Optical lithography is printing photoresist features that are one tenth or smaller than the wavelength of the 193 nm UV light, with the use of various optical correction methods, which model and compensate for several errors in the lithography process down to sub-nanometer, essentially atomic levels.

The process has to rely on accurate and highly repeatable dimensional metrology, which is beyond the conventional one-dimensional line width measurements, and it must account for the contours and shapes of sub-10 nm structures. For this, the critical dimension measurement scanning electron microscope (CD-SEM) is the key metrology tool, but current instruments and methods cannot fulfill the requirements, especially for future sub-10 nm integrated (IC) structures.

For these structures optimized, better SEMs with sharper focus, sophisticated image and data acquisition methods and shape sensitive, physics-based modeling are needed. We report here on a few key improvements in all of these. These methods deliver unprecedented quality results, and serve as a good basis for the development accurate sub-10 nm 3D metrology.

We believe that with the implementation of these new methods 3D metrology is feasible and will serve well IC production, even on sub-10 nm structures.

**Need for better SEM imaging**

Even top-down images reveal a lot of 3D information. On this resist sample of intentional defect arrays delamination is evident. The smallest, about 2 to 3 nm size resist features are clearly visible, therefore measurable. 508 nm horizontal field of view, 6 keV, 86 pA.

The NIST fast imaging method uses 2D Fourier transform to line up many very noisy, fast images with sub-pixel accuracy to acquire a final sharp image. The traditional fast imaging method would keep the letters sharp, but blur the image. The amount of blur, caused by small nm-scale drift, is indicated by the fuzziness of the letters.

**Modeling complex 3D structures**

Measured and modeled sample images match closely using physics-based measurement method. In this case a trapezoid model was used, more sophisticated models are also possible and give closer match in the line shape.

**Pitch, width and line shape by physics**

Highly repeatable pitch values match within less than 1% with x-ray scatterometry results obtained on the same sample. The quality of these measurements would allow for measuring structures with sub-10 nm sizes.

<table>
<thead>
<tr>
<th>Width</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon</td>
<td>37.6 ± 0.5</td>
<td>37.4 ± 0.5</td>
<td>38.0 ± 0.5</td>
<td>37.8 ± 0.5</td>
</tr>
<tr>
<td>Silicon</td>
<td>37.4 ± 0.5</td>
<td>37.4 ± 0.5</td>
<td>37.4 ± 0.5</td>
<td>37.4 ± 0.5</td>
</tr>
</tbody>
</table>

The average instantaneous angles are ~5°, and there are significant asymmetries, with the B lines much sharper on the edges facing the wide gap than the ones facing the narrow gap.

Highly repeatable top and bottom width values match within less than 1% with x-ray scatterometry results obtained on the same sample. The quality of these measurements would allow for measuring structures with sub-10 nm sizes.

There is no physical reason that would make sub-10 nm 3D CD-SEM metrology unfeasible. We need to optimize SEMs, implement better image acquisition methods, and use shape sensitive, model-based evaluation techniques. With these 3D CD-SEM metrology will be able to provide indispensable information even on the smallest IC structures of the future.