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Short Note

Use of Pseudo-Stereo Techmques to Detect Magnetic Stray Field in the SEM

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In the SEM, mains frequency stray magnetic field can displace the position of the probing beam so that it fails to move over the specimen in a raster having the same shape and proportion as that on the display screen. The mismatch of the two rasters produces a distortion in the recorded image, as is shown in Fig. 1, where a linear feature on the sample is rendered as an undulating feature on the display. As each line of the image is usually phase-locked to the frequency of the mains power, which is in turn the most common source of stray magnetic field, the directions of the displacements which make up the distortion will tend to line up in the direction perpendicular to the line-scan direction.

Binocular stereo vision operates by detecting small relative differences in the horizontal position of features in two images of the same object and decoding these differences into variations in height. Normally, in stereo scanning electron microscopy, the horizontal displacements are produced by tilting the specimen after the first micrograph has been made by an amount that approximates the convergence angle of the human eye focused at a comfortable viewing distance (about 7"-10") (*Boyde* 1974). However, it is also possible to use the binocular decoding mechanism to detect other types of displacements, such as those produced by stray field.

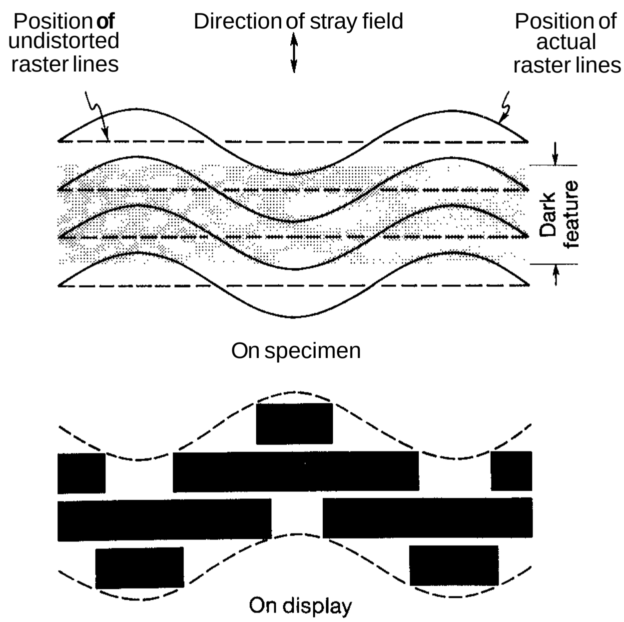

Fig. 1 Schematic diagram of the manner in which the displacement of the probing beam by stray field produces a distorted image of the object

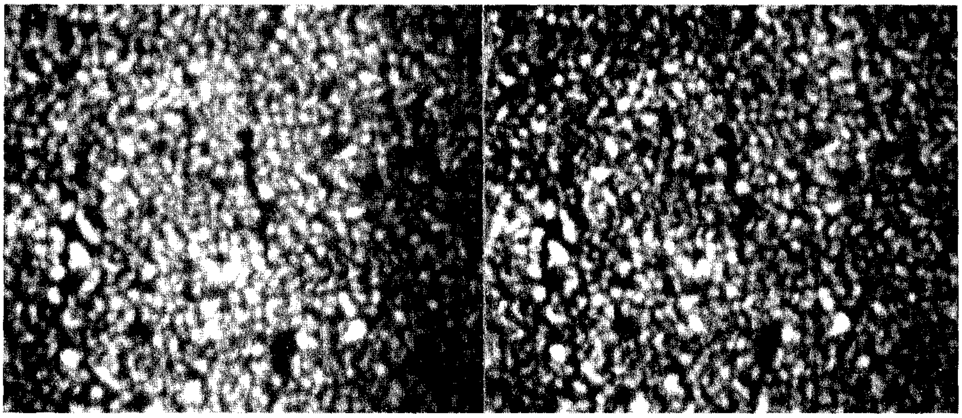

Fig. 2 Pseudo-stereo pair made by taking successive images of the same field, but with scan rotations of 0" and 180". The apparent stereo topography is produced by mains frequency stray magnetic field, as described in the text. The test sample is AuJPd on carbon. (Horizontal field width: 300 nm).

Figure 2 shows a pseudo-stereo pair taken at a magnification of 300,OOOX. Neither image in the pair, viewed alone, appears to be greatly distorted in any way. The righthand member of the pair was taken with the scan rotation at 0" and the lefthand member with the scan rotation at 180". This change in scan rotation has the effect of making the probing beam strike specific features on the specimen at different times and, hence, at a different phase of the mains frequency field. As a result, the image distortions produced by this field are not the same in the two images. If Fig. 2 is viewed in stereo, these distortions are seen as apparent height differences because the micrographs have been rotated so that the direction of the stray field, and hence the displacement, is horizontal, the only direction in which such differences can be decoded using binocular vision. The apparent height difference makes the surface of the flat sample appear to have repeating sets of ripples with crests and troughs that run parallel to the line scan direction. The number of repeating ripples is equal to the number of mains frequency periods required to record the information in each horizontal line. (Because the images in Fig. 2 have been rotated 90" to produce a horizontal stereo parallax, the horizontal lines now run vertically and the ripples run horizontally.)

The general appearance of such pseudo-stereo pairs will always be similar to that in Fig. 2, where the crests run perpendicular to the vertical (slow) scan direction. If the stray field acts in a different direction, then the micrographs must be reoriented so that the resulting distortion is horizontal in order to show the maximum apparent depth. Although a measure of the direction of the stray field can be determined in this way, it should be remembered that the orientation of the raster rotates each time it passes through a magnetic lens. As a result, directional measurements are usually most useful in determining changes in the stray field as various strategies are applied to reduce it.

Pseudo-stereo pictures to demonstrate the presence of stray field can be made without the aid of a scan rotation unit. The only requirement is that features on the specimen should be struck by the beam at different phases of the mains frequency signal in each micrograph of the pair. This can be arranged by moving the sample or allowing it to drift slightly between the two exposures. In this case, the apparent height difference is proportional to the time derivative of the applied stray field over a time period characteristic of the amount of time that the beam takes to travel a distance equal to the imposed displacement or drift.

Stereo analysis of the type described permits very sensitive detection of stray field and it can therefore assist in efforts to eliminate such fields. If they are not eliminated, it will be impossible to make accurate linear measurements of the sample or to evaluate conventional stereo pairs properly. More importantly, it is impossible to analyse resolution test images, because the distortion of the image will tend, to a significant extent, to reduce the apparent size of some of the surface features measured to determine resolution.

Several strategies for reducing stray field were discussed in an earlier note *(Pawley* 1985), but one problem area not previously emphasized will be noted here. This source of stray field is internal to the microscope and is caused by the simultaneous presence of two conditions: misalignment of the column, and mains frequency ripple in the current to a condensor lens. Figure 3 shows such a lens. If aligned correctly, the ripple merely causes the focused spot to move up and down the electron optical axis. However, if the lens is misaligned, there is also a horizontal component to the motion of the spot. Such a mechanism actually produced the distortion observed

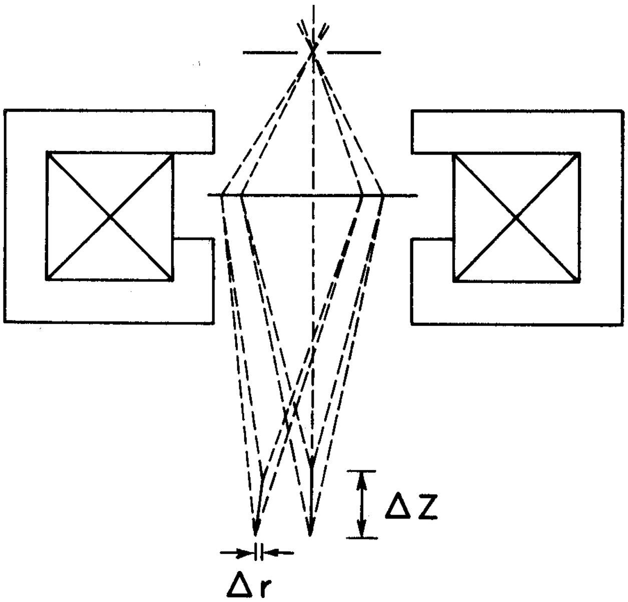

Fig. 3 Schematic diagram showing how mains frequency ripple in the current to a magnetic lens can produce a horizontal displacement of the beam if the lens is misaligned.

in Fig. 2. The problem was eliminated by adding a large capacitor in parallel with the lens coil. This solution improved instrument performance generally because, even when properly aligned, the lens instability had effectively increased the energy spread of the beam projected into the final lens.

Acknowledgement

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References

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