Linewidth measurement for sub-10 nm lithography

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This paper investigates how linewidths can be measured to nanometre accuracy without the use of a transmission electron microscope (TEM). For many years the ultimate resolution of electron beam lithography was around 10 nm but a number of papers have been published in recent years demonstrating sub-10 nm resolution. Most of these papers, while impressive, have one thing in common, namely the apparent resolution of the images is not much better than the linewidths achieved. While a 3 nm error in measurement is acceptable for 30 nm lines, at the sub 10 nm level it becomes a major issue. It is important to be able to distinguish between 5 and 8 nm lithography, but this is questionable when comparing results from different research groups who use different microscopes.

To investigate this issue we fabricated platinum lines using electron beam lithography and lift-off on a 50 nm silicon nitride membrane. Approximately 2 nm of Al was evaporated on to the back face of the membrane to avoid charging during imaging. Linewidth measurements were carried out using two scanning electron microscopes: a Hitachi S4700 and an FEI Nova NanoSEM 630. The imaging modes were secondary electron for the S4700 and secondary, backscattered and transmission for the NanoSEM. All images were taken at 15 kV and are shown in Figure 1.

The measured linewidths from the micrographs are shown in Table 1. This variation between imaging modes is seen more dramatically for narrower lines which measure 10 nm using backscattered electrons but 20 nm with secondaries.

Evidently if there is no apparent resolution below the width of the structure being measured then the width measurement must be taken cautiously. Moreover even if such resolution is apparent the “real” linewidth cannot be taken from the images in a simple manner. The backscattered image is more likely to be representative of the actual width than the secondary electron image which suffers from contamination issues. This has been confirmed in a separate experiment through a comparison of TEM and SEM imaging of metal-coated dielectric lines. Transmission electron microscopy is the gold standard for length measurements on a nanometre scale, but is inconvenient for measuring lithographically defined features. We demonstrate that if a suitable calibration is made, the actual width of a line can be deduced from the backscattered image.

(a) FEI NanoSEM, backscattered detector	21.6 nm
(b) FEI NanoSEM, STEM detector	25.2 nm
(c) FEI NanoSEM, secondary electron detector (TLD)	33.0 nm
(d) Hitachi S4700	28.0 nm

Table 1

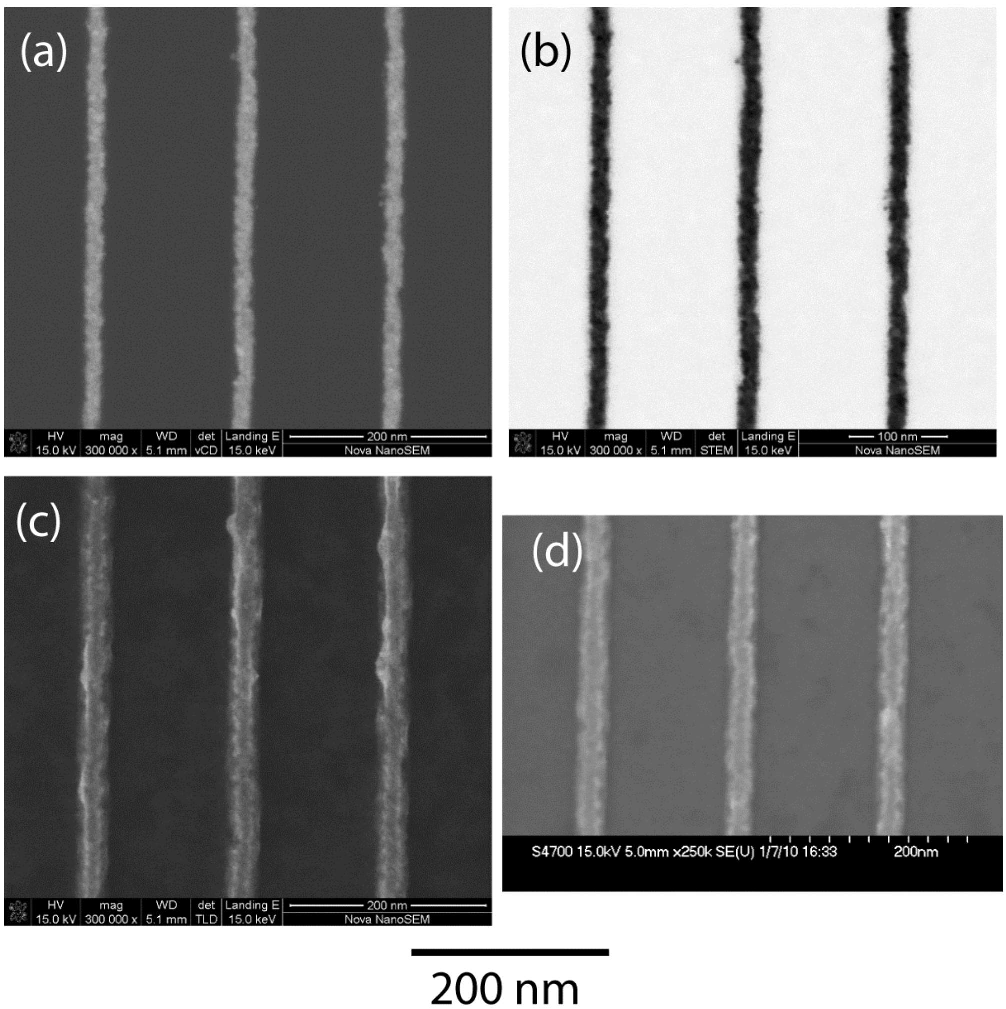

Figure 1. The four images used for the data shown in Table 1. Images (a-c) are of exactly the same region; image (d) was acquired on a different instrument and is of a region a few microns distance from the others.