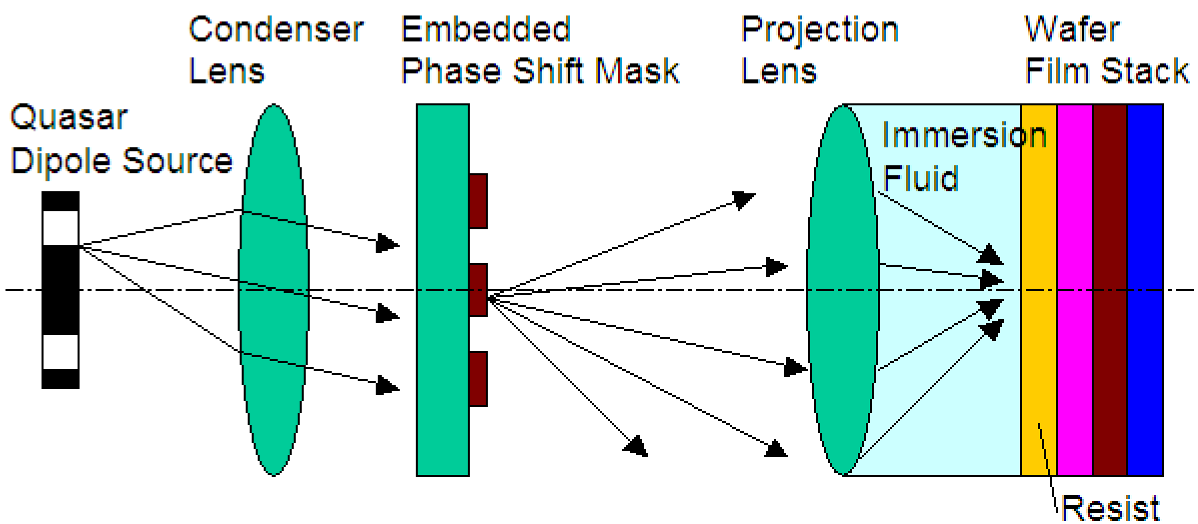
EM EXPLORER At The Edge

Oblique Incidence Effects of 3D Mask in Hyper-NA Lithography

Overview

This example shows the use of the FDTD solver (for 3D thick mask simulation), the lens simulation engine and the film stack simulation engine. By cascading these simulation engines together via TCL scripts, the user is able to rigorously simulate a hyper-NA immersion lithography process under partially coherent oblique illumination.



Projection System

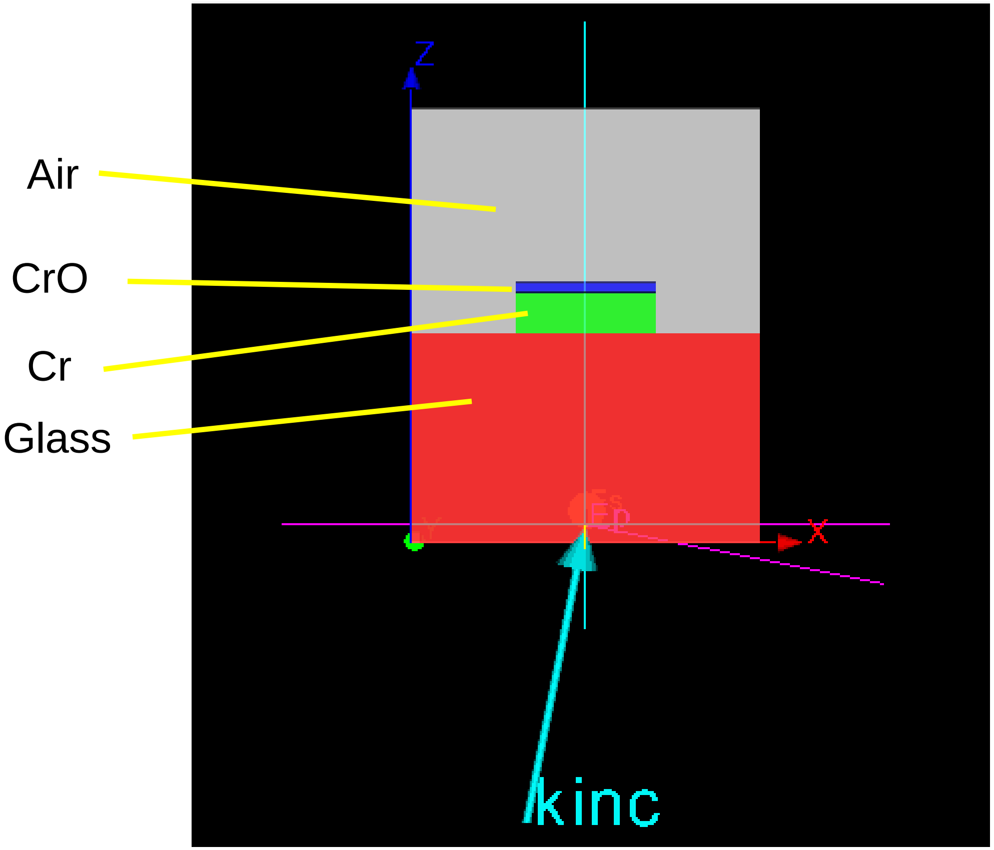
- Wavelength = 193 nm
- NA = 1.35
- Magnification = 0.25 (4x reduction system)
- Immersion Fluid Index = 1.437

Dipole Illumination Source

- The dipole illumination in this example consists of two fan shapes.
  - One at 0°
  - The other at 180°
- Fan size:
  - Outer sigma = 0.95
  - Inner sigma = 0.85
  - Fan angle = 30°

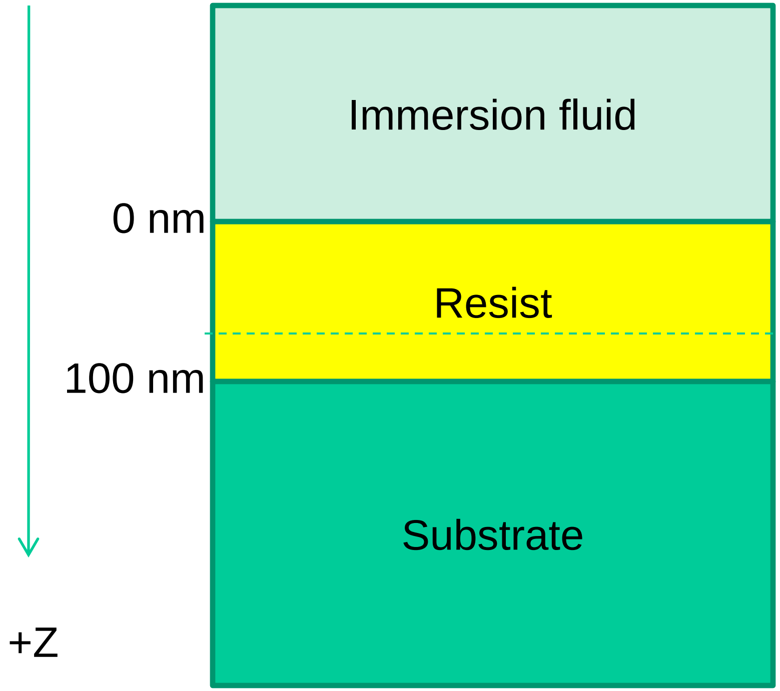
- Polarization: TE (or s, or azimuth) polarization

Binary Chrome Mask



- Two masks of periodic line patterns are simulated in this example.
- One has pitch=80nm and the other has pitch=100nm. Both have line width=40nm.
- All the above dimensions are specified on wafer scale.

Wafer Film Stack



- For simplicity, a substrate with index matched to resist is used in this example.
- Light intensity distribution is computed inside the resist.
- A constant threshold model is used to calculate resist critical dimensions (CD) on the intensity sampled at 80nm below the resist top surface.

Simulation Step 1

- In this step, we compute mask transmission function.
- This can be done in two ways.
  - Normal incidence model: A single transmission function is computed using a normal incident planewave.
  - Oblique incidence model: Multiple, angle-dependent transmission functions are computed using oblique incident planewaves.
- Apparently the former is an approximation to reality.
- In this simulation example, both methods are used and their results are compared.

Simulation Step 2

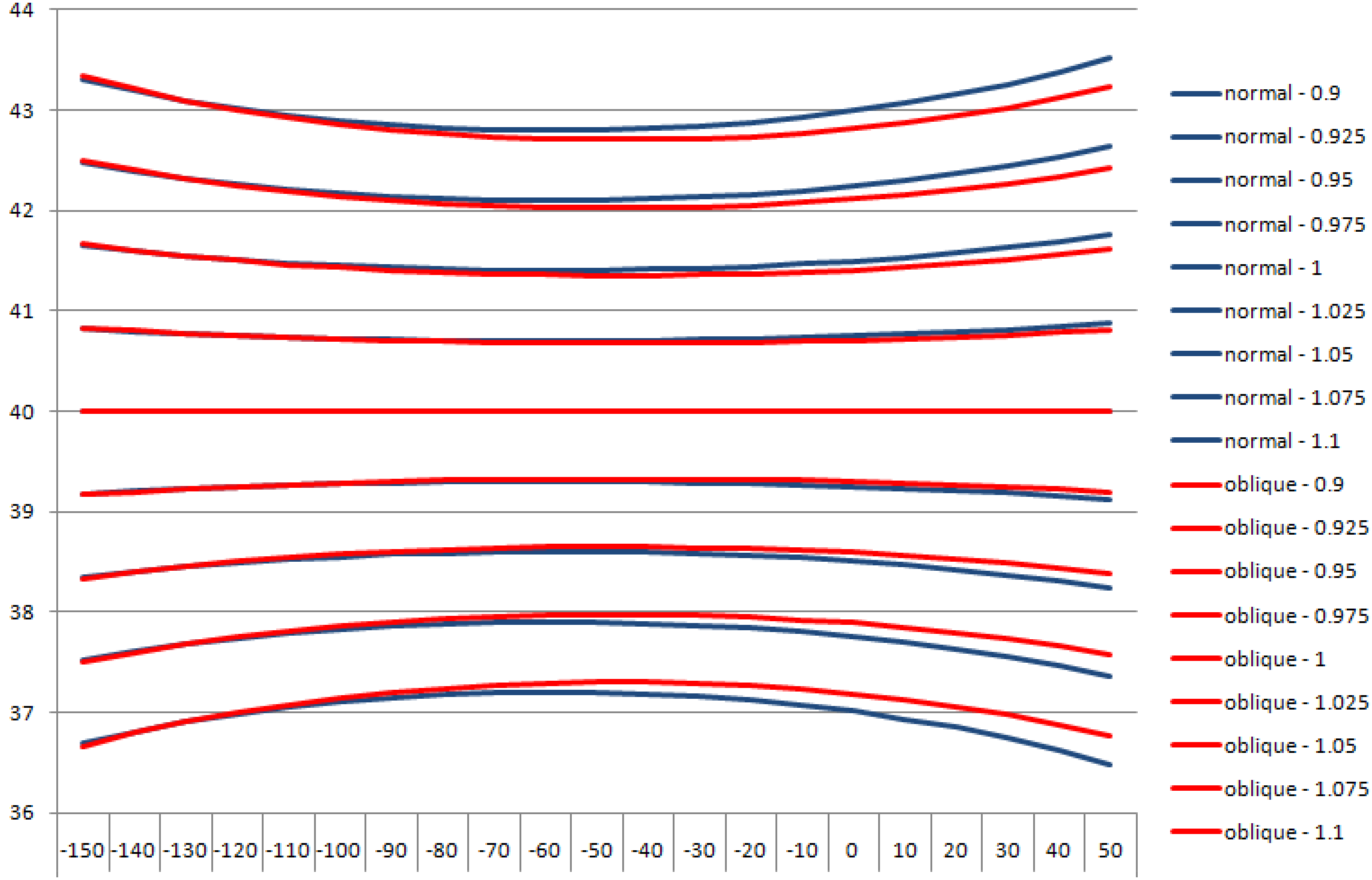
- We compute light intensity distribution inside resist in the step.
- This is done as follows:
  - The source is discretized into a number of point sources.
  - Each point source produces an oblique incident planewave onto the mask.
  - The transmitted near field of the mask can be calculated using the transmission function computed in step 1.
  - The near field is then propagated into the resist using the lens simulation engine and the filmstack simulation engine.
  - The total intensity distribution is obtained by adding the contribution from all point sources together.
- Defocus effects are taken into account in this step.

Simulation Step 3

- Finally we calculate resist CDs using a constant threshold model.
- Nominal exposure dose (i.e., threshold) is first calculated based on an anchor structure.
  - In this example, the structure of pitch=80nm and line width=40nm is chosen as the anchor structure. The anchor CD is set to 40nm at defocus=-60nm.
  - Note, the nominal dose is calculated separately for the normal incidence model and the oblique incidence model.
- Then resist CDs of all structures at various focus and exposure conditions are calculated using the nominal exposure dose.

Bossung Curve

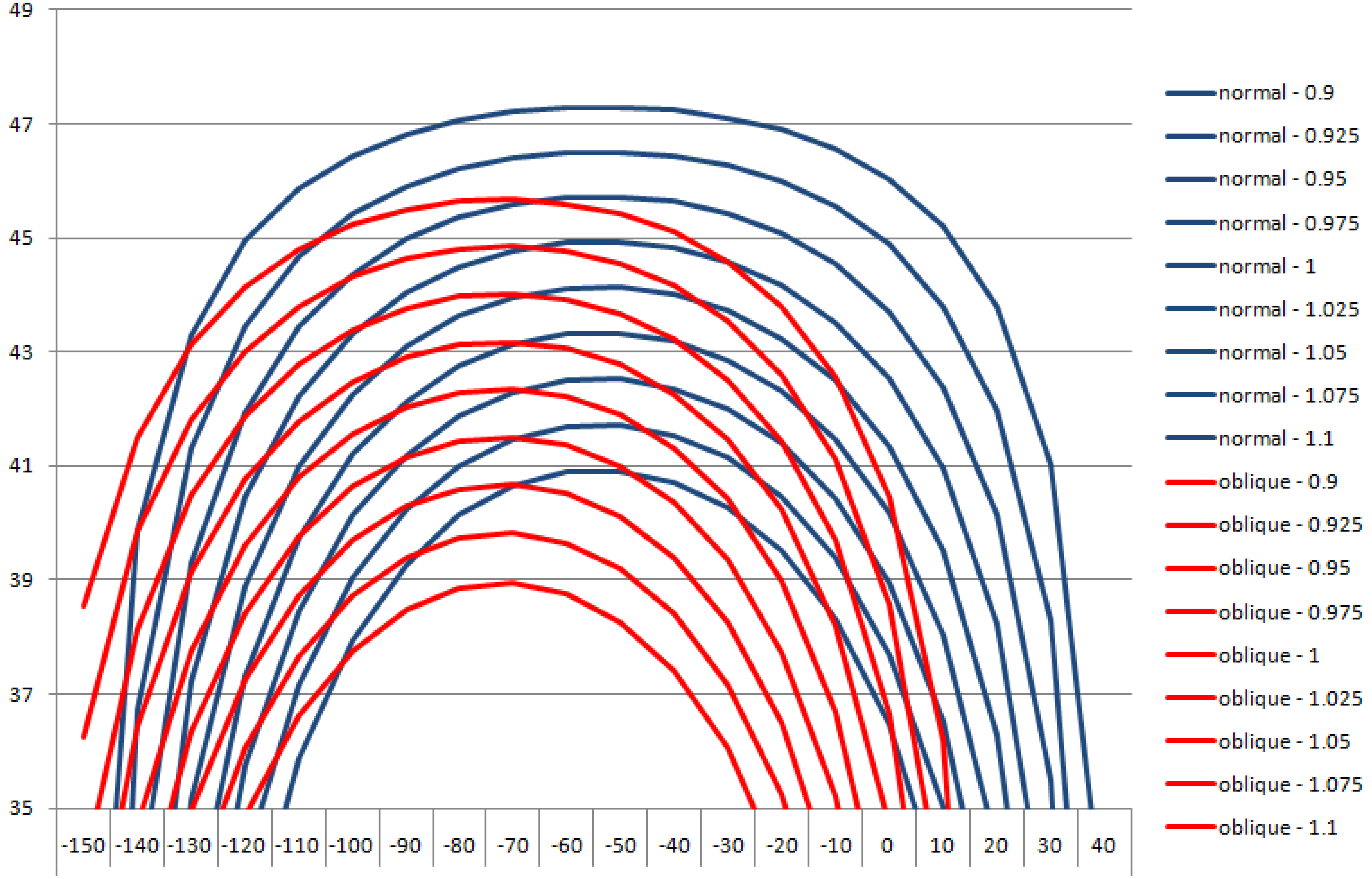
Pitch = 80nm, Width=40nm



The difference is small between normal and oblique incidence models for the anchor structure

Bossung Curve

Pitch = 100nm, Width=40nm



The difference is large between normal and oblique incidence models for non-anchor structures

Sample Resist Images

(Oblique Incidence Model)

F=-100nm F=-50nm F=0nm F=50nm

P=100nm

P=80nm