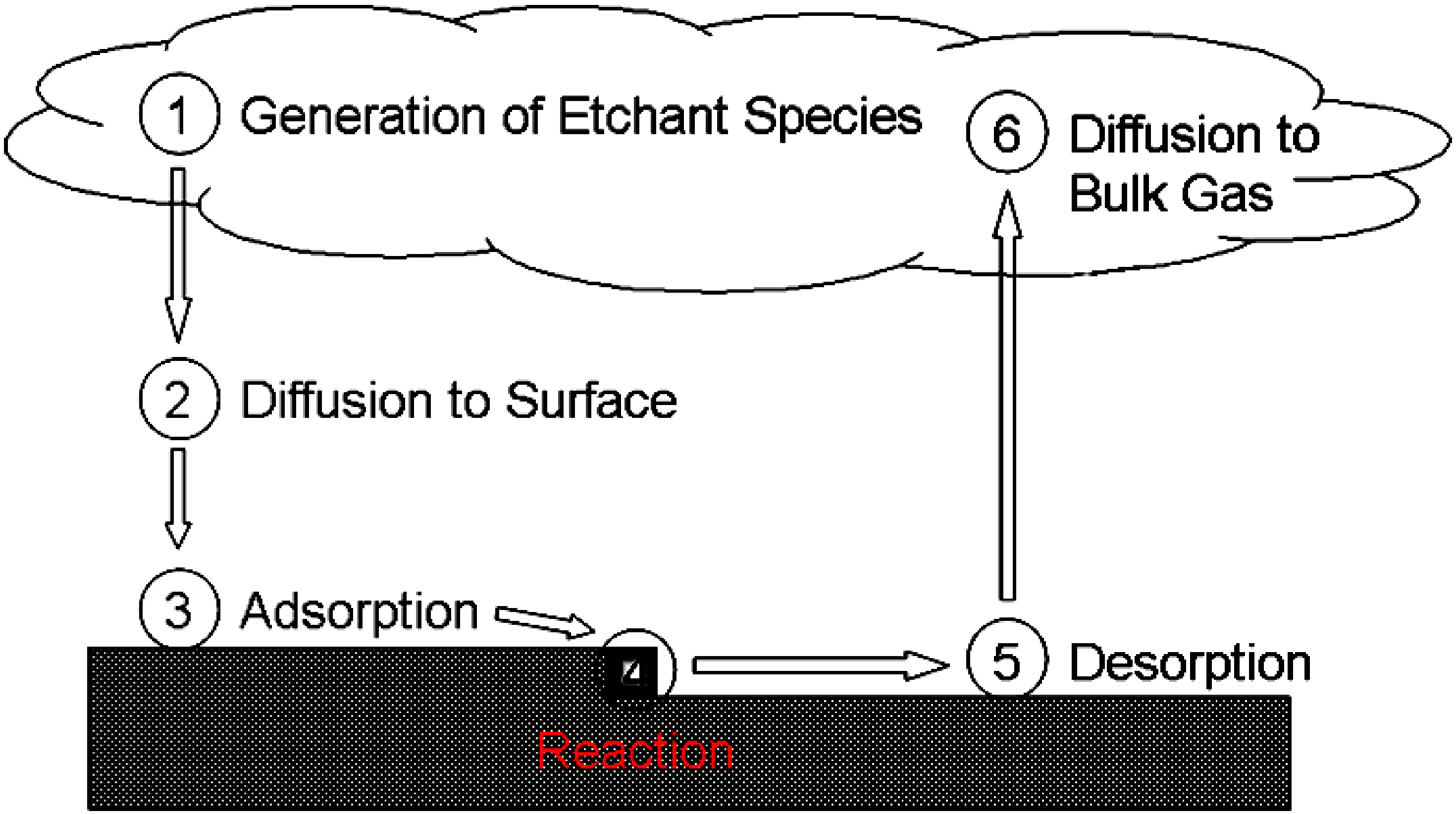
MEMS Etching Technology

There are two classes of etching process:

- **Wet etching:** The material is dissolved when immersed in a chemical solution.

- **Dry etching:** The material is sputtered or dissolved using reactive ions or a vapor phase etching.

Etching Mechanism



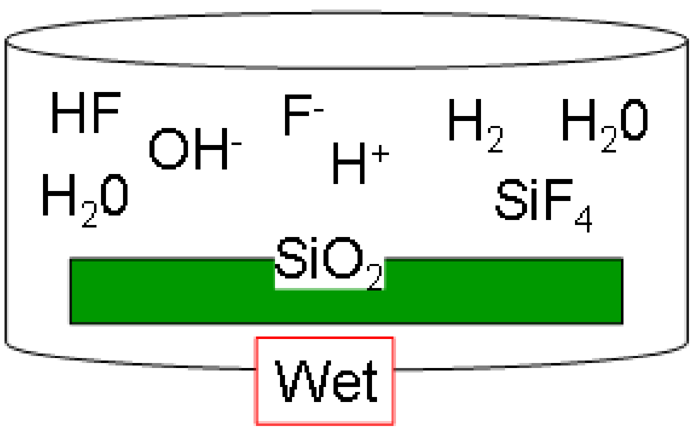
http://www.ee.ucla.edu/~jjudy/classes/ee150L/lectures/EE150L_Lecture_Dry_Etching_files/frame.htm

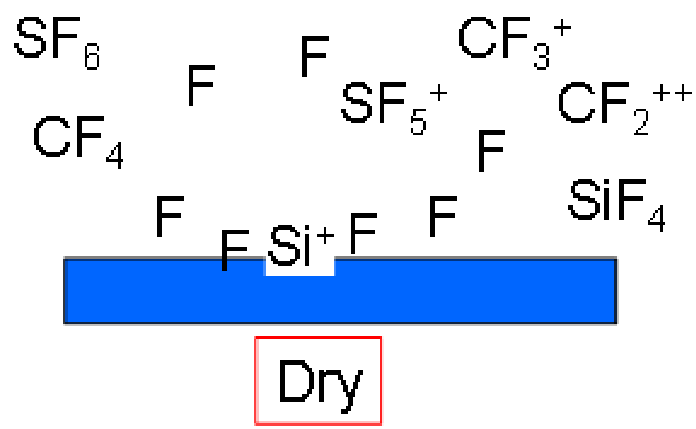
Subtractive Processes

Wet and Dry Etching

- Wet Etching
  - Chemical Reaction
  - Liquid source

- Dry Etching
  - Chemical + Physical Reaction
  - Gas or Vapor phase source





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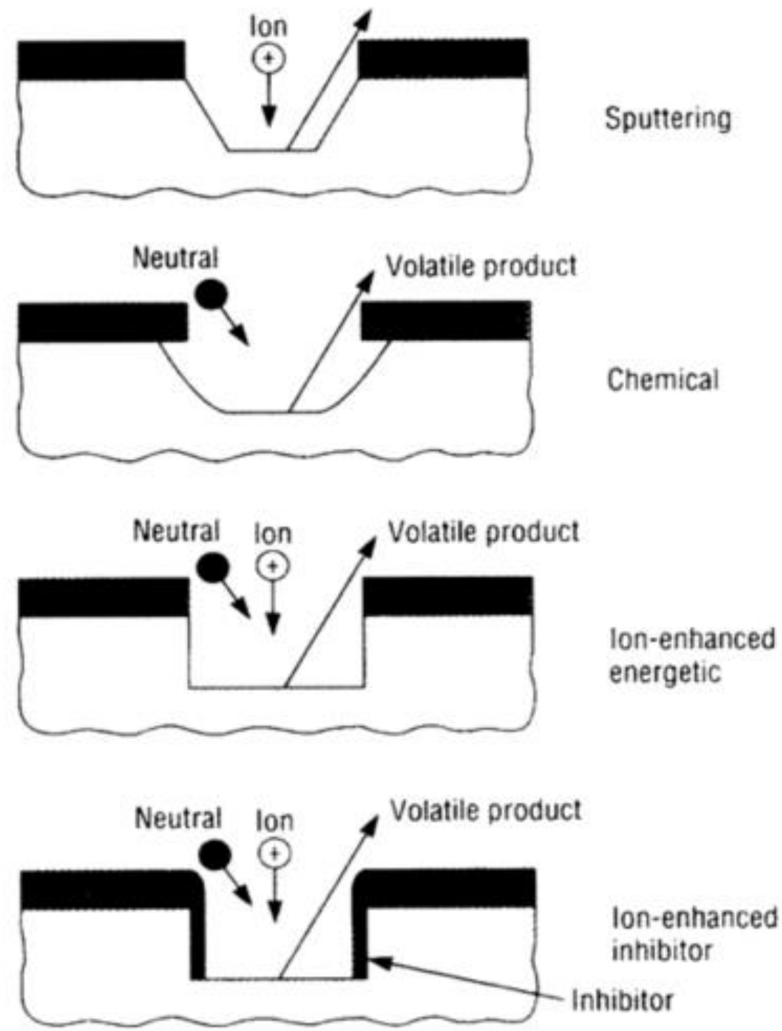
Dry Etching

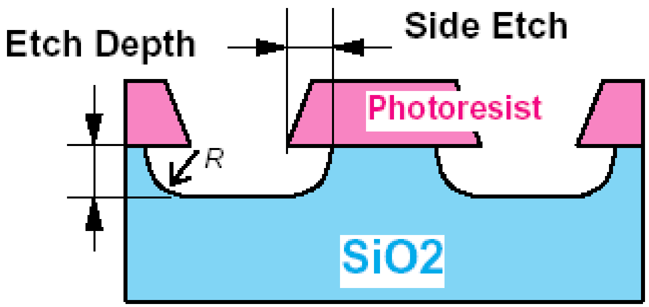
Ion Energy

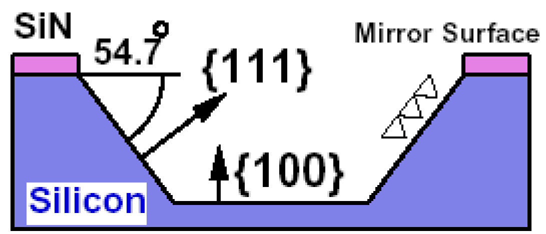
- Physical Etching (Sputtering)
  - Momentum transfer
    $\Rightarrow$ bond breakage
  - Particle Collisions
  - Aniosotropic
- Physical- chemical Etching
  - Ion bombardment to make the surface more reactive
  - Anisotropic
- Chemical Etching
  - Reactive etchant species
  - Isotropic

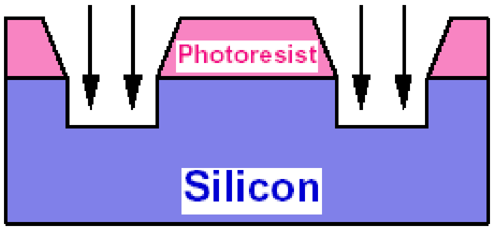
Pressure



Isotropic and Anisotropic in Wet and Dry Etching

<table>
<tr><th></th><th>Isotropic</th><th>Anisotropic</th></tr>
<tr><td>Wet</td><td>

SiO2 / HF</td><td>

Si / KOH, EDP, TMAH
Orientation Dependent</td></tr>
<tr><td>Dry</td><td>For Silicon
- HNA (HF, HNO_3, CH_3COOH)</td><td>

Si / SF6 + Sidewall Protective Gas
Independent of Crystallographic Axis</td></tr>
</table>

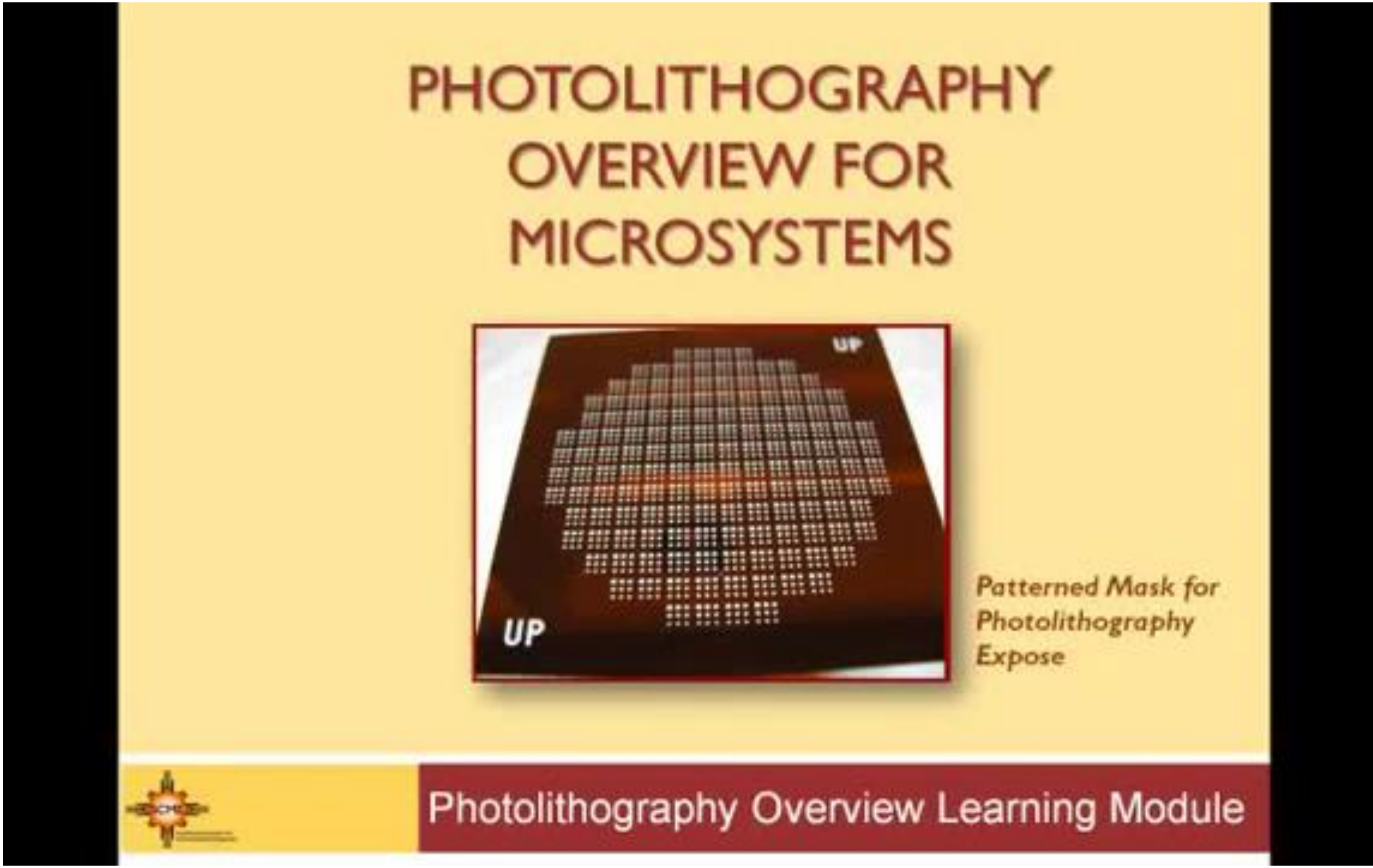
Comparison

Parameter	Wet Etching	Dry Etching
Directionality	Only with single crystal materials	With most materials
Cost	Low	High
Selectivity	Can be very good	Poor
Typical Etch Rate	Fast (1um/min)	Slow (0.1 um/min)
Control	Difficult	Good

Patterning (Pattern Transfer Method)

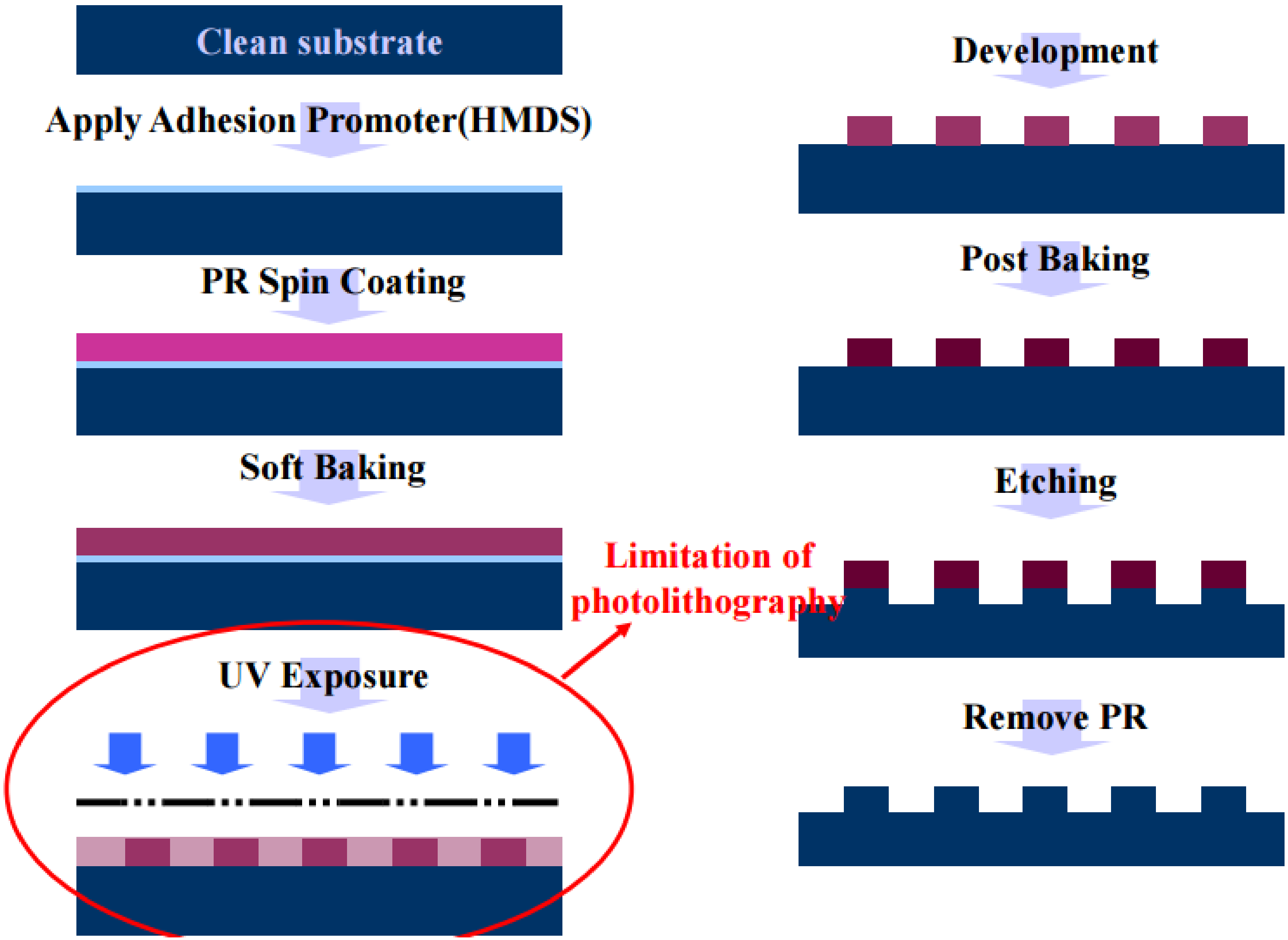
- Photo Lithography
- E-beam Lithography
- Nano-imprinting Lithography
- LIGA

Photolithography

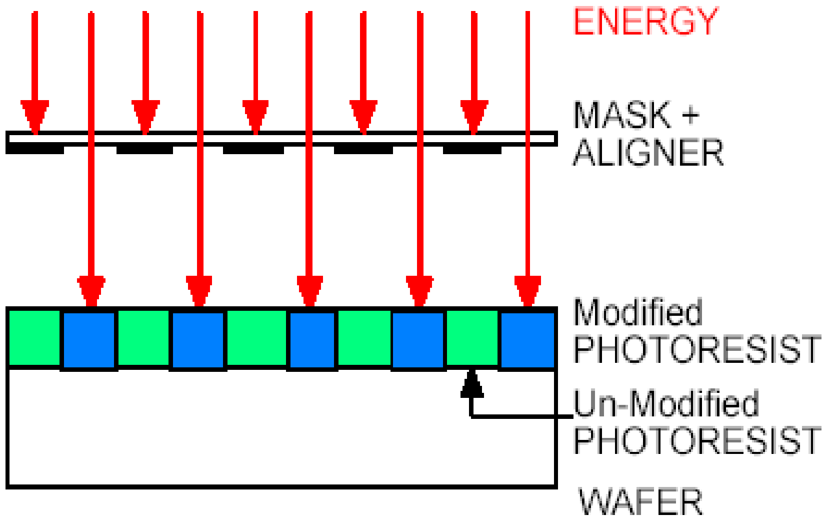


Photolithography

Photoresist process for lithography

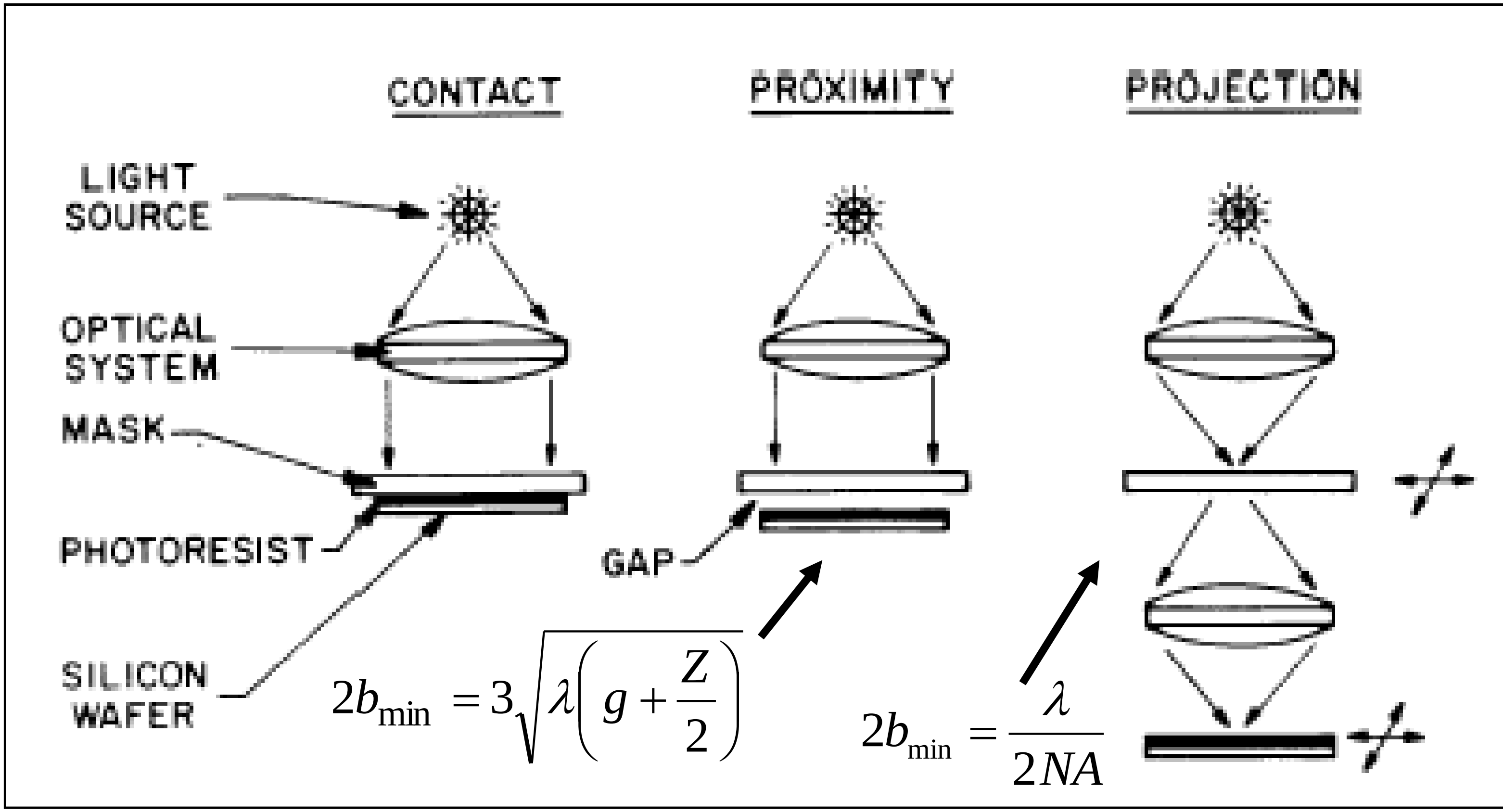


Photolithography



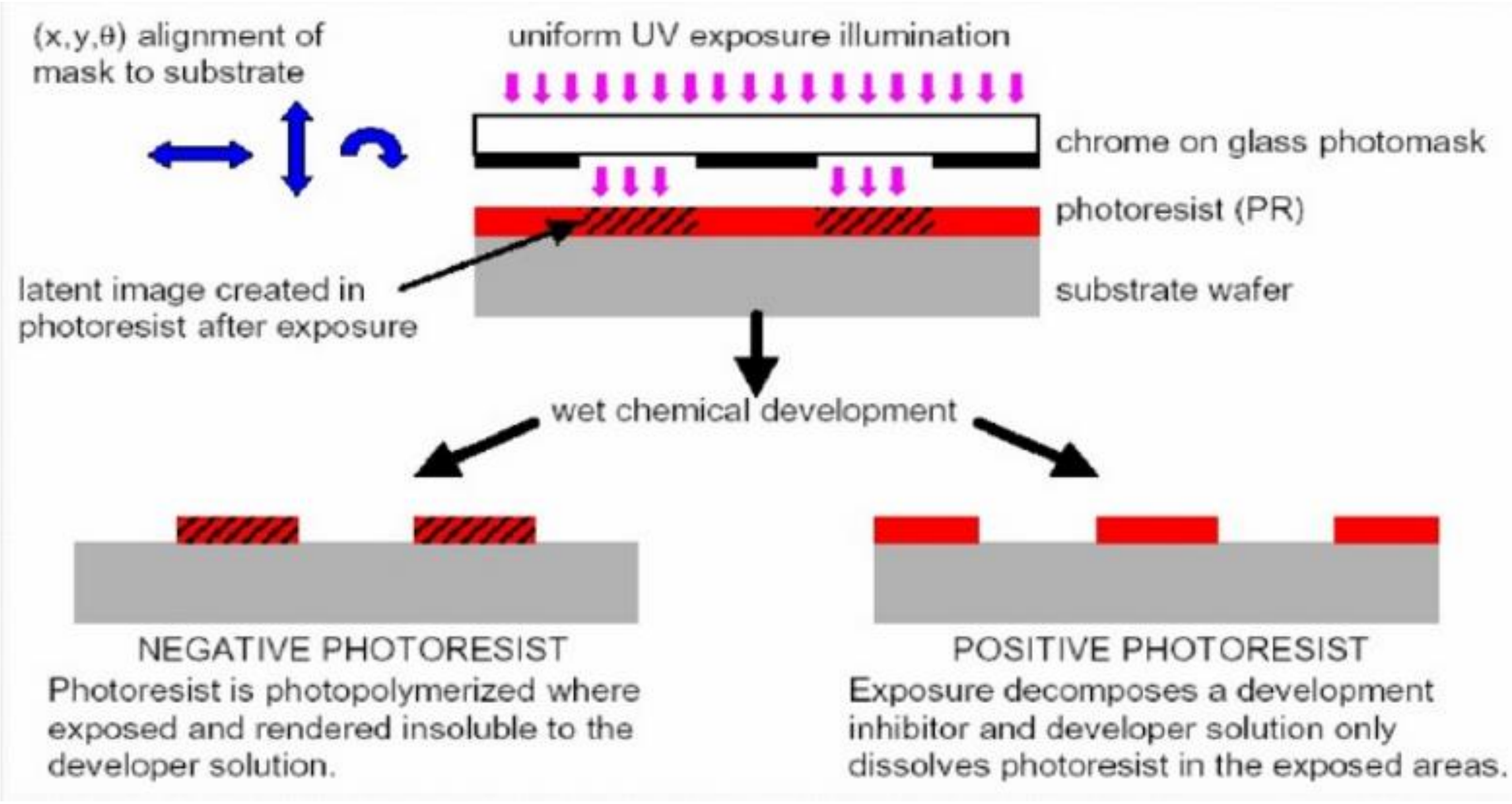
- Energy
  - Change cross linking of polymer chains of a photo-sensitive polymer called photoresist, and modify its dissociation rate in a developer similar to that for developing photos
- Mask
  - Absorber (Dark Area) & window (Open area)
- Resist
  - Transfer image from mask to wafer

Photolithography

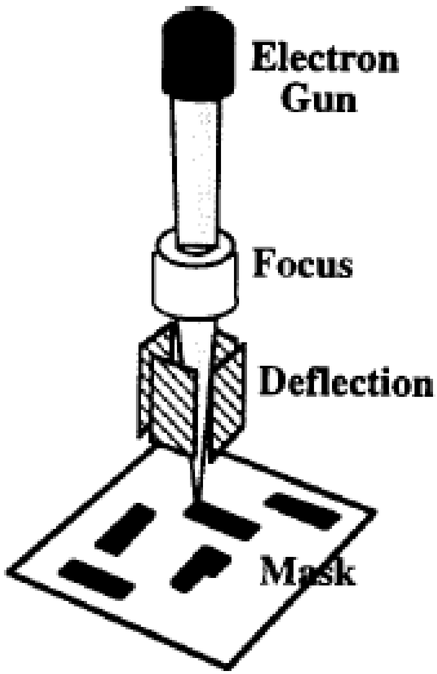


- Contact – not limited by diffraction
- Proximity – 2 ~ 20 μm gap, limited by diffraction
- Projection – limited by diffraction

Photolithography



Electron Beam Lithography



- Minimum beam size (5nm)
- for optical & X-ray masks, and nano-devices

- **Direct writing on resist-coated substrate**
- **No Mask**

Electron Beam Lithography

Energy Sources

		Wavelength	Energy
Light	UV	400 nm	3.1 eV
	Deep UV	250 nm	4.96 eV
	X-Ray	0.5 nm	2480 eV
Particles	Electrons	0.62 Å	20 keV
	Ions	0.12 Å	100 keV

- **Energy**

$$E = h\nu = \frac{hc}{\lambda}$$

- **Minimum Line Width**

$$R = 1.22\frac{\lambda f}{d}$$

Electron Beam Lithography

Comparison

	Optical	Electron Beam
Advantage	♦ Low ~High precision ♦ Fast exposure speed ♦ Relatively low cost	♦ No diffraction ♦ Easy to control ♦ Available for small features
Disadvantage	♦ Light diffraction ♦ Alignment problem ♦ Debris between mask and wafer	♦ Needs vacuum ♦ High system cost ♦ Slow

Electron & Ion Beam Lithography