Oblique Illumination Stereoscopy in the Shadow Electron Microscope

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Oblique illumination, although accompanied by distortion, provides a simple method of obtaining stereoscopic images in a shadow electron microscope. It is not necessary to tilt the specimen.

The point projection or shadow electron microscope [1] is primarily used as a convergent-beam electron diffraction camera [2]. In this mode the specimen is at the same height as the convergent-beam (C.B.) source, i.e., the image of the original source which is formed in the vicinity of the back focal plane of the objective lens. The complimentary operation of the instrument as an underfocussed medium-resolution shadow microscope [3] has recently been accompanied by the introduction of such techniques as selected area diffraction [4] and interferometry [5] which generally use near-axial beams, and stereoscopy of untilted specimens* which requires oblique illumination, such as would be obtained through the off-axis defining apertures of Figure 1.

Stereo imaging clarifies many problems in electron microscopy, for it gives valuable information on the three-dimensional structure of specimens. In conventional transmission instruments stereoscopy requires that the specimen be tilted between successive exposures, which are usually recorded on separate photographic emulsions. This is also a suitable technique for the shadow microscope but the alternative method, which does not involve a tilt stage, has the advantages of speed and simplicity, thus reducing the exposure of the specimen to possibly damaging radiation.

The procedure is illustrated by the ray paths of Figure 2. For simplicity no defining aperture is indicated, and indeed this is often omitted. It is assumed that the C.B. source is underfocussed and on the lens axis and that the distortion introduced by spherical aberration is small. As the specimen is moved in a plane perpendicular to the lens axis the image projected onto the screen or recording plate is translated in the opposite sense. If the specimen is of significant height there will also be a redistribution of image detail. A pair of displaced images separately recorded will be suitable for stereoscopy.

Two or three images can be conveniently recorded on the same emulsion if a field-limiting aperture is employed and moved with the specimen. The stereo pair shown in Fig. 3 differ in incidence angle by 3°. This value can be determined from the ratio of the image displacement to the camera length. This angle is adequate although smaller than the change in tilt angle which one would use with a goniometer.

Oblique illumination necessarily introduces distortion. This can be kept small if the distance between specimen and C.B. source is large, but this involves lower magnification and, if small C.B. sources are used [6], gives rise to Fresnel fringes in the image.

Image pairs are also formed by displacing the source rather than the specimen. This latter method [7] permits one to obtain images simultaneously. With suitable modifications the methods outlined could be applied to other imaging modes.

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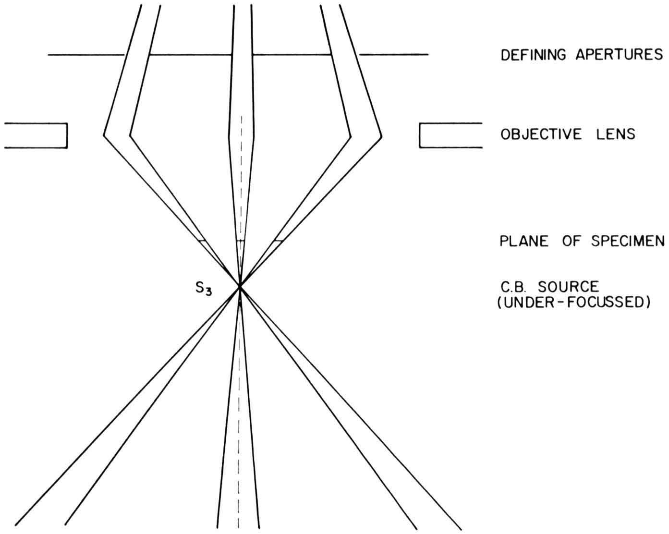

Fig. 1.

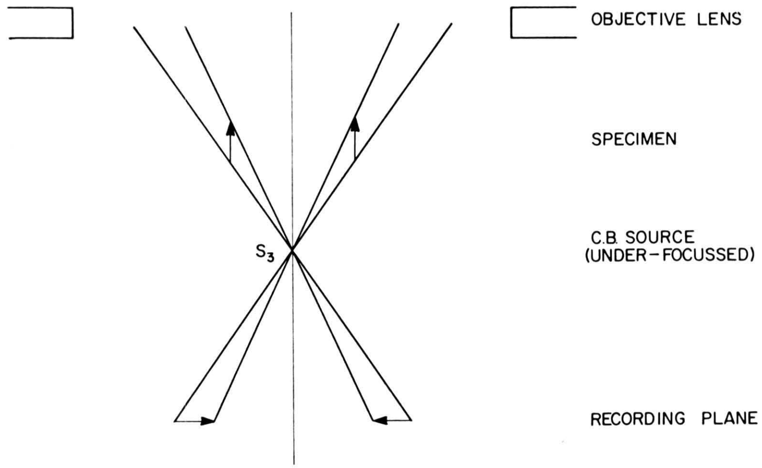

Fig. 2.

Fig. 3

Fig. 1. In the shadow electron microscope oblique illumination of specimens is obtained through off-axis defining apertures.

Fig. 2. Two projected images of the specimen, which is translated between micrographs, provide a stereo pair.

Fig. 3. Stereo pair of images of ZnO crystals formed without tilting the specimen. 10,000×.