The Difference Between Calibration and Image Linearity

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In my last article, I discussed the need for scheduled system checks on scanning electron microscopes. The article used an experience at a local SEM laboratory to point out the importance of monitoring your instrument by performing simple but regular system performance evaluations.

In this article I will discuss some principles behind the performance of imaging systems such as scanning electron and scanning probe microscopes. We will talk about the concepts of image linearity and dimensional calibration.

As you know, both scanning electron and scanning probe microscopes generate an image by moving a probe across the surface of the sample and recording responses to the probe. The resulting pattern is known as a raster scan in which the probe is moved all the way across the sample in one direction, then shifted slightly in the orthogonal direction and the scan repeated. This process needs to proceed properly to generate a faithful and correct image of the sample under examination. One of the reasons to test system performance is to verify that the raster scan process is working correctly. Problems with this process will show up as distortions in the image.

A goal in microscopy is to produce images in which features can be accurately measured, even if accurate dimensional measurements are not used. This may sound like a bold claim, but let me explain. In a scanning microscope, the scan axes (the scan direction and the shift direction in the raster scan) is expected to be orthogonal. Linear and orthogonal scan axes will produce an image in which the apparent size of an object is the same regardless of the position in the image. If the scan axes are skewed (not exactly orthogonal) then the image will be distorted because the apparent position of a particular point will not have a simple correspondence to the actual position on the sample - a square feature on the specimen will be displayed as a parallelogram, for example. Similarly, if the scans are not linear, the image magnification will vary from point to point because the image forming process is not consistent across the sample. These distortions destroy the simple correspondence between each point on the image and each point on the specimen. In simpler terms, it means the size and relative location of a given feature will depend on whether it is located at the left, the center or some other location in the image.

Now we can see why we need a dimensionally accurate image. Even if one is not concerned about actual measurements, we still want a correct and accurate portrayal of the subject under study. If the image is not of sufficient quality to enable accurate measurements, then in reality, it is not a good representation of the sample. Micrographs are not often published with the note that they are "Not to Scale".

Nonlinearity of measuring instruments (including microscopes) can be described quantitatively in two ways. "Image nonlinearity" refers to measurements of absolute feature position within the image. To illustrate, suppose the scan length (full scale) equals 1.0 units. If a feature is truly located halfway between the start and end of the scan (i.e., at the 0.50 point) and the instrument reports instead that the feature is located at the 0.51 point, then the integral nonlinearity for that measurement is 0.01 (or 1 % of full scale). "Differential nonlinearity" refers to the separation of a pair of features. If a given pair of features is truly separated by 0.10 unit, and the instrument reports a separation of 0.099 when the pair is located near the start of the scan and a separation of 0.101 when the pair is located near the end of the scan, then the differential nonlinearity is 2 % (expressed as a percentage of the feature separation).

Typically, differential nonlinearity is of greater significance because measurement of distance between two points on a specimen is the essence of microscopy. Every microscope image is a mapping describing the spatial

relationships between various features of the specimen. For ease of interpretation, it is desirable that this mapping be simple - we want the image to look like the specimen. Even if no measurements are intended, distortion of the relative distances between various portions of the image conveys a false impression of the specimen under examination. This reduces the ability of the image to impart meaningful information to the microscopist.

Image magnification is obviously related to the linearity of the image, since changes in magnification across an image create distortion. However, a linear image does not guarantee correct magnification, nor does calibrated magnification at one point guarantee that it is calibrated at another point. If the image has the same magnification at every point, the scale is also linear at every point. This argument can also be reversed - if the scale is linear at every point then the magnification is the same at every point - but, in either case, the magnification is unknown until properly calibrated.

The only way to guarantee an accurate image is to check the image field at every point using a known reference. Some calibration specimens require significant labor by the operator to perform this analysis. An easy-to-use calibration specimen will provide markers across the entire image. Diffraction grating replicas, for sample, provide a specimen with this characteristic, as do the MOXTEK calibration specimens. In addition to covering the entire image area, it is important to have easily interpreted calibration markers. This is the weakness with microspheres, for example. Their random distribution in both size and position make it difficult to analyze the image linearity or magnification easily and rapidly.

The proper procedure is to image an appropriate calibration specimen under the operating conditions to be used with your experimental sample. A regular grid or periodic straight lines provide an image which your eye can easily analyze for most distortions. With a little practice, the healthy eye can detect a distortion of down to one or two percent. This provides a quick analysis of the image linearity, either identifying problems which need to be addressed or providing assurance that the image is linear. Once image linearity is established, a quick measurement of the calibrated markings at any point on the image will determine the magnification accuracy for the entire image. The magnification can then be adjusted appropriately.

This is a quick, simple procedure which can be performed in under ten minutes and may save you hours of grief. In addition, when your images are published, you will know they are accurate representations of your sample and that your experimental technique is above reproach. ■

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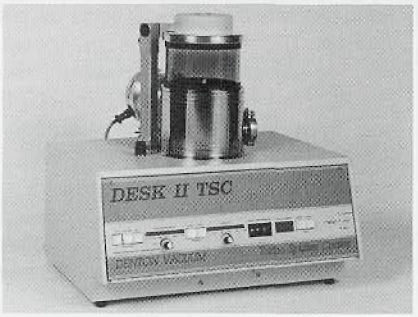

Denton Vacuum, Inc. introduced the newest in their series of table top chromium coating units, the Desk II Turbo Sputter Coater, recently at the MSA/MAS/MSC Conference. The Desk II TSC is a totally self-contained turbo molecular pumped sputter/etch unit. Its integral mechanical pump with on-board 80 l/s turbo pump assures faster and safer operation and takes up less space than systems with awkward floor-mounted pumps. The Desk II TSC comes ready-to-operate with all the required pumps and a starter gold target. The Desk II TSC's unique design is the most advanced in the industry. Lighted push buttons arranged logically by function provide sure, easily reproducible films. To monitor gas pressure and electrical current, the Desk II TSC uses reliable solid state electronic bar graphs instead of analog meters. One of the more advanced features of the Desk II TSC is the ability to etch clean surface contamination from non-delicate samples. This allows the imaging of many samples without the need for coating in today's FESEM's. The Denton Desk II TSC also sputters the typical gold, gold-palladium and platinum films in common use today as well as the newer high resolution materials such as chromium and tungsten for use with today's FESEM. Denton Vacuum, Inc.: (609)439-9100, Fax: (609)439-9111, dMail: j_campbell@dentonvacuum.com or http://www.dentonvacuum.com **Circle Reader Inquiry #40**

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Easy-to-operate EM 208S Transmission Electron Microscope Offers High-Quality Imaging to Life Science Microscopy

The new EM208S transmission electron microscope from Philips Electron Optics offers microscopists in the life sciences excellent imaging capabilities with a user interface that is clear and easy to use. The instrument has been designed for routine image analysis in life sciences, including pathology, anatomy, histology and virology. It is also ideally suited to many industrial applications, e.g., as an instrument for routine quality control of polymers, photographic emulsions, pigments, paints and cosmetics.

The EM2085 is the successor to the field proven EM208. The instrument now incorporates a number of additional features requested by customers, such as the inclusion of a motorized stage and a color monitor.

To facilitate navigation around the sample, the instrument has a computer-controlled, full motorized specimen stage with a reposition accuracy of better than 2 microns (guaranteed, after changing specimen tip). The specimen stage control software stores the XY positions, allowing automatic exposure sequences. By pressing the exposure button, the microscope will move the motor state to the correct position, change the magnification, illumination and focus condition to user selected values and then make the exposure. This sequence will be repeated automatically until all selected positions have been photographed. In addition, the electric motors are coupled to the manual specimen rods. The mechanism blocks the stage when it would be moved out of the grid, protecting it against undesired forces that might otherwise cause mechanical distortion. Philips Electron Instruments: (201)529-6168, Fax: (201)529-2252. **Circle Reader Inquiry #41.**