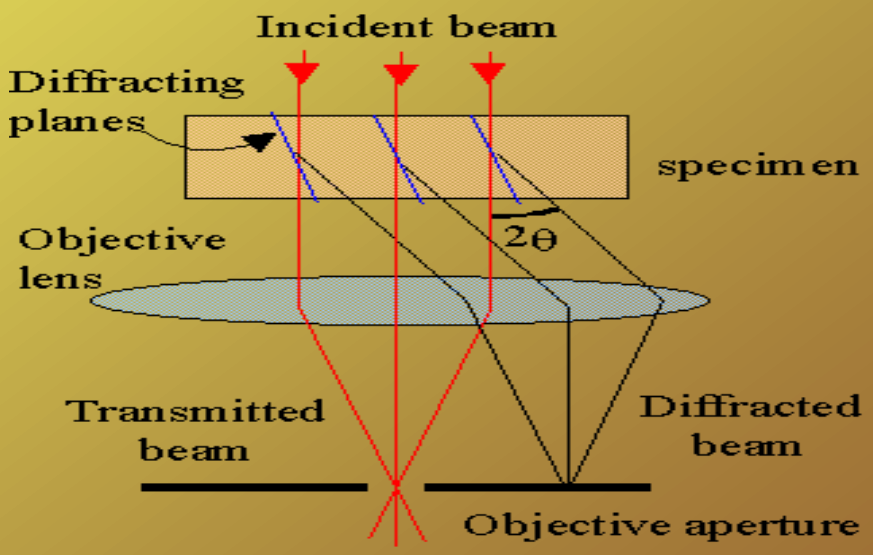
1. Bright Field Mode

2. Dark Field Mode

3. Diffraction Mode

1. Bright Field Imaging

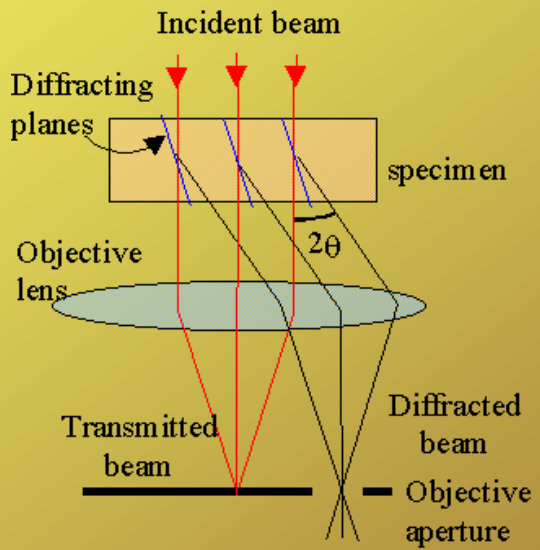
- If the main helping of the near-forward scattered beam is used to form the image
  - transmitted beam
  - 000 beam
  - zero-order beam



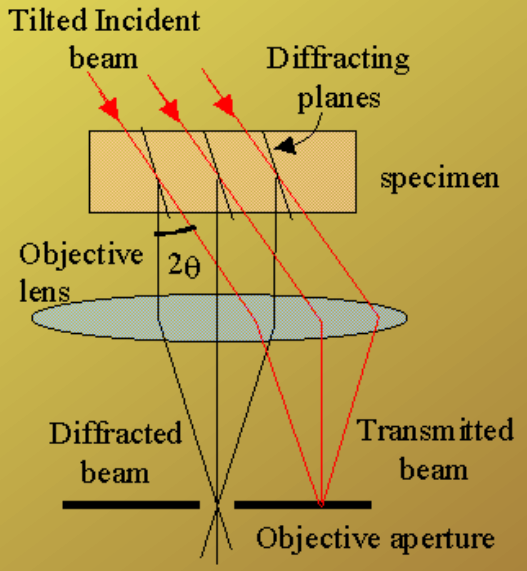
Bright Field Imaging

2. Dark Field Imaging

- If the transmitted beam is excluded from the image formation process
  - off-axis imaging
  - tilted beam imaging

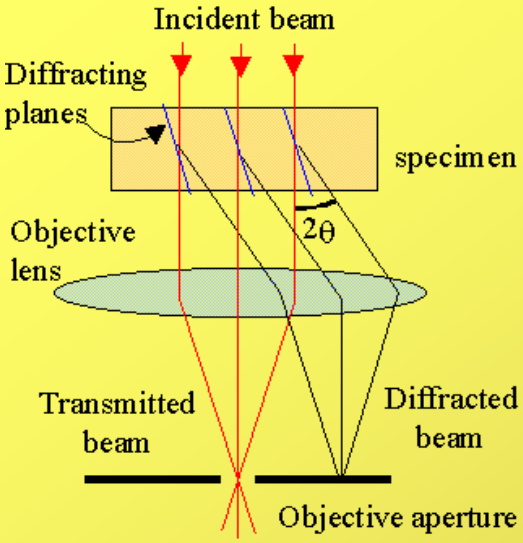


Off-axis Dark Field

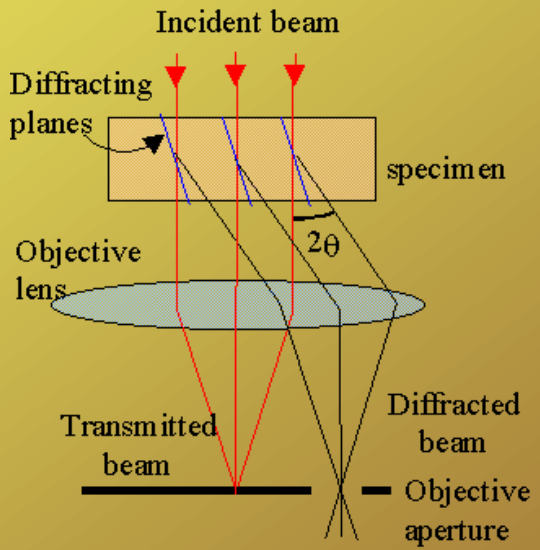


On-axis Dark Field

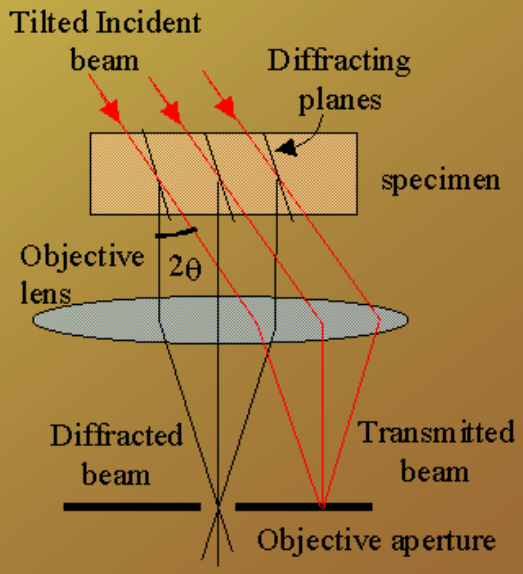
TEM Imaging: Ray Paths



Bright Field Imaging



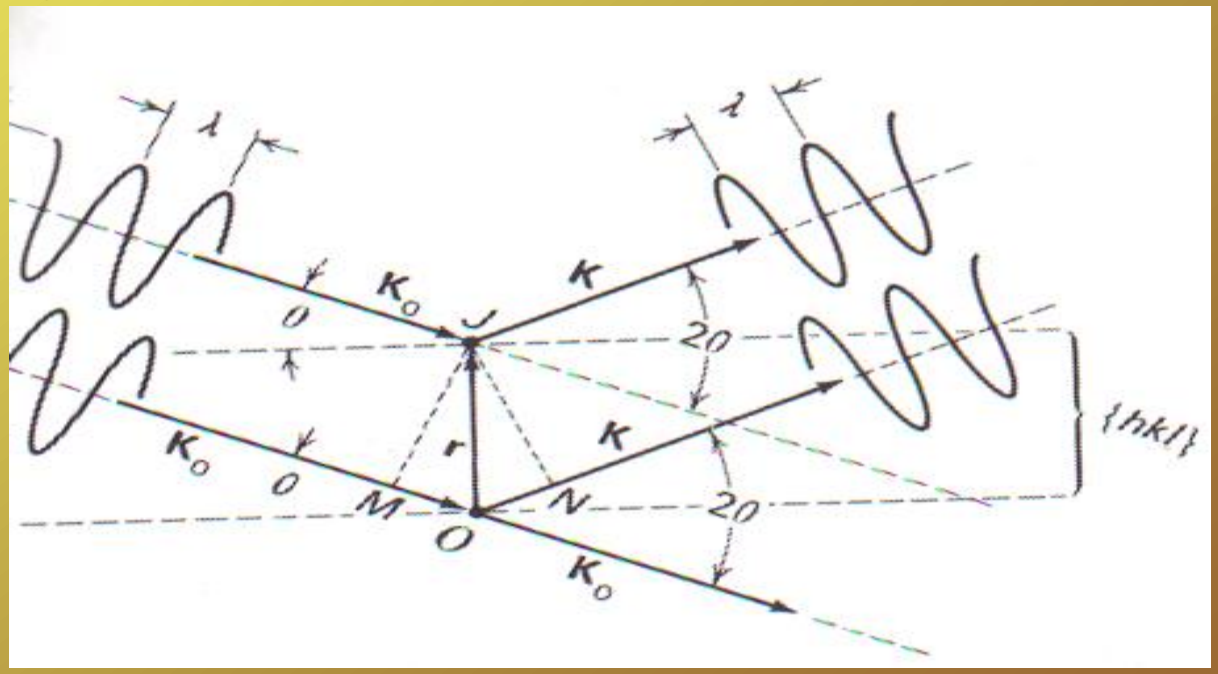
Off-axis Dark Field



On-axis Dark Field

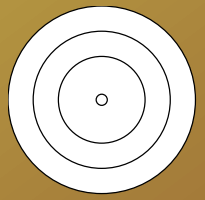
3. Electron Diffraction

- Elastic Scattering Events
  - Bragg diffraction
    - $n\lambda=2d\sin\theta$



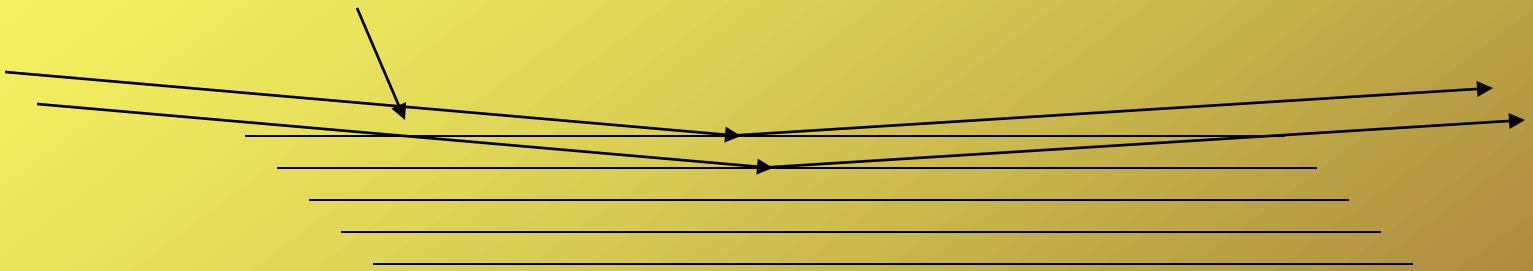
Electron Diffraction

- Four conditions in Back Focal Plane (BFP) of the objective lens:
  - No sample — No reflections (only transmitted beam)
  - Amorphous — Transmitted beam + random scattering
  - Polycrystal — Transmitted beam + rings
  - Single crystal — Transmitted beam + spots



Electron Diffraction

Angle of incidence ~$1/2^0$ to even come close to satisfying the Bragg condition.



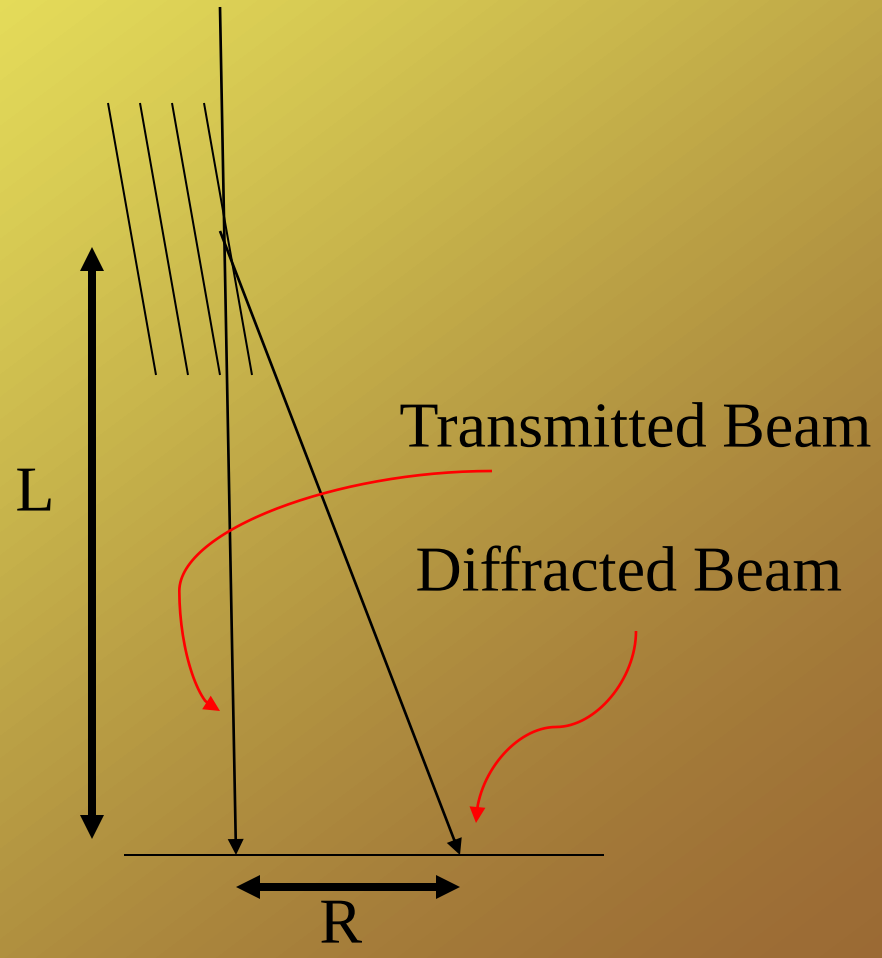
Therefore only the lattice planes close to parallel to the beam are involved in diffraction.

Electron Diffraction

- Think of TEM as a diffraction camera

$$Rd=\lambda L$$

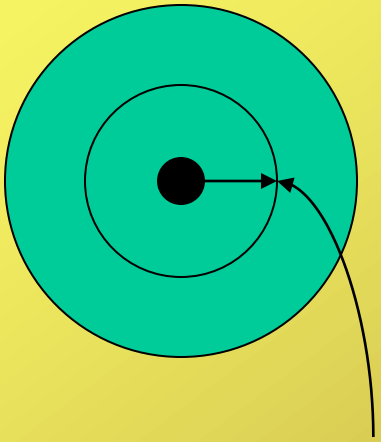
R is measured
d is the unknown
λ is the electron wavelength
L is the camera length
(λL is the camera constant)

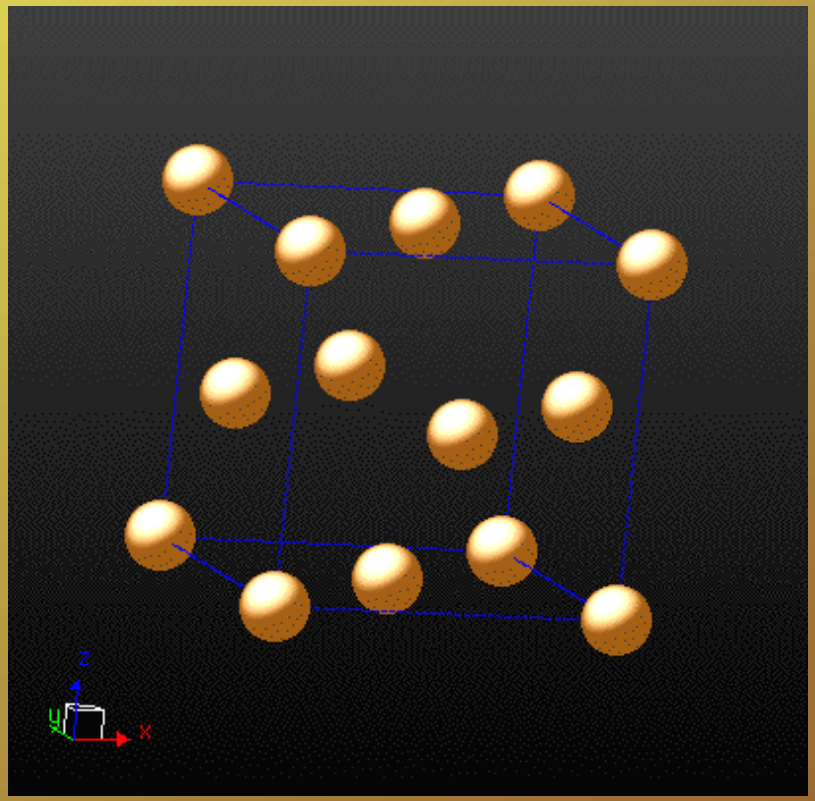


Mutual relationship between lattice spacing and distance from the transmitted spot.

Example

- Au (111) ring [2.35 Å d-spacing]

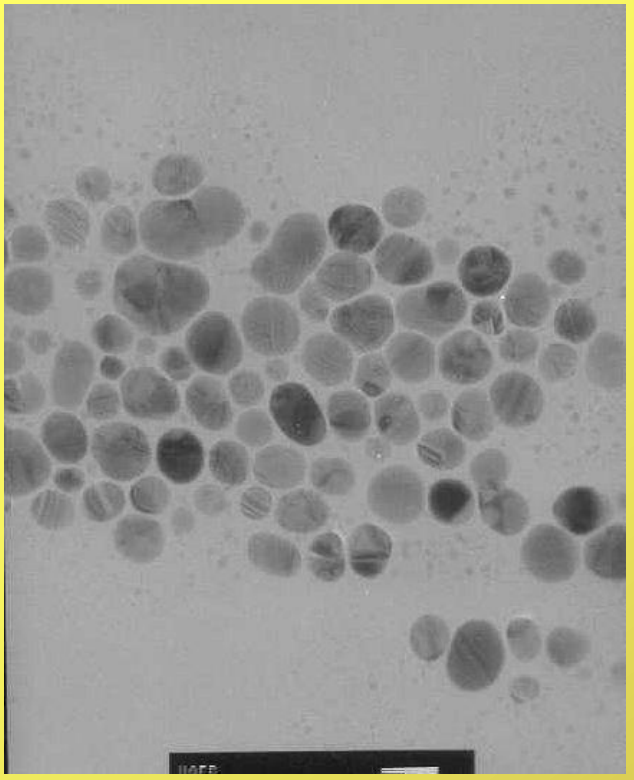




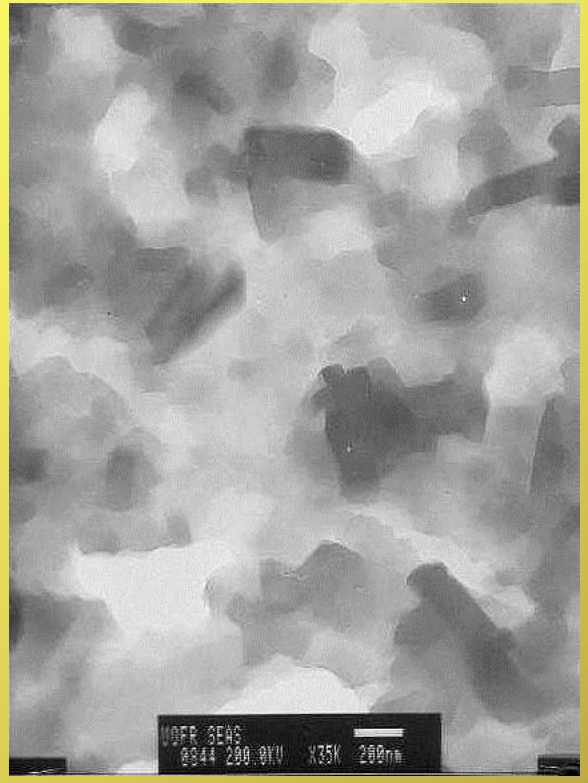
With 200KV and L=65cm the (111) ring should be at about 7.5mm from the transmitted beam

$$Rd=\lambda L$$

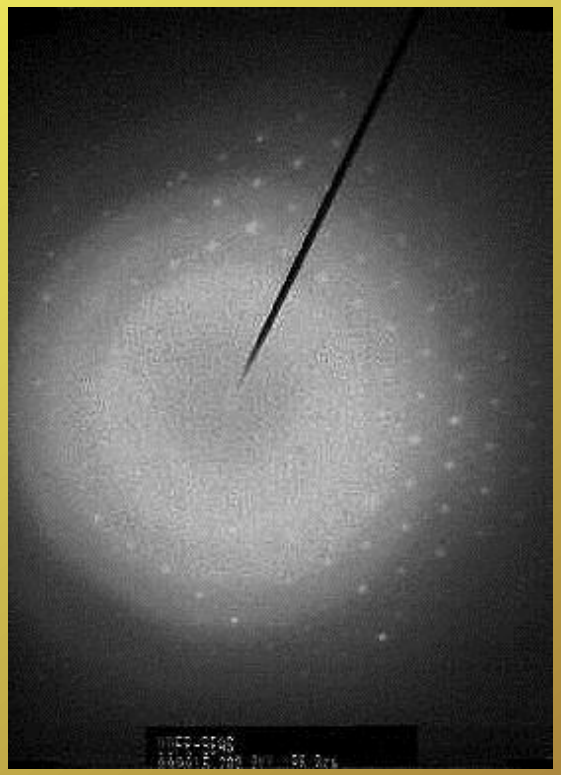
$$R=(0.027A*650mm)\ /2.35A$$



Metal particles



Polymer mix



Electron Diffraction

TEM Images

Comparison Chart

Scanning electron microscope (SEM)	**Transmission electron microscope (TEM)**
Lower resolution of tens of nm (nanometers)	Higher resolution of 1nm or less
Shows only morphology of specimens	Shows multiple characteristics of objects such as crystallization, morphology, stress, and many more
Simple to prepare specimens	Specimen preparation requires thinning which is tiring and time consuming
Cheap	Expensive
Relatively safe to use	Relatively detrimental to human health Source:

Q// What is the difference between a scanning electron microscope and a transmission electron microscope?

The difference lies in their cost, effect on human health, resolution and the information they can obtain from a specimen. The resolution of a scanning electron microscope is lower than that of a transmission electron microscope. While a transmission electron microscope can view the images of objects to atomic level (which is less than 1nm), a scanning electron microscope can only be used to view images that require tens of nm at most. A scanning electron microscope only scans a specimen. This limits the amount of information you can get from the specimen – it can only show the morphology of the specimen. Conversely, a transmission electron microscope can help you see a lot of characteristics of the specimen, such as the stress of the specimen, its crystallization, morphology, and even its holography. When preparing samples to be viewed under these microscopes, each requires different levels of effort. A scanning electron microscope, for instance, can sometimes view specimens directly without preparation. A transmission electron microscope, on the other hand, requires time in order to appropriately thin a specimen, a process that may take up to a day depending on the method used.In addition, a transmission electron microscope costs more than a scanning electron microscope. It is also more detrimental to human health since it has higher energy electron beams.