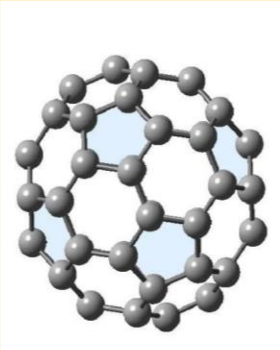


NANO – LECTURE 5

Nano Science and Nanotechnology

Characterization of Nanomaterials Part: 1

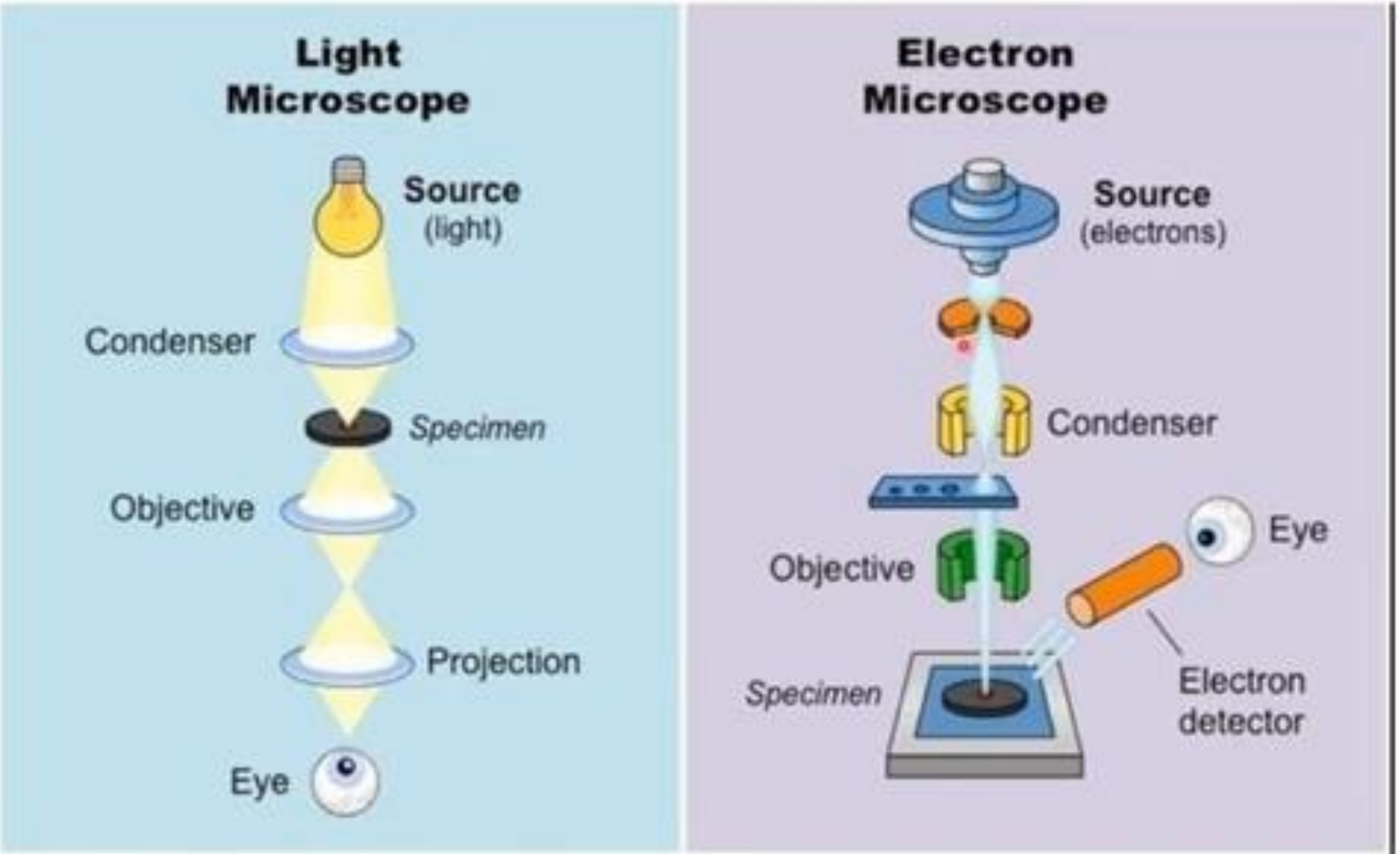
SEM, TEM, AFM

Dr. Mervat Kadhem

Introduction

- Electron microscopes are developed due to limitation of optical microscopes (wavelength of light 0.4 – 0.7 micrometer).

- Electron Microscopes are scientific instruments that use a beam of highly energetic electrons to examine objects on a very fine scale (wavelength of electrons are in nanometers).
- Mainly 2 types:
- Scanning Electron Microscope (SEM) - used to visualize the surface of objects.
- Transmission Electron Microscope (TEM) – allows one the study of the inner structures.



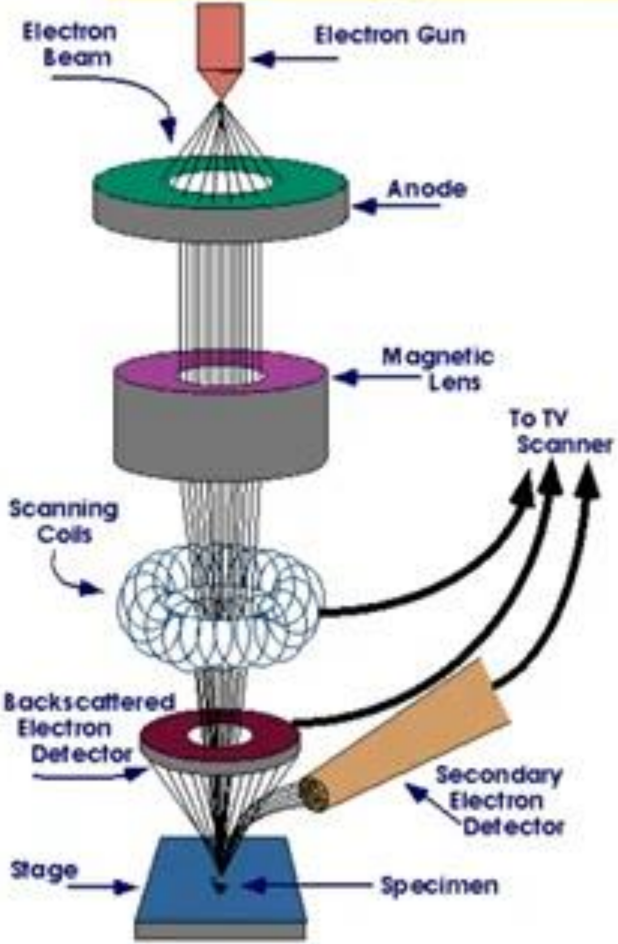
Lenses in Optical microscope: Optical lenses for focusing

Magnetic Lenses: Electromagnets in case of electron microscope

Differences

Optical-light Microscopy	Scanning Electron Microscopy
Illumination source	
Light rays	Electron beam
Resolution	
Below 0.25 µm up to 0.30 µm	Down to 0.4 nm
Magnification/depth of field	
500x to 1500x	2000000x
Small	Large
Lenses material/vacuum	
Optical glass/no need for vacuum	Electromagnets/high vacuum is needed

Scanning Electron microscope (SEM)



SEM: A focused electron beam (2-10 keV) scans on the surface, several types of signals are produced and detected as a function of position on the surface. The space resolution can be as high as 1 nm.

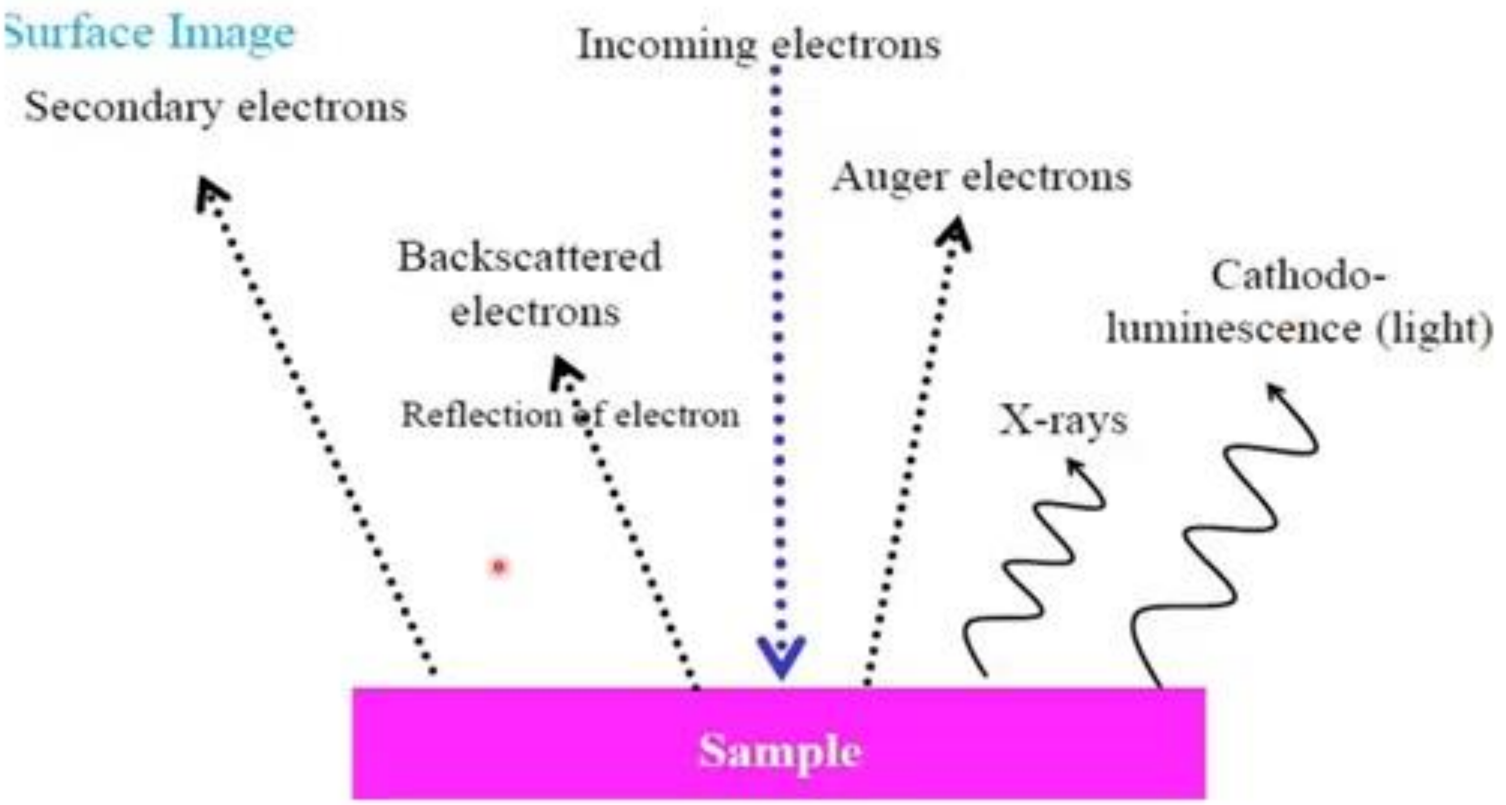
Different type signal gives different information:

a. Secondary electrons: surface structure.

b. Backscattered electrons: surface structure and average elemental information.

c. X-rays and Auger electrons: elemental composition with different thickness-sensitivity.

Signals from the sample

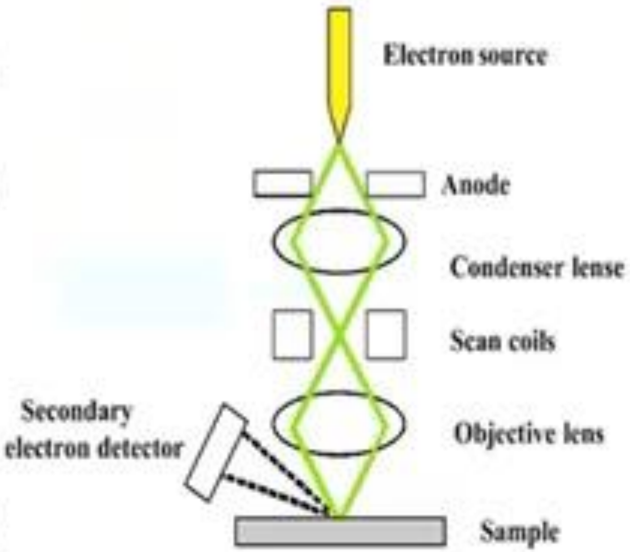


Photograph of a SEM instrument

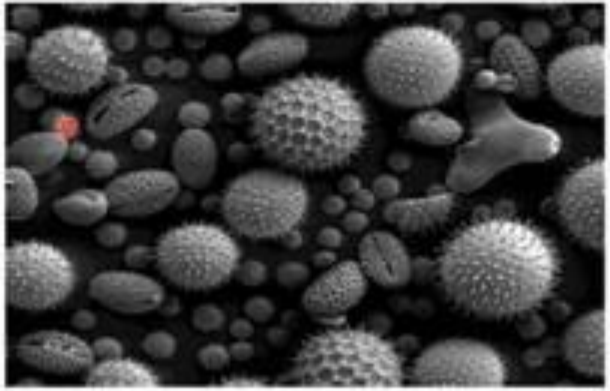
Working of SEM

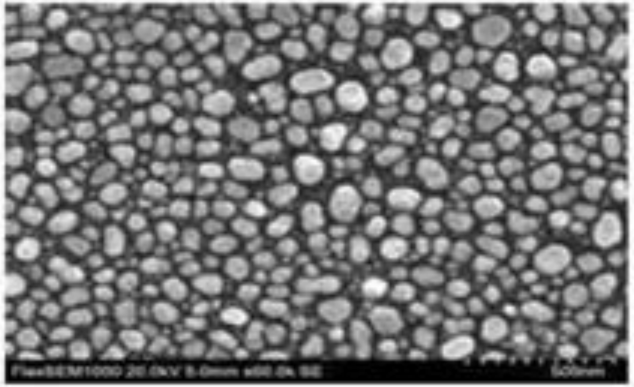
- The electron gun produces an electron beam when tungsten wire is heated by current.
- This beam is accelerated by the anode.
- The beam travels through electromagnetic fields and lenses, which focus the beam down toward the sample.
- A mechanism of deflection coils enables to guide the beam so that it scans the surface of the sample in a rectangular frame.
- When the beam touches the surface of the sample, it produces:
  - Secondary electrons (SE)
  - Back scattered electrons (BSE)
  - X - Rays...
- The emitted SE is collected by SED and convert it into signal that i sent to a screen which produces final image.
- Additional detectors collect these X-rays, BSE and produce corresponding images.

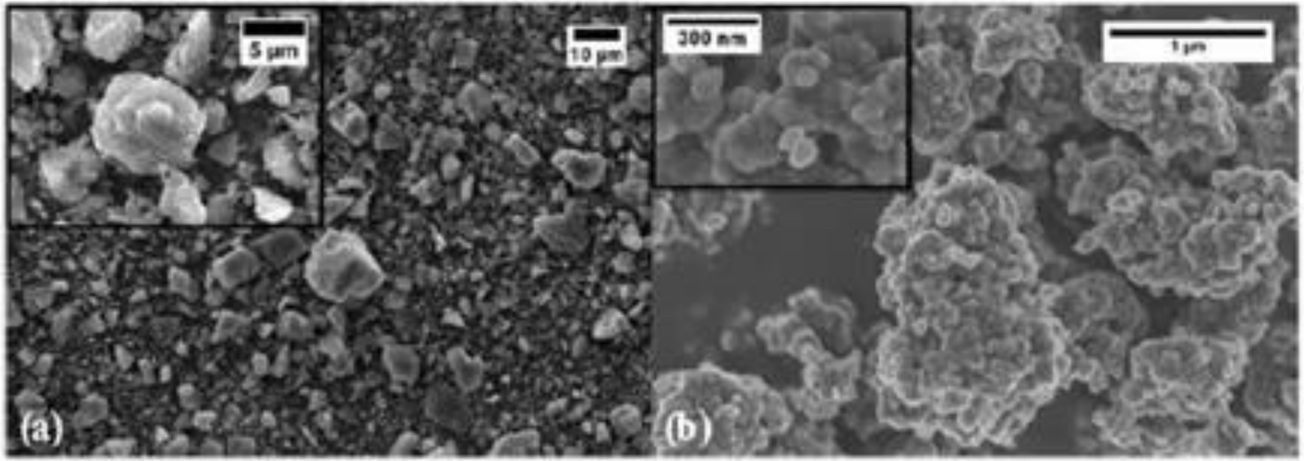
Scanning Electron Microscope



SEM images







ADVANTAGES & DISADVANTAGES OF SEM

Advantages

- It gives detailed 3D and topographical imaging and the versatile information garnered from different detectors.
- This instrument works very fast.
- Modern SEMs allow for the generation of data in digital form.
- Most SEM samples require minimal preparation actions.

Disadvantages

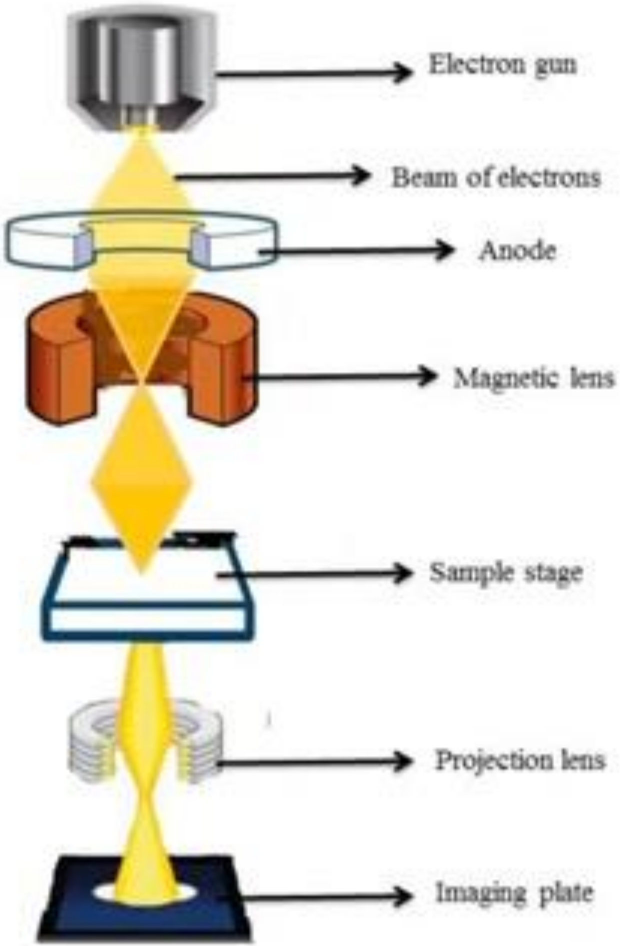
- SEMs are expensive and large.
- Special training is required to operate an SEM.
- The preparation of samples can result in artifacts.
- SEMs are limited to solid samples.
- SEMs carry a small risk of radiation exposure associated with the electrons that scatter from beneath the sample surface.

Transmission electron Microscope (TEM)

- **Transmission electron microscopy (TEM) is a microscopy technique in which a beam of electrons is transmitted through a specimen to form an image.**
- **TEMs can magnify objects up to 2 million times.**
- **The working principle is similar to SEM.**

Working of TEM

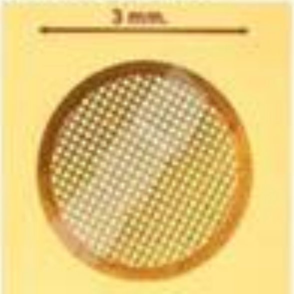
- A heated tungsten filament in the electron gun produces electrons that get focus on the specimen by the condenser lenses.
- Magnetic lenses are used to focus the beam of electrons of the specimen. By the assistance offered by the column tube of the condenser lens into the vacuum creating a clear image, the vacuum allows electrons to produce a clear image without collision with any air molecules which may deflect them.
- On reaching the specimen, the specimen scatters the electrons focusing them on the magnetic lenses forming a large clear image, and if it passes through a fluorescent screen it forms a polychromatic image.
- The denser the specimen, the more the electrons are scattered forming a darker image because fewer electron reaches the screen for visualization while thinner, more transparent specimens appear brighter.



Preparation of specimen for visualization by TEM

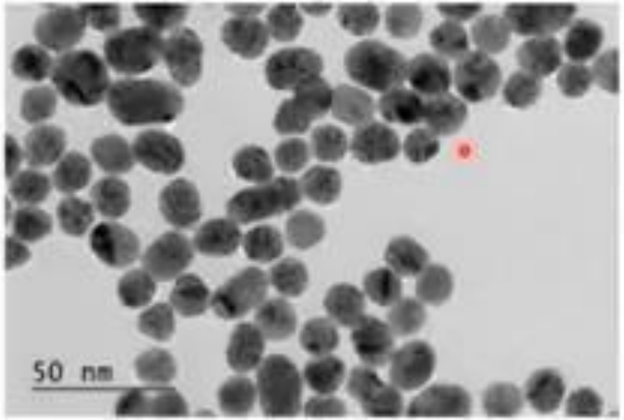
- The specimen to be viewed under the TEM must undergo a special preparation technique to enable visualization and creation of a clear image.

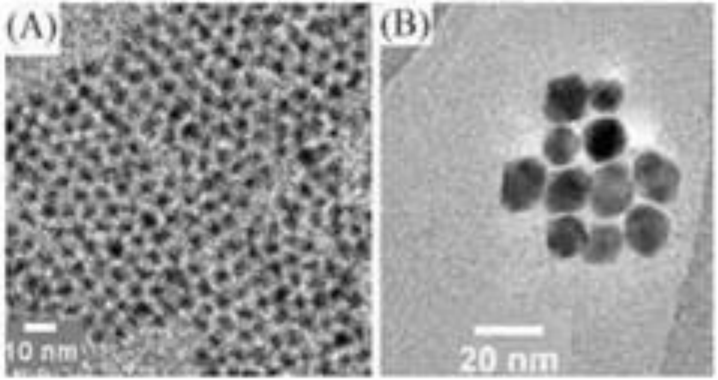
- Electrons are easily absorbed and easily scattered on solid elements, showing poor visualization for thick specimens. And therefore, very thin specimens are used for accurate and clear visualization forming a clear image as well. The specimen should be about 20-100 nm thin and 0.025-0.1nm diameter, as small as that of a bacterial cell.



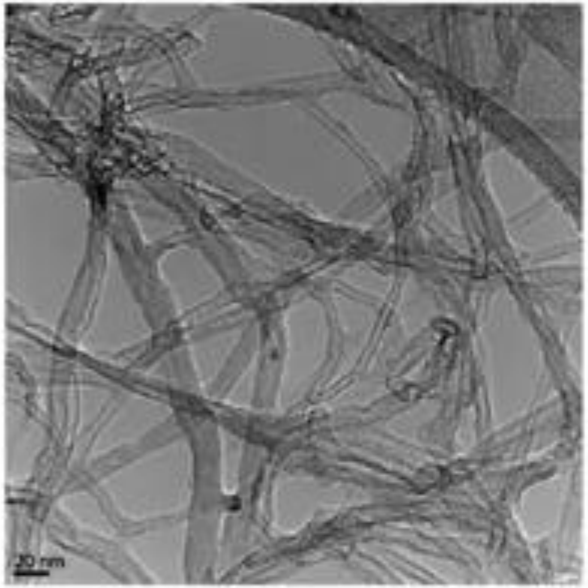
TEM Grid

TEM Images





Nanoparticles



Carbon nanotubes

Applications of Transmission Electron Microscope (TEM)

TEM is used in a wide variety of fields From Biology, Microbiology, Nanotechnology, forensic studies, etc. Some of these applications include:

- **To visualize and study cell structures of bacteria, viruses, and fungi**
- **To view bacteria flagella and plasmids**
- **To view the shapes and sizes of microbial cell organelles**
- **To study and differentiate between plant and animal cells.**
- **Its also used in nanotechnology to study nanoparticles such as ZnO nanoparticles**
- **It is used to detect and identify fractures, damaged microparticles which further enable repair mechanisms of the particles.**

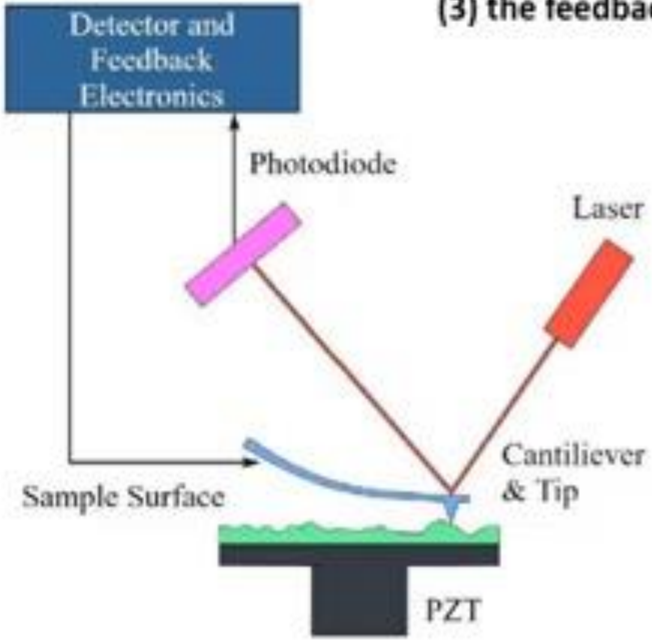
Limitations of TEM

- TEMs are large and very expensive
- Laborious sample preparation
- Potential artifacts from sample preparation
- Operation and analysis requires special training
- Samples are limited to those that are electron transparent, able to tolerate the vacuum chamber and small enough to fit in the chamber
- TEMs require special housing and maintenance
- Images are black and white

Atomic Force Microscope (AFM)

- **Introduction**
- The atomic force microscope (AFM) was invented in1986 by Binnig, Quate and Gerber.
- The AFM raster scans a sharp probe over the surface of a sample and measures the changes in force between the probe tip and the sample.

Atomic Force Microscope



Basic set-up of an AFM

The ability of an AFM to achieve near atomic scale resolution depends on the three essential components:

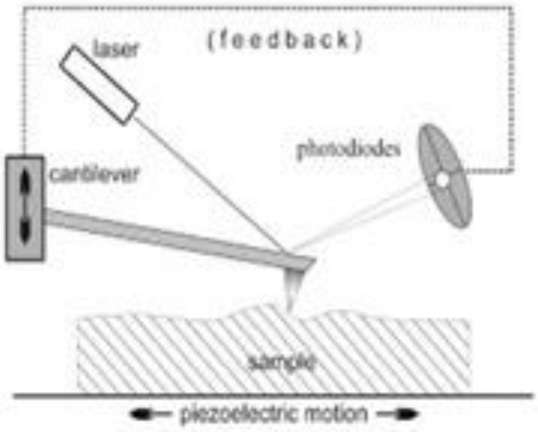
(1) a cantilever with a sharp tip,

(2) a scanner that controls the *x-y-z* position, and

(3) the feedback control and loop.

Principle

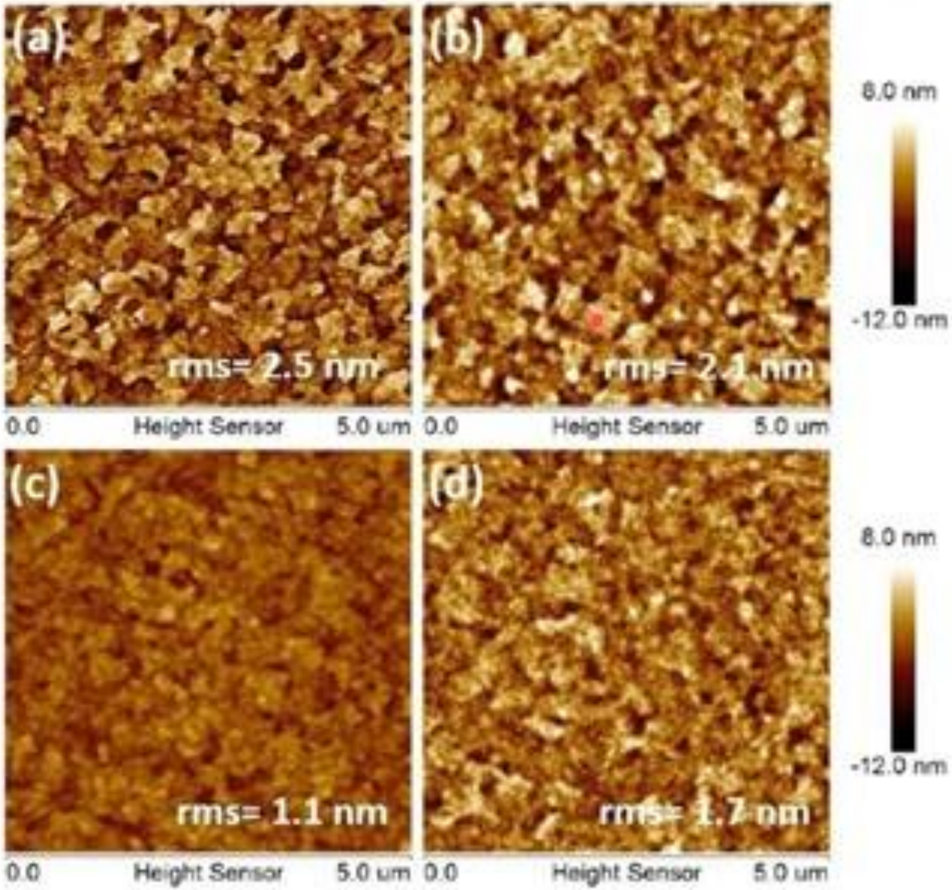
- The AFM consists of a cantilever with a sharp tip (probe) at its end that is used to scan the specimen surface.
- The cantilever is typically silicon or silicon nitride with a tip radius of curvature on the order of nanometers.
- When the tip is brought into proximity of a sample surface, forces between the tip and the sample lead to a deflection of the cantilever according to Hooke's law.
- Depending on the situation, forces that are measured in AFM include mechanical contact force, van der Waals forces, capillary forces, chemical bonding, electrostatic forces.



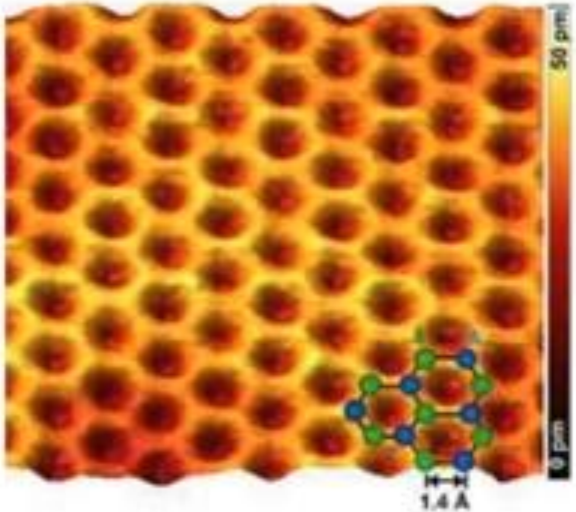
Applications

- The AFM is useful for obtaining three-dimensional topographic information of insulating and conducting structures with lateral resolution down to 1.5 nm and vertical resolution down to 0.05 nm.
- These samples include clusters of atoms and molecules, individual macromolecules, and biologic al species (cells, DNA, proteins).
- Minimal sample preparation involved for AFM imaging.
- The AFM can operate in gas, ambient, and fluid environments and can measure physical properties including elasticity, adhesion, hardness, friction and chemical functionality.

AFM images



Thin Film on ITO substrate



Graphene

Thanks for Watching