The Transmission Electron Microscope (TEM)

This is one of the most commonly used instruments. Its geometry is shown in Figure 6.2. The source *S* of the electron beam may be a tungsten filament, but other materials like lanthanum hexaboride are also used. The beam path, the placement of the lenses, the specimen, the aperture etc, follow the plan of the light microscope as seen in the figure. The entire arrangement, including the specimen, has to be placed in high vacuum to avoid extraneous scattering and absorption of the electrons by air. The lenses are magnetic lenses in the electron microscope and unlike as in the light microscope, the image is not viewed directly through an eyepiece, but is projected on to a fluorescent screen on which the electrons form the image. An extra aperture called the objective aperture is placed in the electron microscope and not normally in the light microscope. This is because the image forming process in the TEM is different from that in light microscopes. In a light microscope, light is transmitted or absorbed by the specimen. This creates a contrast between the different parts of it and hence the image. In the TEMs the situation is quite different and most of the incident beam passes through the specimen unimpeded and very little is absorbed. Figure 6.2 shows that only a small portion is actually scattered in the forward direction. It is this forward-scattered fraction that is used to form the image. Contrast is created by differentiating between electrons scattered into wide angles from those scattered into small angles. The objective aperture cuts off the large angle electrons, and the amplitude of the electron beam from different portions of the specimen is different leading to amplitude contrast. Most biological materials however do not have enough contrast to be viewed unless they are stained. Dark field imaging is also possible and is achieved by cutting out the unscattered beam.

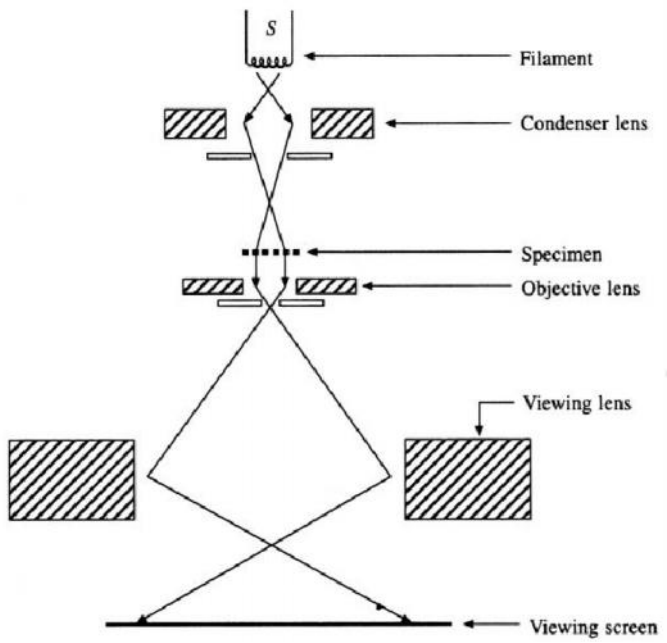

Figure 6.2 Schematic diagram of a transmission electron microscope

The Scanning Electron Microscope (SEM)

A SEM is very useful in obtaining images of the surface of thick specimens. In the scanning transmission mode (STEM), the SEM can also be used to study thin specimens and in this respect has some advantages over the conventional TEM. Figure 6.3 is a schematic illustration of the construction of the SEM. The most obvious difference as compared to a TEM is that the electron beam, after passing through the condenser lens is deflected in a raster pattern over the specimen stage, similar to the pattern in a television picture tube. The objective lens is split into two parts. One part is placed between the condenser lens and the specimen and can in fact be regarded as an additional condenser lens, which focuses the electron beam onto a small spot on the specimen. Image signals can be collected by the detector *D,* which is placed on the same side of the specimen as the source and the raster coils. This detector is used in the surface-scanning mode and collects the secondary electrons knocked out of the specimen by the primary beam, as well as the back scattered electrons reflected from the surface of the sample. Image signals can also be collected in the scanning transmission mode by the detector *D* after passing through the second half of the objective. These are the forwardscattered electrons.

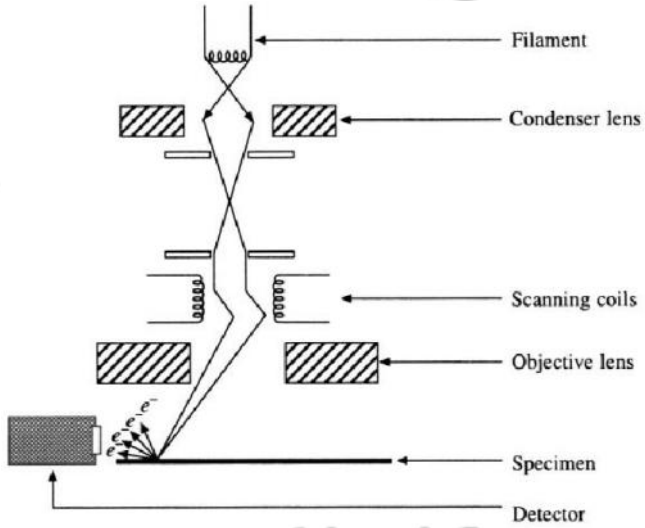

Figure 6.3 Schematic representation of a scanning electron microscope

Images obtained in the STEM mode are very similar to those obtained in the fixed beam TEM. The surface SEM image is quite different. In particular, the contrast in the surface imaging arises partly from the different scattering powers of the different atoms in the specimen, and partly from variations in the topography. In both the STEM mode as well as the surface SEM modes the images are generated in the following way: As the electron beam scans the specimen, the scattered electrons from each position is measured by the detector, one after the other in time. The measured intensities are displayed on the imaging screen one after the other in space, in the same type of raster scan as the electron beam. Thus if the scattering is high at particular point during the scan, then the corresponding point on the viewing screen is bright. If the scattering is low the corresponding point is dark. This creates an image of the object. The resolution of the image depends on the size of the electron spot used to scan the specimen and this may be as small as 50 Å. Both surface SEM and STEM have changed the use of electron microscopy quite dramatically and have made quantitative studies possible. The scanning principle has also been used more recently in the construction of the atomic force microscope and the scanning tunnelling microscope. These will be discussed later.