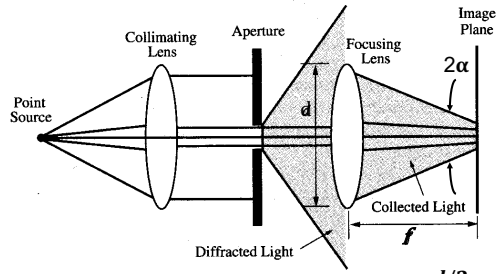
Basics of lithography optics (3): resolution



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

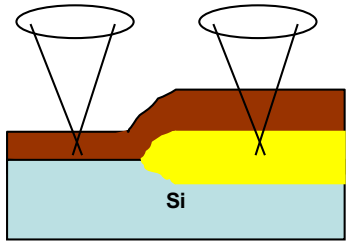
$$\sin\alpha = \frac{d/2}{\sqrt{f^2 + (d/2)^2}} \approx \frac{d}{2f}$$

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

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

1

Basics of lithography optics (4): depth of focus



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

- r & DOF ➔ conflicting requirements
- Planarize the surface

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

2

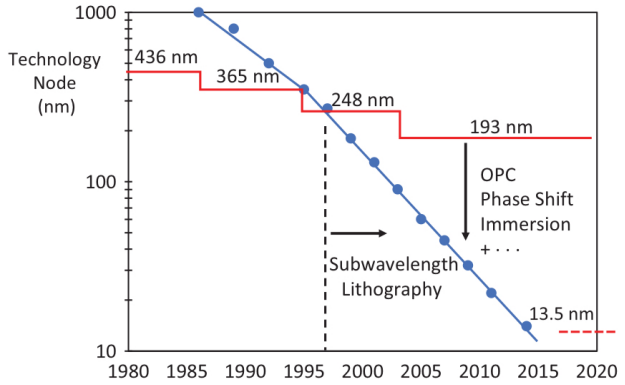
Light Sources

• 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	~ 1nm	

$$\lambda = \frac{hc}{E} \qquad \lambda\,(in\ nm) = \frac{1240}{E\,(in\ eV)}$$

3

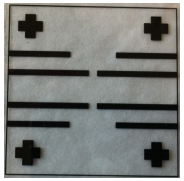
Light Sources (2)



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

4

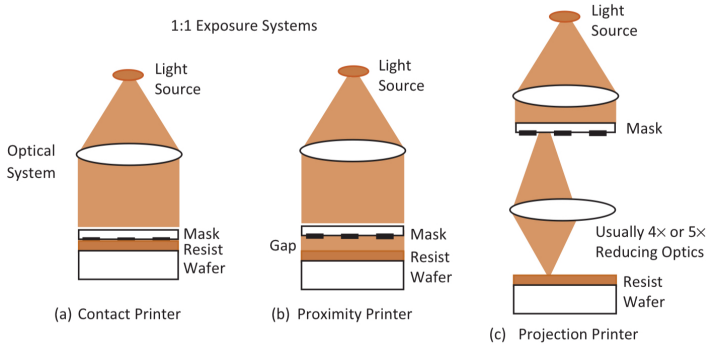
Lithography Masks



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

5

Exposure systems



- Defects
+ Low cost
+ No diffraction effects

- Defects
- Diffraction effects
- higher cost

+ No defects
- Diffraction effects
- highest cost

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

6

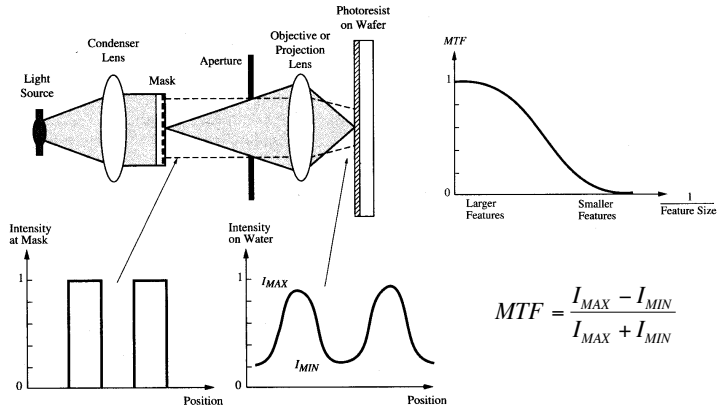
General Technology Trends

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

www.itrs.net

7

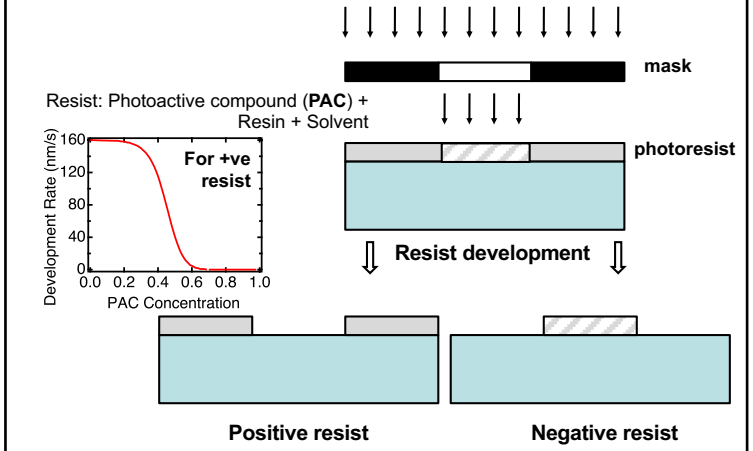
Modulation transfer function (MTF)



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

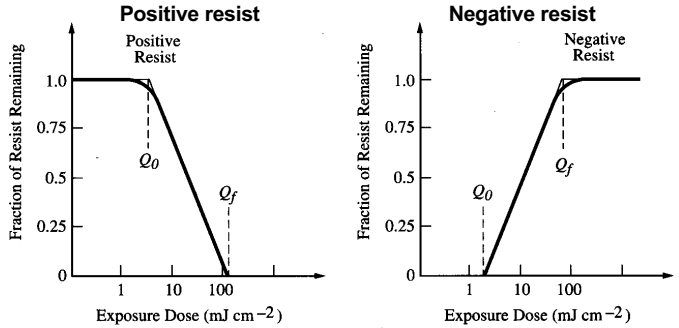
8

Types of Resist



9

Response of resists – resist contrast curve



Contrast; $\gamma = \dfrac{1}{\log\left(\dfrac{Q_f}{Q_0}\right)}$

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

10