ENGR 240 – Science of Materials Laboratory

LAB SEM
SCANNING ELECTRON MICROSCOPY

Introduction

The scanning electron microscope (SEM) is one of the most versatile instruments for the examination and analysis of the microstructural characteristics of solids. Although the SEM and optical microscope share the same primary function – making microstructural features and objects visible to the human eye – the scanning electron microscope offers some distinct advantages over the optical microscope. The SEM uses electrons rather than visible light waves (200 – 750 nm wavelength) for imaging, which allows for observation of relatively large sample features at low magnifications or very fine details (high resolution) at high magnifications. The SEM also offers a large depth of field that provides good focus over rough specimen surfaces. The large depth of focus results in a three-dimensional appearance of the specimen in a SEM compared to the nearly planar or two-dimensional imaging found in optical microscopes. In addition, many attachments are available for scanning electron microscopes, including x-ray spectrometers for chemical composition analysis, backscattered electron detectors for atomic number contrast, transmitted electron detectors, hot and cold stages for microscopic observation of high or low temperature phenomena, tensile testing stages for observation of deformation and fracture, and special stages for analysis of semiconductor devices. Disadvantages of the scanning electron microscope are relatively high initial, operational, and maintenance costs, a high vacuum operating atmosphere that is unsuitable for some specimens, and difficulty in preparing certain types of specimens. Figure 1 schematically illustrates image formation in the optical microscope and the scanning electron microscope.

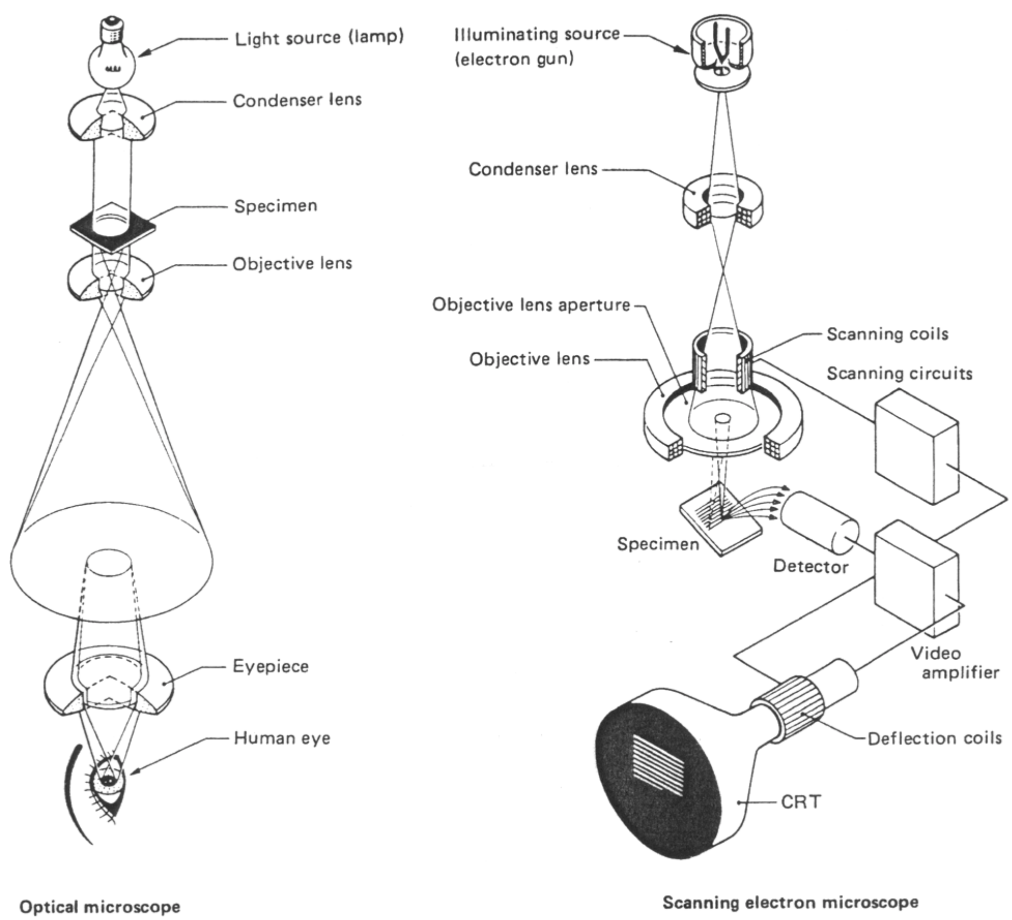

Figure 1. Basic image formation in an optical microscope and a scanning electron microscope.

The basic components of a SEM are the vacuum system, electron gun, lens system, electron detector, imaging system, and the electronics associated with these components. The vacuum system is necessary to minimize the interference of air particles with the electron beam and to prevent rapid oxidation of the tungsten filament. The vacuum system consists of roughing pumps, an oil diffusion pump, and various vacuum fittings, valves and seals that provide a working pressure in the SEM of 10^{-6} to 10^{-4} Torr. The electron gun in our JEOL JSM-35CF SEM contains a tungsten filament that is heated with a filament power supply and maintained at a high negative voltage (typically 10-30 kV) during operation. When the tungsten filament is heated, electrons are emitted from the tip and accelerated to ground by the 10-30 kV potential between the filament and the anode. Figure 2 shows the typical configuration of an electron gun in a SEM. After electrons are emitted from the gun and accelerated down the SEM column in an electron beam, they are controlled and directed to the specimen by a series of electromagnetic lenses and apertures.

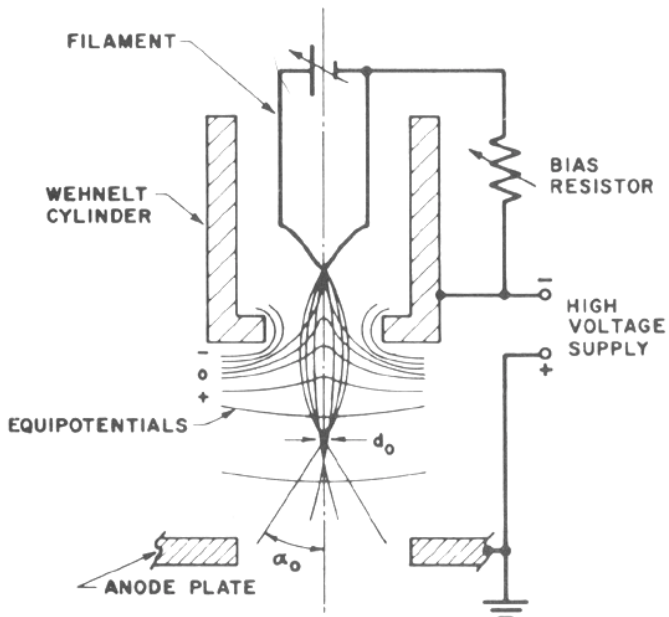

Figure 2. Schematic illustration of SEM electron gun.

When the electrons in the electron beam hit the specimen, a number of electron-specimen interactions may occur. Some of these interactions include elastic scattering of electrons, secondary electron emission (emission of loosely bound electrons of the conduction band), ionization of inner shell electrons (produces x-rays and Auger electrons), and excitation of phonons (causes heating of the specimen). If a sample is thin enough, some electrons will be transmitted all the way through the sample. Different materials and sample geometries will produce different amounts or different types of secondary electrons, backscattered electrons, Auger electrons, transmitted electrons, and x-rays, and all of these interactions may be used for imaging or analysis of the sample. The most common type of imaging in a SEM is secondary electron imaging (SEI), which involves the use of a secondary electron detector. The secondary electron detector collects secondary electrons and some backscattered electrons that are emitted from the specimen surface, amplifies the detected signal, and converts the electron signal into a video signal that is sent to the CRT.

Procedure

For this laboratory experiment, you should provide your own specimens and observe at least two different objects in the SEM. Examine your specimens over a range of magnifications, and use the digital imaging system (the Mac computer with digital imaging card and Adobe Premiere software) to capture at least one image from each specimen. You may want to use the Adobe Photoshop software on the computer to enhance your captured images. See your instructor for specific instructions on the use of the digital image capturing system.

Report

For your report, you should provide a brief description of the specimens you analyzed, a description of the microstructural features that you observed in your specimens at different magnifications, and relevant images of your specimen microstructures. Be sure to indicate the magnification of each image.

References

JEOL JSM-35CF Scanning Microscope Instruction Manual No. IEP35CF-2.
J. I. Goldstein, et al., *Scanning Electron Microscopy and X-Ray Microanalysis*, Plenum Press, New York (1981).