

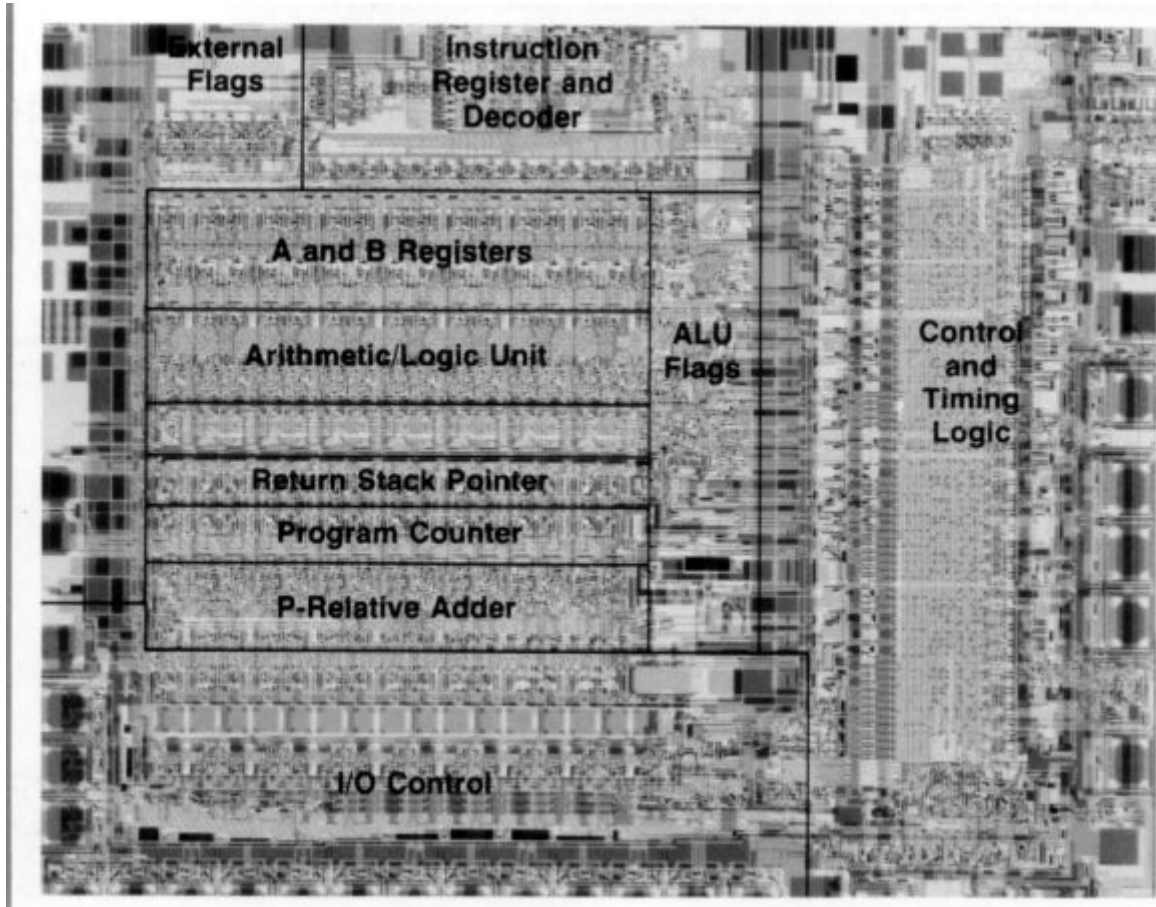
Photolithography Technology and Application

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Art or Science?



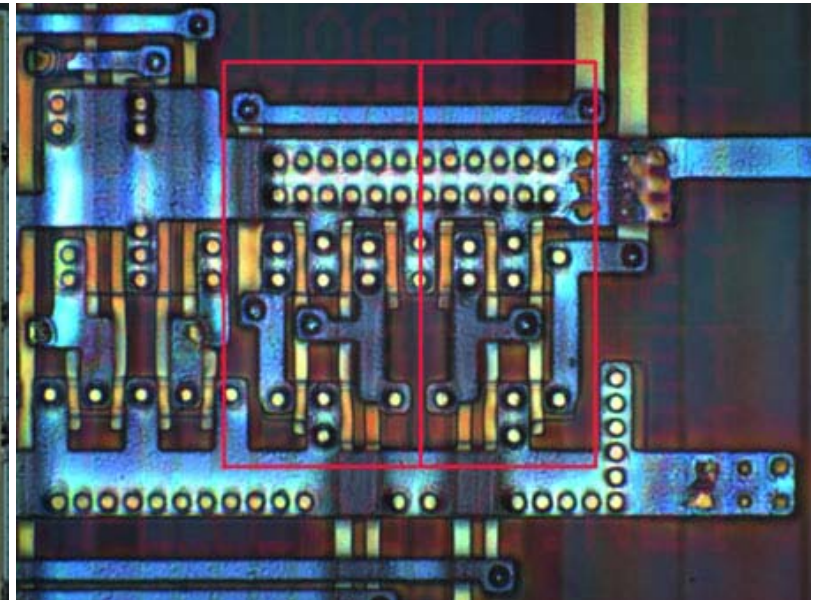
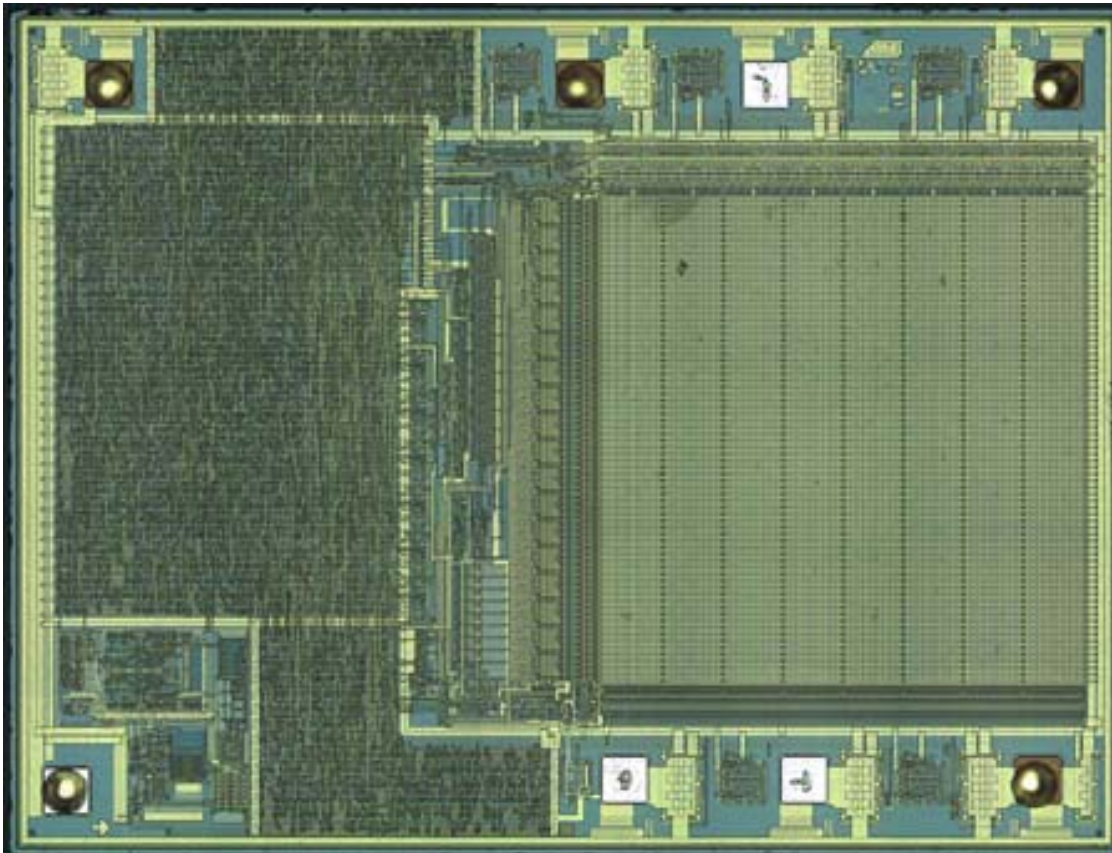
Lind width = 100 to 5
micron meter!!

Resolution = ~ 3 micron

Can you image the latest
transistor size? 22nm,

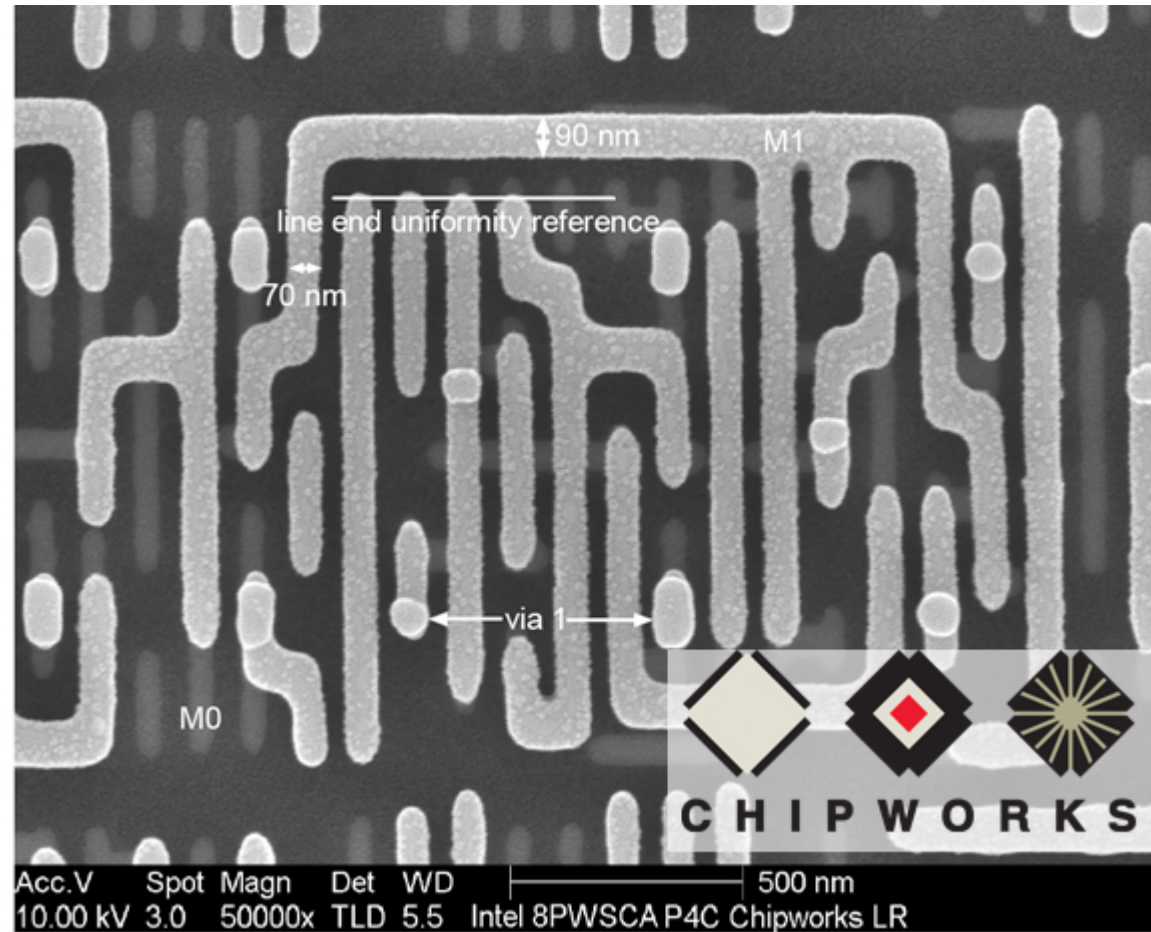
- HP processor, 1977.

Human fine art

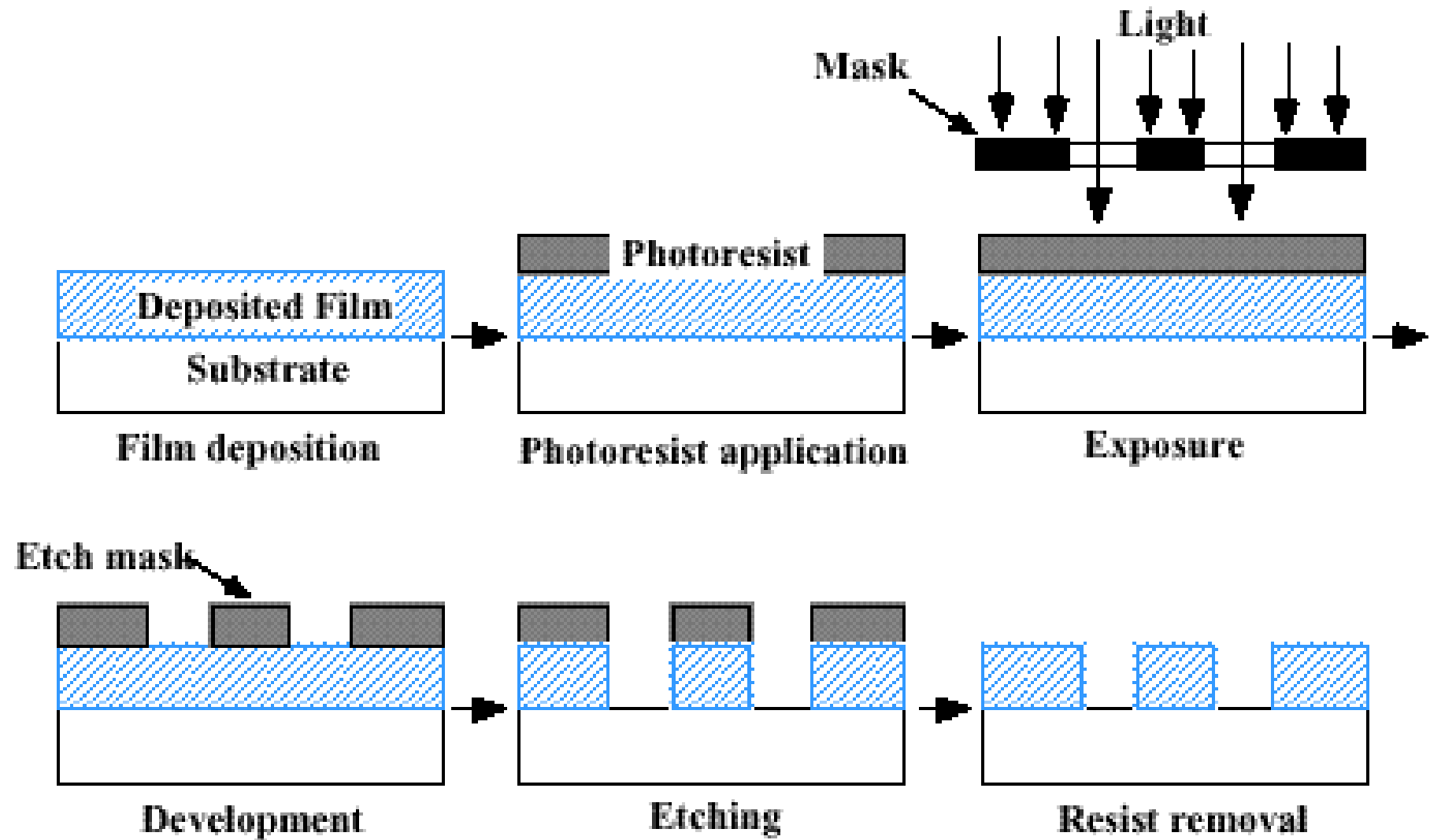


magnified 500x, top metal
(M2) is covering DUAL 2-
Input AND gate

Intel 32 nm technology from the Core i5 660 Microprocessor



How it works



Wiki say...

- **Photolithography** (or "optical lithography") is a process used in [microfabrication](#) to selectively remove parts of a thin film or the bulk of a substrate. It uses light to transfer a geometric pattern from a photo mask to a [light-sensitive](#) chemical *photo resist*, or simply "resist," on the substrate. A series of chemical treatments then engraves the exposure pattern into the material underneath the photo resist.

Function of photolithography

- Generate all layers of patterns
- Transistor
 - Define STI, well implant mask,, define gate W/L, generate LDD, BPSG via, W plug to source/drain,
- Interconnections
 - Contact hole, island, dual damascene, metal line...

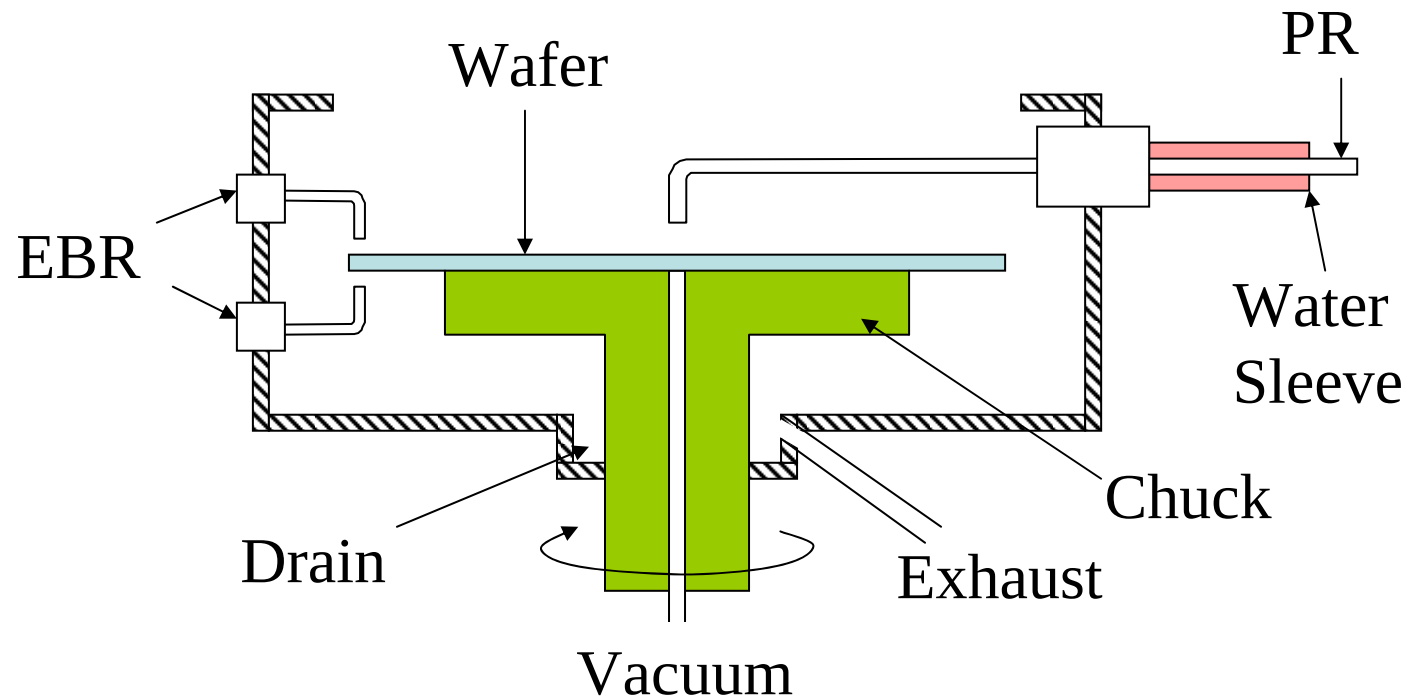
Process flow

- **Singe and Prime: 150C, hexamethyldisilazane (HMDS).**
- **Spin coat: solvent dispensed on the wafer backside, in order to ensure the wafer backside is clear of resist, and on the frontside wafer edge, to remove resist on the edge (“Edge Bead Removal” or “EBR”).**
- **Pre-bake: drives off excess solvent and turns the resist from a liquid into a film.**
- **Expose/Align: patterned by exposure to UV illumination. Exposure is performed through a "mask",**
- **Post-expose bake: finer features and smoother vertical-wall profiles achieved**
- **Develop:**
- **Post-develop bake:**

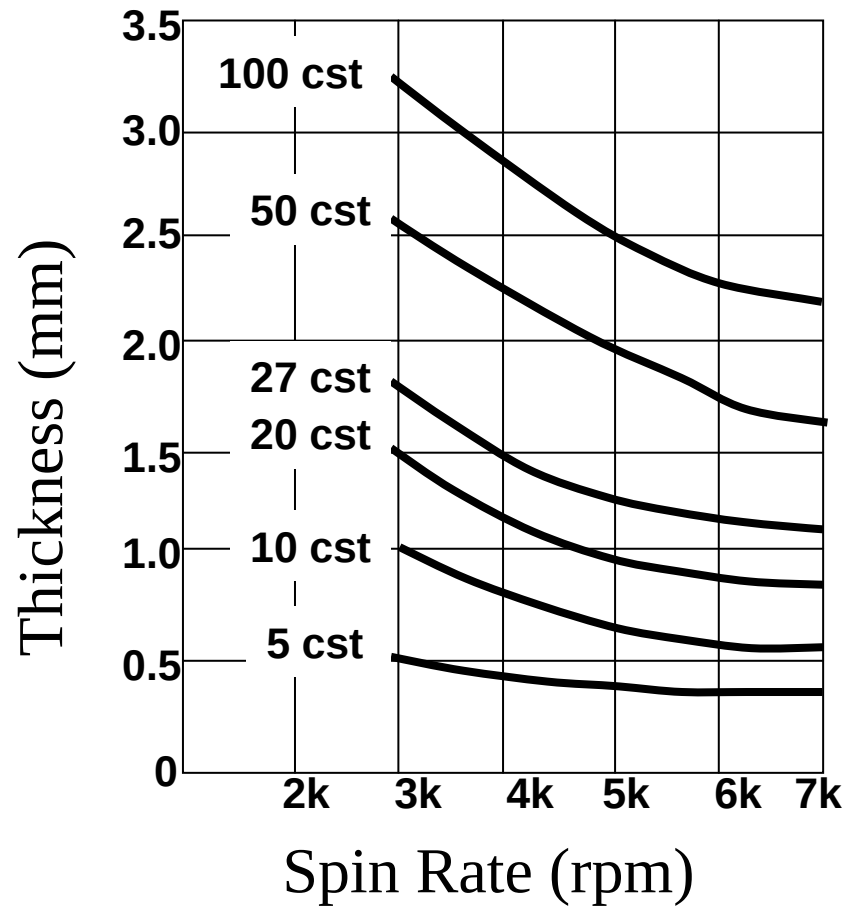
Spin coating

- Coater, Track,
- <http://www.apexicindia.com/SpinCoatingTheory.htm>

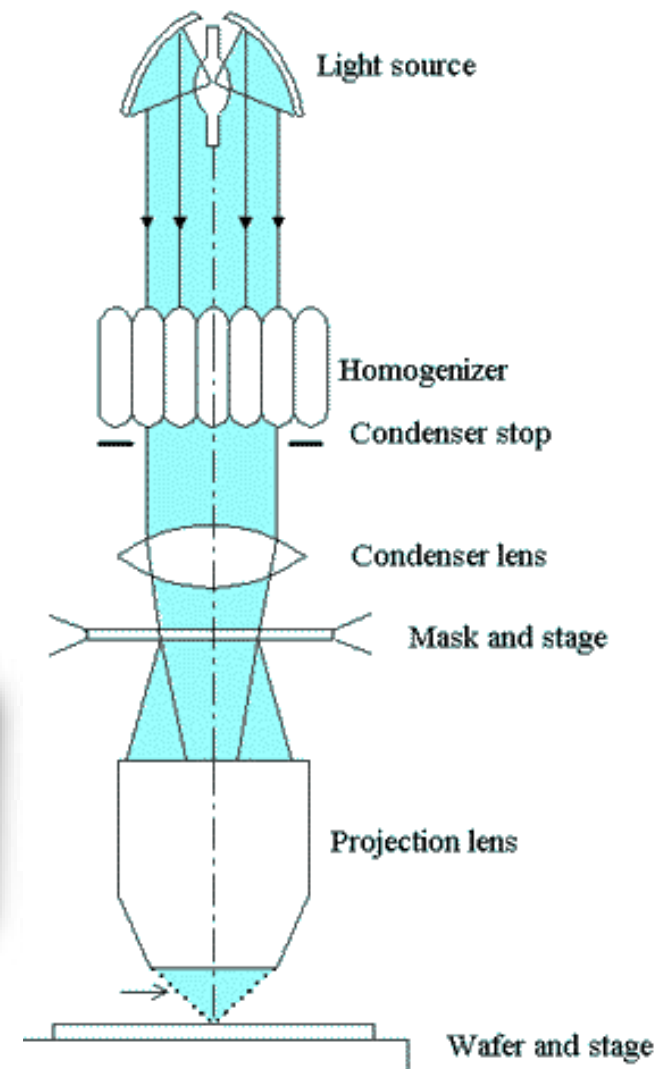
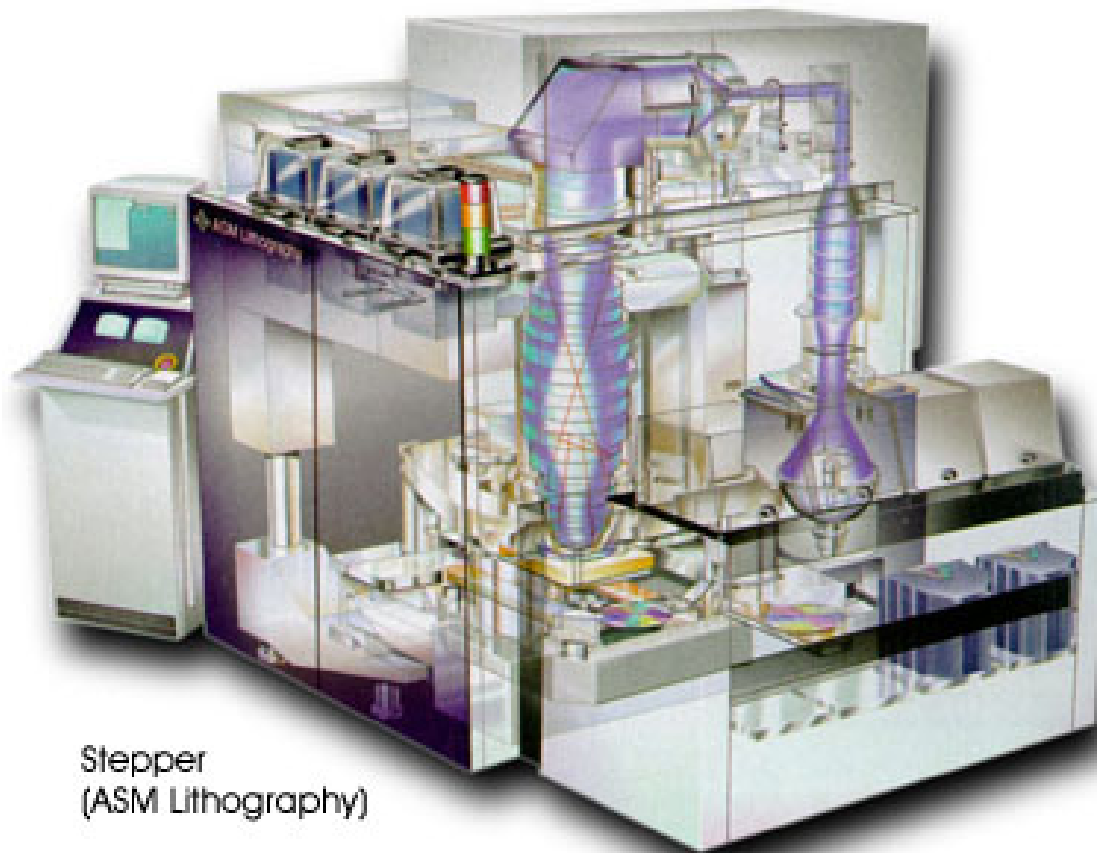
Photoresist Spin Coater



Relationship of Photoresist Thickness to Spin Rate and Viscosity

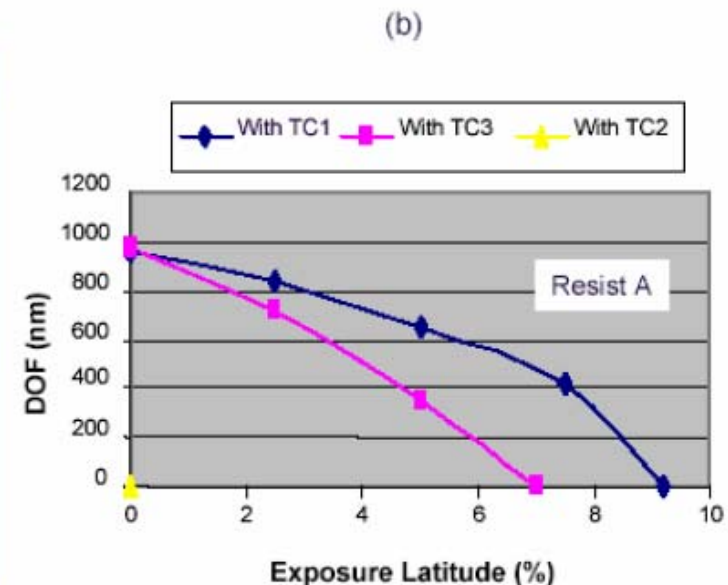
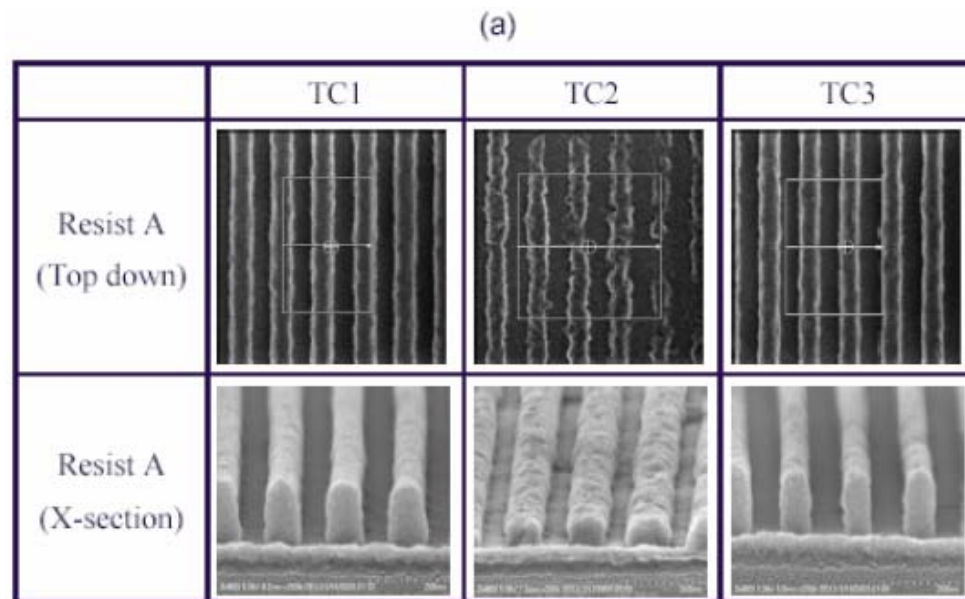


Exposure

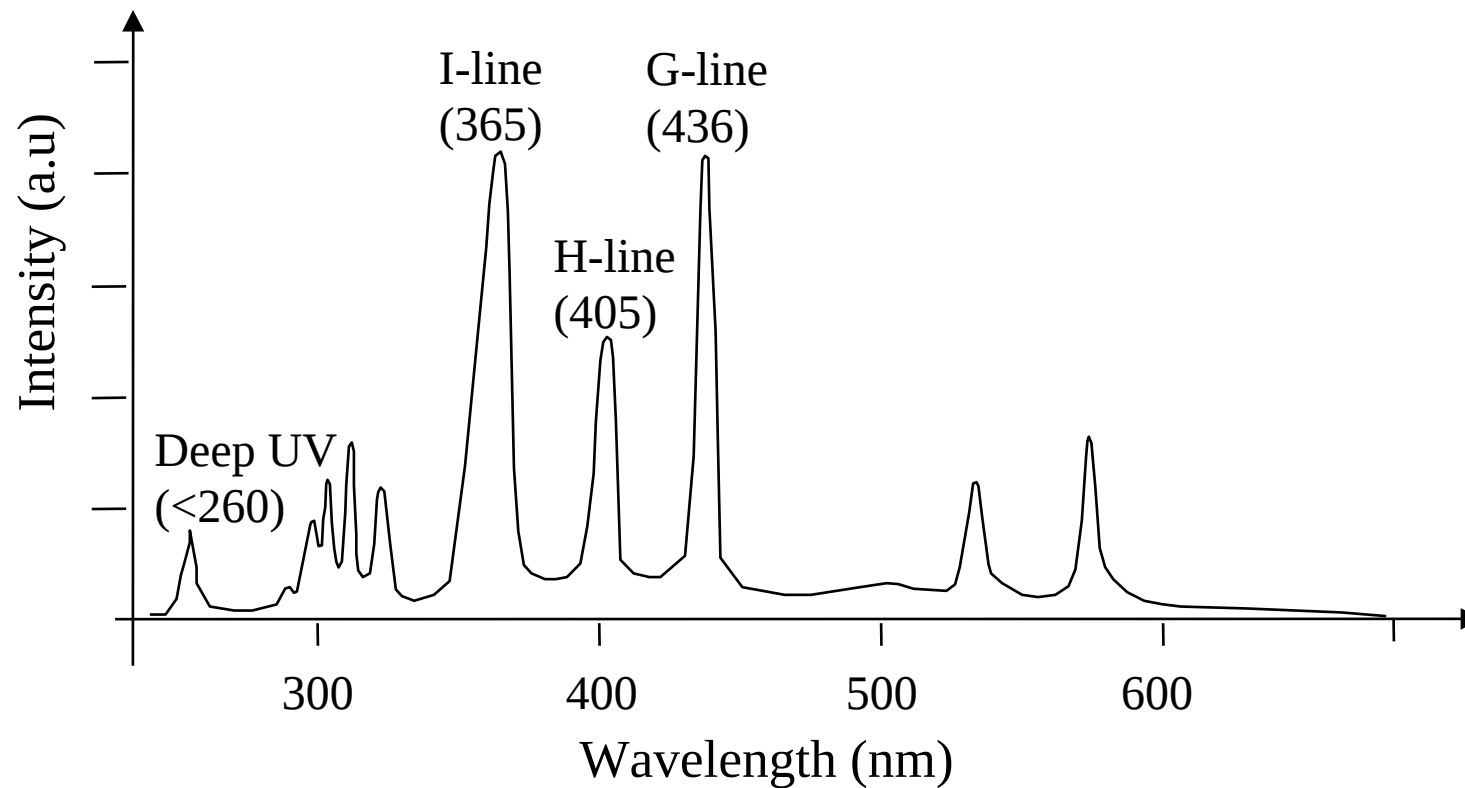


I-line? G-line? DUV??

- Light source vs. resolution $CD = k_1 \cdot \frac{\lambda}{NA}$
- Wavelength improvement
- 436nm—365nm—248nm—193nm



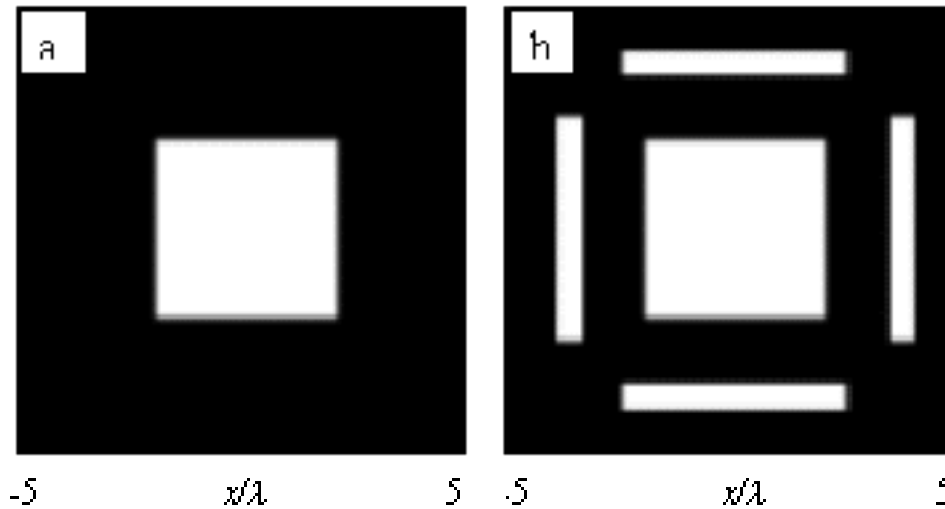
Spectrum of the Mercury Lamp



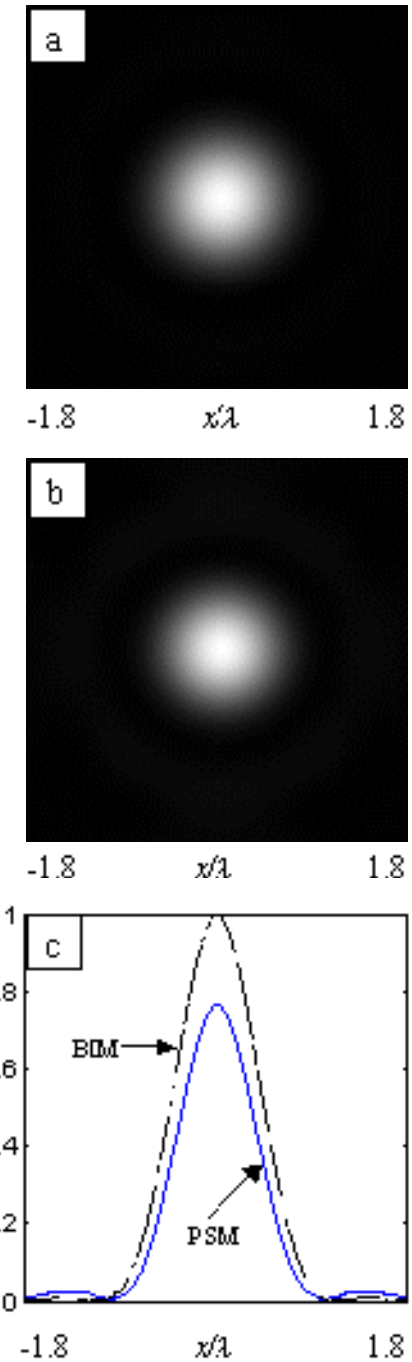
Photolithography Light Sources

	Name	Wavelength (nm)	Application feature size (μm)
Mercury Lamp	G-line	436	0.50
	H-line	405	
	I-line	365	0.35 to 0.25
Excimer Laser	XeF	351	
	XeCl	308	
	KrF (DUV)	248	0.25 to 0.15
	ArF	193	0.18 to 0.13
Fluorine Laser	F ₂	157	0.13 to 0.1

Mask design



Computed intensity patterns at the wafer for the masks ($\text{NA}_0 = 0.6$, $M = 1/5$, $s = 0.7$). (a) BIM, (b) PSM, (c) cross-sections of the intensity patterns in the images of the BIM (dashed) and the PSM (solid).



Comparison of exposure systems

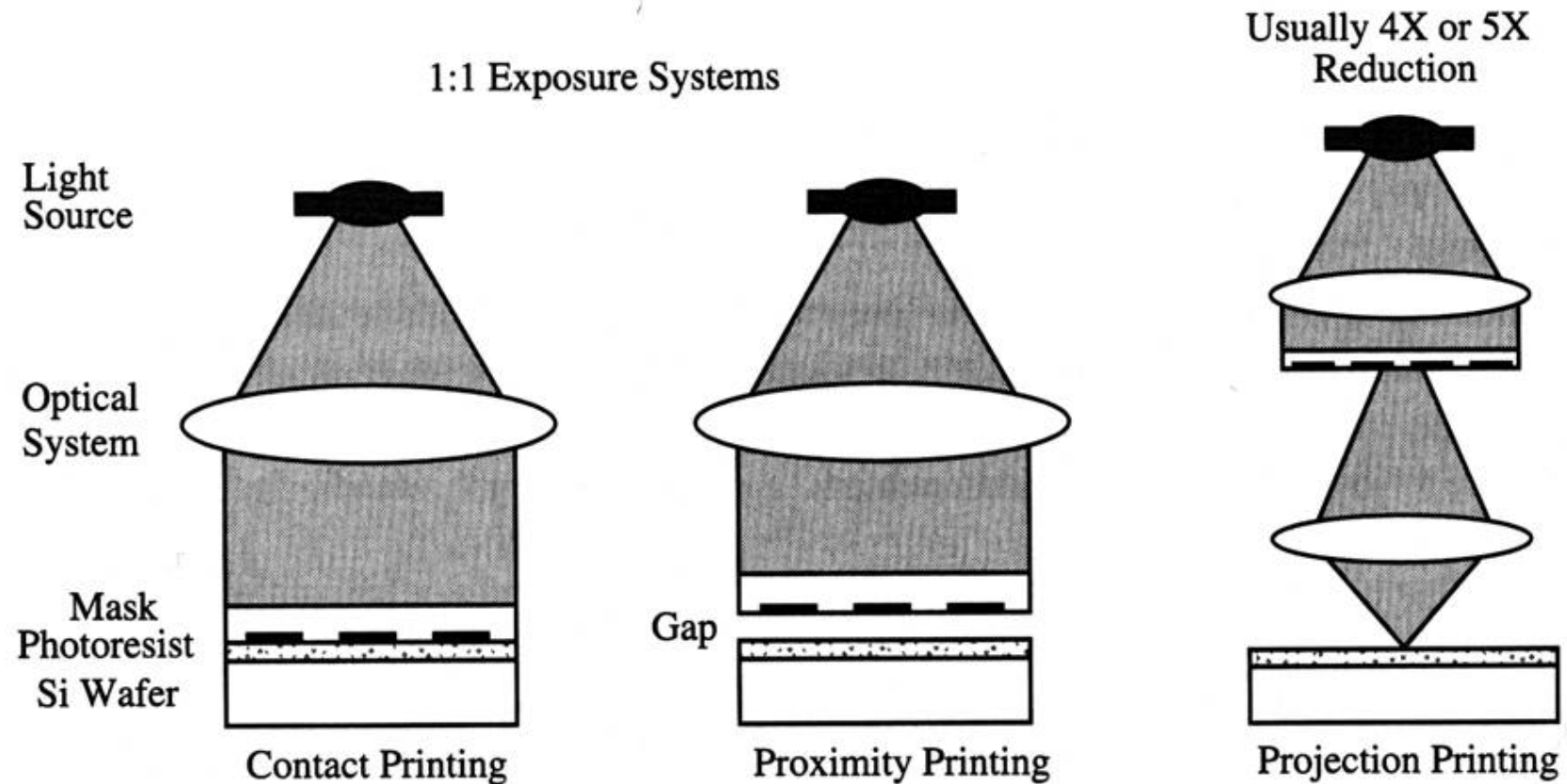


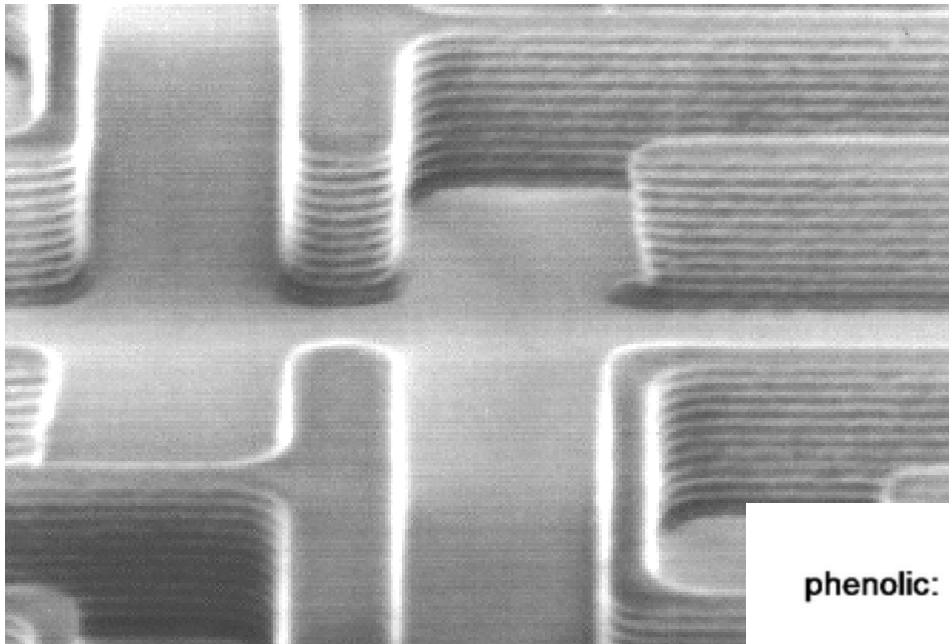
Figure 5-3 Three basic methods of wafer exposure.

Exposure Control

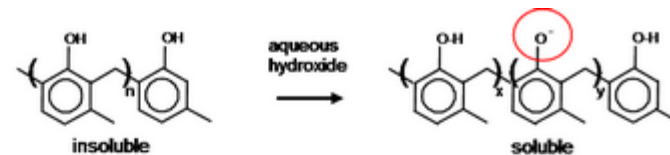
- Exposure light flux is controlled by production of light intensity and exposure time
- Very similar to the exposure of a camera
- Intensity controlled by electrical power
- Adjustable light intensity
- Routine light intensity calibration is required.

Intensity, I , measured in mW/cm^2

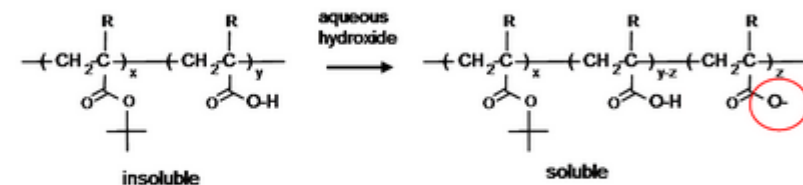
Development



phenolic:

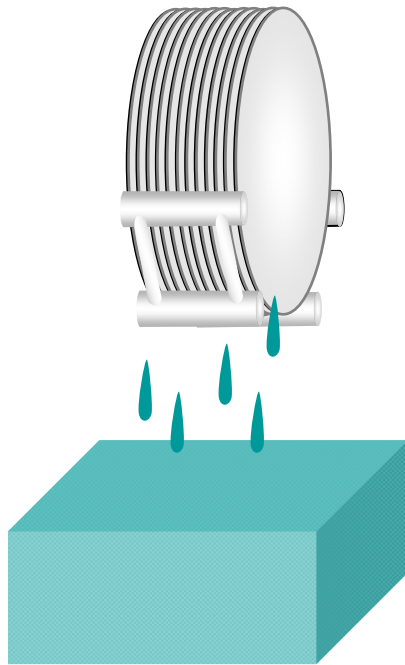


carboxylic acid:

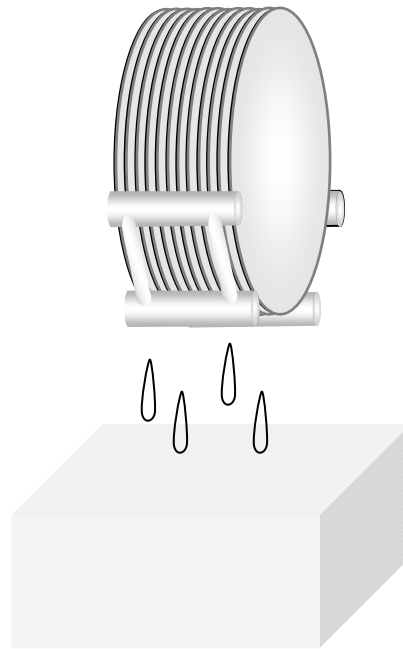


Acid-base chemistry of typical photoresist polymers when immersed in aqueous alkaline developer solutions

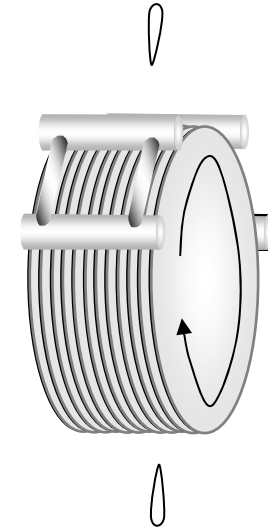
Development: Immersion



Develop

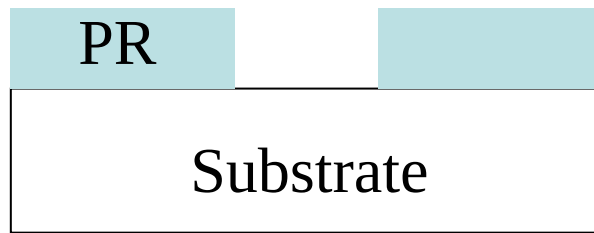


Rinse

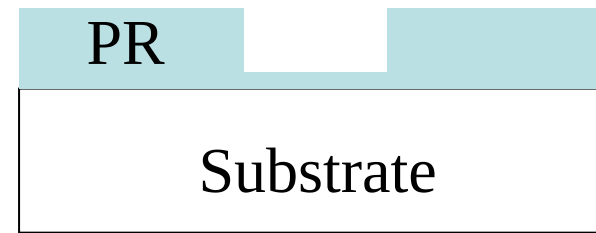


Spin Dry

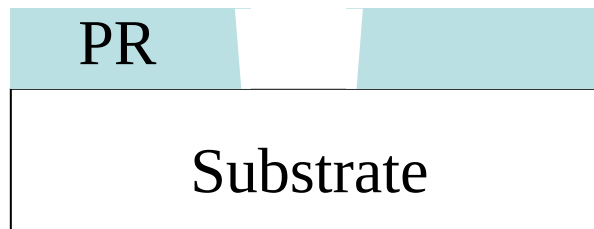
Development Profiles



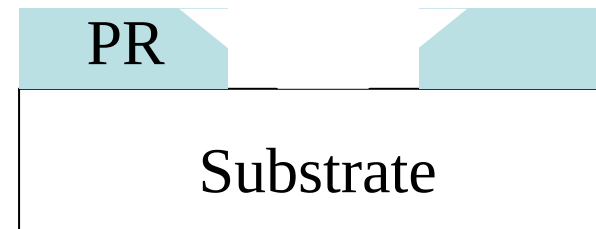
Normal Development



Incomplete Development



Under Development



Over Development

Pattern Inspection

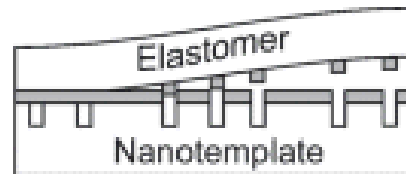
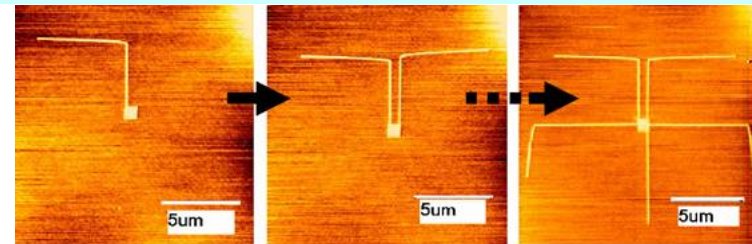
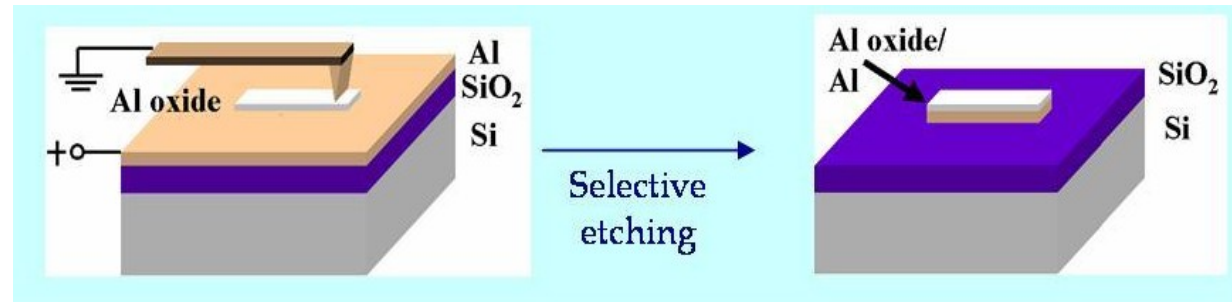
- Inspection, stripped PR and rework
 - Photoresist pattern is temporary
 - Etch or ion implantation pattern is permanent.
- Photolithography process can rework
- Can't rework after etch or implantation.
- Scanning electron microscope (SEM) for small feature size ($< 0.5 \text{ um}$)
- Optical microscope for large feature size

Pattern Inspection

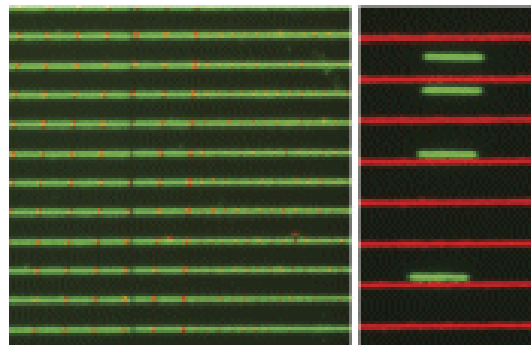
- Overlay or alignment
 - run-out, run-in, reticle rotation, wafer rotation, misplacement in X-direction, and misplacement in Y-direction
- Critical dimension (CD) loss
- Surface irregularities such as scratches, pin holes, stains, contamination, etc.

Other nanolithography

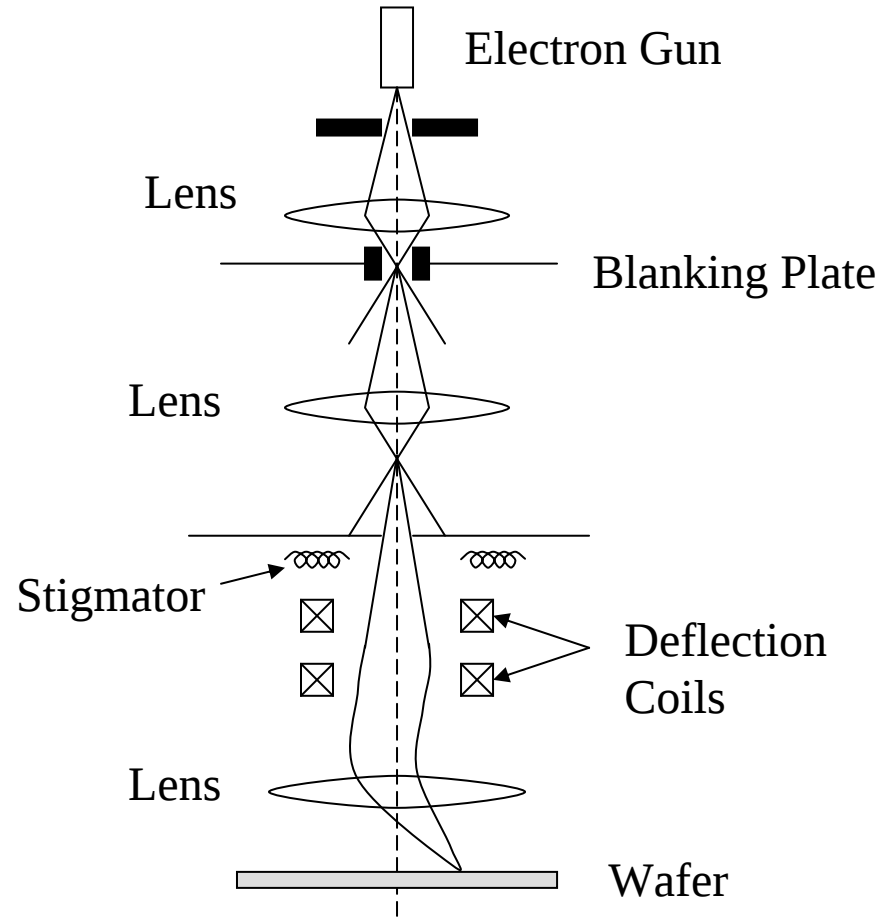
- AFM



- Ink print



Electron Beam Lithography System



Thank you for your attention