SEM thickness measurement at cross-sections:
An unexpected thickness error (of ~60 nm) was found in special cases

Sample: TiO$_2$ layer on silicon wafer

During the imaging process, the image is drifting downward because of charging, elongating the features in the vertical direction.

As a consequence, the layer “thickness” depends on the image acquisition time.

Sample rotated 90 deg

When the thickness is measured in the “fast scan direction” of the electron beam, the true layer thickness is obtained.

Like above, the image is drifting in the direction of the silicon substrate (here: to the left side.)

Note, that 20 nm gold coating did not remove this effect. The drift appeared even worse with the gold coating.
The true layer thickness can be obtained, when the measurement direction is in the “fast scan direction” of the electron beam (= horizontal).

In both cases (20 s and 40 s per frame) the same thickness (240 nm) is obtained.

Pushing the “Freeze” button shows that the layer is aligned in the vertical direction. The layer appears tilted because of the image drift during the 20 s imaging time. With 40 s imaging time the tilt has increased.

Another method to check for true thickness:
1) Compare layer thickness for different acquisition times (20 s and 40 s, or better 80 s). There should be no difference.
2) If there is a difference, take a “Freeze” image, which will give the best value for the thickness.
Image drift must be checked for each sample individually. Similar samples may behave different.

Similar sample of TiO2 on silicon wafer (Layer thickness 500 nm instead of 240 nm).

Sample without coating; Image frame: 40 s

20 nm gold coating; Image frame: 40 s

The complete absence of charging problems for one sample does not mean that other samples will be measured correctly. (The fact that an increased thickness of the non-conducting layer reduced the charging problem is even counter-intuitive.)
Previously, different thickness (240 nm, 270 nm and 300 nm) were measured because of different **acquisition times**.

At different **magnification** we also obtain different values for the layer thickness, because for a large magnification it takes longer until the electron beam travels from the top to the bottom of the film.

Again, the image is drifting in the direction of the silicon substrate (here: to the right side.)
Example: For 240 nm and for 700 nm TiO2 the drift due to charging resulted in a thickness mistake of up to 60 nm. But for 500 nm TiO2 there was no drift and the layer thickness was measured correctly.

Summary: How to recognize errors

Watch for inconsistent results when using different magnification or acquisition time.

Sample which show charging are suspect. Image drift can be seen as jumps in image position before and after completing a frame.

Summary: How to get true distances in SEM images

1) Compare distances for different acquisition times (20 s and 40 s, or better 80 s). There should be no difference.
2) If there is a difference, take a “Freeze” image, which will give the best value.
3) Change the scan angle to 90 deg for the thickness measurement

Summary: WARNINGS

If one sample behaves nicely, it does not mean that the next one will, even if they are similar in nature.

Example: For 240 nm and for 700 nm TiO2 the drift due to charging resulted in a thickness mistake of up to 60 nm. But for 500 nm TiO2 there was no drift and the layer thickness was measured correctly.

Even with a thick conductive coating (here: 20 nm Au) image drift due to charging was present.
SPM (AFM) images at scratches confirm the thickness values obtained with SEM.