STEM vs TEM

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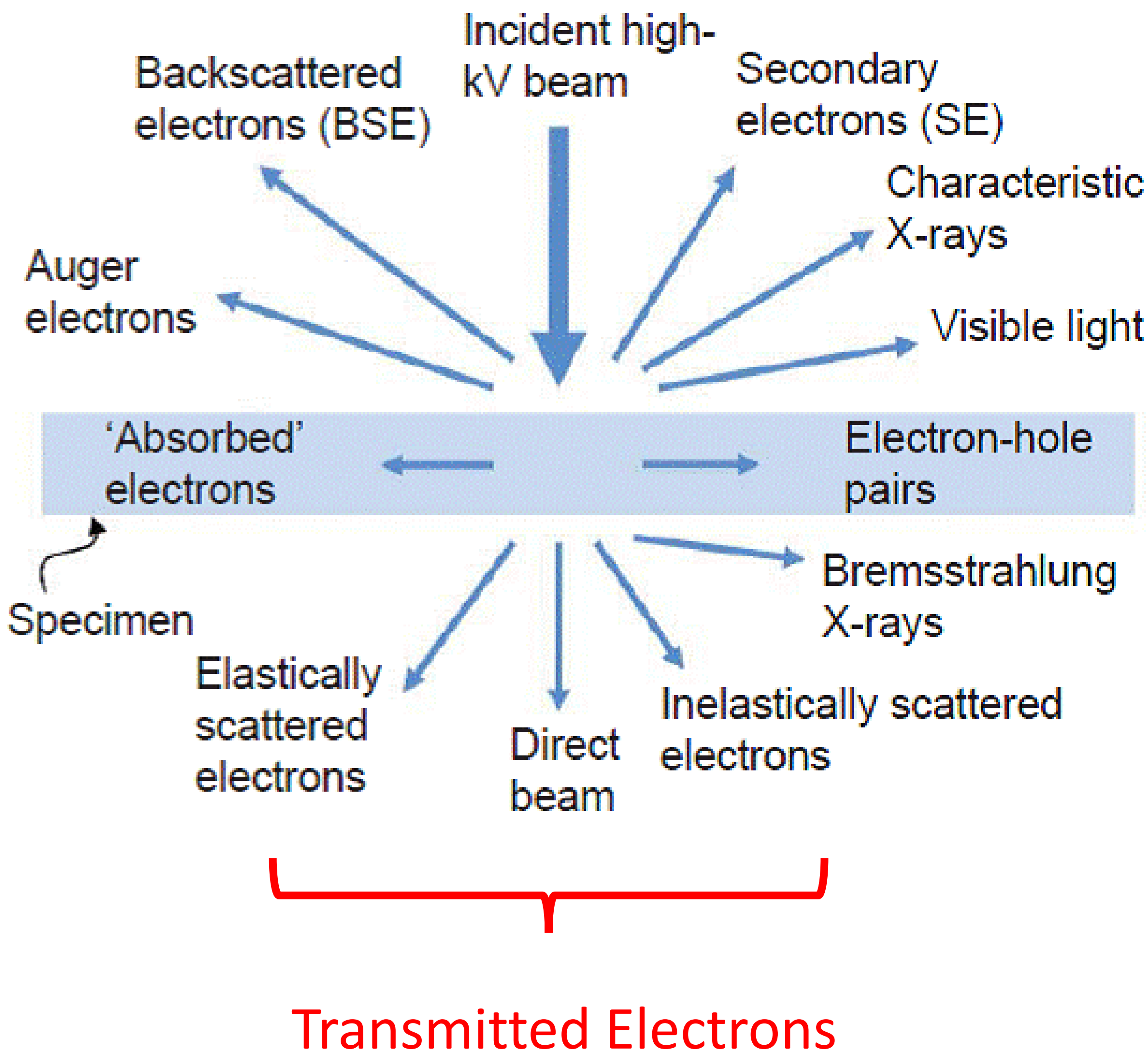
Background : Electron-Specimen Interaction



General Working Principle

- Electron microscopes use beams of electrons, which have wavelengths about 10,000 times shorter than visible light. This shorter wavelengths allow for the images to be better resolved, down to about 0.1 nm.
- An electron beam is produced by heating a tungsten filament and is focused using magnetic fields.
- A high vacuum is needed to prevent collisions between the high-energy electrons and air molecules, which would absorb energy from the electrons.
- A thin sample of about 200 nm is subjected to the high energy electron beam, which is directed using electromagnetic lenses.
- The electrons are elastically or inelastically scattered as they penetrate the sample.
- Either the transmitted electrons or the scattered electrons can be imaged, known as bright-field and dark-field imaging, respectively.

Transmission Electron Microscope (TEM)

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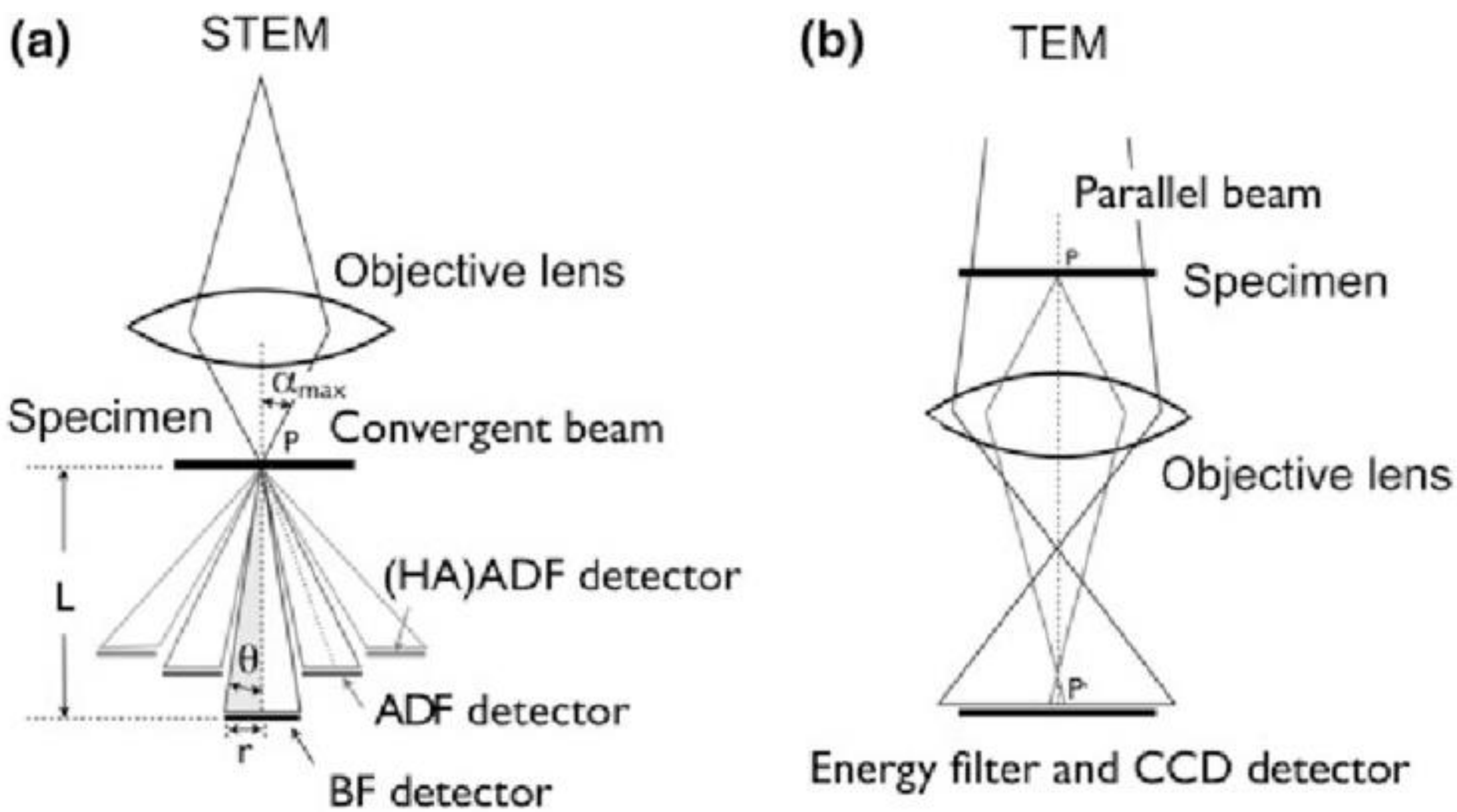
Scanning Coil

Scanning Transmission Electron Microscope (STEM)

Contrasts

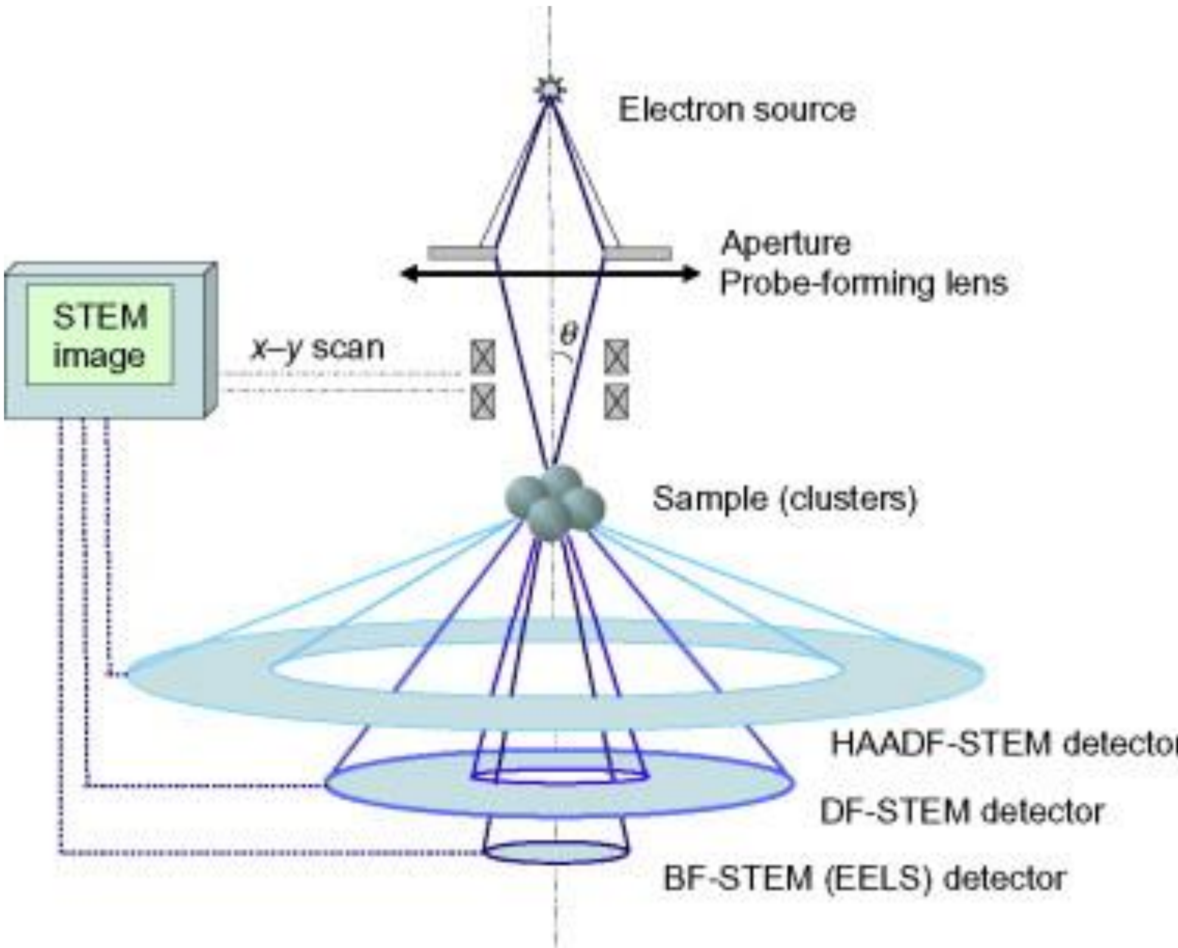
	TEM	STEM
Working Principle	Images are formed by almost parallel electron beam passing through a sufficiently thin specimen.	The electron beam is focused to a fine spot (with the typical spot size 0.05 – 0.2 nm) which is then scanned over the sample so that the sample is illuminated at each point with the beam.
Illumination area	The whole area of interest	Probe is scanned across the specimen
Basics	Interference of coherently scattered electron waves	Incoherent (off-axis) scattering
Electron beam	Wide-beam technique; a close-to-parallel electron beam	Fine focused beam, formed by a probe forming lens
Detector	CCD chip	High Angle Annular Dark Field (HAADF) detector.

Comparison of scheme : TEM and STEM



STEM detectors and imaging modes

Principal advantages over TEM: The use of other signals that cannot be spatially correlated in TEM, including secondary electrons, scattered beam electrons, characteristic X-rays, and electron energy loss.



1.BF (bright-field) detector: Small angles (<0-10 mrad). These images are similar to the bright-field images obtained using TEM.

2. ADF (annular dark-field) detector: larger angles (10-50 mrad)

3. **HAADF (high-angle annular dark-field) detector:** Angles > 50mrad

High Angle Annular Dark-Field Imaging

- High-angle annular dark-field imaging (HAADF) is an STEM technique which produces an annular dark field image formed by very high angle, incoherently scattered electrons.

- **Conventional TEM dark-field imaging** : an objective aperture is used to only collect scattered electrons that pass through.
- **STEM dark-field imaging**: does not use an aperture. An annular dark field detector collects electrons from an annulus around the beam, sampling far more scattered electrons than can pass through an objective aperture.

- Consequently, the contrast mechanisms are different between conventional dark field imaging and STEM dark field.

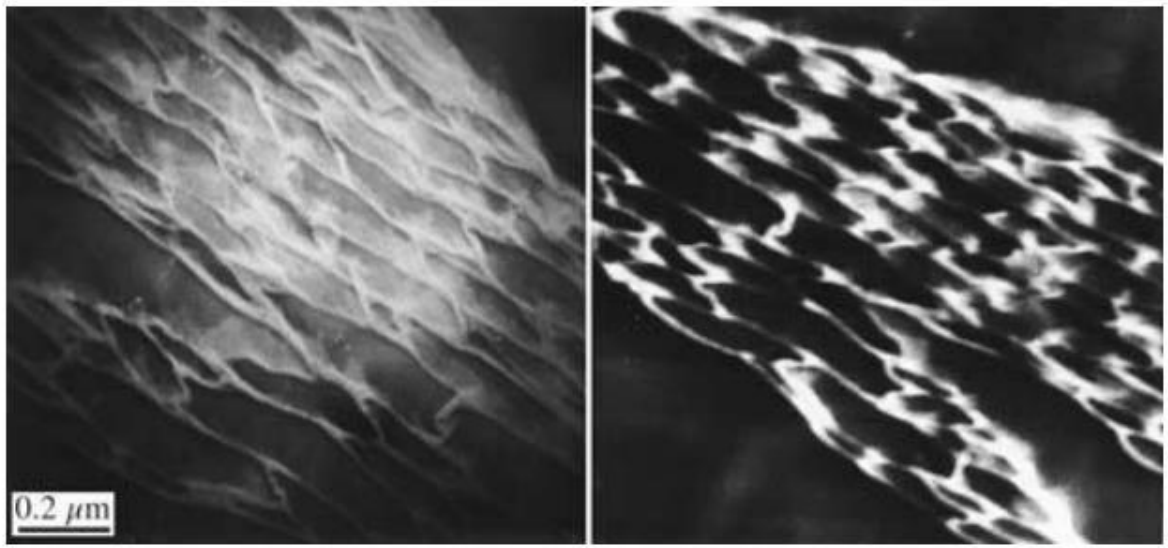
- This gives an advantage in terms of signal collection efficiency and allows the main beam to pass to an EELS detector, allowing both types of measurement to be performed simultaneously.

- **Z contrast images** : For elements with a higher Z, more electrons are scattered at higher angles due to greater electrostatic interactions between the nucleus and electron beam. Because of this, the HAADF detector senses a greater signal from atoms with a higher Z, causing them to appear brighter in the resulting image.

DF: TEM - STEM

STEM ADF contrast is greater than DF TEM Optimal L

TEM-DF



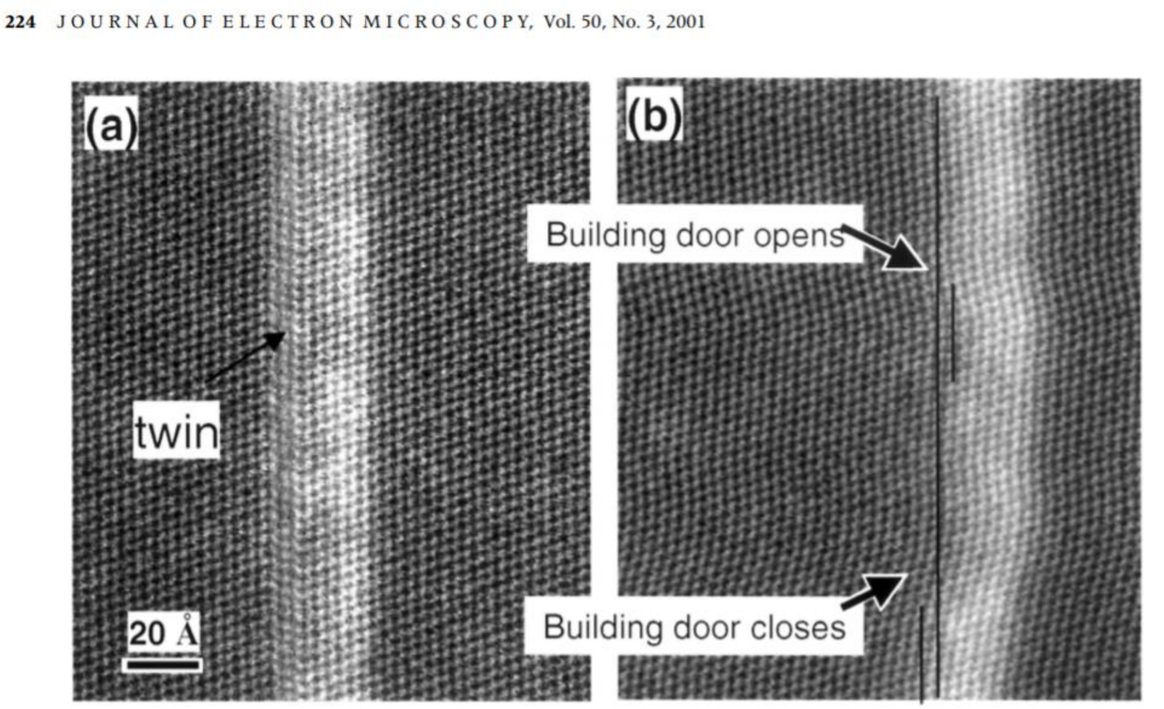
STEM-ADF

The TEM image of the two phase polymer is noisier, but has better resolution.

As the particle size decreases to only several nanometers, there may be difficulties in having enough contrast between the particle and the background.
HAADF may allow for better contrast in materials with lower Z compared to conventional TEM imaging.

Disadvantages

High resolution scanning transmission electron microscopes require exceptionally stable room environments. In order to obtain atomic resolution images in STEM, the level of vibration, temperature fluctuations, electromagnetic waves, and acoustic waves must be limited in the room housing the microscope



Arsenic-delta doped layer grown on (111) Si, viewed along a [110] zone axis.

History

The first STEM : In 1938 by Baron Manfred von Ardenne, Berlin. The results were inferior to those of transmission electron microscopy. The microscope was destroyed in an air raid in 1944, and von Ardenne did not return to his work after World War II.

In 1970s, Albert Crewe at the University of Chicago developed the field emission gun and added a high quality objective lens to create a modern STEM, demonstrated the ability to image atoms using an annular dark field detector, developed the cold field emission electron source and built a STEM able to visualize single heavy atoms on thin carbon substrates.

By the late 1980s and early 1990s, improvements in STEM technology allowed for samples to be imaged with better than 2 Å resolution, meaning that atomic structure could be imaged in some materials.

Thank You