Handbook of Microscopy

Applications in Materials Science, Solid-State Physics and Chemistry

Edited by
S. Amelinckx, D. van Dyck,
J. van Landuyt, G. van Tendeloo

Methods II

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S. Amelinckx, D. van Dyck, J. van Landuyt,
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2 Scanning Beam Methods

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2.1 Scanning Electron Microscopy

2.1.1 Introduction

The scanning electron microscope (SEM) is the most widely used of all electron beam instruments. It owes its popularity to the versatility of its various modes of imaging, the excellent spatial resolution of its images, the ease with which the micrographs that are generated can be interpreted, the modest demands that are made on specimen preparation, and its 'user-friendliness'. At one end of its operating range the SEM provides images which can readily be compared to those of conventional optical microscopes, while at the other end its capabilities are complementary to instruments such as scanning tunneling (STM) or atomic force (AFM) microscopes. While its resolution can now approach 0.5 nm, rivaling that of a transmission electron microscope, it can handle specimens as large as production size silicon wafers.

The SEM had its origins in the work of von Ardenne [1, 2] who added scanning coils to a transmission electron microscope. A photographic plate beneath the electron transparent sample was mechanically scanned in synchronism with the beam to produce the image. The first recognizably modern SEM was described by Zworykin et al. [3]. This instrument incorporated most of the features of current instruments, such as a cathode-ray-tube display and a secondary electron detector, and achieved a resolution of 5 nm on solid specimens. In 1948 Oatley [4] and his students commenced their work on the development of the SEM leading in 1965 to the first commercial machine the Cambridge Scientific Instruments Mark 1 'Stereoscan'. There are now seven or eight manufacturers of these instruments in Europe, the USA, and Japan, and it is estimated that about 20 000 SEMs are in use worldwide.

The SEM is a mapping, rather than an imaging, device (Fig. 1) and so is a member of the same class of instruments as the facsimile machine, the scanning probe microscope, and the confocal optical microscope. The sample is probed by a beam of electrons scanned across the surface. Radiations from the specimen, stimulated by the incident beam, are detected, amplified, and used to modulate the brightness of a second beam of electrons scanned, synchronously with the first beam, across a cathode ray tube display. If the area scanned on the display tube is $A \times A$ and the corresponding area scanned on the sample is $B \times B$ then the linear magnification $M = A/B$. The magnification is therefore geometric in origin and may be changed by varying the area