

ATHENA/Optolith Simulation of Proximity Lithography

1. Introduction

Photolithography simulation is a very important part of TCAD. Accurate and predictive lithography simulation saves time and money spent on development and calibration of semiconductor technology processes. Photolithography simulation has also become a critical element of modern design for manufacturability (DFM) flows. Most lithography simulators are focused on resolution enhancement for projection imaging. This “standard” lithography technology is getting more expensive for each subsequent technology node. The proximity printing (i.e. imaging without reduction lens) is obviously more cost effective in printing relatively big features on micron scale. This method is effectively used in many applications, e.g. power device and flat panel display manufacturing. This paper briefly discusses implementation and use of proximity printing module in ATHENA/Optolith.

2. Proximity Lithography

Proximity lithography is used to print images without expensive projection systems. The scheme of proximity lithography system is shown in Figure 3.

Light illumination of the mask creates the diffraction pattern in the resist film placed on some distanced (called gap) from the mask plane. Due to the diffraction effects in the gap, the aerial image in the resist film is a distorted representation of the mask shapes. The extend of distortion depends on the gap size as well as on the radiation wavelength and size and shape of the mask features.

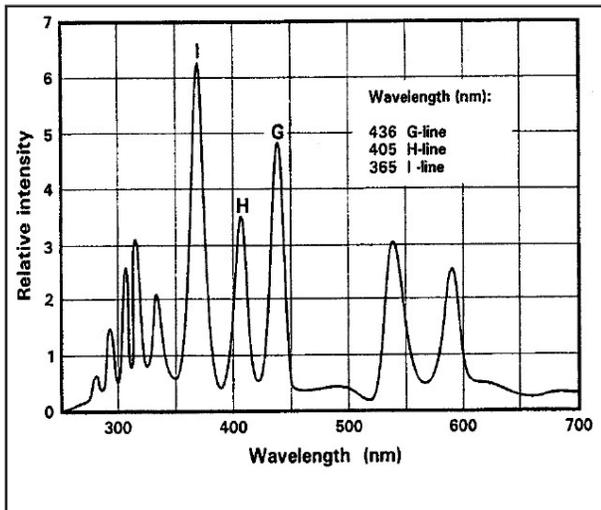


Figure 2. Spectrum of a high pressure Hg lamp.

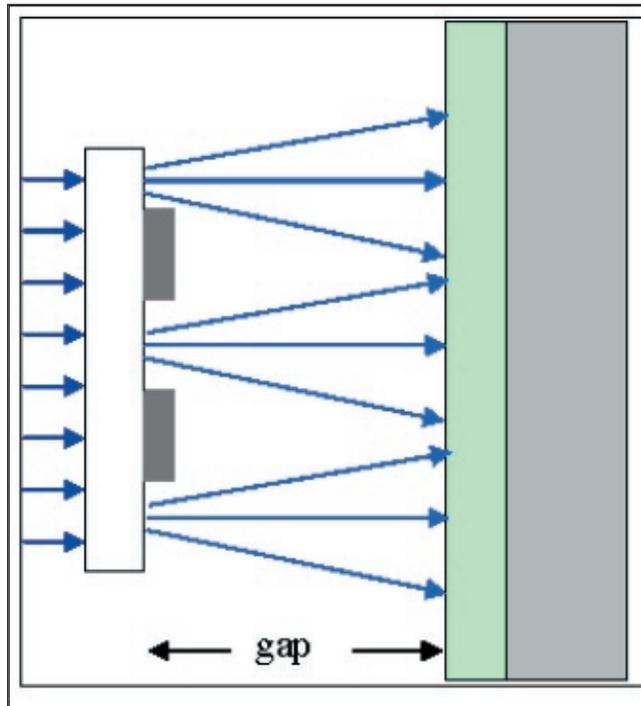


Figure 1. Scheme of proximity optical system

The broadband illumination is typically used for proximity printing. Figure 2 shows the light spectrum of a high pressure Hg lamp. In proximity lithography simulation this spectrum could be approximated by multiple exposure method in which images from main lines (i-, h-, and g-lines) could be superimposed.

3. Simulation Model and Parameters

Optolith simulates all four key steps of the photolithography processing: imaging module calculates aerial image of the mask features; exposure modules simulates light propagation through photoresist and calculates photo active component (PAC) distribution; post-exposure bake module simulates redistribution (diffusion) of PAC; and development module calculates removal of exposed photoresist. The last three modules are the same for projection and proximity lithography, while a separate imaging module is implemented for proximity printing. Proximity imaging is invoked by specifying parameter GAP (the distance between mask plane and resist surface) in the IMAGE statement.

The proximity lithography image is calculated by the Fresnel diffraction using Fast Fourier Transform (FFT). The simplified version of Beam Propagation Method

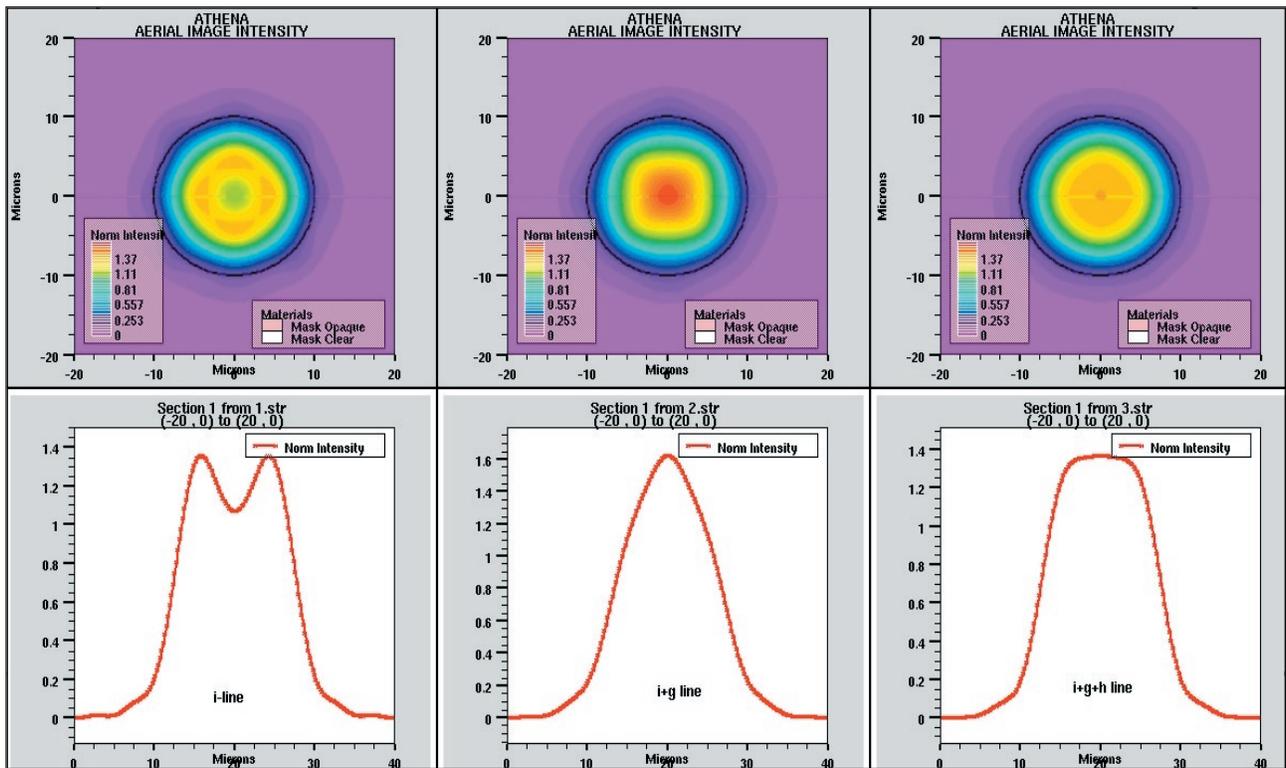


Figure 3. Simulated aerial image intensity.

(BPM) is used to describe light propagation through the gap. Unlike more complicated BPM in photoresist, in this case the gap is filled with homogeneous material, so refractive index does not depend on coordinates in the gap. The model is implemented for rectangular and circular masks as well as for masks consist of one or several rings. The parameters X.CIRCLE, Z.CIRCLE, RADIUS, RINGWIDTH, and MULTIRING in the LAYOUT statement can be used to specify the circular or ring mask features. Also, the half-tone masks can be specified by the TRANSMIT parameter in the LAYOUT statement.

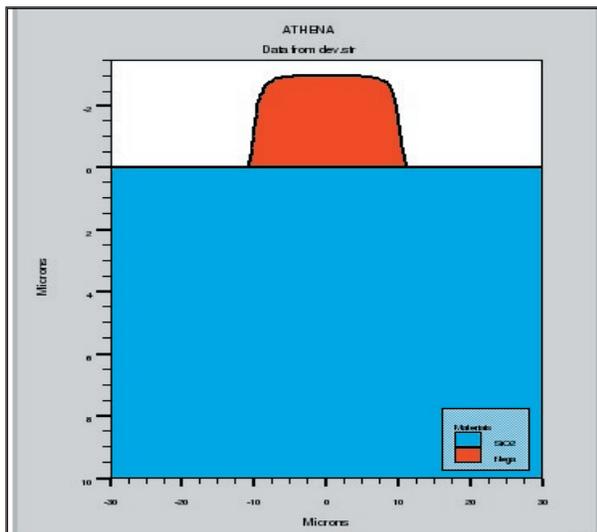


Figure 4. Simulated resist shape.

The example of aerial images of a circular mask with diameter of 20 microns is shown in Figure 3. Note, that as expected the best resolution is achieved for the broadband illumination approximated by combination of i-, h-, and g-lines.

The exposure A, B, and C parameters as well as Dill's development rate parameters E_1 , E_2 , and E_3 are usually provided by the photoresist manufacturers. However, they might be not provided for a specific broadband illumination. In this case some parameter fitting as needed. Several practical tools provided by Silvaco could be used for such fitting/calibration. These include *Optimizer* and DBInternal capabilities of *DeckBuild* and *Virtual Wafer Fab (VWF)* and its *Production Tools*.

Finally, Figure 4 shows an example of simulated photoresist shape obtained by proximity printing with approximated broadband illumination (shown in the third plot of Figure 3).

4. Summary

This article describes capabilities of proximity printing module of *ATHENA/Optolith*. It is shown that the module can be successfully used for different aspects of lithography process design including optimization of exposure dose, light intensity, photoresist thickness, half-tone mask transmittance, mask shapes, and other parameters.