EECS 243 – Advanced IC Processing and Layout

Fall 2000 **Office Hours** **Prof. A. R. Neureuther,**
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Solution Homework # 5

5.1 Electron-beam system resolution and current

System	V	Source	ΔE	α	I	λ	d_d	d_s	d_c	d_0	d (rsln)	
	kV	type	eV	mR	pA	nm	nm	nm	nm	nm	nm	
SEM	1	FE	0.2	3	100	0.039	15.8	0.7	12	0	19.8	low kV Problem
SEM	20	FE	0.2	5	300	0.009	2.12	1.25	1	0	2.66	
Lith 25nm	35	LaB_6	2	5	NO!	0.007	1.6	31.3	57.1	NO!	25	need short f
Lith 70 nm	35	LaB_6	2	5	40	0.007	1.6	31.3	57.1	25.6	70	still low I

The LEO SEM has a resolution of 2.5 nm at 1 kV. The spot size FWHM is 1.7 times larger at 4.3 nm. This resolution is possible due to the extraction being at 2.5 kV, higher yet internal voltages and the slowing of the electrons to 1 kV as they leave the pole piece and head to the wafer. The JOEL electron-beam writer has a resolution in SEM mode of 8 nm and a resolution in writing mode (with 300 PA of current) of 38 nm. The JOEL likely has 1) a shorter focal length (of say 5 cm), 2) slightly better source energy control and 3) perhaps a slightly larger brightness.

5.2 Electron-material interaction

At 1, 20 and 35 KeV.

a) Grun range = 0.038 μm, 7.25 μm and 19.3 μm.

b) The electron energy deposition at the resist surface is 195, 20.4 and 13.4 $(J/cm^3)/(\mu c/cm^2)$.

c) The standard deviation of the forward scattering $s_f = \left(\frac{0.5z}{V}\right)^{1.75}$ is 16.7 nm for 10nm resist at 1KeV, 16.7nm and 6.3nm for 200nm resist at 20 and 35 KeV.

5.3 Shot noise

EUV photons with a 13.4 nm wavelength expose a resist with an absorption constant $\alpha = 5\ \mu m^{-1}$ at an exposure dose of 20 mJ/cm^2.

a) The deposited energy density at the surface is the product of the exposure dose and absorption constant and is 1000 J/cm^3.

b) The energy per photon is (1,240 eV-nm)/13.4 nm = 92.5 eV. The number of photons absorbed per unit volume is D = $(1000 J/cm^3)/(92.5\ eV \times 1.6 \times 10^{-19}\ eV/J) = 6.75 \times 10^{19}\ cm^{-3}$.

c) The average distance between absorbed photons is s = cube root of $[1/(6.75 \times 10^{19})]$ = 2.5 nm.

d) The expected number of events inside a sphere of radius 3 nm is the volume of the sphere times the density D of absorbed photons. $N_{expected} = (4\pi/3)\ (3nm)^3\ D = 7.64$ events. The probability that a sphere of radius 3nm has no exposure events inside is $e^{-Nexpeccted} = e^{-7.64} = 4.8\ 10^{-4}$.

e) The 20^{th} power of ten is e raised to the (20 x 2.31) = 46.2. Thus the expected number of events is 46.2. Setting $(4\pi/3)\ (r)^3\ D = 46.2$ events and solving for r gives r= 5.47nm. (An exposure shot noise tolerant linewidth might be one that is 10 times larger than this radius or 54.7 nm).