Photolithography

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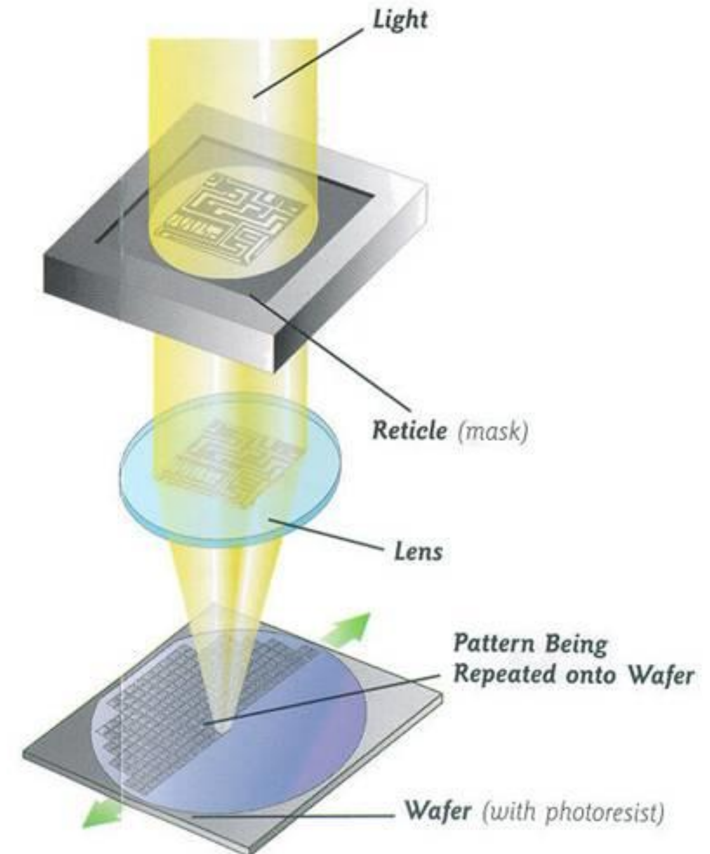
GIST

1. Introduction

Photo(Light**)** + **Litho**(Stone) + **Graphy**(Write) = Photolithography

- Photolithography is a process used to selectively remove parts of a thin film in micro-fabrication

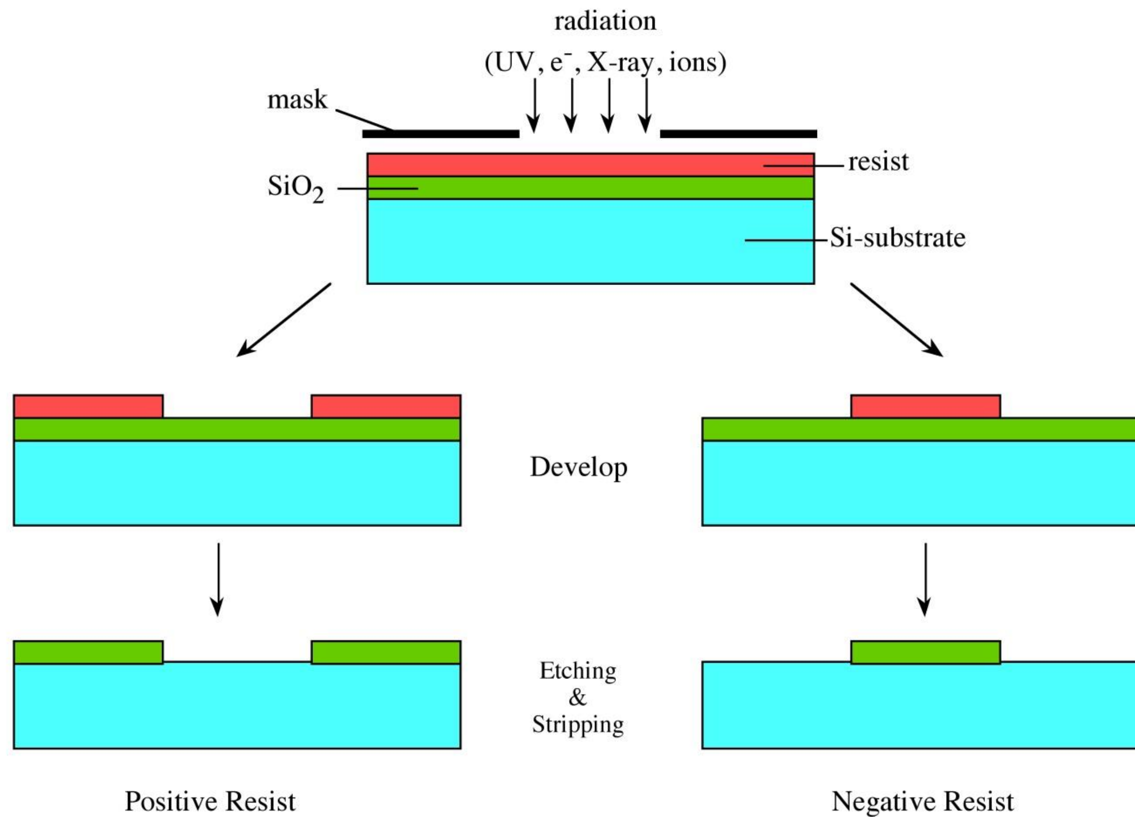
- It used light to transfer a geometric pattern form a photomask to a light-sensitive chemical photoresist on the substrate



https://willson.cm.utexas.edu/Research/Sub_Files/Immersion/index.php

2. Positive and Negative Photoresist

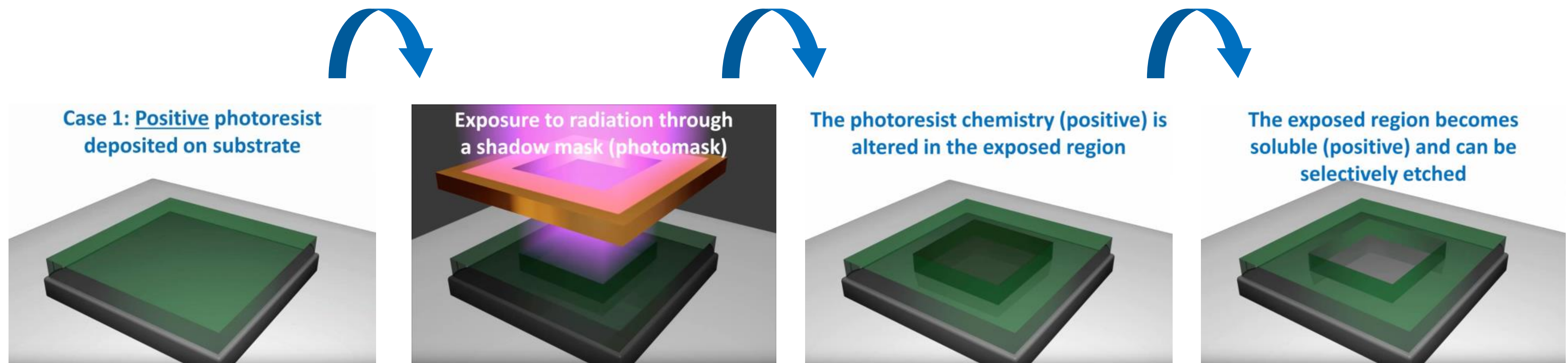
Positive and Negative Photoresist



http://cnx.org/contents/KZdIG-zX@2/Composition-and-Photochemical-

2. Positive and Negative Photoresist

Positive Photoresist

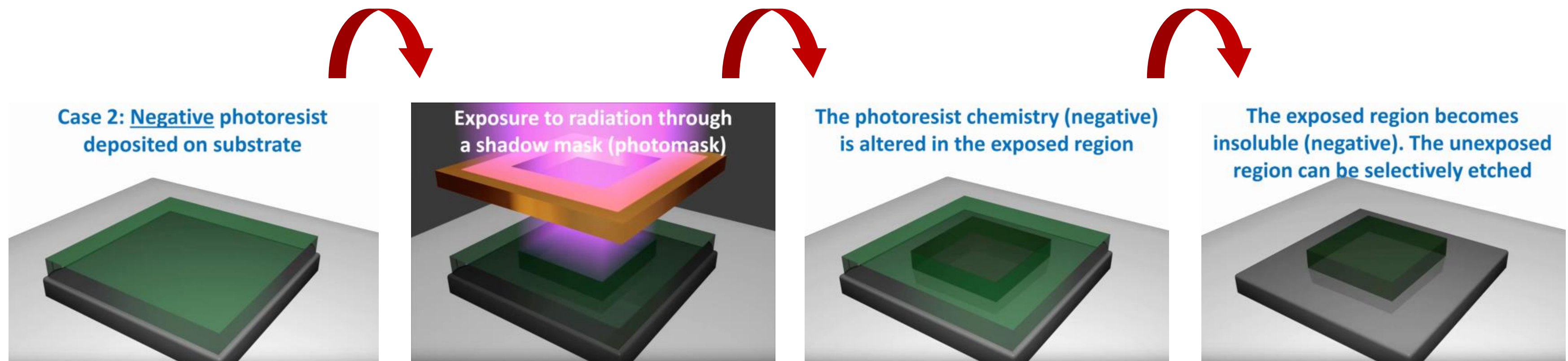


- Positive photoresist deposited in substrate
- Exposure to radiation through a shadow mask(photomask)
- The photoresist chemistry(positive) is altered in the exposed region
- The exposed region becomes soluble(positive) and can be selectively etched

https://www.youtube.com/watch?v=-pflilEyUIE

2. Positive and Negative Photoresist

Negative Photoresist



- Negative photoresist deposited in substrate
- Exposure to radiation through a shadow mask(photomask)
- The photoresist chemistry(negative) is altered in the exposed region
- The exposed region becomes insoluble(negative) and then the unexposed region can be selectively etched

https://www.youtube.com/watch?v=-pflilEyUIE

2. Positive and Negative Photoresist

Comparison of Positive & Negative Photoresist

Characteristics	Positive Resist	Negative Resist
Contrast	Higher	Lower
Developer	Aqueous based	Organic solvent
Develop Process Window	Small	Very wide
Lift-off	Yes	No
Minimum Feature	0.5μm and below	2.0μm
Plasma Etch Resistance	Very good	Not very good
Proximity Effect	Prints isolated holes or trenches better	Prints isolated lines better
Step Coverage	Better	Lower
Swelling in Developer	No	Yes
Thermal Stability	Good	Fair

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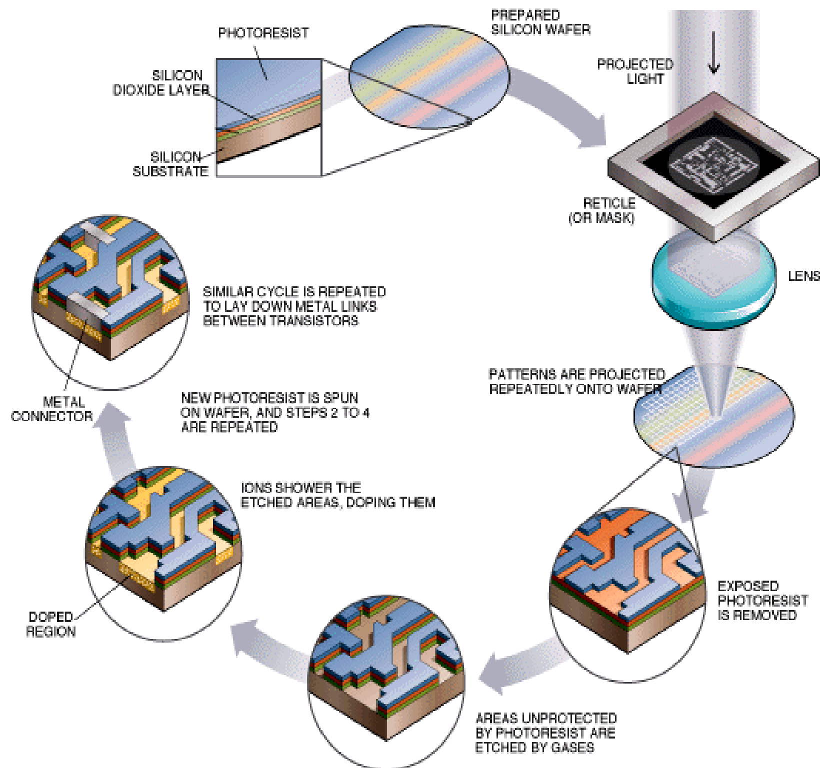
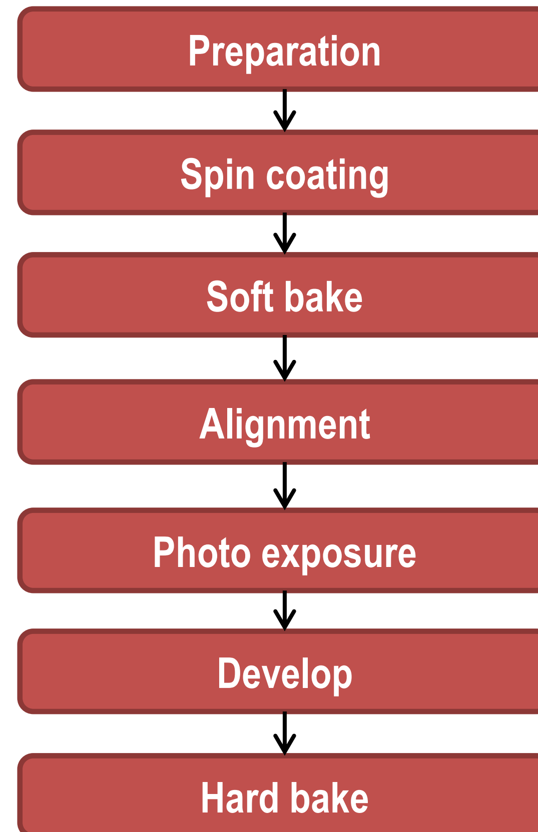
3. Photolithography process

Photolithography - Seven steps process flow





http://blog.associatie.kuleuven.be/danhuayao/introduction-of-the-metallic-contamination/

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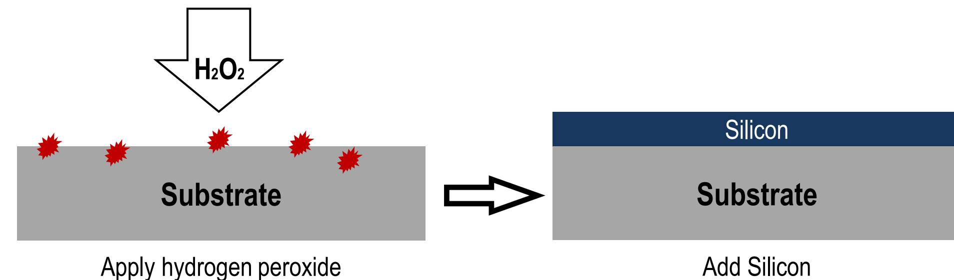
3. Photolithography process

I) Preparation

i) Cleaning Silicon deposition

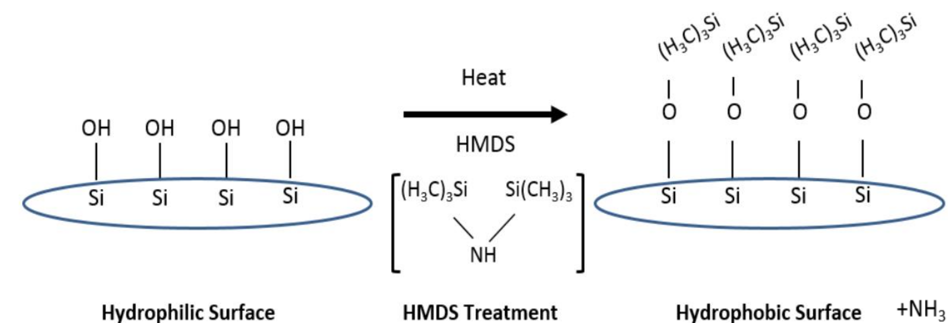
- To prevent partial delamination of the photoresist film during pattern develop, wet etch or plating, substrate surfaces must be properly cleaned and dehydrated prior to coating



ii) HMDS(HexaMethylDiSilazane): $(H_3C)_3$Si-NH-Si$(CH_3)_3$

- Applying HMDS to dehydrated wafers is one common method for achieving the surface hydrophobicity required to prevent photoresist delamination

- The surface is exposed to vapor phase HMDS

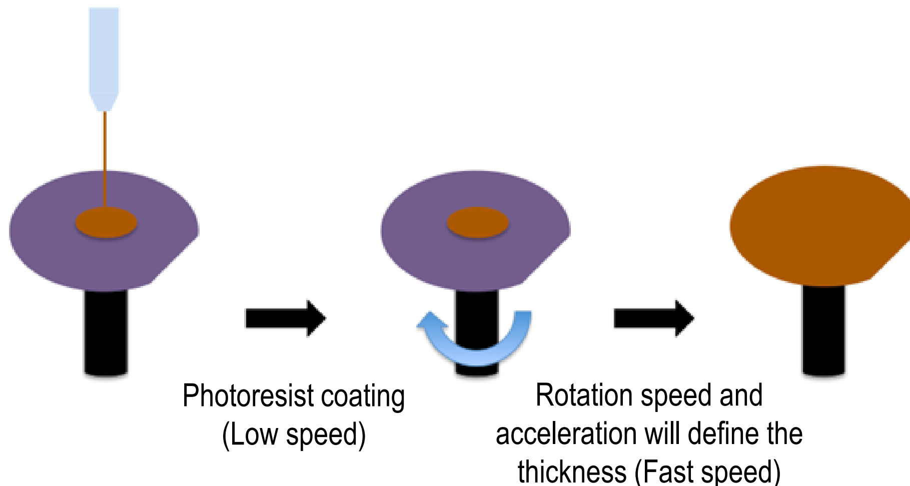


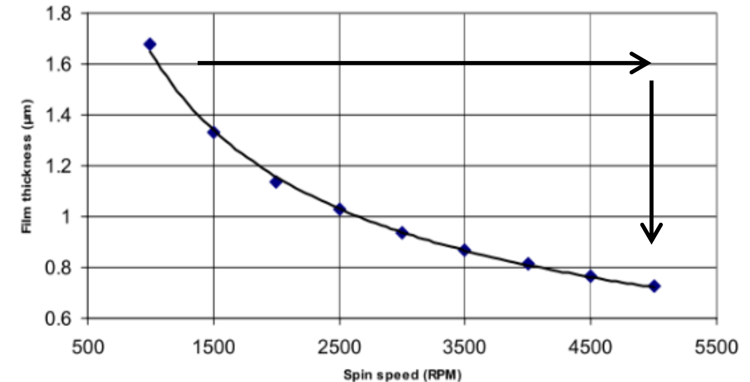
http://www.cnf.cornell.edu/cnf_process_photo_resists.html, http://www.imicromaterials.com/index.php/technical/HMDS

3. Photolithography process

II) Spin coating

- Spin coating is the standard coating method for flat wafer
- The substrate is rotated at high speed in order to spread the fluid by centrifugal force
- Solution viscosity and the spinning speed are parameters which influence the layer forming process
- Higher spin speeds during this step will result in thinner resist films and lower RPM will yield thicker resist films





http://www.elveflow.com/microfluidic-tutorials/soft-lithography-reviews-and-tutorials/introduction-in-soft-lithography/pdms-membrane-thickness-of-a-spin-coated-pdms-layer/

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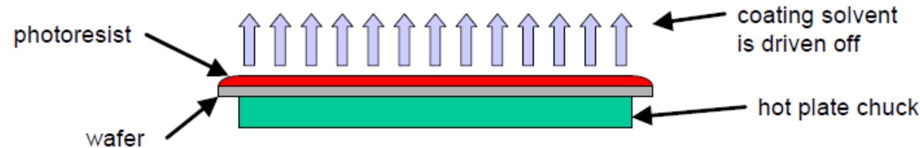
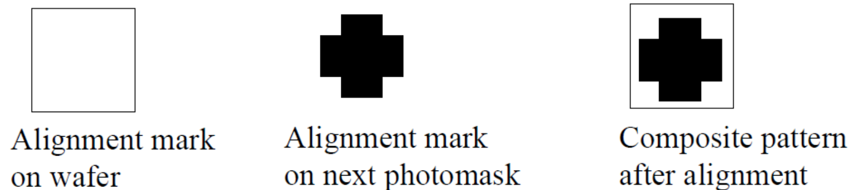
3. Photolithography process

III) Soft bake



- Almost all of the solvent are removed from a photoresist coating during soft bake
- The photoresist coating becomes photosensitive after successful soft bake
- Soft bakes are commonly performed on hot plates and typical temperatures range from 90˚C to 110˚C.

IV) Alignment

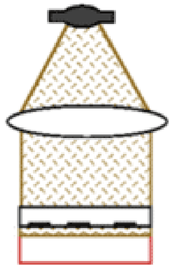


- 3 degrees (x, y, angle) of freedom between mask and wafer
- Use alignment marks on mask and wafer to register patterns prior to exposure
- Modern steppers use automatic pattern alignment systems, which takes 1-5 sec to align to exposure

http://www.ee.ucr.edu/~jianlin/EE136/EE136-Spring08/EE136-Lecture-4.pdf , http://www.ee.ucr.edu/~jianlin/EE136/EE136-Spring08/EE136-Lecture-4.pdf

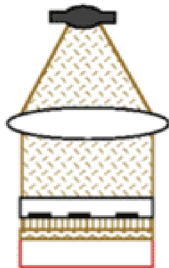
3. Photolithography process

V) Photo exposure



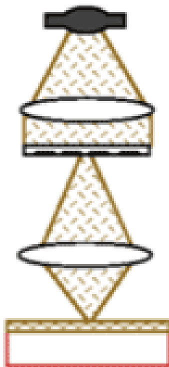
i) Contact Printing

- The resist coated silicon wafer is brought into physical contact with the glass photomask
- The problem with contact can damage the mask and cause defects in the pattern



ii) Proximity Printing

- A small gap, 10 to 25 microns wide, is maintained between the wafer and the mask during exposure
- Approximately 2- to 4-micron resolution is possible with proximity printing



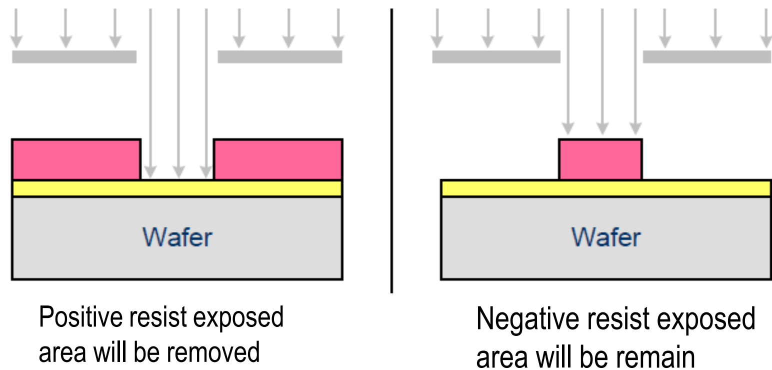
iii) Projection Printing

- An image of the patterns on the mask is projected onto the coated wafer, which is many centimeters
- In order to achieve high resolution, only a small portion of the mask is imaged
- Projection printings are capable of approximately 1-micron resolution.

http://www.microchem.com/Tech-LithoTerms.htm

3. Photolithography process

VI) Develop



: Illustration of positive and negative resist after development

- The exposed wafers are developed in dipping baths (multiple wafers) or in spray processes(one wafers)

- Depending on the type of resist (negative/positive) exposed areas are soluble or insoluble in developing chemicals and a patterned wafer remains after development

VII) Hard bake

- Used to stabilize and harden the developed photoresist prior to processing steps that the resist will mask
- Post bake removes any remaining tracing of the coating solvent or developer
- Higher temperature(120˚C~150˚C) than soft bake

https://www.halbleiter.org/pdf/pdf_en/Photolithography/Photolithography%20-%20Development%20and%20inspection.pdf

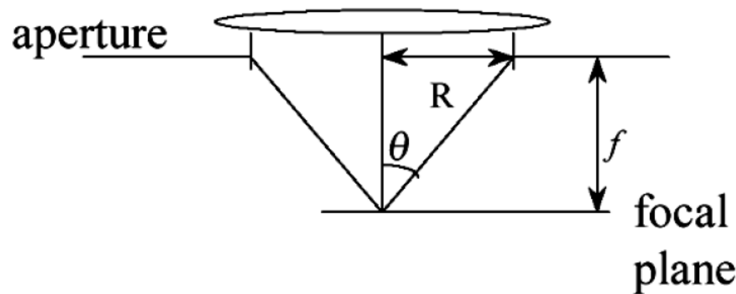
4. Trade off

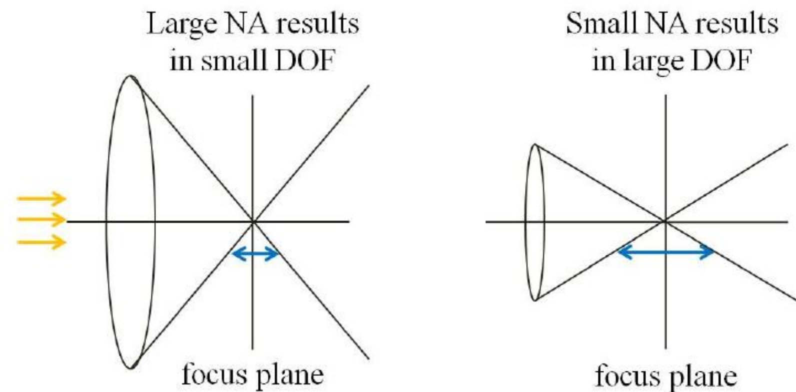
Resolution $\leftrightarrow$ Depth of Focus

i) Resolution $= k_1 \frac{\lambda}{NA}$

$\rightarrow NA = n\sin\theta$

ii) Depth of Focus $= k_2 \frac{\lambda}{NA^2}$





- High NA systems resolve much smaller features, however the photoresist film used must be quite thin in order to remain within the reduced focus window

- Shorter wavelength incident energy provides better resolution but again, depth of focus is reduced

http://www-inst.eecs.berkeley.edu/~ee143/fa10/lectures/Lec_04.pdf, http://old.kps.or.kr/storage/webzine_uploadfiles/1507_article.pdf

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Thank you

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