KSU CET UNIT

FIRST YEAR NOTES

CET UNIT

3.3.3 Scanning Electron Microscopy(SEM)

Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM) and Atomic Force Microscopy (AFM) are important surface characterization techniques used in nanotechnology. A scanning electron microscope (SEM) is a powerful magnification tool that utilizes focused beam of electrons to obtain information. Given sufficient light, the human eye can distinguish two points 0.2 mm apart, without the aid of any additional lenses. This distance is called the resolving power or resolution of the eye. Resolving power of microscopes depends on the wavelength of light used. Optical microscopes can improve the resolution only up to a magnification of 400 times, so that we can see objects of size in micro level, like bacteria. The resolution power of electron microscopy is very high (≈10 nm) since electrons are used for illumination (wavelength of electrons are 10^5 times shorter than that of light). Therefore nano-sized particles can be seen with the help of SEM or TEM.

Principle: SEM produces images of a sample by scanning the surface with a focused beam of electrons. The interaction of electron beam with the atoms near the surface of the sample results in the production of secondary electrons (SE), back scattered electrons (BSE) and X-rays. These signals are then detected by appropriate detectors and can be used to obtain information about the surface topography and composition. The high-resolution, three-dimensional images produced by SEM makes them invaluable in a variety of science and industry applications.

Secondary electrons (SE): They are electrons that are directly knocked out from the atom by primary/incidental electron beam. They have low energy ($< 50eV$) and give information about topography.

Back scattered electrons (BSE): They are incidental electrons that are reflected backwards. They have high energy (¿50 eV) compared to SE. They give information about topography and composition. BSE comes from deeper regions of the sample where as SE originates from the surface and that's why BSE and SE carry different types of information.

X-rays: X-rays, emitted from beneath the sample surface, can provide element and mineral information.

Instrumentation SEMs consist of the following components:

1. **Electron Source:** Generates beam of energetic electrons. They are of two types:

    (a) Thermionic gun (produces electron beam at high temperature, eg:- W filament, LaB_6 etc)

    (b) Field emission gun (produces electron beam under strong electric field)

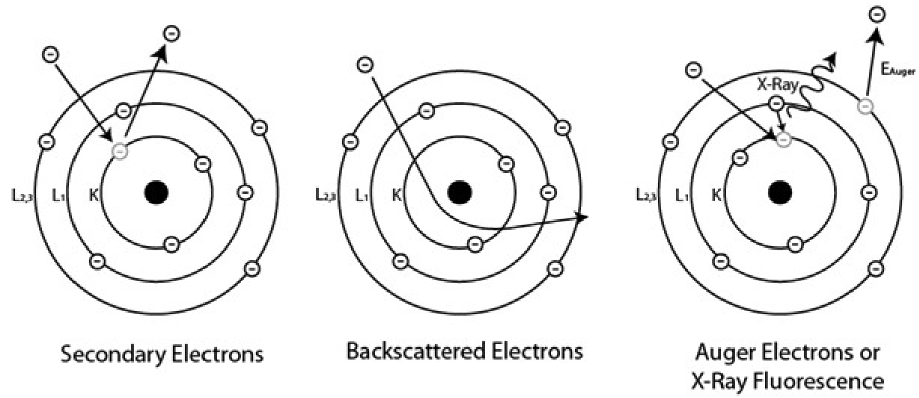

Figure 3.13: Interaction of electrons with sample

2. **Anode:** Accelerates the electron beam. As the velocity of the electron increases wavelength decreases (according to the De Broglie relation, $\lambda = h/mV$) and thus enhances the resolution power.

3. **Vacuum chamber:** High vacuum minimises the scattering of electron beam.

4. **Condenser lens:** It is the electromagnetic lens used to focus the electron beam into small, thin and coherent beam. Generally tubes wrapped in coils, known as solenoids, are used as condenser lenses.

5. **Objective lens:** It is also an electromagnetic lens. Electron beam passes through the scanning coils of objective lens that deflect the beam in raster fashion over a rectangular area of sample surface.

6. **Sample chamber:** The sample is kept in the sample chamber.

7. **Detectors:** There are suitable detectors to detect SE, BSE and X-rays.

8. **PC control:** To provide the SEM image.

Working: Electron gun generates a beam of energetic electrons which are accelerated using the anode. The accelerated electrons are then focused into a coherent beam using condenser lens. Objective lens then focuses the beam onto the stage, where the solid sample is placed. SE, BSE and X-rays produced from the sample are detected using suitable detectors and black and white, three dimensional images are obtained after processing. SEM data provides information about size, shape, texture and composition of the sample. Image magnification can be up to 10 nanometers and, although it is not as powerful as its TEM counterpart.

Note: Most of the samples require some preparation before being placed in the vacuum chamber. Of the variety of different preparation processes, the two most commonly used prior to SEM analysis are sputter coating for non-conductive samples and dehydration for most biological specimens.

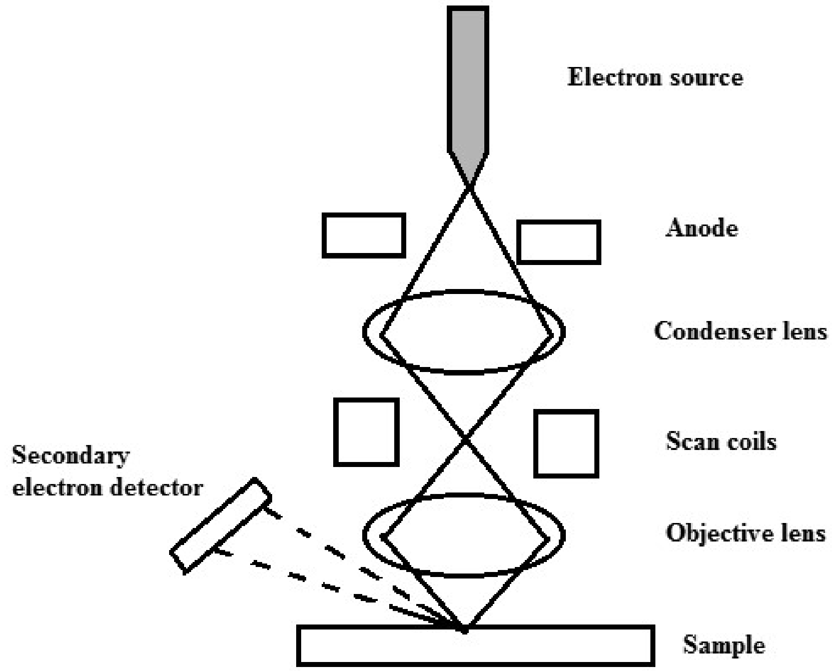

Figure 3.14: Block diagram of SEM

Applications

1. SEM helps in the characterizations of solid materials.

2. It can detect and analyze surface fractures, surface contamination and provide information in microstructures.

3. It helps to reveal spatial variations in chemical compositions and to identify cystalline structures,

4. It is used as an essential research tool in fields such as life science, nano-science, gemology, medical and forensic science.

5. SEMs have practical industrial and technological applications such as semiconductor inspection, production line of miniscule products and assembly of microchips for computers.

3.4 Questions

1. Define the following terms a) mobile phase b) stationary phase c) elution

2. What are the classifications of chromatography ?

3. Discuss the applications of column chromatography