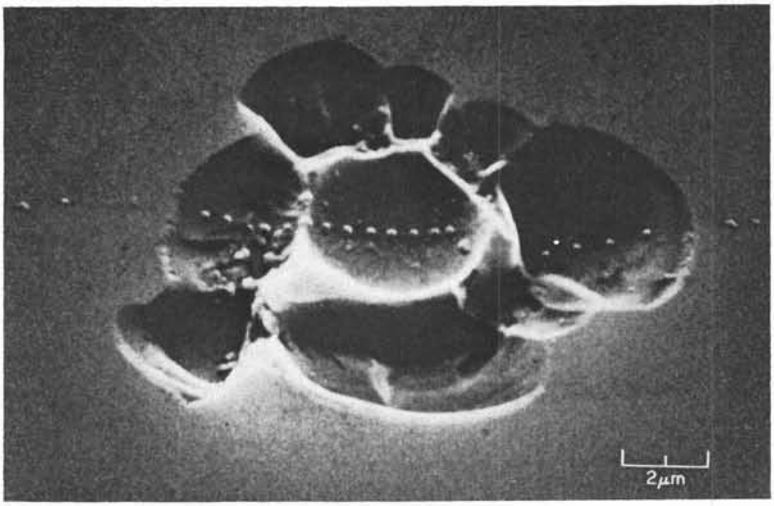

FIG. 1. Results of the profiling technique shown on a micrograph of a crater formed in glass by the impact of a polystyrene sphere. The angle of tilt of the SEM stage is 45°.

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Profiling with the Electron Microscope

A technique is applied to the scanning electron microscope rendering depths and curvatures of surfaces where stereo is not practical.

(Abstract on next page)

THE SCANNING electron microscope (SEM) has been used for stereometry of small objects and surfaces, and the measurement techniques have been described in detail.[1,2] In studies of microcraters in various materials,[3] it was often difficult to determine crater depths from SEM micrographs at high magnification (10,000×) because of smooth featureless surfaces in the crater pits and on the undisturbed face of the target. But definite detail is necessary for making accurate measurements on stereographic pairs of micrographs. In attempts to overcome the problem, a technique was developed for the presentation of contour information on a single photomicrograph.[4]

This technique utilizes the ever present surface contamination problem[5,6] that occurs in most SEMs. Wherever the primary electron beam strikes the surface, a layer of material

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[1] G. S. Lane, The Application of Stereographic Techniques to the Scanning Electron Microscope, *J. Phys. E. 2*, 565 (1969).

[2] J. B. F. Cripps and H. Sang, Stereo Height Measurements in Scanning Electron Microscopy, *Rev. Sci. Instrum. 41*, 1825 (1970).

[3] J.-C. Mandeville and J. F. Vedder, Microcraters Formed in Glass by Low Density Projectiles, *Earth Planet. Sci. Lett.* **11,** 297 (1971).

[4] During the preparation of this paper the authors were unaware of a similar technique used by Brandis *et al.* (E. K. Brandis, F. W. Anderson, and R. Hoover, Reduction of Carbon Contamination in the SEM, Proceedings of the Fourth Annual Scanning Electron Microscope Symposium, eds. O. Johari and I. Corvin (IIT Research Institute, Chicago, Ill., 1971) 105–112.)

[5] P. R. Thornton, *Scanning Electron Microscopy* (Chapman and Hall, Ltd., London, England, 1968) 168–171.

[6] R. K. Hart, T. F. Kassner, and J. K. Maurin, The Contamination of Surfaces During High-Energy Electron Irradiation, *Phil. Mag.* **21,** 453 (1970).

ABSTRACT: *A profiling technique for use with a scanning electron microscope presents depth information on a single micrograph of a specimen. With a stationary electron beam, a series of contamination spots is formed in a line across the specimen parallel to the tilt axis with the axis at 0°. Then a micrograph is taken with the specimen at a large tilt angle. Relative depths and curvatures of the surfaces along the dotted line are readily apparent. The depths are derived from the lateral displacements of the points by correcting for the angle of tilt and the magnification. The micrographs are valuable for projection and display where stereo viewers are not practical or available.*

builds up. A conical deposit forms at the point of impingement of a stationary beam. In the present technique, a series of cones is formed in a straight line across the crater in a direction Y parallel to the tilt axis of the specimen holder with the tilt angle θ at 0°. Then, with the holder tilted to 45°, for example, a micrograph is taken. Figure 1 shows a microcrater subjected to this procedure. Relative depths and curvatures of the surfaces are readily apparent. Depths Z are easily determined by measuring the lateral displacements ΔX of points and correcting for the angle of tilt and magnification M. Thus, $Z=\Delta X/M \sin\theta$. If $\theta=45°$ and if the ratio of the magnification in the Y-direction to that in the X-direction is $\cos 45°$, the image will be rectified; and the depth will equal the lateral displacement on the scale of the picture. Divide the displacement by the Y-magnification to get the true depth.

Details in the procedure depend on the SEM and specimen. A grid on the face of the cathode-ray tube serves as a reference for the line or lines and the location of selected points of the profile, in order that the whole image need be presented only at the start of the procedure. The beam spot can be automatically stepped across the specimen. The time required to form an adequate spot depends on the surface, the rate of contamination, the magnification and the sharpness of focus of the primary beam. Ten to 100 seconds are required to form a usable cone at 10,000 diameters magnification with a well focused beam. To minimize drift of the spot off the selected line and loss of focus, the traverse time should be minimized. A correction for drift can be made in determinations of depths by measuring the offset of the points from the line on a micrograph of the sample at 0° tilt. For the profile, a large angle of tilt gives the best impression of depth; but the walls of a deep crater will block the view of the bottom of the pit if the angle is too great. Originally attempts were made to form a continuous line across the crater, but resolution of points along the line is then poor and the time required to form the line is quite long.

This technique can obviously be applied to studies of other features in the SEM. It is most useful in instances where surfaces lack detail and where the variation in level is slight. The resulting micrographs are valuable for use in projectors or for presentations where stereo viewers are not available.

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