Optolith 2D Lithography Simulator

Advanced 2D Optical Lithography Simulator
Optolith is a powerful non-planar 2D lithography simulator that models all aspects of modern deep sub-micron lithography. It provides a fast and accurate alternative to costly experimental studies for evaluation mask printability and process control.
Key Benefits

- Models non-planar underlying topography effects
- 2D aerial image formation
- Projection, proximity, and contact systems
- g, h, i, DUV, and broad line sources
- Phase shifting, binary, and partially transmissive masks
- Defocus, arbitrary illuminator shape, spatial filtering, and partial coherence effects
- Complex Resist definition. Large library or user definable
Key Applications

- Photo Process development tool
- Post Process Analysis
- Using MaskViews, Optolith is fully interfaced to all commercial IC layout tools conforming to GDSII and CIF formats
- Simulation of dose effect on the photoresist optical properties during the exposure
- Verify printability of masks before committing resources to the fabrication of test wafers
Optolith 2D Lithography Simulator

Typical Lithography Process
Typical Lithography Process Flow

- Resist definition
- Resist deposition
- Mask setup
- Optical System Definition
- Exposure
- Post Exposure Bake
- Develop resist
- Operation, eg, Implant
- Remove resist
Complete Photolithography Process

- OiR 32
- AZ135OJ
- TSMR-V3
- AZ1318-SFD
- KTI820
- MD-PR1024
- XP-8843
- S-1400
- Shipley-1470
- Spectralith-5100

Resist Definition
- Can choose one or more of the 16 standard resists in the library
- Can define own resist by defining the Dill parameters
- Possible to define top and bottom Anti-reflective coatings, eg AquaTar
Complete Photolithography Process – Resist Deposition

- Here we deposit a 1.5um layer of AZ1350J resist onto a Non-Planar SiO2 formation
Complete Photolithography Process – Mask Setup

- 3 ways of importing Mask Information
- Manually creating a mask in MaskViews
- Directly within the ATHENA framework
- Possible to import a cutline across a GDSII or CIF file
- Defocus can be defined here
Complete Photolithography Process – Mask Setup

- Cutline across a GDSII outline can be used as input to Optolith
- Pink layer used to mask off Poly Etch, Yellow layer used to mask off Metal Etch
Complete Photolithography Process – Optical System Definition

- Illumination Source Wavelength and X, Z Tilt
- Illumination Source shape
- Projection system and Pupil type
- Aberration and Astigmatism
Complete Photolithography Process - Exposure

- User defined Dose
- Top, Bottom and Internal reflections considered
- Multiple exposure possible
Complete Photolithography Process – Post Exposure Bake

- Diffusion of PAC into resist
- Can Reflow resist according to material parameters
Complete Photolithography Process – Develop Resist

- Multiple Development models available
- Develop time and number of steps for etch defined here
- Sidewall angle can be calculated
Complete Photolithography Process – Operation and Resist Removal

- Here we see the trench has been implanted into and the resist removed
- Seamlessly integrates with ATHENA program group
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Process Analysis Capabilities
Exposure Dose Effect

- Intensity distributions and corresponding developed resist profiles obtained with and without the effect of dose on the photoresist optical properties.
Optical Proximity Correction (OPC)

- Optolith allows users to optimize mask design using interactive optical proximity correction for the printed image.
- Corrections are applied to the simulated aerial image to compensate for typical printability problems, including corner rounding, non-uniform linewidths, and line shortening.
Optical Proximity Correction (OPC)

- The layout file is either drawn within or imported into MaskViews.
- By overlaying the aerial image calculated by Optolith, deviations between the printed image and the layout are identified.
Optical Proximity Correction (OPC)

- TonyPlot displays the calculated image profile. Corrections for the differences between the image profile and the mask are applied by the addition of serifs to the mask.
Optical Proximity Correction (OPC)

- Improved agreement between the mask and the image produced with the Optolith OPC generator
Optical Proximity Correction (OPC)

- Cross-sectional view of the biased and unbiased image profile illustrates the enhanced printability of the corrected image.
- Both the contrast and the slope of the biased image are improved within the mask pattern.
The correction of the aerial image is performed through a series of iterative steps.

Corrections are made to the mask by adding or shifting serifs, and the corrected image is simulated using Optolith.
Multi-Parameter Process Control

- Optolith provides powerful extraction capabilities for geometrical parameters of the photoresist profile.
- This enables the analysis of CD control using Smile (Bossung) curves and Exposure-Defocus (ED) trees for plotting depth-of-focus and exposure latitude.
The resist profile data extraction features can be easily coupled with the design of experiment (DOE) capabilities of the Virtual Wafer Fab (VWF) to perform multi-parameter CD control experiments.

With optical projection lithography coming close to its resolution limits for deep sub-micron designs, users must consider a broader set of process parameters, such as reticle CD, numerical Aperture (NA), resist thickness, ABC development parameters, and partial coherence for a more complete analysis of lithography processes.
A response surface model (RSM) of the measured CD, presented as a contour plot, shows the ‘window’ of exposure dose and defocus values that yield CD close to the desired reticle CD.
The smile plot shows the measured CD as a function of defocus for a number of exposure doses.

This plot provides insight into the optimization of these parameters, as well as the resulting CD.
These plots illustrate how depth of focus changes with the exposure dose for three values of reticle CD.

This type of analysis is useful to optimize a process in which the lines in a layout appear in multiple focal planes.
Multi-Parameter Process Control

- The sidewall angles are also calculated as a function of exposure dose and depth of focus.
- This type of analysis provides useful information for image printability not available with traditional CD analysis techniques.
Phase Shifted Mask Lithography

- Optolith provides the capability to optimize the critical effects of multi-parameter PSM design
- The characterization of the stepper setup, and the resulting resolution and depth of focus benefits are simulated
Phase Shifted Mask Lithography

- Intensity profile for a checkerboard binary mask with a 0.375µm contact opening
Using a 180 degree phase shifted mask, the intensity profile can be dramatically enhanced.
Phase Shifted Mask Lithography

- ID outline across the mask illustrates the improvement in contrast and resolution of the image produced from the PSM design of Optolith.
Summary

- Optolith is a powerful addition to the ATHENA toolset, allowing flexible simulation of the Lithography process stage onto a non-planar substrate
- Optolith can also be used to improve printability by means of a range of impressive analysis methods