Tutorial on simulation of standing waves and proximity effects in lithography processes using Optolithium

Simulation of standing waves patterns in resist and process modifications to reduce them

Please refer to lecture 24 of the course for the theory behind the simulation experiments.

Objectives:

1. Observation of standing wave patterns in photoresist
2. Post exposure bake for reducing the effect of standing waves
3. Use of anti-reflection coatings to reduce standing wave amplitude

Experimental setup

Load the setup file "standing-waves.opl".

Familiarize yourself with the settings, specifically the following:

- Parameters => Wafer processes
- Parameters => Resist
- Parameters => Mask
- Parameters = > Post Exposure Bake

Observe the simulation outputs:

- Aerial image
- Image in resist
- Exposed latent image
- PEB latent image
- Develop Time Contours
- Resist Profile

In that sequence.

Make notes on your observations.

Experiment 1: Reduction of the impact of standing waves using post exposure bake

1. Set the post exposure bake time to 10 sec. Observe the PEB latent image and resist profile.
2. Change the PEB time to 20 sec, 50 sec and 100 sec. Observe the evolution of the PEB latent image and resist profile with PEB time.
3. Record your observations and comments on the observations.

Experiment 2: Optimization of the PEB time by PEB time sweep.

1. Click on simulations => Simulation Sets
2. Input variables => PostExposureBake => Add ("+") PebTime and PebTemp in that order => PebTime => Start = 10 sec, Stop = 100 sec, Interval = 10 sec, PebTemp => Start = 110^{o}C, Stop = 120^{o}C, Interval = 5^{o}C.

3. Output variables => Resist Profile => Accept => Launch Simulations => Set #1 => Metric: SW Amplitude
4. Record your observations and comments on the observations. What is the minimum PEB time required for achieving the lowest SW amplitude at PEB of 120^{o}C? Comment on the other temperatures.
5. Run individual simulations at the value obtained in 4 above and manually set the PEB parameters under Parameters => Post Exposure Bake. Compare the resist profile obtained with the resist profile for 100 sec PEB.

Experiment 3: Reduction of the standing waves using an ARC layer

1. Set post exposure bake temperature to 120 ^{o}C and time to 50 sec.
2. Record the "Exposed Latent Image in Resist"
3. Parameters => Wafer Processes: Edit "Step 3". We will use a SiON layer below the resist to reduce the standing waves. The refractive index of a typical SiON layer is 2.35 – i 0.61. Insert these values. Set the thickness to 25 nm and observe the "Exposed Latent Image in Resist". How does it compare to the observations in step 1 of this experiment? Set the thickness to 100 nm and observe the "Exposed Latent Image in Resist". Compare with the previous observations.
4. Increase the PEB time to 100 sec. Compare the resist profile with what you observed in step 2 of experiment 1 for PEB time of 100 sec.
5. Record your observations and comment on the results.

Simulation of proximity effects

Objectives:

1. Observation of proximity effects
2. How do proximity effects vary with feature sizes
3. Impact of numerical aperture on proximity effect

Experiment 4: Understanding proximity effect

Please note that for the simulation of proximity effects, we would use the only 2D mask that is available in the mask library of the simulator. Several simulations do not converge and there is some incompatibility with the current versions of the plotting modules of python. We are not able to locate the older versions of the matplotlib package that is required by the program. Hence only aerial image simulations can be executed.

1. Load the setup file "proximity.opl"
2. See Parameters => Mask. Note the features in the mask.
3. See Parameters => Imaging Tool. Note the wavelength of light used and the numerical aperture value.
4. Observe the aerial image. Record your observations on the proximity effect.

Experiment 5: How do proximity effects vary with feature sizes

1. Decrease the Mask Feature Width to 250 nm. Observe the aerial image. Explain the observations.

2. Increase the numerical aperture under Parameters => Imaging Tool, to 0.5. Observe the aerial image. Explain the observations.

Disclaimer: Please note that the various parametric values are chosen to illustrate the lithography process and may not correspond to lithographic processes you may want to execute in experiments. For realistic simulations corresponding to any particular use case, the parameters provided by the supplier of the lithography system, and the supplier of the photo resists, and/or other reliable sources should be used.