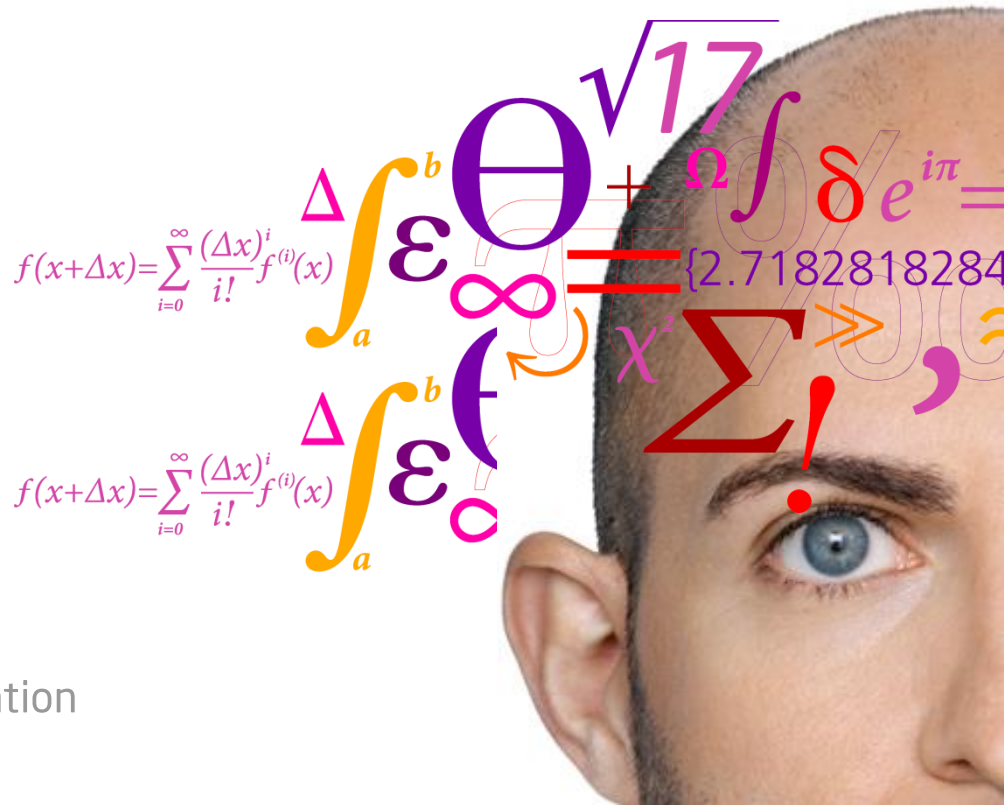
Lithography Tool Package

Process effects and real life process examples

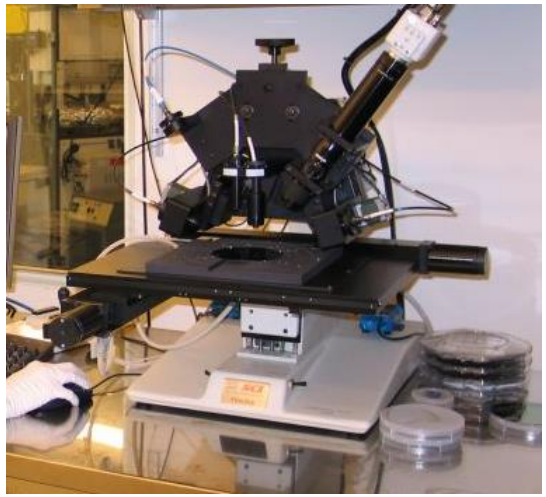


DTU Danchip

National Center for Micro- and Nanofabrication

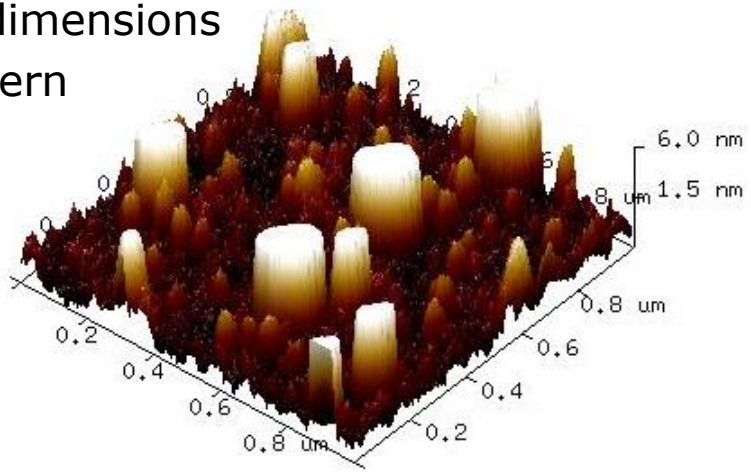
Inspection: characterization methods

- Reflectometry/Ellipsometry
  - Determines film thickness and refractive index using spectral reflectance/polarization
  - Complicated theory and modelling
  - For characterizing coating thickness and uniformity



- Profilometry
  - Mechanical (stylus) or Optical (interferometry/confocal microscope)
  - Measuring film thickness and/or pattern dimensions
  - For checking and documenting resist pattern

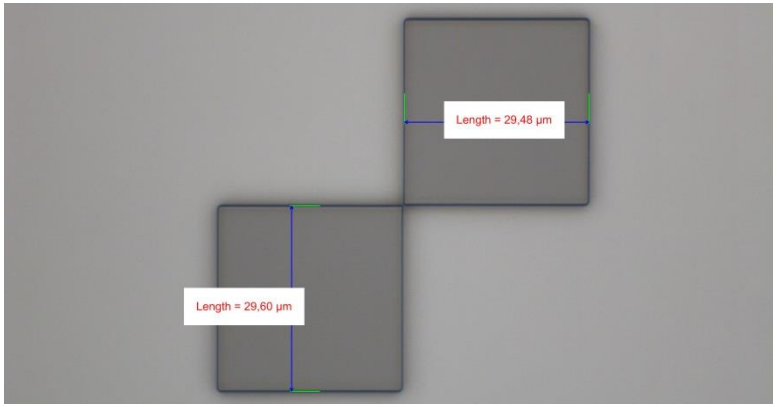
- Atomic Force Microscopy
  - Measuring pattern dimensions
  - Measuring surface roughness
  - For documenting resist pattern

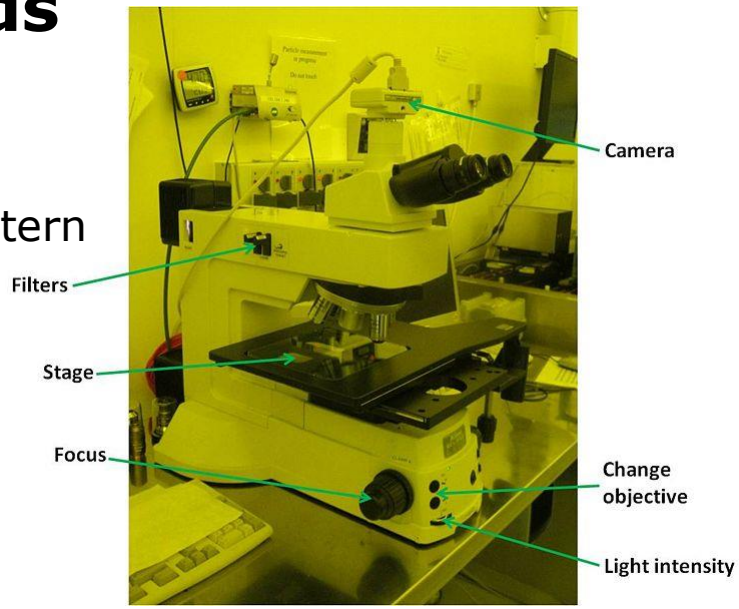


Courtesy of Sonny Massahi

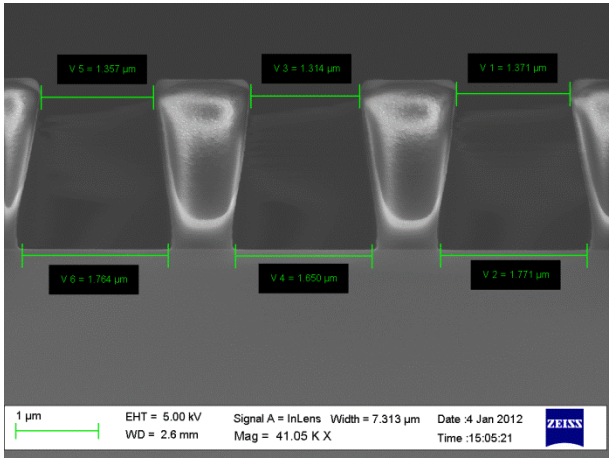
Inspection: imaging methods

- Optical microscopy
  - Measuring pattern dimensions
  - For checking and documenting resist pattern





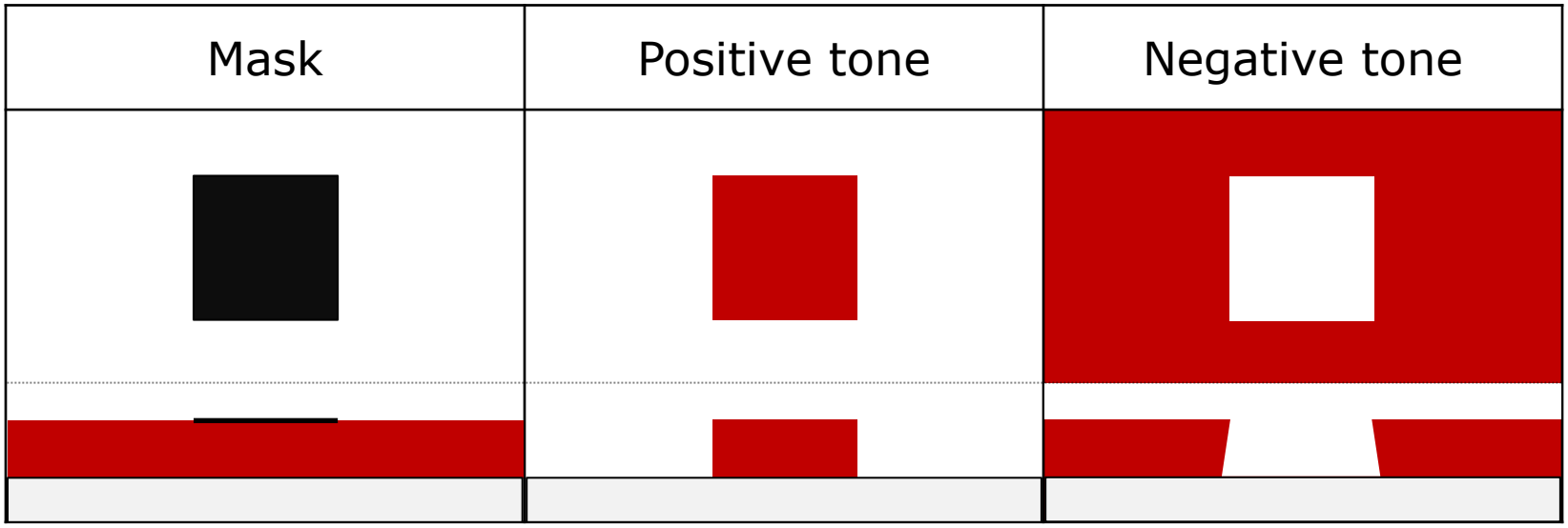
- Scanning Electron Microscopy
  - Measuring pattern dimensions
  - Imaging resist profiles
  - For checking and documenting resist pattern
- Characterization TPT covers SEM



Processing: effects

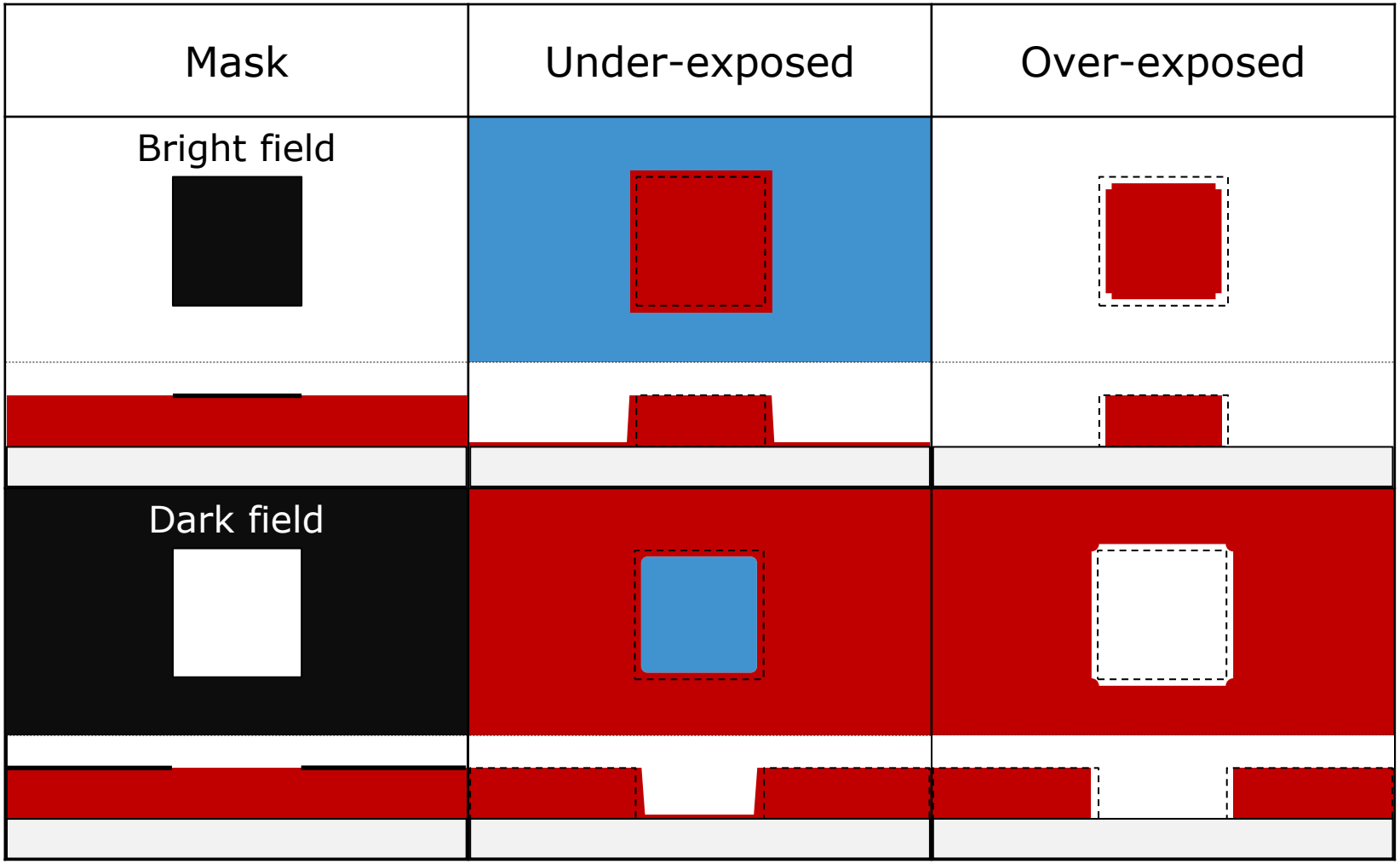
- The following slides shows simplified, exaggerated representations of top-view and cross-section inspection of resist patterns, for a square design, tens of µm in size
- Effects of exposure mode, exposure dose, and development time are shown, first for positive tone resist, then for negative tone resist
- Some effects are also illustrated by OM inspections of a real life process

- Inspection example (bright field design, optimal conditions):

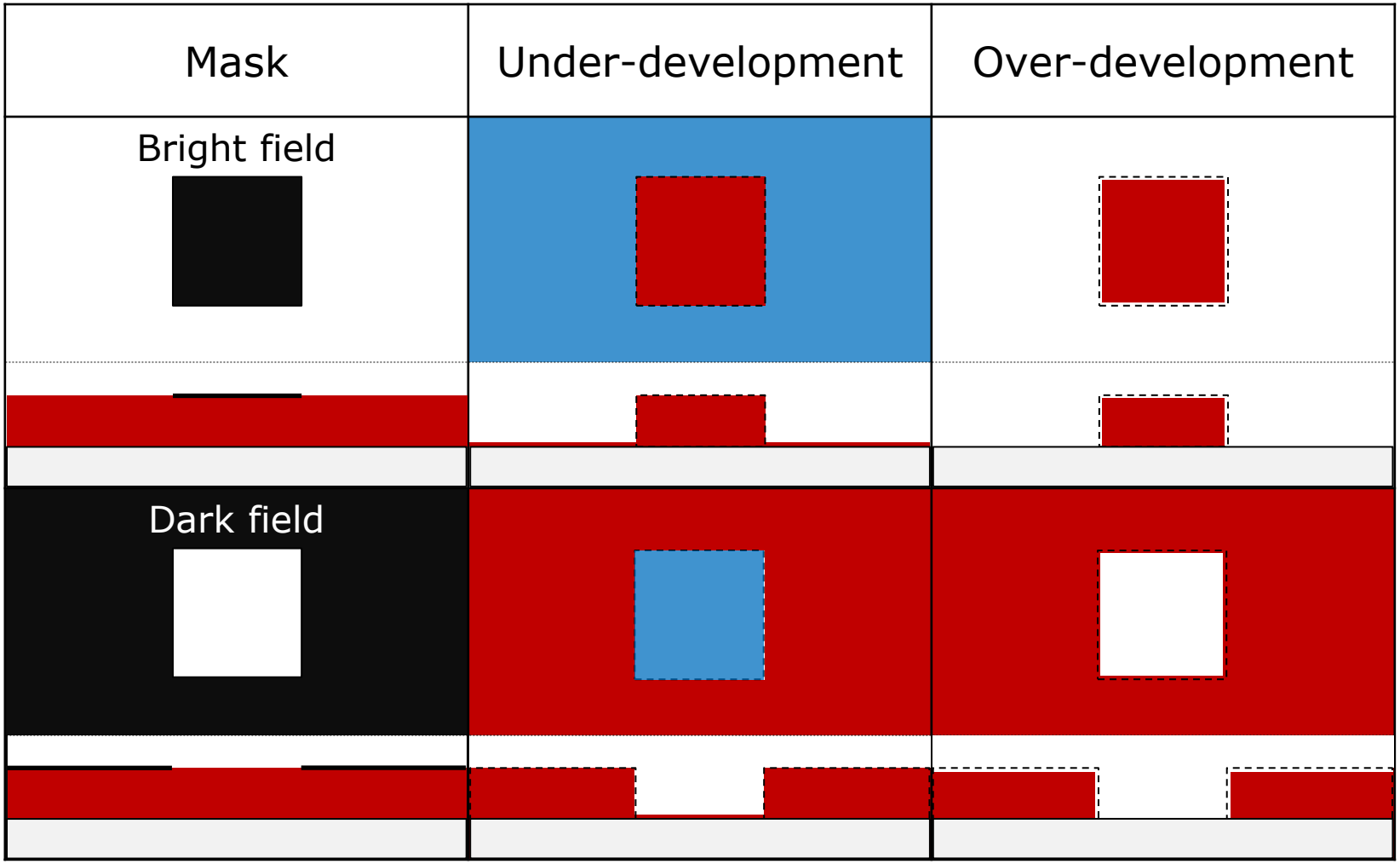


Positive tone resist: exposure mode

Positive tone resist: exposure dose



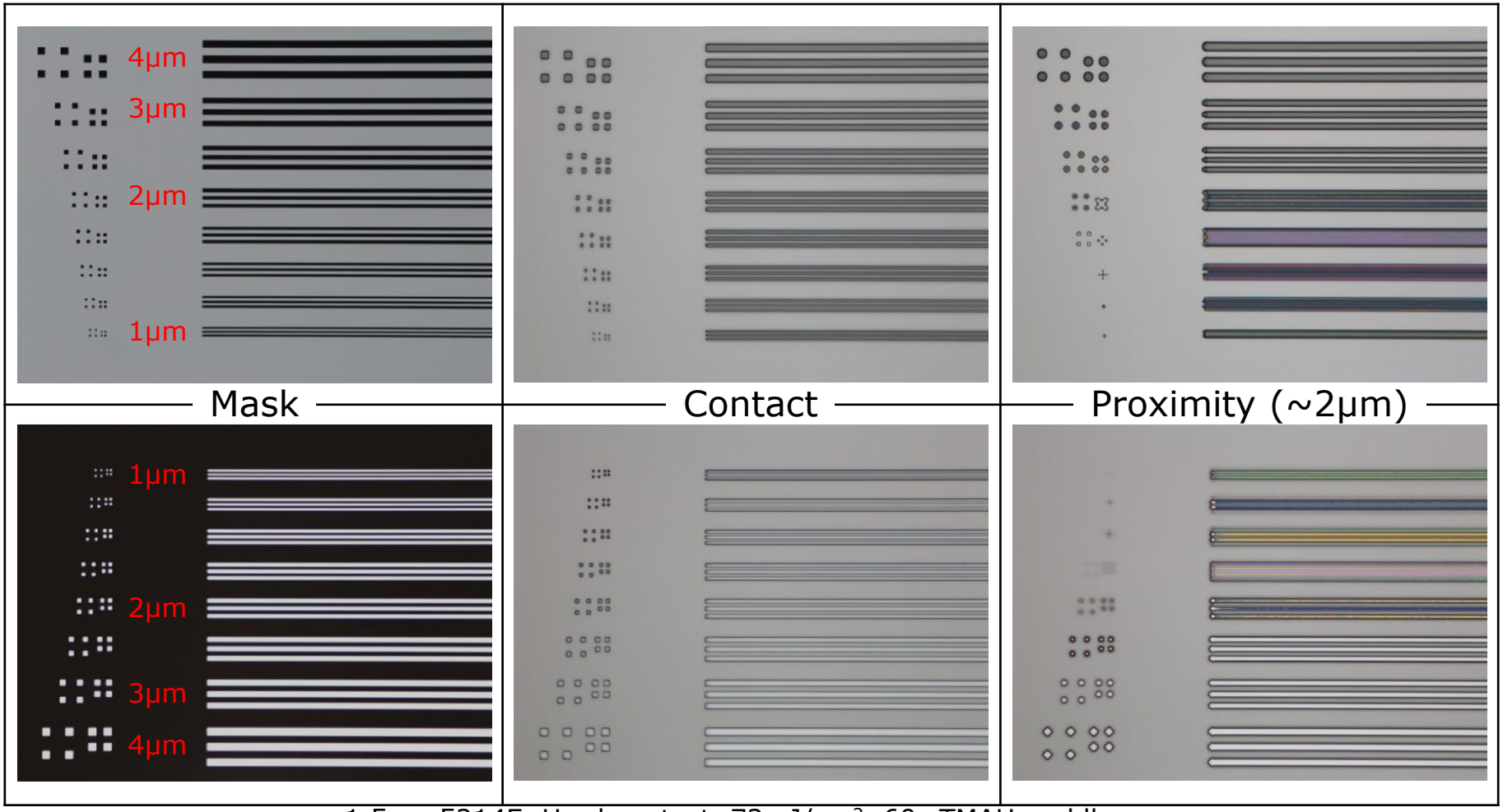
Positive tone resist: development time



AZ 5214E: real life process flow

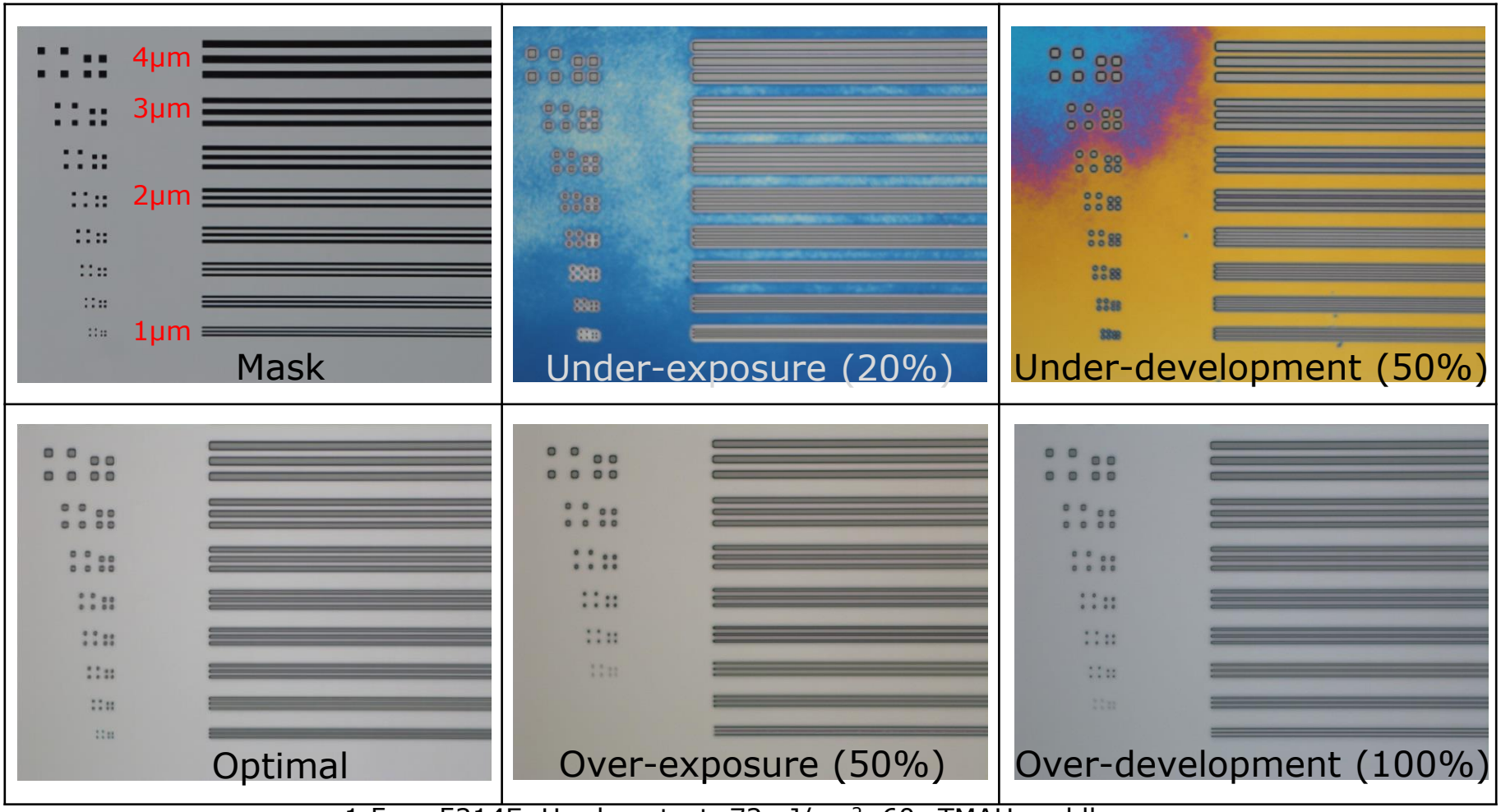
Step	Header	Equipment		Comments
1	Spin coat of AZ 5214E with HMDS priming			
1.1	Coat wafers	Spin Coater: Gamma UV	**Resist:** AZ 5214E (line 3) **Spin:** 30 s @ 4500 rpm (~1.5 µm) **Softbake:** 60 s @ 90 °C **Sequence:** DCH 100mm 5214E 1.5um HMDS	Si substrate HMDS priming: 15 s @ 120°C
2	Exposure			
2.1	Expose	Aligner: MA6 – 2	**Mask:** Litho test **Exposure mode:** Hard contact **Exposure dose:** 72 mJ/cm^2	HC wait time: 10 s Exposure time: 5.5 s @ 13 mW/cm^2
3	Development			
3.1	Develop	Developer: TMAH UV-lithography	**Development in AZ 726 MIF:** single puddle, 60 s **Sequence:** DCH 100mm SP 60s	
4	Inspection			
4.1	Inspection	Optical microscope	**Inspect:** Line and dot patterns, bright field and dark field, using 20X objective	

AZ 5214E: exposure mode



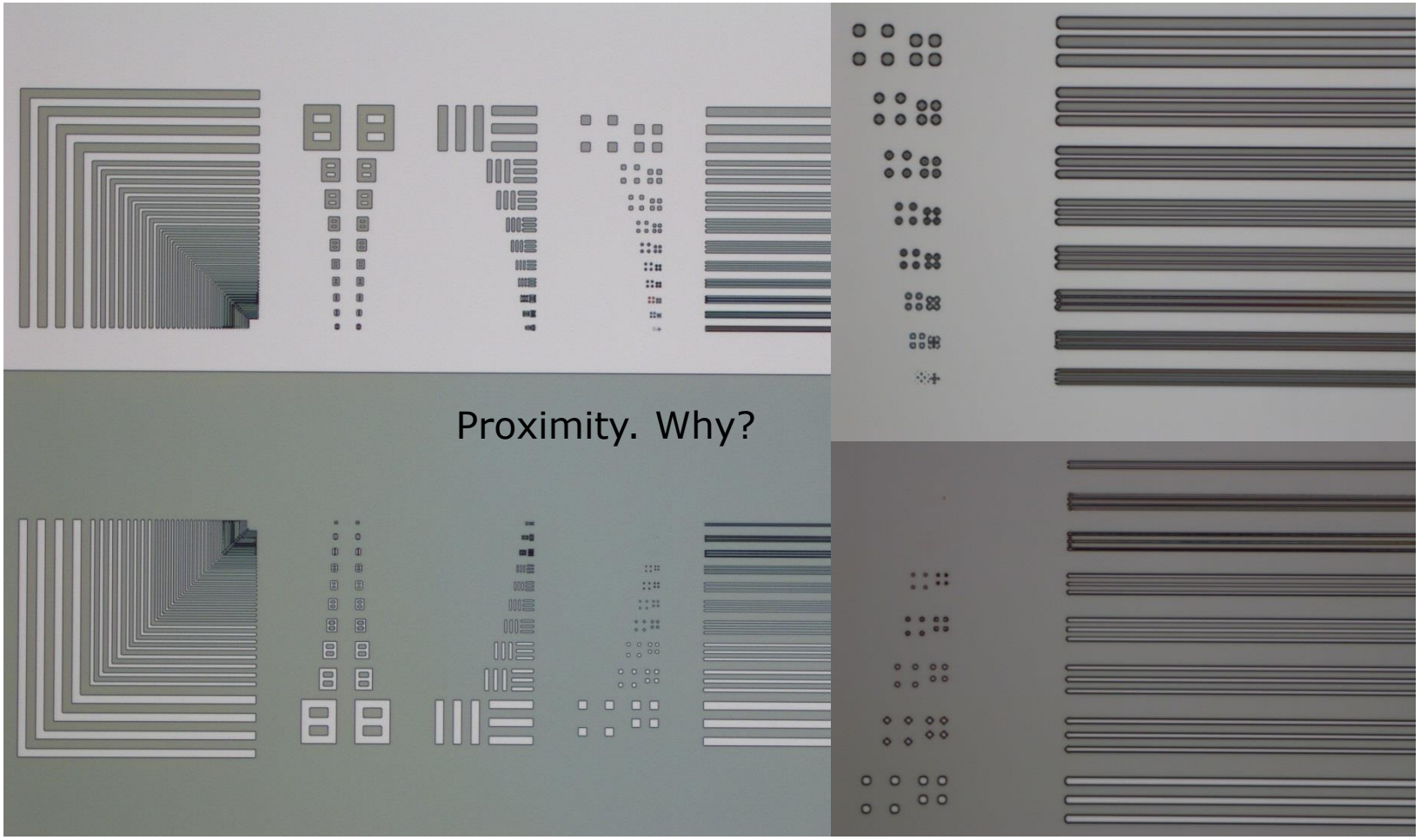
1.5µm 5214E, Hard contact, 72mJ/cm², 60s TMAH puddle

AZ 5214E: process window



1.5µm 5214E, Hard contact, 72mJ/cm^2, 60s TMAH puddle

Exercise: What went wrong?

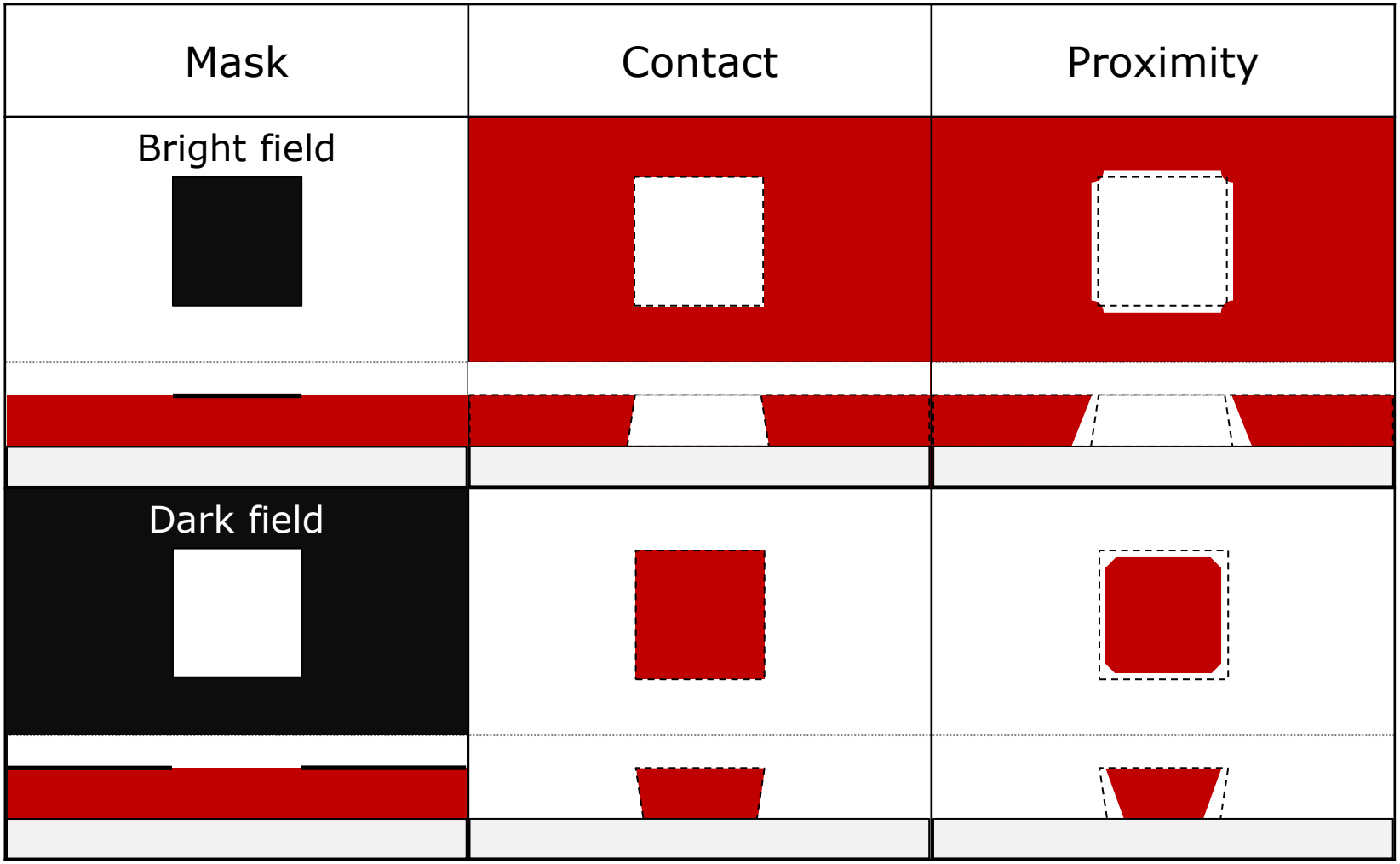


1.5µm MiR 701, Hard contact, 169mJ/cm^2, PEB 60s @ 110°C, 60s TMAH puddle

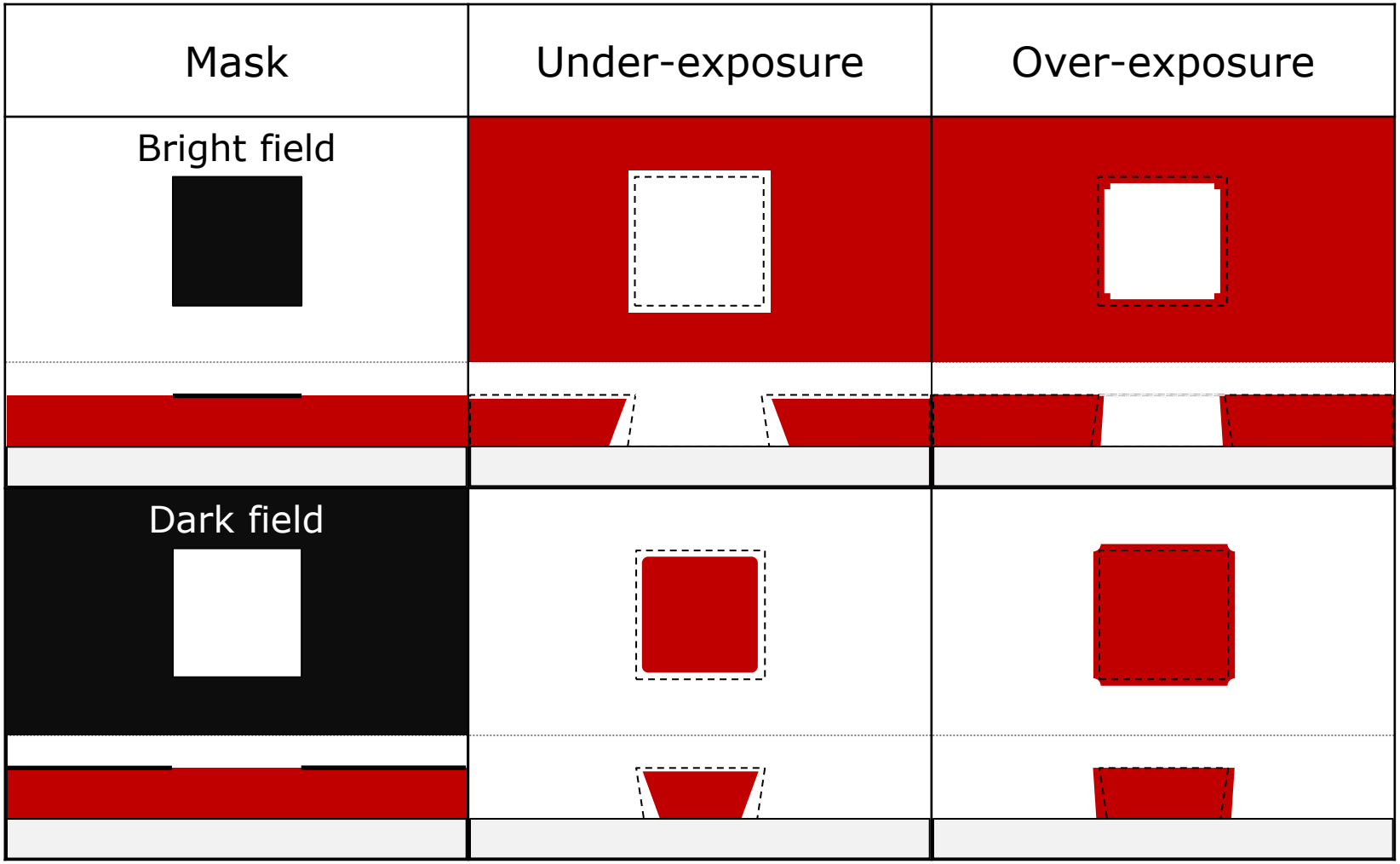
Exercise: a clue…

1.5µm MiR 701, Vacuum contact, 169mJ/cm^2, PEB 60s @ 110°C, 60s TMAH puddle

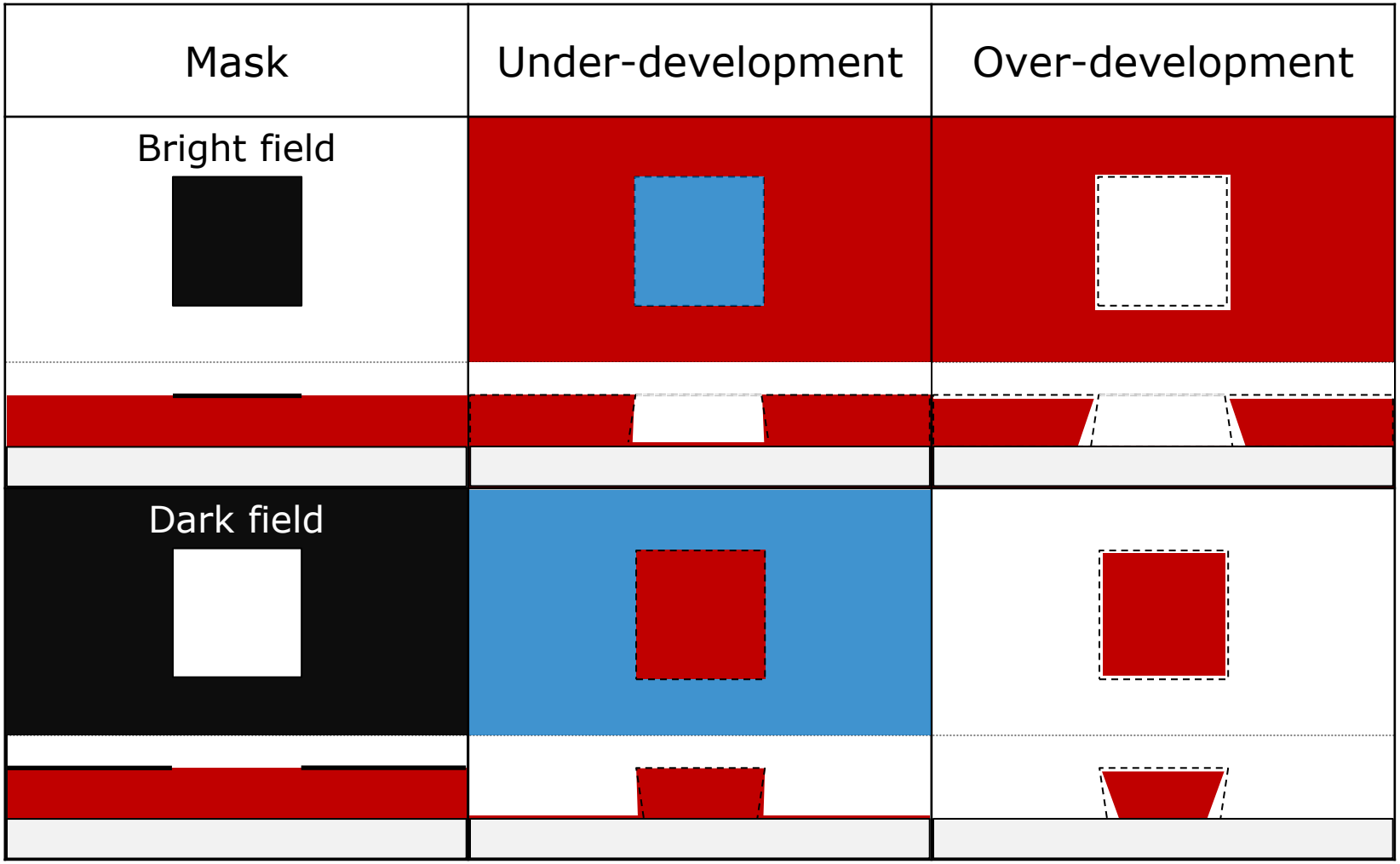
Negative tone resist: exposure mode



Negative tone resist: exposure dose



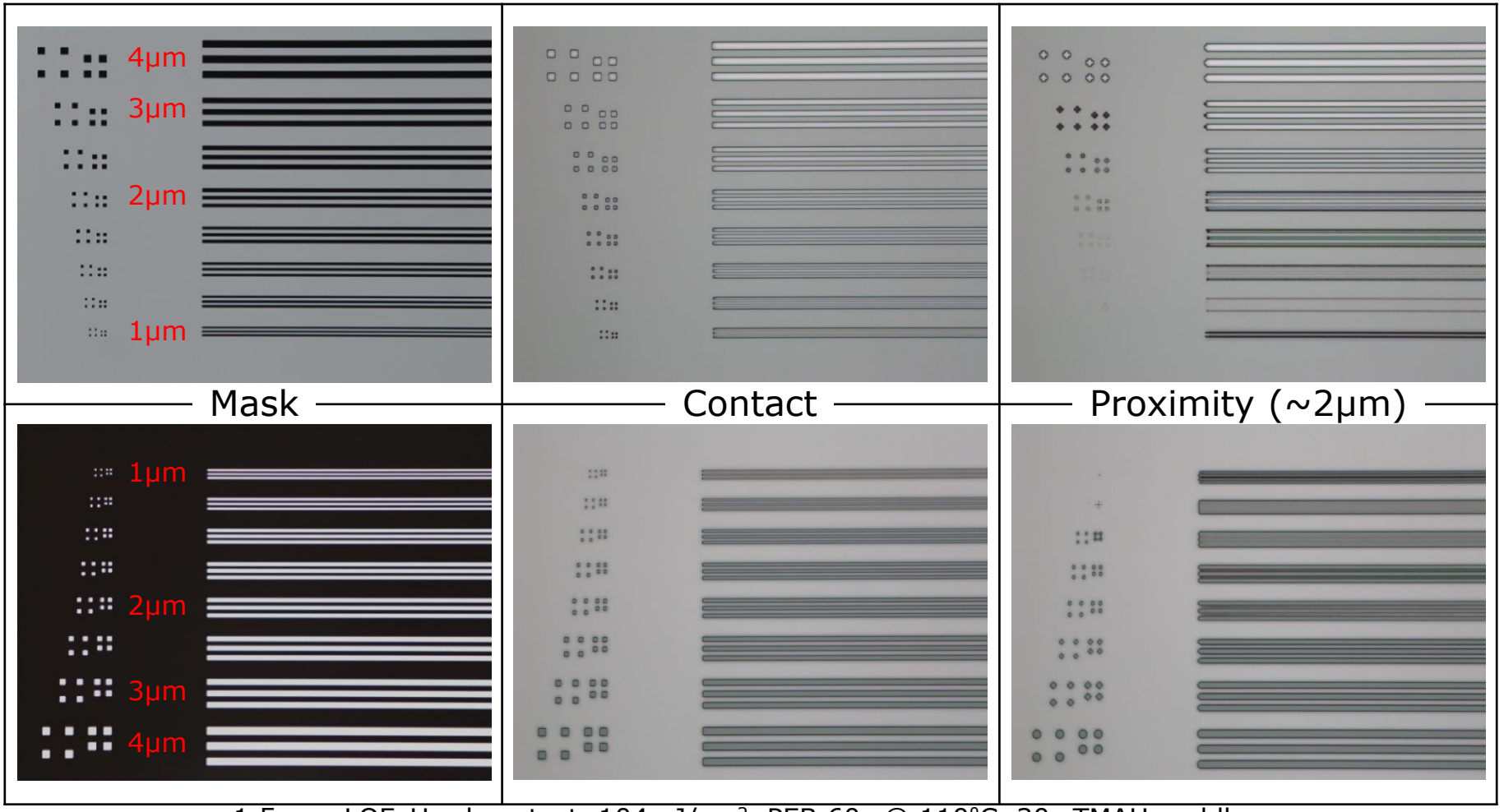
Negative tone resist: development time



AZ nLOF 2020: real life process flow

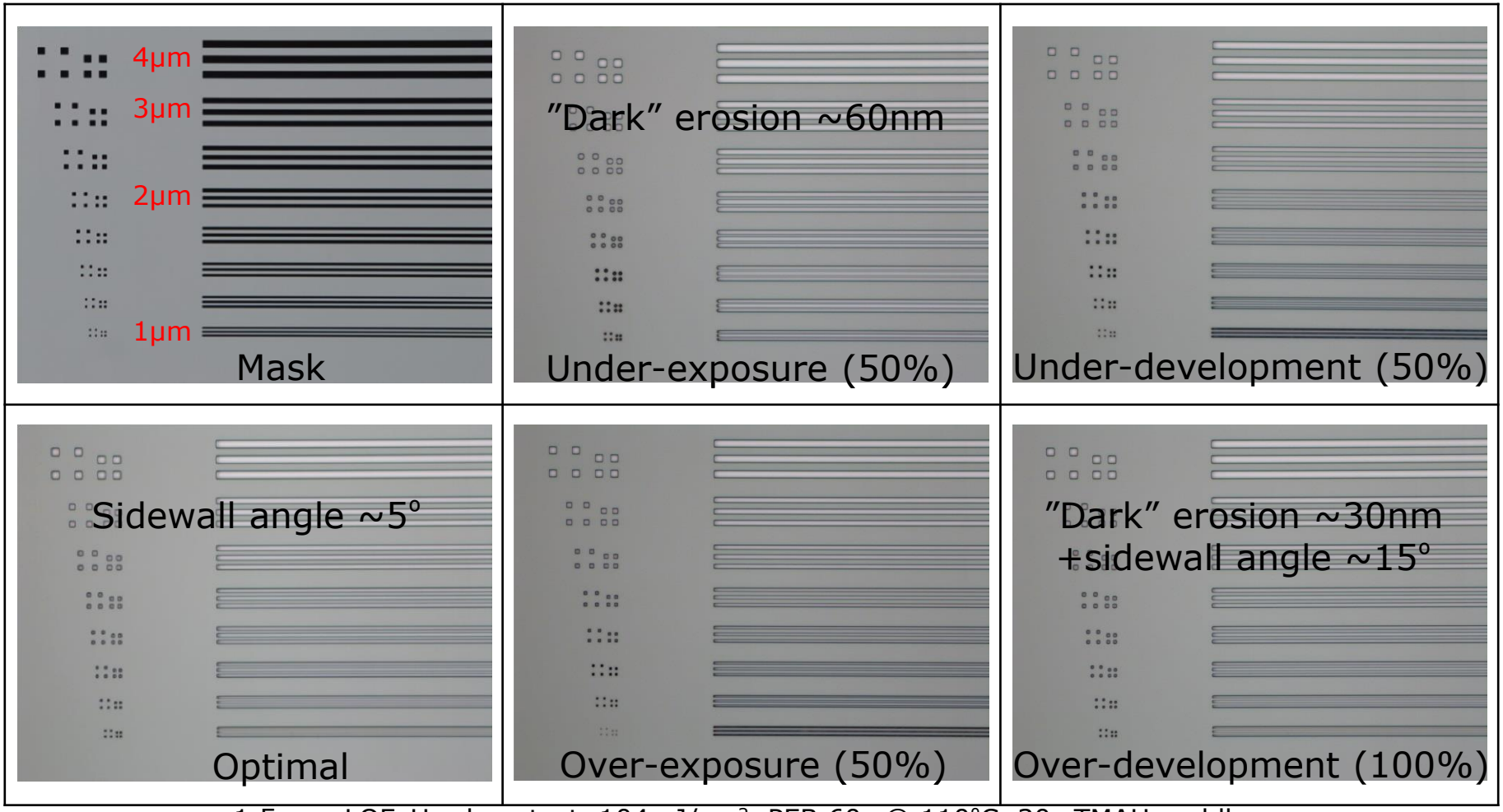
Step	Header	Equipment		Comments
1	Spin coat of AZ nLOF 2020 with HMDS priming			
1.1	Coat wafers	Spin Track 1 + 2	**Resist:** AZ nLOF 2020 (track 2) **Spin:** 30 s @ 6700 rpm (~1.5 µm) **Softbake:** 60 s @ 110 °C **Flow:** T2 nLOF 2020 2um with HMDS	Si substrate HMDS priming: 72 s @ 50°C
2	UV Exposure			
2.1	Exposure	Aligner: MA6 – 2	**Mask:** Litho test **Exposure mode:** Hard contact **Exposure dose:** 104 mJ/cm^2	HC wait time: 10 s Exposure time: 8.6 s @ 13 mW/cm^2
3	Post Exposure Bake			
3.1	Post Exposure Bake	Developer: TMAH UV-lithography	**Post Exposure Bake:** 60 s @ 110 °C **Sequence:** DCH 100mm PEB60s@110C+SP30s	PEB and development is done simultaneously
4	Development			
4.1	Develop	Developer: TMAH UV-lithography	**Development in AZ 726 MIF:** single puddle, 30 s **Sequence:** DCH 100mm PEB60s@110C+SP30s	PEB and development is done simultaneously
5	Inspection			
5.1	Inspection	Optical microscope	**Inspect:** Line and dot patterns, bright field and dark field, using 20X objective	

AZ nLOF 2020: exposure mode

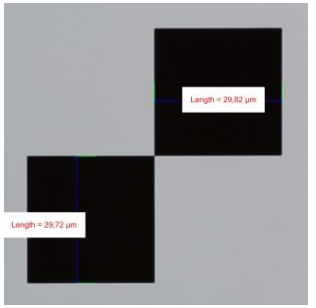


1.5µm nLOF, Hard contact, 104mJ/cm², PEB 60s @ 110°C, 30s TMAH puddle

AZ nLOF 2020: process window



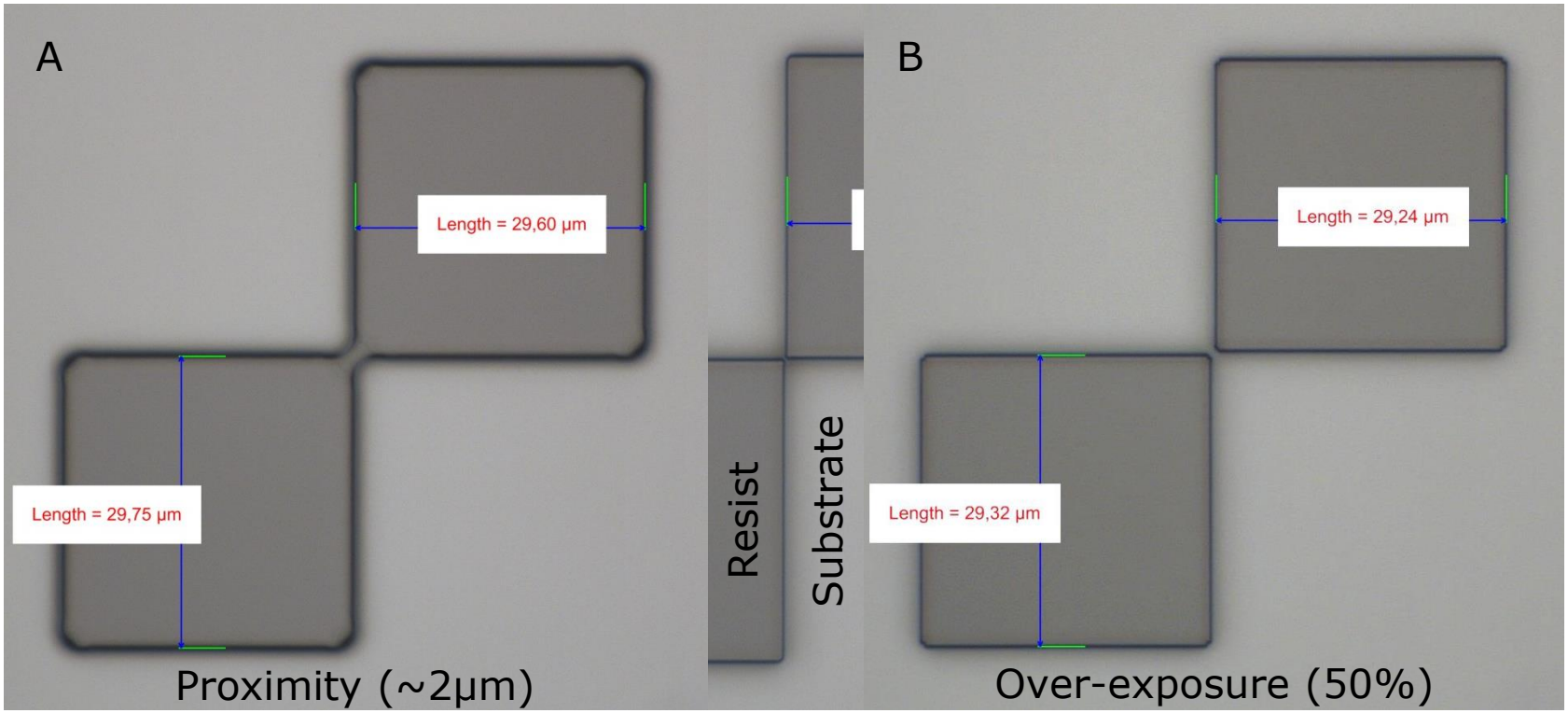
1.5µm nLOF, Hard contact, 104mJ/cm^2, PEB 60s @ 110°C, 30s TMAH puddle



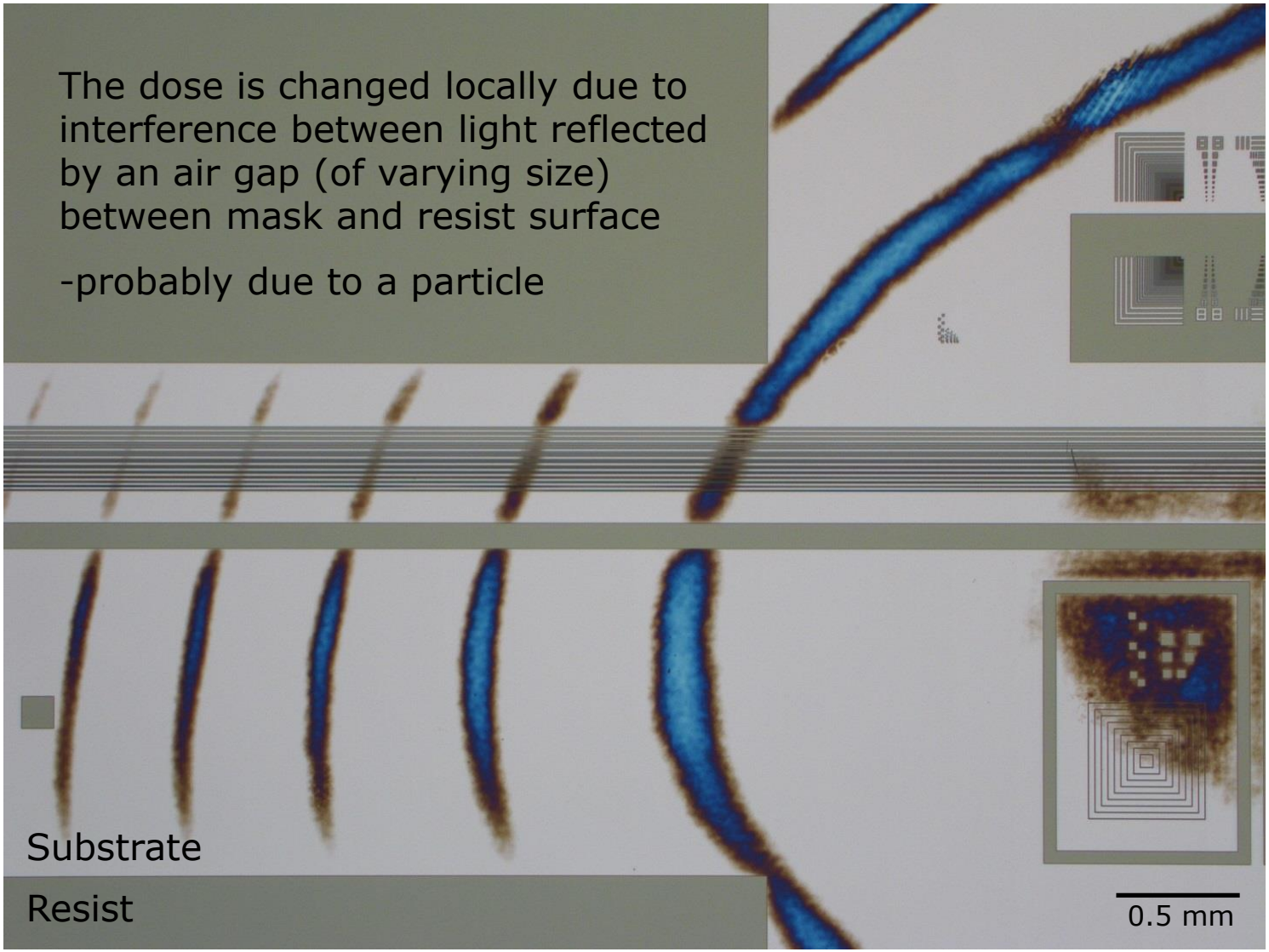
Processing effects: exercise

Consider a bright field design of two 30µm by 30µm squares corner to corner processed using a positive tone resist.

Discuss in teams what process effect may have caused the result in A or B



Processing effects: Newton's rings



Process:

1.5 µm MiR 701

Vacuum contact

156 mJ/cm^2

PEB 60 s @ 110°C

60 s TMAH puddle

Further reading

- MicroChemicals homepage
  - Downloads → Application notes
    www.microchemicals.com/downloads/application_notes.html (2015)
  - Notes on composition, processing, and use of photoresists
  - E.g. "Lithography Trouble-Shooter"
    www.microchemicals.com/support/troubleshooter.html (2015)

- LabAdviser
  - labadviser.danchip.dtu.dk
  - Information on machines, resists, and processes
    labadviser.danchip.dtu.dk/index.php/Specific_Process_Knowledge/Lithography/UVLithography
  - E.g. "Information on UV Exposure Dose"
    labadviser.danchip.dtu.dk/index.php/Specific_Process_Knowledge/Lithography/UVExposure_Dose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