HOW ACCURATE IS YOUR SEM'S MAGNIFICATION?

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With such topics as ISO-9000, TQM (Total Quality Management) and with the Malcolm Baldridge Quality Award being mentioned these days, it may not be long before instrument calibration becomes an issue in your laboratory. Among the many important areas governed will be magnification accuracy of optical microscopes, TEMs, and SEMs. The following brief discussion probes the rather complex subject of SEM magnification accuracy.

What is happening inside the SEM when a particular magnification is chosen? Most modern instruments have microprocessors which determine the appropriate scan coil currents to set for a specific magnification, kV, and working distance. Even if all the above parameters were accurately known, there would still be magnification errors due to non-linearities in the electron optical scanning coils, the viewing, and the recording cathode ray tube systems (manifesting itself as distortion). Working with a tilted specimen also introduces error due to image foreshortening.

Even though your SEM may digitally display the magnification and record, along with a "micrometer marker" (micrometer is the proper S.A. unit) on the photomicrograph, it is most certainly not accurate. It is also likely that the magnification is inaccurate by varying percentages for different magnifications, working distances, or kVs. To determine magnification, one starts with a standard of known accuracy. The standard should have patterns to measure (horizontally and vertically) which span the range of magnification over which the instrument is to be utilized. Standards are available from NIST (National Institute of Standards and Technology) and a limited number of commercial sources, including this author's company.

Standards are available for measuring either "line-width" or "pitch". Which type should you use? Line-width measurements are only valid when made on instrumentation of the same type used for the original measurement and certification of the pattern. Traceability will be lost when, for instance, a reflection optical system is used to certify a line-width standard which is later used on an SEM. The pitch represents a single pattern cycle (from the start or middle of one bar to the start or middle of the following bar). Pitch measurement standards certified using one type of microscopy are valid for any other type of microscopy.

Determination of the correct working distance may be the greatest source of error in the SEM. It is determined from an algorithm which takes into account the current in the objective lens required to focus an image under a specific kV. Lens non-linearities such as magnetic saturation at high kVs, hysterias, and inhomogeneities in the magnetic lens material or uneven coil windings all contribute to errors. Only after defining the error sources can we begin to understand how to work at the highest accuracy.

Assuming the instrument is aligned properly, the following steps should be followed:

1) Verify that the "micrometer marker" is displayed with the proper length on *both* the viewing and recording CRTs.

2) Choose a typical set of operating conditions (working distances and kV). Insure that the stage tilt is zero. Vary the magnification over a range which brackets your needs. Determine the accuracy in both the X and Y directions at each of these magnifications. Also check for distortion.

3) Vary the kV and working distance methodically and check the X and Y magnification accuracy as previously done.

4) Check the magnification reproducibility by changing the conditions, and removing and re-introducing the specimen.

After surveying several instruments having various ages, we have determined that some instruments can achieve a +/- 2% accuracy in both X and Y axes over a large range of conditions. Other SEMs exhibited serious scan distortions and magnification errors of -10% to +20% with different degrees of errors in the X and Y axes as conditions are changed. Know your instruments magnification accuracy and what you can achieve under the specific conditions used before committing yourself.