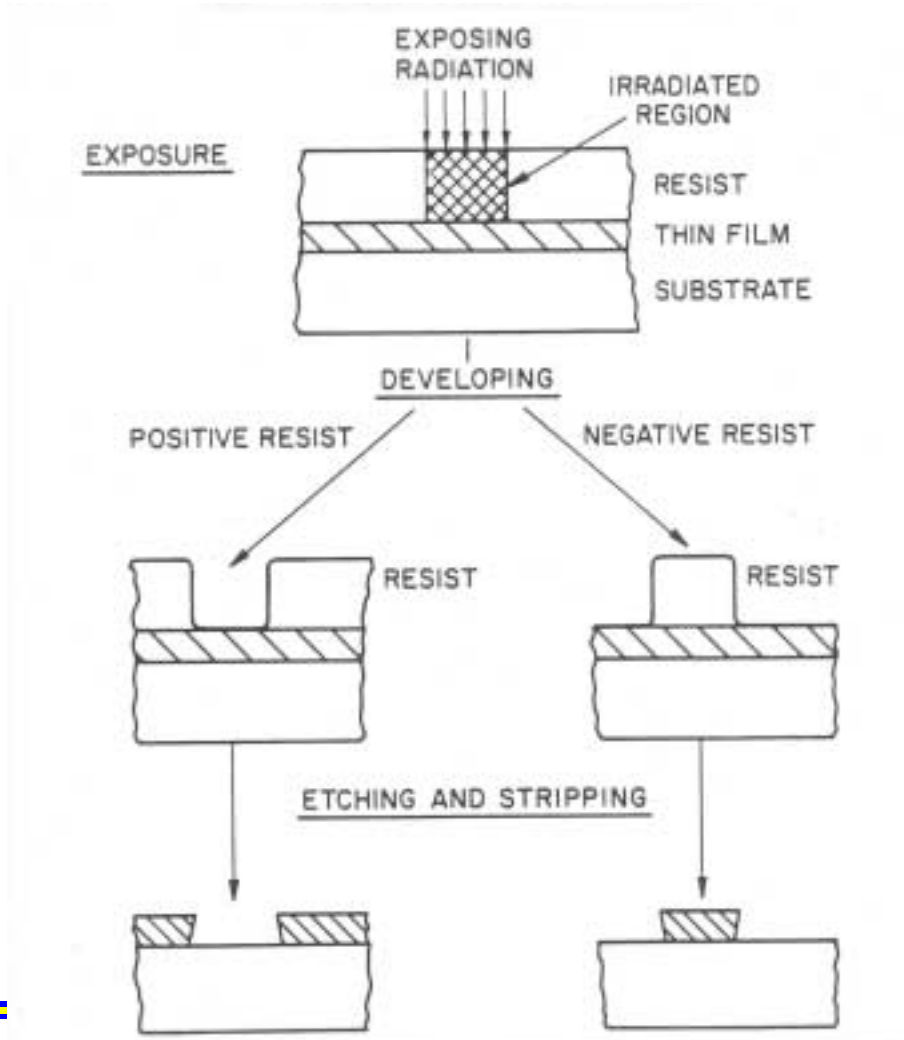
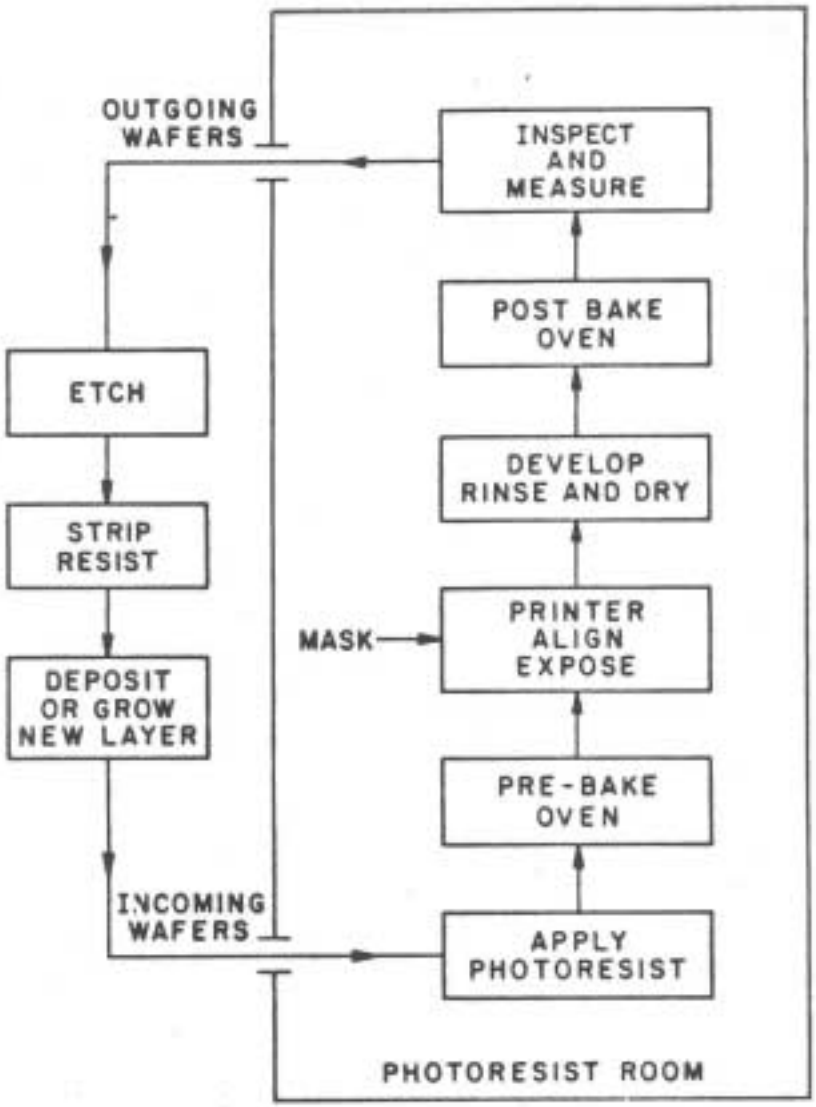
Lithography

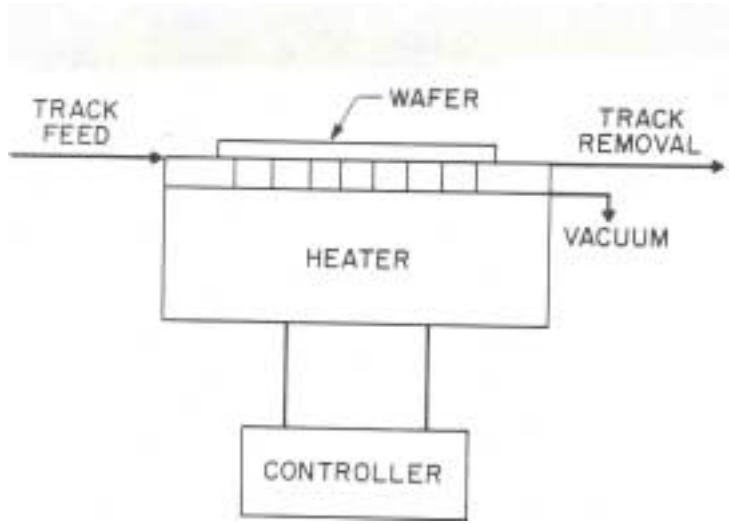
- Lithography is the process of transferring two dimensional patterns (e.g., a circuit pattern) on a mask to an underlying film or substrate.
- Most often the mask is a light sensitive polymer which allows the patterns to be transferred onto the polymer film. Such a light sensitive polymer is called a photoresist.
- Photolithography uses ultraviolet radiation from a Hg light source (now we use excimer lasers) to transfer the pattern from the mask to the photoresist and is the dominant technology in IC fabrication today.
- Future generations of lithography make use of x-rays, electrons or focused ion beams instead of photons (light).

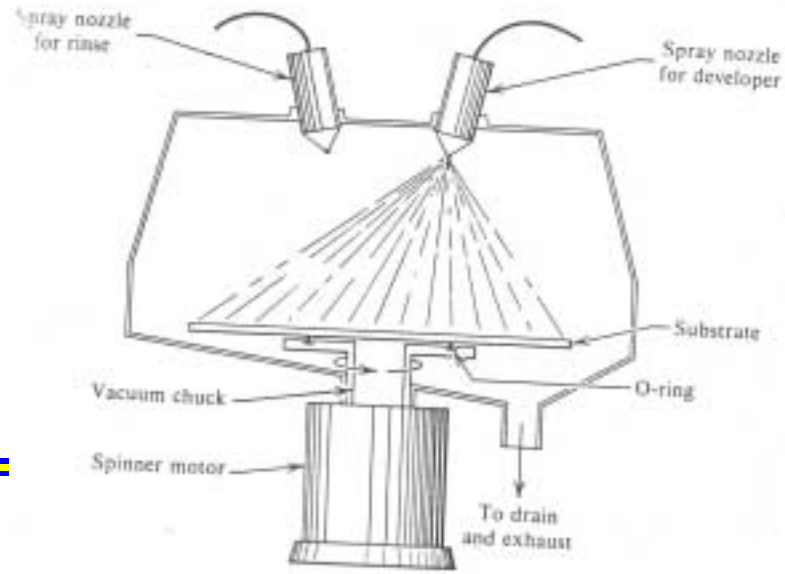
Patterning thin films by Lithography



Lithography is used many times in IC manufacturing and complexity of the IC is measured in “mask levels”







Application of photoresist

- Photoresist are high molecular weight polymers dissolved in organic solvents
- The goal in applying the photoresist is to obtain uniform, adherent, defect free polymeric film over the entire substrate. Uniformity must be ± 5 nm.
- The polymer solution is spin coated. Spin coating is acoplished by flooding the substrate surface with the resist solution and rapidly roatating it at constant speed. $\omega \sim$ 1000-10,000 rpm.
- First the substrate is cleaned. Contaminated substrate surface is a source of problems. Contamination causes poor adhesion and particles cause “comet tail” defects.
- Polymer must be compatible with the substrate surface for good adhesion. Sometimes adhesion promoters such as Hexamethyldisiloxane (for Si substrates) are used.

Spin coating

- Consists of 4 steps
  1) Flooding the substrate with the resist solution.
  2) Accelerating to the desired rotation speed.
  3) Spinning at constant speed to near dryness.
  4) Remove the edge bead.
- The solvent evaporates as the substrate is spinning and the solution is spreading on the substrate.
- Thickness t is a function of ; $t = f(\omega, c, \eta, \text{solvent, environmental factors})$

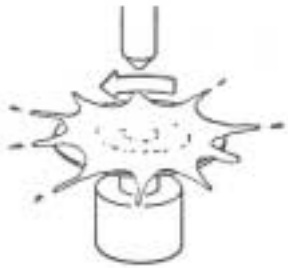
  ω = spin speed

  c = polymer concentration in solvent

  η = polymer viscosity

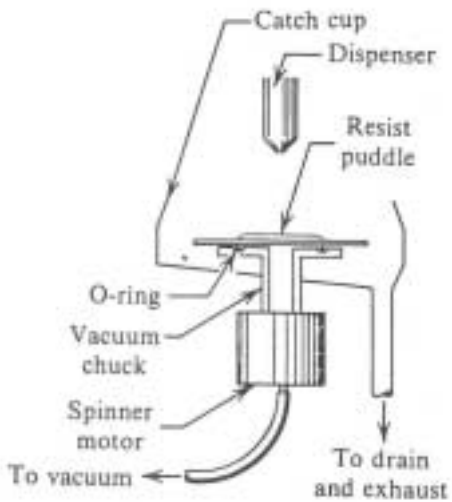
Photoresist Spinning

(a)



(c)

(e)

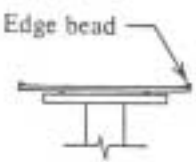


Resist dispense

(b)

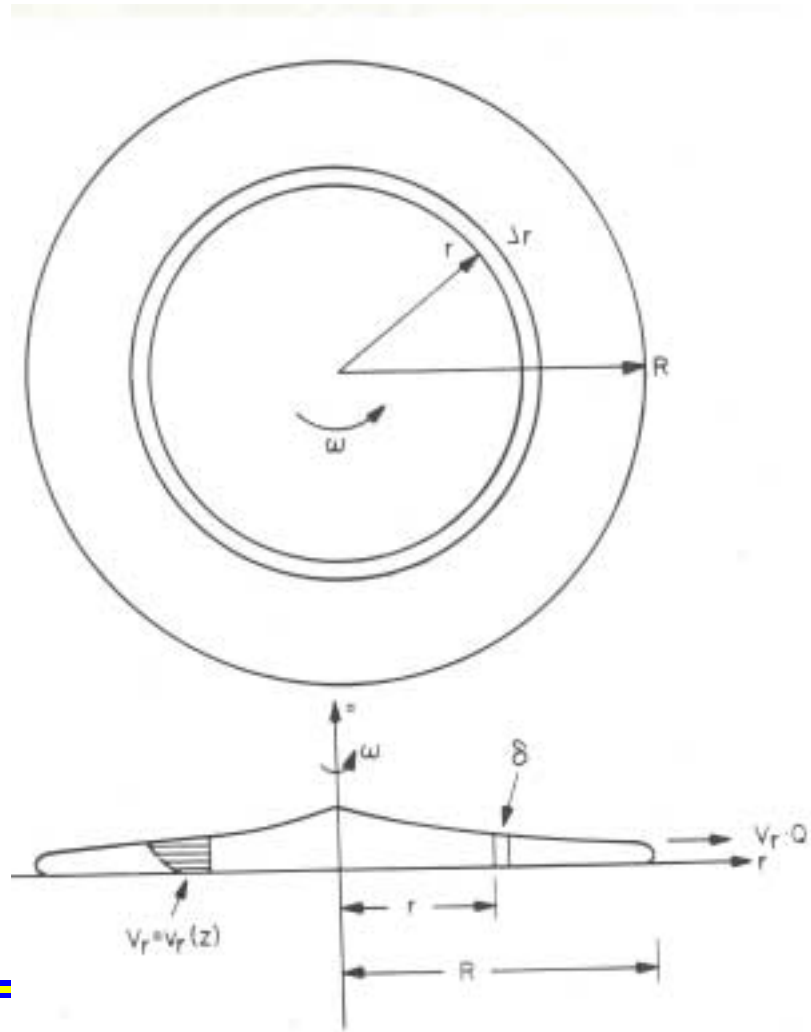
Spinning process

(d)



Coated wafer

(f)



Spin coating

- For a given system of polymer and solvent t = f(ω) only.

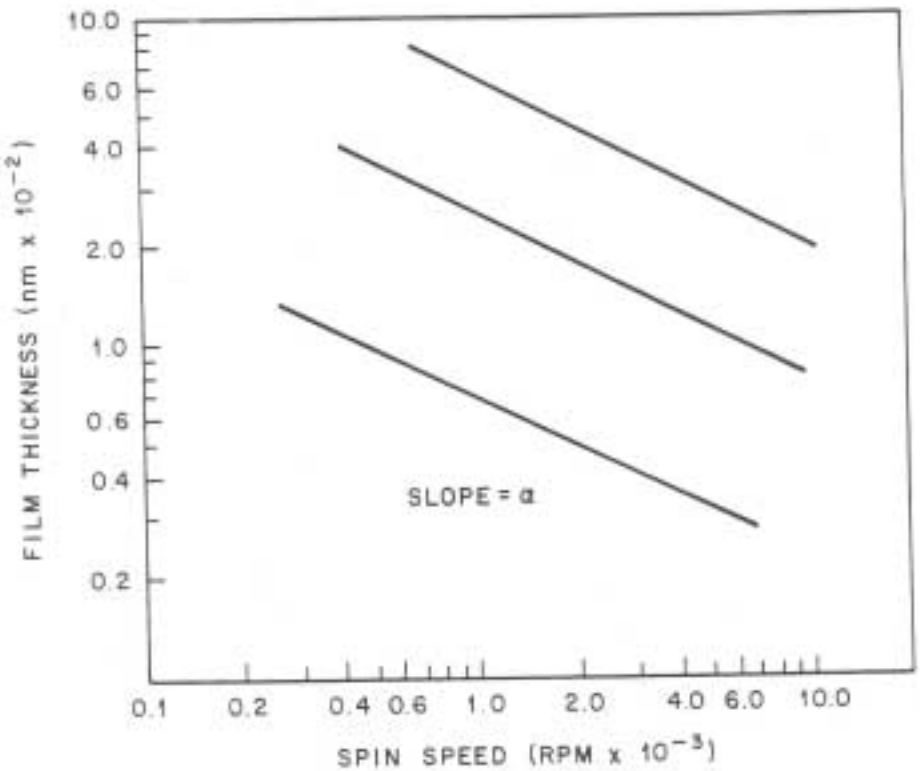
$$t = \frac{k}{\omega^{\alpha}} \quad \alpha \approx 1/2$$

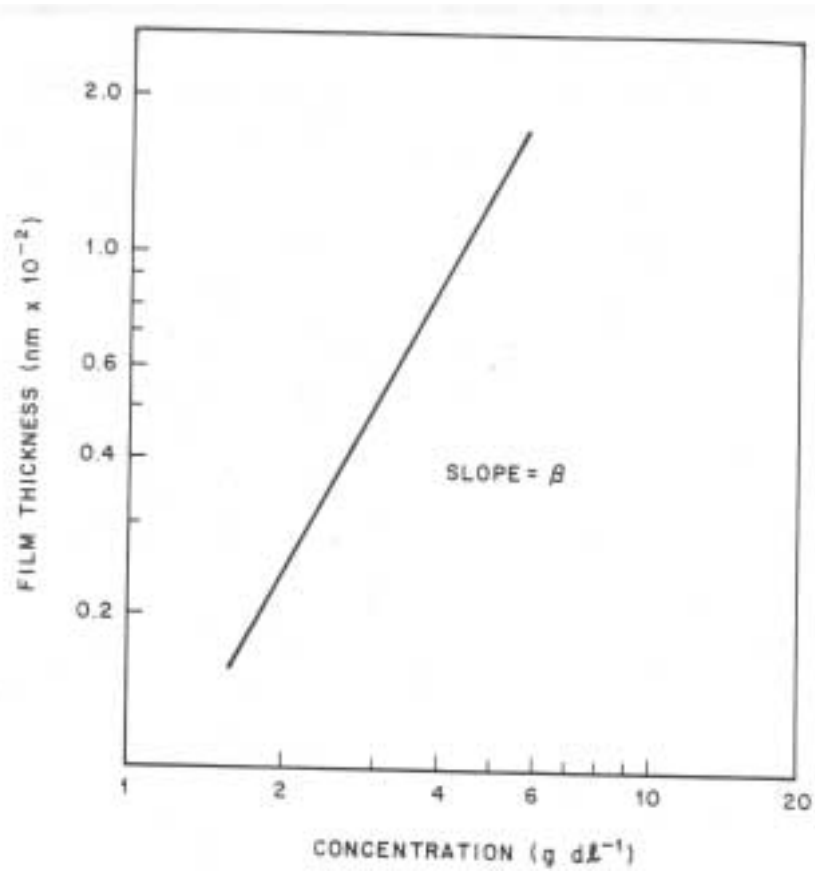
- If polymer concentration increases k is increased $k=k'c^{\beta}$.
- Similarly s a function of viscosity k increases $k=k''\eta^{\gamma}$.
- Combining these gives

$$t = K\frac{c^{\beta}\eta^{\gamma}}{\omega^{\alpha}}$$

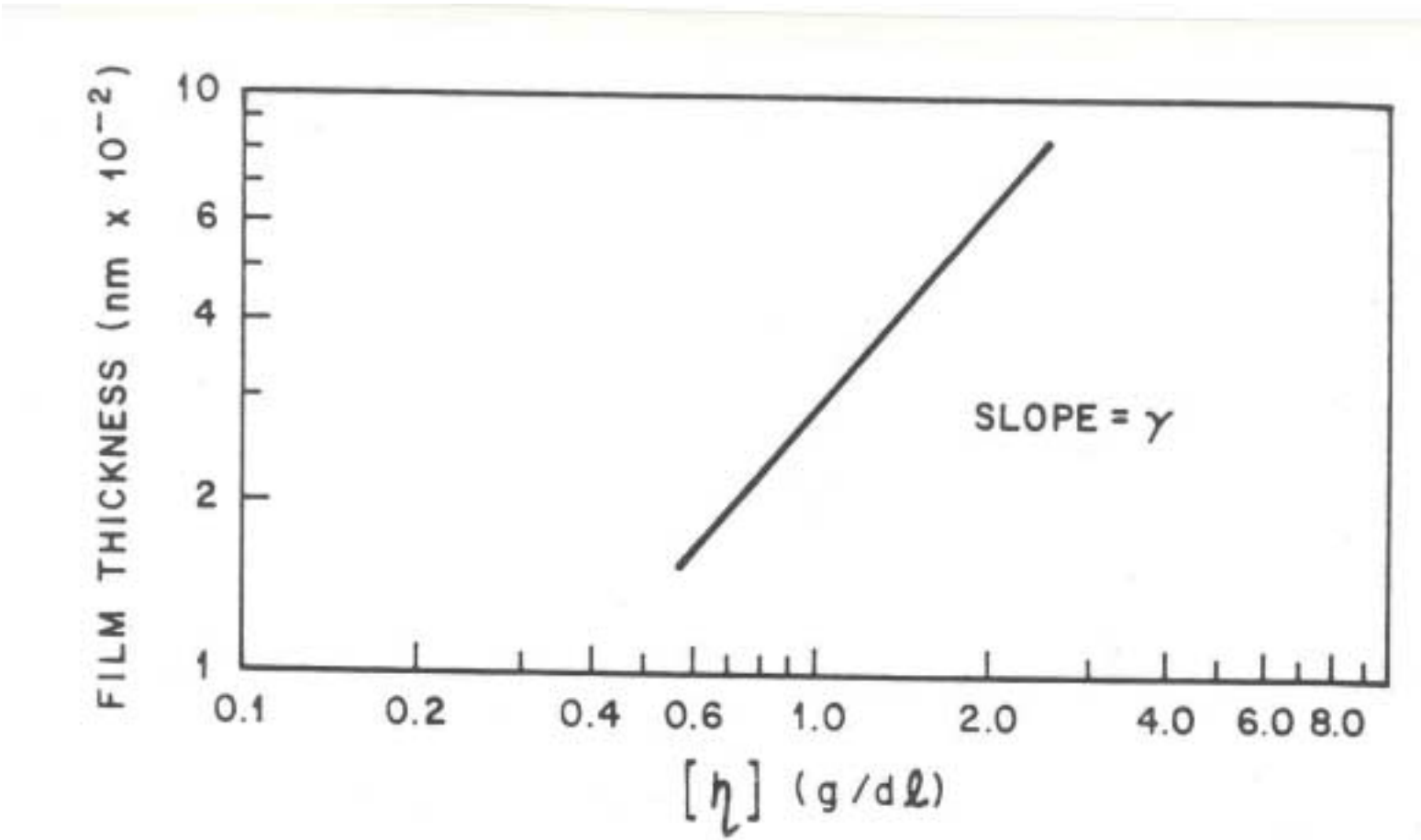
- For a given photoresist system this data would be supplied by the photoresist supplier.

Thickness t is a function of ω = spin speed
c = polymer concentration in solvent





Thickness as a function of the viscosity



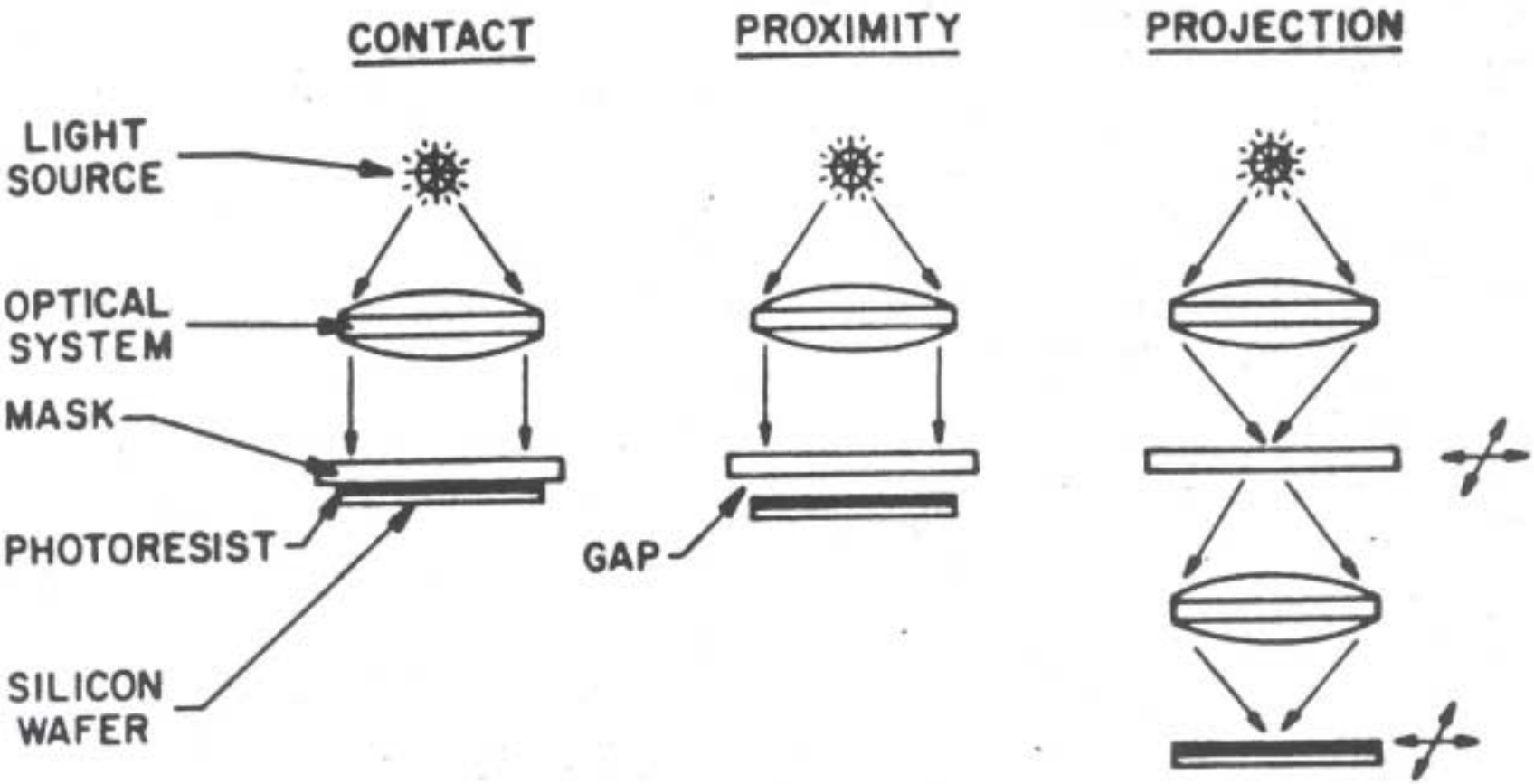
Spin coating

- Solvents: Most spinning solvents are based on esters of ethyleneglycol (Cellosolve, Cellosolve acetates). But these are carcinogens. There has been a switch to esters of linear high molecular weight acids.
- Criteria for choosing solvents:

1) Polymer must have a large radius of gyration (R_g) in the solvent. Radius of gyration is the mean square end to end distance. Larger the R_g, the more extended the polymer is and the better it is for spinning. If R_g is small, the polymer eventually becomes immiscible and precipitates.

2) Polymer must remain in solvent in the entire spinning process otherwise aggregation leads to pinholes and opaque spots. As solvent evaporates c and η increase. Solvent volatility must be low enough that c and η do not change rapidly during spinning.

Three methods of “printing”



Contact & Proximity printing

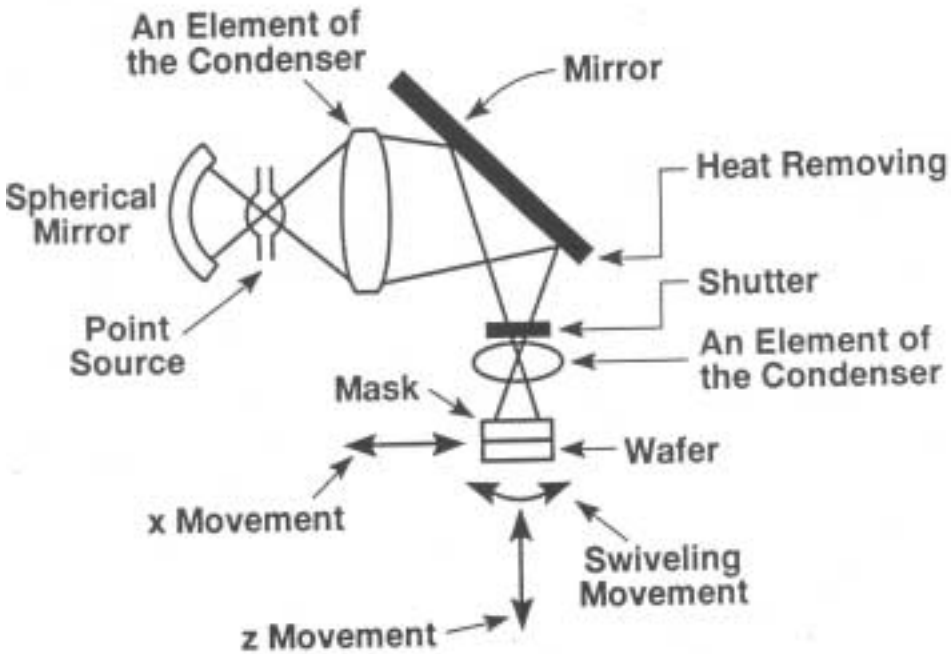
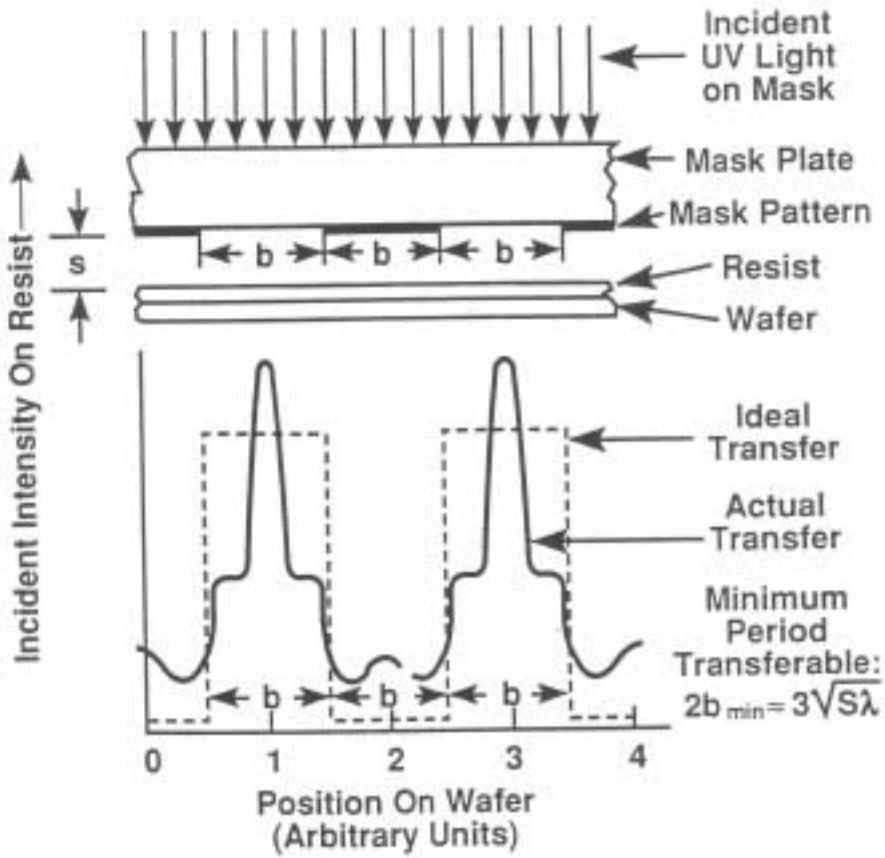
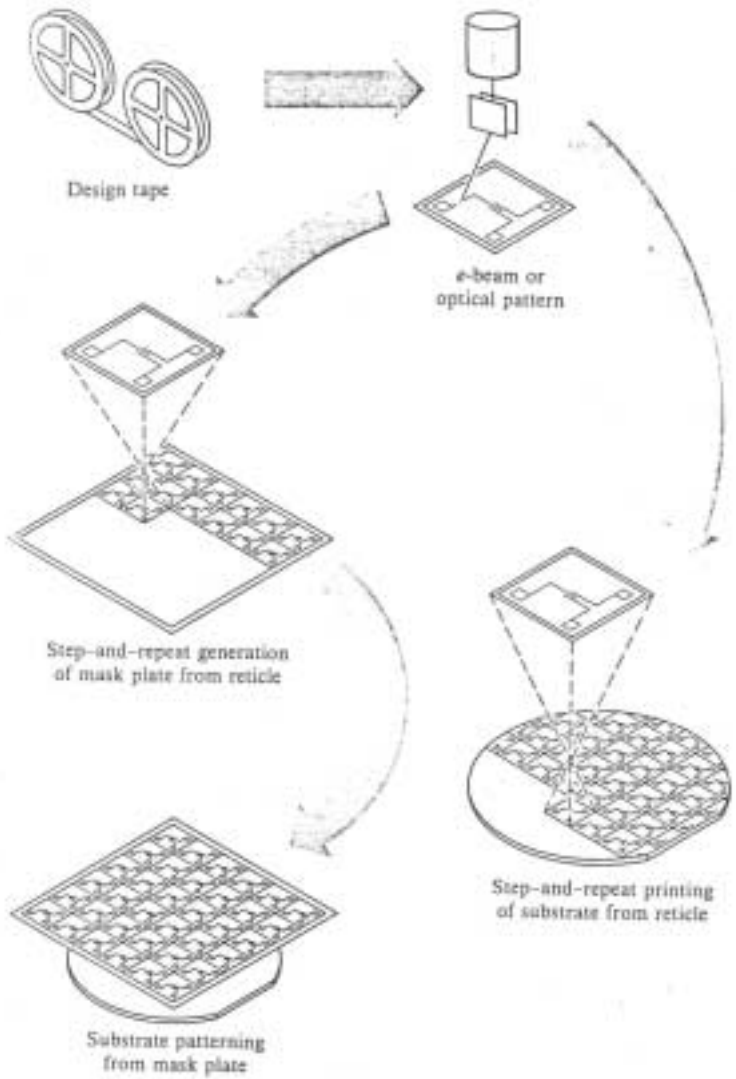


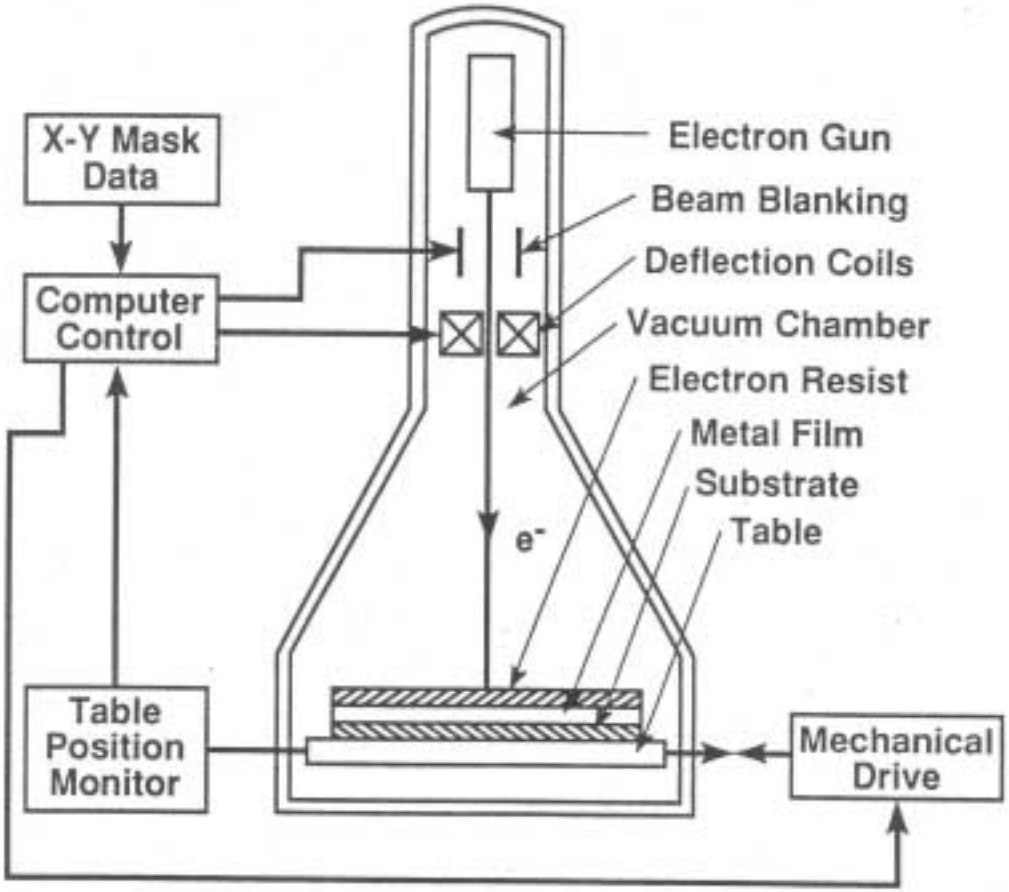
Figure 2. Schematic of contact–proximity printing.

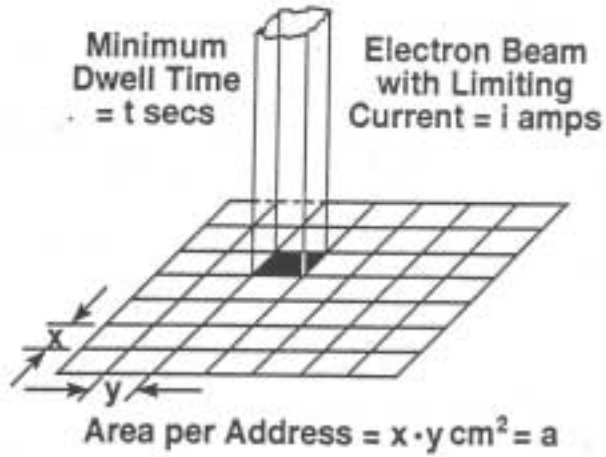


Step Scan


Design tape
e-beam or
optical pattern
Step-and-repeat generation
of mask plate from reticle
Step-and-repeat printing
of substrate from reticle
Substrate patterning
from mask plate

E-beam lithography $E=h\nu=hc/\lambda$





Evolution of Lithographic methods