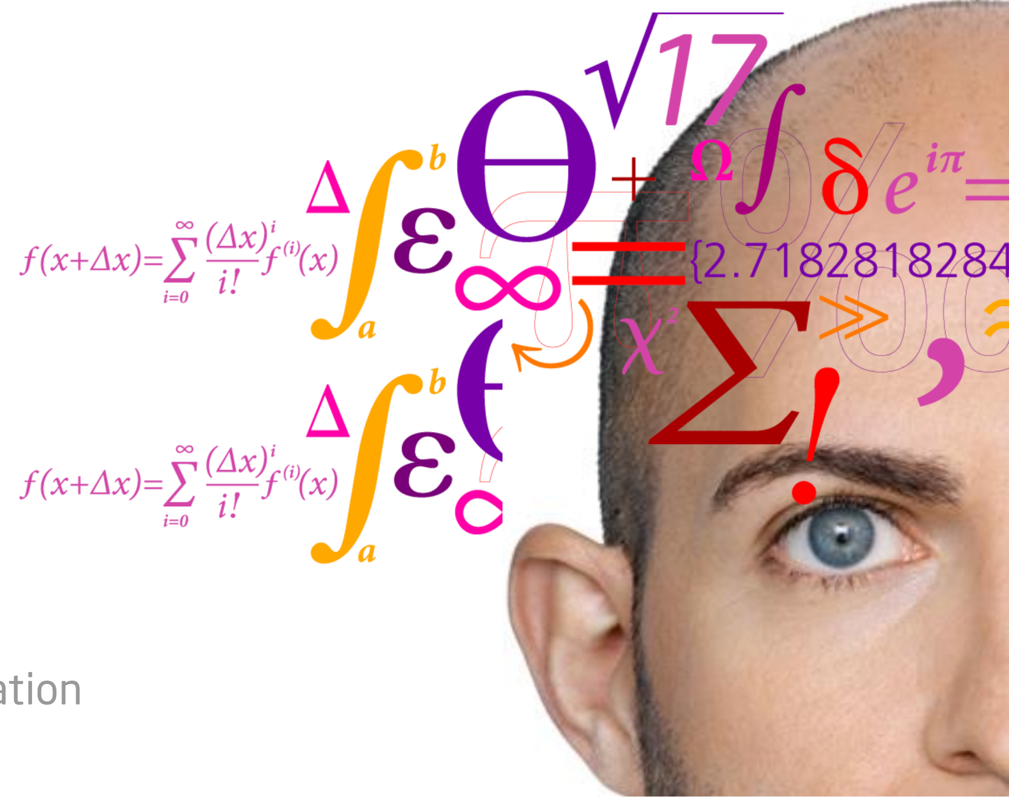
Lithography Tool Package

Photoresist



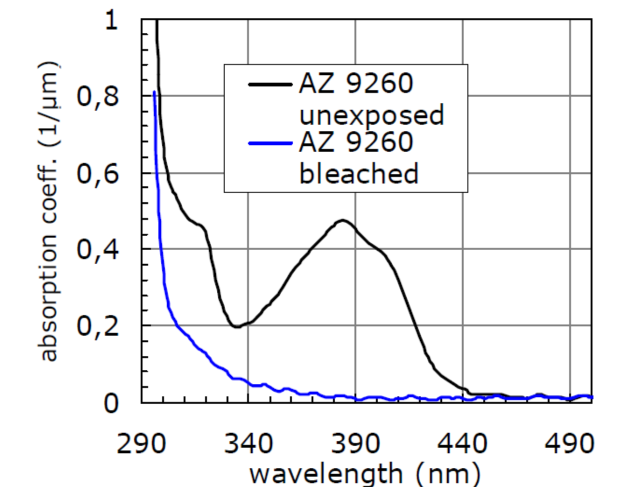
DTU Danchip

National Center for Micro- and Nanofabrication

Photoresist: composition

- **Resin**: Monomers or polymer chains of varying length (solid at RT)
- **Photo-active component** (PAC): Reacts with UV-light during exposure and changes the resin
- **Solvent** (~70%): Dissolves the resin in order to enable coating

- Optical properties
  - Absorbs UV-light (spectral sensitivity)
  - Absorption decreases during exposure = bleaching
- Thermal stability
  - Good up to ~100ºC
  - At higher temperatures: reflow (rounding), embrittlement, burning
- Chemical resistance
  - Acid: good
  - Base: poor (develops)
  - Solvent: bad (dissolves)

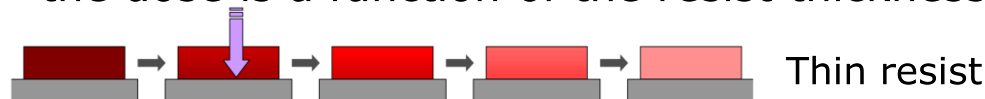


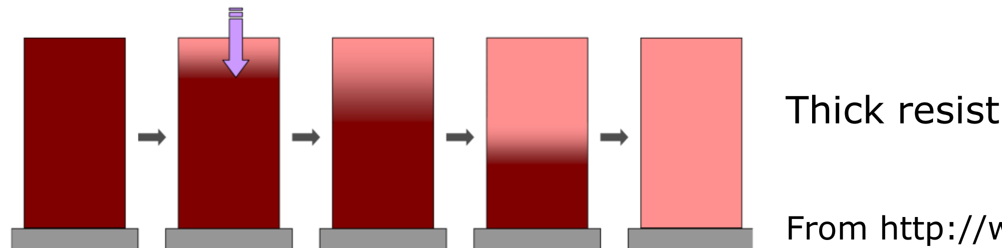
From http://www.microchemicals.eu/

Photoresist: tone

Positive tone

- Exposed resist becomes soluble in developer
- Polarity change or chain scission
- Bleaching during exposure enables straight sidewalls even for thick resist
  - the dose is a function of the resist thickness and the intensity





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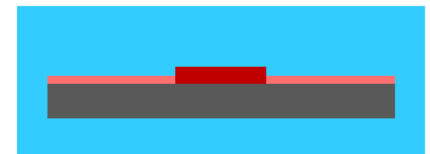
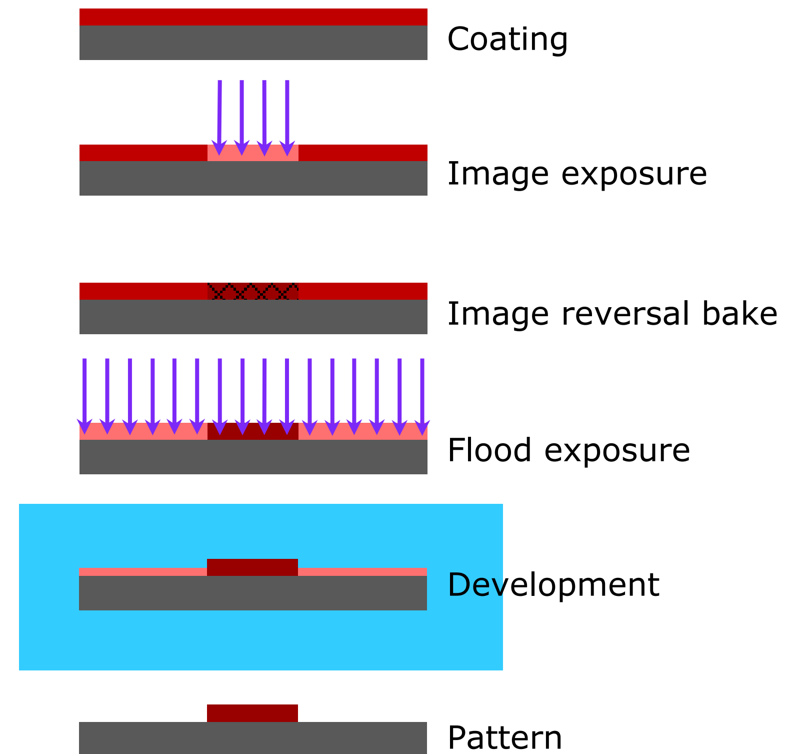


Negative tone

- Exposed resist becomes insoluble in developer
- Polarity change or cross-linking (usually requires PEB)
- Special case: no bleaching → always negative sidewalls
  - the dose is approximately constant

Photoresist: special categories

- Image reversal resist
  - Positive resist changed to negative by additional process steps
  - Cross-linker (NH_3) is added, activated by the *image reversal bake*
  - The temperature of the image reversal bake is a critical parameter
  - Requires flood exposure before development



- Chemically amplified resists
  - Photo-initiation is catalytic
  - Requires PEB
  - Dose = light + heat
    → higher throughput

Photoresist: contrast

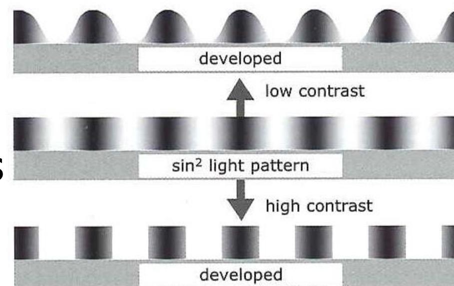
- Ideally, at least for high resolution, the response of a resist to exposure should be a step function, i.e. no development below a threshold dose; full development above the threshold dose
- In reality, development starts at a dose, D_O, but finishes at a higher dose, D_C (dose to clear), leading to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

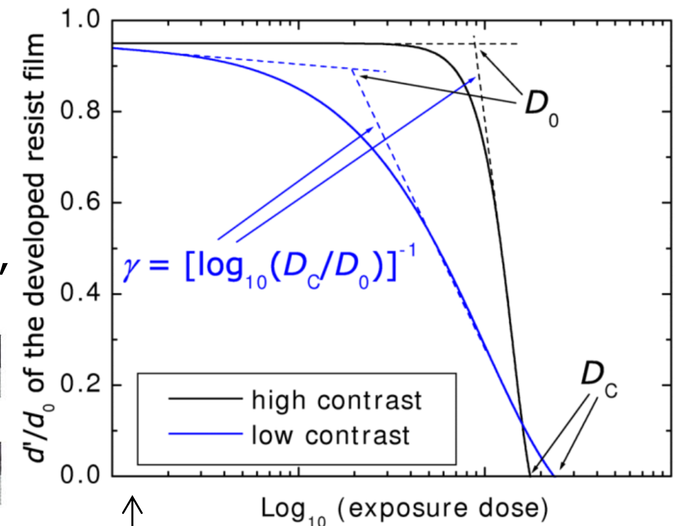
  $\gamma = \frac{1}{log\left(\frac{D_C}{D_O}\right)}$, for a positive resist

- 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





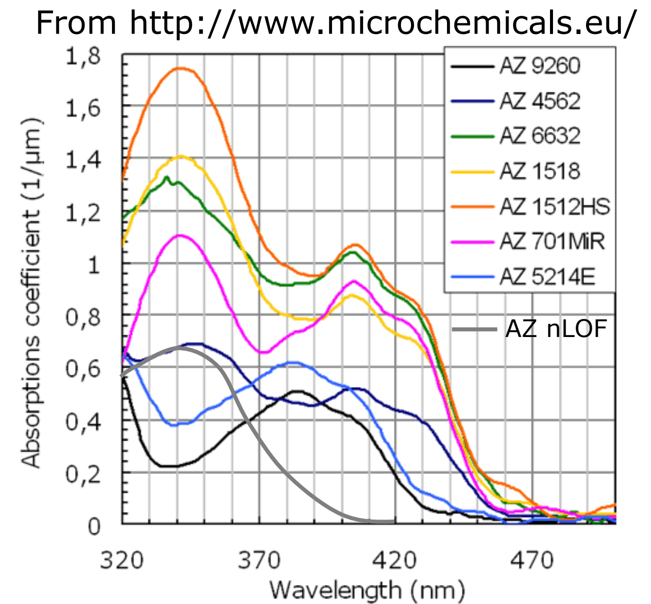
← From http://www.microchemicals.eu/

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

Photoresists at Danchip

- Standard UV-resists at Danchip are
  - Manufactured by AZ-Electronic Materials (formerly Hoechst/Clariant)
  - Distributed by MicroChemicals GmbH

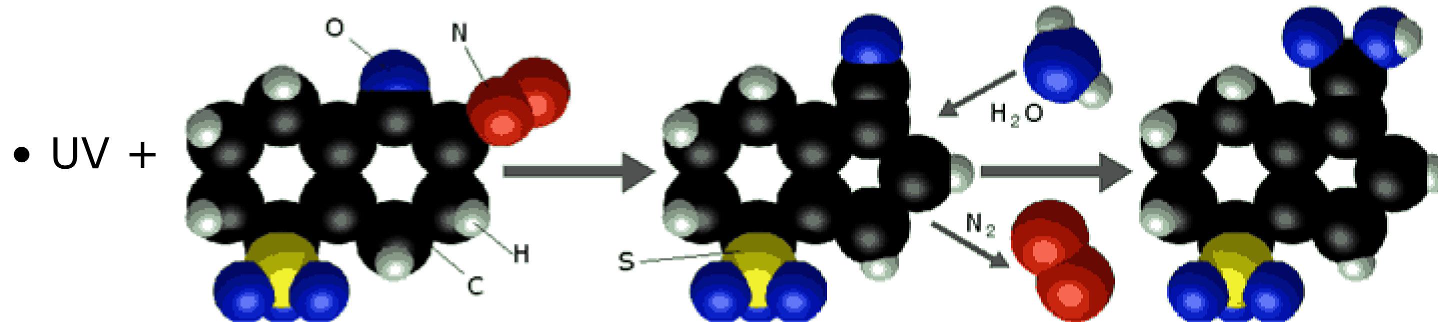
- nLOF doesn't bleach
- 5214E can be image reversed
- Spectral sensitivity ------------------------→



	MiR 701	nLOF 2020	5214E	4562
Positive	x		x	x
Negative		x	x	
Thickness	1.5 – 4 µm	1.5 – 4 µm	1.5 – 4 µm	5 – 10 µm
351B	(x)	(x)	x	x
726 MIF	x	x	x	x

Photoresist: photo-chemistry

- AZ 5214E and AZ MiR 701 have **d**iazo**n**aphtho-**q**uinone-sulphonate (DNQ) as the photo-active component, or photo-initiator
- During exposure, DNQ absorbs the exposure light, and transforms into a corboxylic acid while releasing N_2 and absorbing H_2O
- UV +



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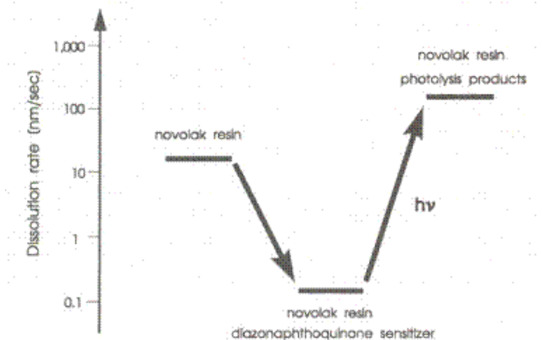
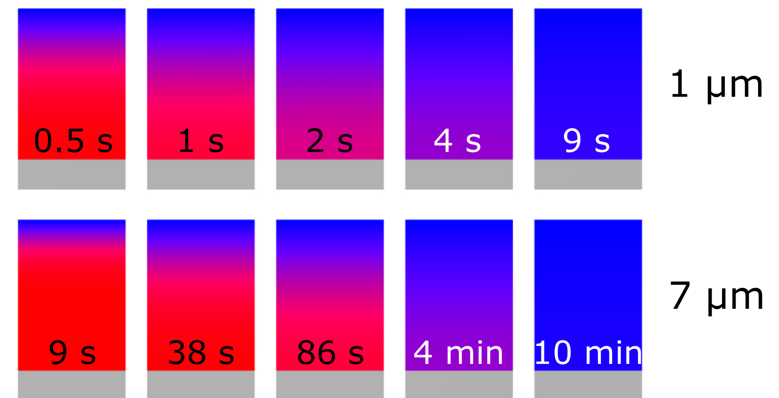
- DNQ lowers the solubility of the resin in the developer, while the corboxylic acid increases the solubility
  - → positive tone resist



From http://www.micronanofab.eu/

Photoresist: photo-chemistry, consequences

- After softbake, the resist has to rehydrate in order to enable exposure
  - 1µm rehydrates in 10s
  - 10µm requires at least 10 minutes
  - Thicker films may require hours to rehydrate
  - Insufficient rehydration leads to under-development and/or non-straight sidewalls



From http://www.microchemicals.eu/

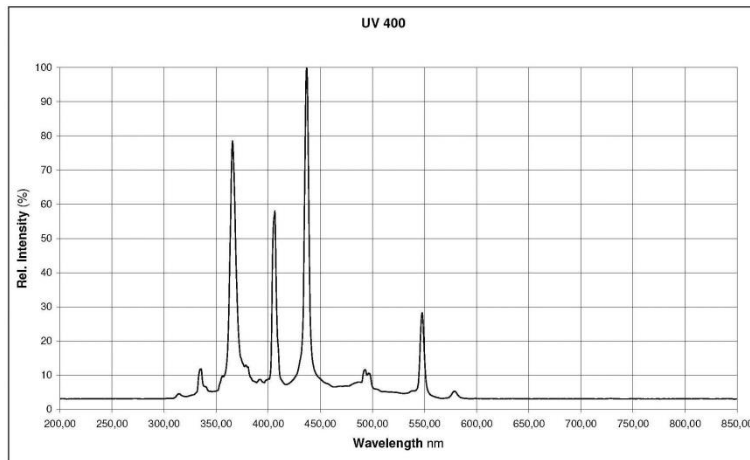
- After exposure, the N_2 has to outgas before any thermal process in order to prevent bubbles from forming
  - Before image reversal bake (5214E), and possibly PEB (MiR 701)
  - 1µm outgasses in ~1 minute, 3µm in ~10 minutes, while a 10µm film may require hours to outgas

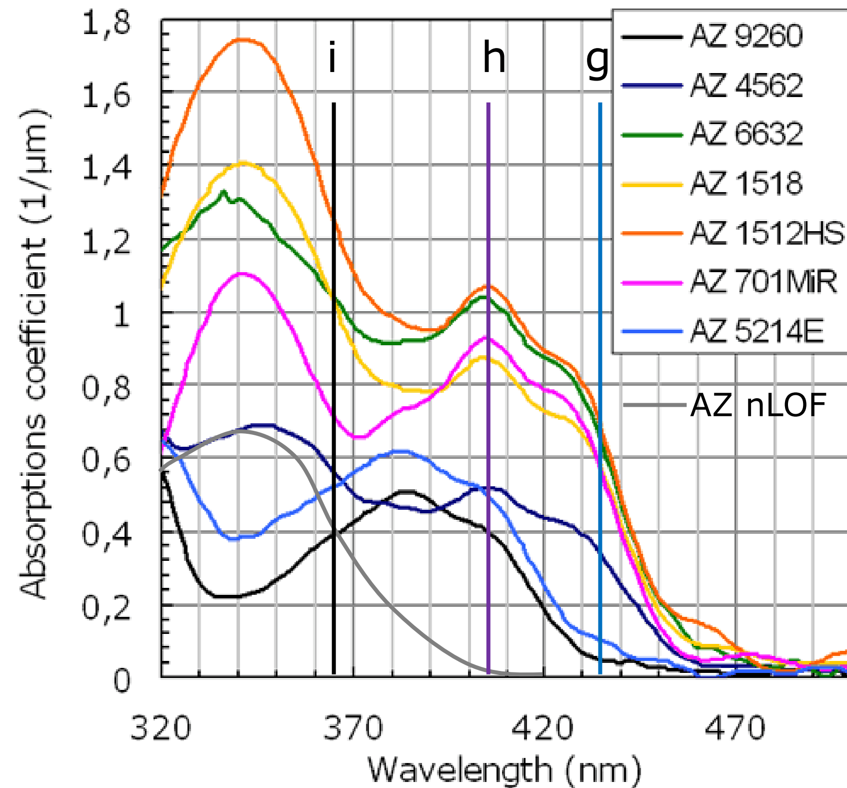
- AZ nLOF 2020 has a different PAC (melamine-based crosslinker), and does not require rehydration or outgassing

Photoresist: exercise

Estimate the change in exposure dose when changing from i-line exposure (365nm) to broadband exposure (365nm + 405nm + 435nm)

- MiR 701
  - ~1/3 dose
- nLOF 2020
  - No change
- 5214E
  - ~1/2 dose





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