Chapter 6
Photolithography

Hong Xiao, Ph. D.
hxiao89@hotmail.com
www2.austin.cc.tx.us/HongXiao/Book.htm

Objectives

- List the four components of the photoresist
- Describe the difference between +PR and –PR
- Describe a photolithography process sequence
- List four alignment and exposure systems
- Describe the wafer movement in a track-stepper integrated system.
- Explain relationships of resolution and depth of focus to wavelength and numerical aperture.

Introduction

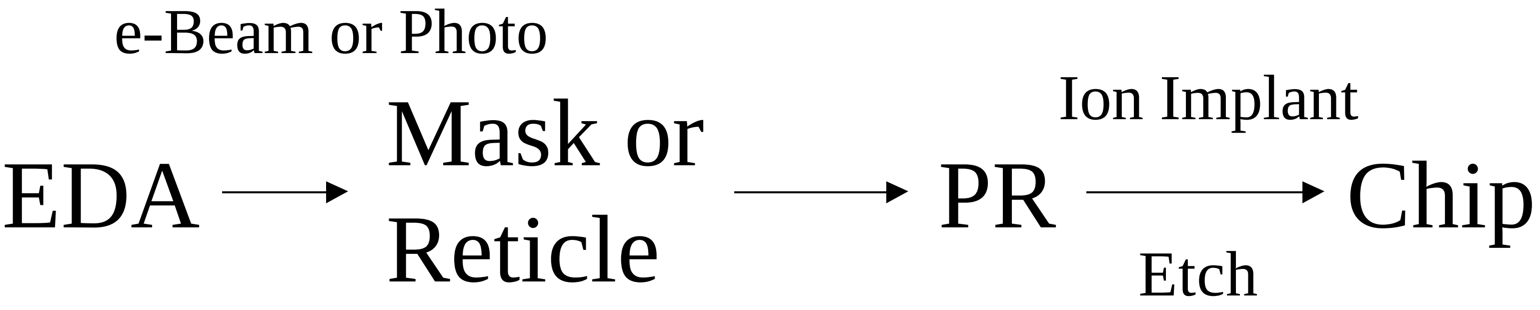
Photolithography

- Temporarily coat photoresist on wafer
- Transfers designed pattern to photoresist
- Most important process in IC fabrication
- 40 to 50% total wafer process time
- Determines the minimum feature size

Applications of Photolithography

- Main application: IC patterning process
- Other applications: Printed electronic board, nameplate, printer plate, and *et al*.

IC Fabrication



e-Beam or Photo

EDA → Mask or Reticle → PR → Chip

Ion Implant

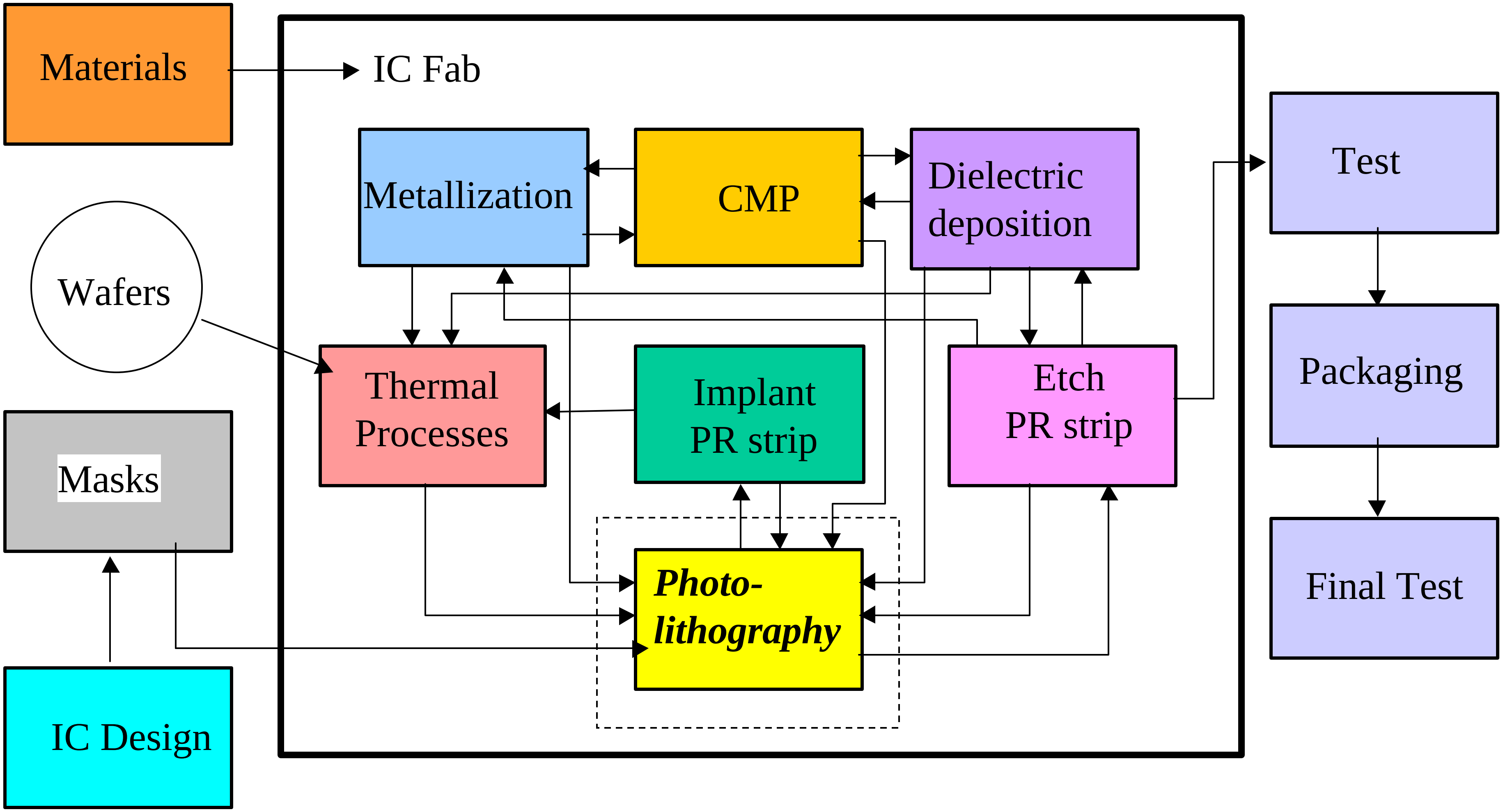
Etch

Photolithography

EDA: Electronic Design Automation

PR: Photoresist

IC Processing Flow



Photolithography Requirements

- High Resolution
- High PR Sensitivity
- Precision Alignment
- Precise Process Parameters Control
- Low Defect Density

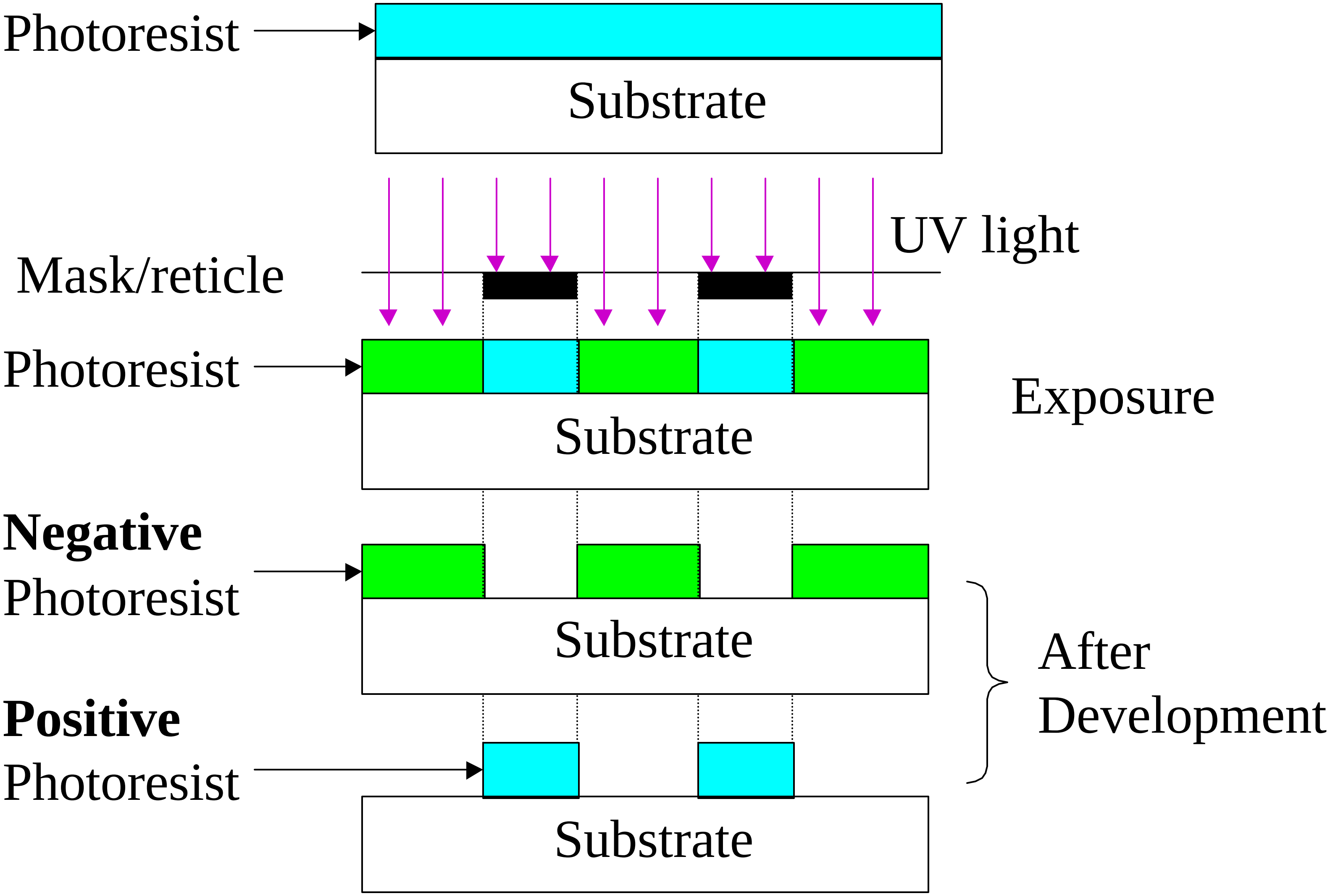
Photoresist

- Photo sensitive material
- Temporarily coated on wafer surface
- Transfer design image on it through exposure
- Very similar to the photo sensitive coating on the film for camera

Photoresist

Negative Photoresist	**Positive Photoresist**
• Becomes insoluble after exposure	• Becomes soluble after exposure
• When developed, the unexposed parts dissolved.	• When developed, the exposed parts dissolved
• Cheaper	• Better resolution

Negative and Positive Photoresists



Photoresist Chemistry

- Start with printed circuit
- Adapted in 1950 in semiconductor industry
- Critical to the patterning process
- Negative and positive photoresist

Photoresist Composition

- Polymer
- Solvents
- Sensitizers
- Additives

Polymer

- Solid organic material
- Transfers designed pattern to wafer surface
- Changes solubility due to photochemical reaction when exposed to UV light.
- Positive PR: from insoluble to soluble
- Negative PR: from soluble to insoluble

Solvent

- Dissolves polymers into liquid
- Allow application of thin PR layers by spinning.

Sensitizers

- Controls and/or modifies photochemical reaction of resist during exposure.
- Determines exposure time and intensity

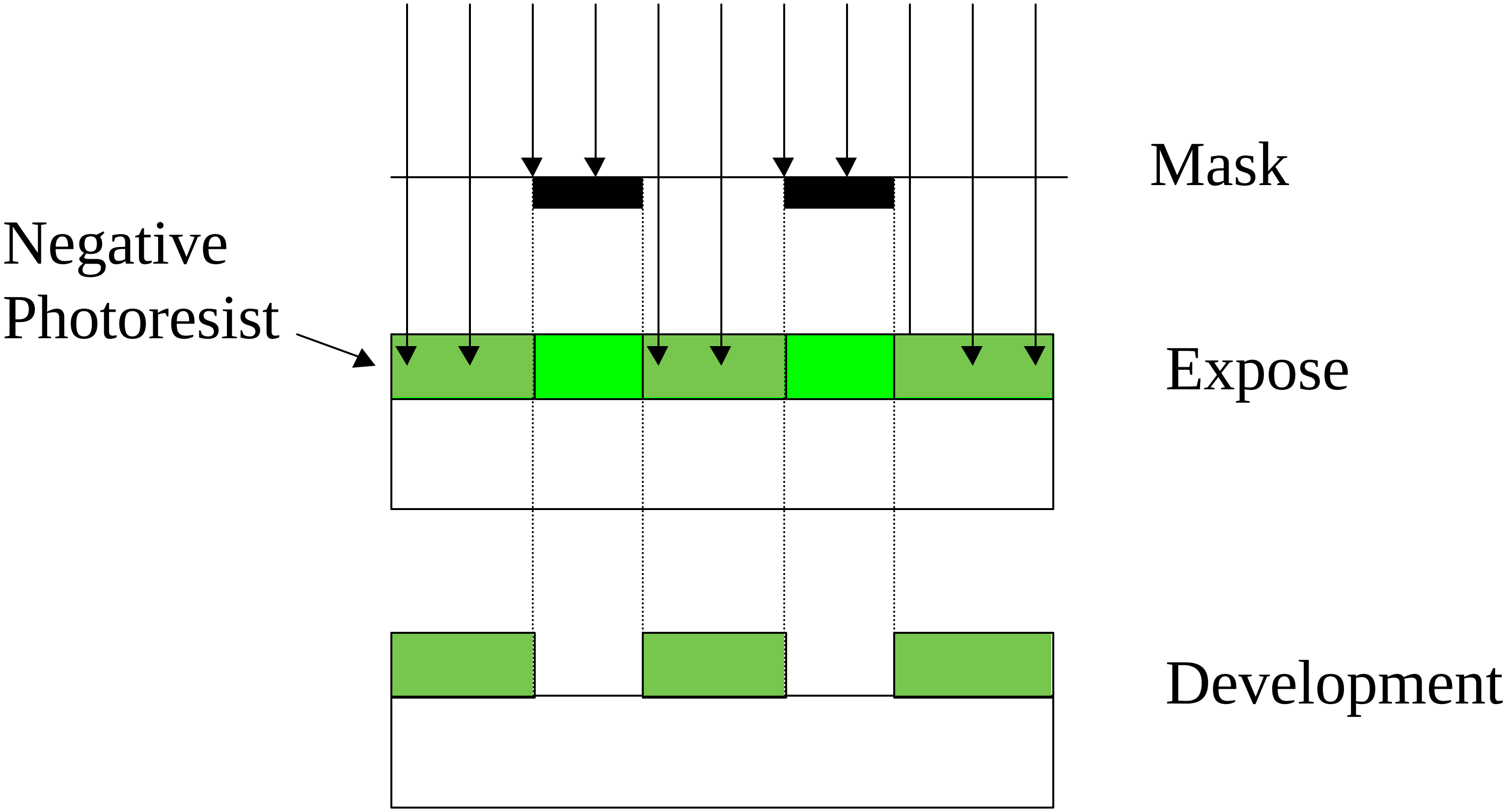
Additives

- Various added chemical to achieve desired process results, such as dyes to reduce reflection.

Negative Resist

- Most negative PR are polyisoprene type
- Exposed PR becomes cross-linked polymer
- Cross-linked polymer has higher chemical etch resistance.
- Unexposed part will be dissolved in development solution.

Negative Photoresist

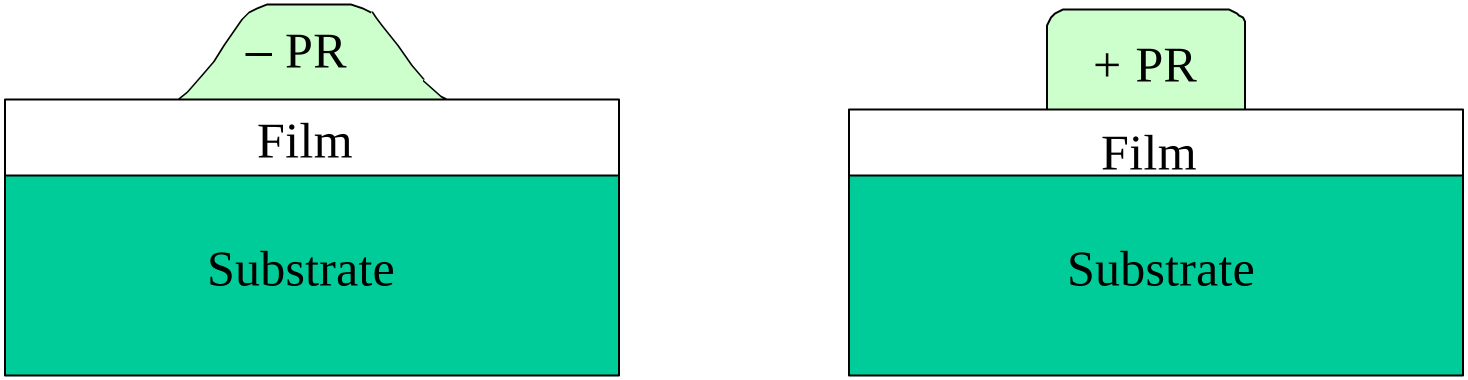


Negative Photoresist

Disadvantages

- Polymer absorbs the development solvent
- Poor resolution due to PR swelling
- Environmental and safety issues due to the main solvents xylene.

Comparison of Photoresists



Positive Photoresist

- Exposed part dissolve in developer solution
- Image the same that on the mask
- Higher resolution
- Commonly used in IC fabs

Positive Photoresist

- Novolac resin polymer
- Acetate type solvents
- Sensitizer cross-linked within the resin
- Energy from the light dissociates the sensitizer and breaks down the cross-links
- Resin becomes more soluble in base solution

Question

- Positive photoresist can achieve much higher resolution than negative photoresist, why didn’t people use it before the 1980s?

- Positive photoresist is much more expensive therefore negative photoresist was used until it had to be replaced when the minimum feature size was shrunk to smaller than 3 μm.

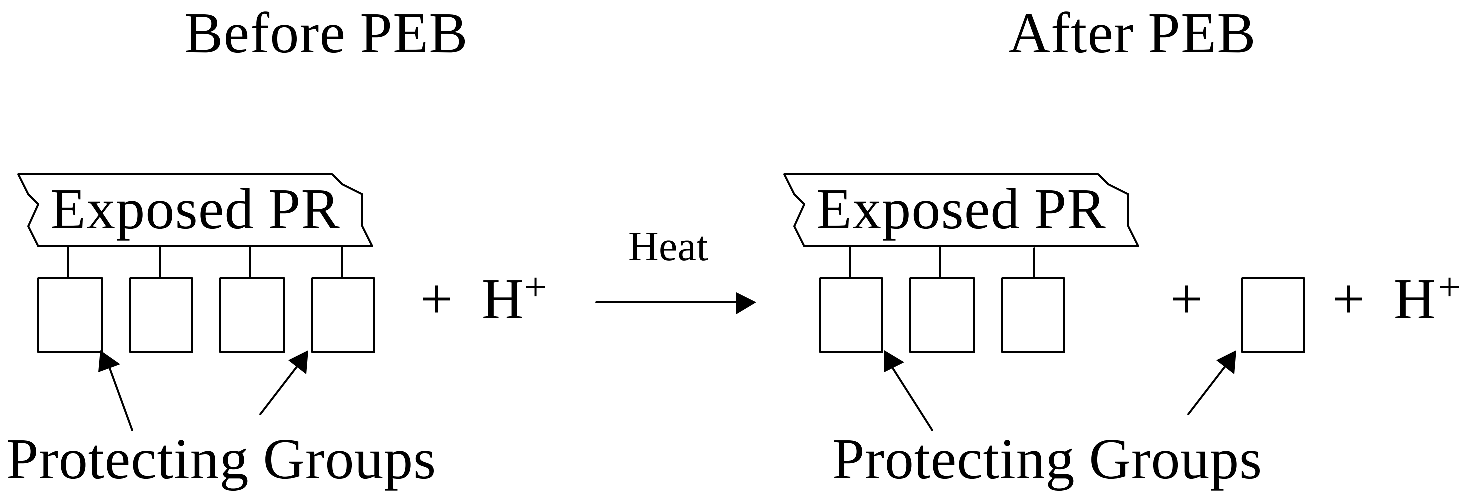
Chemically Amplified Photoresists

- Deep ultraviolet (DUV), $\lambda \leq 248$ nm
- Light source: excimer lasers
- Light intensity is lower than I-line (365 nm) from high-pressure mercury lamp
- Need different kind of photoresist

Chemically Amplified Photoresists

- Catalysis effect is used to increase the effective sensitivity of the photoresist
- A photo-acid is created in PR when it exposes to DUV light
- During PEB, head-induced acid diffusion causes amplification in a catalytic reaction
- Acid removes protection groups
- Exposed part will be removed by developer

Chemically Amplified Photoresist


Before PEB

After PEB

Requirement of Photoresist

- High resolution
  - Thinner PR film has higher the resolution
  - Thinner PR film, the lower the etching and ion implantation resistance
- High etch resistance
- Good adhesion
- Wider process latitude
  - Higher tolerance to process condition change

Photoresist Physical Properties

- Photoresist must be able to withstand process conditions
  - Coating, spinning, baking, developing.
  - Etch resistance
  - Ion implantation blocking

Photoresist Performance Factor

- Resolution
- Adhesion
- Expose rate, Sensitivity and Exposure Source
- Process latitude
- Pinholes
- Particle and Contamination Levels
- Step Coverage
- Thermal Flow

Resolution Capability

- The smallest opening or space that can produced in a photoresist layer.
- Related to particular processes including expose source and developing process.
- Thinner layer has better resolution.
- Etch and implantation barrier and pinhole-free require thicker layer
- Positive resist has better resolution due to the smaller size of polymer.

Photoresist Characteristics Summary

Parameter	Negative	Positive
Polymer	Polyisoprene	Novolac Resin
Photo-reaction	Polymerization	Photo-solubilization
Sensitizer	Provide free radicals for polymer cross-link	Changes film to base soluble
Additives	Dyes	Dyes

Photolithography Process

Basic Steps of Photolithography

- Photoresist coating
- Alignment and exposure
- Development

Basic Steps, Old Technology

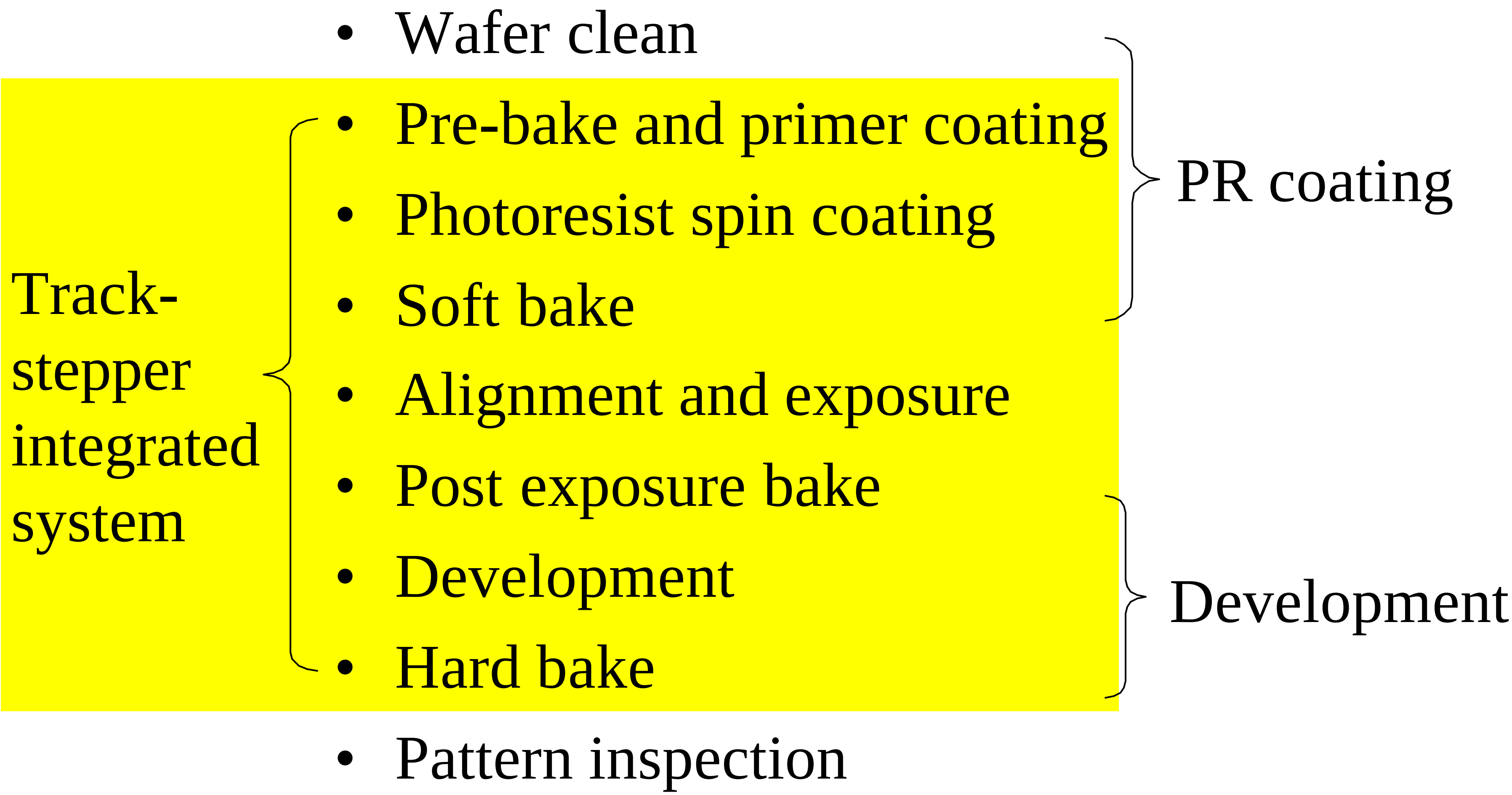
- Wafer clean
- Dehydration bake
- Spin coating primer and PR
- Soft bake

PR coating

- Alignment and exposure
- Development
- Pattern inspection
- Hard bake

Development

Basic Steps, Advanced Technology



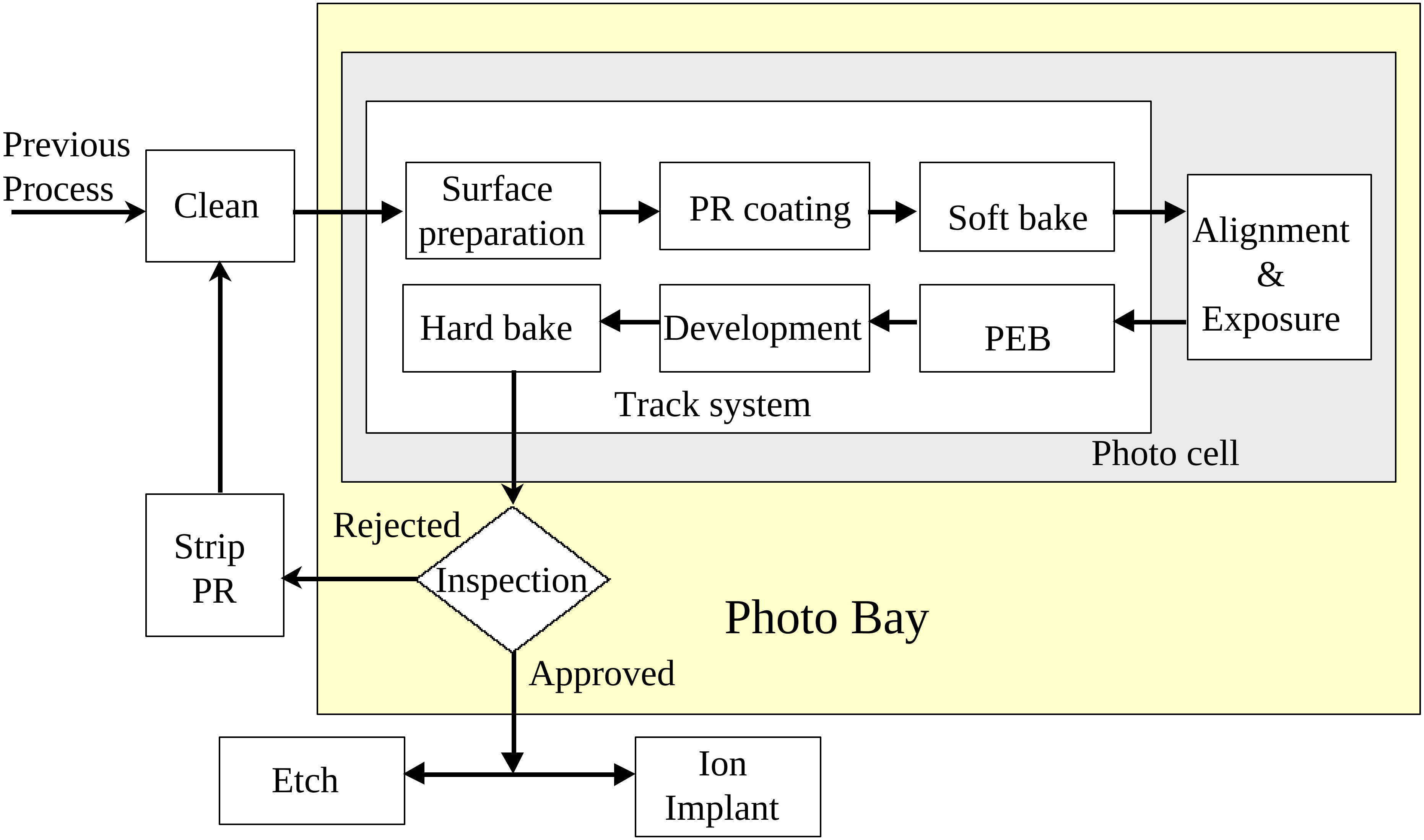
- Wafer clean
- Pre-bake and primer coating
- Photoresist spin coating
- Soft bake
- Alignment and exposure
- Post exposure bake
- Development
- Hard bake
- Pattern inspection

Track-stepper integrated system

PR coating

Development

Figure 6.5



Previous Process

Clean

Surface preparation

PR coating

Soft bake

Alignment & Exposure

PEB

Development

Hard bake

Track system

Photo cell

Inspection

Rejected

Strip PR

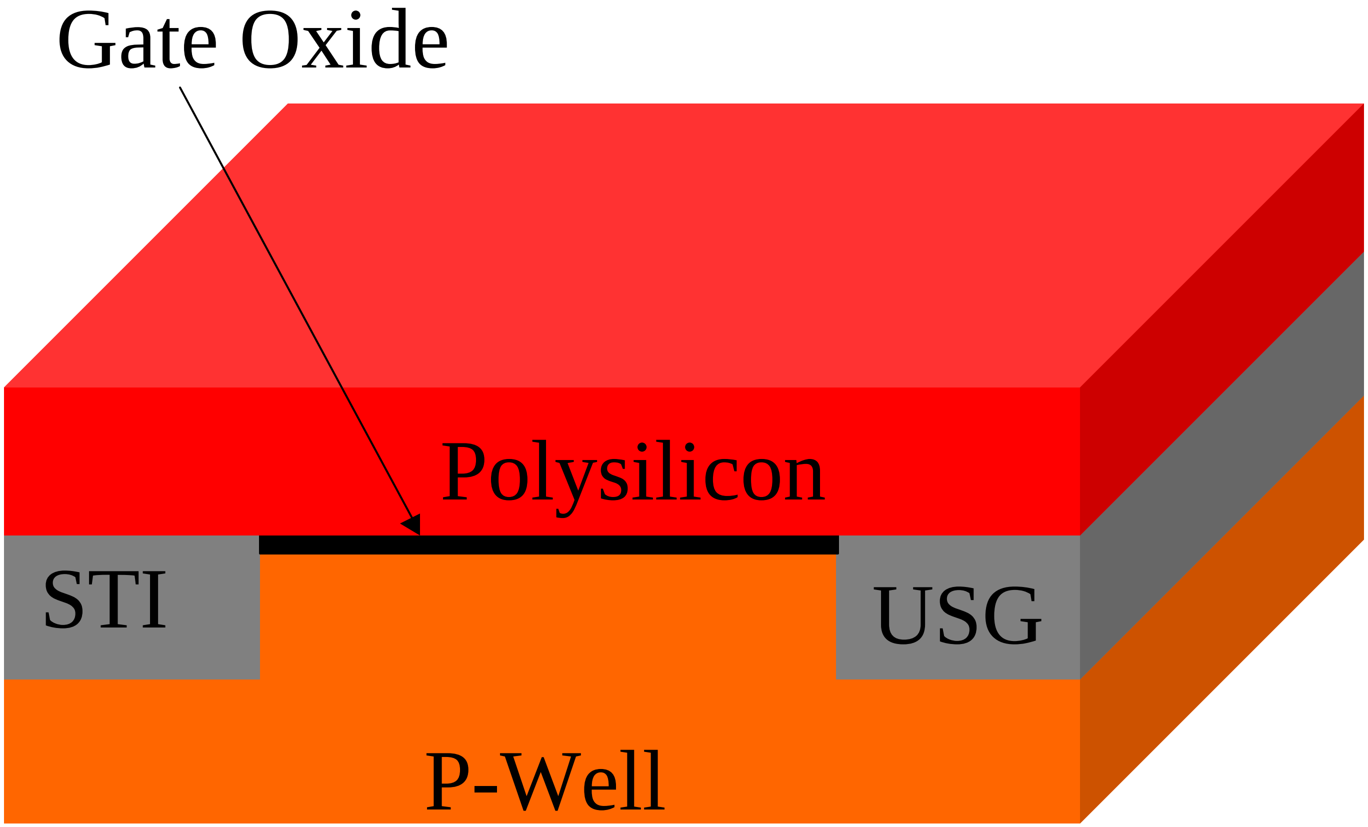
Approved

Photo Bay

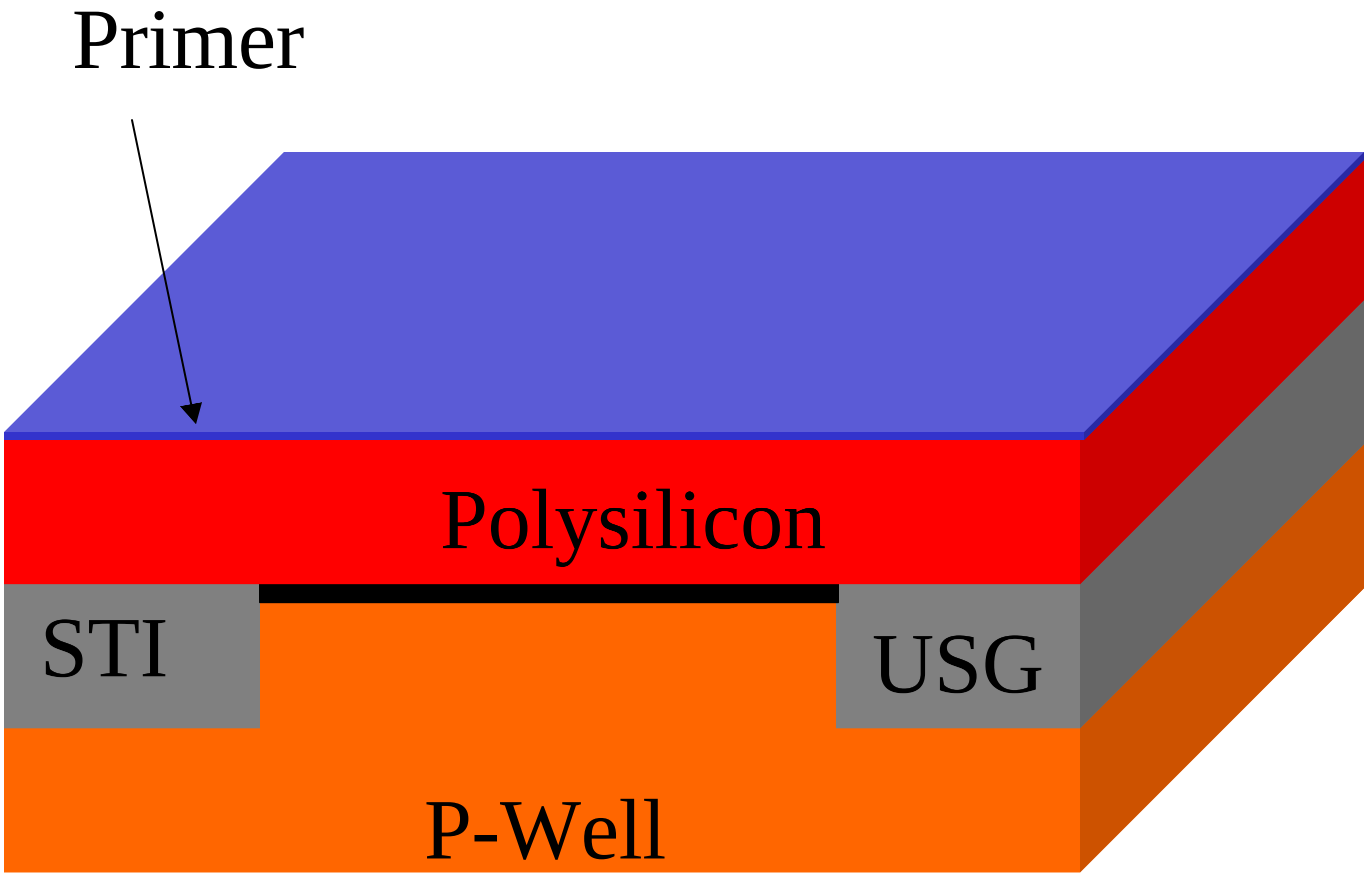
Etch

Ion Implant

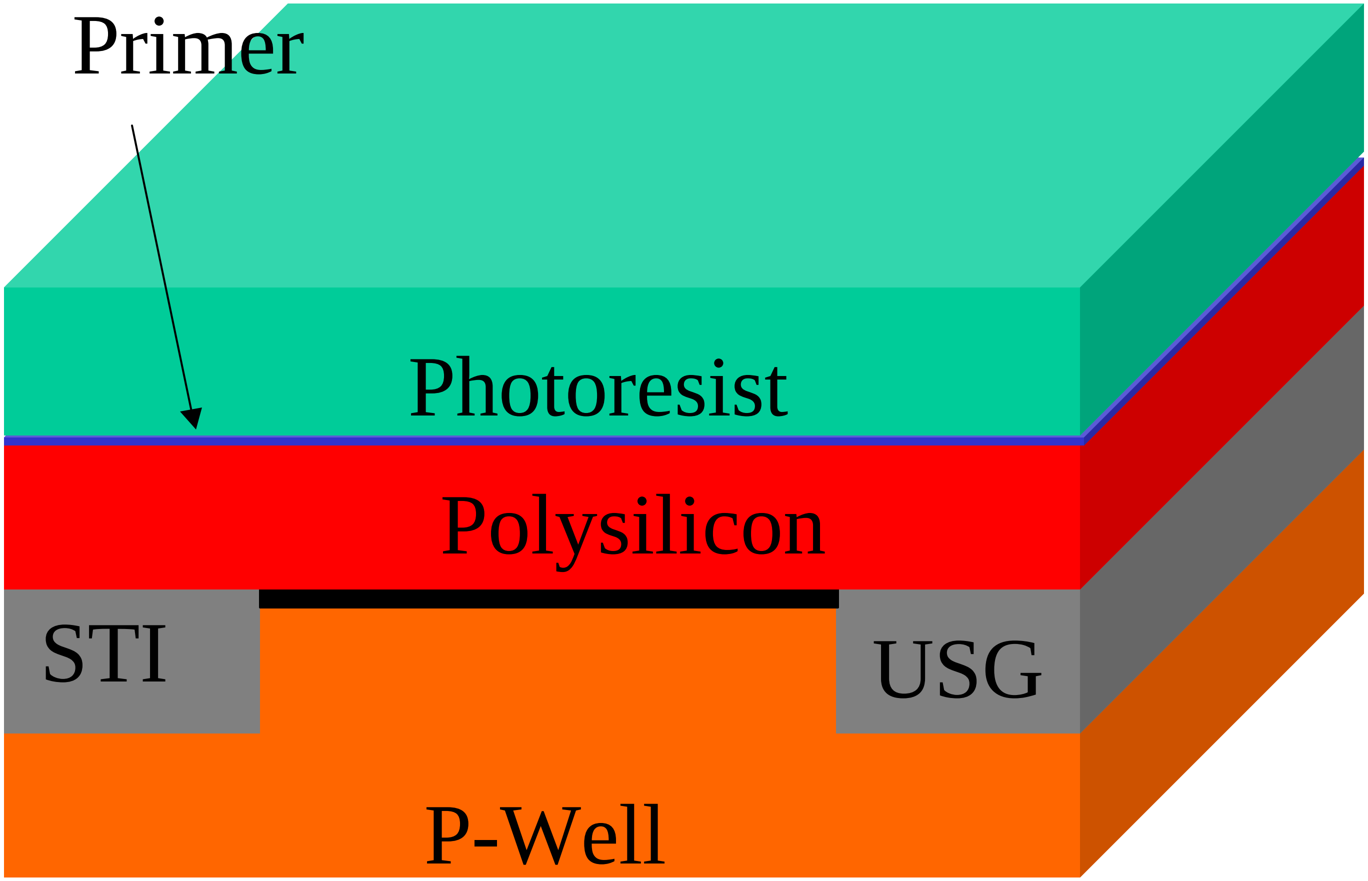
Wafer Clean



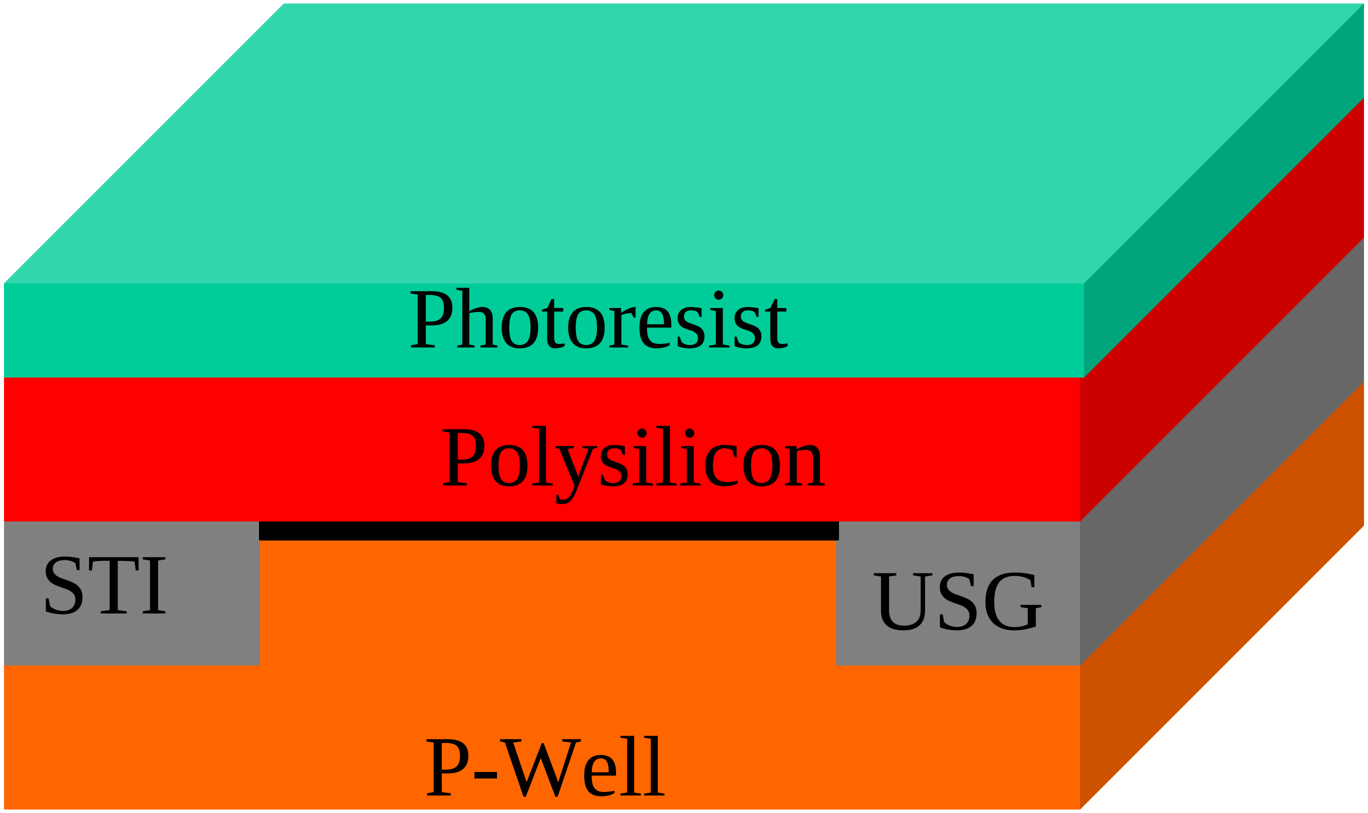
Pre-bake and Primer Vapor



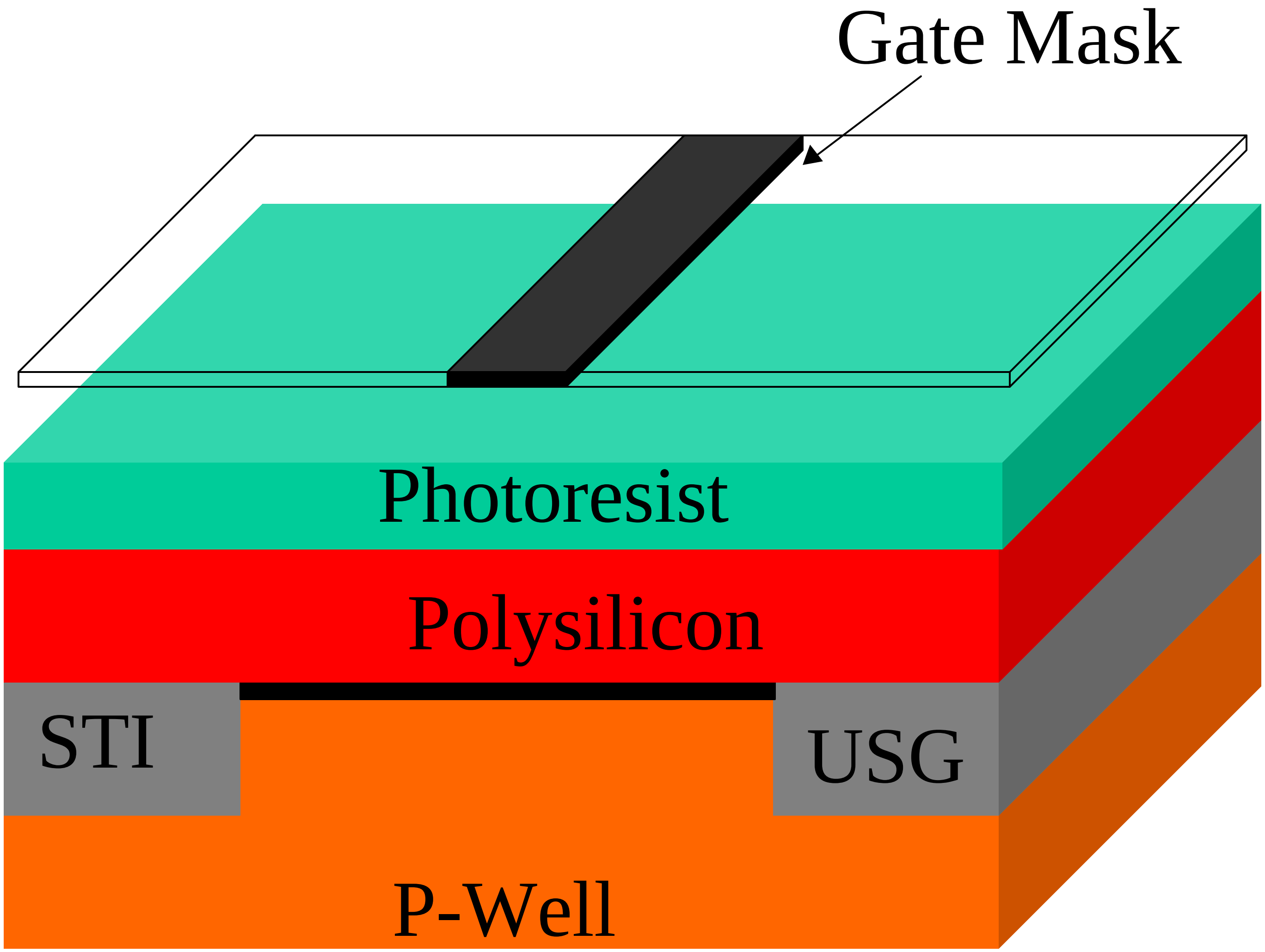
Photoresist Coating



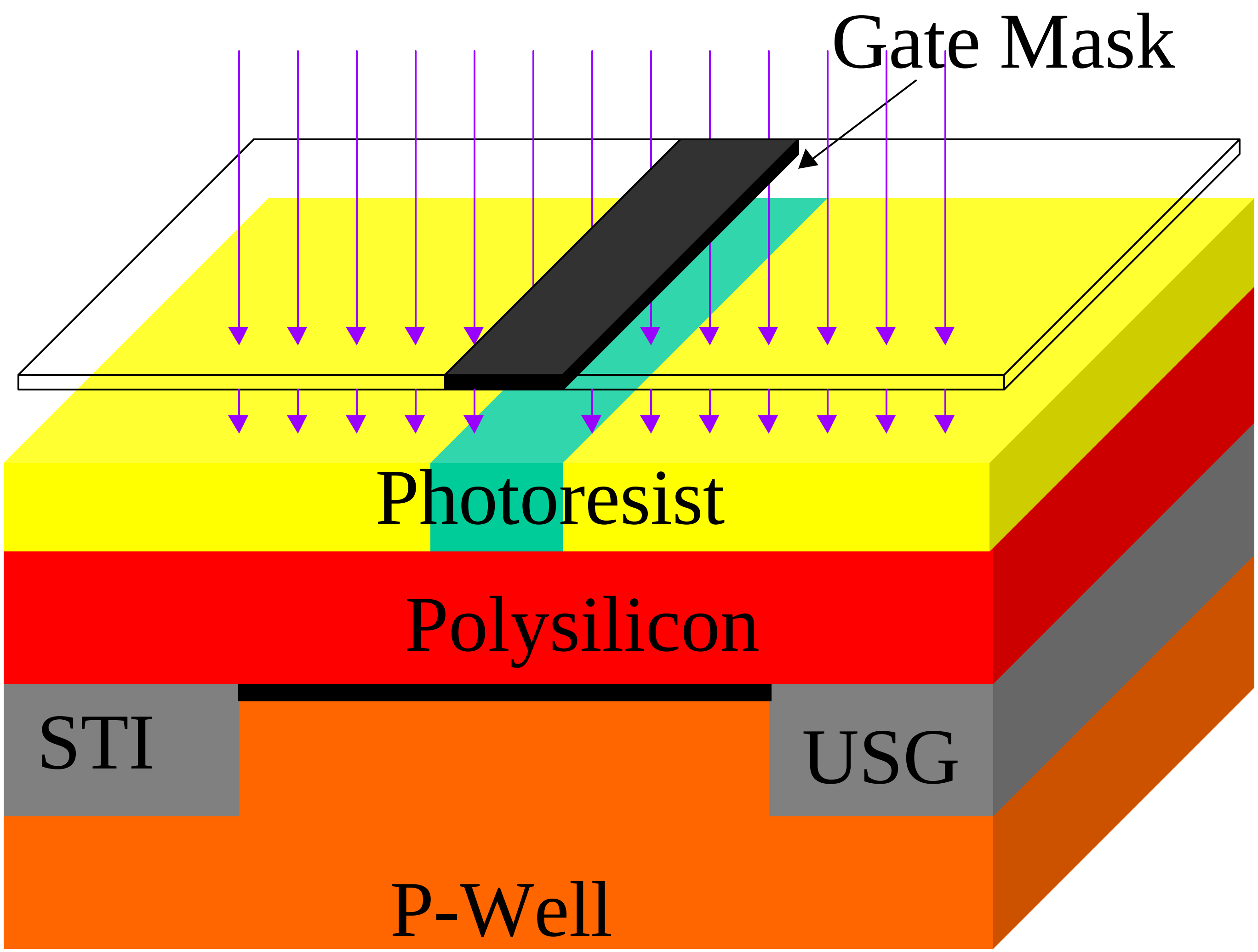
Soft Bake



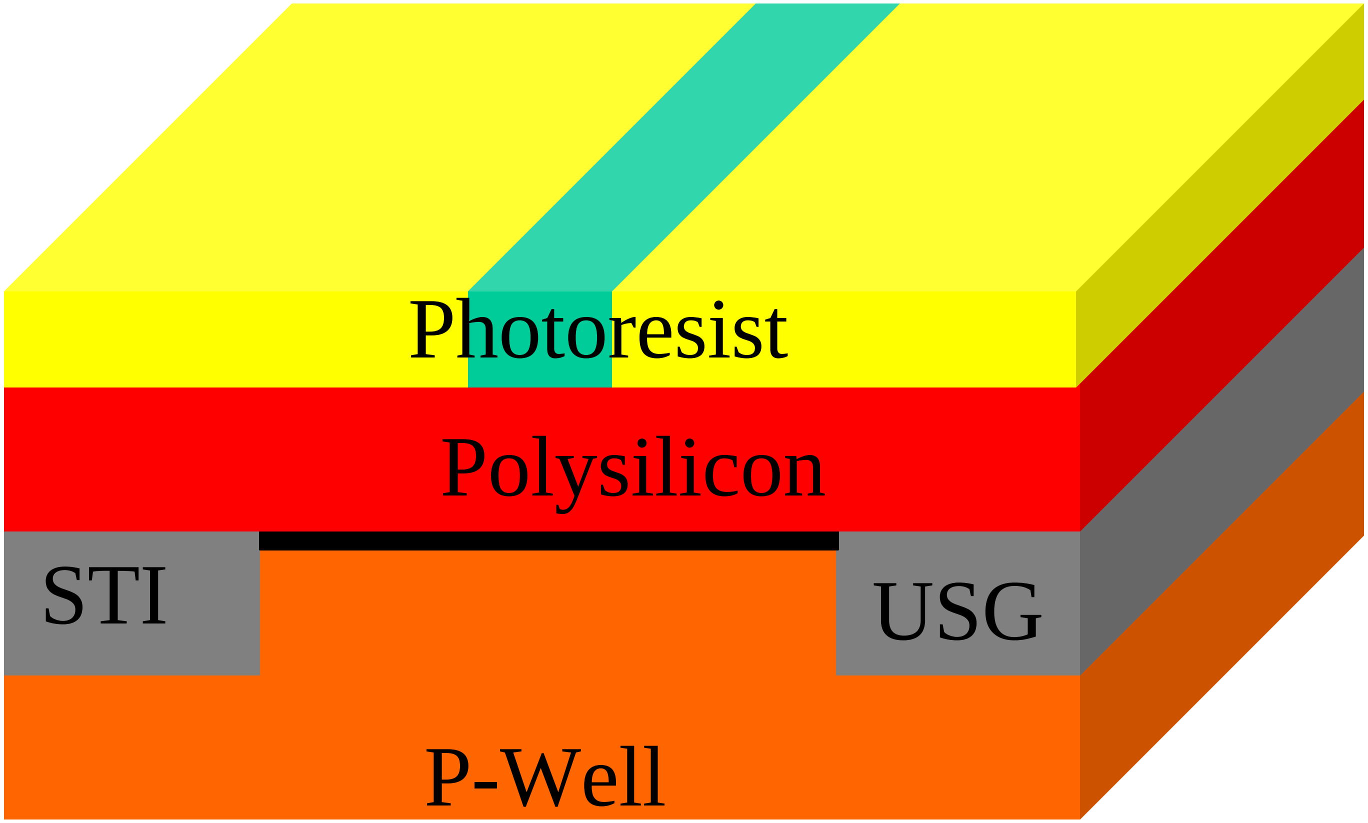
Alignment and Exposure



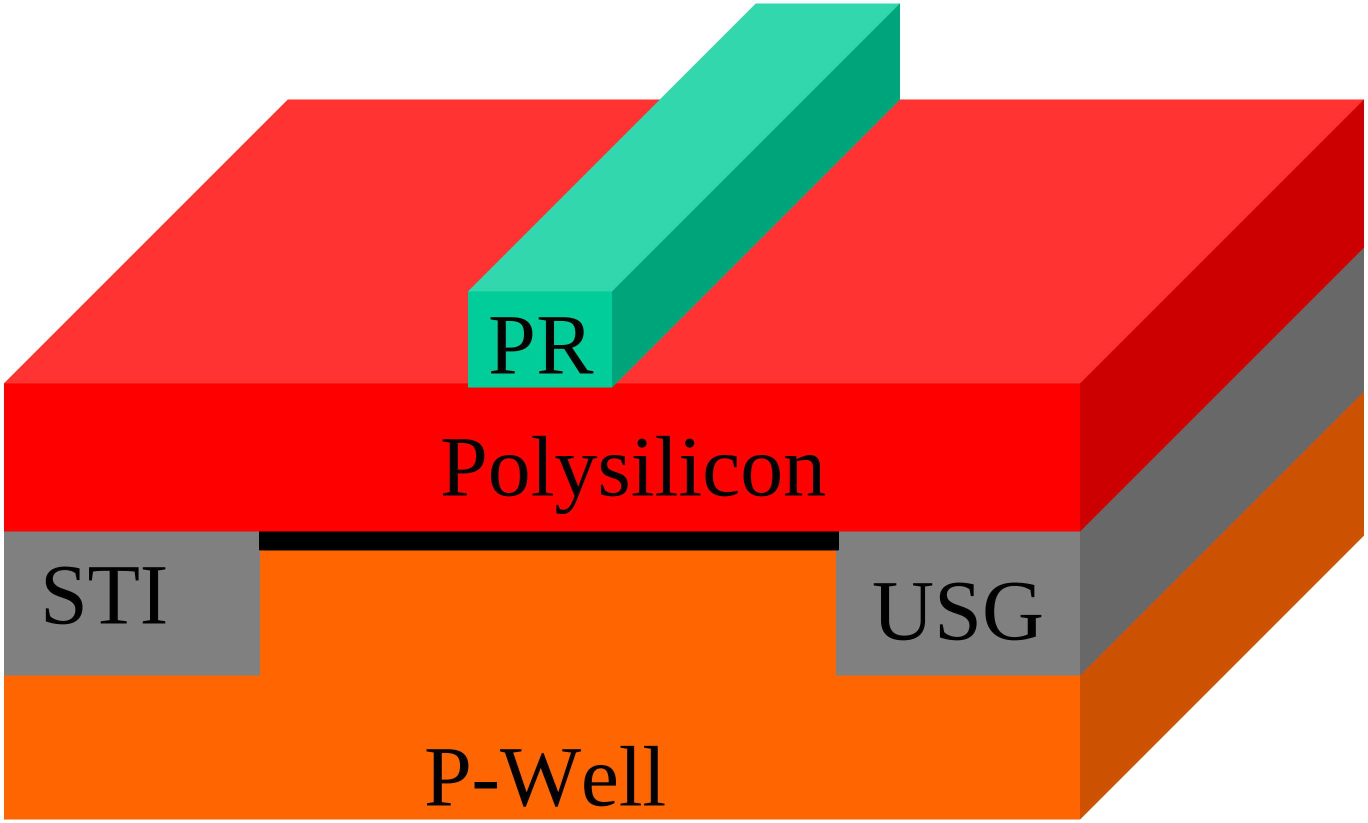
Alignment and Exposure



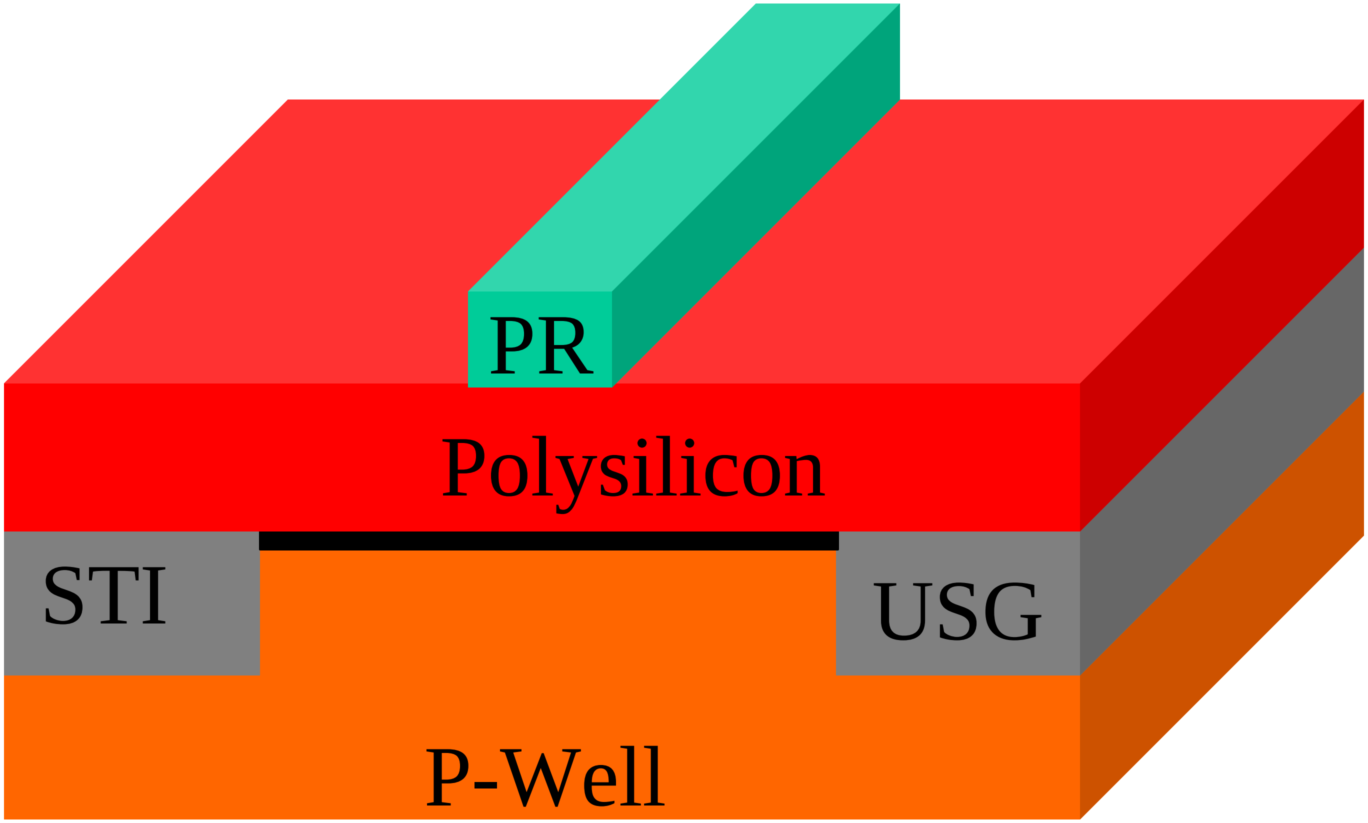
Post Exposure Bake



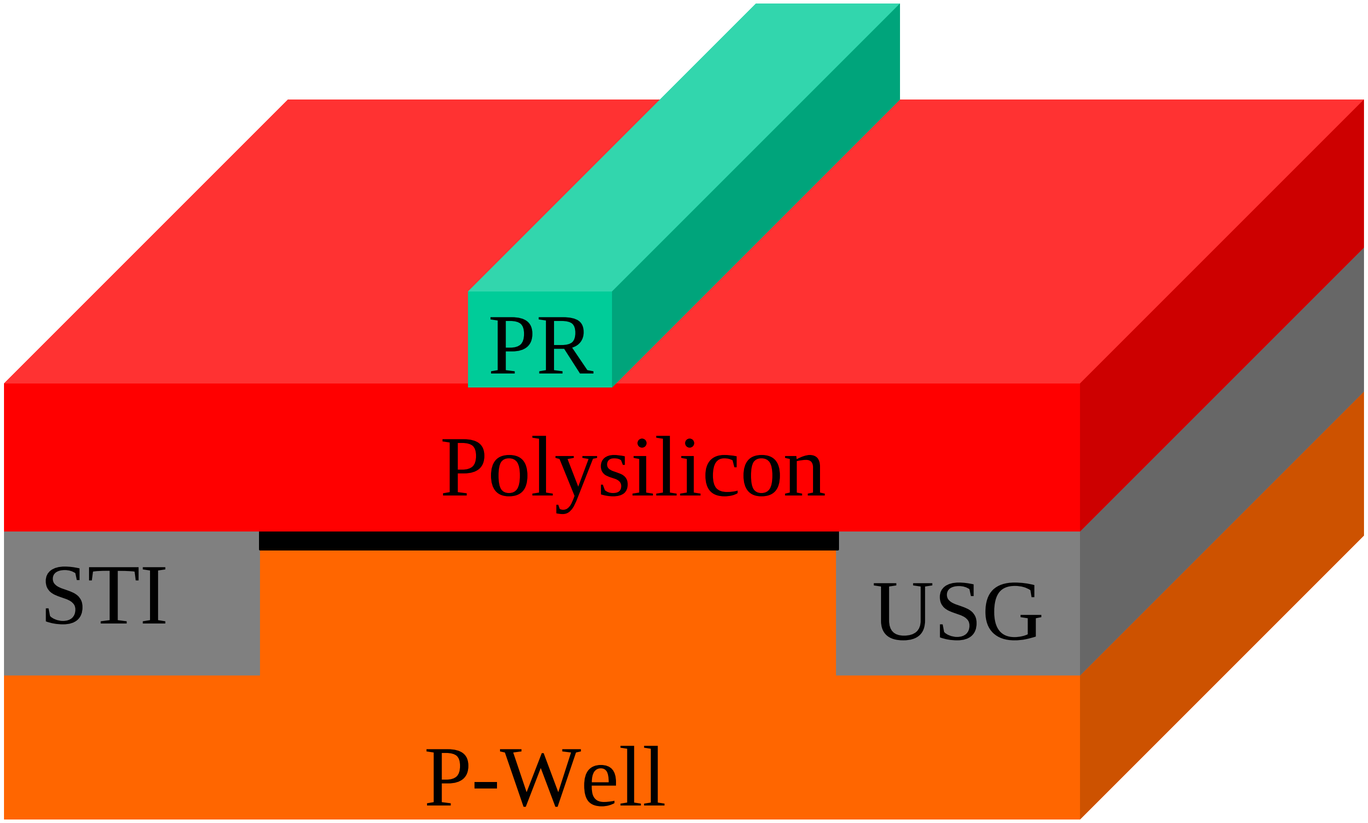
Development



Hard Bake



Pattern Inspection



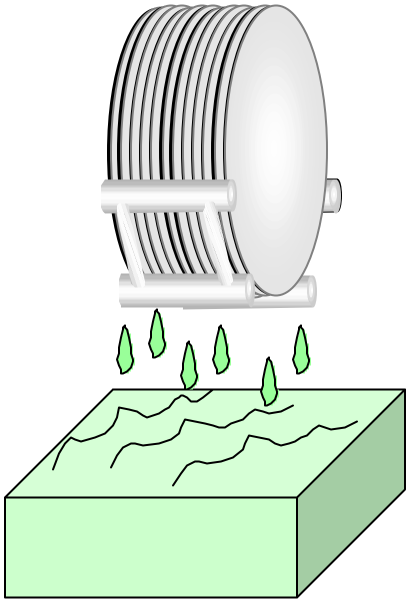
Wafer Clean

- Remove contaminants
- Remove particulate
- Reduce pinholes and other defects
- Improve photoresist adhesion
- Basic steps
  - Chemical clean
  - Rinse
  - Dry

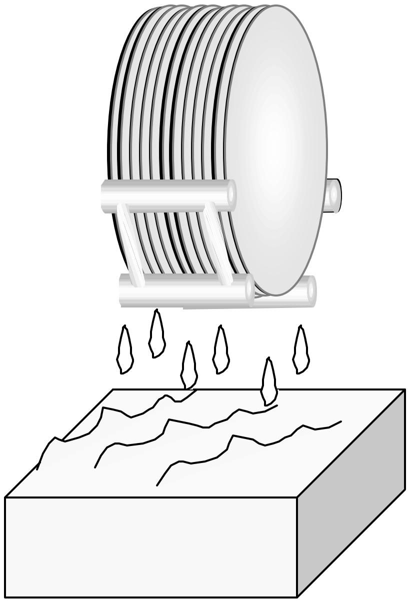
Photolithography Process, Clean

- Older ways
  - – High-pressure nitrogen blow-off
  - – Rotating brush scrubber
  - – High-pressure water stream

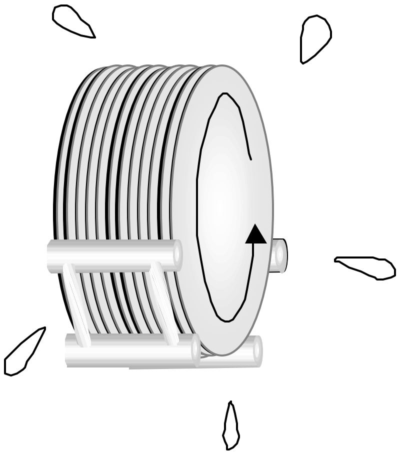
Wafer Clean Process



Chemical Clean



Rinse



Dry

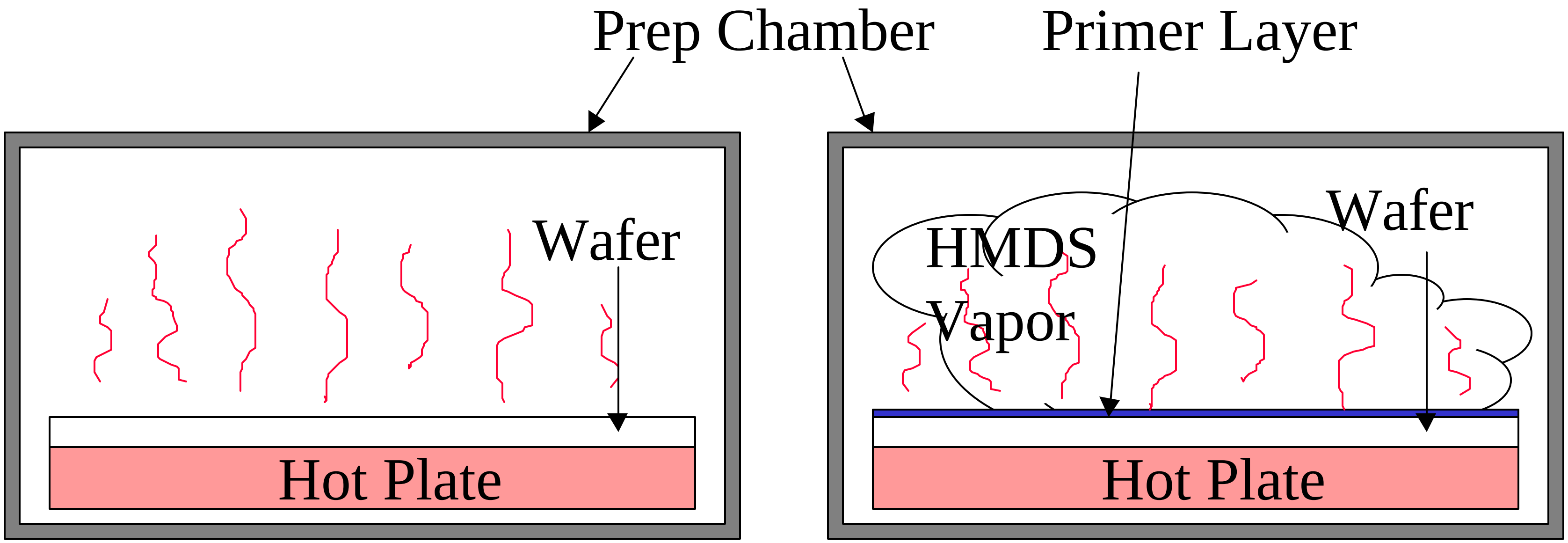
Photolithography Process, Prebake

- Dehydration bake
- Remove moisture from wafer surface
- Promote adhesion between PR and surface
- Usually around 100 °C
- Integration with primer coating

Photolithography Process, Primer

- Promotes adhesion of PR to wafer surface
- Wildly used: Hexamethyldisilazane (HMDS)
- HMDS vapor coating prior to PR spin coating
- Usually performed in-situ with pre-bake
- Chill plate to cool down wafer before PR coating

Pre-bake and Primer Vapor Coating



Dehydration Bake

Primer Vapor Coating

Wafer Cooling

- Wafer need to cool down
- Water-cooled chill plate
- Temperature can affect PR viscosity
  - Affect PR spin coating thickness

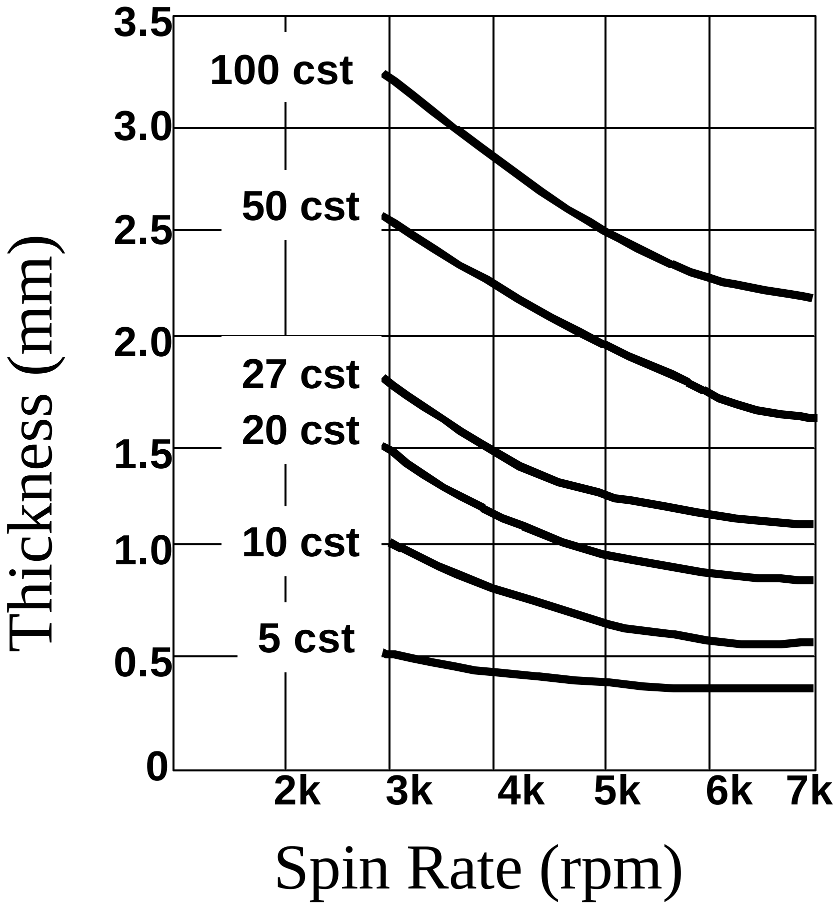
Spin Coating

- Wafer sit on a vacuum chuck
- Rotate at high speed
- Liquid photoresist applied at center of wafer
- Photoresist spread by centrifugal force
- Evenly coat on wafer surface

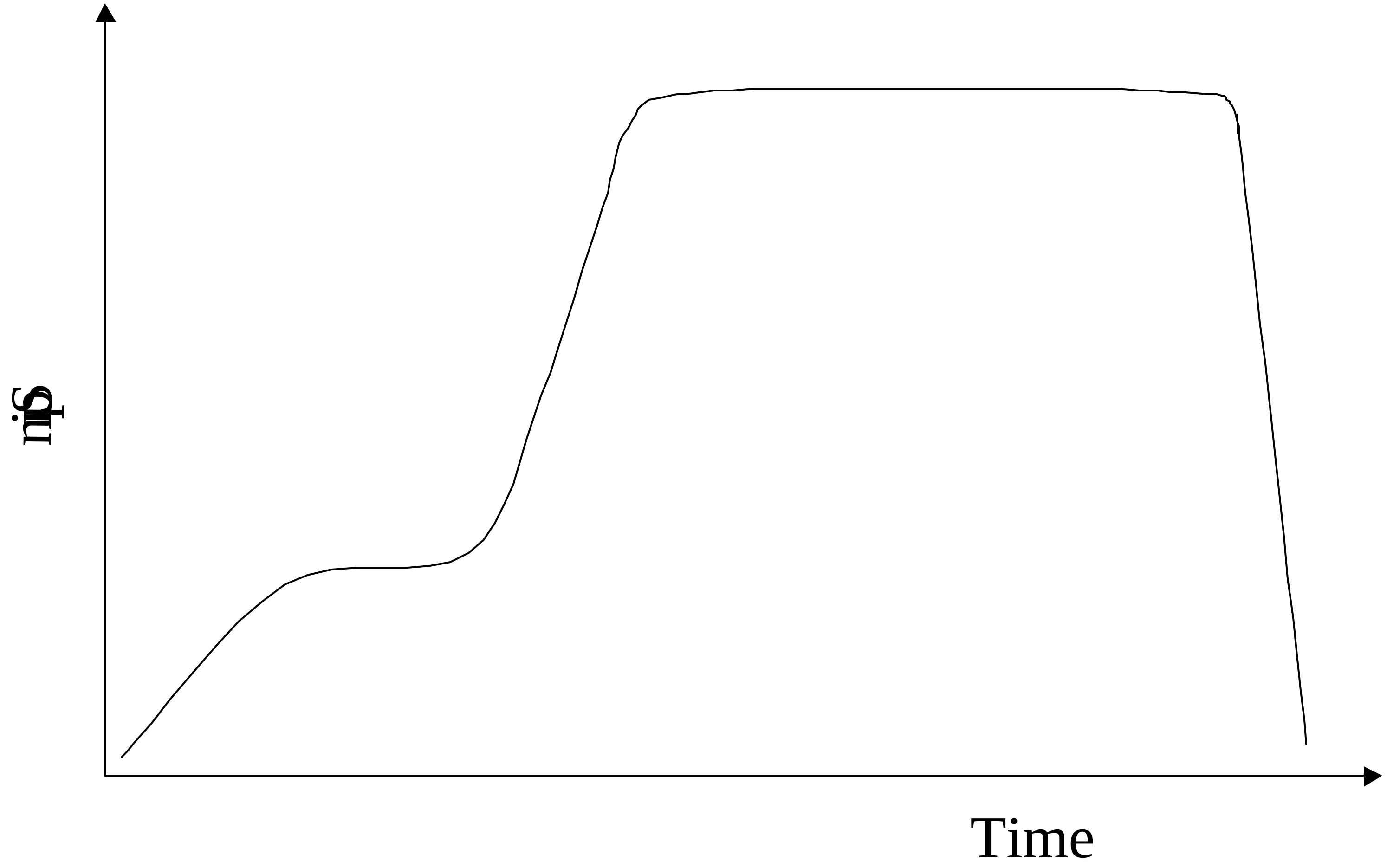
Viscosity

- Fluids stick on the solid surface
- Affect PR thickness in spin coating
- Related to PR type and temperature
- Need high spin rate for uniform coating

Relationship of Photoresist Thickness to Spin Rate and Viscosity



Dynamic Spin Rate



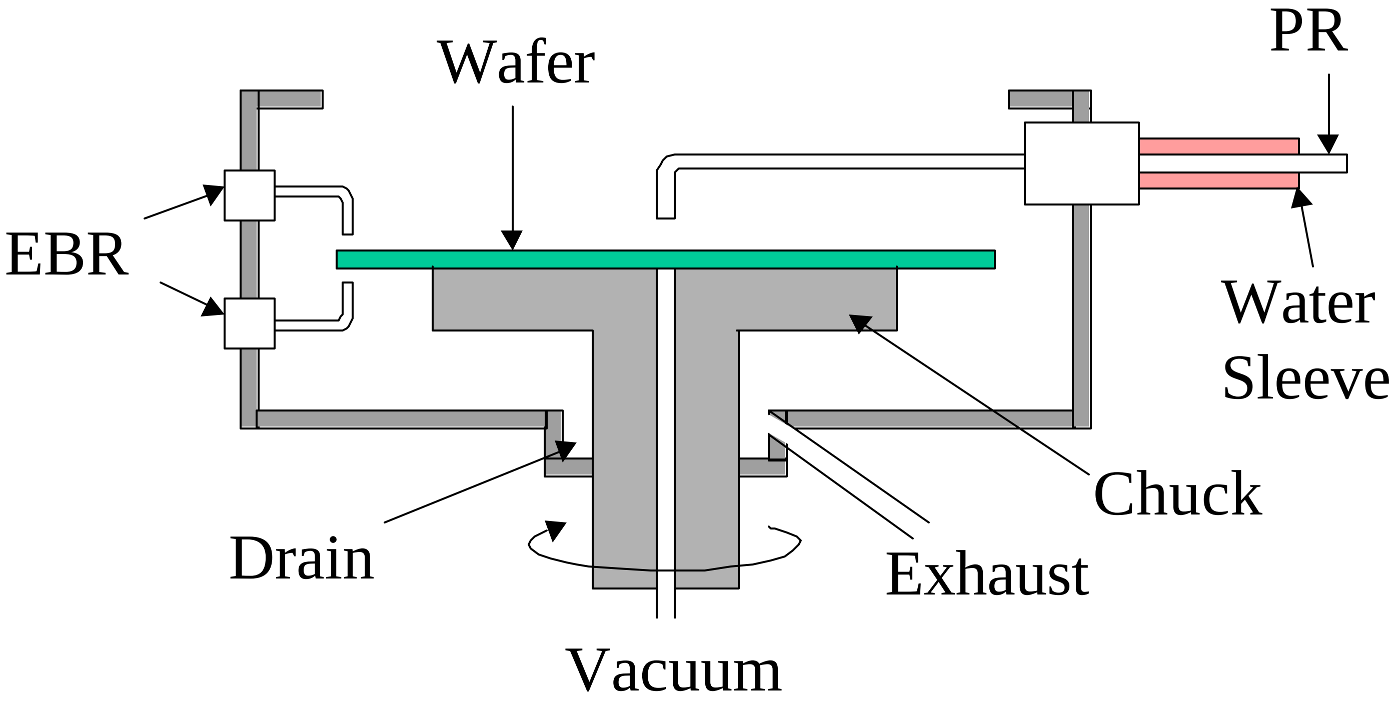
PR Spin Coater

- Photoresist spread on spinning wafer surface
- Wafer held on a vacuum chuck
- Slow spin ~ 500 rpm
- Ramp up to ~ 3000 - 7000 rpm

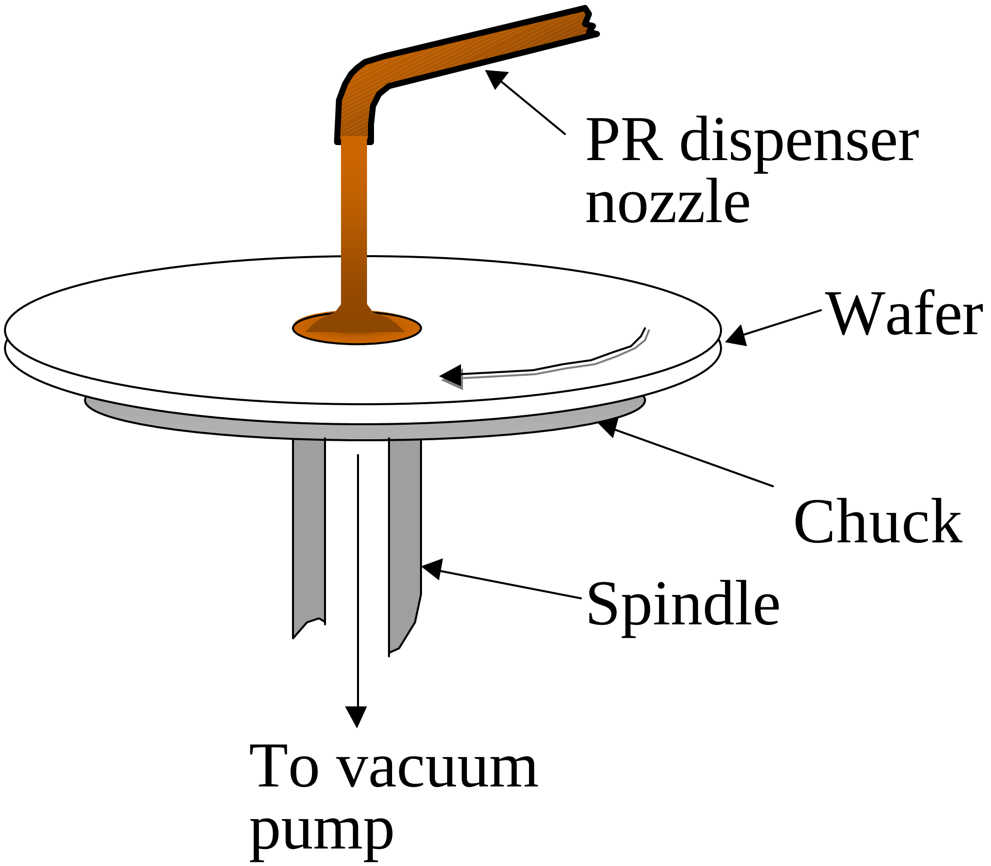
Spin Coater

- Automatic wafer loading system from robot of track system
- Vacuum chuck to hold wafer
- Resist containment and drain
- Exhaust features
- Controllable spin motor
- Dispenser and dispenser pump
- Edge bead removal

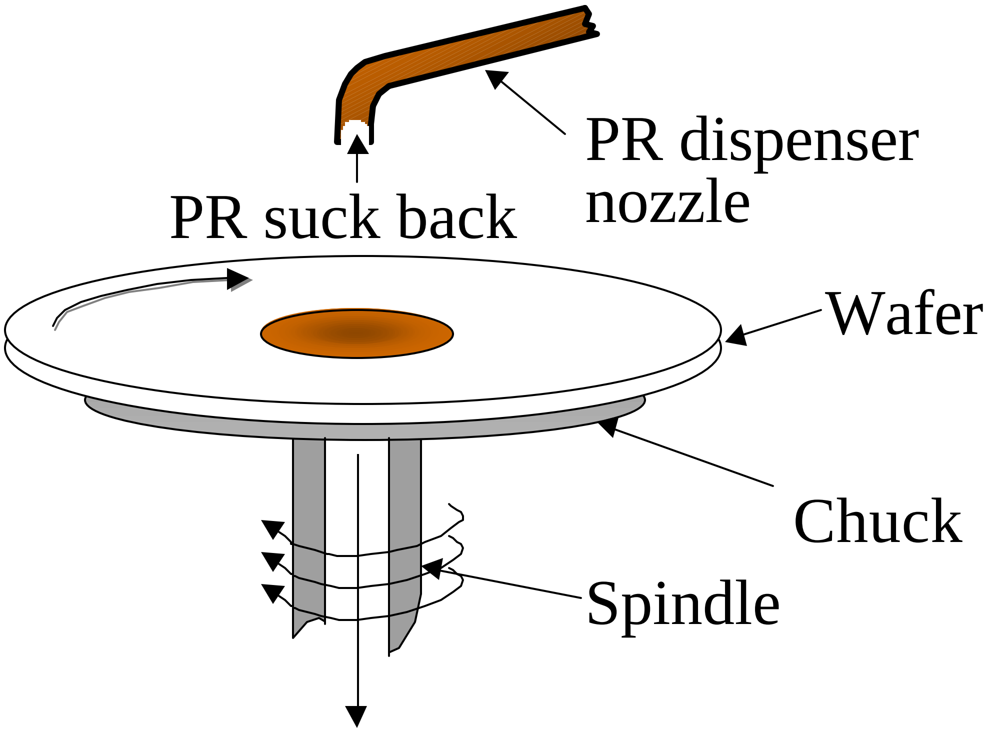
Photoresist Spin Coater



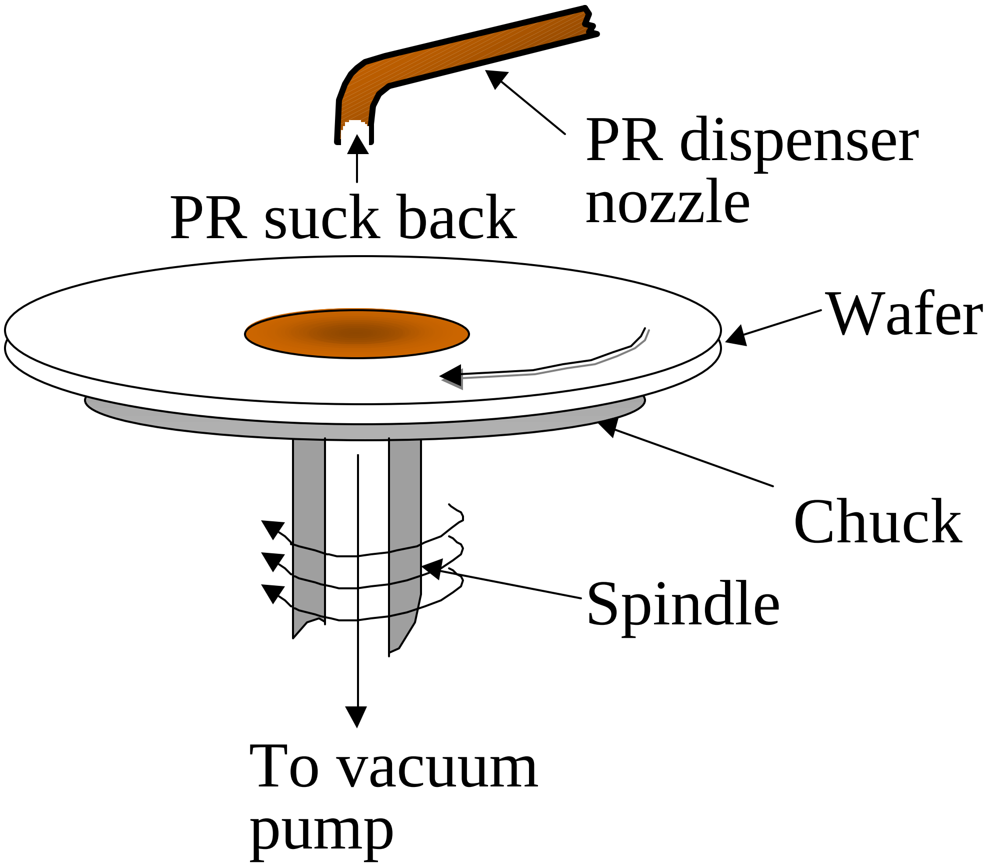
Photoresist Applying



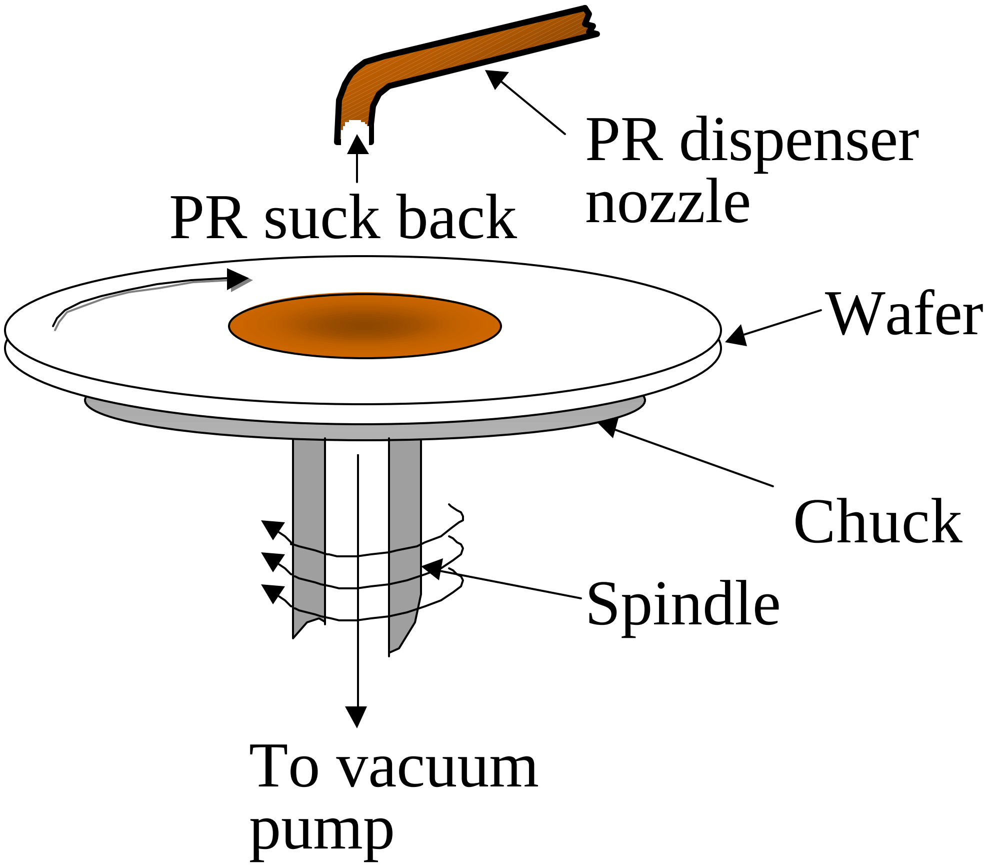
Photoresist Suck Back



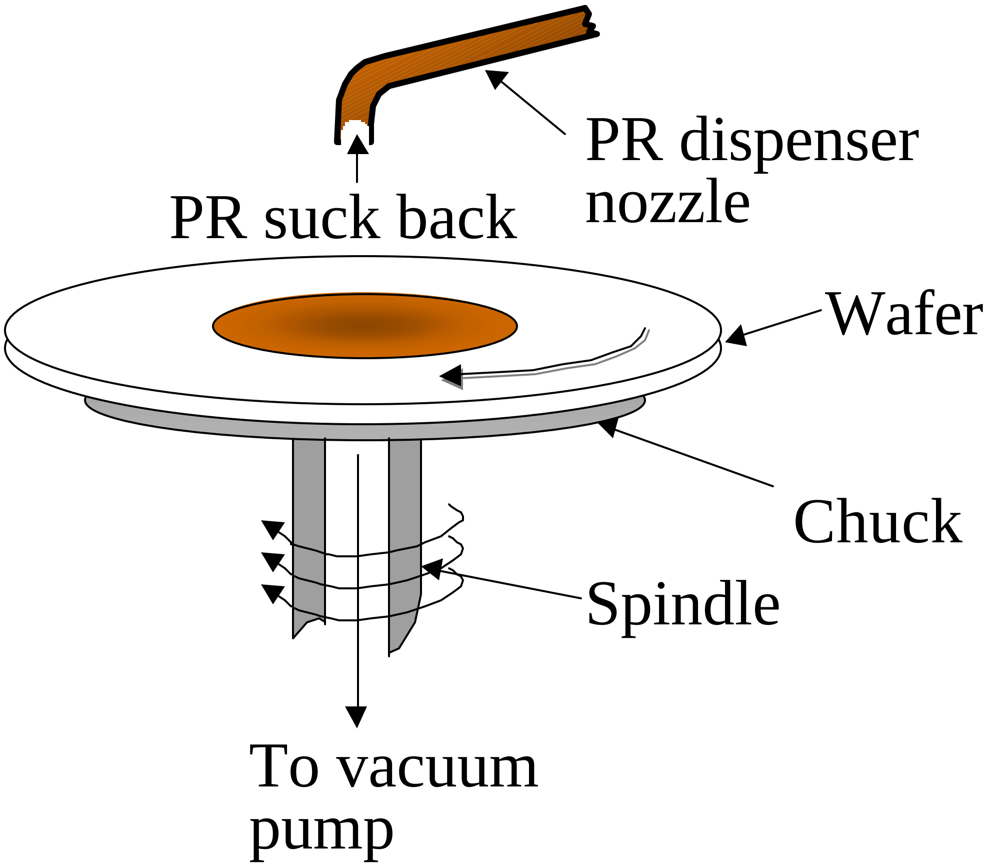
Photoresist Spin Coating



Photoresist Spin Coating



Photoresist Spin Coating


PR dispenser nozzle

PR suck back

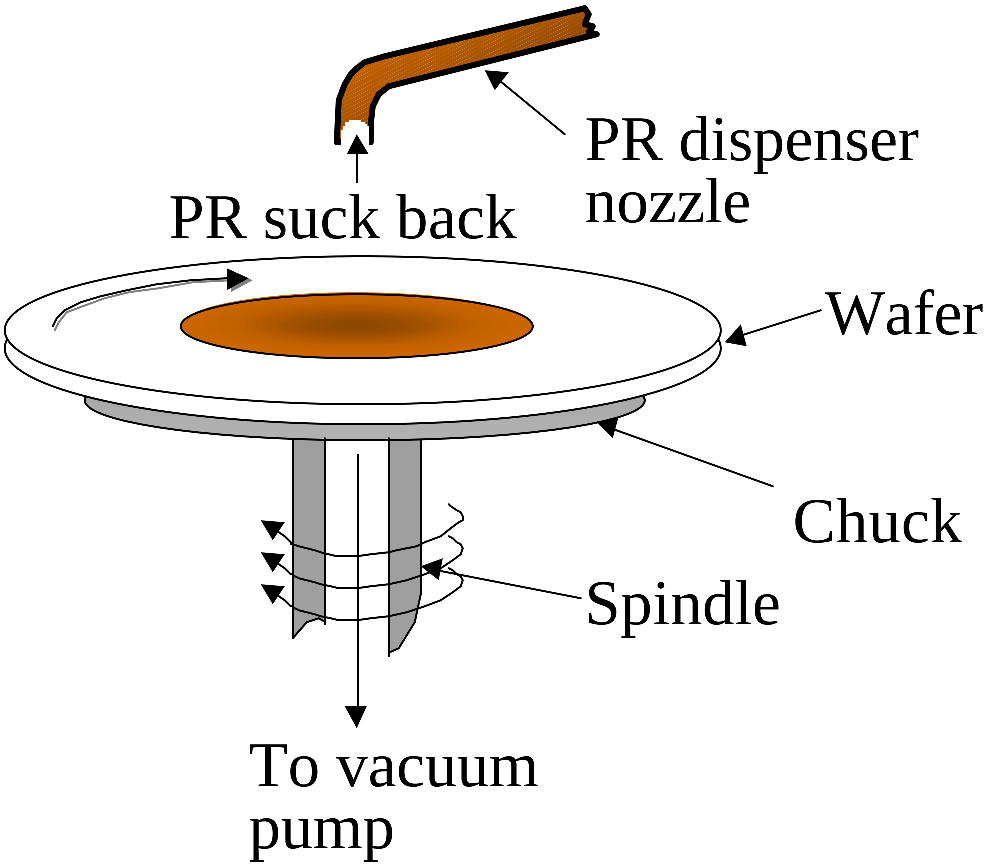
Wafer

Chuck

Spindle

To vacuum pump

Photoresist Spin Coating



PR dispenser nozzle

PR suck back

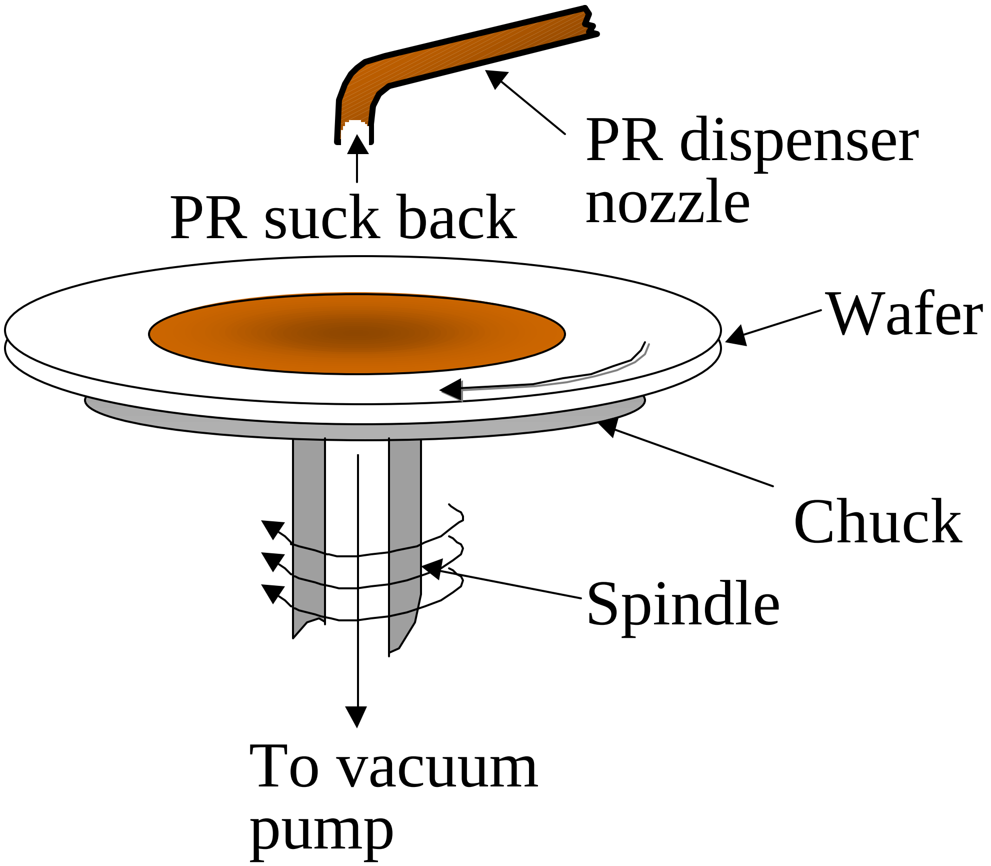
Wafer

Chuck

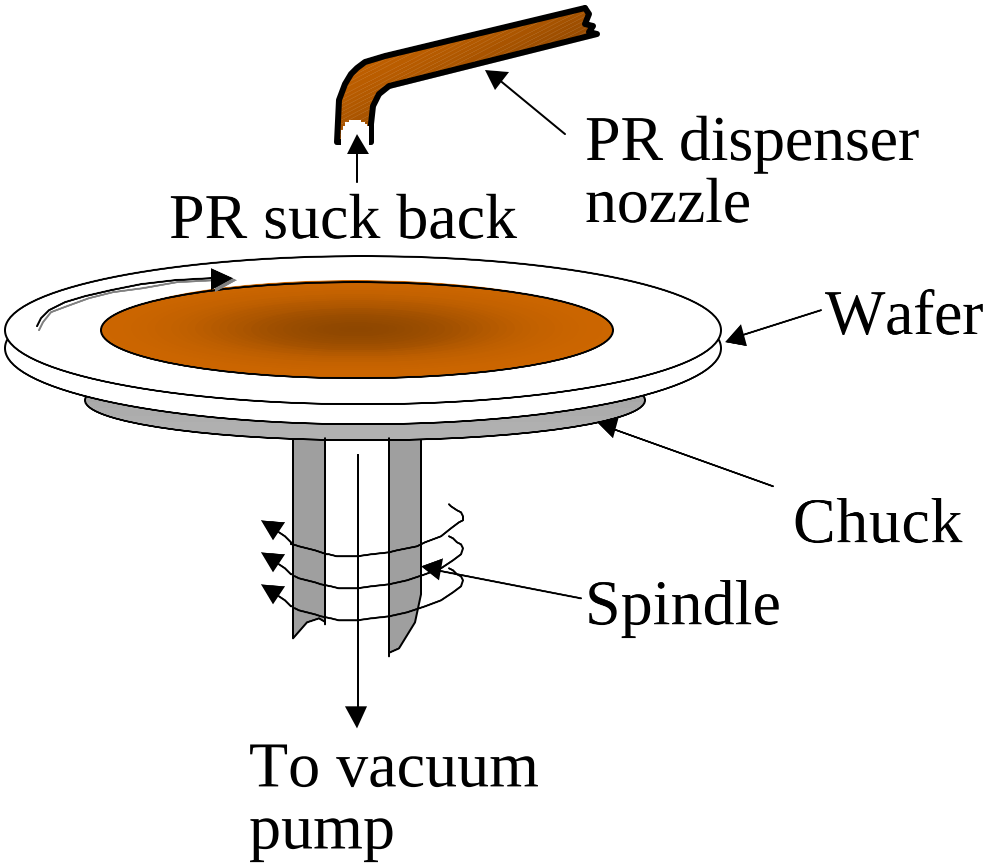
Spindle

To vacuum pump

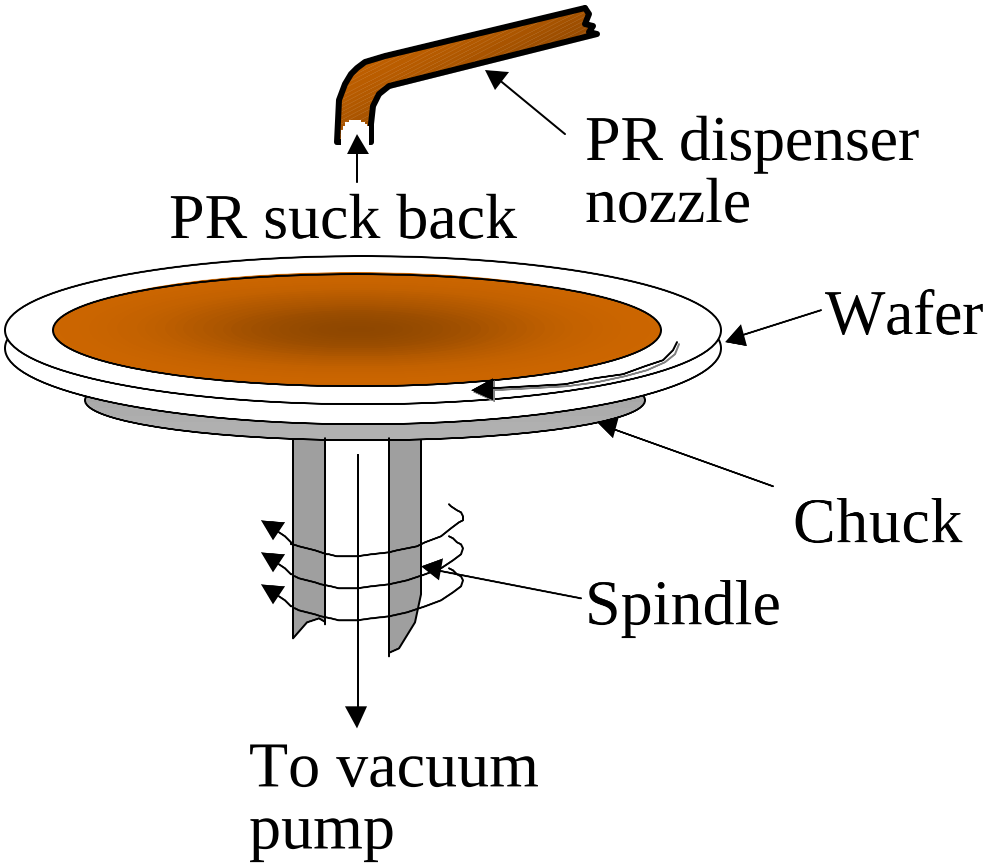
Photoresist Spin Coating



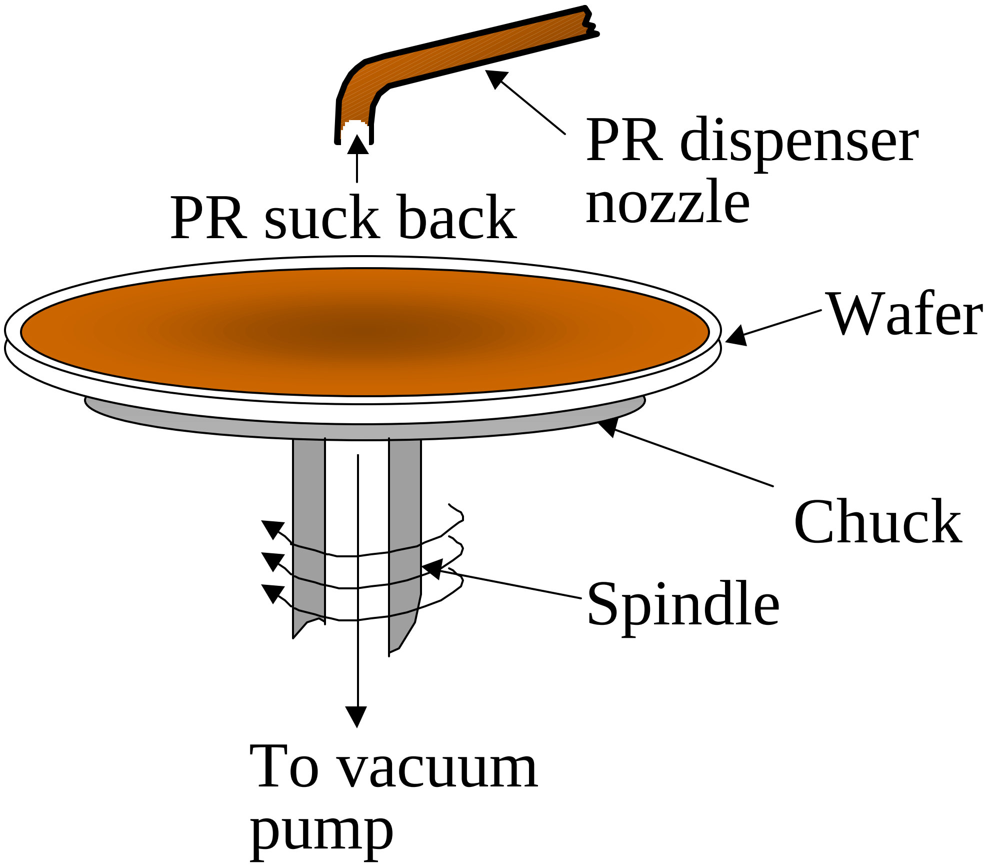
Photoresist Spin Coating



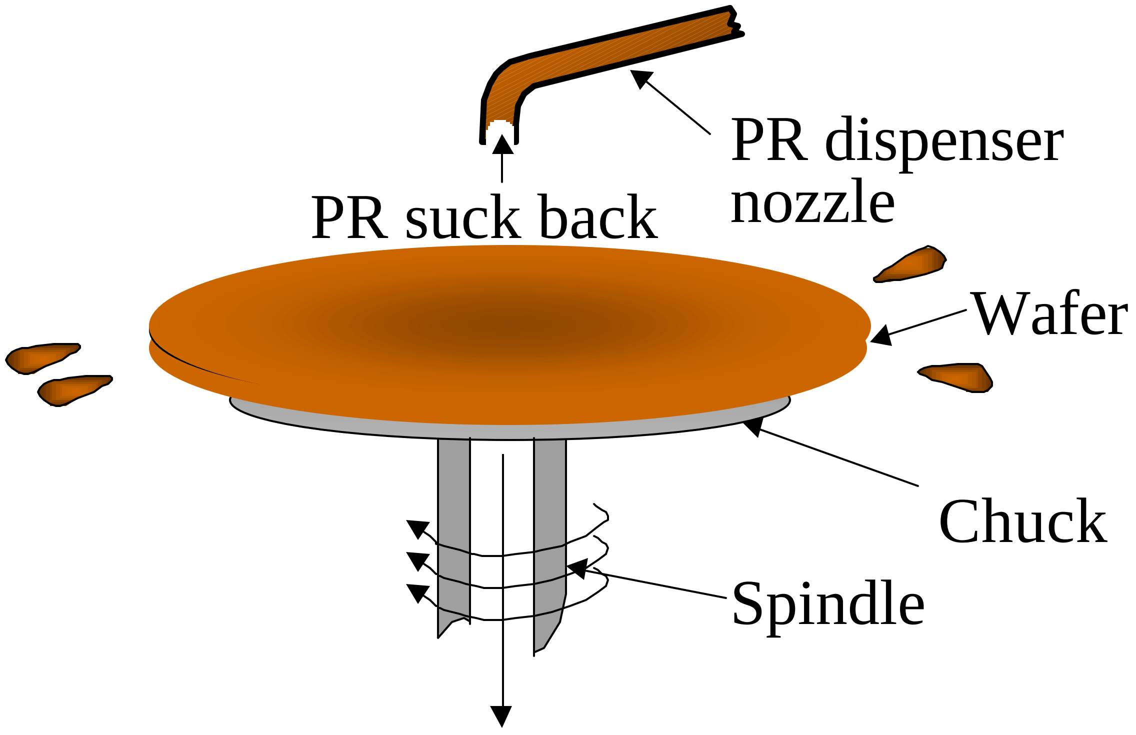
Photoresist Spin Coating



Photoresist Spin Coating



Photoresist Spin Coating



PR dispenser nozzle

PR suck back

Wafer

Chuck

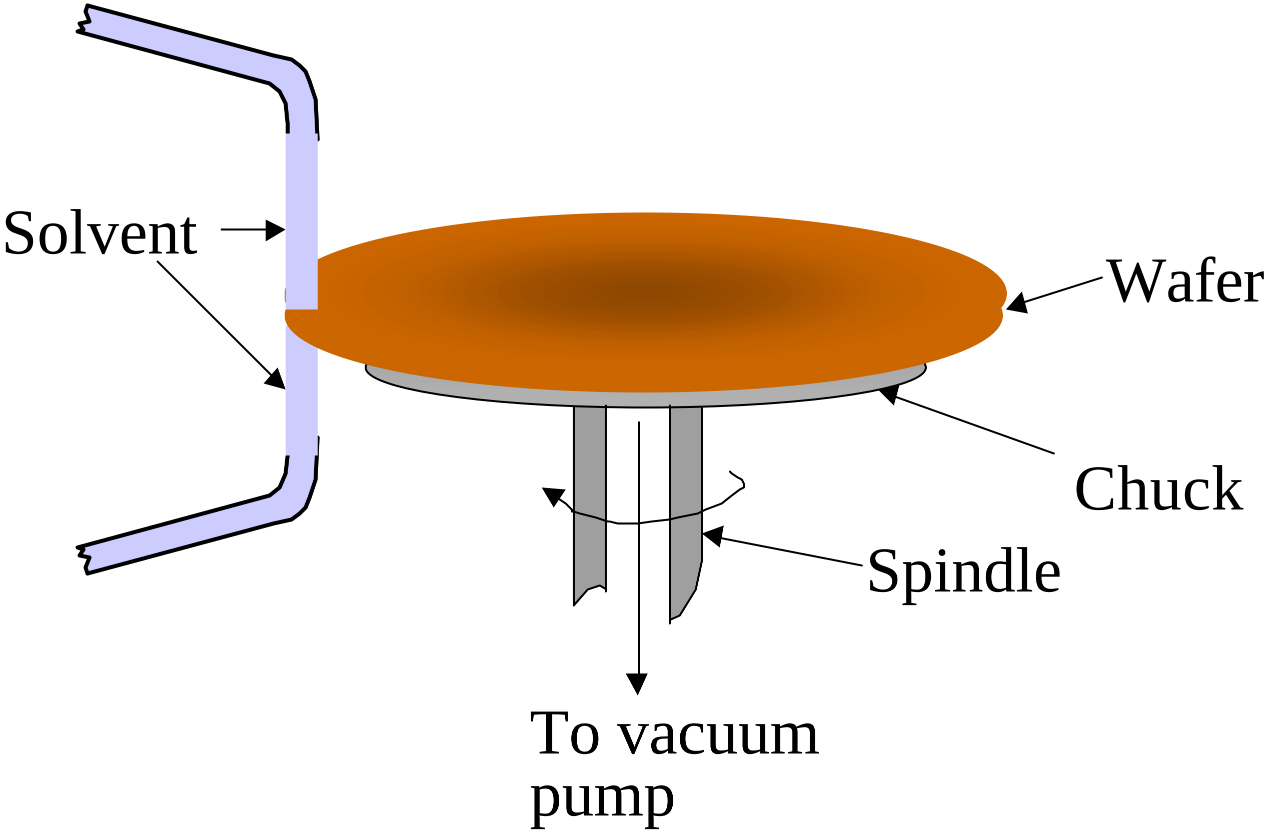
Spindle

To vacuum pump

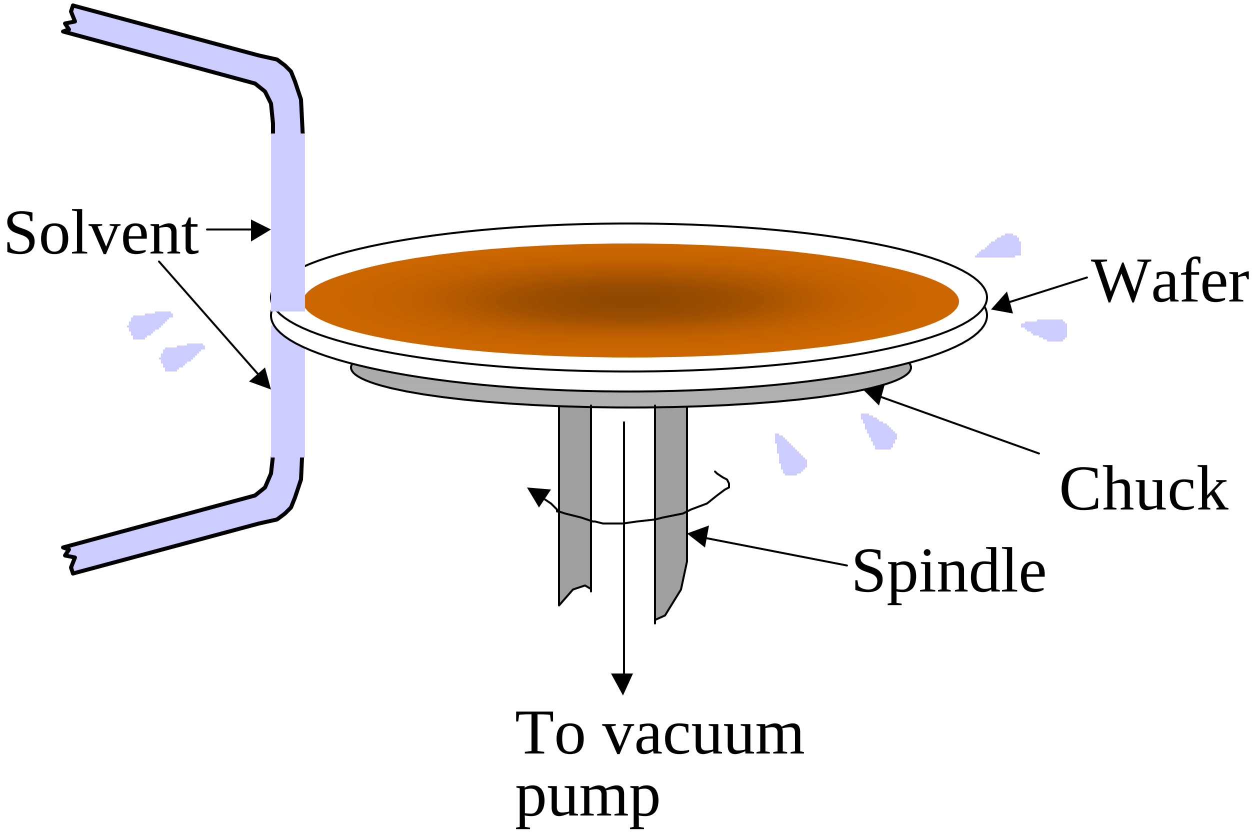
Edge Bead Removal (EBR)

- PR spread to the edges and backside
- PR could flakes off during mechanical handling and causes particles
- Front and back chemical EBR
- Front optical EBR

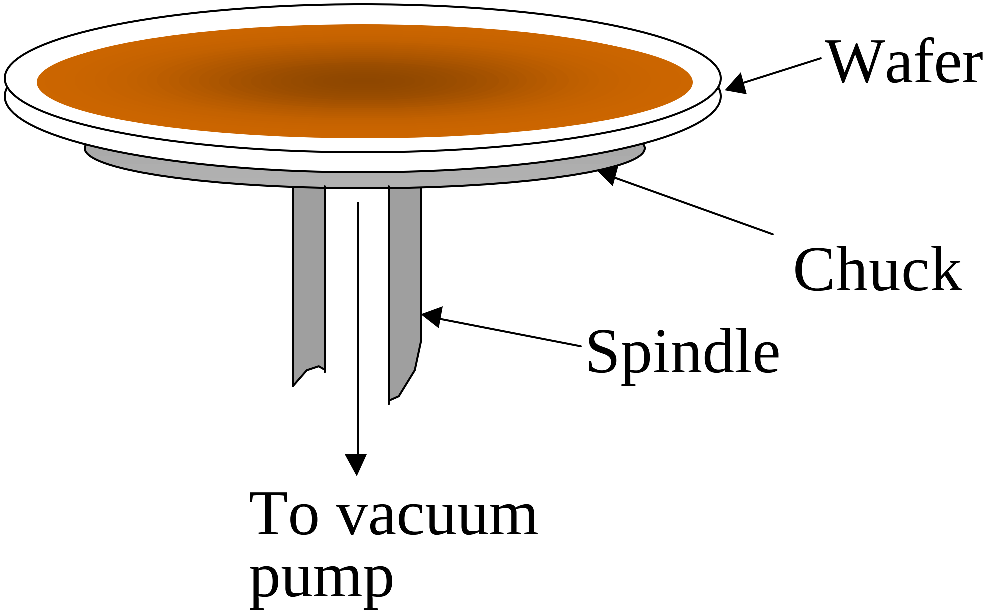
Edge Bead Removal



Edge Bead Removal



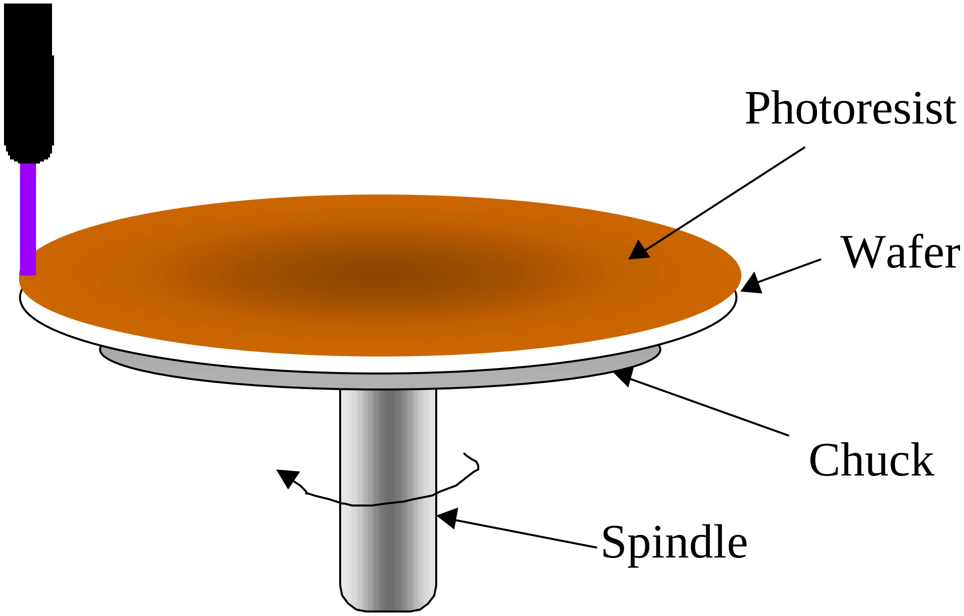
Ready For Soft Bake



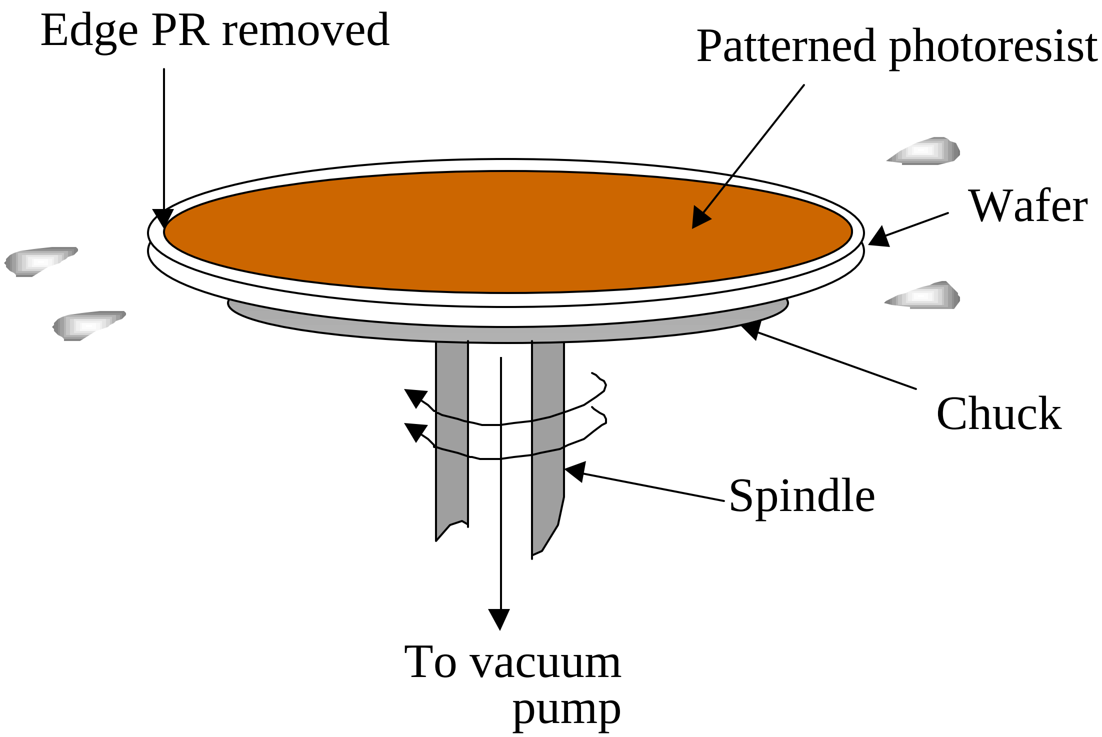
Optical Edge Bead Removal

- After alignment and exposure
- Wafer edge expose (WEE)
- Exposed photoresist at edge dissolves during development

Optical Edge Bead Removal



Developer Spin Off



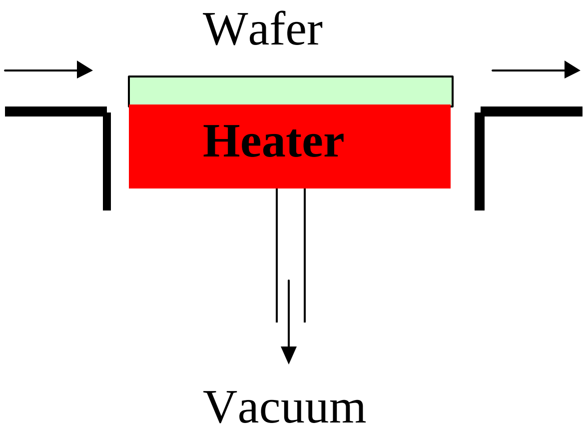
Soft Bake

- Evaporating most of solvents in PR
- Solvents help to make a thin PR but absorb radiation and affect adhesion
- Soft baking time and temperature are determined by the matrix evaluations
- Over bake: polymerized, less photo-sensitivity
- Under bake: affect adhesion and exposure

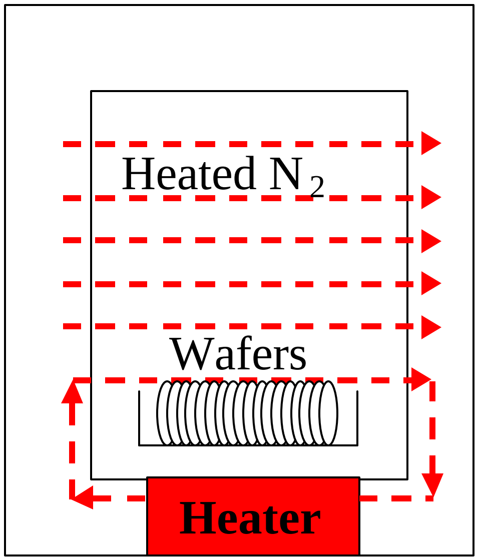
Soft Bake

- **Hot plates**
- Convection oven
- Infrared oven
- Microwave oven

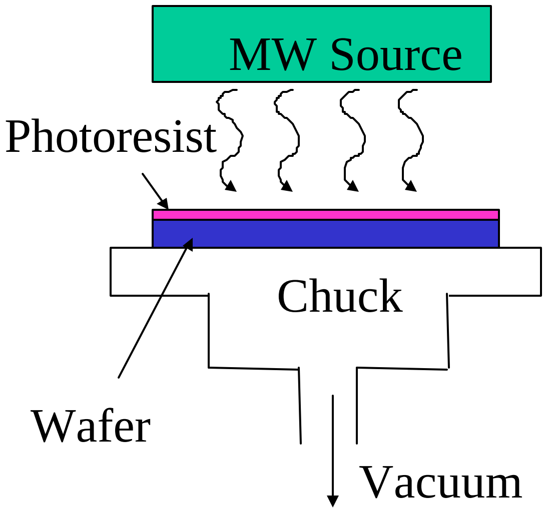
Baking Systems



Hot plate



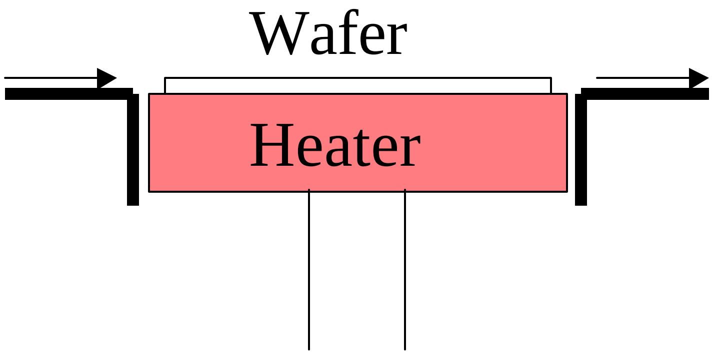
Convection oven



Microwave oven

Hot Plates

- Widely used in the industry
- Back side heating, no surface “crust”
- In-line track system



Wafer Cooling

- Need to cool down to ambient temperature
- Water-cooled chill plate
- Silicon thermal expansion rate: $2.5\times10^{-6}/°C$
- For 8 inch (200 mm) wafer, 1 °C change causes 0.5 μm difference in diameter

Alignment and Exposure

- Most critical process for IC fabrication
- Most expensive tool (stepper) in an IC fab.
- Most challenging technology
- Determines the minimum feature size
- Currently 0.18 μm and pushing to 0.13 μm

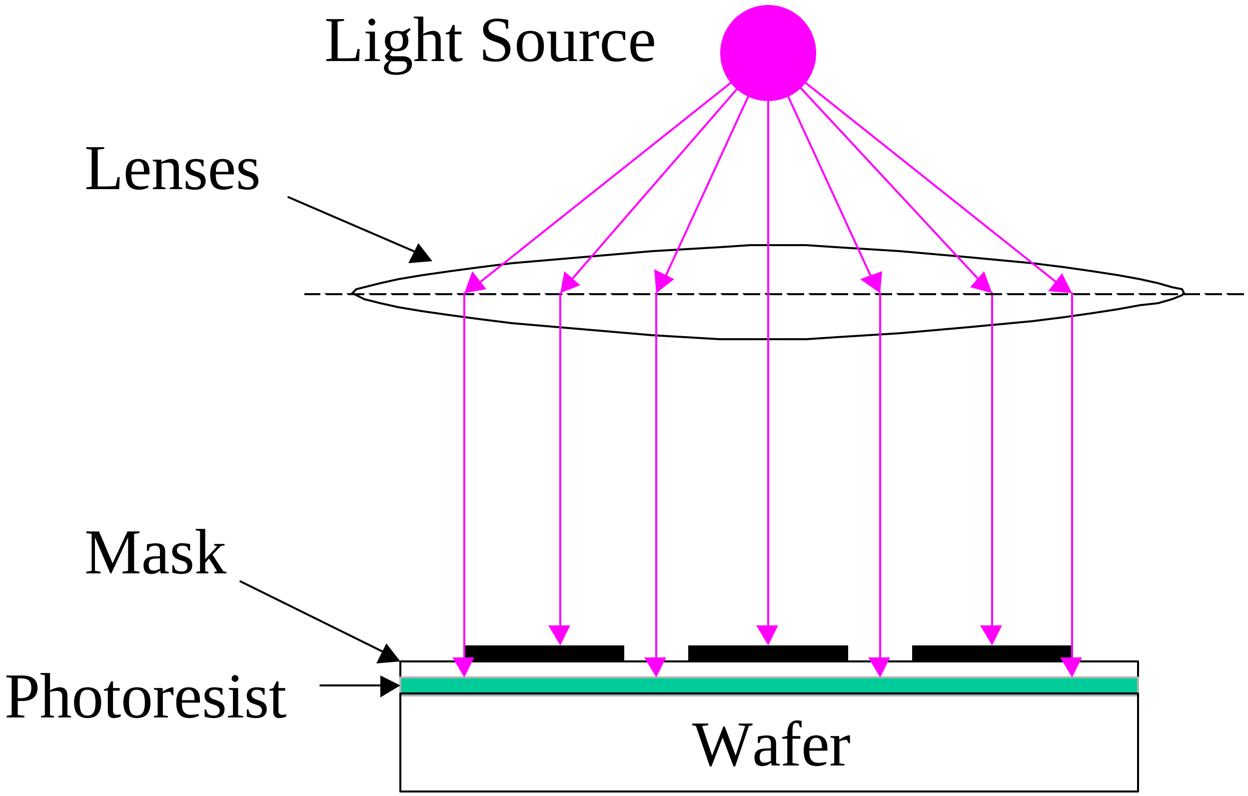
Alignment and Exposure Tools

- Contact printer
- Proximity printer
- Projection printer
- Stepper

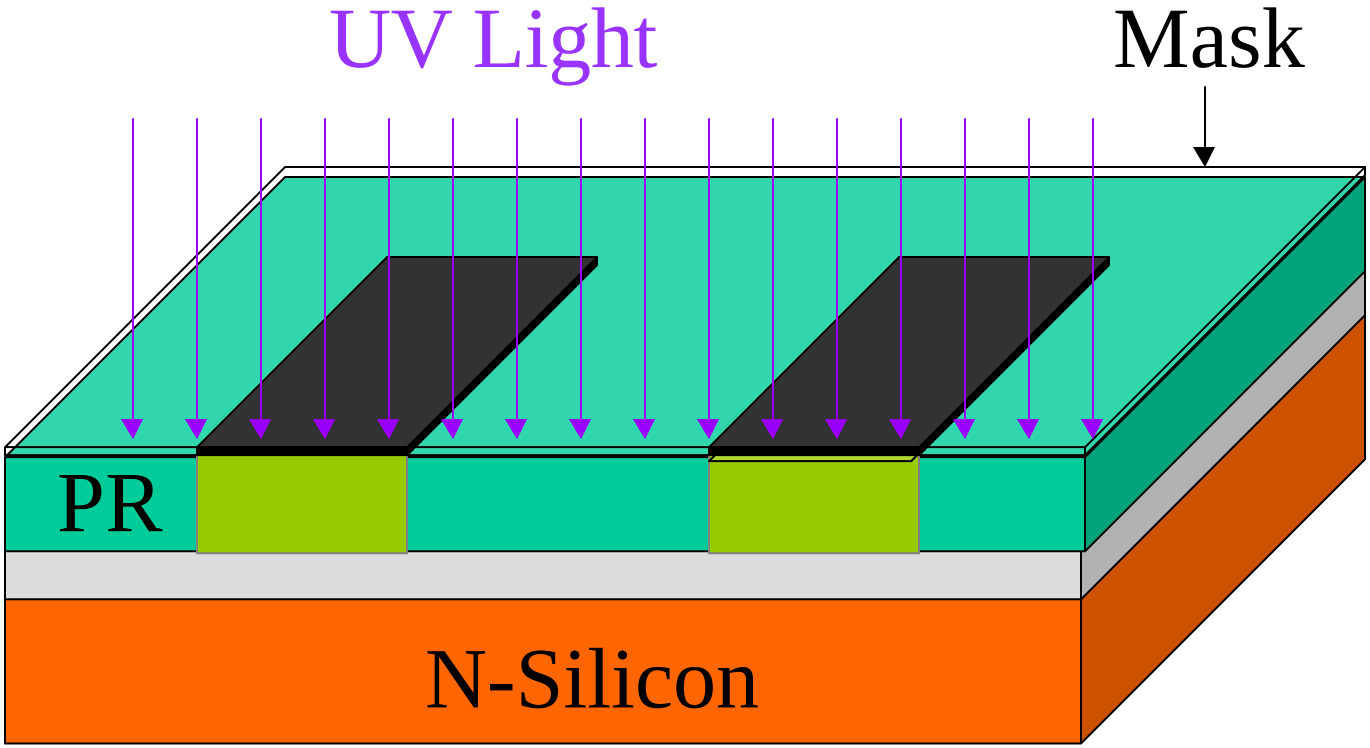
Contact Printer

- Simple equipment
- Use before mid-70s
- Resolution: capable for sub-micron
- Direct mask-wafer contact, limited mask lifetime
- Particles

Contact Printer



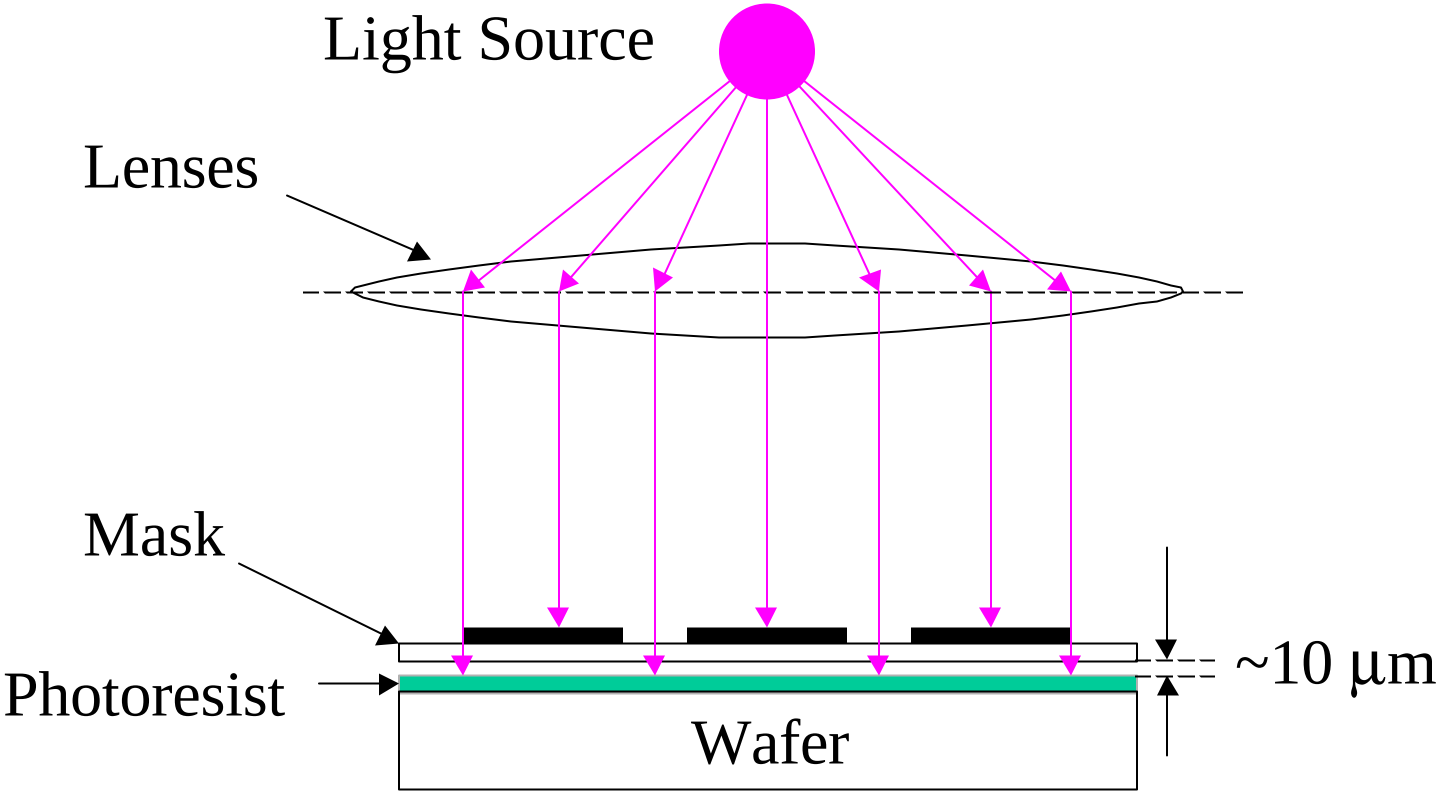
Contact Printing



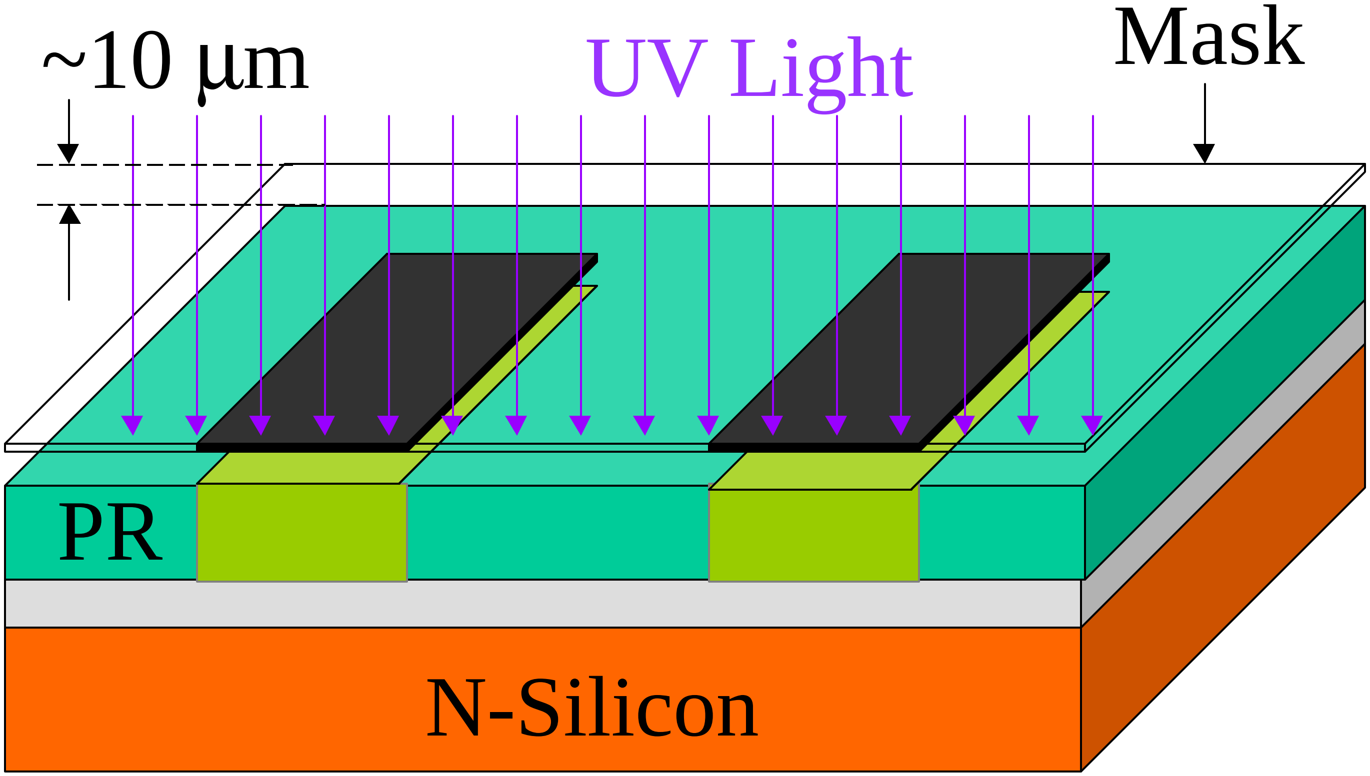
Proximity Printer

- ~ 10 μm from wafer surface
- No direct contact
- Longer mask lifetime
- Resolution: > 3 μm

Proximity Printer



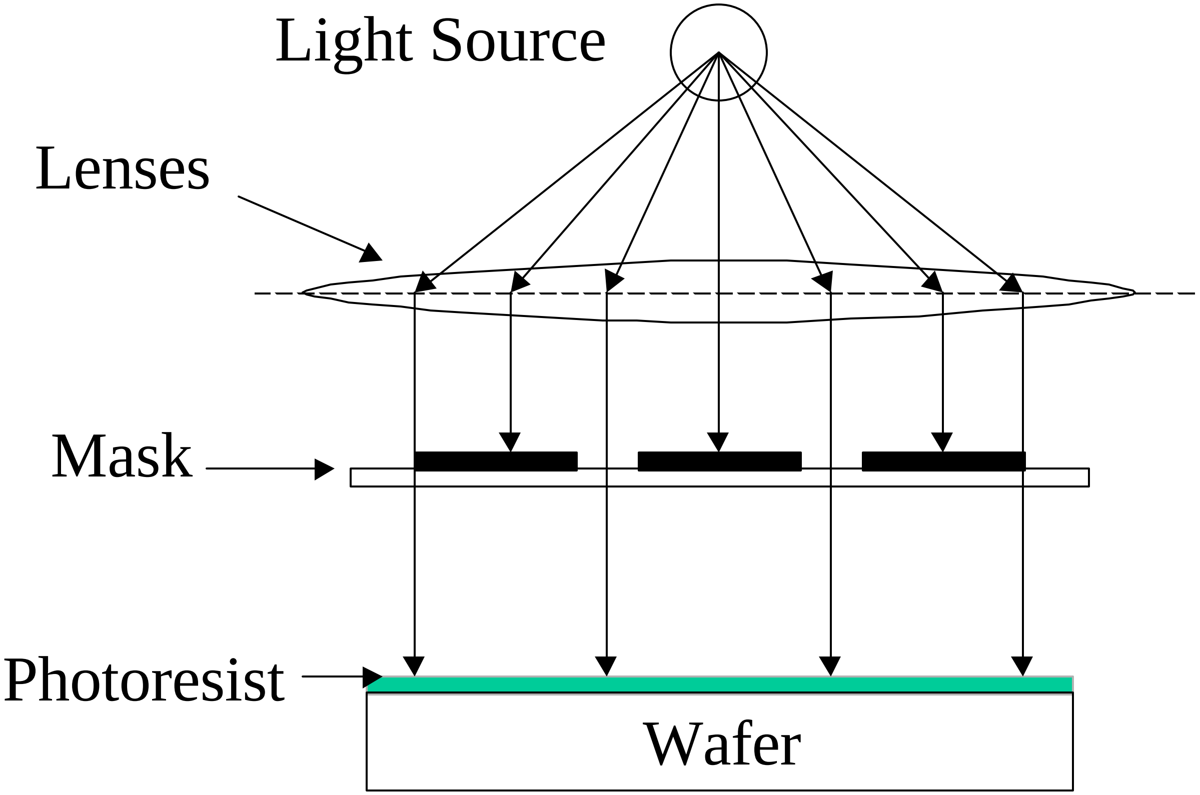
Proximity Printing



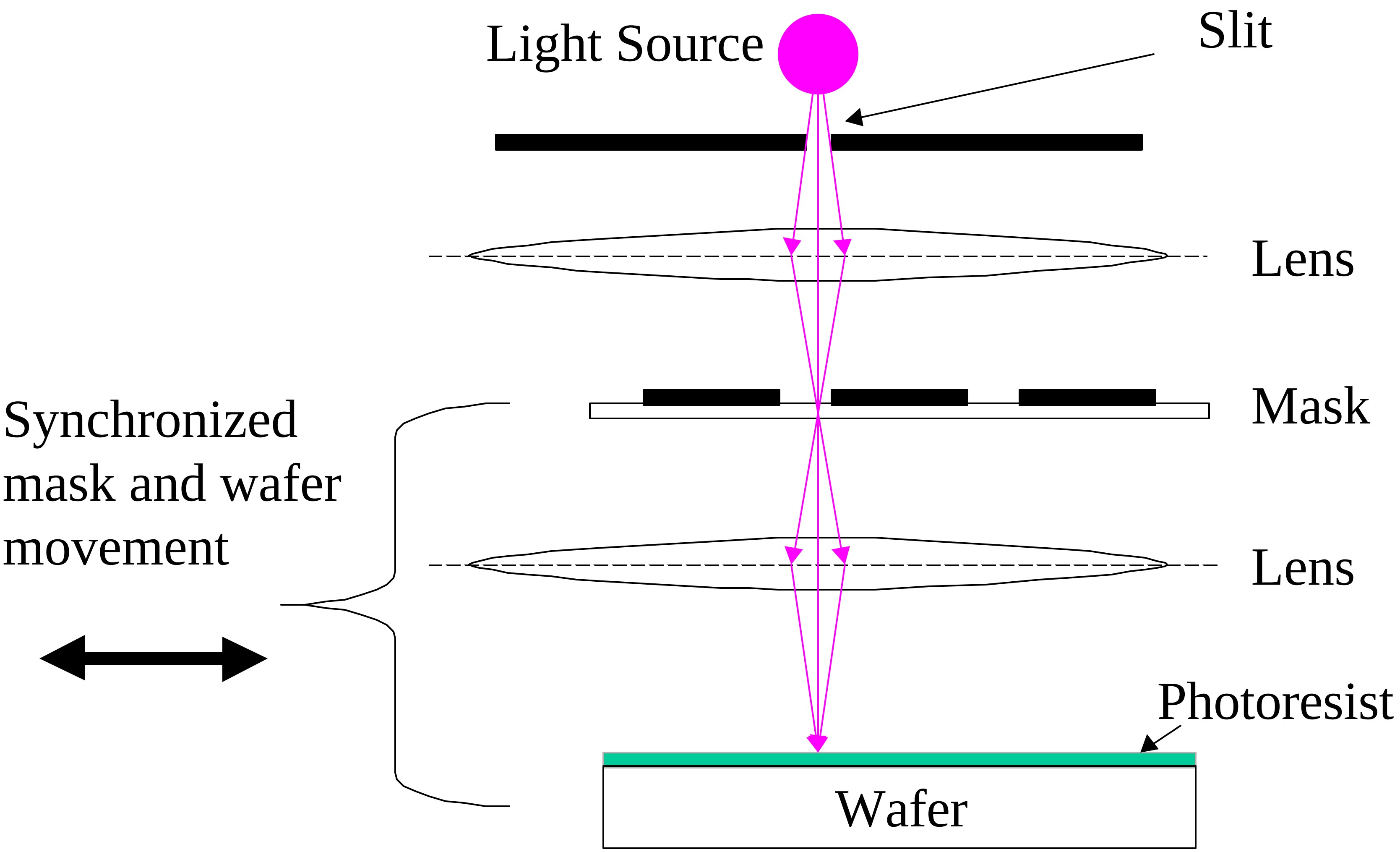
Projection Printer

- Works like an overhead projector
- Mask to wafer, 1:1
- Resolution to about 1 μm

Projection System



Scanning Projection System



Stepper

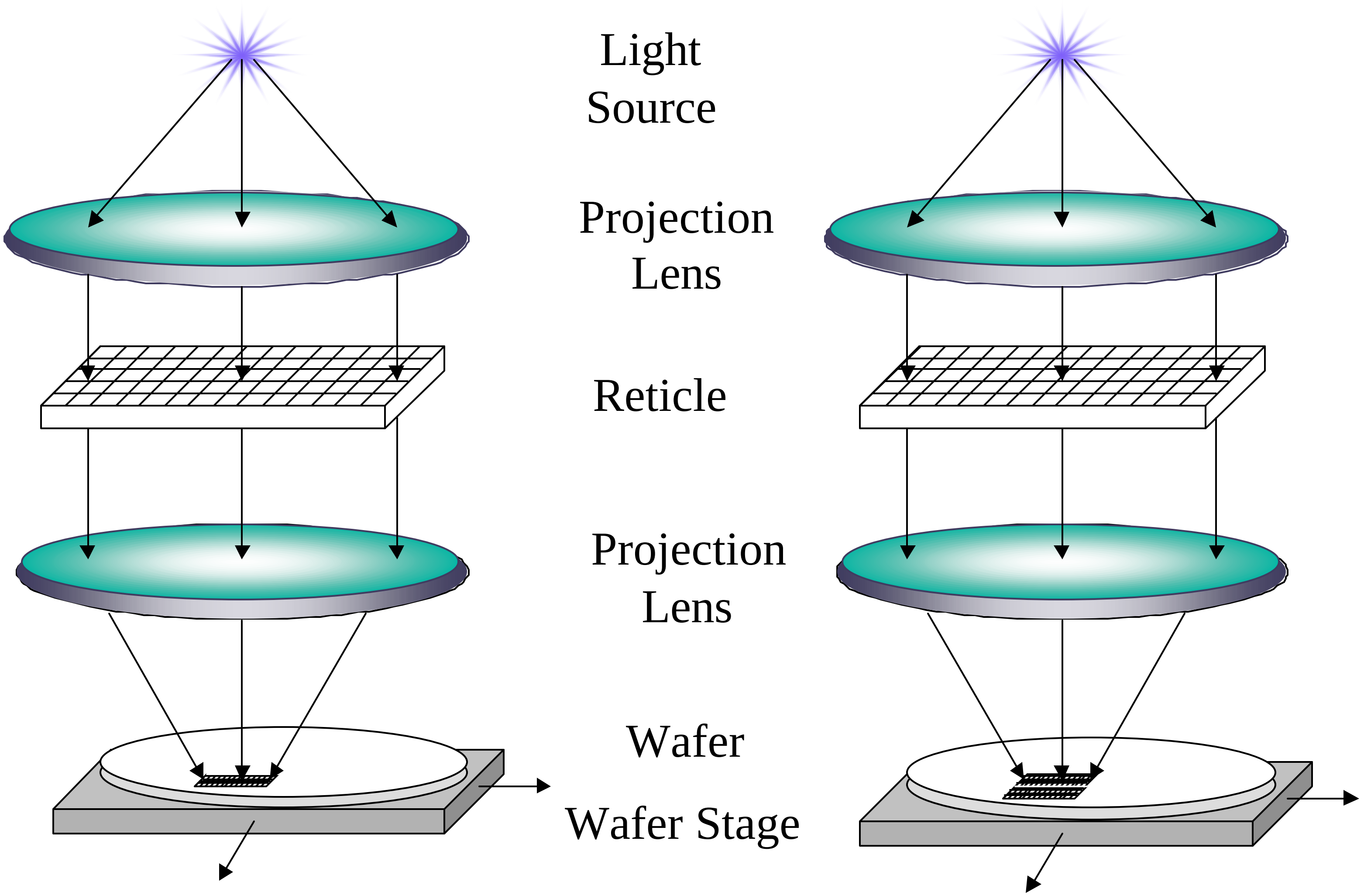
- Most popular used photolithography tool in the advanced IC fabs
- Reduction of image gives high resolution
- 0.25 μm and beyond
- Very expensive

Q & A

- Why does the 5:1 shrink ratio is more popular than the 10:1 shrink ratio?

- 10:1 image shrink has better resolution than 5:1 image shrink. However, it only exposes a quarter of the area, which means total exposure time will be quadrupled.

Step-&-Repeat Alignment/Exposure



Light Source

Projection Lens

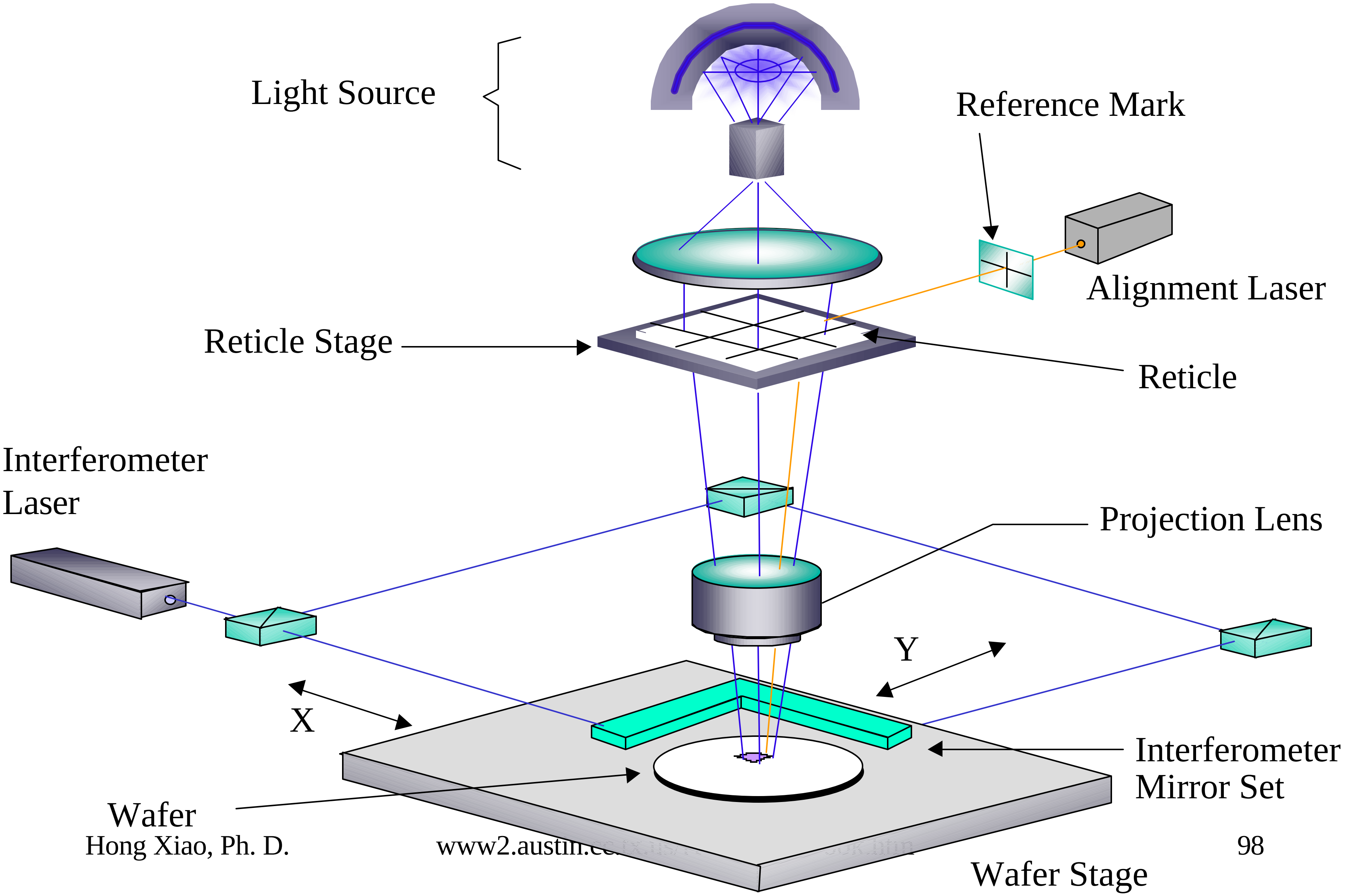
Reticle

Projection Lens

Wafer

Wafer Stage

Step&Repeat Alignment System



Light Source

Reference Mark

Alignment Laser

Reticle Stage

Reticle

Interferometer
Laser

Projection Lens

Y

X

Interferometer
Mirror Set

Wafer

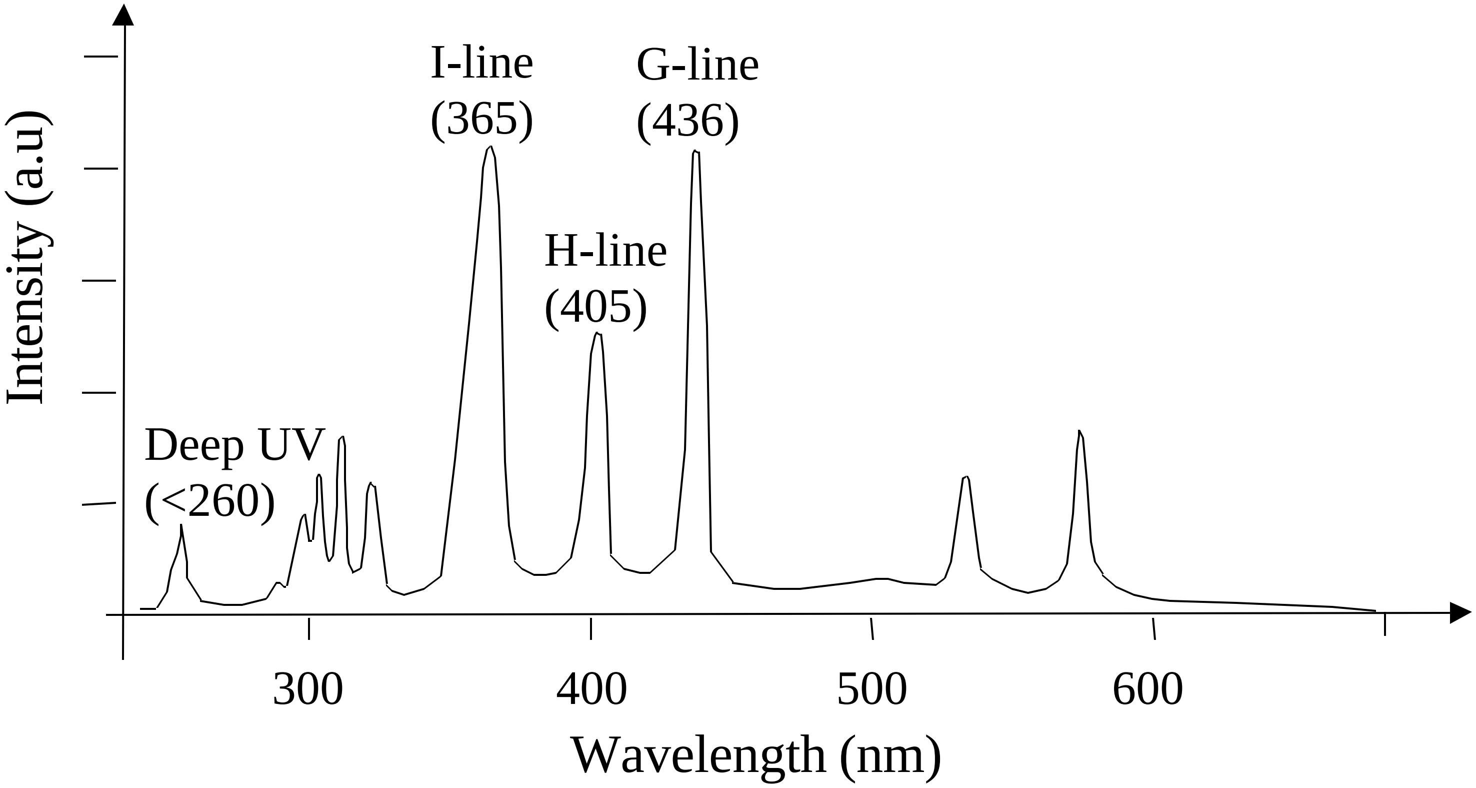
Wafer Stage

Exposure Light Source

- Short wavelength
- High intensity
- Stable

- High-pressure mercury lamp
- Excimer laser

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

Exposure Control

- Exposure 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

Question

- Someone did a routine illuminator intensity calibration with a reticle still on the stage. What kind of problem will it induce?

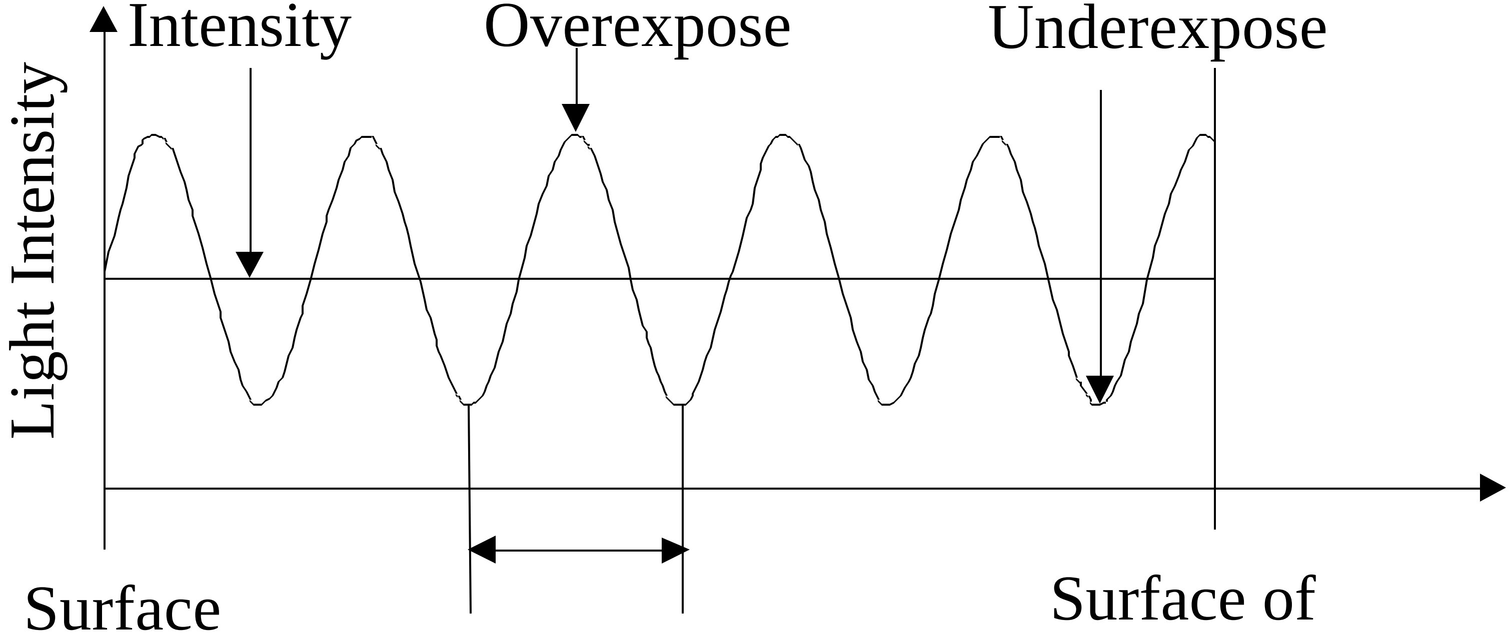
Answer

- Since the reticle can block some light, photodetector on wafer stage will receive less photons than it should receive. Therefore, it will give a lower reading. To calibrate, the applied power will be increased and the light intensity will be higher than it should be. It could cause overexposure and CD loss.

Standing Wave Effect

- Interference of the incident and reflection lights
- Periodically overexposure and underexposure
- Affects photolithography resolution.

Standing Wave Intensity



Average
Intensity

Constructive
Interference,
Overexpose

Destructive
Interference,
Underexpose

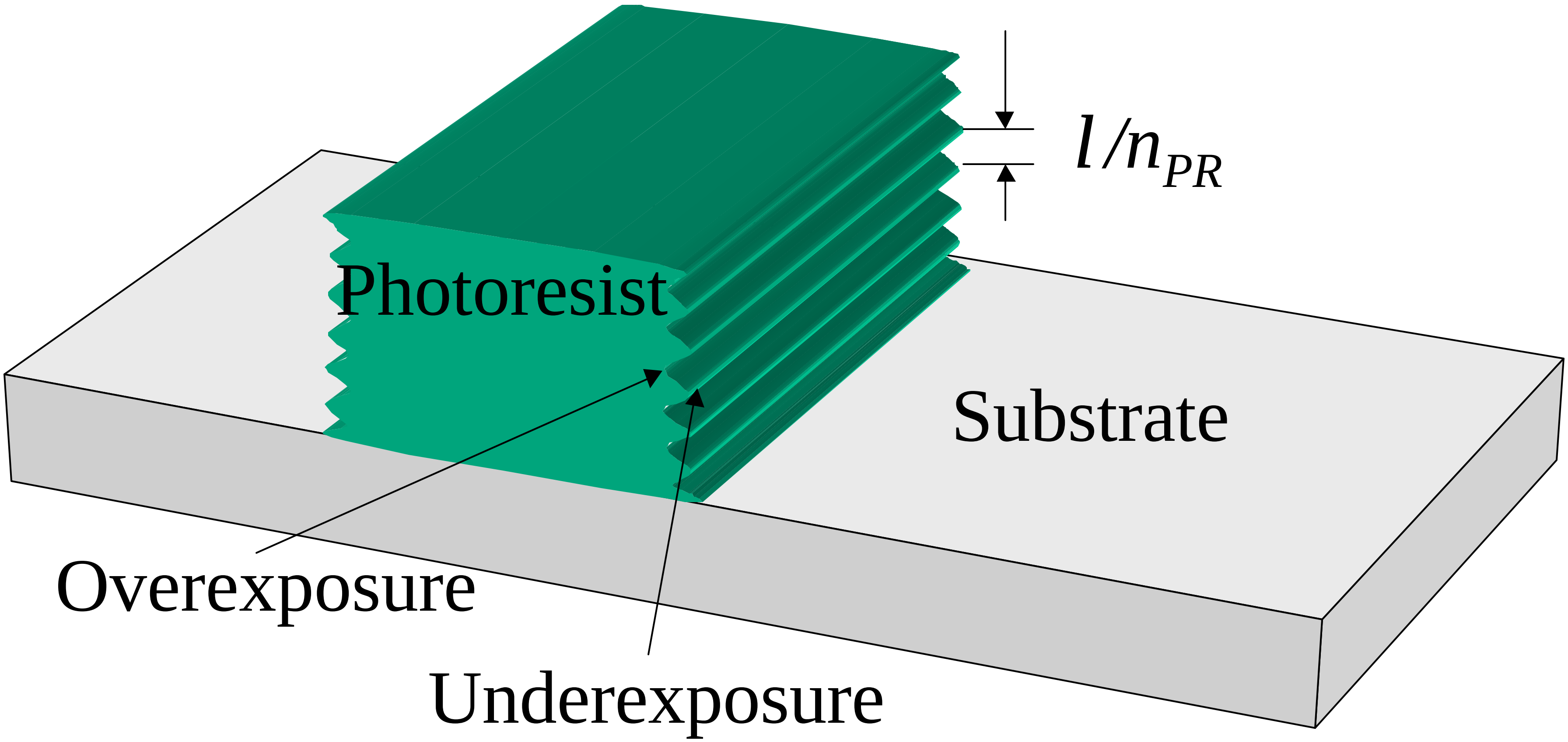
Light Intensity

Surface
the of PR

l/n_{PR}

Surface of
the substrate

Standing Wave Effect on Photoresist



Post Exposure Bake

- Photoresist glass transition temperature T_g
- Baking temperature higher than T_g
- Thermal movement of photoresist molecules
- Rearrangement of the overexposed and underexposed PR molecules
- Average out standing wave effect,
- Smooth PR sidewall and improve resolution

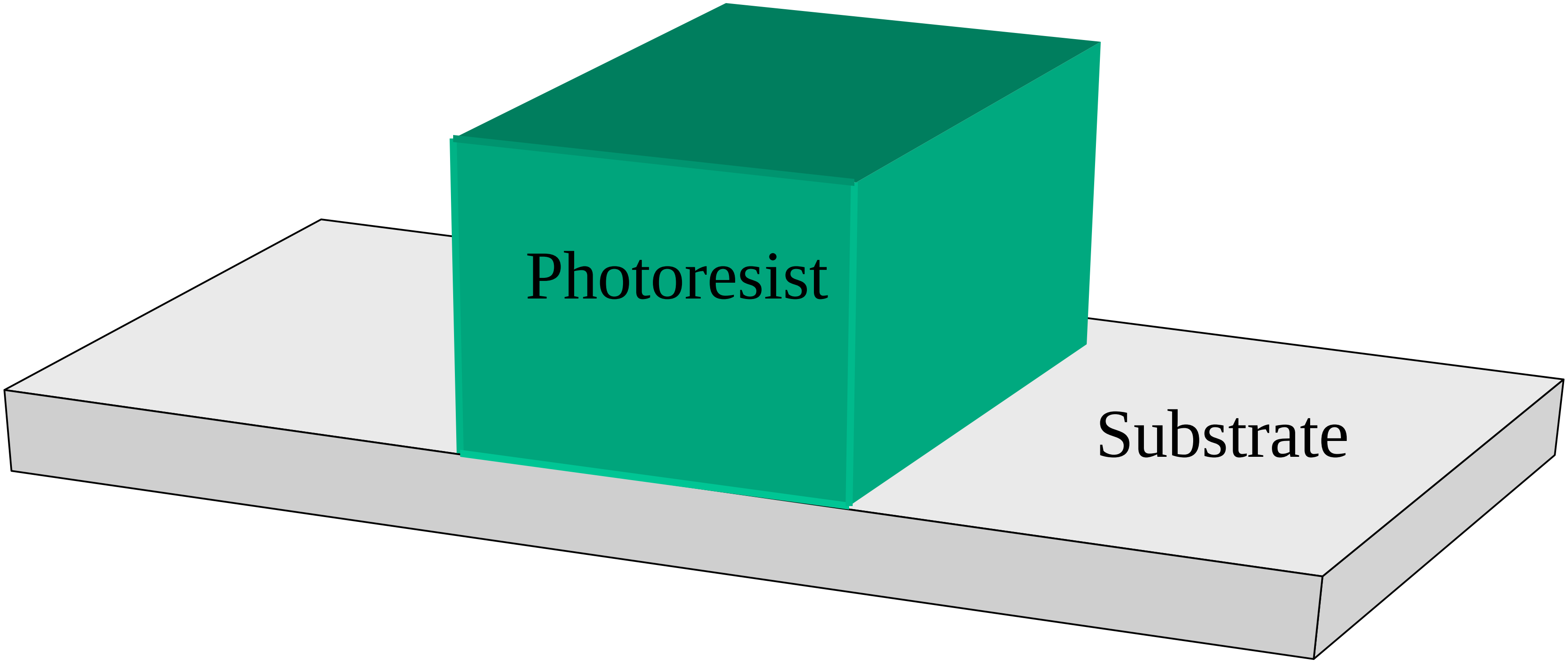
Post Exposure Bake

- For DUV chemical amplified photoresist, PEB provides the heat needed for acid diffusion and amplification.
- After the PEB process, the images of the exposed areas appear on the photoresist, due to the significant chemical change after the acid amplification

Post Exposure Bake

- PEB normally uses hot plate at 110 to 130 °C for about 1 minute.
- For the same kind of PR, PEB usually requires a higher temperature than soft bake.
- Insufficient PEB will not completely eliminate the standing wave pattern,
- Over-baking will cause polymerization and affects photoresist development

PEB Minimizes Standing Wave Effect



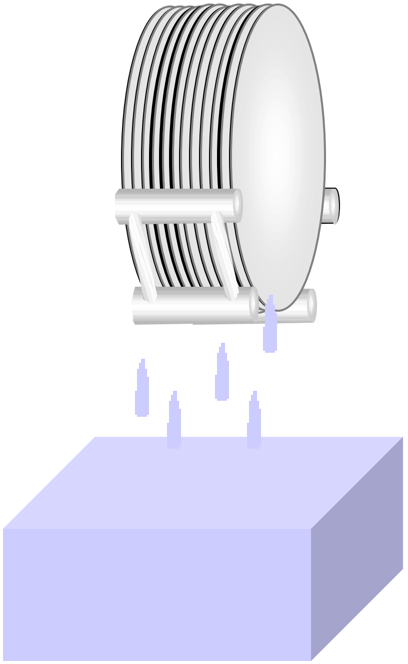
Wafer Cooling

- After PEB the wafer is put on a chill plate to cool down to the ambient temperature before sent to the development process
- High temperature can accelerate chemical reaction and cause over-development,
- PR CD loss

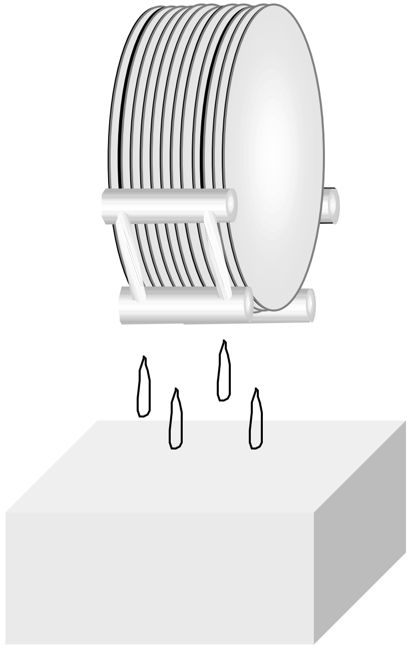
Development

- Developer solvent dissolves the softened part of photoresist
- Transfer the pattern from mask or reticle to photoresist
- Three basic steps:
  - Development
  - Rinse
  - Dry

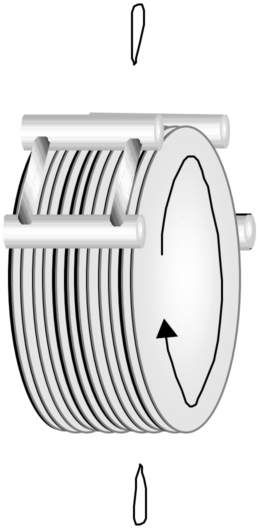
Development: Immersion



Develop



Rinse

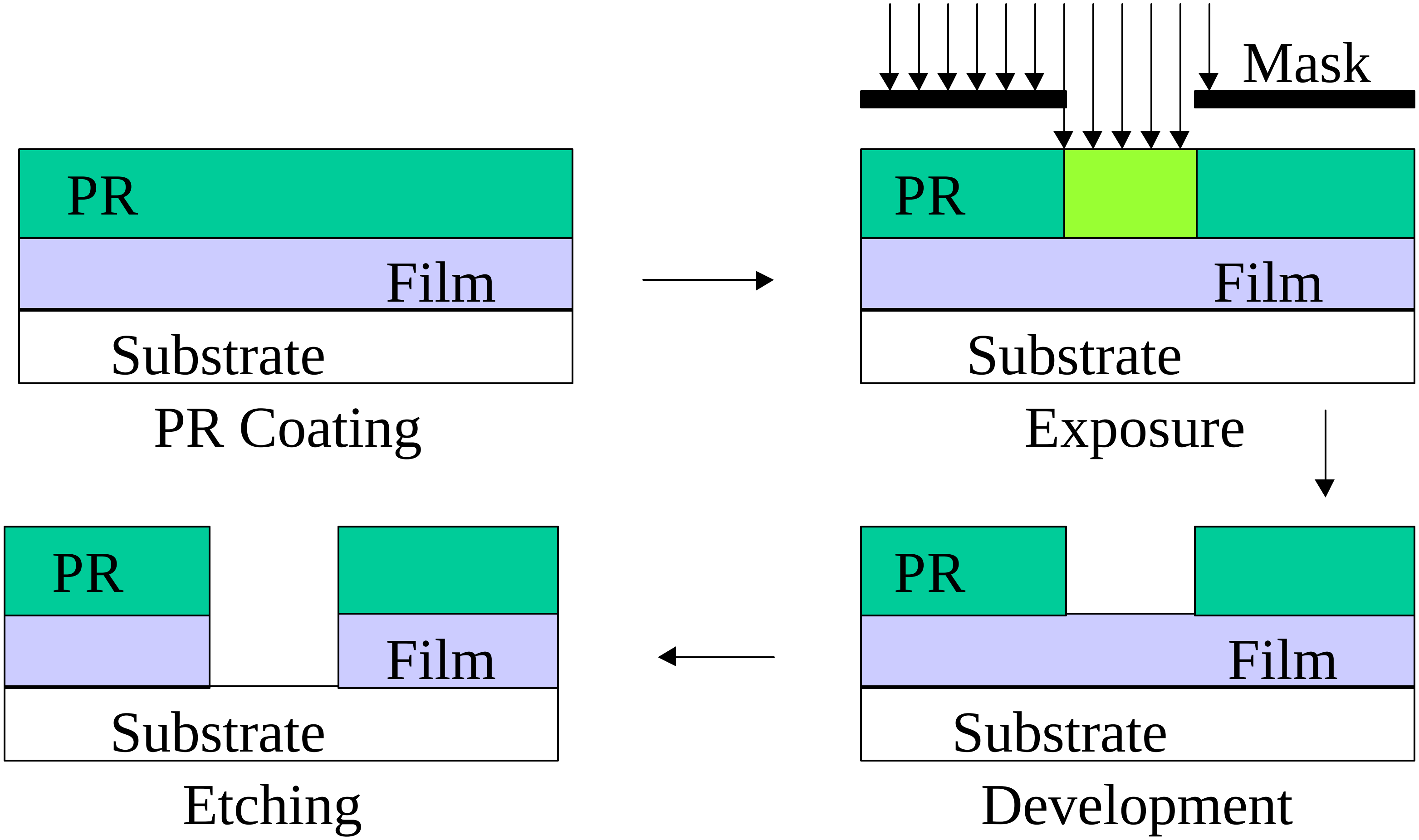


Spin Dry

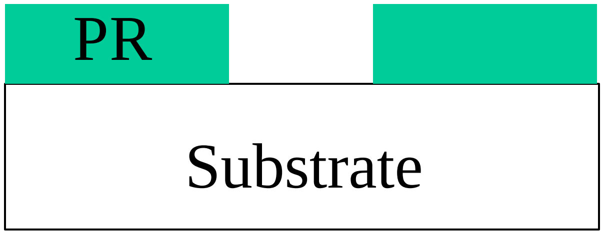
Developer Solution

- +PR normally uses weak base solution
- The most commonly used one is the tetramethyl ammonium hydride, or TMAH ($(CH_3)_4NOH$).

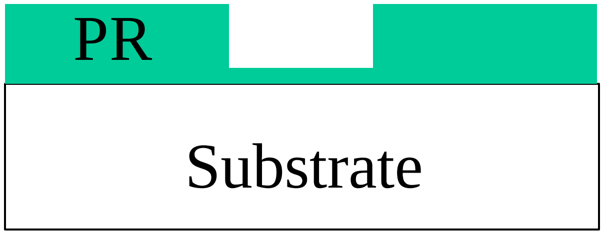
Development



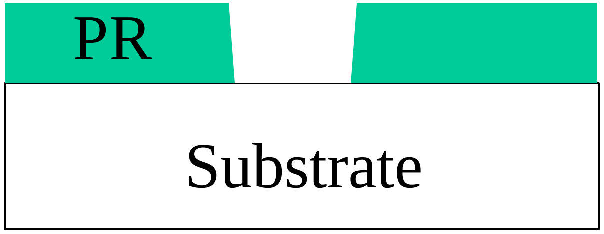
Development Profiles



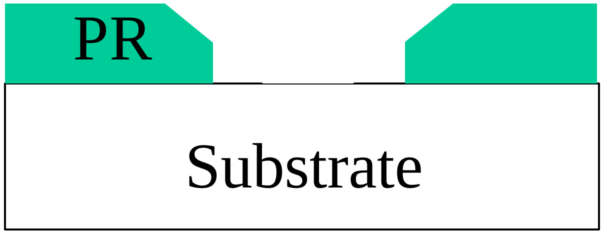
Normal Development



Incomplete Development



Under Development

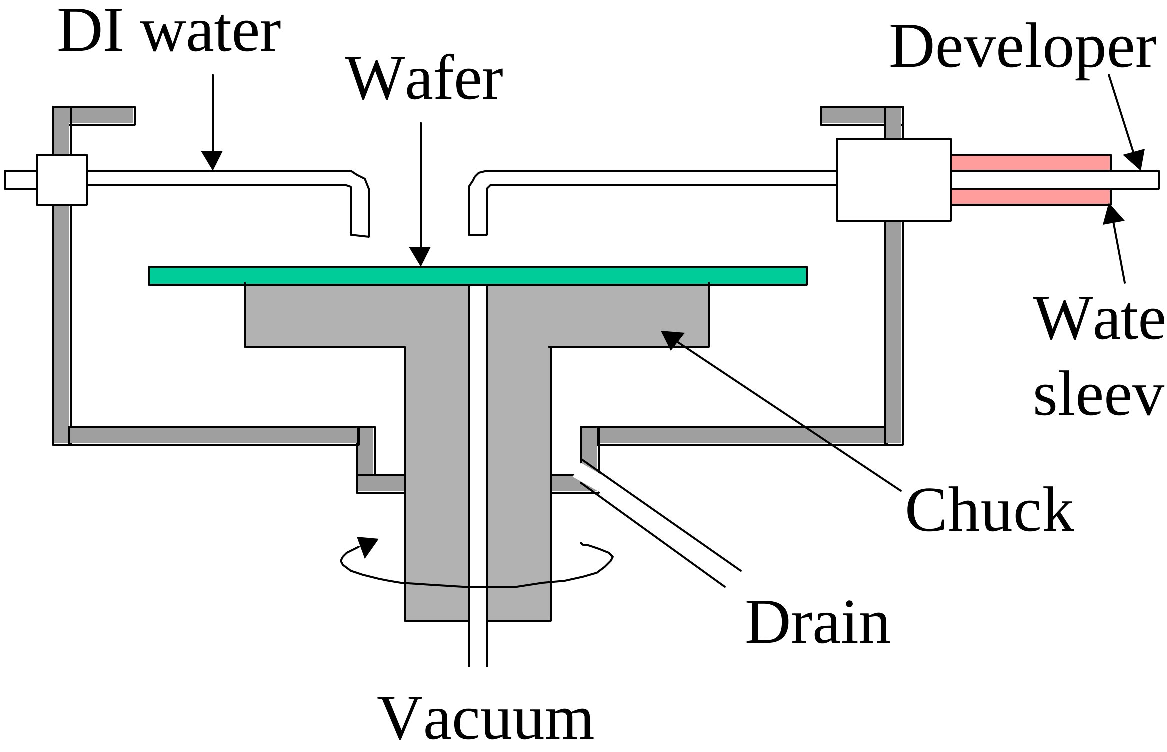


Over Development

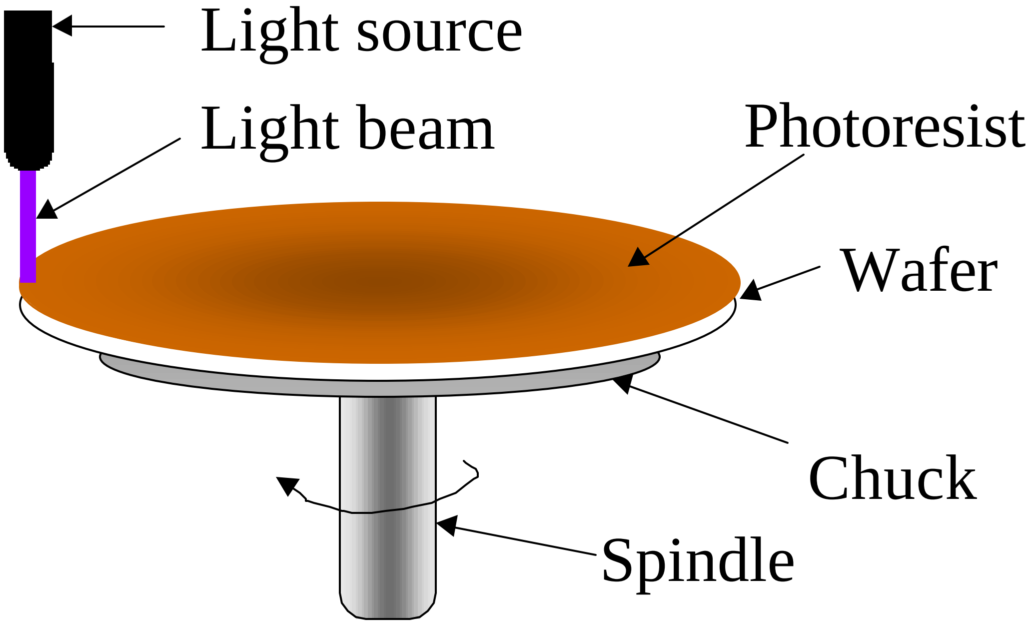
Developer Solutions

	Positive PR	Negative PR
Developer	TMAH	Xylene
Rinse	DI Water	n-Butylacetate

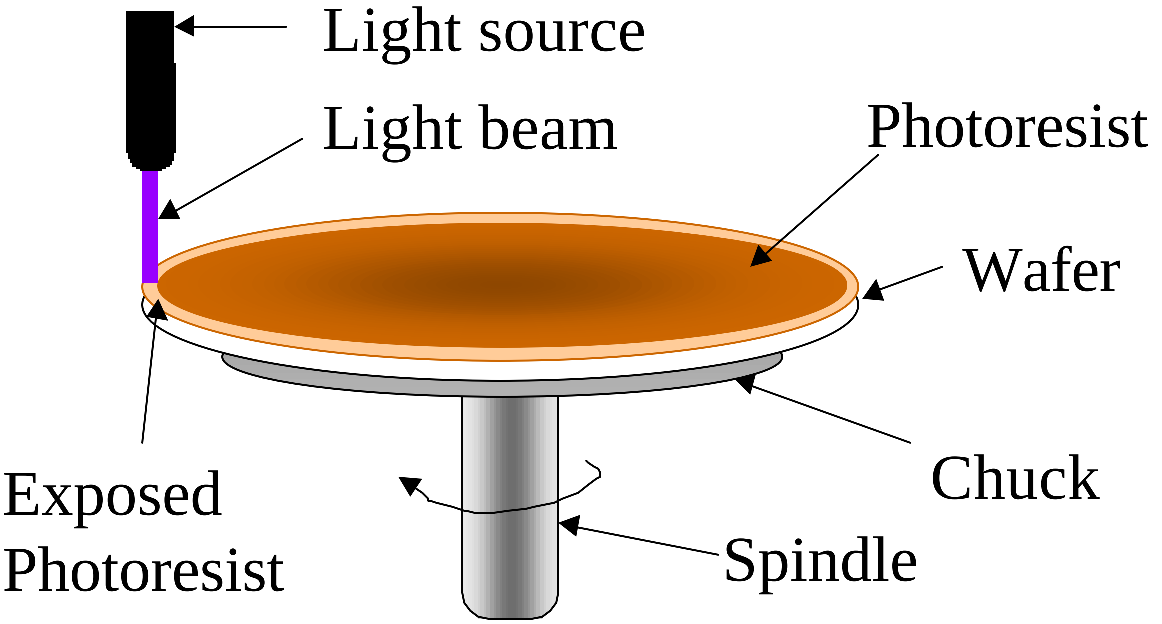
Schematic of a Spin Developer



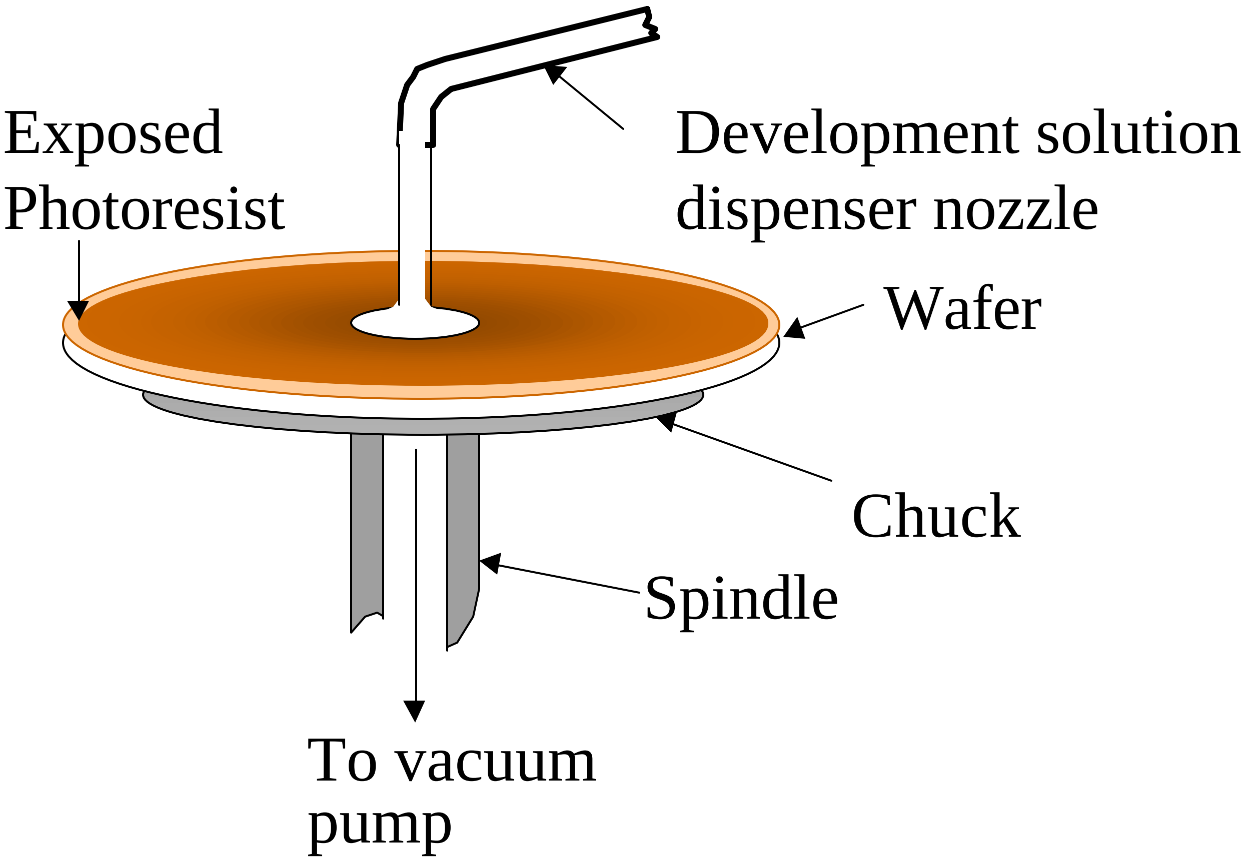
Optical Edge Bead Removal Exposure



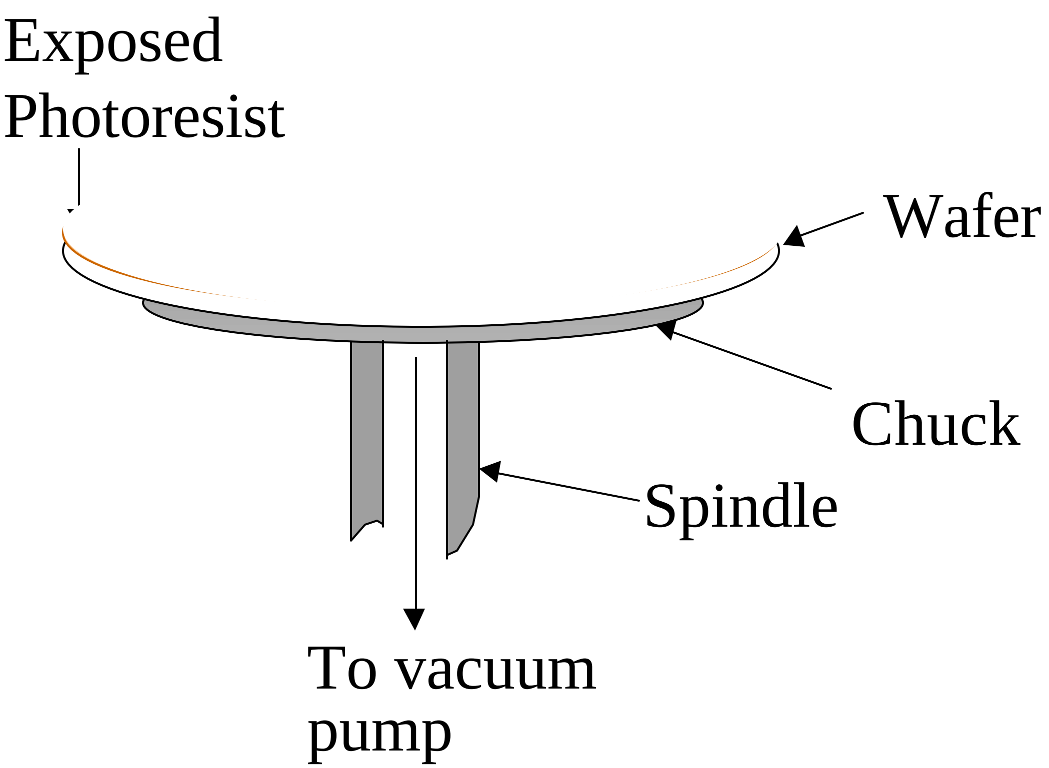
Optical Edge Bead Removal Exposure



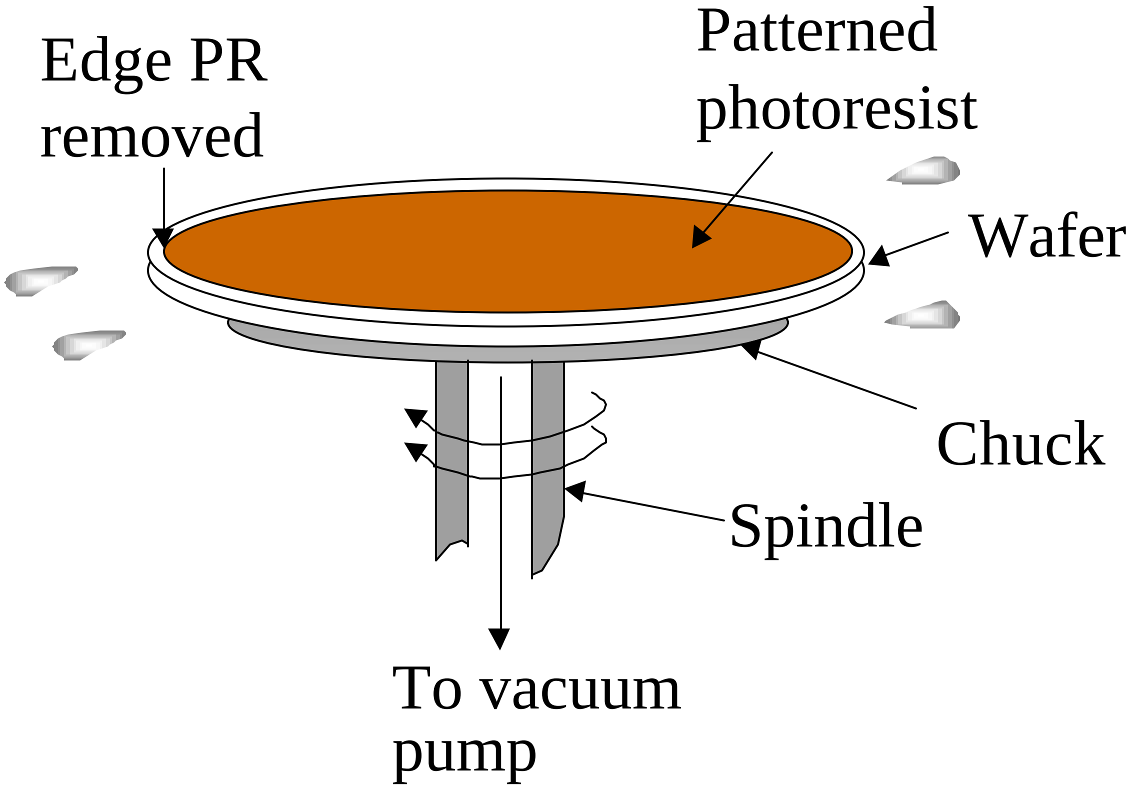
Applying Development Solution



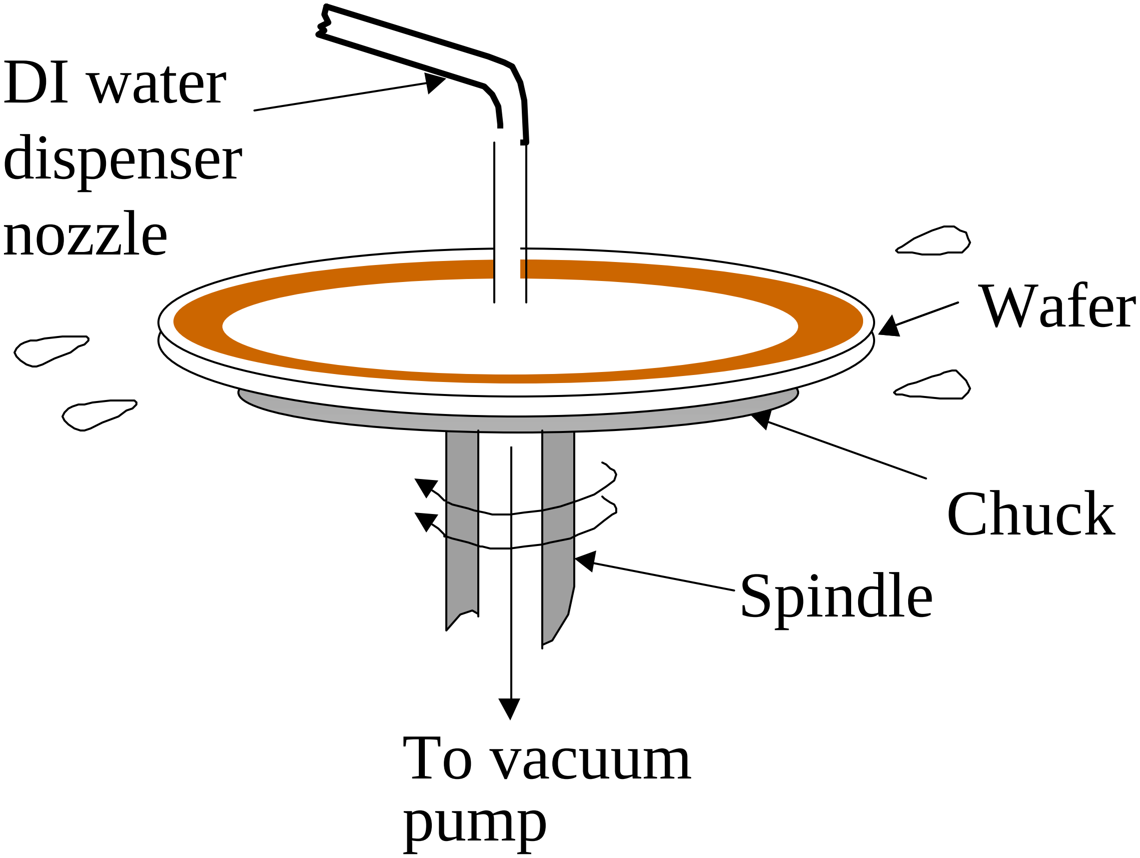
Applying Development Solution



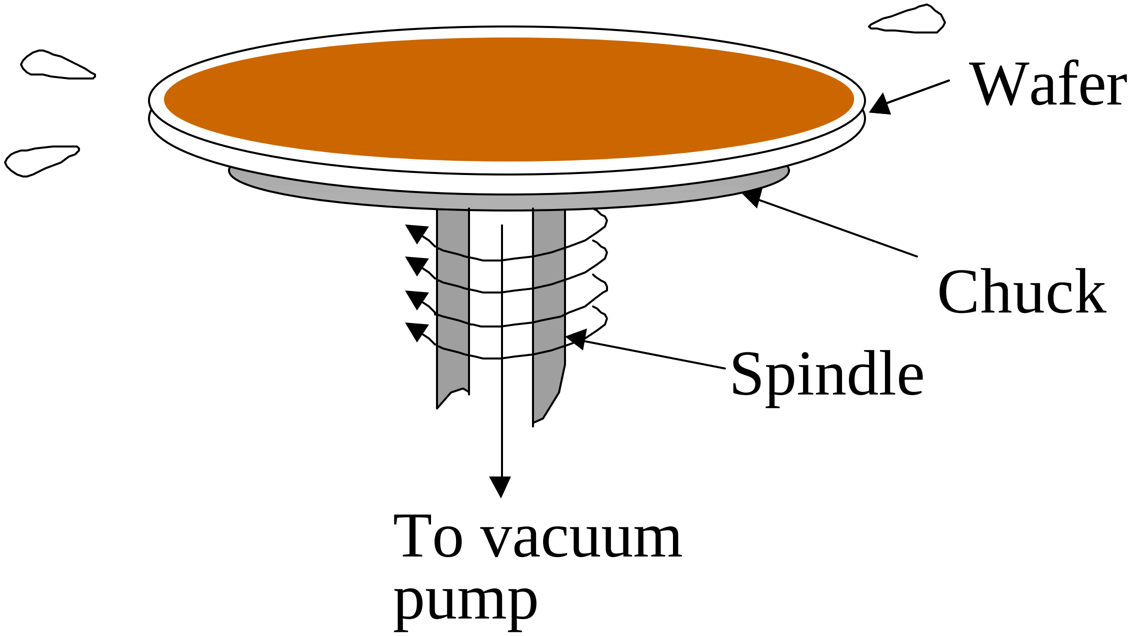
Development Solution Spin Off



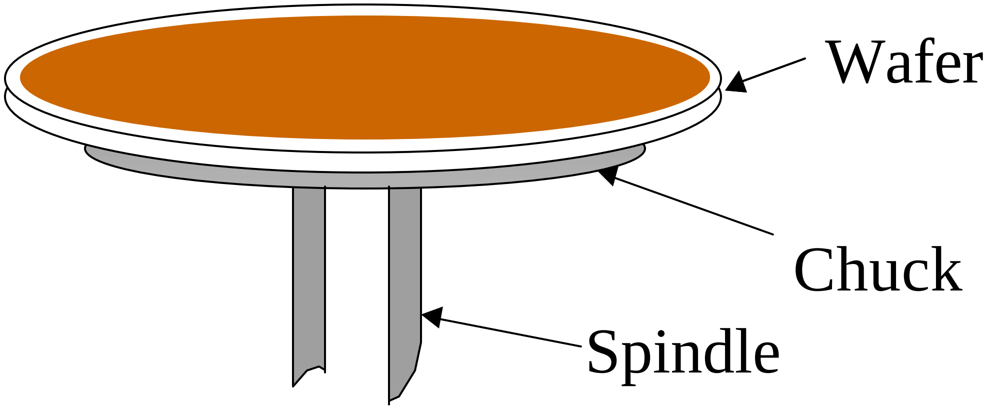
DI Water Rinse



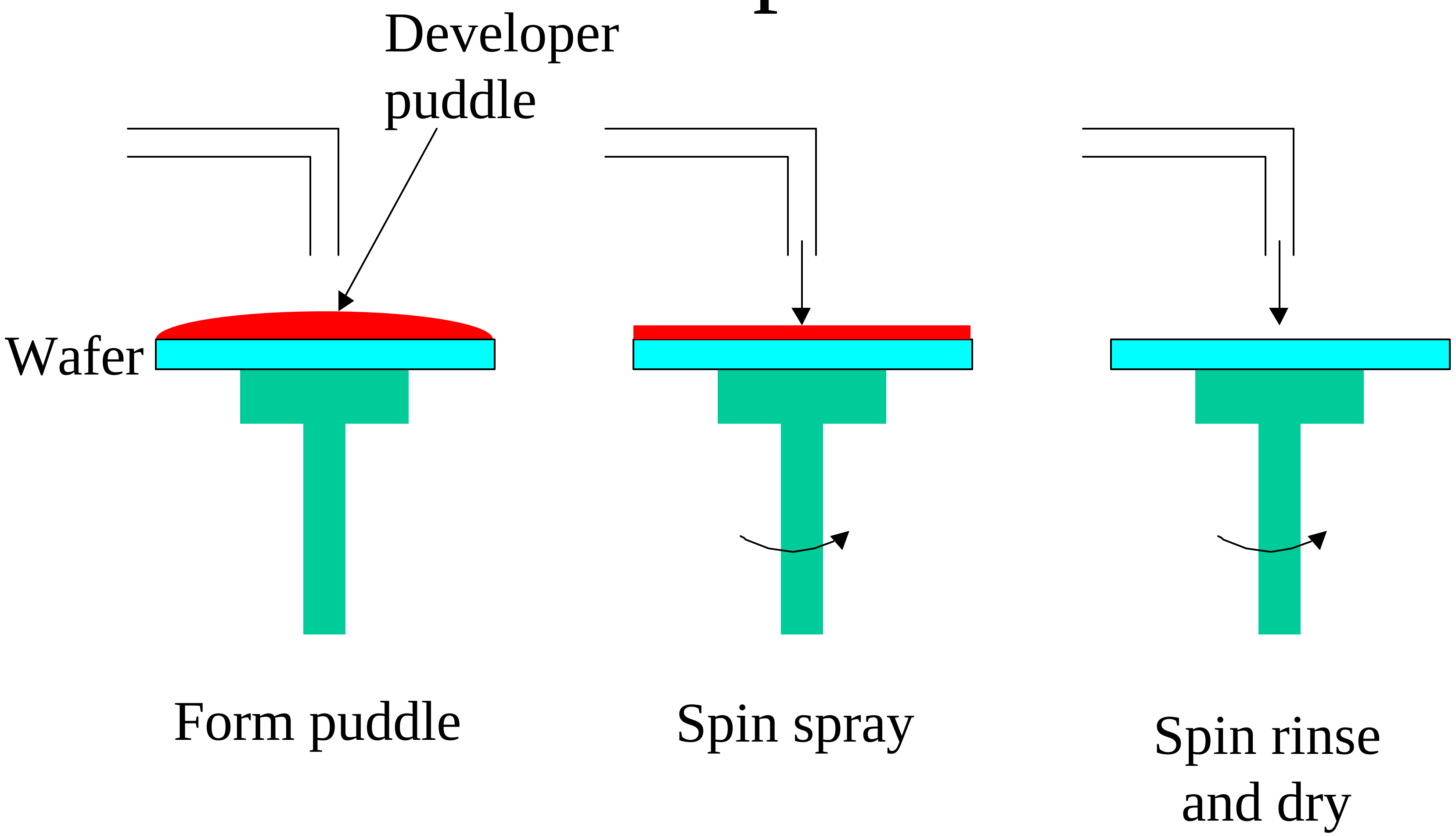
Spin Dry



Ready For Next Step



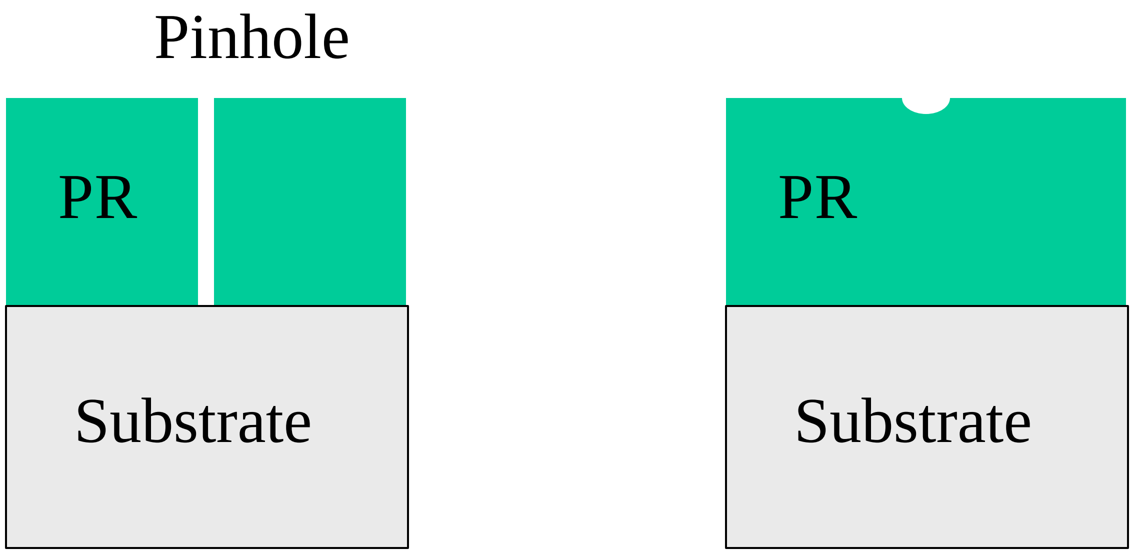
Development



Hard Bake

- Evaporating all solvents in PR
- Improving etch and implantation resistance
- Improve PR adhesion with surface
- Polymerize and stabilize photoresist
- PR flow to fill pinhole

PR Pinhole Fill by Thermal Flow



Hard Bake

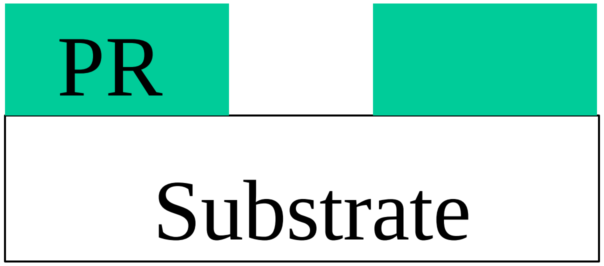
- Hot plate is commonly used
- Can be performed in a oven after inspection
- Hard bake temperature: 100 to 130 °C
- Baking time is about 1 to 2 minutes
- Hard bake temperature normally is higher than the soft bake temperature for the same kind of photoresist

Hard Bake

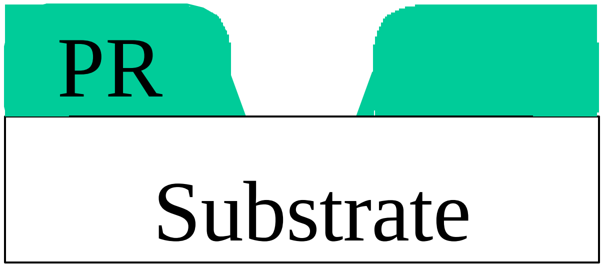
- Under-bake
  - Photoresist is not filly polymerized
  - High photoresist etch rate
  - Poor adhesion
- Over-baking
  - PR flow and bad resolution

Photoresist Flow

- Over baking can causes too much PR flow, which affects photolithography resolution.



Normal Baking



Over Baking

Q & A

- If wrong PR is refilled in the spinner, what could be the consequence?
- Each PR has its own sensitivity & viscosity, require its own spin rates, ramp rates, and time, baking times and temperature, exposure intensities and times, developer solutions and development conditions.
- Pattern transfer will fail.

Pattern Inspection

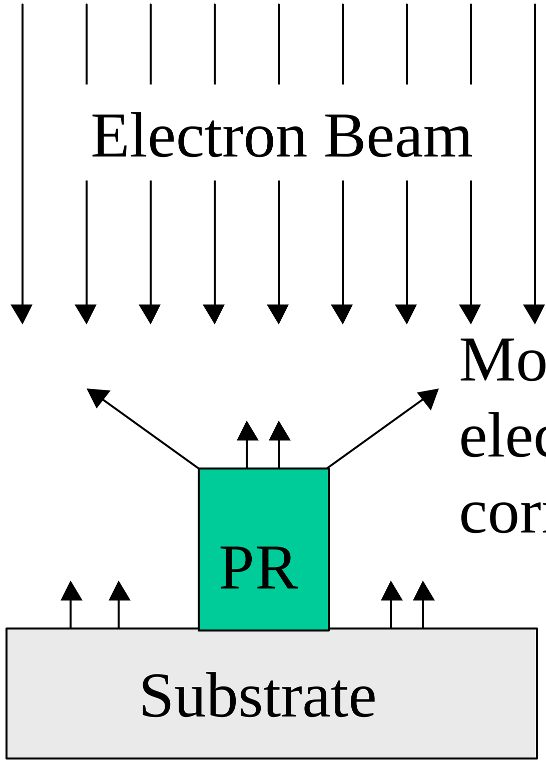
- Fail inspection, stripped PR and rework
  - Photoresist pattern is temporary
  - Etch or ion implantation pattern is permanent.
- Photolithography process can rework
- Can’t rework after etch or implantation.
- Scanning electron microscope (SEM)
- Optical microscope

Q & A

- Why can’t optical microscope be used for the 0.25 μm feature inspection?

- Because the feature size (0.25 μm = 2500 Å) is smaller than the wavelength of the visible light, which is from 3900 Å (violet) to 7500 Å (red)..

Electron Microscope



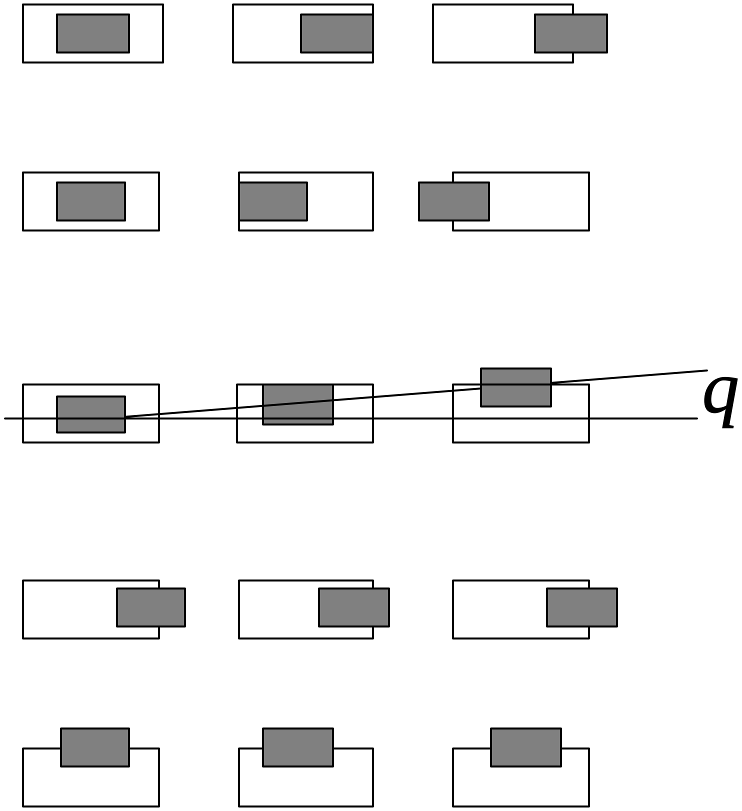
More secondary electrons on the corners

Less secondary electrons on the sidewall and plate surface

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)
- Surface irregularities such as scratches, pin holes, stains, contamination, etc.

Misalignment Cases



Run-out

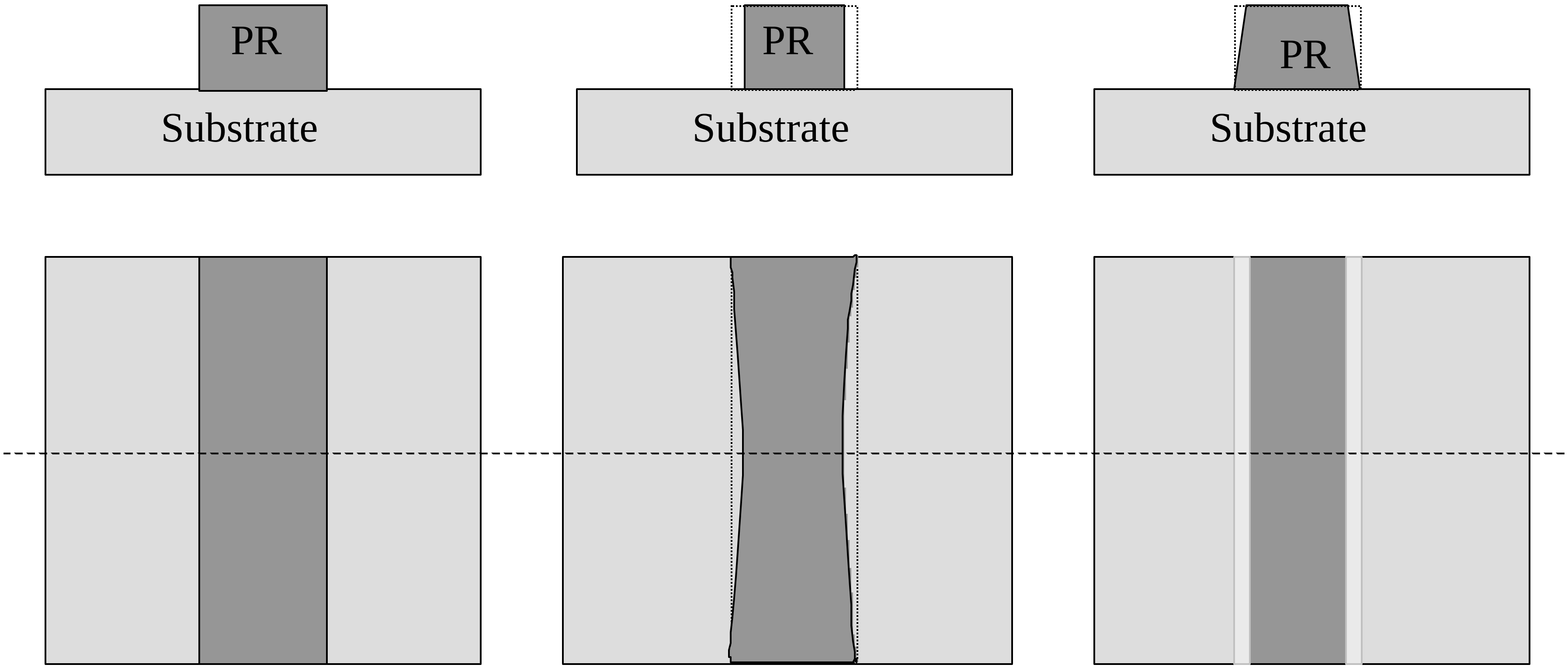
Run-in

Reticle rotation
Wafer rotation

Misplacement in x-direction

Misplacement in y-direction

Critical Dimension



Good CD

CD Loss

Sloped Edge

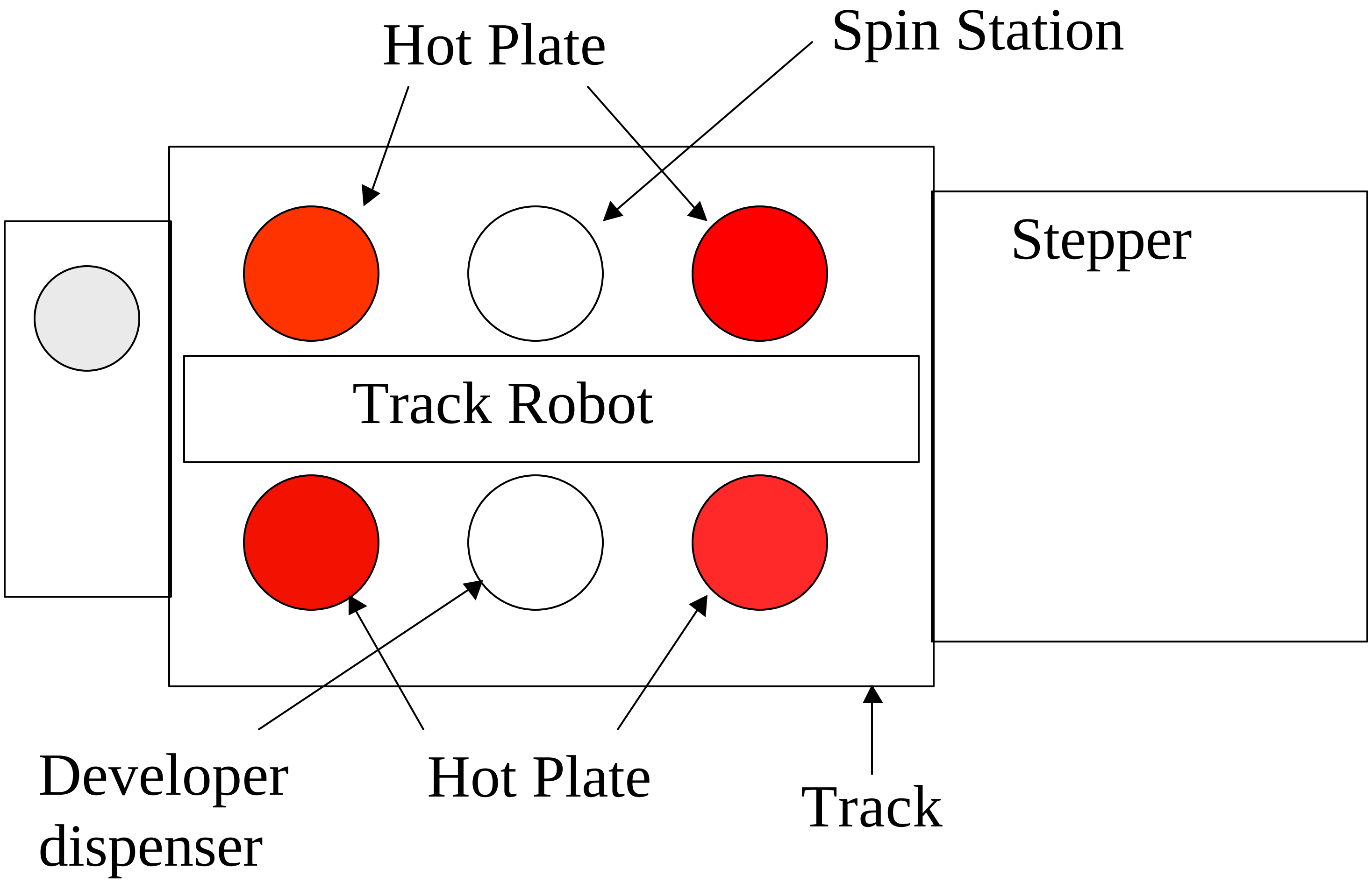
Pattern Inspection

- If the wafers pass the inspection, they will move out of photo bay and go to the next process step
- Either etch or ion implantation

Track-Stepper System or Photo Cell

- Integrated process system of photoresist coating, exposure and development
- Center track robot
- Higher throughput
- Improves process yield

Wafer In



Hot Plate

Spin Station

Stepper

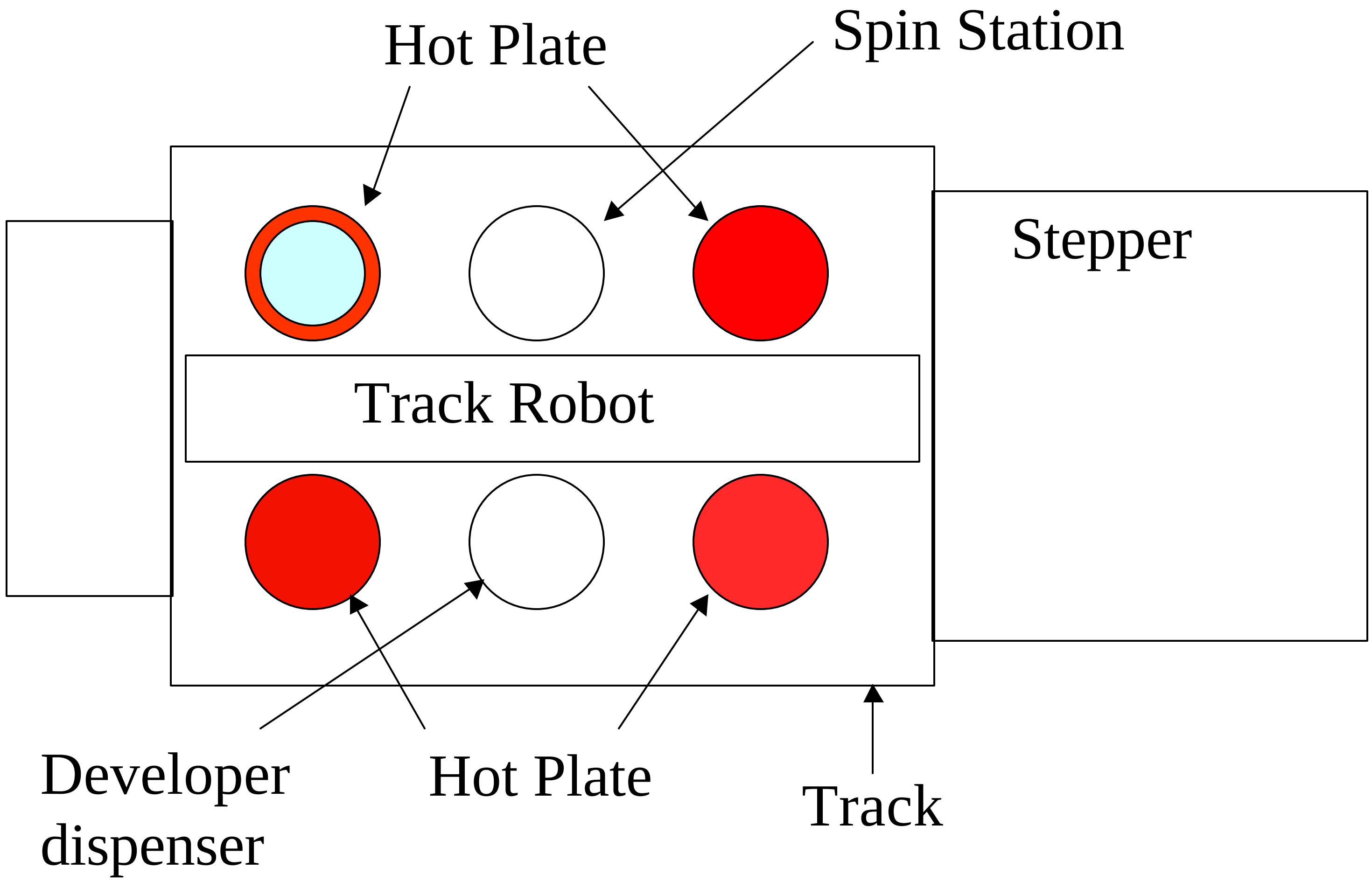
Track Robot

Developer dispenser

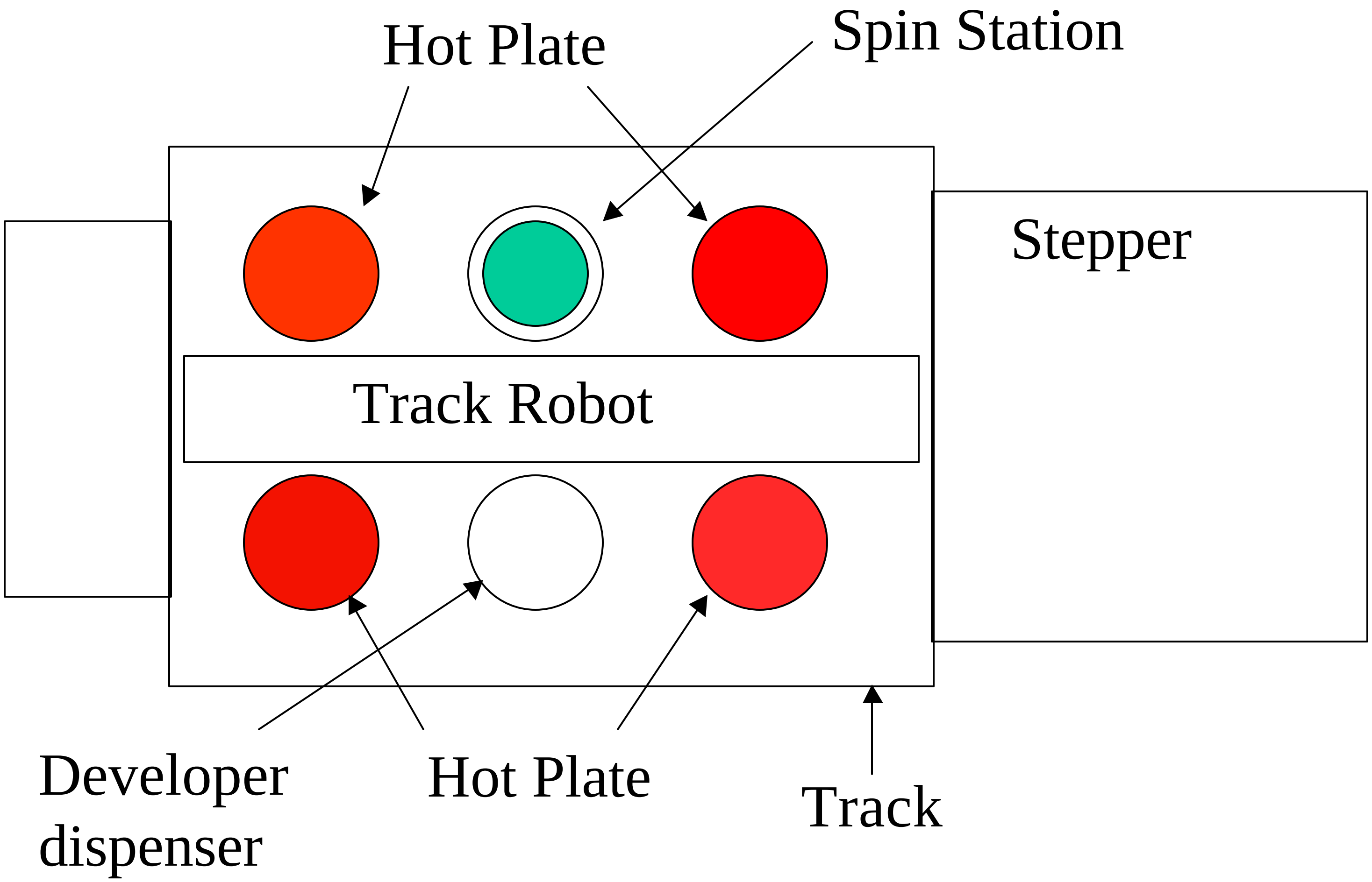
Hot Plate

Track

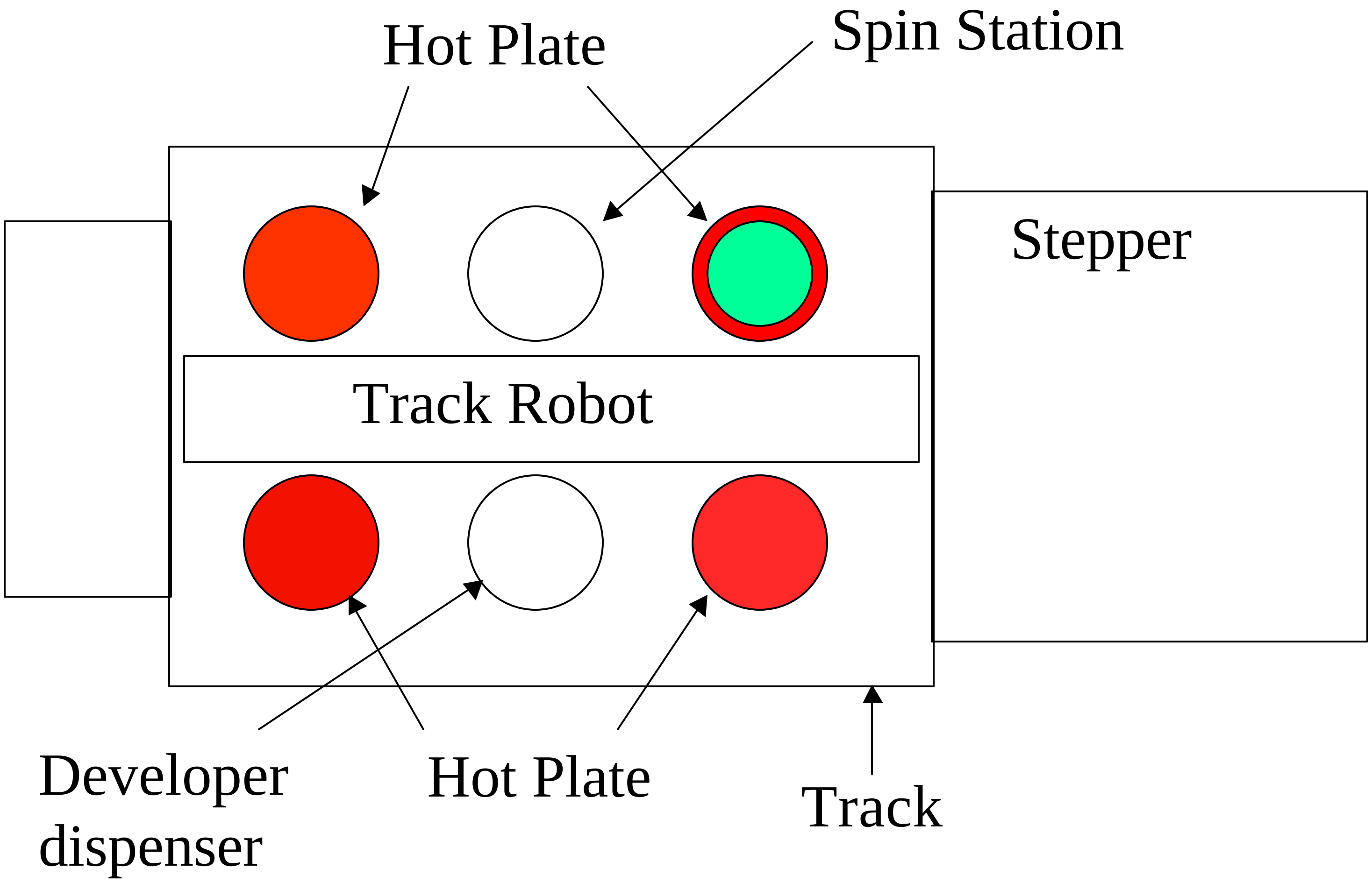
Pre-bake and Primer Vapor Coating



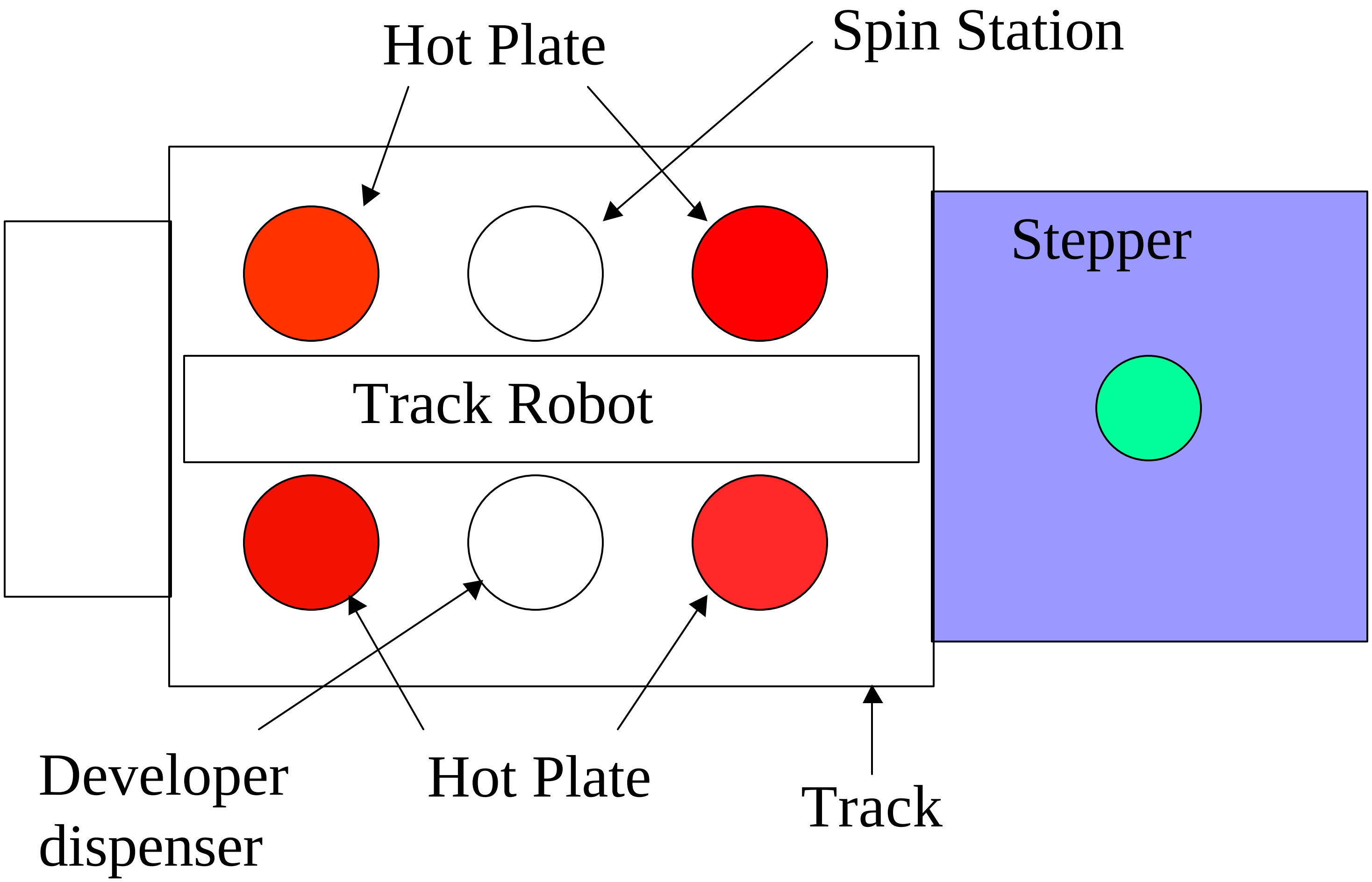
Photoresist Spin Coating



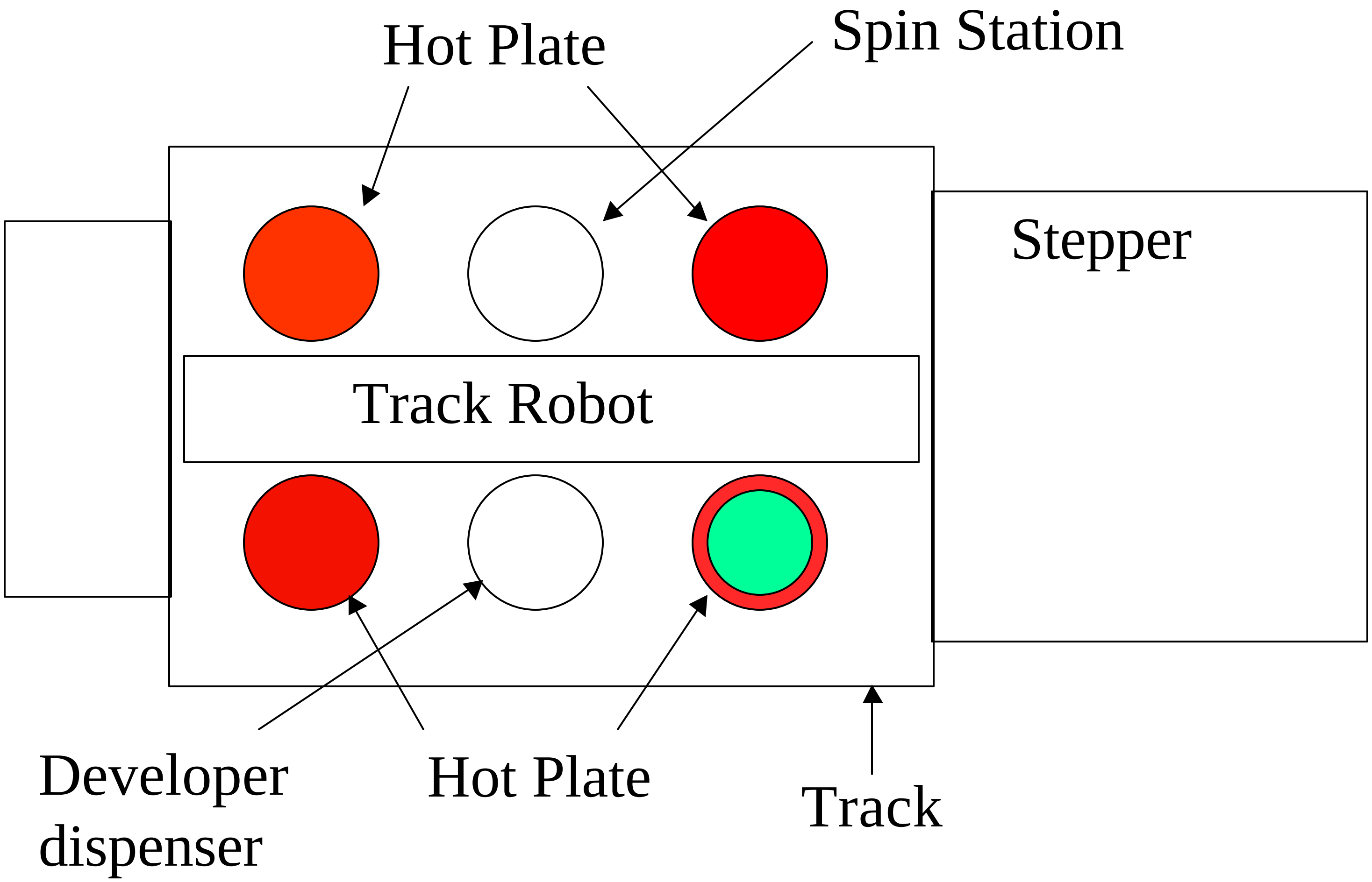
Soft Bake


Hot Plate
Spin Station
Stepper
Track Robot
Developer dispenser
Hot Plate
Track

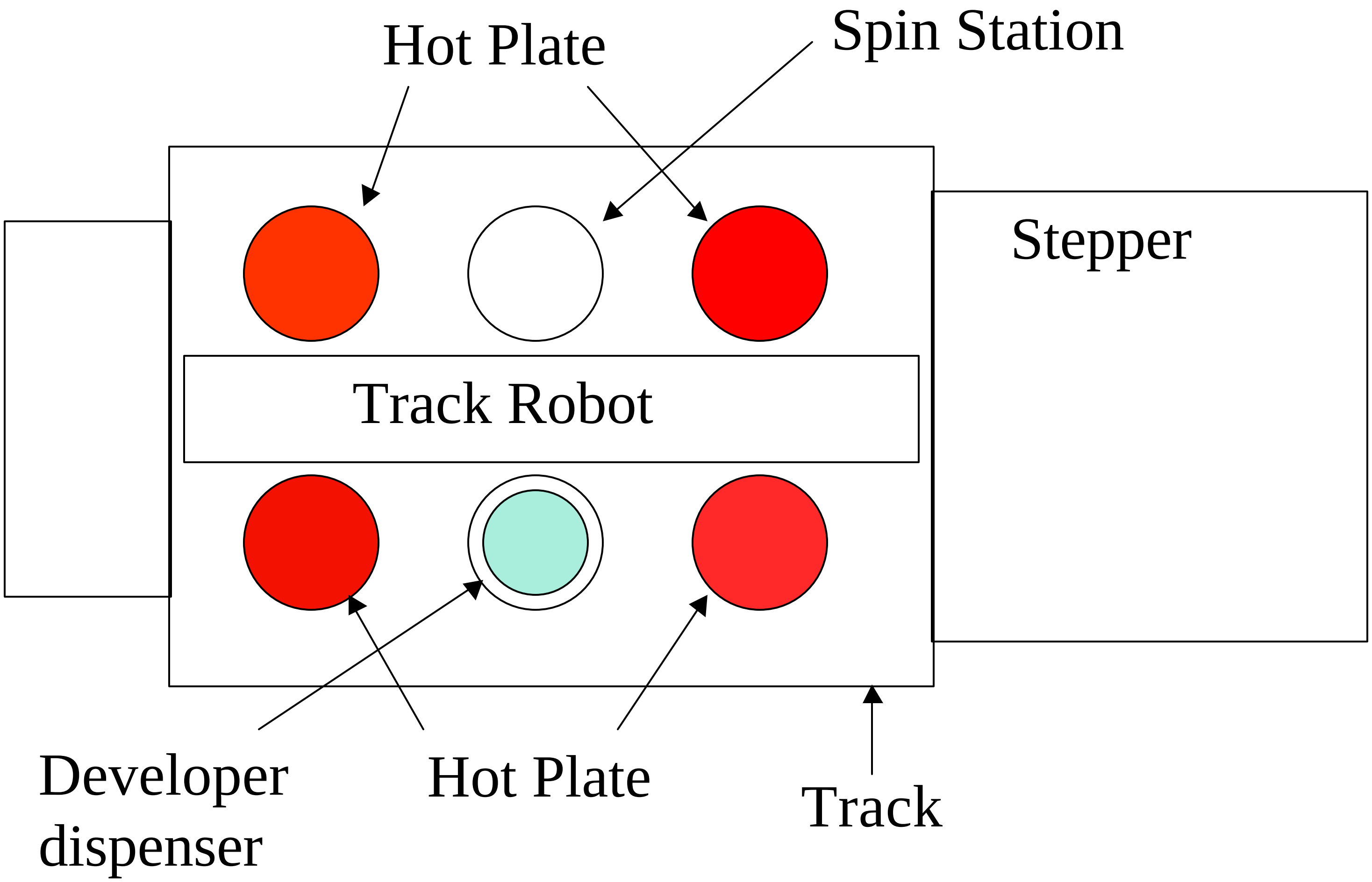
Alignment and Exposure



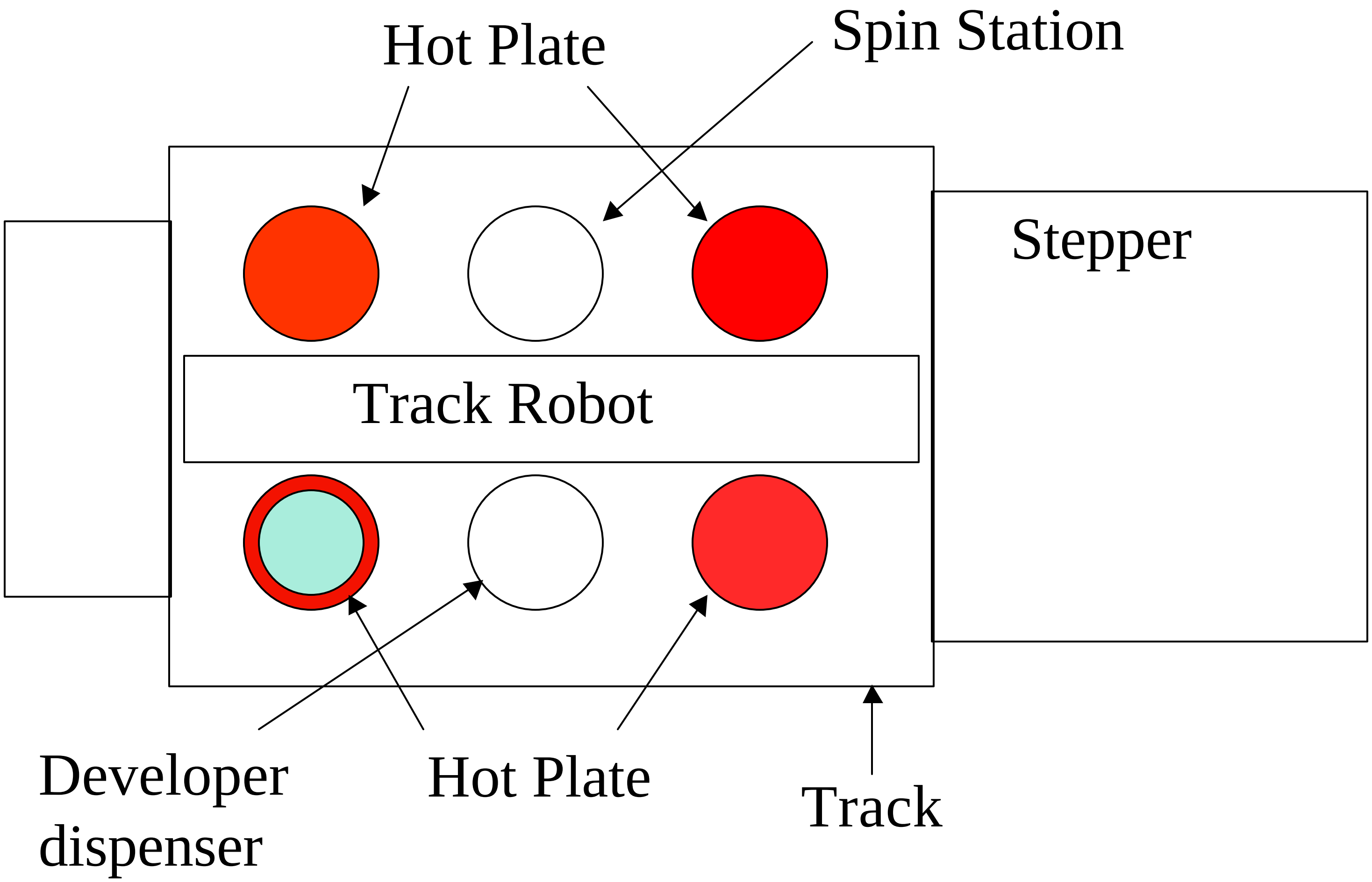
Post Exposure Bake (PEB)



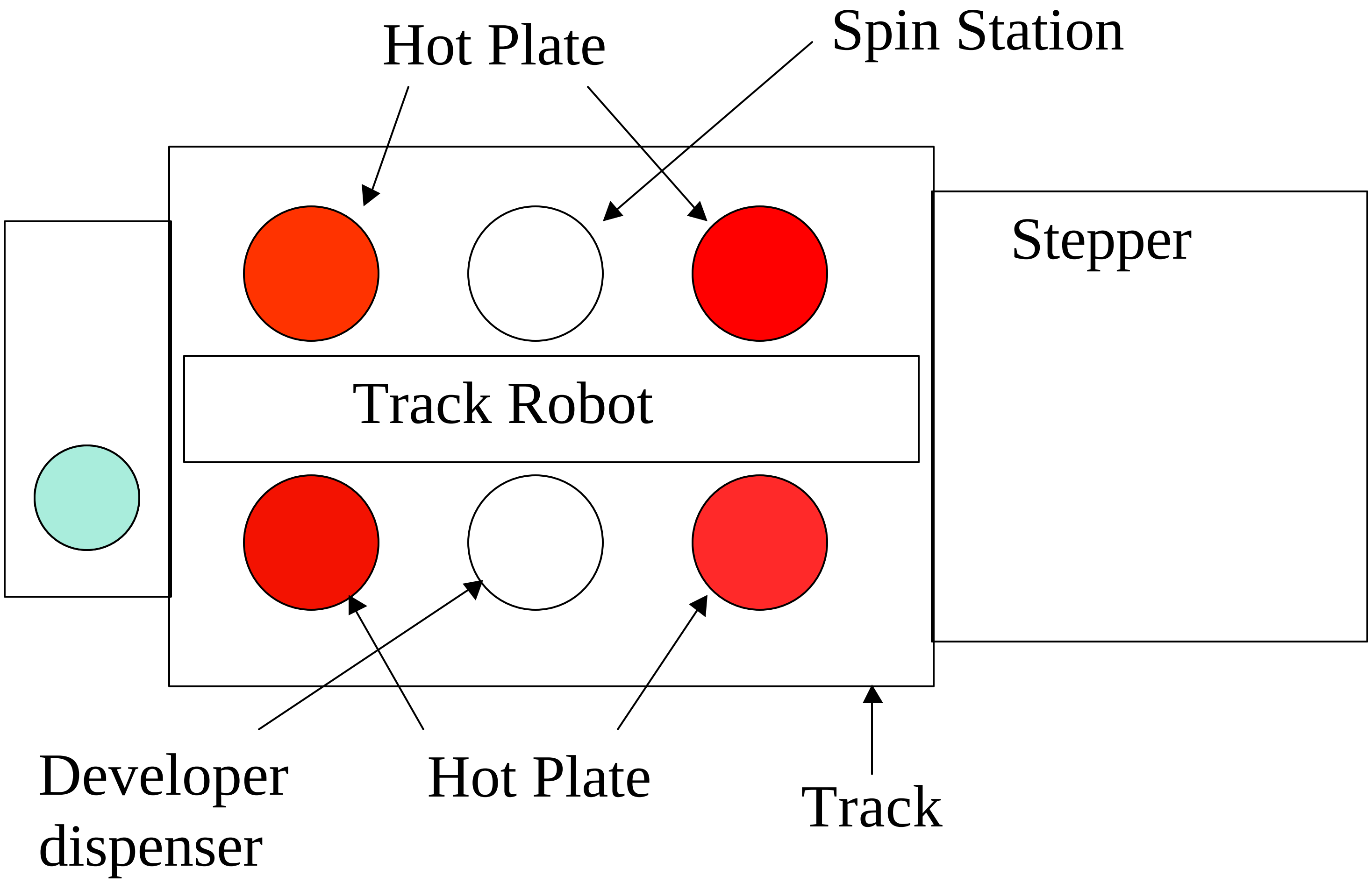
Development



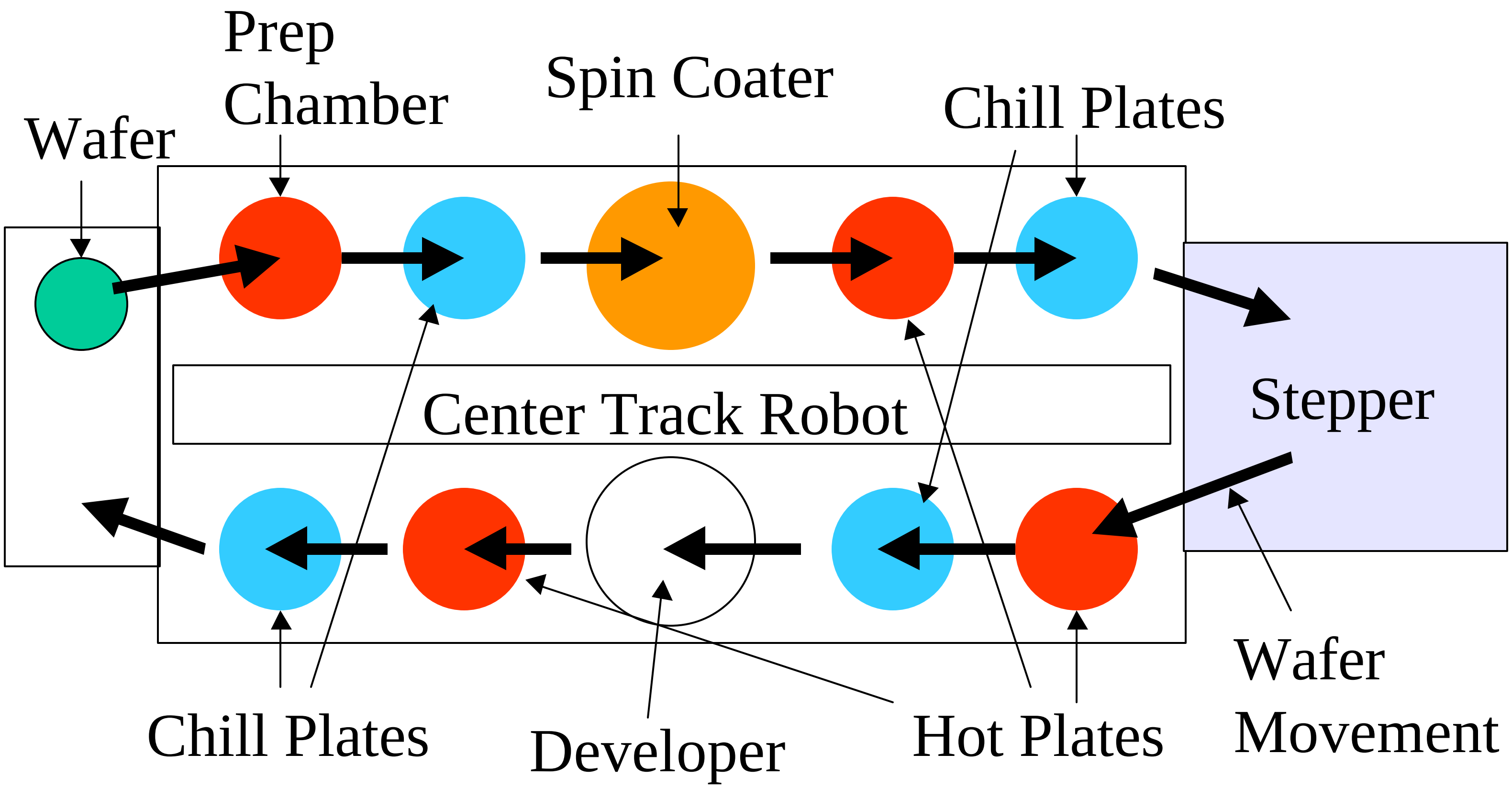
Hard Bake


Hot Plate
Spin Station
Stepper
Track Robot
Developer
dispenser
Hot Plate
Track

Wafer out


Hot Plate
Spin Station
Stepper
Track Robot
Developer dispenser
Hot Plate
Track

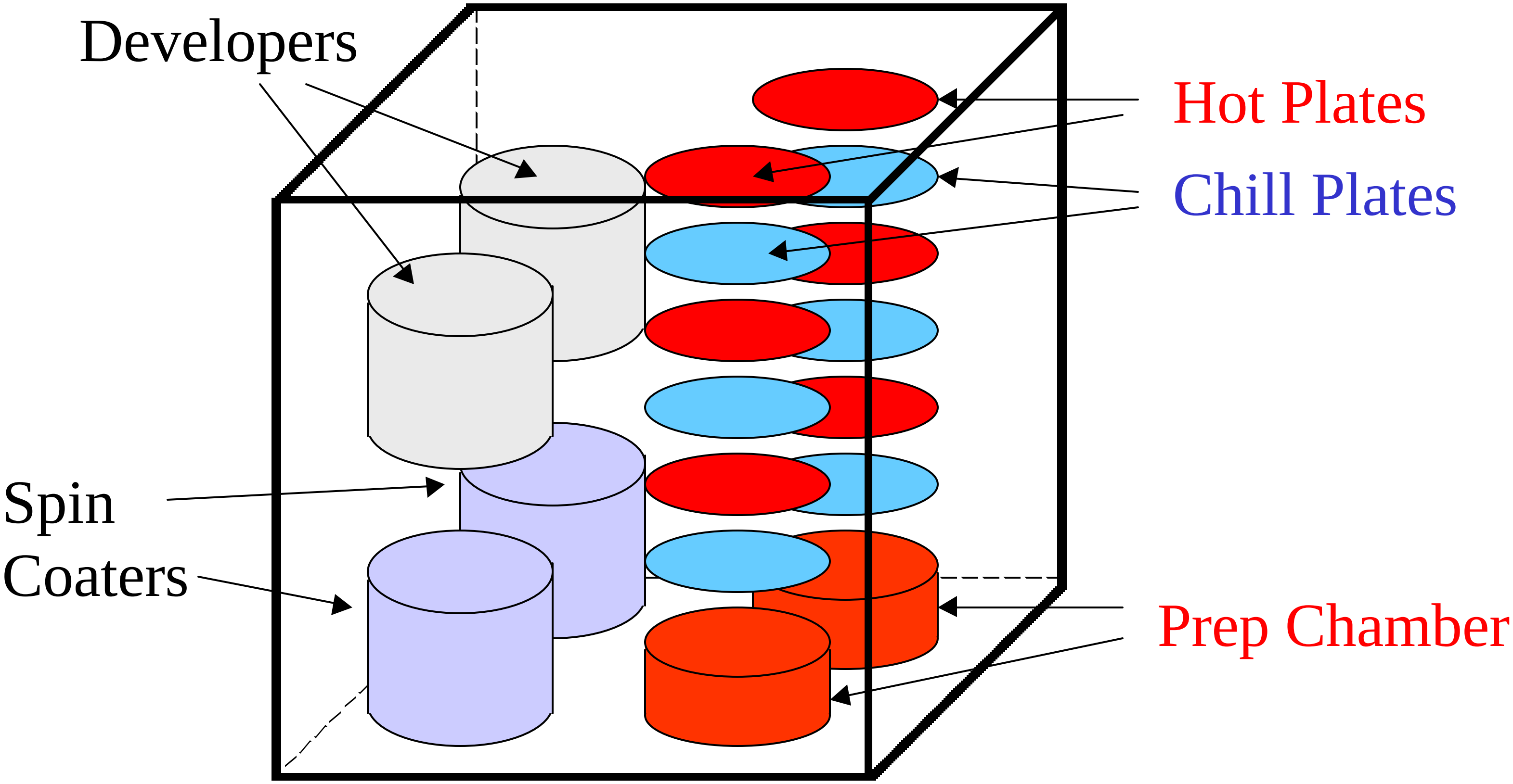
Schematic of a Photo Cell



Stacked Track System

- Smaller footprint
- Lower cost of ownership (COO)

Stacked Track System



Future Trends

- Smaller feature size
- Higher resolution
- Reducing wavelength
- Phase-shift mask

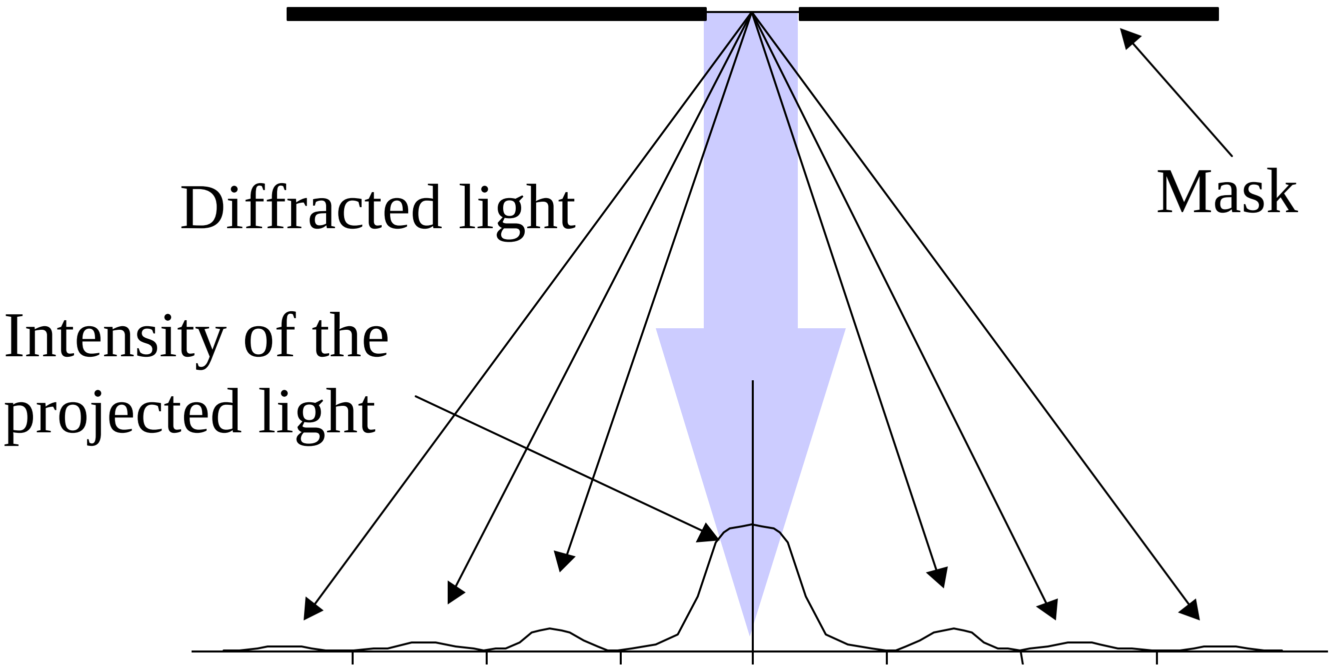
Optical Lithography

- Optics
- Light diffraction
- Resolution
- Depth of focus (DOF)

Diffraction

- Basic property of optics
- Light is a wave
- Wave diffracts
- Diffraction affects resolution

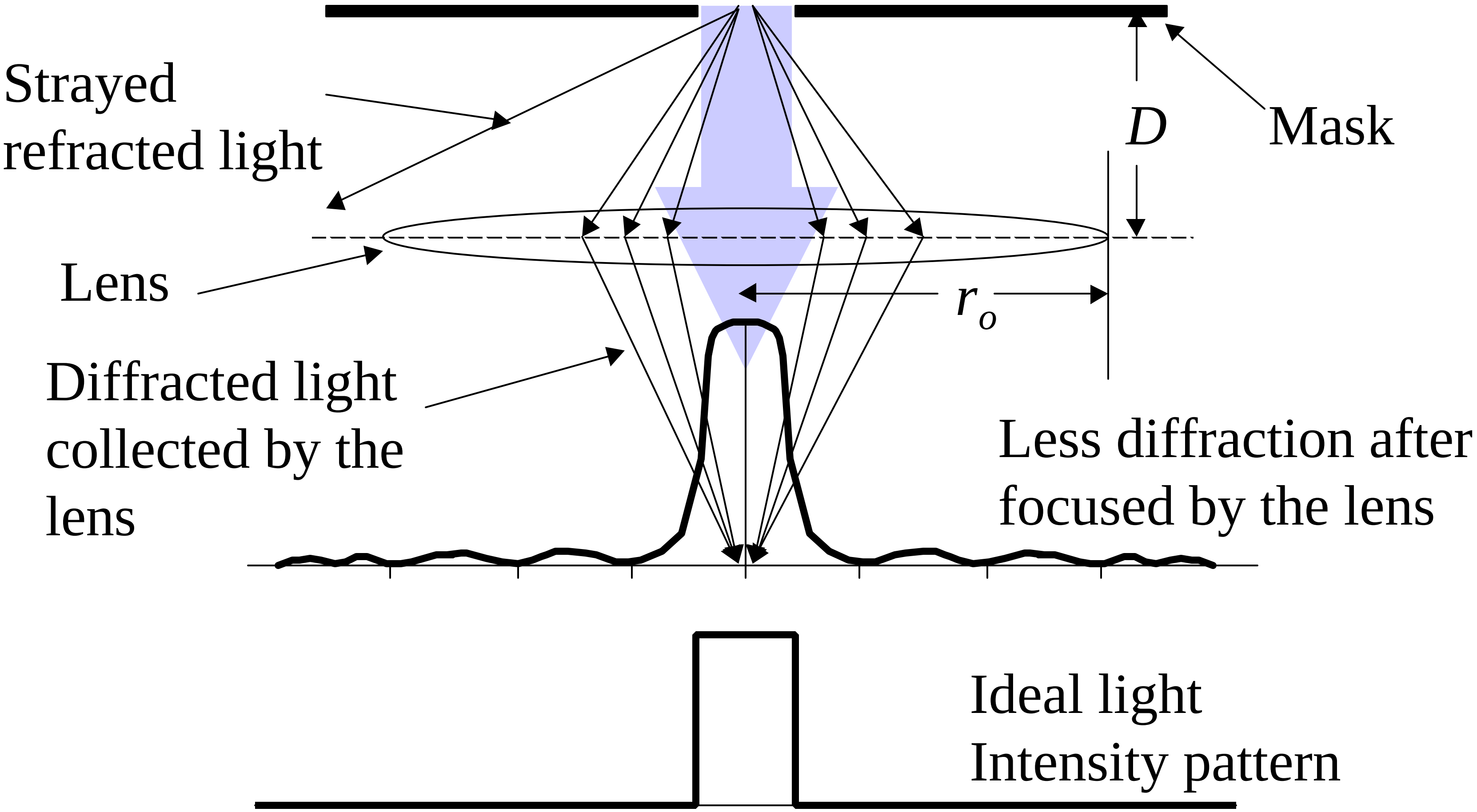
Light Diffraction Without Lens



Diffraction Reduction

- Short wavelength waves have less diffraction
- Optical lens can collect diffracted light and enhance the image

Light Diffraction With Lens



Strayed refracted light

Lens

Diffracted light collected by the lens

Less diffraction after focused by the lens

Ideal light Intensity pattern

Numerical Aperture

- *NA* is the ability of a lens to collect diffracted light
- $NA = 2 r_0 / D$
  - r_0 : radius of the lens
  - D = the distance of the object from the lens
- Lens with larger *NA* can capture higher order of diffracted light and generate sharper image.

Resolution

- The achievable, repeatable minimum feature size
- Determined by the wavelength of the light and the numerical aperture of the system. The resolution can be expressed as

Resolution

$$R = \frac{K_1 l}{NA}$$

- K_1 is the system constant, l is the wavelength of the light, $NA = 2\ r_o/D$, is the numerical aperture
- NA: capability of lens to collect diffraction light

Exercise 1, $K_1 = 0.6$

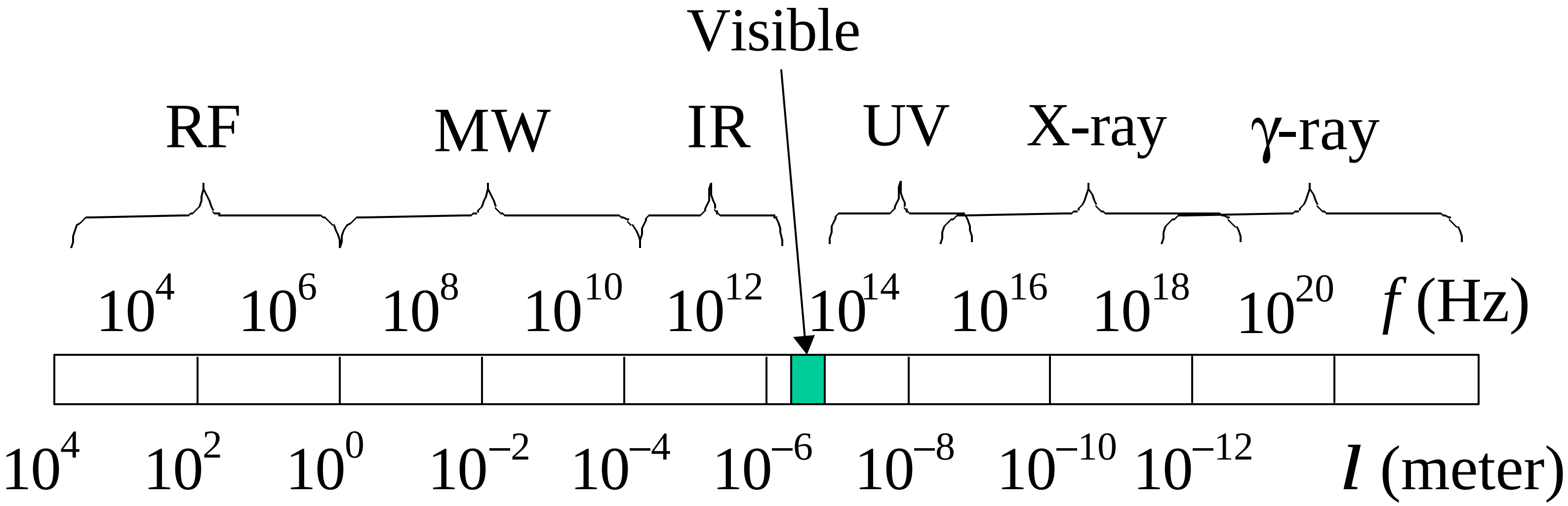
$$R = \frac{K_1 l}{NA}$$

	l	NA	R
G-line	**436 nm**	**0.60**	**____ mm**
I-line	**365 nm**	**0.60**	**____ mm**
DUV	**248 nm**	**0.60**	**____ mm**
	193 nm	**0.60**	**____ mm**

To Improve Resolution

- Increase NA
  - – Larger lens, could be too expensive and unpractical
  - – Reduce DOF and cause fabrication difficulties
- Reduce wavelength
  - – Need develop light source, PR and equipment
  - – Limitation for reducing wavelength
  - – UV to DUV, to EUV, and to X-Ray
- Reduce K_1
  - – Phase shift mask

Wavelength and Frequency of Electromagnetic Wave



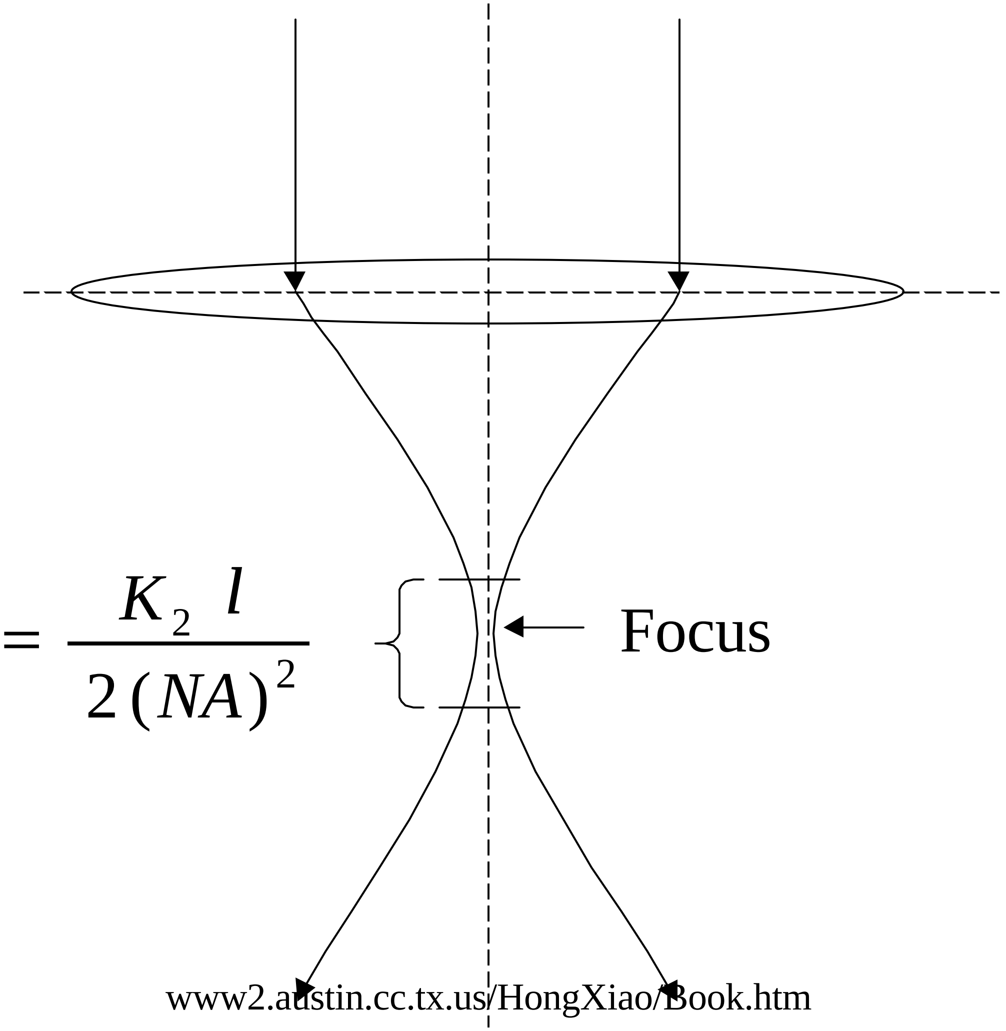
RF: Radio frequency; MW: Microwave; IR: infrared; and UV: ultraviolet

Depth of focus

- The range that light is in focus and can achieve good resolution of projected image
- Depth of focus can be expressed as:

$$DOF = \frac{K_2 l}{2(NA)^2}$$

Depth of Focus



$$DOF = \frac{K_2\ l}{2(NA)^2}$$

Exercise 2, $K_2 = 0.6$

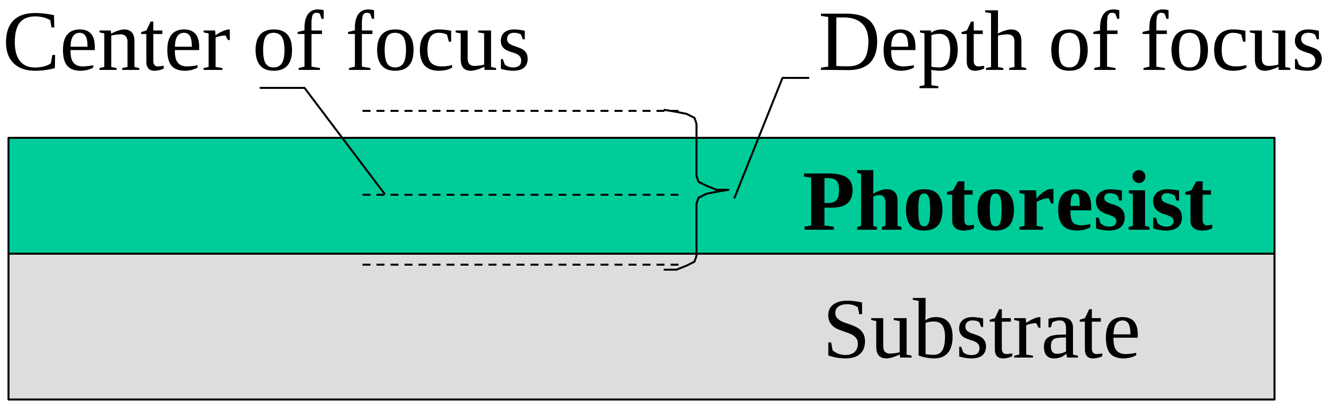
$$DOF = \frac{K_2 l}{2(NA)^2}$$

	l	*NA*	*DOF*
G-line	**436 nm**	**0.60**	**____ mm**
I-line	**365 nm**	**0.60**	**____ mm**
DUV	**248 nm**	**0.60**	**____ mm**
	193 nm	**0.60**	**____ mm**

Depth of Focus

- Smaller numerical aperture, larger DOF
  - – Disposable cameras with very small lenses
  - – Almost everything is in focus
  - – Bad resolution
- Prefer reduce wavelength than increase *NA* to improve resolution
- High resolution, small DOF
- Focus at the middle of PR layer

Focus on the Mid-Plain to Optimize the Resolution



Surface Planarization Requirement

- Higher resolution requires
  - Shorter l
  - Larger *NA*.
- Both reduces *DOF*
- Wafer surface must be highly planarized.
- CMP is required for 0.25 μm feature patterning.

I-line and DUV

- Mercury i-line, 365 nm
  - Commonly used in 0.35 μm lithography
- DUV KrF excimer laser, 248 nm
  - 0.25 μm, 0.18 μm and 0.13 μm lithography
- ArF excimer laser,193 nm
  - Application: < 0.13 μm
- F_2 excimer laser 157 nm
  - Still in R&D, < 0.10 μm application

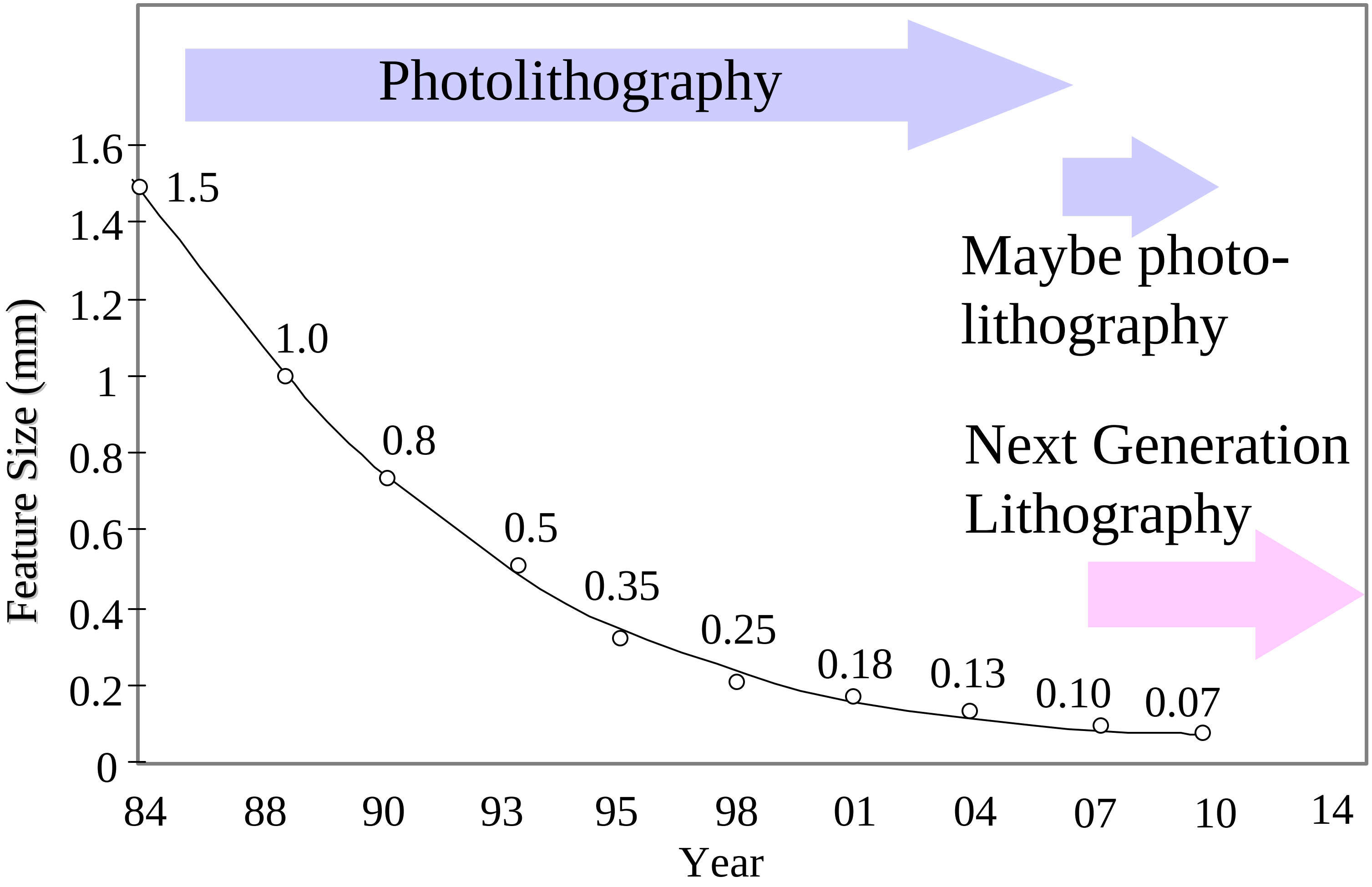
I-line and DUV

- SiO_2 strongly absorbs UV when $\lambda < 180$ nm
- Silica lenses and masks can’t be used
- 157 nm F_2 laser photolithography
  - Fused silica with low OH concentration, fluorine doped silica, and calcium fluoride (CaF_2),
  - With phase-shift mask, even 0.035 μm is possible
- Further delay next generation lithography

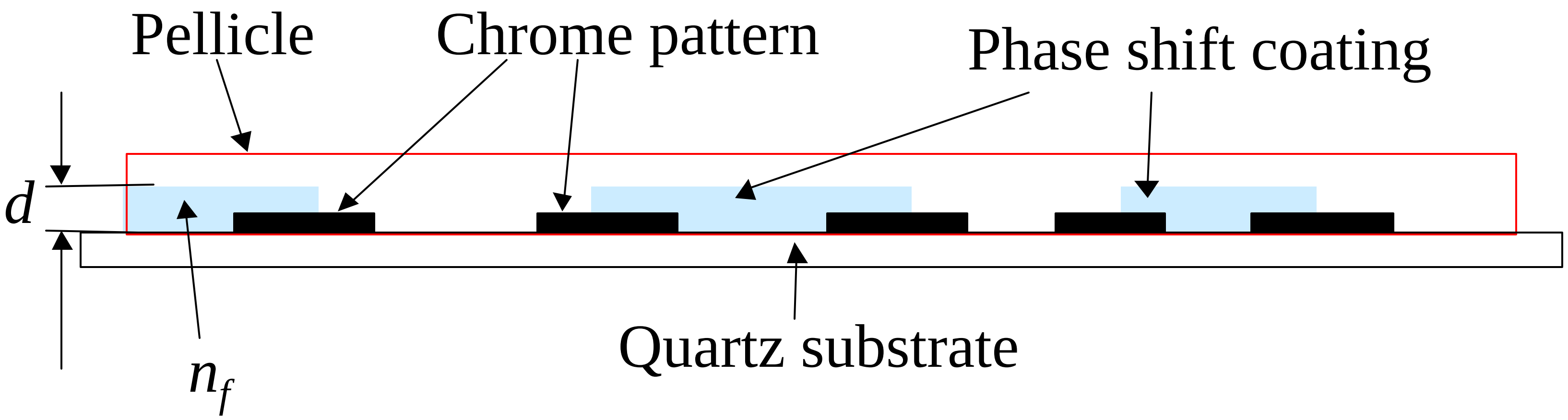
Next Generation Lithography (NGL)

- Extreme UV (EUV) lithography
- X-Ray lithography
- Electron beam (E-beam) lithography

Future Trends



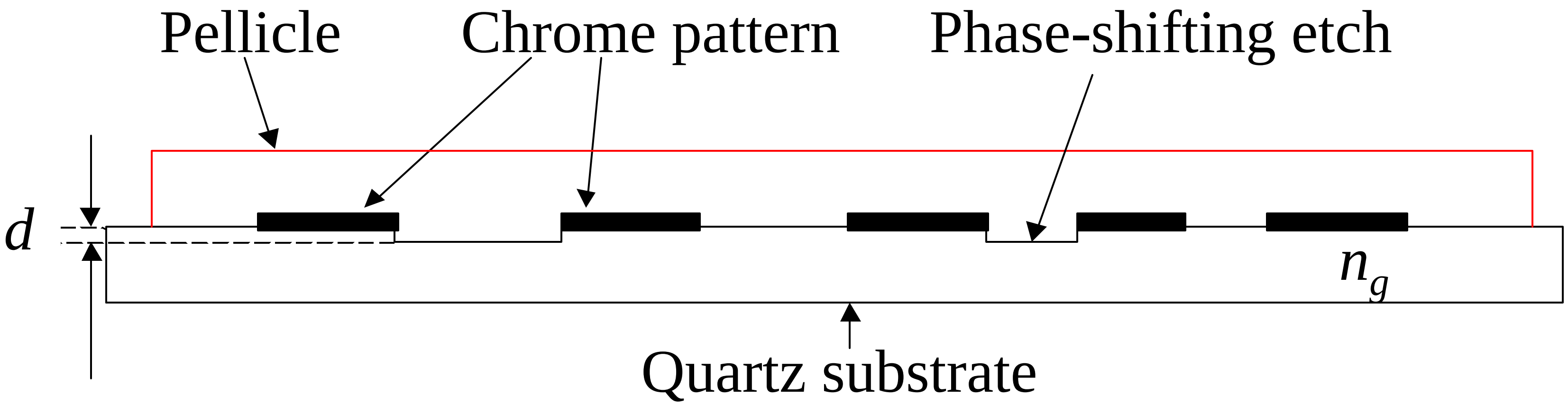
Phase Shift Mask



$$d(n_f - 1) = l/2$$

n_f : Refractive index of phase shift coating

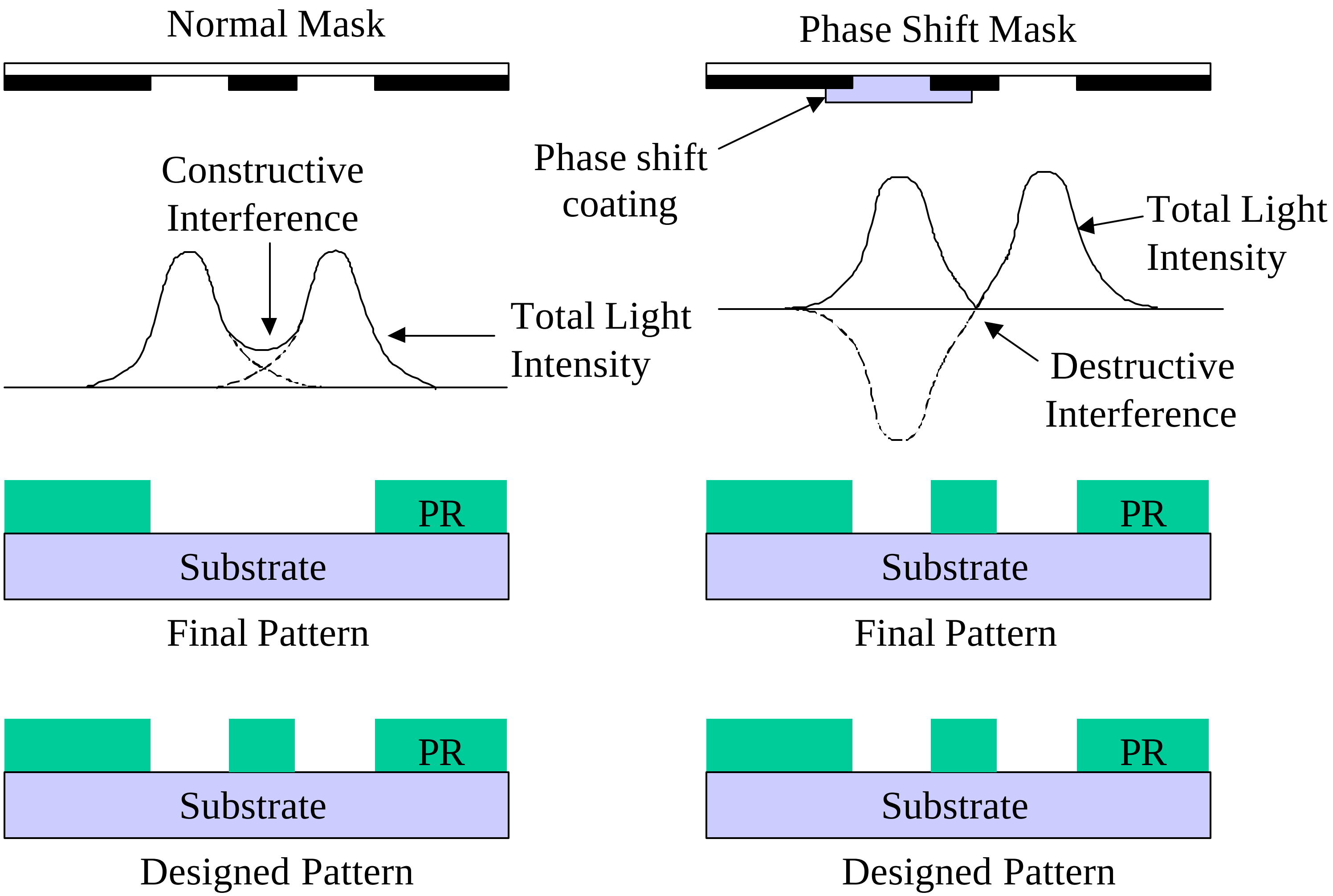
Phase Shift Mask



$$d(n_g - 1) = l/2$$

n_g: refractive index of the quartz substrate

Phase Shift Mask Patterning



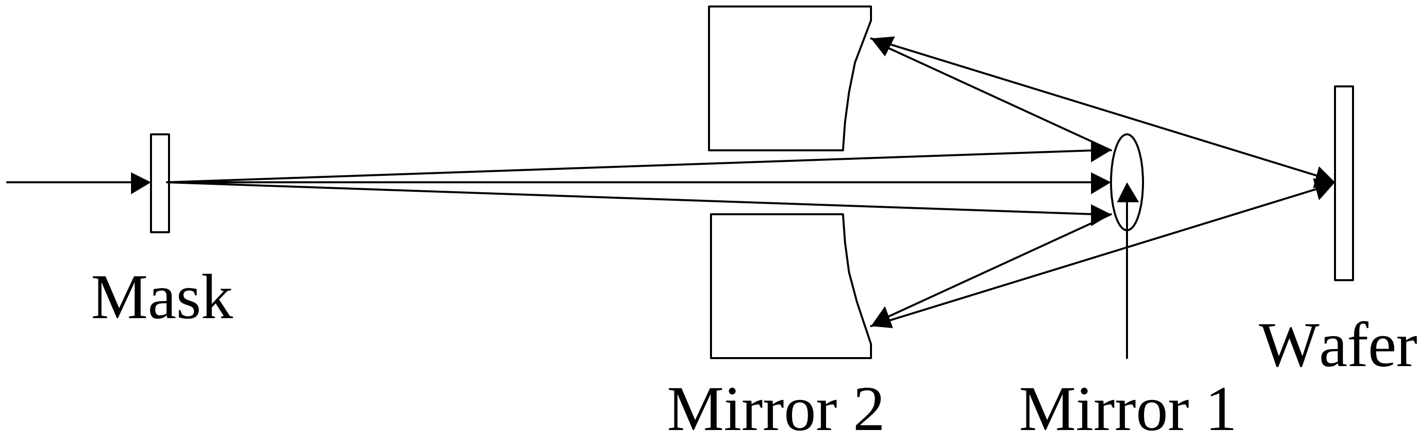
Future Trends

- Even shorter wavelength
  - 193 nm
  - 157 nm
    - Silicate glass absorbs UV light when $\lambda < 180$ nm
    - CaF_2 optical system
- Next generation lithography (NGL)
  - Extreme UV (EVU)
  - Electron Beam
  - X-ray (?)

EUV

- λ = 10 to 14 nm
- Higher resolution
- Mirror based
- Projected application ~ 2010
- 0.1 μm and beyond

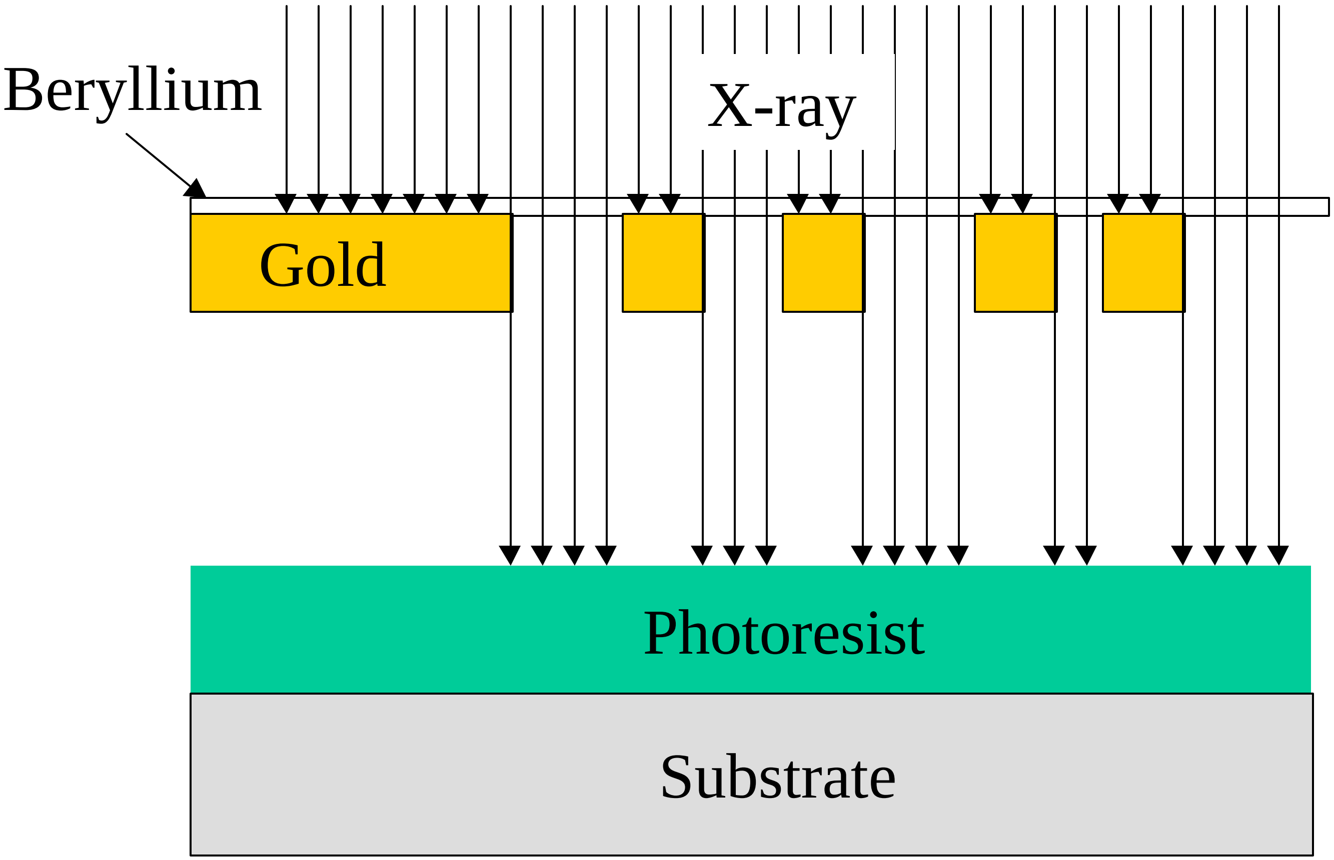
EUV Lithography



X-ray lithography

- Similar to proximity printer
- Difficult to find pure X-ray source
- Challenge on mask making
- Unlikely will be used in production

X-ray Printing



Optical Mask and X-ray Mask

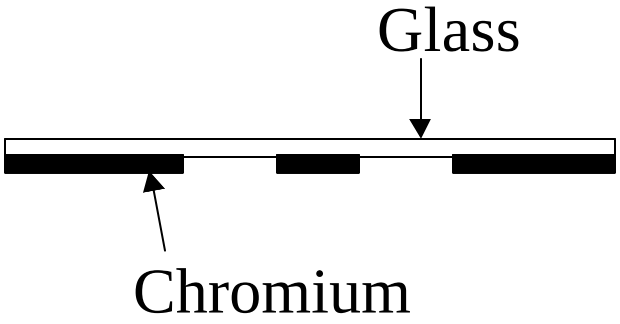
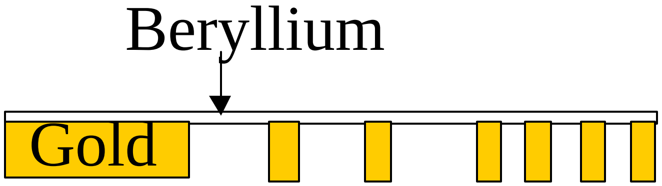


Photo Mask

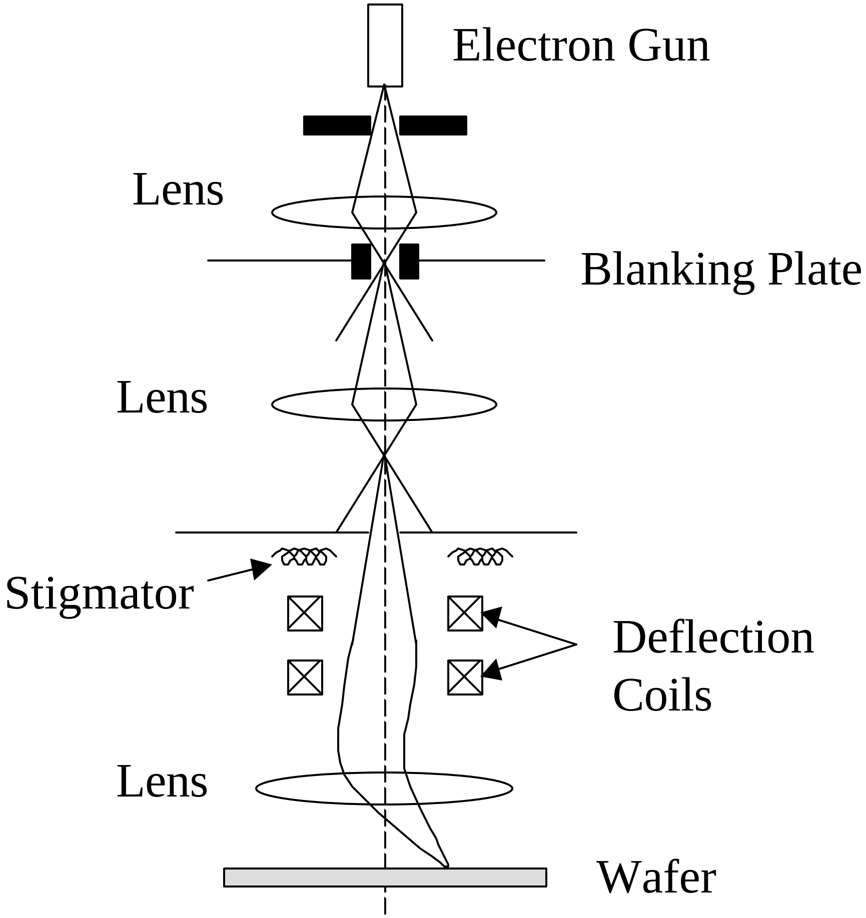


X-ray Mask

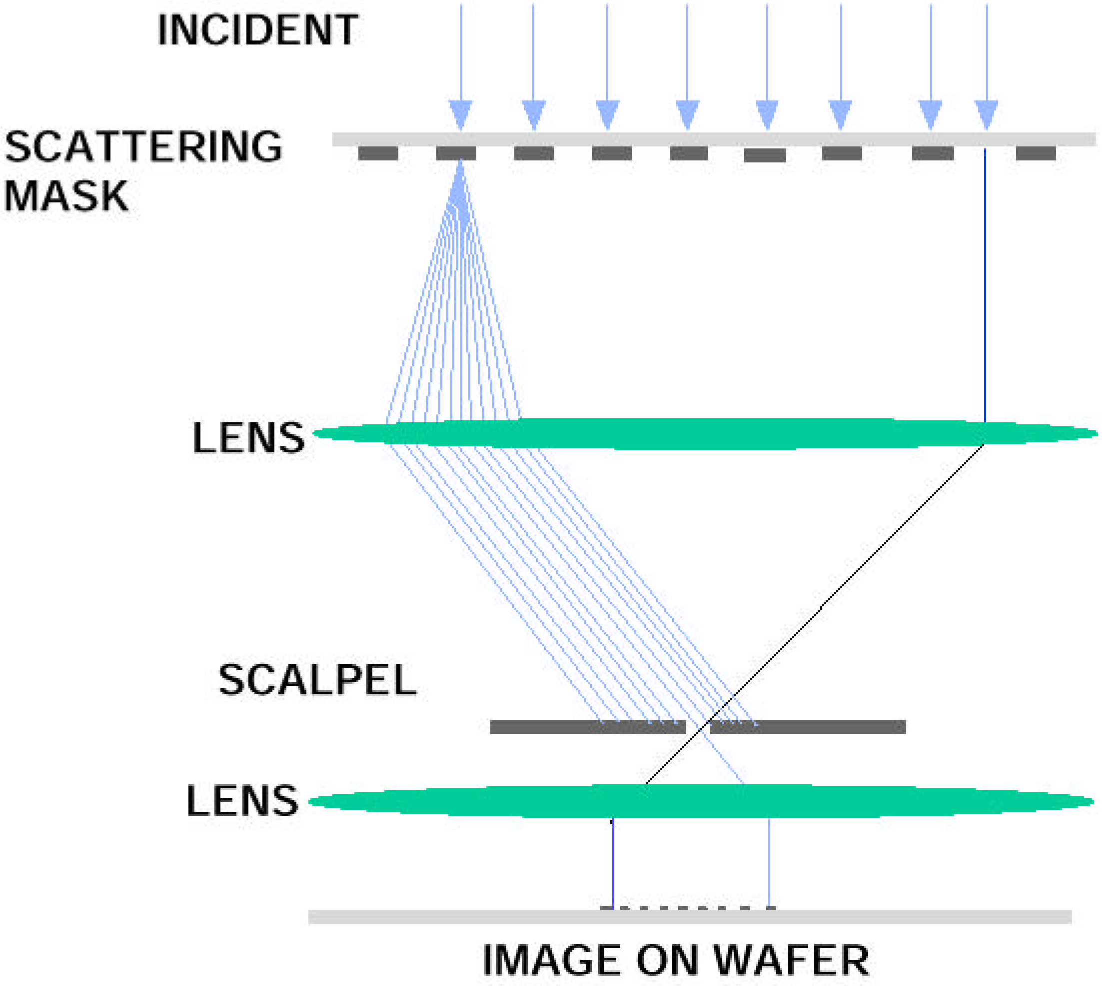
E-Beam

- Used for making mask and reticles
- Smallest geometry achieved: 0.014 μm
- Direct print possible, no mask is required
  - Low throughput
- Scattering exposure system (SCALPEL) looks promising
  - Tool development
  - Reticle making
  - Resist development

Electron Beam Lithography System



SCALPEL



Ion Beam Lithography

- Can achieve higher resolution
  - Direct writing and projection resist exposing
  - Direct ion implantation and ion beam sputtering patterned etch, save some process steps
- Serial writing, low throughput
- Unlikely will be used in the mass production
- Mask and reticle repairing
- IC device defect detection and repairing

Safety

- Chemical
- Mechanical
- Electrical
- Radiation

Chemical Safety

- Wet clean
  - – Sulfuric acid (H_2SO_4): corrosive
  - – Hydrogen peroxide (H_2O_2): strong oxidizer
- Xylene (solvent and developer of –PR): flammable and explosive
- HMDS (primer): flammable and explosive
- TMAH (+PR development solution): poisonous and corrosive

Chemical Safety

- Mercury (Hg, UV lamp) vapor
  - highly toxic;
- Chlorine (Cl_2, excimer laser)
  - toxic and corrosive
- Fluorine (F_2, excimer laser)
  - toxic and corrosive

Mechanical Safety

- Moving Parts
- Hot surface
- High pressure lump

Electrical Safety

- High voltage electric power supply
- Power off
- Ground static charges
- Tag-out and lock-out

Radiation Safety

- UV light can break chemical bonds
- Organic molecules have long-chain structure
- More vulnerable to the UV damage
- UV light can be used to kill bacteria for sterilization
- Can cause eye injury if direct look at UV source
- UV protection goggle sometimes is required.

Summary

- Photolithography: temporary patterning process
- Most critical process steps in IC processing
- Requirement: high resolution, low defect density
- Photoresist, positive and negative
- Process steps: Pre-bake and Primer coating, PR spin coating, soft bake, exposure, PEB, development, hard bake, and inspection
- NGL: EUV and e-beam lithography