

SEM Image Sharpness Analysis¹

M.T. Postek* and A.E. Vladar**

*NIST, Gaithersburgh MD, **Hewlett-Packard, ULSI Research Laboratories, Palo Alto, CA.

Fully automated or semi-automated scanning electron microscopes (SEM) are now commonly used in semiconductor production and other forms of manufacturing. The industry requires that an automated instrument must be routinely capable of 5 nm resolution (or better) at 1.0 kV accelerating voltage for the measurement of nominal 0.25-0.35 micrometer semiconductor critical dimensions. Testing and proving that the instrument is performing at this level on a day-by-day basis is an industry need and concern which has been the object of a study at NIST. The fundamentals and results are discussed in this paper.

In scanning electron microscopy, two of the most important instrument parameters are the size and shape of the primary electron beam and any image taken in a scanning electron microscope is the result of the sample and electron probe interaction. The low frequency changes in the video signal, collected from the sample, contain information about the larger features and the high frequency changes carry information of finer details. The sharper the image, the larger the number of high frequency components making up that image. Fast Fourier Transform (FFT) analysis of an SEM image can be employed to provide qualitative and ultimately quantitative information regarding the SEM image quality.

Figure 1a is a micrograph of a heavily gold coated zinc oxide powder viewed at 1.5 keV. The image appears unsharp due to SEM performance and induced astigmatism. Figure 1b is a much sharper micrograph at 1.0 keV on that same sample. Figure 1c is a high accelerating voltage image. It is apparent that the sharpness of the image improves from Figure 1a through 1c. The FFT power spectra of the images are shown in Figures 1d, e and f, respectively. The high frequency information increases as the image gets sharper and the center part of the power spectra gets broader

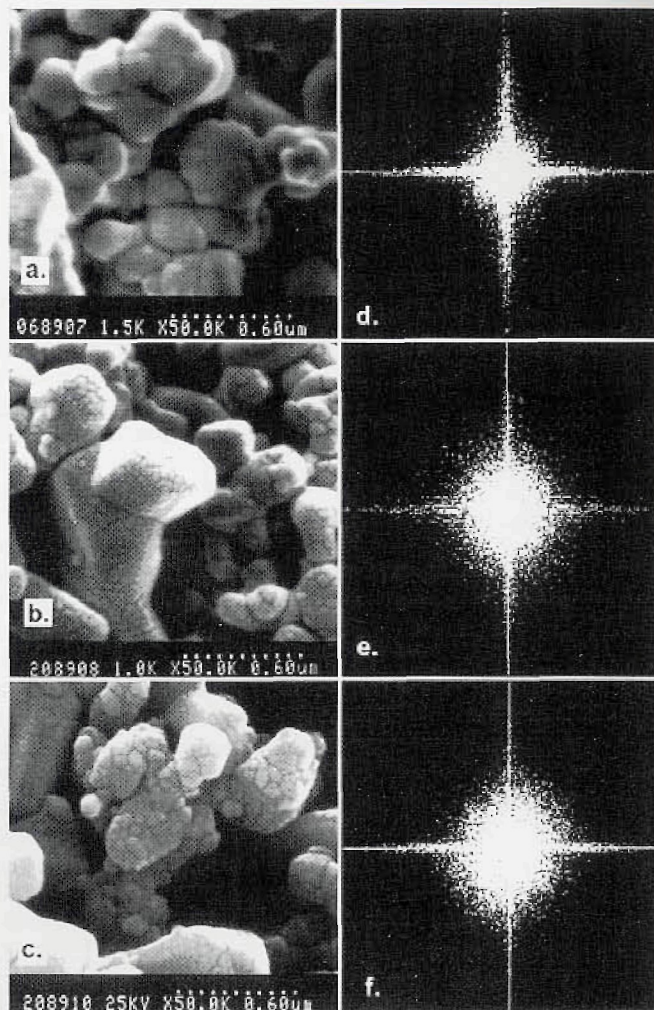


FIG. 1. Image sharpness evaluation. Displayed are three scanning electron micrographs of varying quality and the respective FFT analysis. Note how the high frequency components of the image increase as the image improves in sharpness.

which is clearly shown in Figures 1d, e and f. This characteristic can be used in calculations to compute relative sharpness of an image series. Using ISAAC², with the use of a script containing the FFT routine, the frequency domain representation was computed in both x and y. With this sampling algorithm, the calculations occurred on the central two third of the images in order to minimize the effect of any possible distortions of the original image. The x and y sums were saved as text files. Further calculations were accomplished with spreadsheet software.

The technique described here, utilizing the sharpness concept, is facilitated by the use of the FFT techniques to analyze the electron micrograph to obtain the evaluation. This is not the first application of Fourier techniques to SEM images³ but it is the first integrated approach considering the sample, computer analysis and measurement algorithm. This technique can be used to check and optimize two basic parameters of the primary electron beam, the focus and astigmatism. It also facilitates the periodic resolution determination of the SEM in an objective and quantitative form. ■

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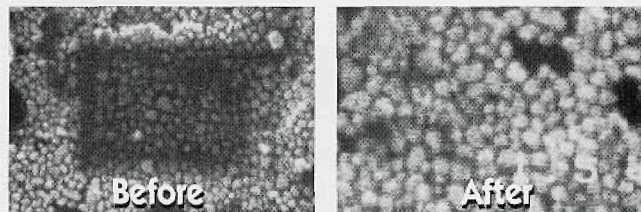
2. M.T. Postek and A.E. Vladar, *Scanning* 18(1996)1-7.

3. T.A. Dodson and D.C. Joy, *Proc. XIIth Int. Cong. for EM*. San Francisco Press. (1990)406-407.

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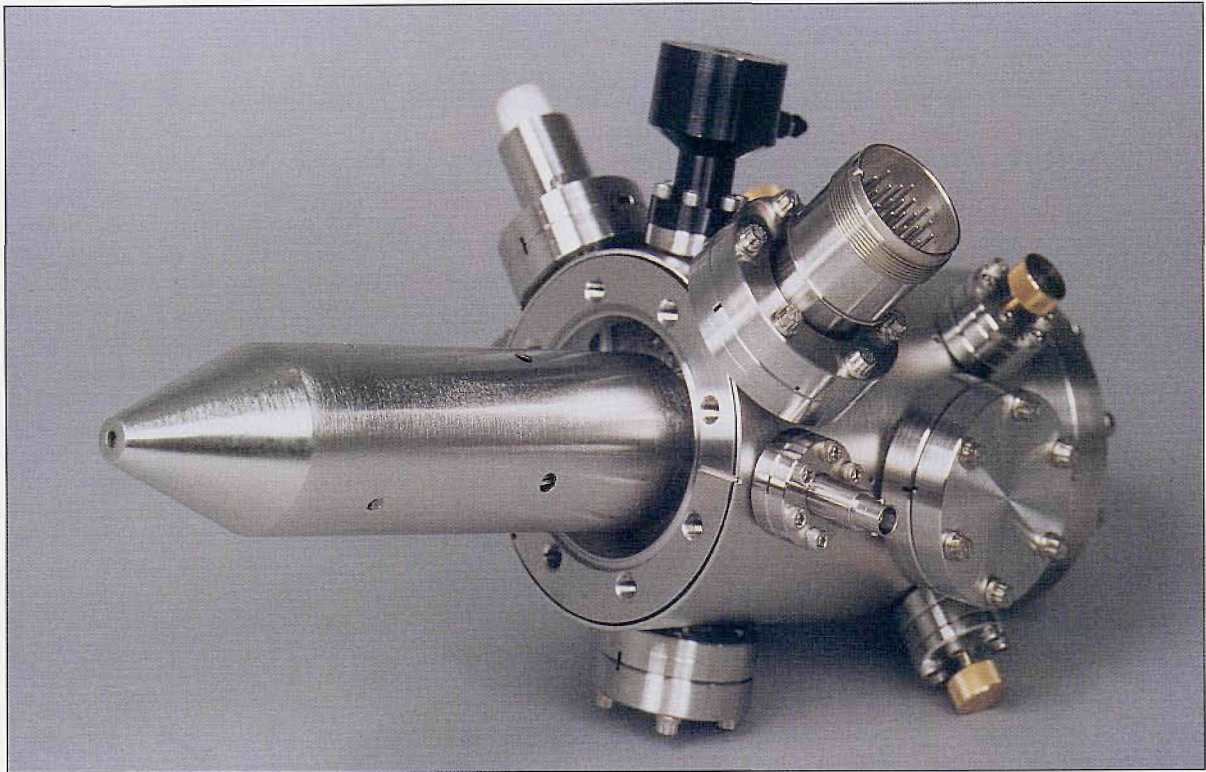
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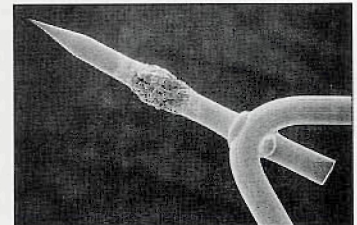
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