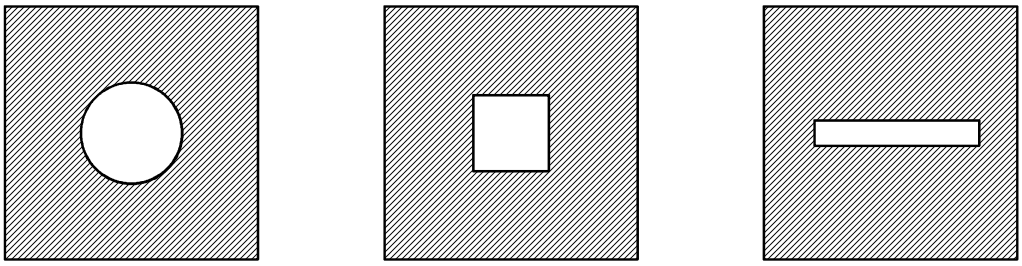
N.Cheung, Sp 2008

EE 243: ADVANCED IC PROCESSING AND LAYOUT

Homework Assignment #6 (Due Mar 19 Wed)

Problem 1 Printing of small defects

Projection printing is used to print small transparent defects of three different shapes but equal areas (0.4 λ/NA × 0.4 λ/NA). Which one of the three defects will have the highest peak intensity ? Explain concisely (with sketches if necessary) your reasoning.



Hint: For defects sizes smaller than the Rayleigh limit ($0.61\frac{\lambda}{NA}$), the patterns behaves like a collection of coherent points sources within the transparent area. The intensity on the image plane is just the square of the summation of the electric fields contributed by sources at x_i:

$$I(x) = \left| \sum_i E_i \ (x - x_i) \right|^2$$

Problem 2 Projection Printed Feature Type Effects: Go to **LAVA** at **http://cuervo.eecs.berkeley.edu/Volcano/** then **Applications** and then the **Pattern and Aberration Interaction.** Leave **Aberration** blank and select **Mask** and then the upper left icon with a vertical line end. Click on **Submit to SPLAT** to get the intensity across the line near the line end. Then rotate the yellow cut line to see the intensity through the line end. The normalized feature size is 0.6 λ/NA (the default is λ = 0.5 and NA = 0.5). Toggle the colors of your choice (B&W on light background saves ink) and **then print or save as jpg file**.
[Hint:] Best to use cut-lines of a fixed length such as 2.0 um, print result, draw a line and from the 0 and 1.5 intercepts compute the slope.

a) Compare the image slope at the 0.3 intensity level normalized to λ/NA. for the two features (the graphs are normalized to λ/NA).

b) Evaluate the normalized image log slope = $NILS = w\frac{\partial(\ln I)}{\partial x} = \frac{w}{I}\frac{\partial I}{\partial x} = S_I^x$ for these two images. Assume a value of I = 0.3 to simplify the calculation. In practice the maximum value of the formula along the image is used. This is because the exposure level might be adjusted to find the best set-point and NILS accounts for this. Any units will work because the sensitivity of I to x written as S_I^x is a unit less quantity and is the fractional change per fractional change. The minimal acceptable value is about 2.5 for printing in photoresist.

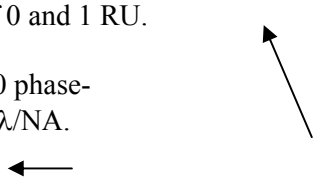
c) Repeat for a defocus of 1 Rayleigh unit. That is in **Select Aberration** set the **defocus** to 1.0 in units of λ/NA. You may need to go back to the LAVA main page to completely reset the applet so that the input file shows 4: 1.0. After the plot is made, check the value that was used by clicking **Back to Main Panel**.

Problem 2 Annular Illumination:
A periodic line pattern of a k_1 =0.4 line and k_1 = 0.4 space is to be printed. Use the LAVA Basic Projection printing Applet for simulation.

a) First, ***estimate*** (not simulate) the optimum Off-Axis Illumination (OAI) pupil position (perpendicular to this line). Show your reasoning.
b) Use an annular illumination with result from part a) as the average annulus radius and an annular width of 0.1 of the pupil radius to simulate the pattern. Record the maximum and minimum intensities and compute the contrast for focal positions of 0 and 1 RU.

Problem 3 Alternating Phase-Shift Masks: Run the deck shown for a 180 phase-shifting mask that has a mask period of 1.4 λ/NA and a wafer period of 0.7 λ/NA.

a) Find the **contrast** in focus (**Change 4: 0.44 to 4: 0.0**).
b) Find the duty cycle [(region of x where I(x) < 0.3)/(period)]
c) Find the **contrast** for 1 RU defocus (**Change 4: 0.0 to 4: 1.0**).



If you are interested, the detailed values are available by deleting DrawPlot.html in the URL and hitting return to access the sessions. Then look in the .txt file corresponding to the feature type.