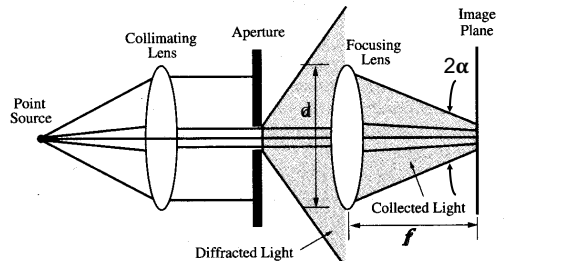




Basics of lithography optics (3): resolution



$$\text{Resolution, } r = 1.22f \frac{\lambda}{d}$$

$$\sin \alpha = \frac{d/2}{\sqrt{f^2 + (d/2)^2}} \approx \frac{d}{2f}$$

$$r = 0.61 \frac{\lambda}{\sin \alpha} = 0.61 \frac{\lambda}{n \sin \alpha} = k_1 \frac{\lambda}{NA}$$

Silicon VLSI Technology, J. D. Plummer, M. D. Deal, P. B. Griffin

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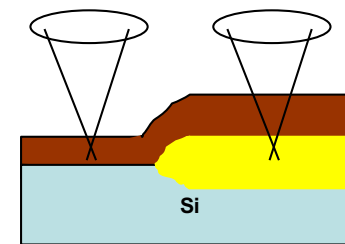
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1

1



Basics of lithography optics (4): depth of focus



$$DOF = \pm k_2 \frac{\lambda}{NA^2}$$

- r & $DOF \rightarrow$ conflicting requirements
- Planarize the surface

<http://blog.hhcolorlab.com/photo-lab-post/shallow-depth-of-focus-contest>

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2

2



Light Sources

- g-line 436 nm Hg arc lamp
- i-line 365 nm Hg arc lamp
- 248nm KrF Excimer Laser
- 193nm ArF Excimer Laser
- 193nm/immersion ArF Excimer Laser, water ($n = 1.33$)
- EUV 13.5 nm Laser produced plasma

- E-beam $\sim 1\text{nm}$

$$\lambda = \frac{hc}{E}$$

$$\lambda \text{ (in nm)} = \frac{1240}{E \text{ (in eV)}}$$

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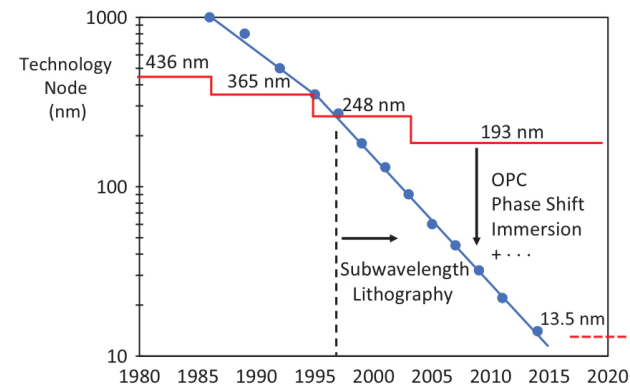
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Light Sources (2)



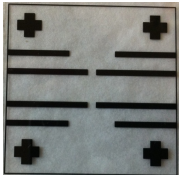
Plummer and Griffin, Integrated Circuit Fabrication: Science and Technology, 2023

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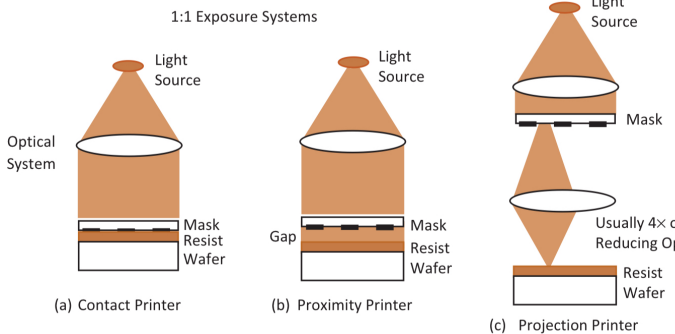


Lithography Masks

- Substrate material is transparent to light: glass, transparency sheets
- The opaque layer: chrome, black ink
- Maskless lithography is possible for low throughput applications

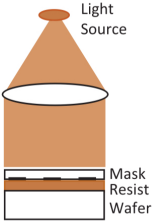
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5

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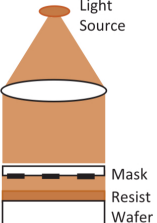
Exposure systems

1:1 Exposure Systems



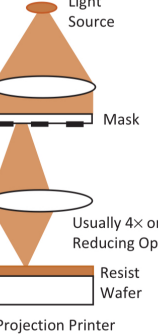
(a) Contact Printer

- Defects
- + Low cost
- + No diffraction effects



(b) Proximity Printer

- Defects
- Diffraction effects
- higher cost




(c) Projection Printer

- + No defects
- Diffraction effects
- highest cost

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6

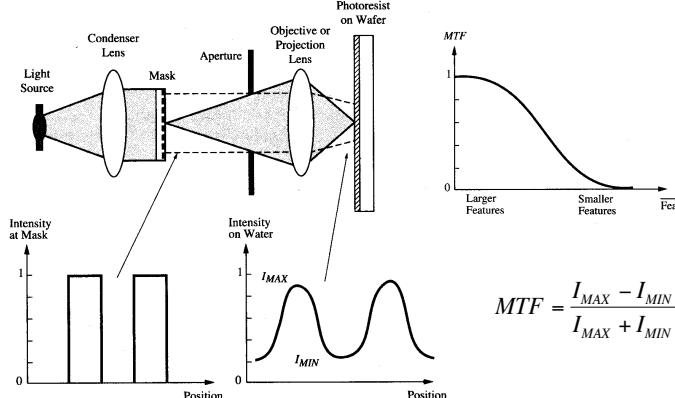


General Technology Trends

Year of Production	2007	2008	2009	2010	2011	2012	2013	2014	2015
DRAM ½ pitch (nm) (contacted)	65	57	50	45	40	36	32	28	25
DRAM and Flash									
DRAM ½ pitch (nm)	65	57	50	45	40	36	32	28	25
Flash ½ pitch (nm) (un-contacted poly)	54	45	40	36	32	28	25	23	20
Contact in resist (nm)	72	62	55	50	44	39	35	31	28
Contact after etch (nm)	65	57	50	45	40	36	32	28	25
Overlay [A] (3 sigma) (nm)	13	11.3	10.0	9.0	8.0	7.1	6.4	5.7	5.1
CD control (3 sigma) (nm) [B]	5.6	4.7	4.2	3.7	3.3	2.9	2.6	2.3	2.1
MPU									
MPU/ASIC Metal 1 (M1) ½ pitch (nm)	68	59	52	45	40	36	32	28	25
MPU gate in resist (nm)	42	38	34	30	27	24	21	19	17
MPU physical gate length (nm) *	25	23	20	18	16	14	13	11	10
Contact in resist (nm)	84	73	64	56	50	44	39	35	31
Contact after etch (nm)	77	67	58	51	45	40	36	32	28
Gate CD control (3 sigma) (nm) [B] **	2.6	2.3	2.1	1.9	1.7	1.5	1.3	1.2	1.0

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7

7



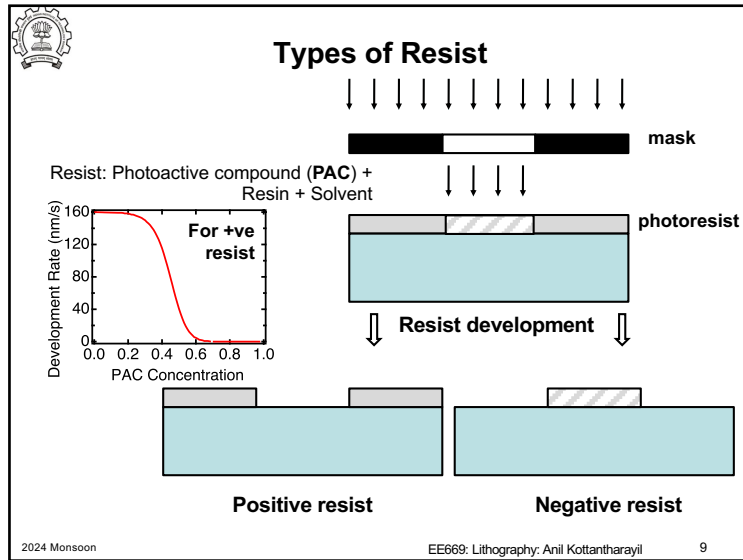
Modulation transfer function (MTF)

The diagram illustrates the optical system for lithography, showing the light path from the Light Source through the Condenser Lens, Mask, Aperture, and Objective or Projection Lens to the Photoresist on the Wafer. It also includes a graph of Intensity at Mask vs Position, showing the intensity profile on the wafer with peaks (I_{MAX}) and troughs (I_{MIN}), and a graph of MTF vs Feature Size, showing the relationship between MTF and feature size.

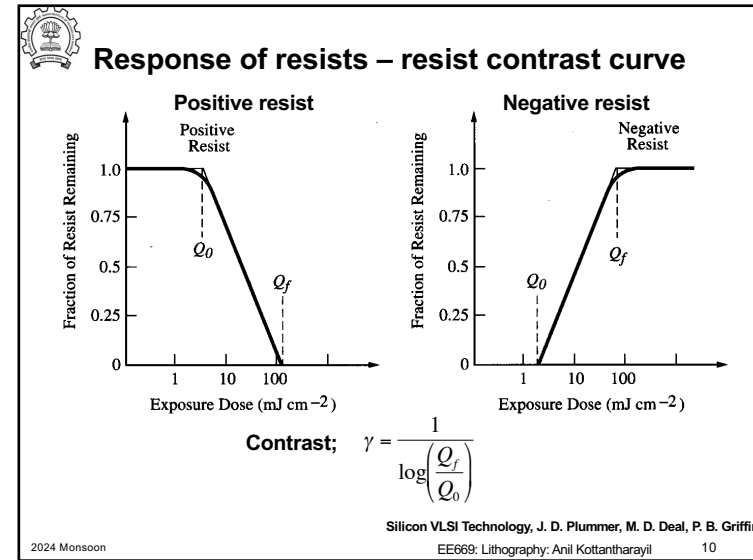
$$MTF = \frac{I_{MAX} - I_{MIN}}{I_{MAX} + I_{MIN}}$$

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8

8



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10