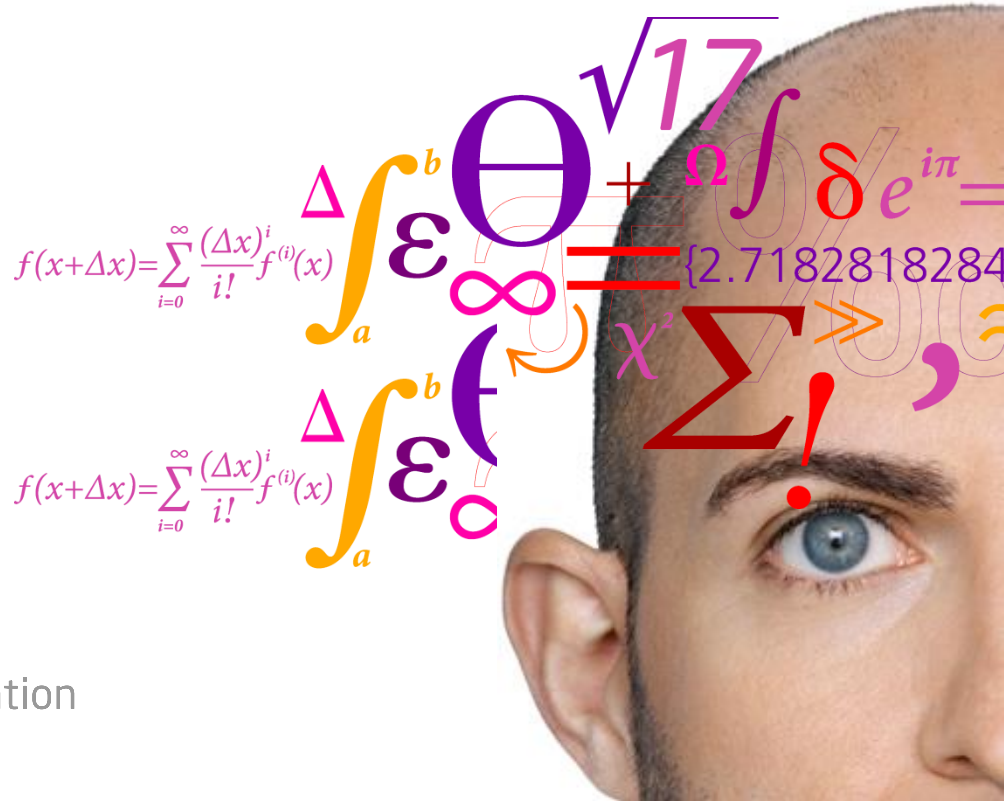
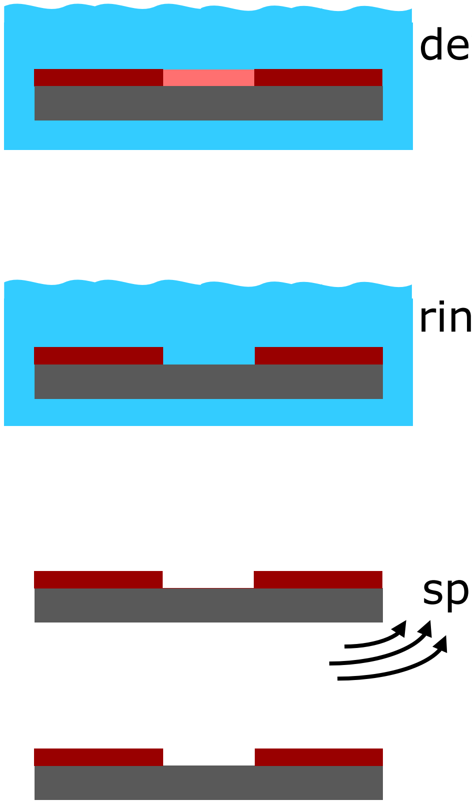
Lithography Tool Package

Development



DTU Danchip
National Center for Micro- and Nanofabrication

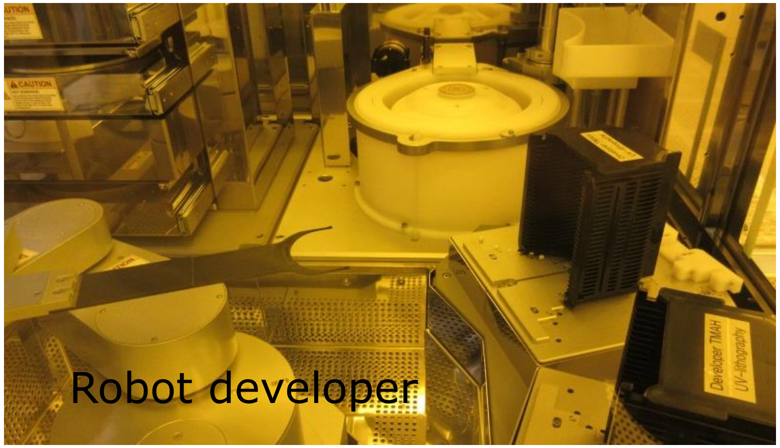
Development



developer

rinse (H_2O)

spin drying



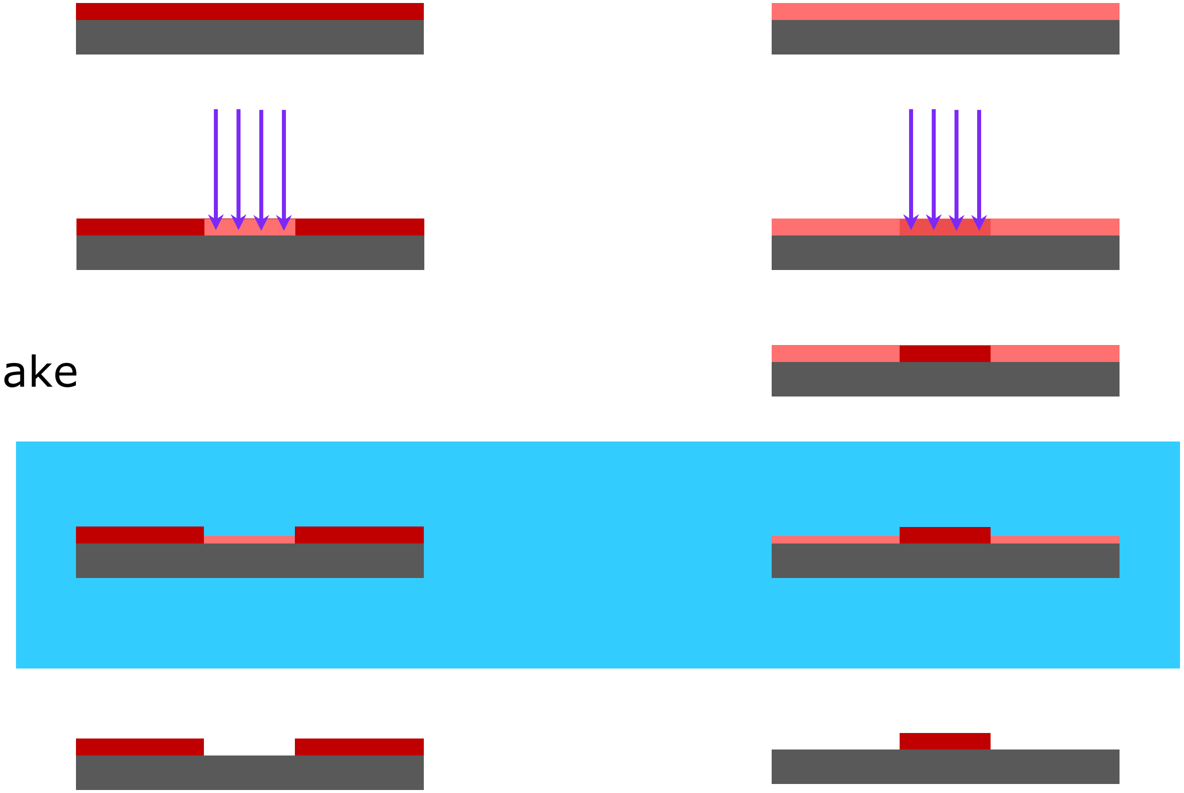
Development: principle

- In the exposure, light activates the *photo-active compound* which changes the solubility of the resist in the developer in the exposed areas
- In some resists, the photo-chemistry is a catalytic process, which is activated/assisted thermally in a so-called **P**ost-**E**xposure **B**ake (PEB)
- The developer may be a solvent, or an aqueous solution (usually a base)
- During development, the soluble parts are dissolved, leaving a pattern of resist on the substrate
- The development process is terminated by rinsing (solvent and/or water)

Methods

- Submersion: the substrate is submerged in a bath of developer
- Puddle: developer is dispensed onto the surface of the substrate, and held there by surface tension
- Spray: developer is sprayed onto the substrate

Development: resist tone



Positive tone **Negative tone**

Coating

Exposure

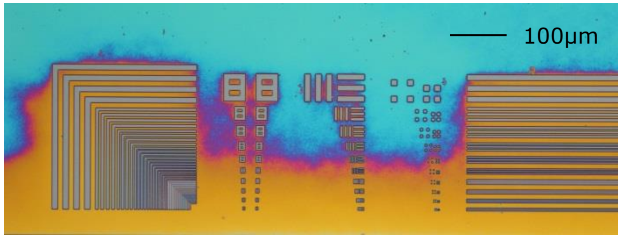
Post-exposure bake

Development

Pattern

Development: effects

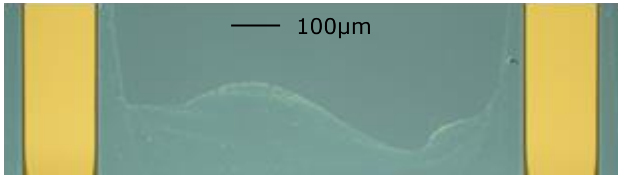
- **Under-development**: resist remaining between pattern
  - – Increase development time
  - – Increase exposure dose



Under-developed resist

- **Dark erosion**: pattern attacked by the developer
  - – Minimize development time
  - – Optimize softbake parameters

- **Scumming**: resist residues left behind on the substrate
  - – Substrate and developer dependent



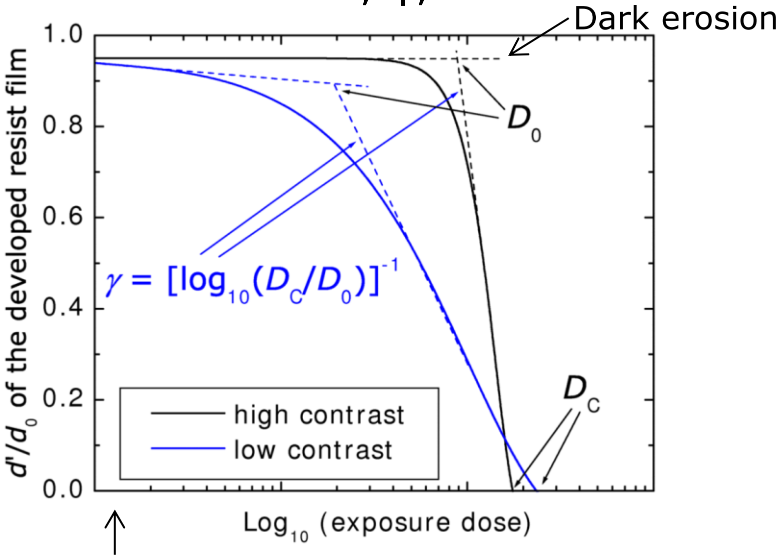
Scumming on SiO_2. Courtesy of Sonny Massahi

- Forgetting PEB leads to
  - – under-development of positive tone resist
  - – full development (no pattern) of negative tone resist

Photoresist: contrast

- Ideally, at least for high resolution, the response of a resist to exposure should be a step function, i.e. no development below a threshold dose; full development above the threshold dose
- In reality, development starts at a dose, D_O, but finishes at a higher dose, D_C (dose to clear), leading to the definition of **contrast**, γ, as the slope of the transition:

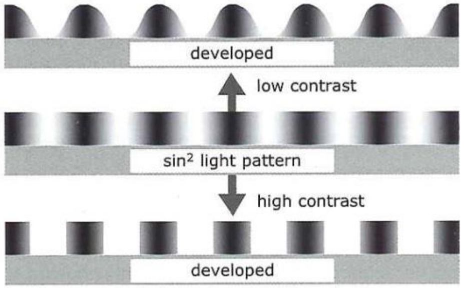
  $\gamma = \frac{1}{log\left(\frac{D_C}{D_O}\right)}$, for a positive resist



- For a negative resist, the curve is reversed:

  $\gamma = \frac{1}{log\left(\frac{D_O}{D_i}\right)}$, D_i being the "fully insoluble dose"

- Contrast determines how the image from the exposure transfers to the resist pattern



← From http://www.microchemicals.eu/

- Contrast depends on many factors: Developer chemistry, concentration, and temperature; Resist type and thickness; Softbake parameters; etc.

Developers at DTU Danchip

- AZ 351B
  - NaOH in water
  - buffer additive (for submersion)
- AZ 726 MIF
  - TetraMethylAmmonium Hydroxide in water
  - wetting agent (for puddle)
- mr-Dev 600
  - PGMEA for SU-8 development

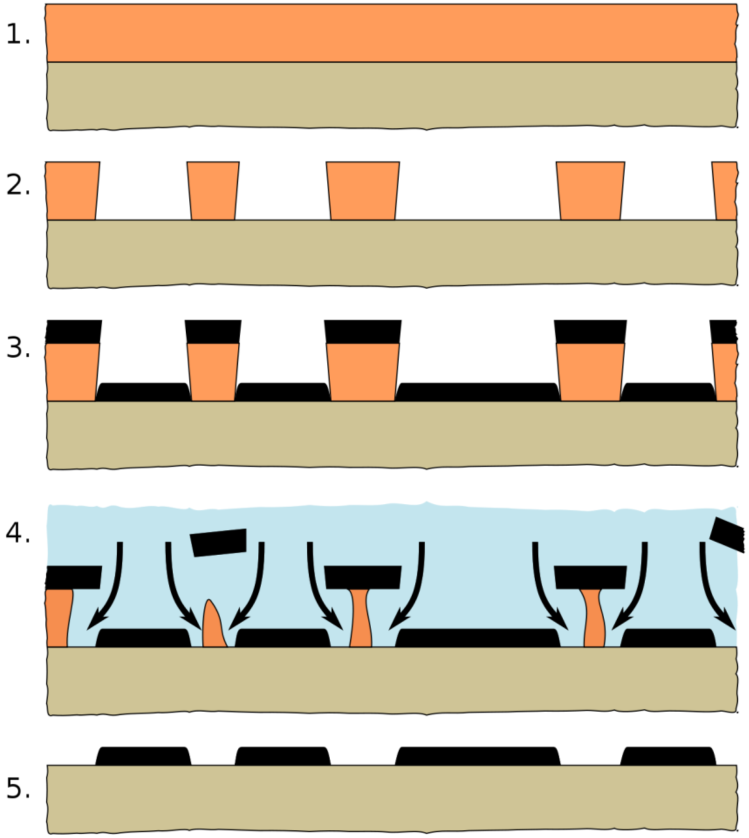
	MiR 701	**nLOF 2020**	**5214E**	**4562**	**SU-8**
Thickness	1.5–4 µm	1.5–4 µm	1.5–4 µm	5–10 µm	4–200 µm
Positive	x		x	x	
Negative		x	x		x
AZ 351B	(x)	(x)	x	x	
AZ 726 MIF	x	x	x	x	
mr-Dev 600					x

After lithography: pattern transfer

- **Etching**
  - Resist pattern is transferred to substrate or hard mask
  - Wet: liquid chemical, possibly heat
  - Dry: gas, possibly plasma
  - Scumming leads to micro-masking → roughness
- **Electroplating**
  - The resist patterns growth of a metal film
  - Film growth by electro-chemical reduction of ions (electrolyte)
  - Requires conductive substrate or seed layer
  - Scumming leads to partial film growth
- **Implantation**
  - The resist patterns doping of the substrate
  - Selective doping of substrate using accelerated ions

After lithography: pattern transfer

- **Lift-off**
  - A thinfilm (usually metal) is deposited on top of the resist pattern
  - Requires directional deposition (non-conformal)
  - After deposition the resist is dissolved, leaving only the part film of the film that was deposited on substrate
  - Best result with negative sidewalls
  - Scumming leads to poor adhesion/contact
  - Method: solvent and ultrasound



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After lithography: post-processing

De-scum

- Before pattern transfer
- Methods:
  - Plasma ashing (low power and short time)
  - BHF (silicon substrate)

Hardbake

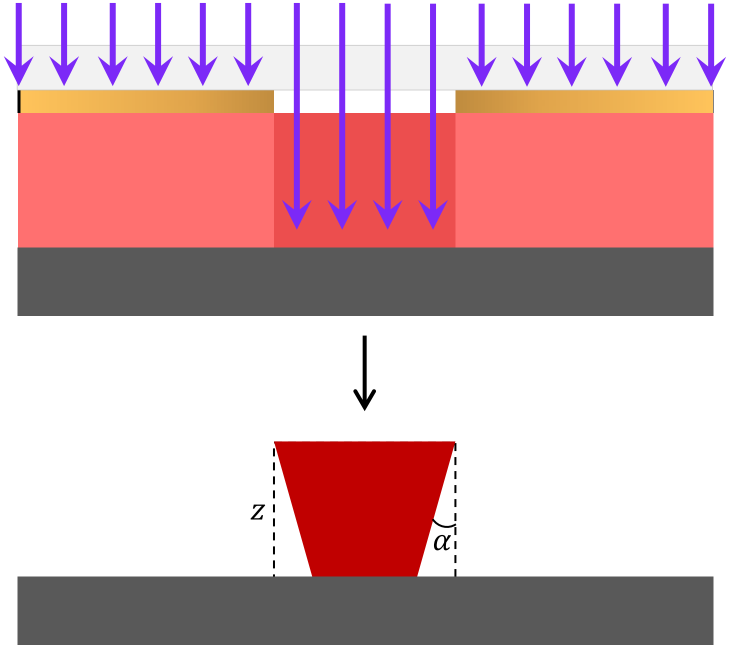
- Before pattern transfer in order to increase the mechanical, thermal, or chemical resistance, and/or increase adhesion
- Method:
  - Baking at 130–150 °C

Resist strip

- After pattern transfer
- Methods:
  - Plasma ashing (high power and long time)
  - Solvent and ultrasound

After lithography: exercise

- In contact lithography for lift-off, would the resolution be limited by diffraction, or by the 15° negative sidewall angle of the resist?
- Assume:
  - i-line lithography (λ=365nm)
  - Resist thickness z=2µm
  - No gap during exposure (s=0)



- R_c = 0.91µm
- R_a = 1.07µm (assuming c=0)
- Sidewall angle limits resolution

$$R_c = \frac{3}{2}\sqrt{\lambda\left(\frac{z}{2}\right)}$$

$$R_a = 2z\tan\alpha \ \ (+c)$$

Outline

1. **Introduction**
    - UV lithography
    - DUV Stepper
    - E-beam writer
2. **Spin coating**
    - Resist composition
    - Pre-treatment
    - Principle
    - Softbake
    - Spin curve
3. **Exposure**
    - Hardware
    - Process parameters
    - Resolution
    - Alignment
    - Photo-chemistry
4. **Development**
    - Principle
    - Effects
    - Resist contrast
    - Pattern transfer
    - Post-processing
5. **Process effects and examples**
    - Inspection methods
    - Process effects
    - Real life process examples