

Electron microscopy

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An Introduction to Electron Microscopy



An electron microscope uses a beam of electrons to create an image. This is unlike traditional light microscopy which uses visible light and a system of lenses. Electron Microscopes are capable of much higher resolving power and magnification. However they are usually much larger, more complex, and require a great deal of technical expertise compared to light microscopes to use.

Around 1870, a German physicist known as Ernst Abbe's created a formula which proposed the resolution of a lens was limited by the wave nature of light, and this limit was approximately half a micrometre. This meant that a light microscope could distinguish objects on a broad cellular level, but would struggle to differentiate intracellular structures and other smaller particles. For example, a red blood cell has a width approximately 6-8 micrometres. This presented a significant obstacle, and it was until the end of the first third of the 20th century that several generations of brilliant scientists (such as Ernst Ruska and Maximillion Knoll) theorized and demonstrated that a new form of microscopy was possible using electrons instead of light.

Electron microscopes use an electromagnetic lens to control the path of an electron beam. This magnetic lens is similar to the optical lens in light microscopy. Faster electrons will have a shorter wavelength, and the resolution of an electron microscope is directly proportional to the wavelength of the irradiation which will form the image. Therefore reducing the wavelength will increase the resolution, and today objects can be magnified many millions of times their original size. The two main types of electron microscopy are Transmission Electron Microscopy and Scanning Electron Microscopy. Transmission Electron Microscopy was the original form. It involves using a cathode to emit a high voltage electron beam towards a sample.

The electromagnetic lenses are composed of tubes with coils wrapped around them. When an electric current is passed through the coils, an electromagnetic field and this can be used to direct electrons to the sample in the same way a lens would in light microscopy. The sample in Transmission Electron Microscopy must be thinly sliced and the technique can only produce a black and white image.

Another type of electron microscopy is Scanning Electron Microscopy. In SEM electrons are displaced from the sample and sent to a detector, which can produce three-dimensional information about the texture and morphology.

The electron microscope is in his principle the (electron) analog of the optical microscope (https://www.wikilectures.eu/index.php?title=Optical_microscopy&fbclid=IwAR0HVDId_RvcfzbVFZE0g0mhs3EuM6j4m7NjtnIlyzr4Dg1CAzclAmbTKVOI) . Optical lenses are replaced by electromagnetic lenses , and instead of photons we use electrons for examining the objects. The resolution and maximum usable magnification of the optical microscope are limited by the wavelength range of visible light. It is true that the smallest distance of two objects that can still be detected under a microscope is half the wavelength of the light being used. The physical limit of the resolution of the optical microscope is less than 200 nm and the maximum useful magnification of the microscope with high quality optics and immersion object does not exceed 1500 x. Wavelengths of accelerated electrons are many orders of magnitude smaller than wavelengths of visible light photons. That is why , the electron microscope has a much more higher resolution and can achieve a much higher magnification (up to 1 000 000 x) .

The wavelength of the electron at the accelerating voltage of 10 kV is only 0.0123 nm.

$p = m \cdot v$ = momentum, h = Planck constant, m = mass of electron, e = charge of electron,
 U = accelerating voltage

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2meU}}$$

The function of lenses in the electron microscope occupies suitably shaped electromagnetic fields. The object under observation is placed in a vacuum and "elucidated" by a bunch of electrons that scatters through the passage and lands on the shade.

Types of microscopes

TEM transmission electron microscope - non-moving pack of electrons. Detections of electrons is possible due to passed sample on a fluorescent shader or a detector.

SEM scanning electron microscope - moving pack of electrons, detection of surface is possible due to reflected secondary electrons.

SPM Scanning Probe Microscopy - is a complex of methods designated to detect structure of a surface on atom level resolution.

AFM - microscopy of atom forces is based on mapping layout on the surface of a sample. These forces are mapped by closing the apex to surface which leads to creation of either repulsive or attractive force leading to bending the crossbeam where the apex is situated. This bending is scanned by a laser sensor. Advantage of this method is a possibility of studying both conducting and non-conducting materials.

STM - Scanning tunnel microscopy is one of the SPM methods. Its principle is based on quantum physics. There is a current between apex of a electrode and a examined sample thanks to tunnel effect even though the apex is not directly touching the sample. With the movement above the sample, the distance of the apex is changing so the tunnel current would remain the same. One of a few advantages of this method is that it is capable of provide atomic resolution, whereas it is a quite simple process. It does not require as difficult preparation as the other methods. On the other hand, it allows only to examine the surface of the sample.

SNOM - scanning near-field optical microscope