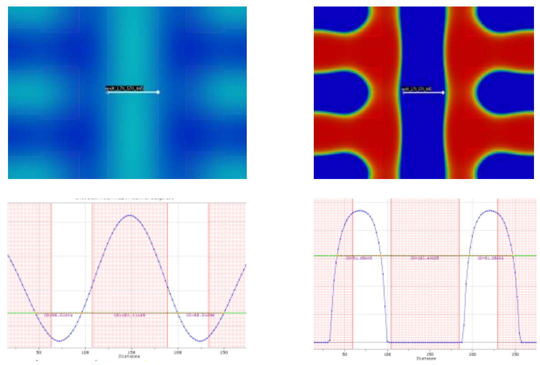
Fast Resist Development Model for Photolithography Process Simulation

Artak Isoyan, Lawrence S. Melvin III
Synopsys, Inc. 2025 NW Cornelius Pass Road, Hillsboro, OR 97124, United States
e-mail: isoyan@synopsys.com

Optical microlithography is a key technology used in integrated circuit fabrication. Its success can be attributed to the fidelity of layout pattern transfer to silicon, its high throughput, and its high yield. However, optical proximity effects create serious CD control problems. The proximity effects observed on real wafers are usually much larger than those expected from pure optical (diffraction) theory. This suggests that resist material and processing are important determinants of final wafer proximity effects. Traditionally, the use of lithography simulation has been for analysis of aerial image and cutlines. As the feature size becomes smaller, it becomes more important to include resist development processes to improve the robustness of the lithography process simulation [1-4]. Methods proposed for achieving this have included full-3D models of chemically amplified resists and simplified acid diffusion models. However, it is generally difficult to achieve both sufficient levels of accuracy and practical speeds of calculation, hence, it is necessary to model process simulation using specially developed approximation algorithms for CPU time consumption. For more accurate optical proximity correction (OPC), more sophisticated resist modeling is required. A few of the factors which affect resist are standing waves, pre- and post-exposure bake, acid diffusion and the development process. These effects are not the same for all resists, making resist modeling more complicated than a simple constant threshold model. The main criteria for an OPC resist model are prediction accuracy and fast calculation. The model should include all resist development process dependant parameters to produce necessary accuracy for advanced process nodes.

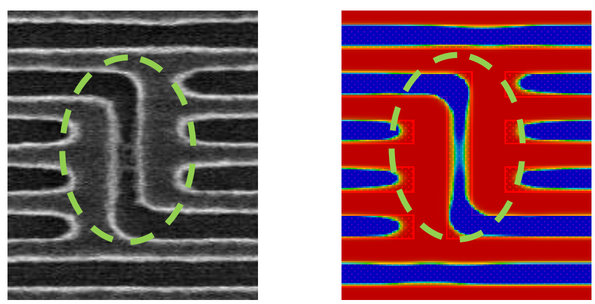
All optical models (including chemically amplified resist, diffusion and acid generation models) use a threshold model, where a critical energy and greater of optical exposure causes the resist to be removed. Also, this simple threshold model is true only for a specific resist image depth. To produce a completely developed resist profile, either multiple slices through the resist thickness are necessary, or the absorbed energy in the resist must be computed and then a time-dependant resist development model must be used. This significantly increases the computational time and complexity of the model.

In this study a new method for fast resist development process simulation proposed. This method takes into account the combination of all resist development dependant parameters. The method is based on the resist response function of exposure and development, in both the lateral and longitudinal directions. As a result, the model takes into account all resist development dependant parameters. This study proposes the implementation of the fast resist development model and extraction of the resist-process parameters through an optimization model. The optimization model takes the CD data from an experimental representative test pattern and the computed CD. A cost function (based on ΔCD) is minimized over the resist parameters. The verification of the optimized resist parameters will be done by comparing the computed CD with the experimental or simulated input CD data.



a) b)

Fig.1. An example of aerial image (a) and proposed resist model image (b) and their intensity plots.



a) b)

Fig.2. SEM image (a) of standard test pattern with pinching area and modeled resist image (b). Notice the good agreement with model.

References:

1. K. Hattori, J . Abe, H. Fukuda, Proc. of SPIE Vol. 4691, 1243-1253 (2002).
2. J. Li, Q. Yan, L. S. Melvin III, J. Vac. Sci. Technol. B **26**(**5**), 1808-1812 (2008).
3. Yoshihisa Sensu, Mariko Isono, Atsushi Sekiguchi, Mikio Kadoi and Toshiharu Matsuzawa, IEEJ Transactions on Fundamentals and Materials 124, 286 (2004).
4. Sang-Kon Kim and Hye-Keun Oh, Journal of the Korean Physical Society, Vol. 41, No. 4, pp. 456-460 (2002).