Limits of model-based CD-SEM metrology

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Although the critical dimension (CD) is getting smaller following the ITRS roadmap, the scanning electron microscope (CD-SEM) is still the most general purpose tool used for non-destructive metrology in the semiconductor industry. However, we are now dealing with patterns dimensions in the same order of magnitude as the electron interaction volume and therefore, the usual edge-based metrology methods fail, because the edge effects are mixed up for sub 20 nm Si lines (see Figure 1).

Like scatterometry has extended the resolution of optical metrology through complex modeling of light-matter interaction, some electrons-matter simulation models[1] have been proposed. They could be used to improve accuracy and precision of CD-SEM metrology. However, these model-based approaches have their own fundamental limits mainly due to probe size with respect to the considered structure and noise. This paper analyses these limits assuming the model is perfect and the microscope has no systematic defect.

In this simulation study, we have used the model proposed by D. Nyyssonen[2], assuming to perfectly represent the SEM effects in the image.
For computational reasons, we have limited ourselves to the one-dimension signal profiles. The feature of interest is limited to trapezoidal lines with various CD, sidewall angles (SWA) and heights (see Figure 2). We have carried out the study with several beam energies, tilts and probe sizes.

Sensitivity analysis shows surprisingly that with typical noise amplitude, even sidewall angle and height can be determined with a reasonable precision using top view SEM images (see Figure 3). Since these precision figures depend on the geometries, we provide useful tables giving the ultimate precision for various dimensions (CD, height, SWA).
More details will be discussed during the conference.

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[1] C. A. Mack and B. D. Bunday, in (International Society for Optics and Photonics, 2015), p. 94240F.
[2] D. Nyyssonen, Proceedings of SPIE - The International Society for Optical Engineering 921, 48 (1988).

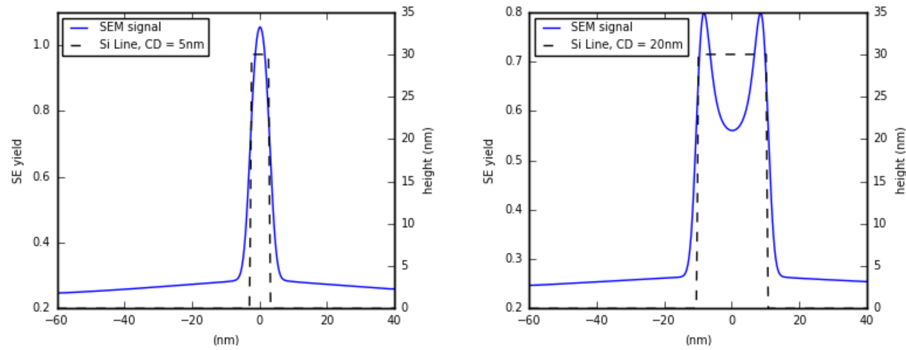

Figure 1: Simulated SEM signals for two Si lines, with CD of 5 nm (left) and 20 nm (right).

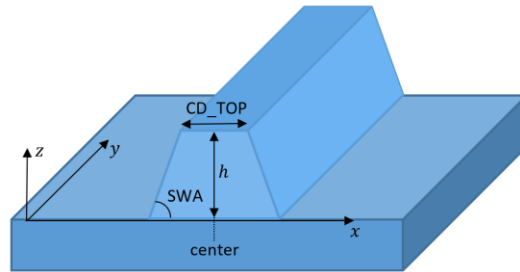

Figure 2: Trapezoidal Line. The line is defined by four parameters: the top CD (CD_TOP), the Sidewall Angle (SWA), the height (h) and the center of the line.

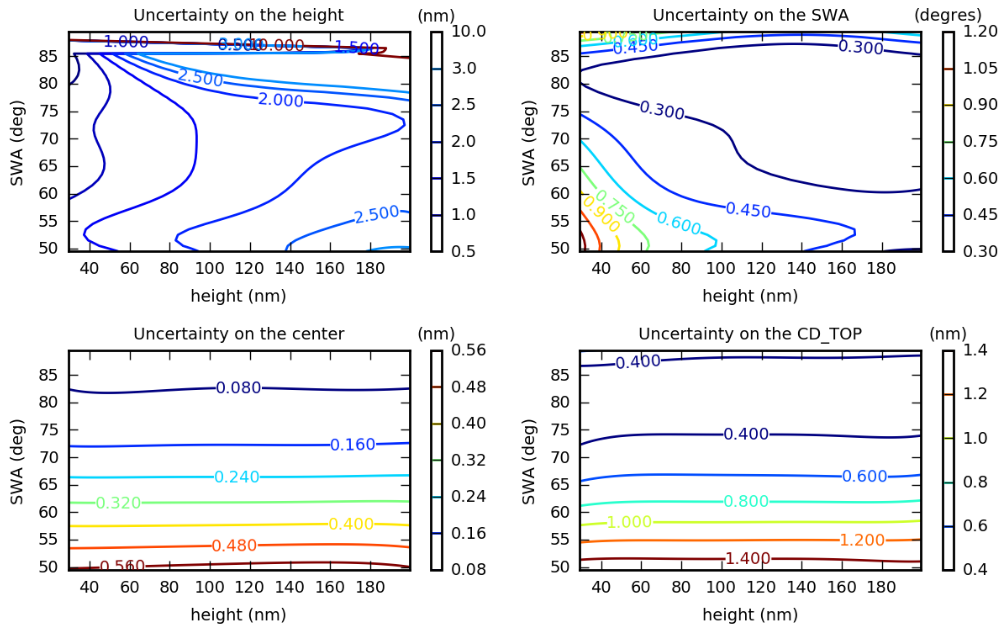

Figure 3 : Uncertainty on parameters estimation as a function of the SWA and the height of the line. The top CD of the line is 20 nm. The electron beam energy is 2500 eV, and the incidence is normal (zero tilt condition).