ECE 6450 Homework #5

1.) An i-line proximity printer is used to print metal lines on a wafer that is non-planar due to previously printed features in underlying layers. The printer is capable of 20 um gaps. A.) If the photoresist thickness varies from 3 um to 12 um (a little bit of an extreme case), what is the minimum line widths that can be printed in the regions with thin and thick resist (add the resist thickness to the gap thickness in your calculations)? B.) If the proximity printer is replaced with a contact printer (zero gap), what are the new minimum printable features possible?

2.) By the year 2008, the "semiconductor roadmap" calls for exposure tools with wavelengths of 157 nm, a process that results in a k of 0.35 and optics with a numerical aperture (NA) of 0.8. A.) What is the minimum printable feature in a stepper system? B.) What is the depth of focus? C.) Discuss the limitations these systems will impose on the planarization of the wafer? (This is a key challenge for process development.)

3.) A photoresist with a contrast of 0.85 at 248 nm is used with a projection system capable of a minimum optical intensity in the areal image (on the wafer) of 25 mW/cm^2. A.) What maximum intensity is required of the exposure tool to insure the pattern is transferred to the wafer? B.) If the photoresist requires 400 mJ/cm^2 to insure all the resist is removed in developer, what is the minimum exposure time required to insure complete removal of the resist in the developer? C.) What is the maximum exposure time allowed to insure the low intensity (dark fields) of the areal image are not removed in the developer solution.

ECE 6450   Solutions for Homework #5

1.) Since all the resist must be exposed the effective gap is the sum of the air gap (20 um) and the resist thickness (3-12 um). Thus,

$$W \min \approx \sqrt{0.9(0.365)(20+3)} = 2.75 \ \mu m$$
$$W \min \approx \sqrt{0.9(0.365)(20+12)} = 3.25 \ \mu m$$

while for a contact printer,

$$W \min \approx \sqrt{0.9(0.365)(3)} = 1.0 \ \mu m$$
$$W \min \approx \sqrt{0.9(0.365)(12)} = 2.0 \ \mu m$$

2.)

$$W \min \approx k \frac{\lambda}{NA} = 0.35 \frac{0.157}{0.8} = 0.069 \ \mu m$$

$$\sigma = \frac{\lambda}{NA^2} = \frac{0.157}{0.8^2} = 0.245 \ \mu m$$

The depth of focus is less than a micron. Thus, the full stepper field (sometimes 2-3 cm on a side) must be flat with less than 0.245 um. This is a strong constraint and is the main reason the damascene process sequence (discussed in class is being perfected).

3.) A.) For the pattern to be transferred, CMTF<MTF. Thus,

$$\frac{10^{1/0.85} - 1}{10^{1/0.85} + 1} < \frac{I - 25}{I + 25} \Rightarrow I > 375 \ mW / cm^2$$

B.) The minimum time is defined by,

$$t(375 \ mW / cm^2) > 400 \ mJ / cm^2 \Rightarrow t > 1.1 \ \sec onds$$

C.) The maximum time is defined by,

$$t(25 \ mW / cm \ \ ) < 400 \ mJ / cm^2 \Rightarrow t < 16 \ \sec onds$$