Errata - Fundamental Principles of Optical Lithography by Chris A. Mack

Errors not yet corrected:

1. p. 45, equation (2.51) is missing the 1/pitch scaling factor that is required when using the comb function. The correct equation should read

$$t_m(x,y) = \sum_{j=-\infty}^{\infty}\sum_{k=-\infty}^{\infty} t_r(x + jp_x, y + kp_y) = t_r(x,y) \otimes \frac{1}{p_x p_y} comb\left(\frac{x}{p_x}, \frac{y}{p_y}\right)$$

2. p. 63, the sentence before equation (2.101), the phrase in parentheses should be changed from "(that is, an integration over the image plane)" to "(that is, an integration over the object plane)".

3. p. 64, last sentence in paragraph following equation (2.105), the phrase "expressed as convolutions in the image plane" should be changed to "expressed as convolutions in the object plane".

4. p. 187, equation (4.162) is missing the divide symbol (/) between the wavelength and Avogadro's number. The correct equation should read

$$C = \frac{\Phi a_m \lambda}{N_A hc}$$

5. p230, equation (6.20), the 2D *RDPSF* is missing a 2 in the denominator. The correct equation is

$$RDPSF(r) = -\frac{1}{2\pi\sigma_D^2} Ei\left(-\frac{r^2}{2\sigma_D^2}\right)$$

6. p251, the sentence after equation (6.98) should be changed from "The rest of the *CovPSF* simply gives the ratio $dV/2\sigma_D$ …" to "The rest of the *CovPSF* simply gives the ratio dV/σ_D …".

7. p286, equation (7.80) should read

$$t_{dev} = \int_0^D \frac{dz}{r(z)} = \frac{1}{r_0}\int_0^D \left(\frac{I_z(0)}{I_z(z)}\right)^{\gamma} dz$$

8. p490, glossary entry for Zernike Polynomial, the name "Fritz Zernike" should be correctly spelled as "Frits Zernike".

Errors corrected in the Second Printing:

1. p48, bottom of first paragraph, the reference "see section 2.1.3" should read "see section 2.1.4".

2. p238, last sentence of the first paragraph should be deleted: "In general, the Poisson distribution is a good approximation to the binomial distribution whenever $TL > 1$ (that is, you expect to see more than one photon in the allotted time)."

3. p239, first paragraph of section 6.4.2, the last sentence "And, for any reasonably large volume ($CV > 1$), this binomial distribution will also be well approximated by a Poisson distribution." should be changed to "And, as before, this binomial distribution will also become a Poisson distribution by letting dV go to zero."

4. p244, the sentence preceding equation (6.62) should be changed from "After exposure, the number of photogenerated acid molecules Y will be" to "After exposure, the number of remaining (unexposed) PAG molecules Y will be".

5. p245. the sentence preceding equation (6.66) should be changed from "At this point it is useful to relate the number of acid molecules per unit volume Y to the…" to "At this point it is useful to relate the number of remaining PAG molecules per unit volume Y to the…"

6. p246, 2nd paragraph, the sentence "Ignoring the photon shot noise, the probability distribution for the number of acids in a given volume is approximately Poisson" should be changed to "Ignoring the photon shot noise, the probability distribution for the number of acids in a given volume is Poisson" (that is, the word "approximately" should be deleted).

7. p246, the first part of equation (6.72) is incorrect. It should be:

$$\sigma_{h^*} = \sqrt{\frac{\langle h^* \rangle}{\langle n_{0-PAG} \rangle}}$$

8. p249, equation (6.90) should read

$$CovPSF = \frac{1}{dV\, t_{PEB}^2} \int_0^{t_{PEB}} \int_0^{t_{PEB}} E\big(y(t)\, y(t')\big)\, dt\, dt'$$

9. p249, equation (6.93) should read

$$P(y(t') = 1 \,|\, y(t) = 1) = \lim_{r' \to 0} \frac{e^{-r'^2/2\sigma^2}}{\sqrt{2\pi}\sigma} dV\,, \quad \sigma^2 = 2D\left|t - t'\right|$$

10. p250, equation (6.94) should read

$$CovPSF = \frac{dV}{4\pi D\, t_{PEB}^2} \int_0^{t_{PEB}} \frac{e^{-r^2/4Dt}}{\sqrt{t}} dt \int_0^{t_{PEB}} \frac{e^{-r'^2/4D\left|t-t'\right|}}{\sqrt{\left|t-t'\right|}} dt'$$

(note that the only change is that the second instance of *r* is replaced by *r*'.)

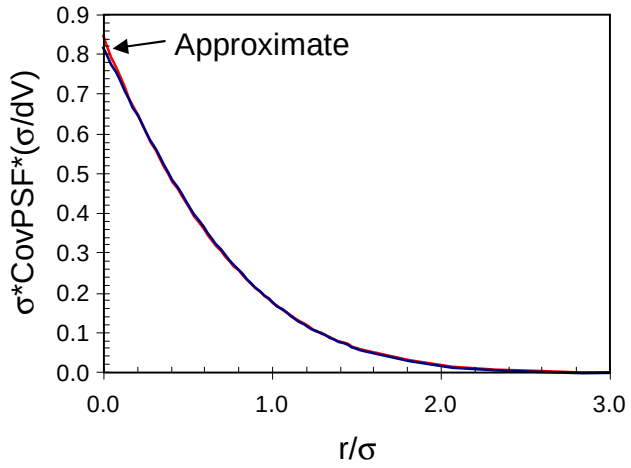
11. p250, equation (6.95) should be changed to

$$\lim_{r'\to 0}\frac{1}{\sqrt{4\pi D}\,t_{PEB}}\int_0^{t_{PEB}}\frac{e^{-r'^2/4D|t-t'|}}{\sqrt{|t-t'|}}dt' = \frac{t_{PEB}-t}{t_{PEB}}RDPSF(0,t_{PEB}-t)+\frac{t}{t_{PEB}}RDPSF(0,t)$$

12. p250, the sentence before equation (6.97) should be changed from "A numerical integration shows that the 1D *CovPSF* is very similar to the *RDPSF*, but with the diffusion length replaced by $\sigma/2$:" to "A numerical integration shows that the 1D *CovPSF* is very similar to the 1D *RDPSF*:". Additionally, equation (6.97) should be changed to

$$CovPSF(r)\approx 1.05\frac{dV}{\sigma}RDPSF\left(r\right)$$

13. Figure 6.9 should be replaced by



14. p250, last paragraph, the second sentence should be changed from "The shape of the *CovPSF* is very similar to that of the *RDPSF*, but with an effective diffusion length that is less by a factor of 2." to "The shape of the *CovPSF* is very similar to that of the *RDPSF*."

15. p251, the bottom equation (6.98) should be changed to

$$\sigma_{h_{eff}}\approx\sqrt{\frac{dV}{\sigma_D}}\sigma_h$$

16. p251, the third sentence after equation (6.98) should be changed from "In other words, *dV*/2 represents how close the acid must come to a blocked site before it can potentially participate in

a deblocking reaction (called the capture range, *a*).” to “In other words, *dV*/2 represents how close the acid must come to a blocked site before it can potentially participate in a deblocking reaction (called the capture radius, *a*).”

17. p251, equation (6.99) should be changed to

$$\sigma_{h_{eff}} \approx \left(\frac{2a}{\sigma_D}\right)^{\frac{p}{2}} \sigma_h$$

18. p253, equations (6.110) - (6.112) should all be changed by replacing “*a*” with “2*a*”:

$$\sigma_m^2 = \frac{\langle m \rangle}{\langle n_{0-blocked} \rangle} + \left(\langle m \rangle \ln\langle m \rangle\right)^2 \left(\frac{\sigma_h}{\langle h \rangle}\right)^2 \left(\frac{2a}{\sigma_D}\right)^p \tag{6.110}$$

$$\sigma_m^2 = \frac{\langle m \rangle}{\langle n_{0-blocked} \rangle} + \left(\frac{\langle m \rangle \ln\langle m \rangle}{\langle h \rangle}\right)^2 \left(\frac{2a}{\sigma_D}\right)^p \left(\frac{\langle h \rangle}{\langle n_{0-PAG} \rangle} + \frac{\left[\left(1-\langle h \rangle\right)\ln\left(1-\langle h \rangle\right)\right]^2}{\langle n \rangle}\right) \tag{6.111}$$

$$\left(\frac{\sigma_m}{\langle m \rangle}\right)^2 = \frac{1}{\langle n_{0-blocked} \rangle \langle m \rangle} + \left(K_{amp} t_{PEB}\right)^2 \left(\frac{2a}{\sigma_D}\right)^p \left(\frac{\langle h \rangle}{\langle n_{0-PAG} \rangle} + \frac{\left[\left(1-\langle h \rangle\right)\ln\left(1-\langle h \rangle\right)\right]^2}{\langle n \rangle}\right) \tag{6.112}$$

19. p253, equation (6.114) should be changed to

$$\begin{aligned}\left(\frac{\sigma_m}{\langle m \rangle}\right)^2 &= \frac{1}{\langle n_{0-blocked} \rangle \langle m \rangle} + \left(2\pi {\sigma_D}^2 a \langle G_0 \rangle N_A\right)^2 \left(\frac{2a}{\sigma_D}\right)^3 \left(\frac{\langle h \rangle}{\langle n_{0-PAG} \rangle}\right) \\ &= \frac{1}{\langle n_{0-blocked} \rangle \langle m \rangle} + 32\pi^2 \left(\frac{\sigma_D a^5}{V^2}\right) \langle h \rangle \langle n_{0-PAG} \rangle \\ &= \frac{1}{V}\left[\frac{1}{\langle M_0 \rangle N_A \langle m \rangle} + 32\pi^2 \sigma_D a^5 \langle h \rangle \langle G_0 \rangle N_A\right]\end{aligned}$$

20. p253, in the paragraph following equation (6.114), the text that reads “$\sigma_D/9 = 5$” should read “$\sigma_D/2a = 5$”.

21. p254, figure 6.10, the *x*-axis label should be changed from “σ_D/a” to “$\sigma_D/2a$”.

22. p305, second line of section 8.2.3, the word “methodology” should read “method”.

23. p357, line 4, the statement “*k* less than about 0.8” should read “k_1 less than about 0.8”.

24. p404-406, equations (9.92) and (9.95) – (9.99) should all be changed by replacing "*a*" with "2*a*":

$$\sigma_{m^*}^2 = \frac{\langle m^* \rangle}{\langle n_{0-blocked} \rangle} + \left(\langle m^* \rangle \ln\langle m^* \rangle\right)^2 \left(\frac{2a}{\sigma_D}\right)^p \left(\frac{1}{\langle n_{0-PAG} \rangle \langle h \rangle} + \frac{\left[\left(1-\langle h \rangle\right)\ln\left(1-\langle h \rangle\right)\right]^2}{\langle h \rangle^2 \langle n \rangle}\right) \tag{9.92}$$

$$\sigma_{m^*} = \sqrt{\frac{\langle m^* \rangle}{\langle n_{0-blocked} \rangle} + \left(\langle m^* \rangle \ln\langle m^* \rangle\right)^2 \left(\frac{2a}{\sigma_D}\right)^p \left(\frac{1}{\langle n_{0-PAG} \rangle \langle h \rangle}\right)} \tag{9.95}$$

$$LER \propto \frac{{\sigma_D}^2}{1 - e^{-\pi^2 {\sigma_D}^2 / 2L^2}} \sqrt{\frac{\langle m^* \rangle}{\langle n_{0-blocked} \rangle} + \left(\langle m^* \rangle \ln\langle m^* \rangle\right)^2 \left(\frac{2a}{\sigma_D}\right)^p \left(\frac{1}{\langle n_{0-PAG} \rangle \langle h \rangle}\right)} \tag{9.96}$$

$$LER \propto \frac{{\sigma_D}^2}{1 - e^{-\pi^2 {\sigma_D}^2 / 2L^2}} \sqrt{1 - (K_{amp} t_{PEB}) \langle m^* \rangle \ln\langle m^* \rangle \left(\frac{2a}{\sigma_D}\right)^p \frac{\langle n_{0-block} \rangle}{\langle n_{0-PAG} \rangle}} \tag{9.97}$$

$$LER \propto \left(1 + \frac{\pi^2 {\sigma_D}^2}{4L^2}\right) \sqrt{1 - (K_{amp} t_{PEB}) \langle m^* \rangle \ln\langle m^* \rangle \left(\frac{2a}{\sigma_D}\right)^p \frac{\langle n_{0-block} \rangle}{\langle n_{0-PAG} \rangle}} \tag{9.98}$$

$$LER \propto \frac{{\sigma_D}^2}{1 - e^{-\pi^2 {\sigma_D}^2 / 2L^2}} \sqrt{1 + 15\left(\frac{2a}{\sigma_D}\right)^p} \tag{9.99}$$

25. p406, Figure 9.28, references in the figure and in the figure caption to a = 1, 2, and 3 nm should be changed to 0.5, 1.0 and 1.5 nm.

26. p406, first sentence of the last paragraph before the start of the Summary section, the sentence "… deprotection capture range *a*, 1, 2, and 3 nm" should be changed to "… deprotection capture range *a*, 0.5, 1.0, and 1.5 nm".

27. Chapter 10, homework problem 10.1, the last sentence should be changed from "Assume equal lines and spaces, …" to "Assume a 193-nm wavelength, equal lines and spaces, …".

28. Chapter 10, homework problem 10.11. Add to the end of the problem the question: "What is the result for the case of equal lines and spaces?"

Additionally, my brief bio on the back cover of the book mistakenly lists my affiliation as KLA-Tencor. I left KLA-Tencor in November, 2005 and now exist as an independent "Gentleman Scientist".