Homework #10 Solutions

Problem #36

(a) The mask is made of a very thin piece of glass with Cr as the absorber. The mask is flexible and it is comformable to the substrate for intimate contact. Because of this, the resolution the alignment and the exposure uniformity across the wafer can be improved.

(b) Practical resolution is about 0.6 (220nm/2) = 70nm linewidth. This is also shown experimentally.

(c) This is a matter of opinion. Difficulty of making the mask and inspecting it is one reason. Dust particles on the mask are hard to remove. Another is the fear in the industry that such contact would cause damage, though this has never been demonstrated. Alignment of mask to substrate is another potential problem.

(d) This tool can be made very inexpensively. It is easy to operate and can print very small features. For these reasons, it is very useful for research.

(e) Resolution should scale with wavelength, so the answer given in (b) should be multiplied by 400/220 = 1.8.

Problem #37

a) According to Hecht, $I(\theta) = I(0)\left(\frac{\sin\beta}{\beta}\right)^2$, where $\beta = \frac{2\pi W}{\lambda}\sin\theta$, or $\theta \approx \sin\theta = \frac{\lambda\beta}{2\pi W}$. The image width *W'* is $W' = 2G\tan\theta \approx 2G\theta \approx \frac{G\lambda\beta}{\pi W}$.

b) We can define W' to be either the FWHM of the main lobe, or the distance between the first zero crossings of the sinc function. For FWHM, for W=0.5 um, $\beta = 1.8955 \Rightarrow W' = 1.33\mu m$ For zero crossings, $\beta = \pi \Rightarrow W' = 2.2\mu m$

c) Results in part b) are not reasonable because the conditions for Fraunhoffer diffraction are not met. For Fraunhoffer diffraction we should have $W^2/(\lambda G) << 1$ and for these parameters it equals 0.25. Also, the slit is only two wavelengths wide, so the model is not accurate. A more accurate model can be established with Fresnel diffraction. The model presented in the article, which is based on treating the slit as a metal-clad waveguide, is far more accurate than either the Fraunhofer or the Fresnel model.

Problem #41 (aka 38)

Since $I = (E)^2 \propto e^{-2\frac{2\pi}{\lambda}kx}$ where k is the imaginary part of the refractive index, for 95% attenuation, $x = \frac{\ln(0.05)}{-4\pi k}\lambda = 30nm$.