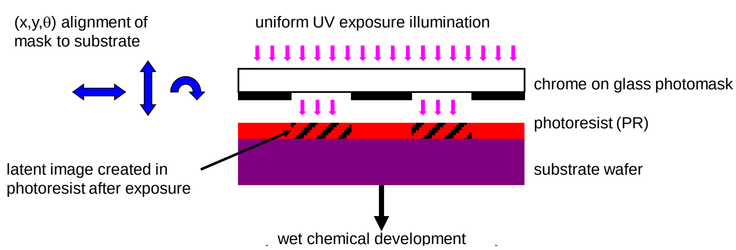
EE 527 MICROFABRICATION

Lecture 16

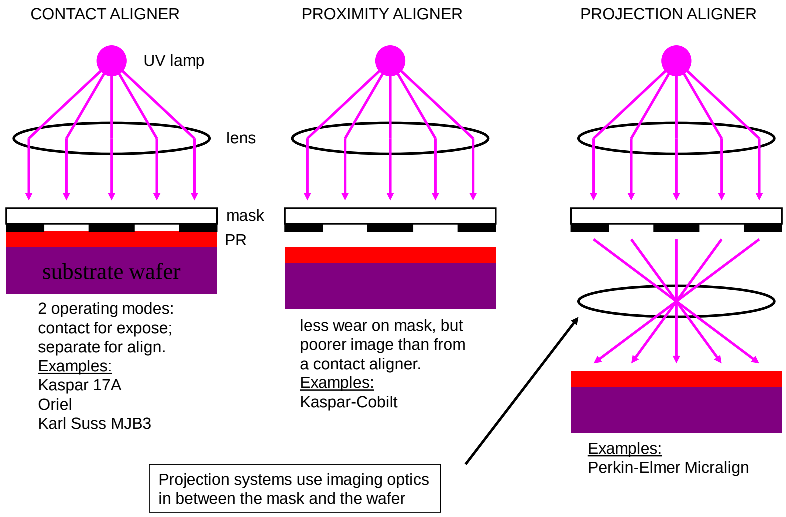
Tai-Chang Chen
University of Washington

UNIVERSITY OF WASHINGTON

OVERVIEW OF ALIGN/EXPOSE/DEVELOP STEPS



ALIGNMENT AND EXPOSURE HARDWARE - 1



ALIGNMENT AND EXPOSURE HARDWARE - 2

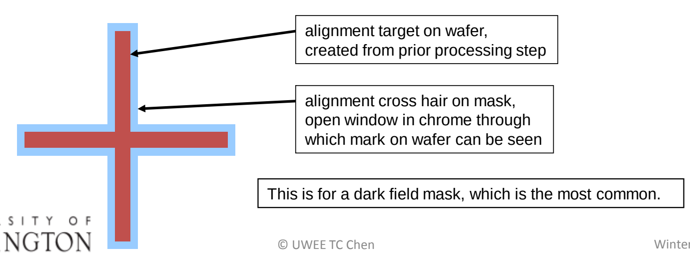
- For simple contact, proximity, and projection systems, the mask is the same size and scale as the printed wafer pattern. I.e. the reproduction ratio is 1:1.
- Projection systems give the ability to change the reproduction ratio. Going to 10:1 reduction allows larger size patterns on the mask, which is more robust to mask defects.
- The mask size can get unwieldy for large wafers.
- Most wafers contain an array of the same pattern, so only one cell of the array is needed on the mask. This system is called Direct Step on Wafer (DSW). These machines are also called "Steppers"
- The advantage of steppers: only 1 cell of pattern is needed.
- The disadvantage of steppers: the 1 cell of the pattern on the mask must be perfect – absolutely no defects, since it gets used for all die.

ALIGNMENT AND EXPOSURE HARDWARE - 3

- Higher end research systems go one step further and use Direct Write on Wafer (DWW) exposure systems.
- This can be accomplished using:
  - Excimer lasers for geometries down to 1-2 μm,
  - Focused ion beams for geometries down to 100-200 nm, or
  - Electron beams for geometries down to 30-50 nm.
- No mask is needed for these technologies.
- These are serial processes, and the wafer cycle time is proportional to the beam writing time – the smaller the spot, the longer it takes!

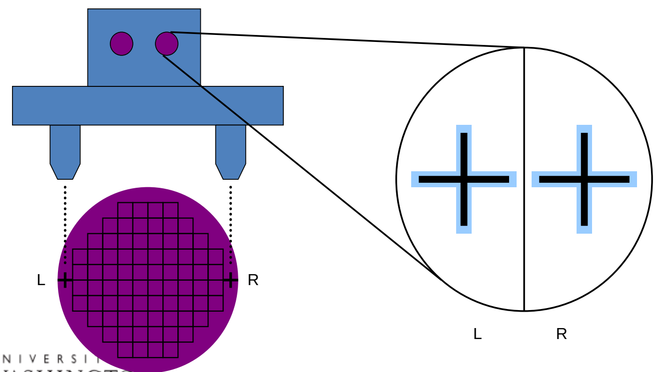
MASK TO WAFER ALIGNMENT - 1

- There are 3 degrees of freedom between mask and wafer: (x,y,θ)
- Use alignment marks on the wafer (the target) and on the mask (the cross hair) to register patterns prior to exposure.
- Modern process lines (steppers) use automatic pattern recognition and alignment systems.
  - Usually takes 1-5 seconds to align and expose on a modern stepper.
  - Experienced human operators usually take 30-45 seconds with well-designed alignment marks.



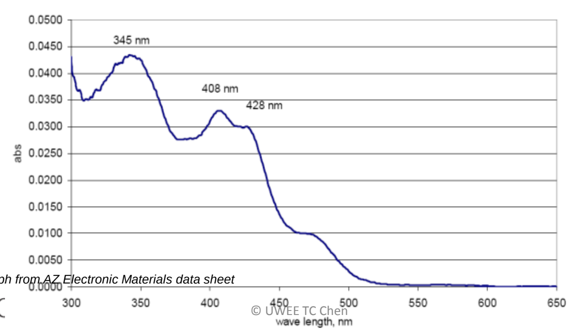
MASK TO WAFER ALIGNMENT - 2

- This normally requires at least two alignment mark sets on opposite sides of the wafer or the stepped region.
- A split-field microscope is used to make alignment easier:



PHOTORESIST SPECTRAL ABSORPTION

- Most positive photoresists are sensitive to light in the ultraviolet to blue-green range, λ ~ 300 to 500 nm.
- Photolithography areas must have the light filtered to only 550 – 700 nm (green to red). Because the filters absorb the blue wavelengths, they appear yellow, and photolithography areas appear to have yellow illumination.
- The absorption graph below is for AZ-1500 series positive photoresists.



Graph from AZ Electronic Materials data sheet

EXPOSURE

- The exposure dose D is the amount of optical radiation that is applied to the photoresist, usually expressed in mJ/cm^2.
  - The Dose-To-Print (DTP) is the required dose to create a full thickness latent image in the photoresist.
  - The DTP is directly proportional to the photoresist thickness d.
- The exposure intensity I is the optical power density at the photoresist image plane, usually expressed in mW/cm^2.
- The exposure time t_e is the duration of the optical radiation (seconds).
- $D = I*t_e$.
- Example: Oriel 350W 3-inch aligner / high pressure Hg-arc exposure system and 1.2 µm thick AZ-1512 photoresist:
  - $I = 10.0\ mW/cm^2$, (check this value periodically, since the lamp ages!)
  - $DTP = 200\ mJ/cm^2$, so set the exposure time for
  - $t_e = DTP/I = 20.0$ seconds.

POSTBAKE (HARD BAKE) - 1

- Used to stabilize and harden the developed photoresist prior to processing steps that the resist will mask.
- An important parameter is the plastic flow or glass transition temperature.
- The postbake removes any remaining traces of the coating solvent or developer.
- This eliminates the solvent burst effects in vacuum processing.
- Postbake introduces some stress into the photoresist.
- Some shrinkage of the photoresist may occur.
- Longer or hotter postbake makes resist removal much more difficult.

POSTBAKE (HARD BAKE) - 2

- A firm postbake is needed for acid etching, e.g. BOE.
- Postbake is not needed for processes in which a soft resist is desired, e.g. metal liftoff patterning.
- Photoresist will undergo plastic flow with sufficient time and/or temperature:
  - Resist reflow can be used for tailoring sidewall angles.

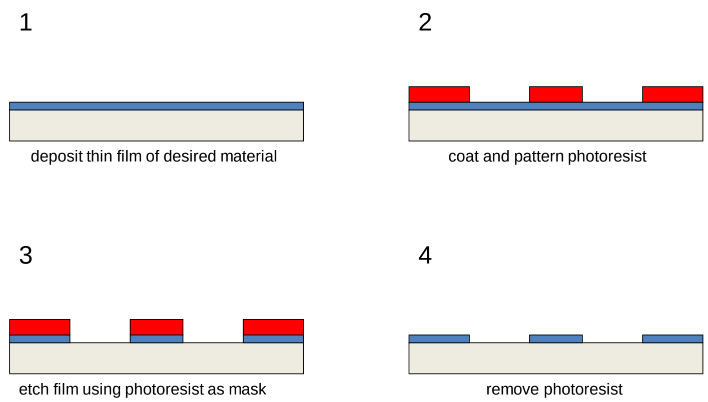
PHOTORESIST REMOVAL (STRIPPING)

- Want to remove the photoresist and any of its residues.
- Simple solvents are generally sufficient for non-postbaked photoresists:
  - Positive photoresists:
    - acetone
    - trichloroethylene (TCE)
    - phenol-based strippers (Indus-Ri-Chem/EKC J-100)
  - Negative photoresists:
    - methyl ethyl ketone (MEK), $CH_3COC_2H_5$
    - methyl isobutyl ketone (MIBK), $CH_3COC_4H_9$
- Plasma etching with O_2 (ashing) is also effective for removing organic polymer debris.

BASICS OF PHOTOLITHOGRAPHY FOR PROCESSING

- Microfabrication processes:
  - Additive → deposition
  - Subtractive → etching
  - Modifying → doping, annealing, or curing
- Two primary techniques for patterning additive and subtractive processes:
  - Etch-back:
    - Photoresist is applied overtop of the layer to be patterned.
    - Unwanted material is etched away using the photoresist as a mask.
  - Lift-off:
    - The patterned layer is deposited over top of the photoresist.
    - Unwanted material is lifted off when the resist is stripped.

ETCH-BACK



NOTE: photoresist has same polarity as final film; photoresist never touches the substrate wafer.

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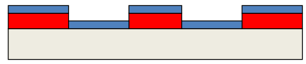
LIFT-OFF

1

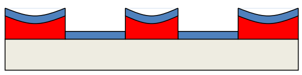
coat and pattern photoresist

2



deposit thin film of desired material

3



swell photoresist with a solvent

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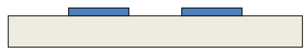

remove photoresist and thin film above it

NOTE: photoresist has opposite polarity as final film;
excess deposited film never touches the substrate wafer.

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