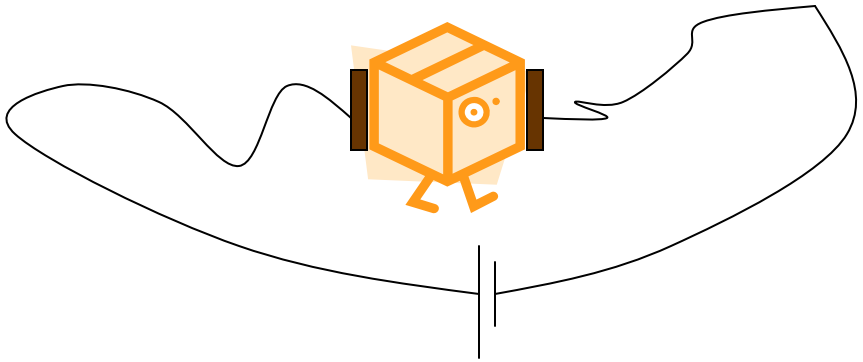
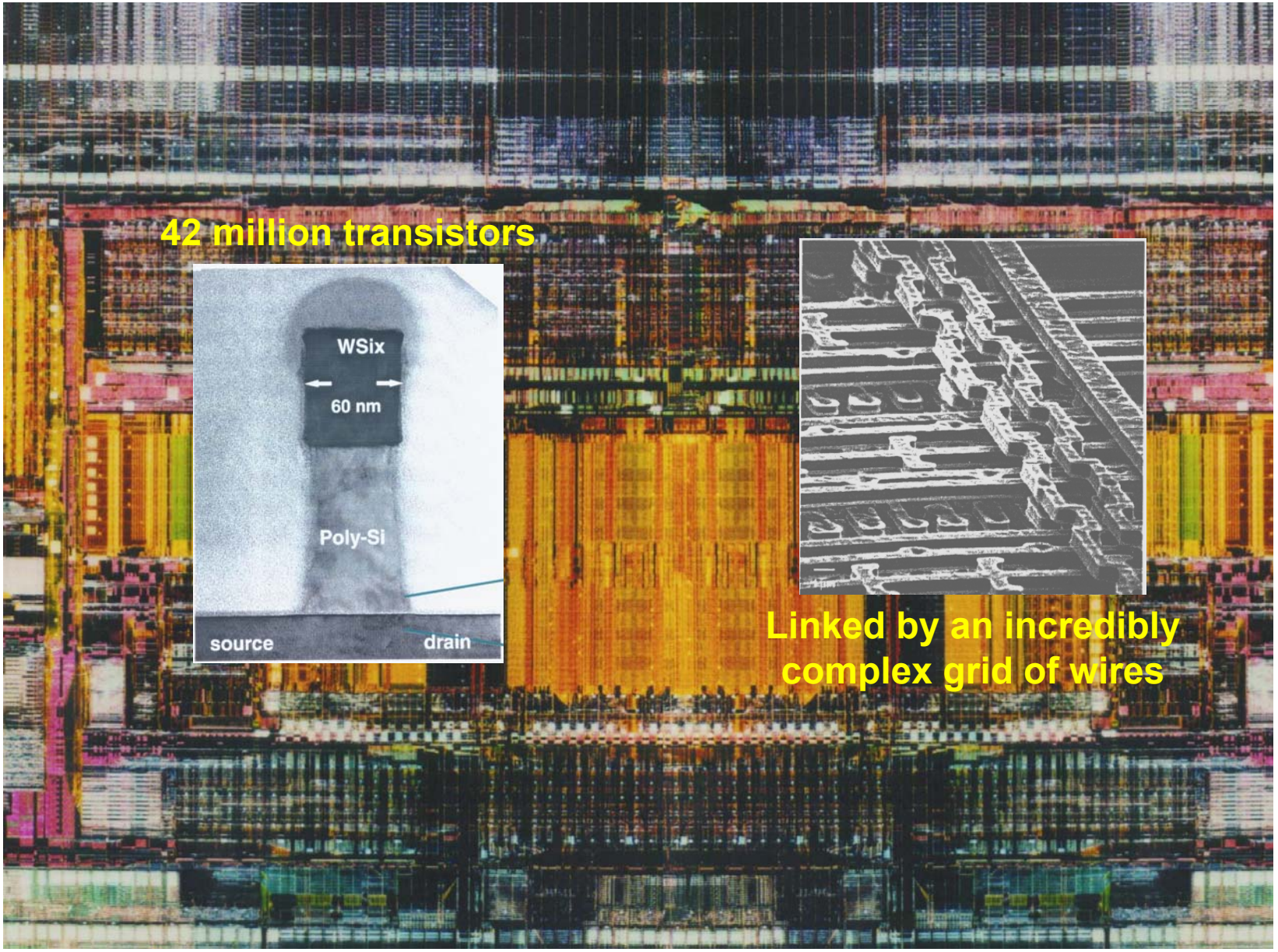
What are the key elements of this 'new' fabrication technology?

- Making a pattern (template)
- Transferring that template into your material

1. Lithography
2. Metalization and making contact to the outside world
3. Defining local electronic behavior: doping
4. Isolating electronic regions: oxidation
5. Carving out different regions of the material: etching



An Information-transfer Challenge



The insides of a Pentium 4

The energy/pattern transfer process

- The 'film' as an energy detector

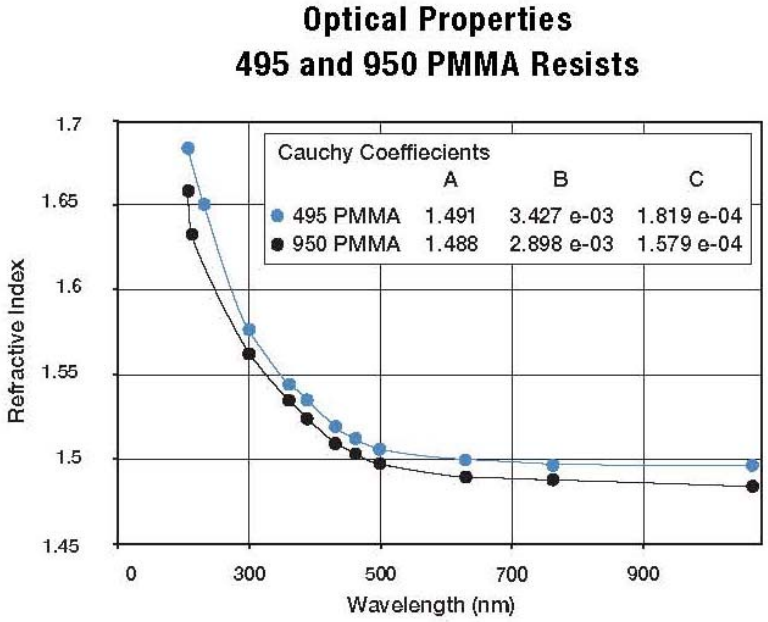


Figure 10

'NOVOLAC' film

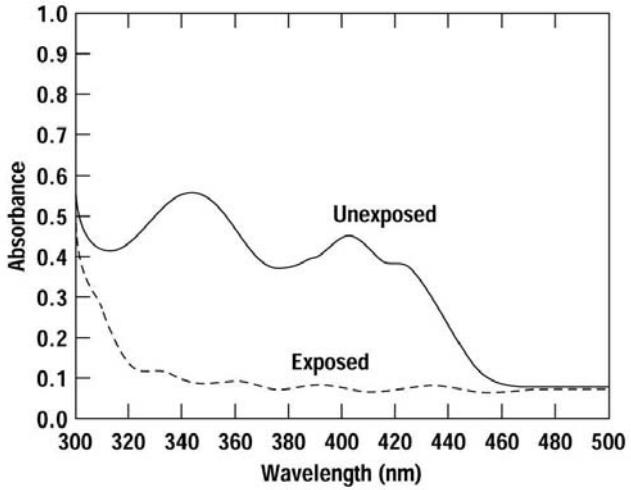
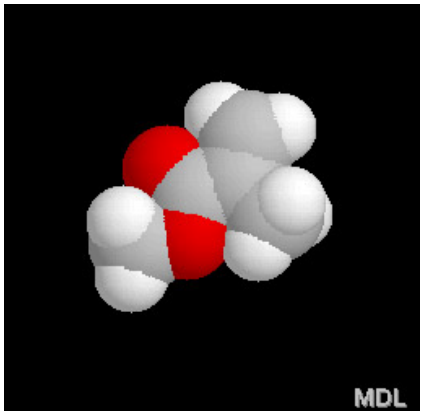
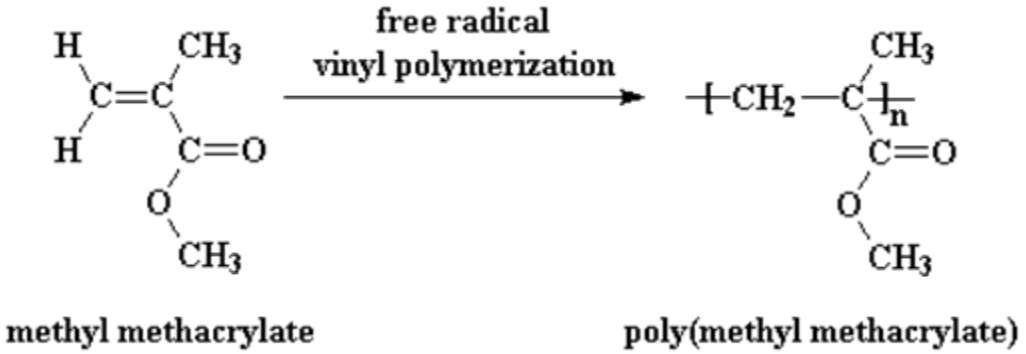


Figure 8.13 Total absorbance of a layer of SPR511-A resist before and after exposure. The difference between the two curves is the actinic absorbance *(courtesy Shipley)*.

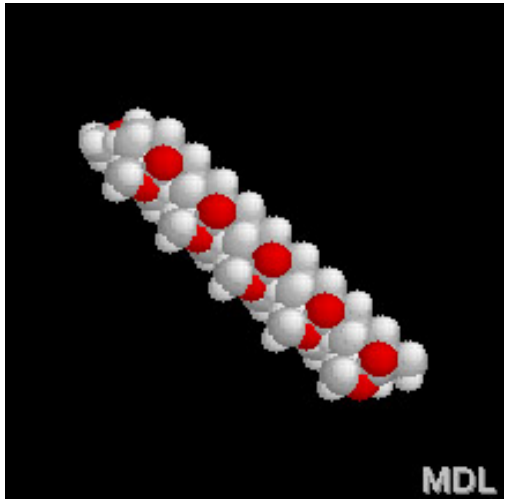
'transduction': of an optical pattern (light/dark) into patterns in the film

Poly (methyl methacrylate): PMMA





Simple breaking of bonds



http://pslc.ws/macrog/kidsmac/pmma.htm

NOVOLAC Resists

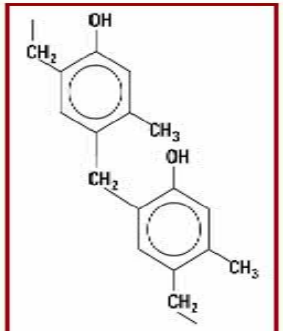


Figure 8.4 Meta-cresol novolac, a commonly used resin material in g- and i-line applications. The basic ring structure may be repeated from 5 to 200 times.

RESIN

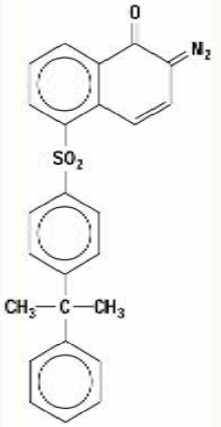


Figure 8.5 Diazo-quinone (DQ), the most commonly used photoactive compound for g- and i-line applications. The right-hand ring is not an aromatic but has a double bond.

PAC

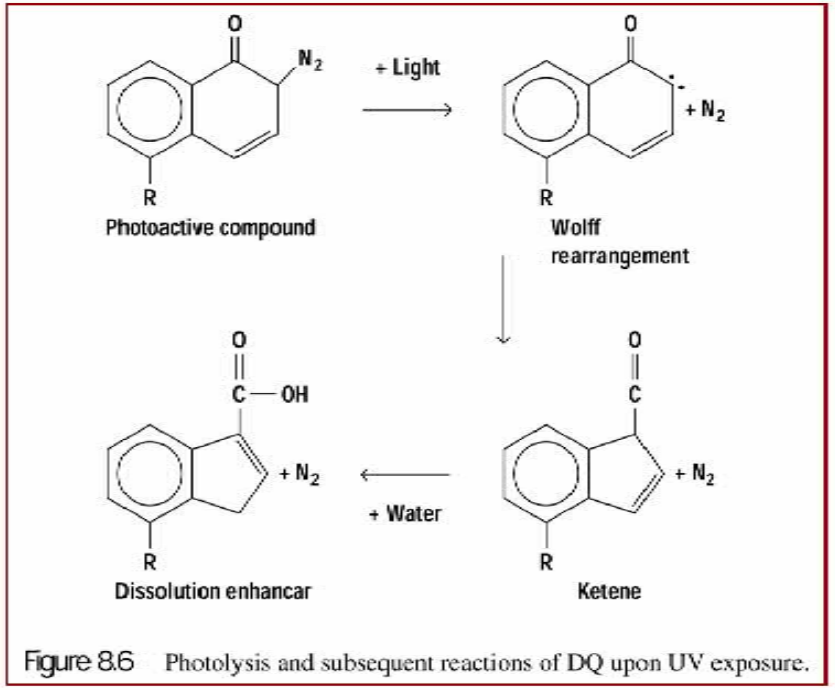
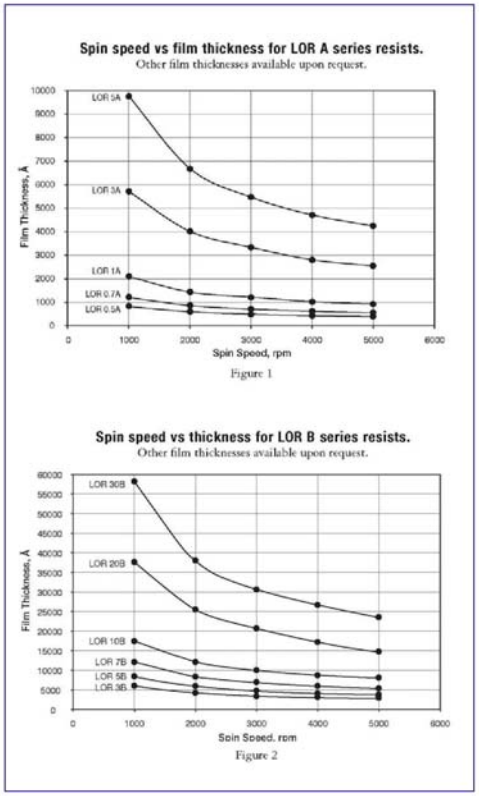


Figure 8.6 Photolysis and subsequent reactions of DQ upon UV exposure.

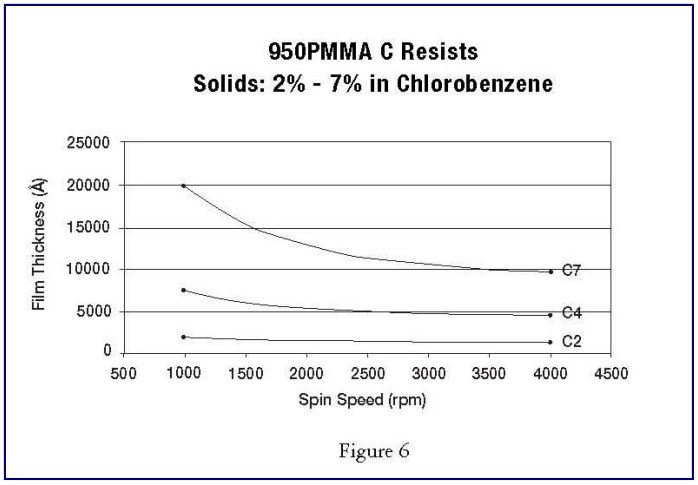
3 components: (1) Resin, (2) Photo-active component, (3) solvent
Why use 3 components? Wouldn't one component be simpler, less Expensive?

Questions, questions, questions….

- What form of matter are these optical materials?
- How do you apply them to the silicon wafer? (or material of choice)
- How thick should you make the photo-sensitive material?
- Does the uniformity of the thickness matter?

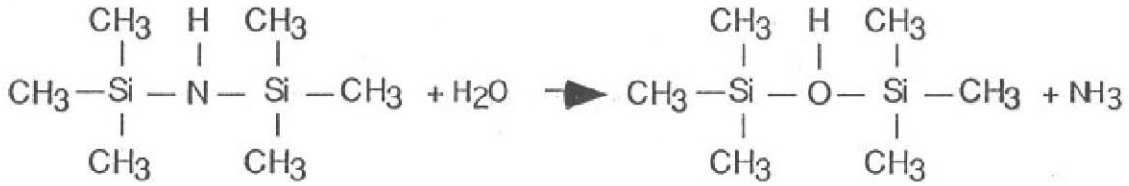


MCC LOR resist

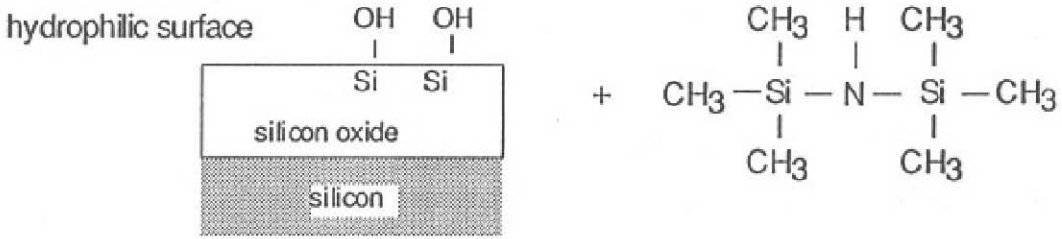


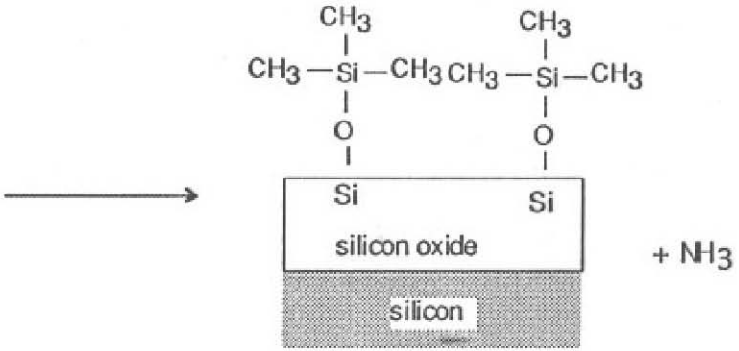
Hexamethyl Disilizane (HMDS)

Free water reaction:



Surface reaction:





Effects of 'Hardbake'

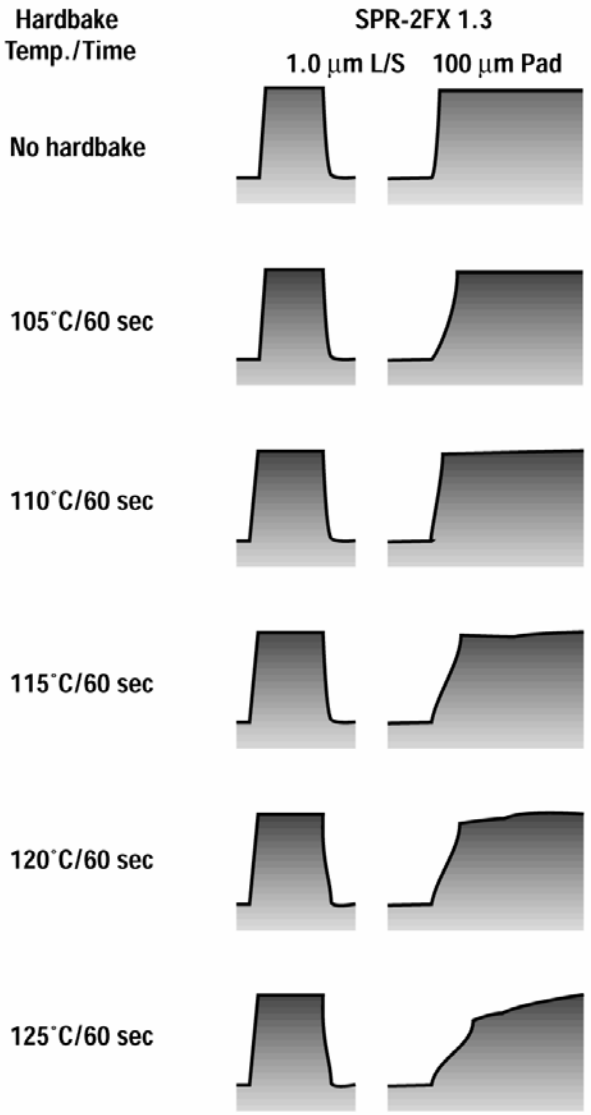
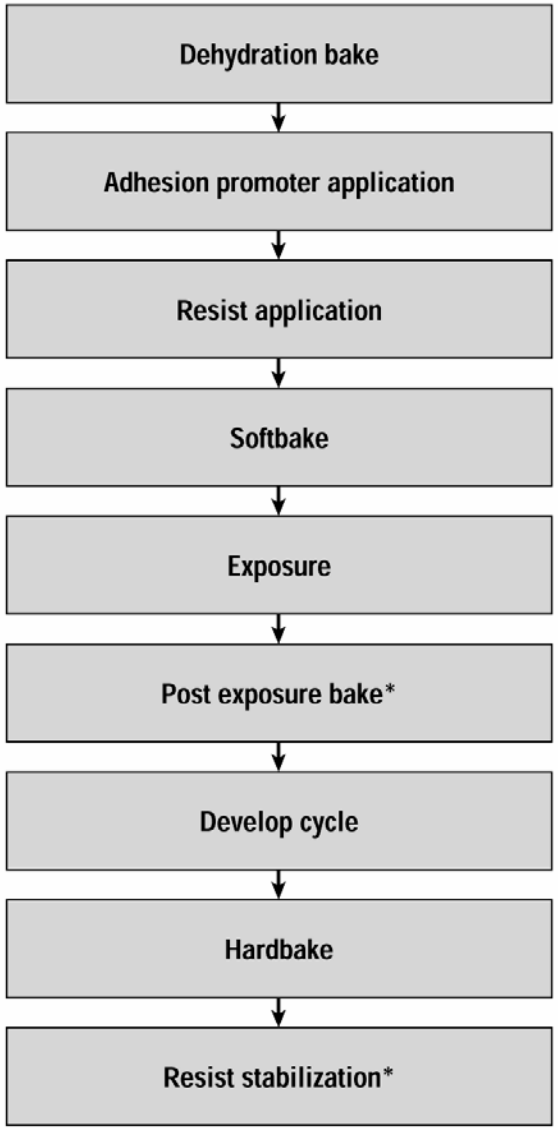


Figure 8.11 Resist profiles of a 1-mm line and space and a large feature in SPR-2FX resist for different hardbake temperatures *(courtesy Shipley)*.

Process Flow for Lithography



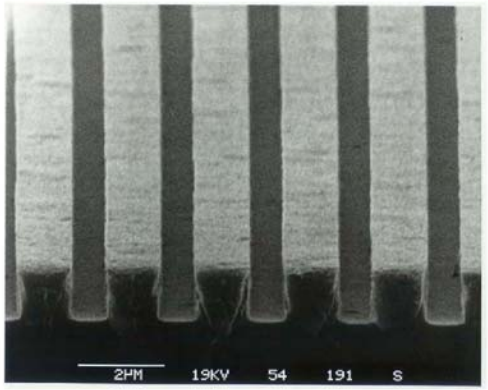
*Optional steps

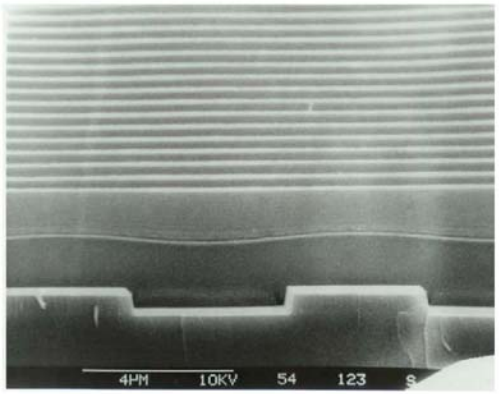
Figure 8.9 Typical process flow in a photolithography step.

What is a 'good' photoresist?

- How do we evaluate/compare resists and process conditions?

Photoresist Profiles & Coverage





M. Ha, GCA Corp.

Dissolution of un-exposed resist

What is the ideal developer concentration?

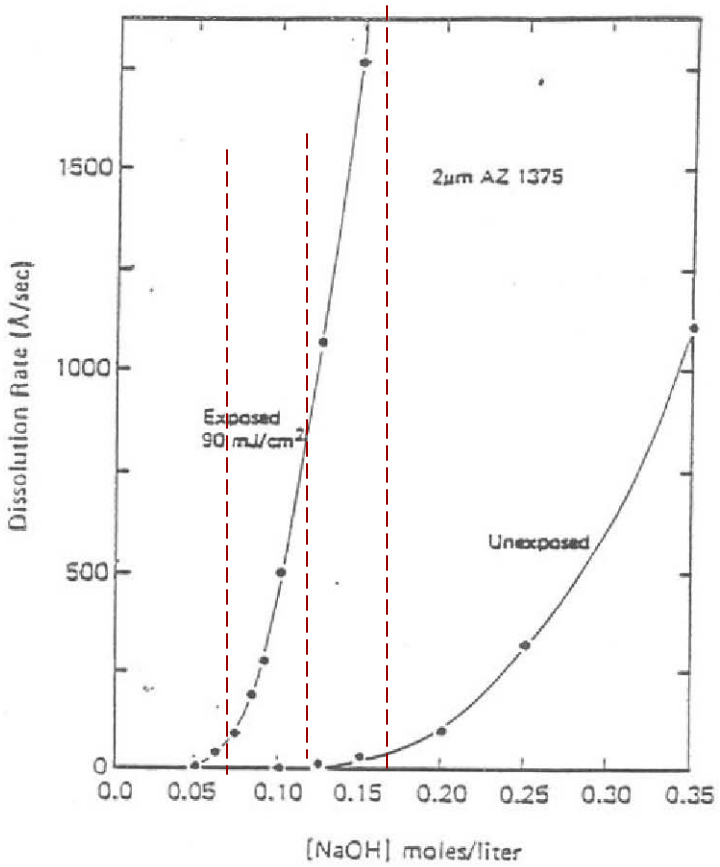


Figure 2: Dissolution rates of exposed and unexposed AZ-1375 resist as a function of developer sodium hydroxide concentration.

Contrast Curves

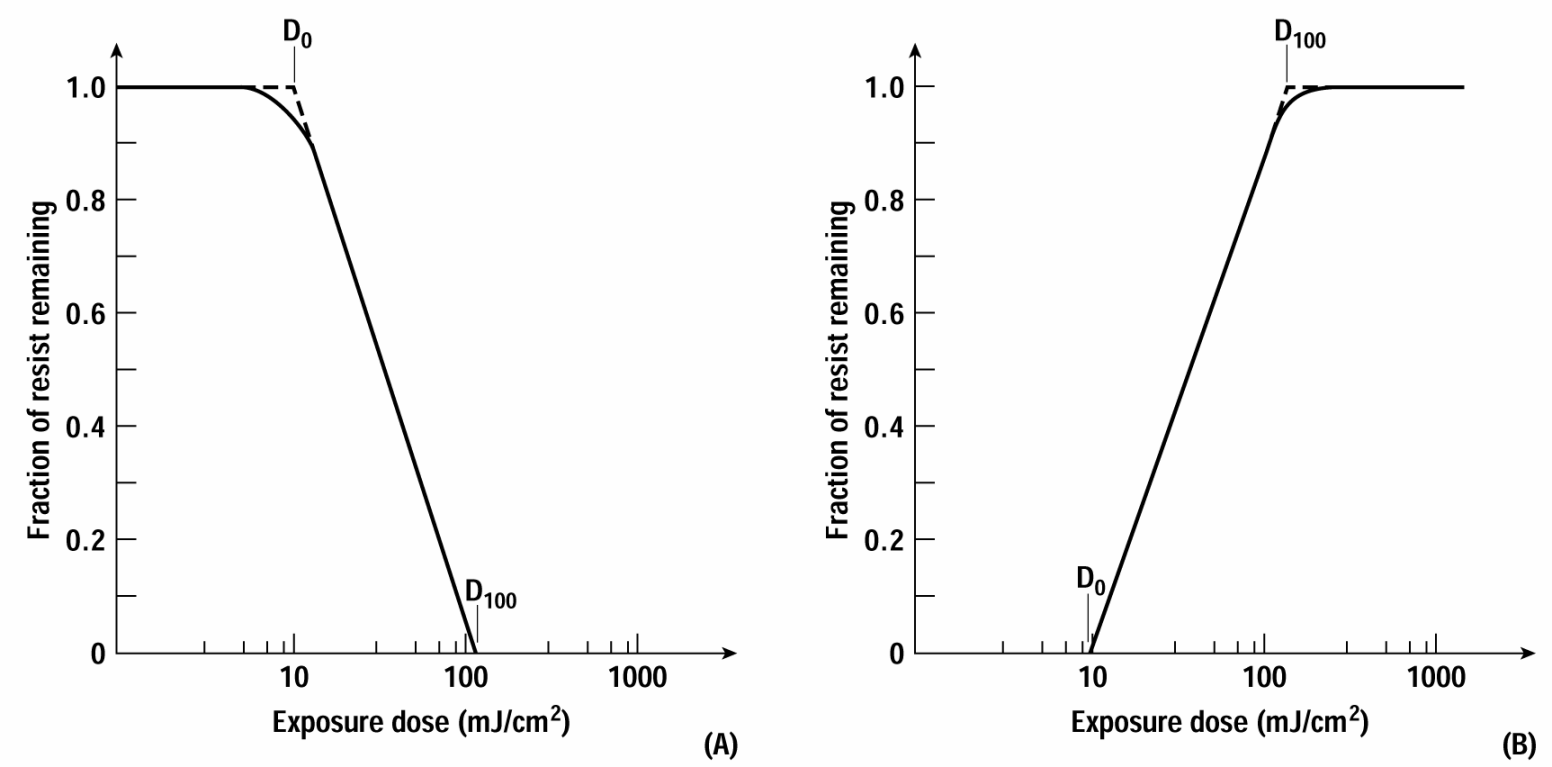


Figure 8.7 Contrast curves for idealized resists: (A) postitive tone and (B) negative tone.

Contrast depends on resist AND developer

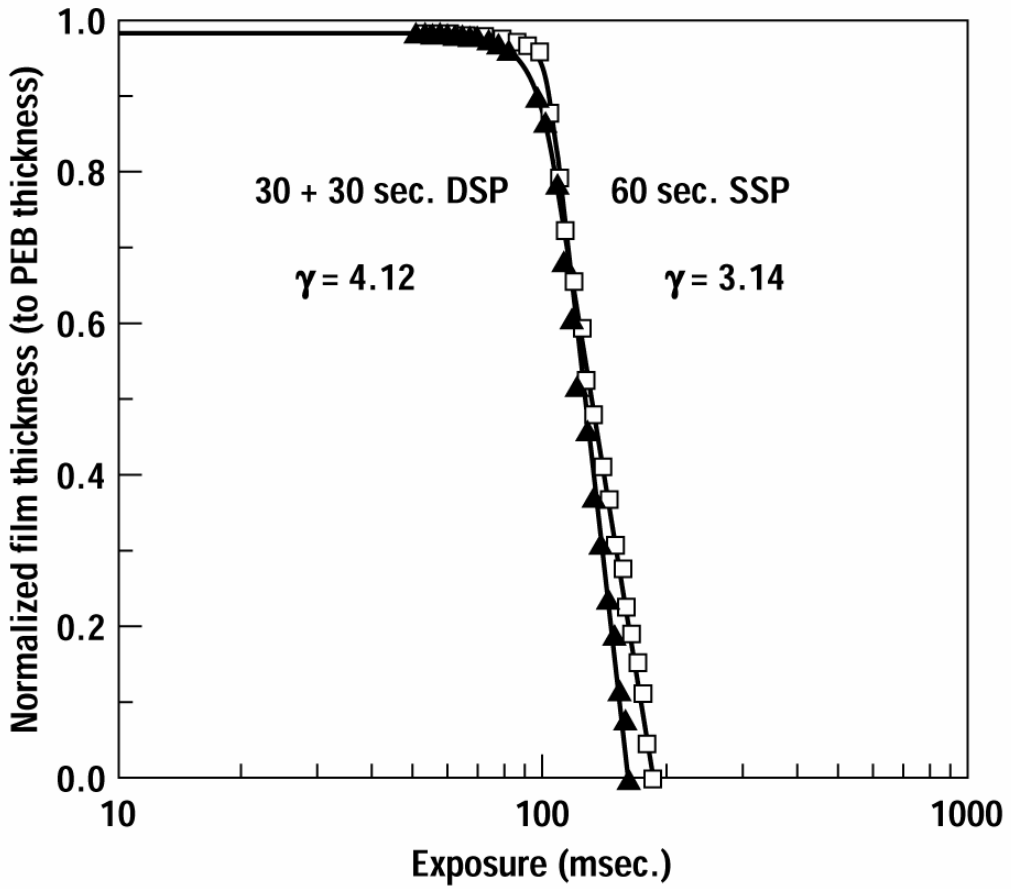
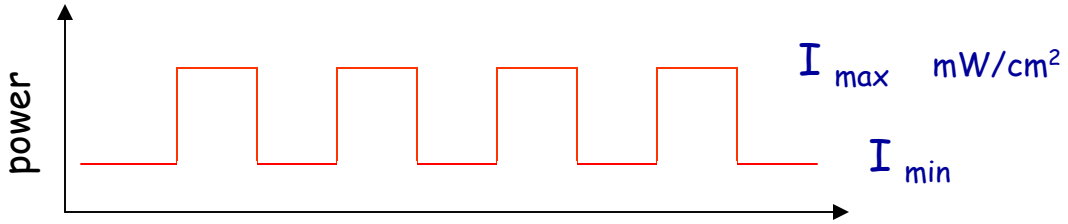
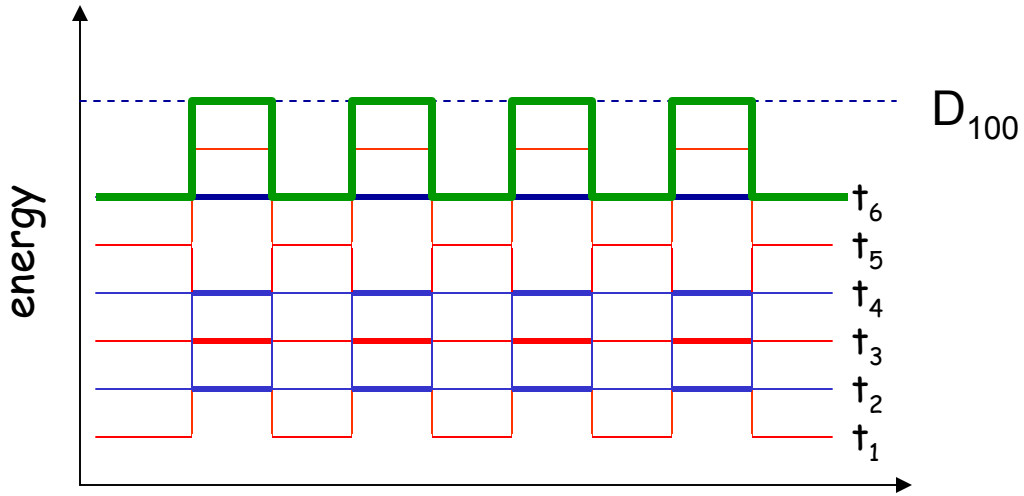
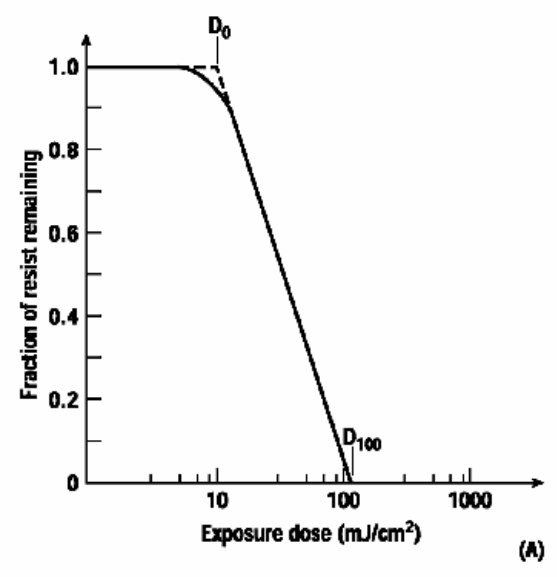


Figure 8.10 Contrast curves for Megaposit SPR500 resist using MF CD-26 developer *(courtesy Shipley)*.

Pattern of light and dark at the mask







The photoresist 'sees' the green curve of energy (dose)
For the contrast curve of the resist, how could you calculate the resist profile?

Absorption in the photoresist

Optical absorption in the resist leads to a gradient in 'deposited energy'
(can be measured by converted PAC)

$$I = I_o \exp\{-\alpha z\}$$

Dilemma:

1. Photoresist ABSORPTION of light necessary to bring about chemical change, BUT
2. A large absorption, and a large a means the right the 'bottom' of the resist not receive the right dose to remove all the photoresist

What to do???

These profiles assume 'perfect' gratings. What are the resist images?

Photobleaching

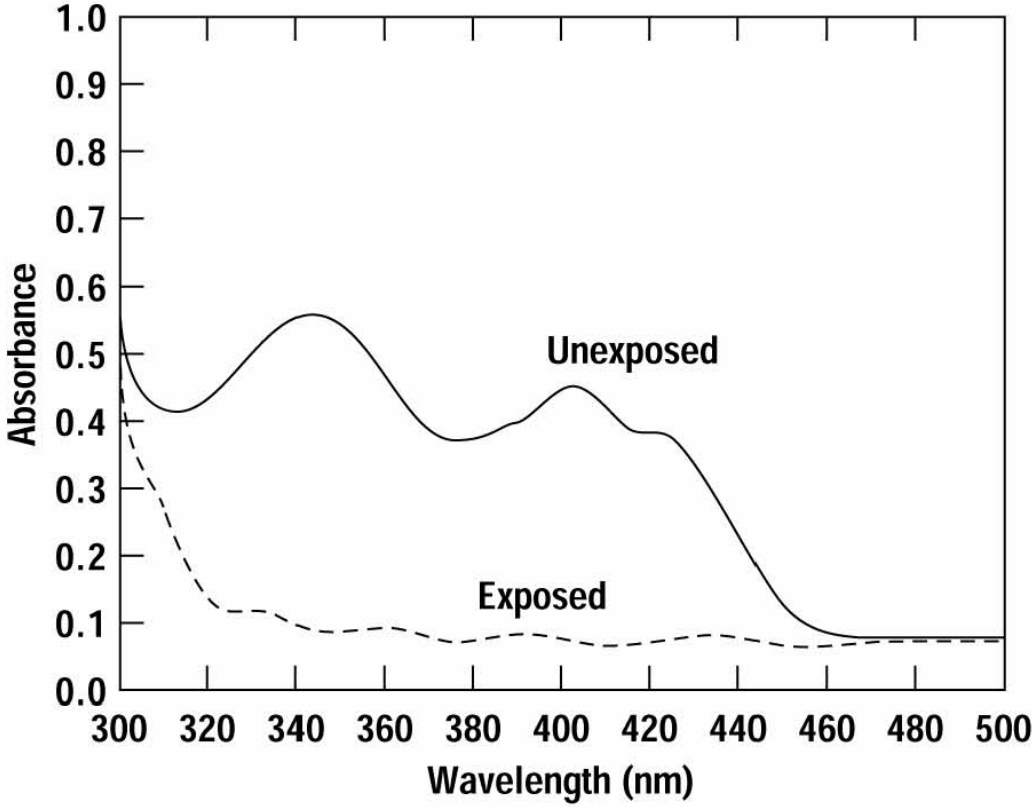


Figure 8.13 Total absorbance of a layer of SPR511-A resist before and after exposure. The difference between the two curves is the actinic absorbance *(courtesy Shipley).*

Major Emission Lines of Hg Lamp

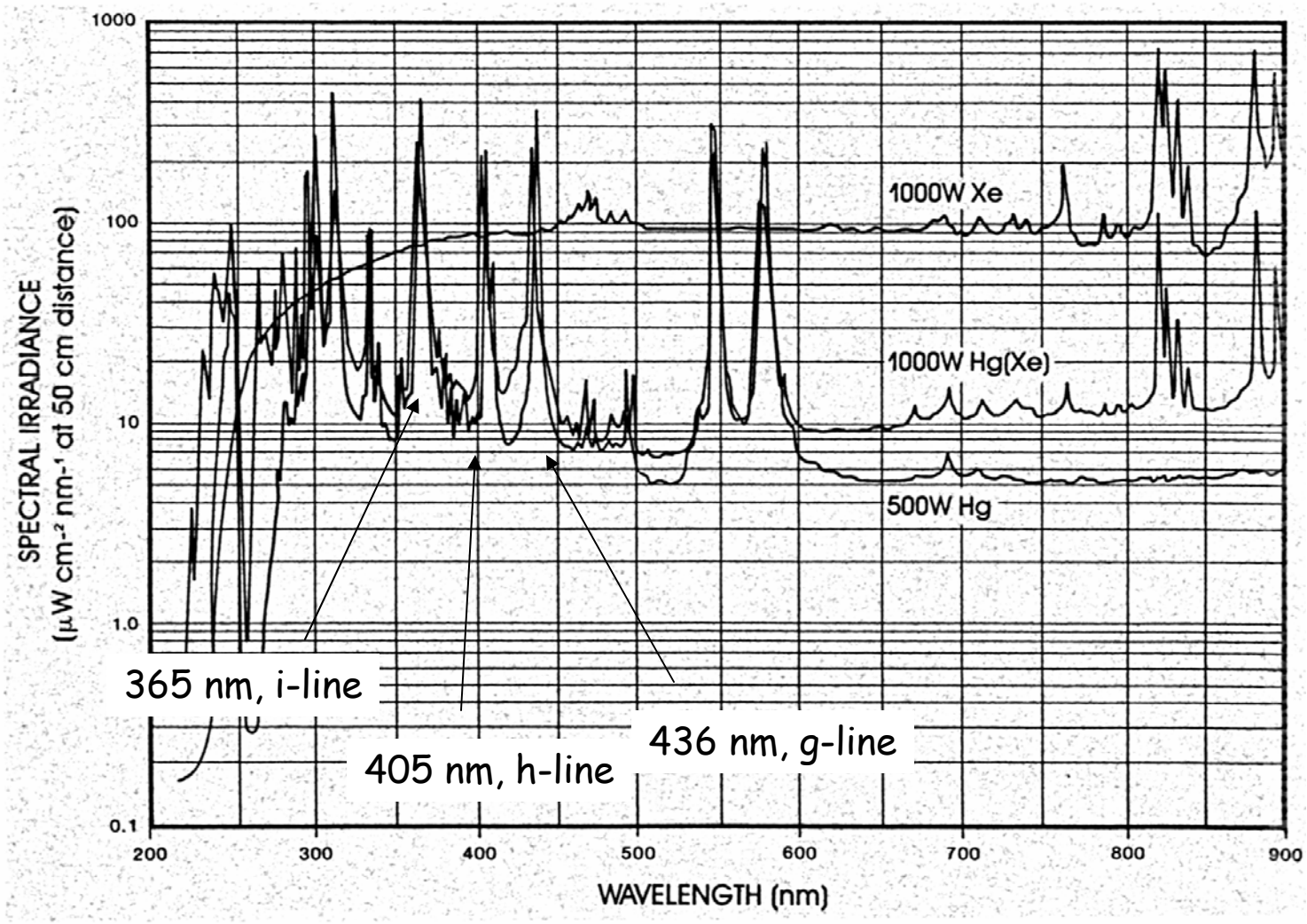


Figure 7.11 Line spectra for mercury and xenon arc lamps *(courtesy of Oriel Corporation).*

Choice of Optics for Lithography

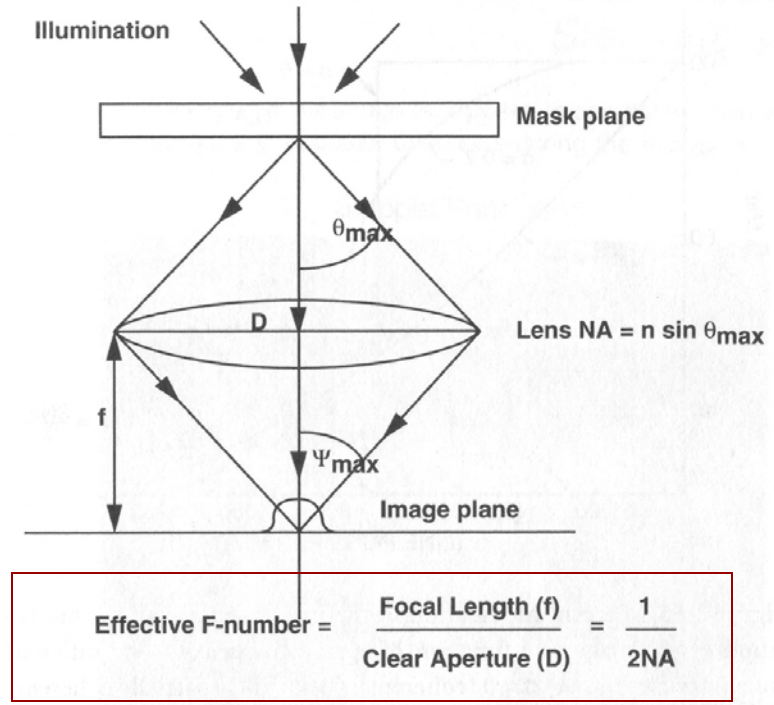
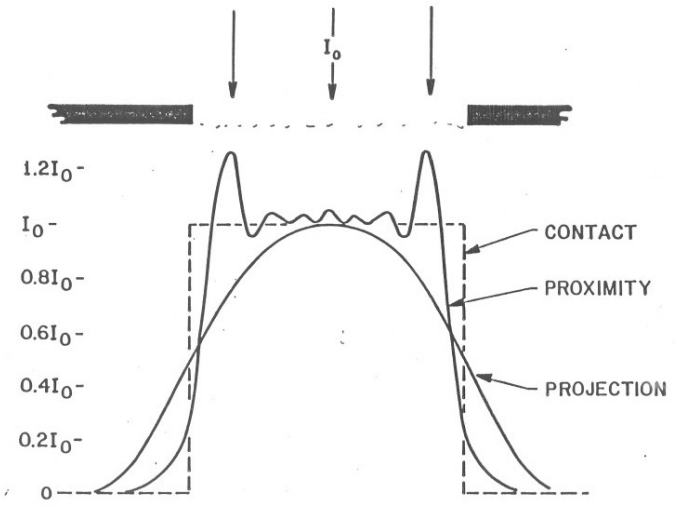


Figure 1.16 Relationship between the object, image, and focal length and diameter of a lens to define the numerical aperture.

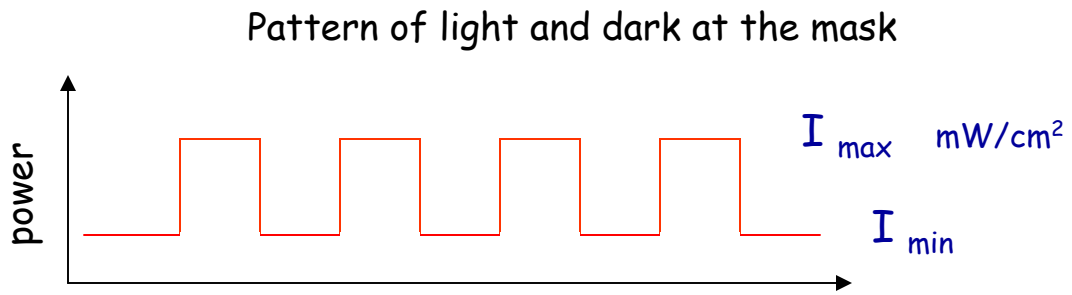


Numerical aperture of the lens (NA)
Table 7.5 gives some values of NA

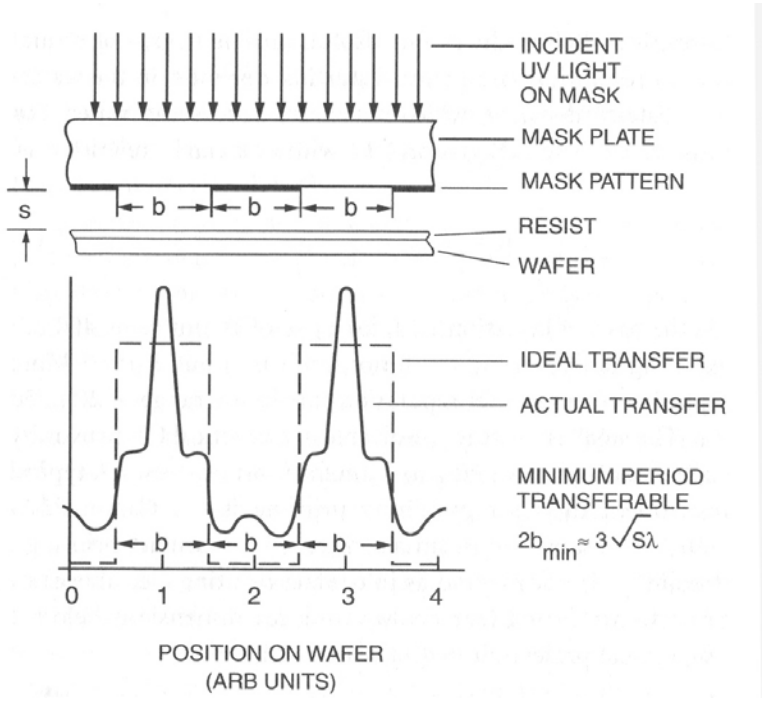
Minimum feature size ~ λ/NA
Depth of focus ~ $\lambda/(NA)^2$

Figure of merit for the optics?

Modulation Transfer Function



Diffraction of Light: influencing the resist pattern



Fundamentals of Microfabrication,
M. Madou

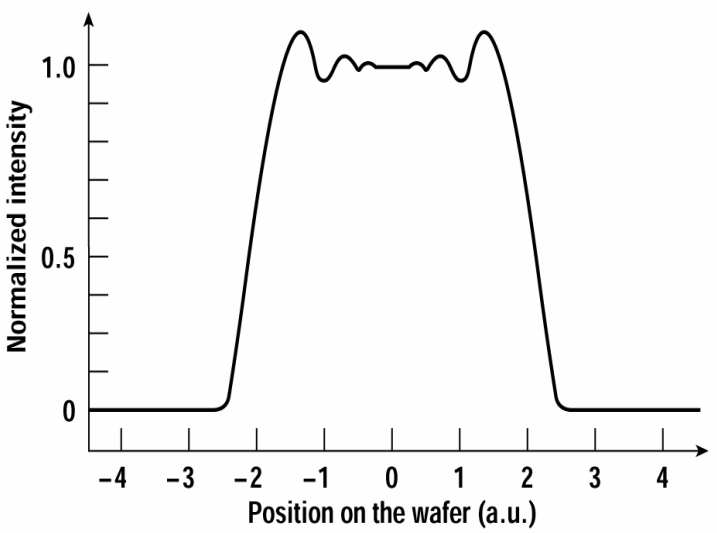


Figure 7.6 Typical near field (Fresnel) diffraction pattern.

'Near-field'

Diffraction of Light: influencing the resist pattern

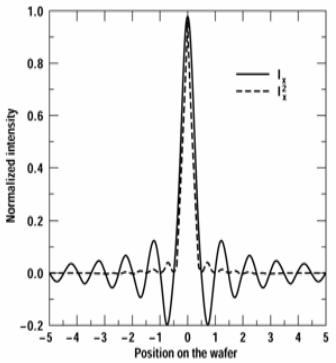


Figure 7.7 Typical far field (Fraunhofer) image.

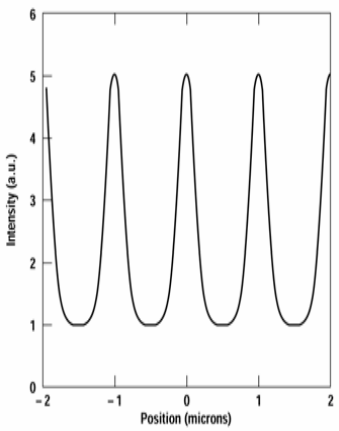
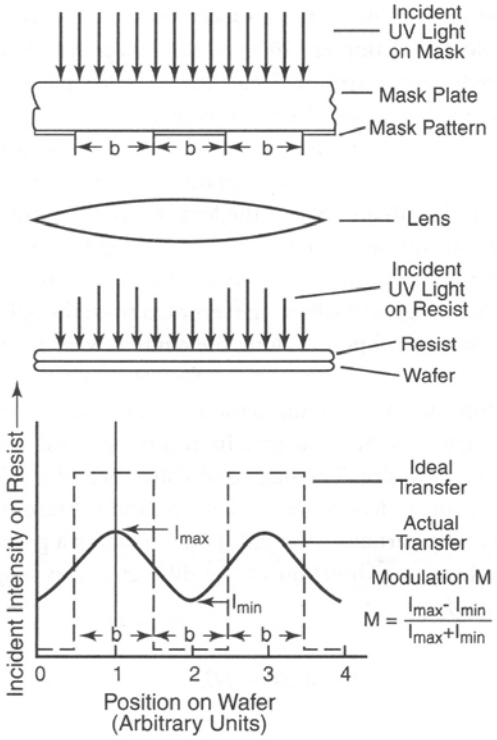
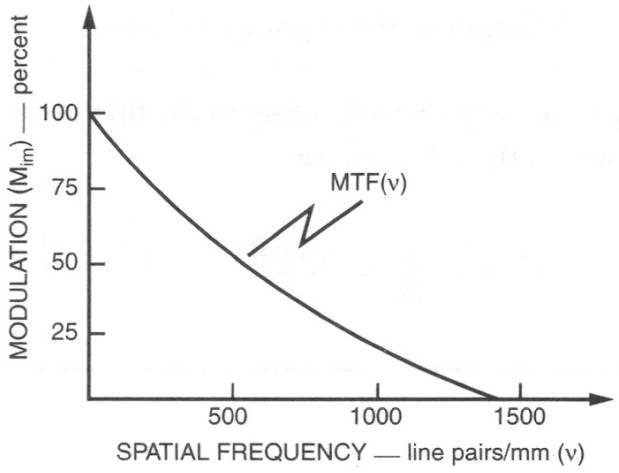


Figure 7.8 Far field image for a diffraction grating.





Fundamentals of Microfabrication,
M. Madou

'Far-field'

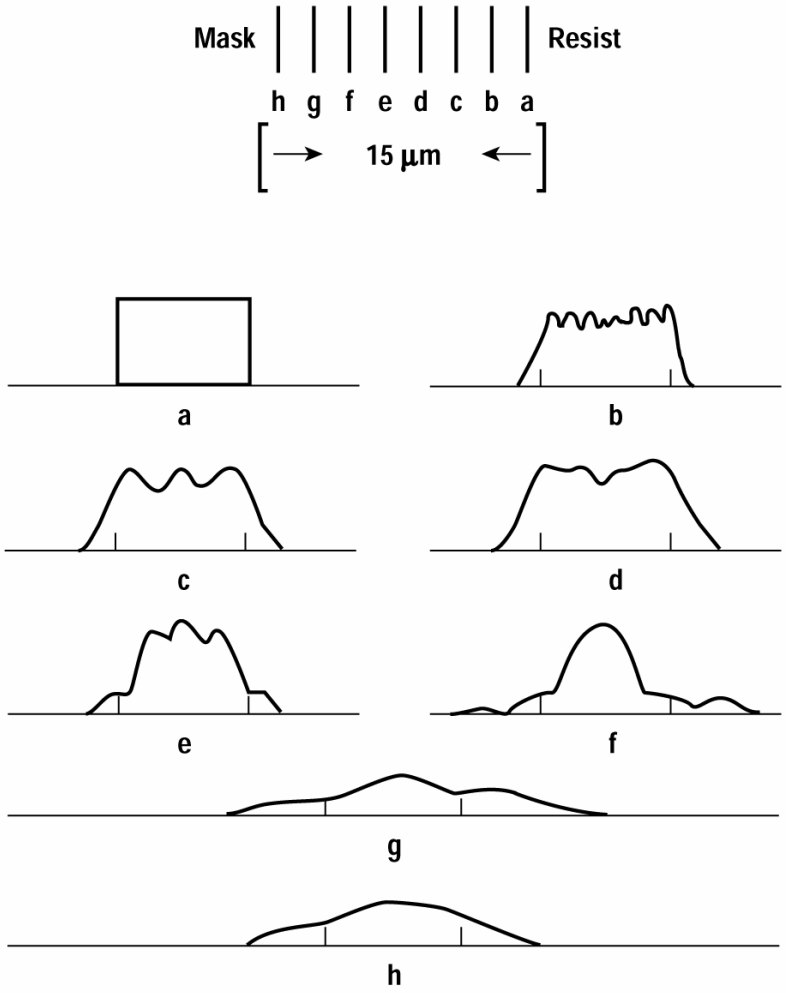


Figure 7.16 Intensity as a function of position on the wafer for a proximity printing system where the gap increases linearly from $g = 0$ to $g = 15$ mm *(after Geikas and Ables)*.

Resist image:
Distance between mask and substrate

Optical Projection System

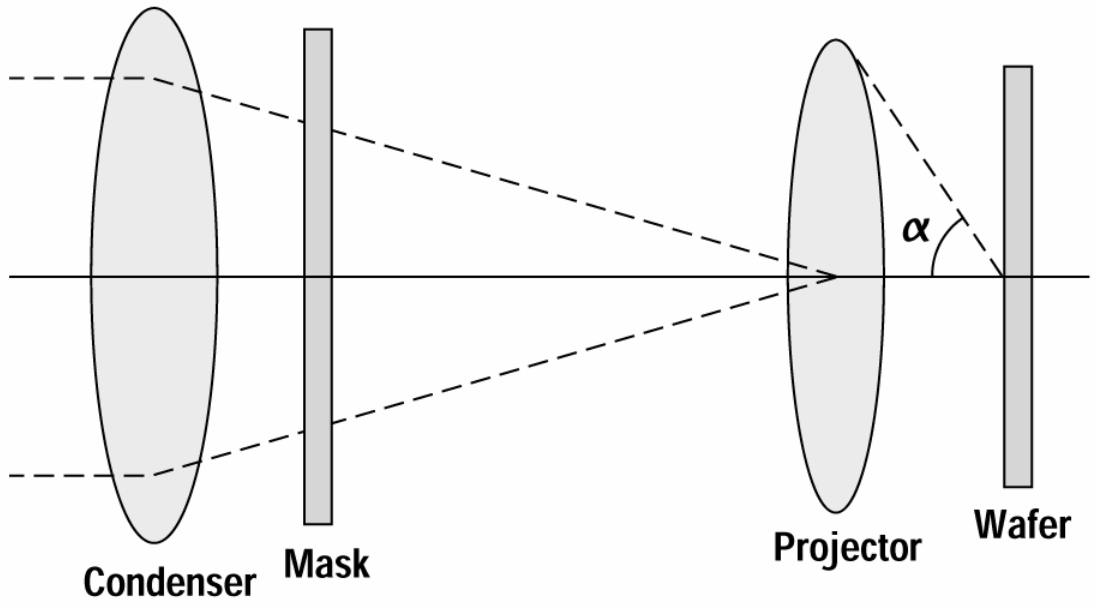
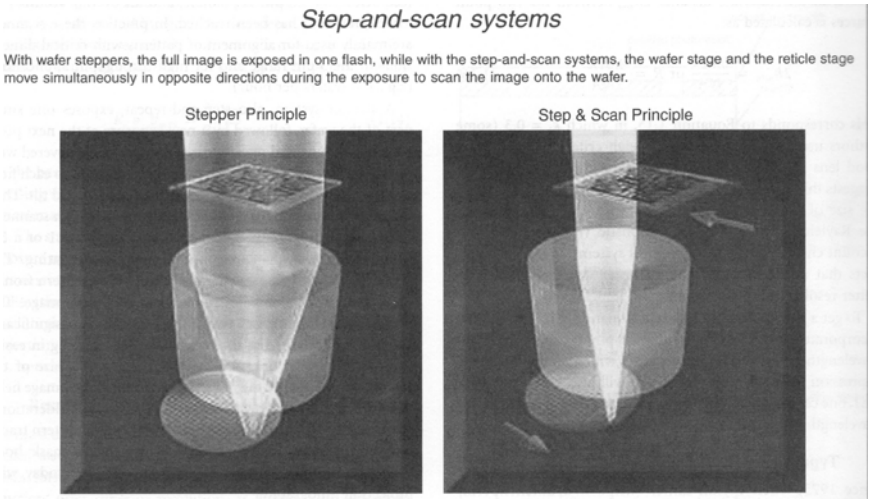
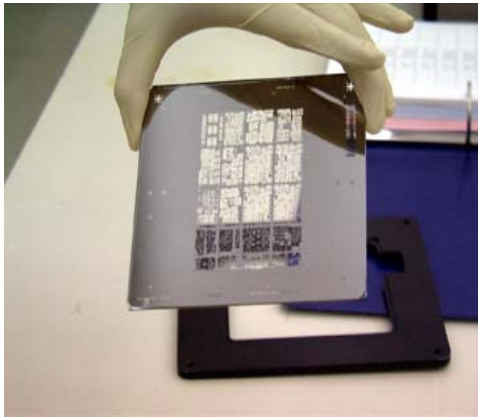


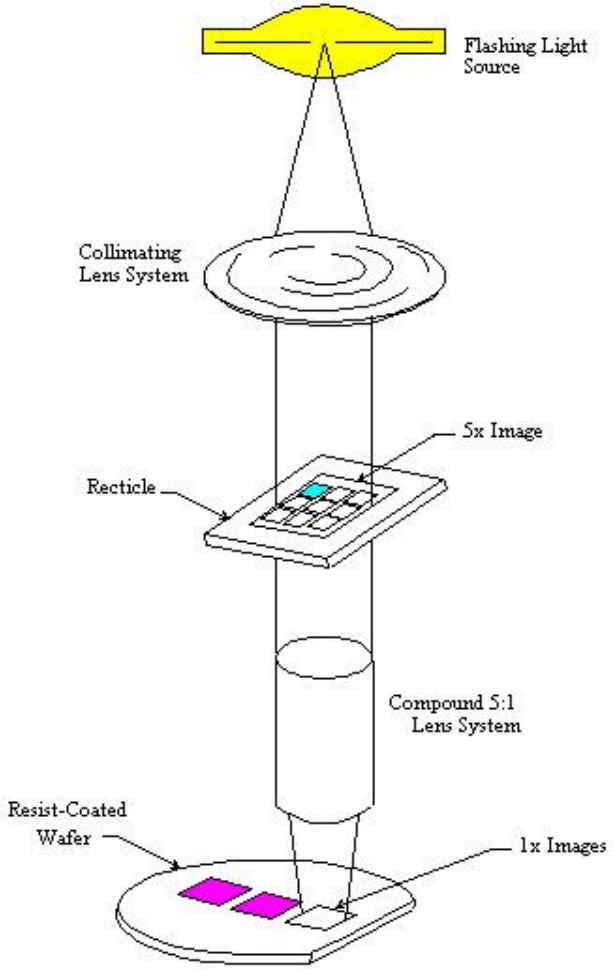
Figure 7.17 Schematic for the optical train of a simple projection printer.

Optical 'Steppers'



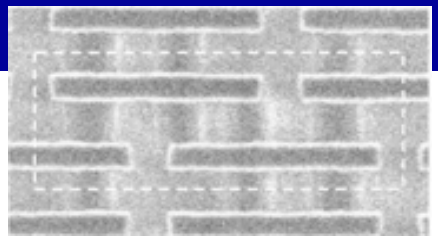
Fundamentals of Microfabrication, M. Madou



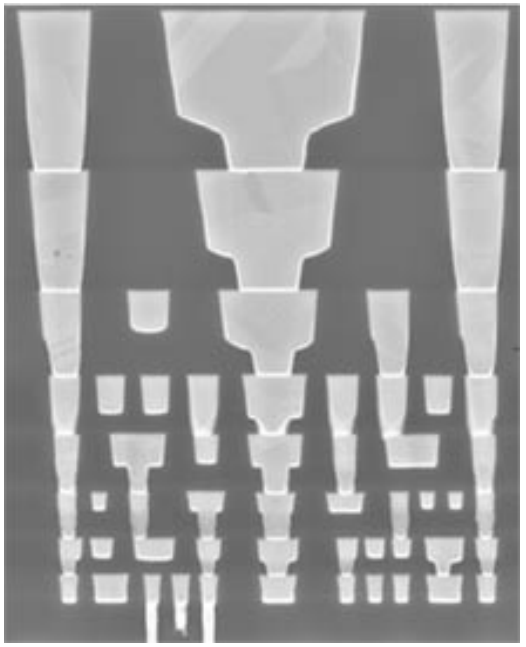


http://www.mse.vt.edu/faculty/hendricks/mse4206/GaAsTEK/Lithography/ladv.htm#Section4

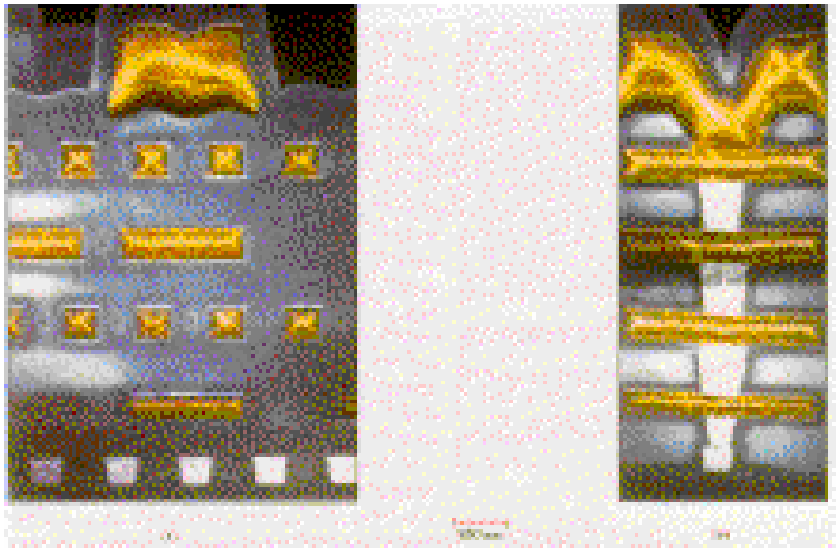
Why are minimum feature size (spatial resolution) and depth of focus important?



Intel SRAM memory cell
0.346 square microns
(6 transistors)
45 nm technology



Intel 65 nm technology



IBM 0.5 micron technology

MTF versus CMTF

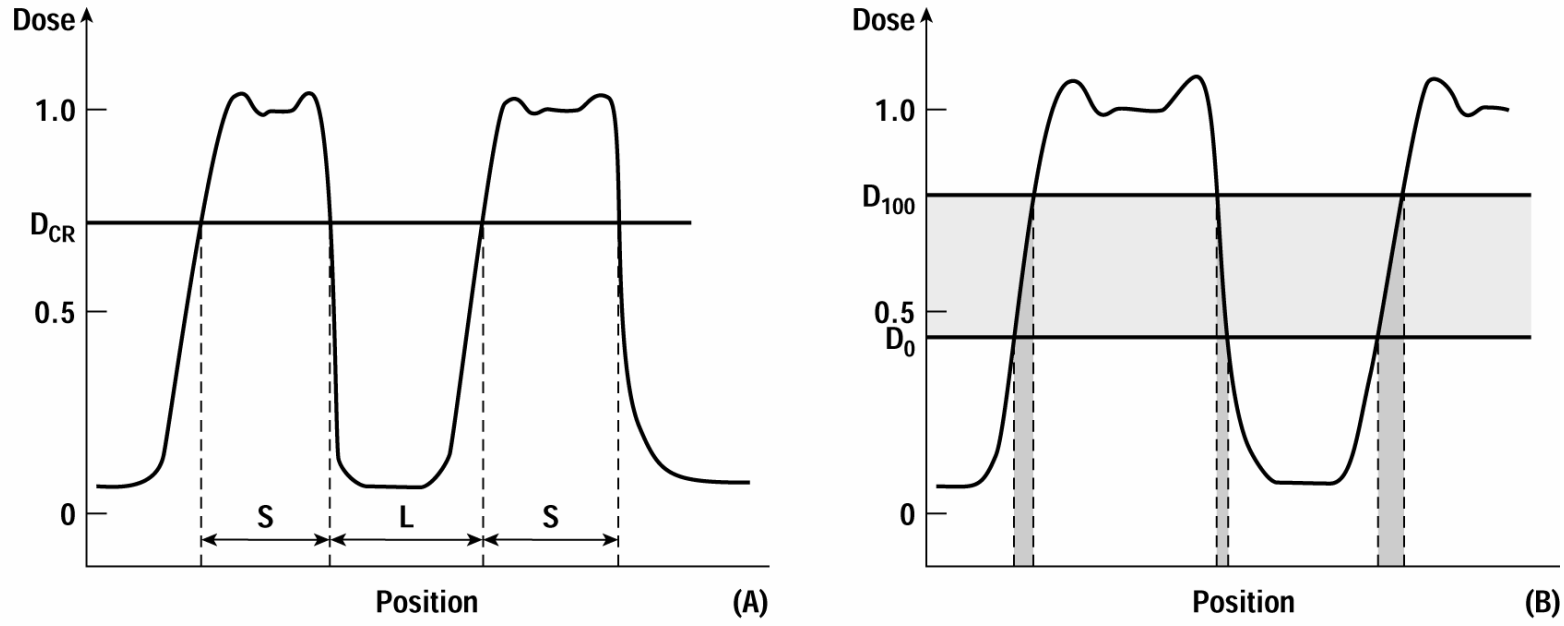


Figure 7.9 Plot of dose versus position on the wafer. Dose is given by the intensity of the light in the aerial image multiplied by the exposure time. Typical units are mJ/cm^2.