Free scanning electron microscope (sem) and transmission electron microscope (tem...

Technology

Electron microscopes refer to those microscopes that make use of an electron beam to light a specimen producing a magnified image. These microscopes are used to study structures that are either invisible through naked eyes or those that are too small to be clearly seen using a light microscope. The two major types of electron microscope are Transmission Electron Microscopy or TEM and Scanning Electron Microscopy or SEM (Mooney, 1996).

Transmission Electron Microscopy employs a high voltage electron beam in order to create an image (NE, 2013). The TEM is made up of various components including electromagnetic lens system, electron source, sample holder, and imaging system. Electron source is provided by an electron gun that functions by emitting a beam of electrons into the vacuum that accelerates between the anode and the cathode. The electromagnetic lens system works to focus the beam of electrons emitted by the electron gun. The sample handler is made up of a mechanical arm and holds the sample to be observed. The imaging system consists of intermediate and projector lenses and works to create a magnified image of the sample (Amrita Vishwa Vidyapeetham, 2013).

Figure 1: Diagram showing the four major components of a transmission electron microscope (Amrita Vishwa Vidyapeetham, 2013)

Production of the electron beam used in TEM is done by an electron gun. The electron gun is usually equipped with a tungsten filament cathode, which is the electron source. The electron beam produced is then stimulated using an anode at +100 keV with respect to the cathode. The beam is then focused by electromagnetic and electrostatic lenses and then transmitted through the specimen being viewed. The specimen partially allows the electrons to pass through while scattering other electrons out of the beam. When the electron beam emerges from the specimen, it carries the specimen information which is then magnified by the objective lenses. The information in the image may be viewed by projecting the image onto a screen that is coated with scintillator or phosphor material. The image may also be viewed by being photographically recorded using a photographic film that is placed directly to the beam. The image may also be viewed by coupling a high-resolution phosphor by means of a fiber optic light guide or lens optical system directed to a CCD (charge-coupled device) sensor camera. The detected image may then be displayed on a computer or monitor (NE, 2013).

TEM resolution is mainly limited by spherical aberration although the new generation aberration correctors have the capability to partially overcome this limitation. Consequently, this has enhanced resolution of the image created by TEM (NE, 2013).

Advantages of TEMs are that they have a high resolution and are able to provide direct imaging of the crystalline lattice. The TEMs have the capability of delineating the defects that are in the sample. The TEMs have no metallic stain-coating that is required and are thus convenient for structural imaging of materials that are organic in nature. Electron diffraction techniques that are used in TEM include disorder and defect identification, phase identification, symmetry and structure determination, and lattice parameter measurement (Zang, 2013).

Disadvantages of TEMs include difficulties in preparing a sample that is electron-transparent from a bulk source. This is due to the electron or conductivity density, as well as sample thickness. The machines are large and have a high price. Sample preparation is very laborious and operating the machine and data analysis requires specialized training. Images obtained from the microscope are black and white (Zang, 2013).

Scanning electron microscope (SEM) is the other kind of electron microscope and consists of several components. These components are electron source, sample stage, electron lenses, detectors and display or data output devices. The electron source is where electrons originate and are produced by the electron gun. Sample stage is the location where the sample is placed, and electron lenses are used to produce an image that is clear and detailed. Detectors are used to detect the different ways through which the electron beam and the sample object interact. The display is used to show the image that has been generated by the microscope. The SEM produces different types of signals that include secondary electrons, backscattered electrons, and characteristic X-rays (Zang, 2013).

Unlike the transmission electron microscope where high voltage electrons are the ones that carry the image developed from the specimen, SEM does not carry the specimen image. Image production in SEM is done through specimen probing using a focused electron beam. This focused electron beam is first scanned across the specimen area. The interaction of the specimen and the electron beam causes the beam to lose its energy. The lost energy is then converted into other forms of energy such as heat, emitted in the form of low-energy secondary electrons, or as backscattered electrons. The lost energy is also emitted as light or X-rays that provide signals that carry the information on the specimen properties such as its composition and topography. In general, SEM has an image resolution that is poorer than the image resolution attained using TEM. However, since imaging of SEM relies on surface processes instead of transmission as it is the case in TEM imaging, SEM is able to process bulk samples measuring up to several centimeters. SEM also has greater field depth and is thus capable of producing images that are a three-dimensional representation of the shape of the sample.

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Figure 2: Comparison between the SEM and TEM (Radboud University, 2010)

Some of the advantages of SEM are that the microscope has a wide range of applications due to the detailed three-dimensional imaging, as well as the topographical imaging that the system provides. Operation of SEM is easy given the proper training and with the advances in technology operation of SEM is becoming ever more user-friendly. The instrument has a fast working speed with most analysis taking less than five minutes. Although samples need to be prepared before they are placed in the chamber, most of the SEM samples do not involve complex preparations procedures (Anderson, 2010).

The first disadvantage of SEMs is that they are very expensive. The machines are large and, therefore, require a large area for operation. SEMs require to be housed in special areas where there are no magnetic, electric or vibration interferences. Maintenance of SEMs is strict and involves maintaining a steady current, voltage getting to the electromagnetic coils, as well as proper maintenance of cool water in circulation. SEM is only limited to samples that are solid and inorganic in nature and small sized to fit in the vacuum chamber. SEMs have a low resolution in the range of a few tens of nanometers (Anderson, 2010).

The scanning transmission electron microscope or STEM is another invaluable tool used to characterize nanostructures and provides a wide range of different imaging modes that are capable of providing information on the elemental and electronic composition of a single atom. STEM has a similar working principle as SEM where it forms a focused electron beam which is scanned over the sample collecting the desired signals to form an image. The main difference from SEM is that a thin specimen is used in order to make transmission modes of imaging available (Zhou & Wang, 2007).

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