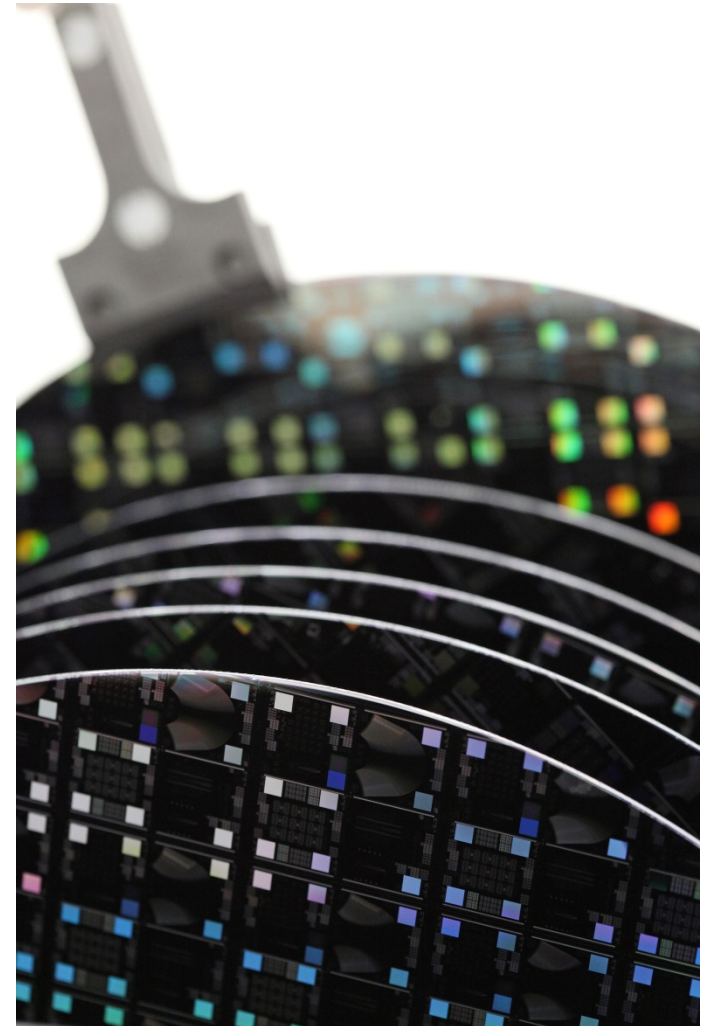


Lithography Tool Package

6. Process effects and real life process examples

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Outline

1. Introduction

- Process steps in UV lithography

2. Spin coating

- Resist composition
- Pre-treatment
- Principle
- Softbake
- Spin curve

3. Exposure

- Hardware
- Process parameters
- Resolution
- Alignment

4. Development

- Principle
- Effects
- Resist tone, photo-chemistry, and contrast

5. Post-processing and characterization

- Post processing
- Characterization methods

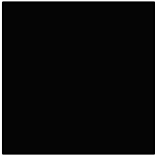





6. Process effects and examples

- Process effects
- Real life process examples

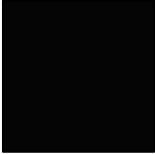





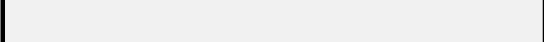
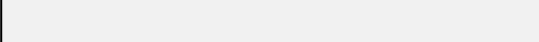
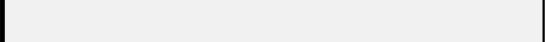
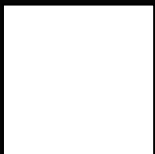
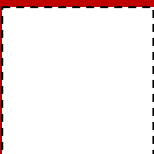
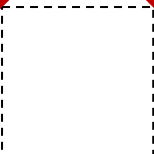








Processing: effects

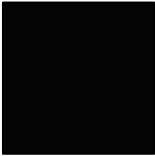
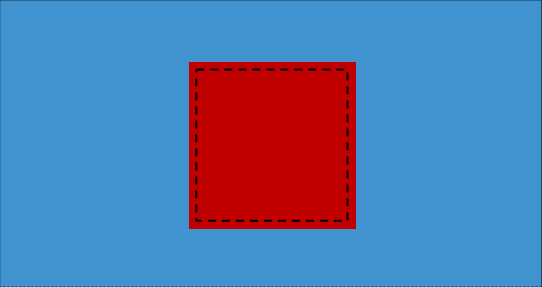
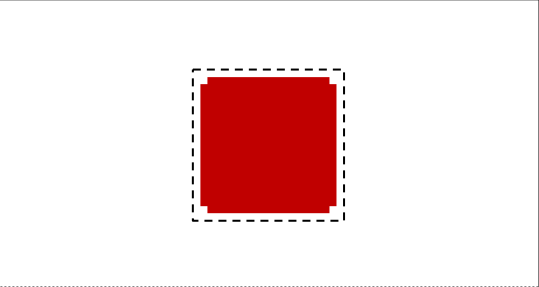



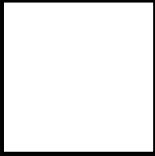
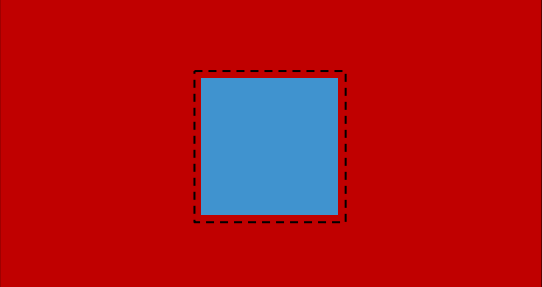
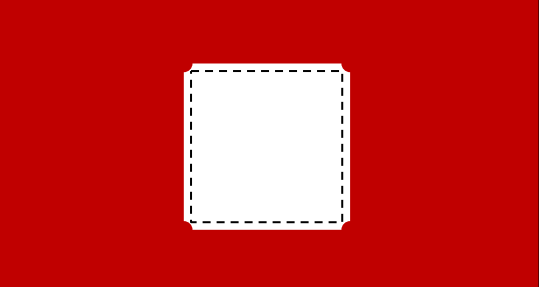


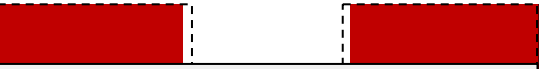
- The following slides shows simplified, exaggerated representations of top-view and cross-section inspection of resist patterns, for a square design, tens of μm in size
- Effects of exposure mode, exposure dose, and development time are shown, first for positive tone resist, then for negative tone resist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

Mask	Positive tone	Negative tone
		
		

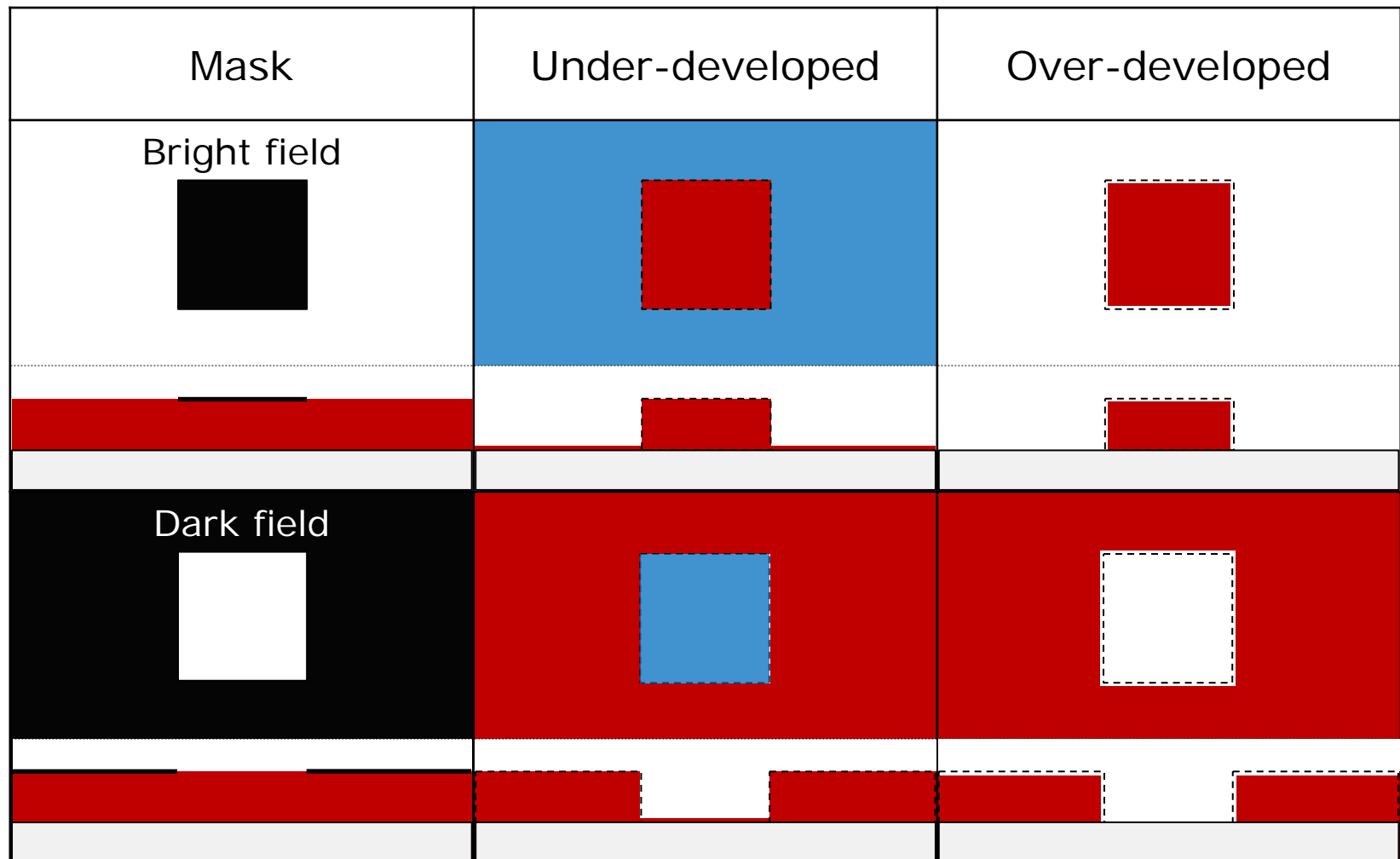
Positive tone resist: exposure mode

Mask	Contact	Proximity
<p>Bright field</p> 		
		
		
<p>Dark field</p> 		
		
		

Positive tone resist: exposure dose

Mask	Under-exposed	Over-exposed
<p>Bright field</p> 		
		
<p>Dark field</p> 		
		

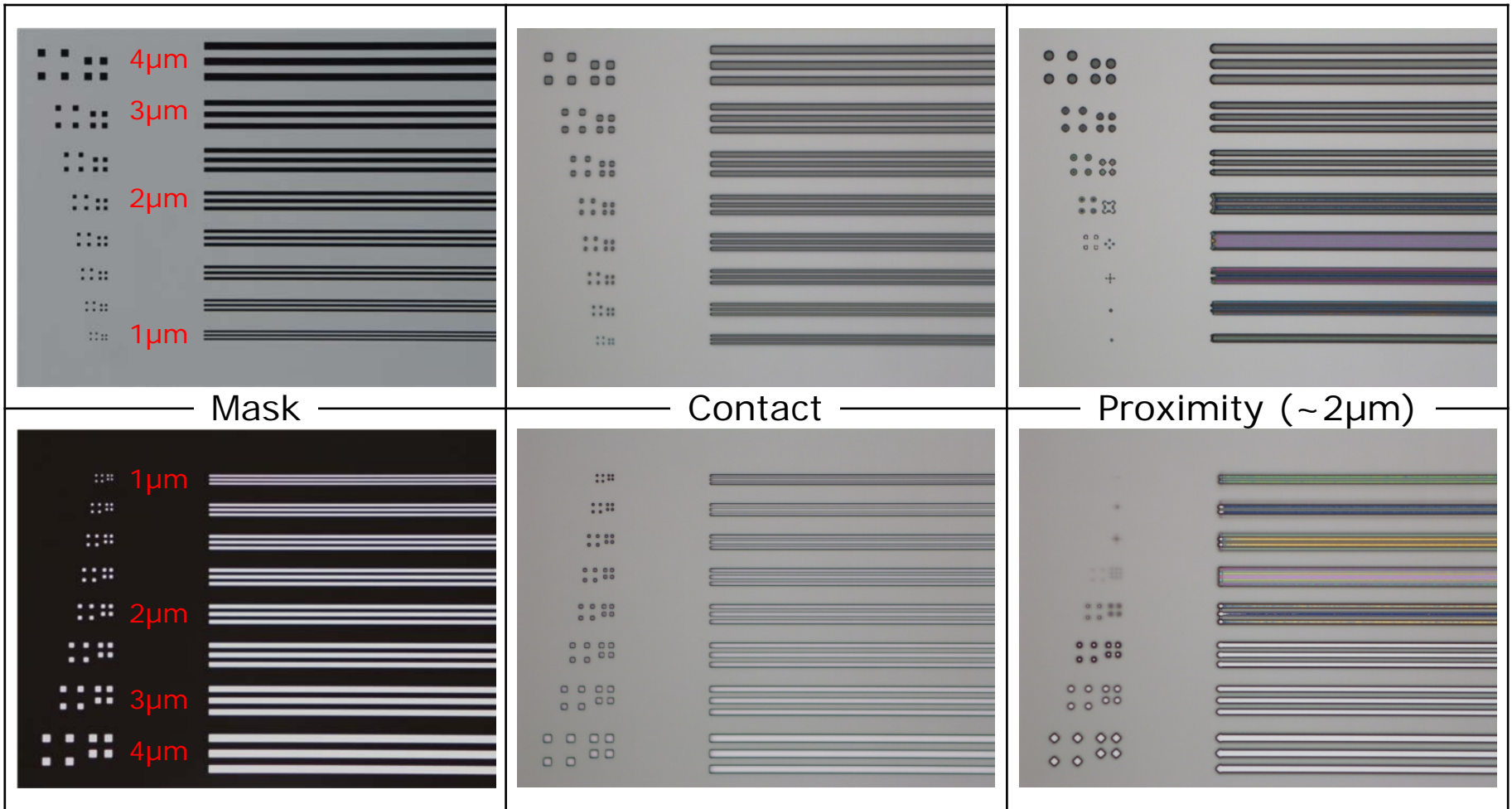
Positive tone resist: development time



AZ 5214E: real life process flow

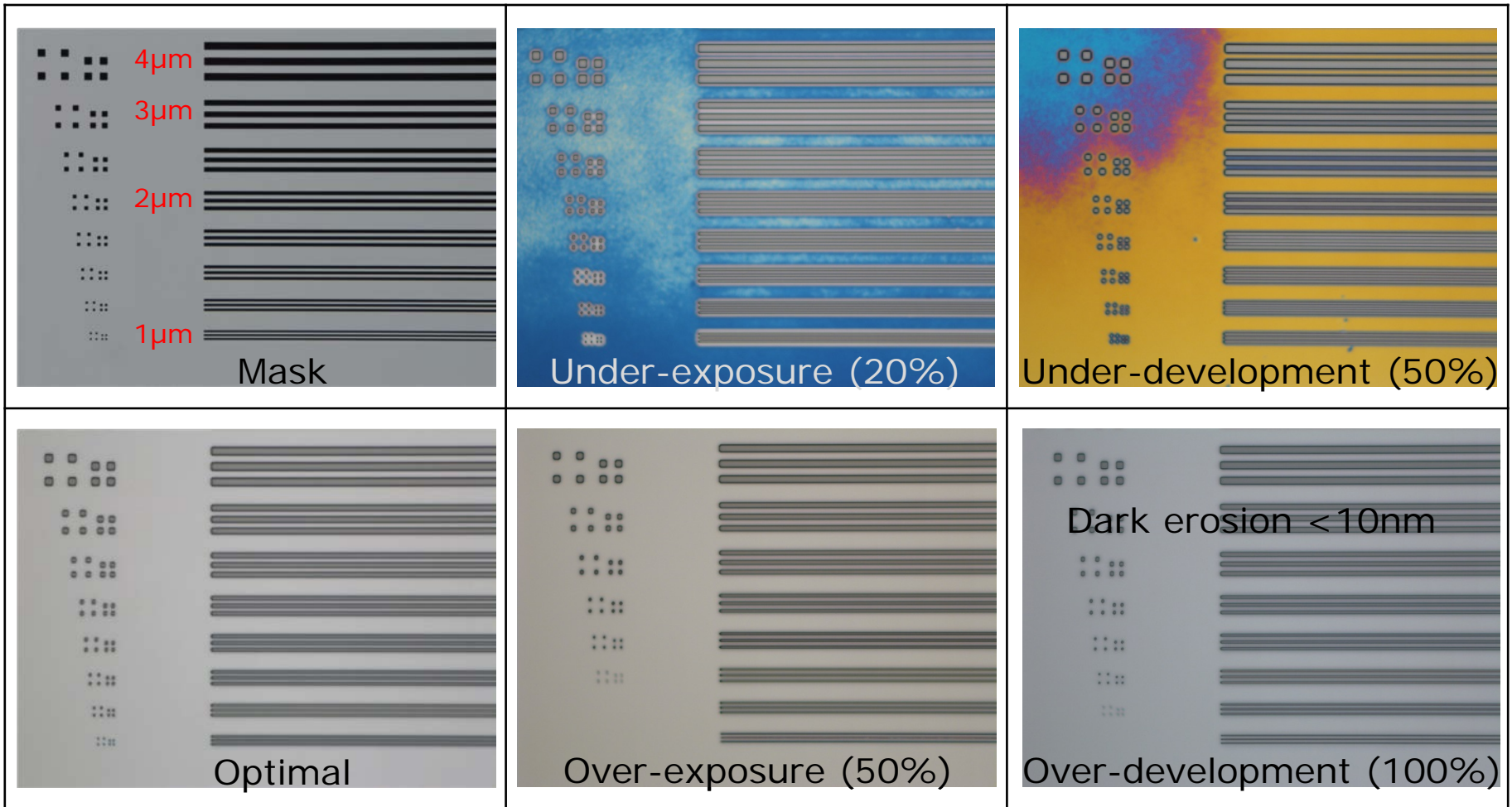
Step Header	Equipment		Comments
1 Spin coat of AZ 5214E with HMDS priming			
1.1 Coat wafers	Spin Coater: Gamma UV	Resist: AZ 5214E (line 3) Spin: 30 s @ 4500 rpm (~1.5 μm) Softbake: 60 s @ 90 °C Sequence: DCH 100mm 5214E 1.5um HMDS	Si substrate HMDS priming: 15 s @ 120°C
2 Exposure			
2.1 Expose	Aligner: 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



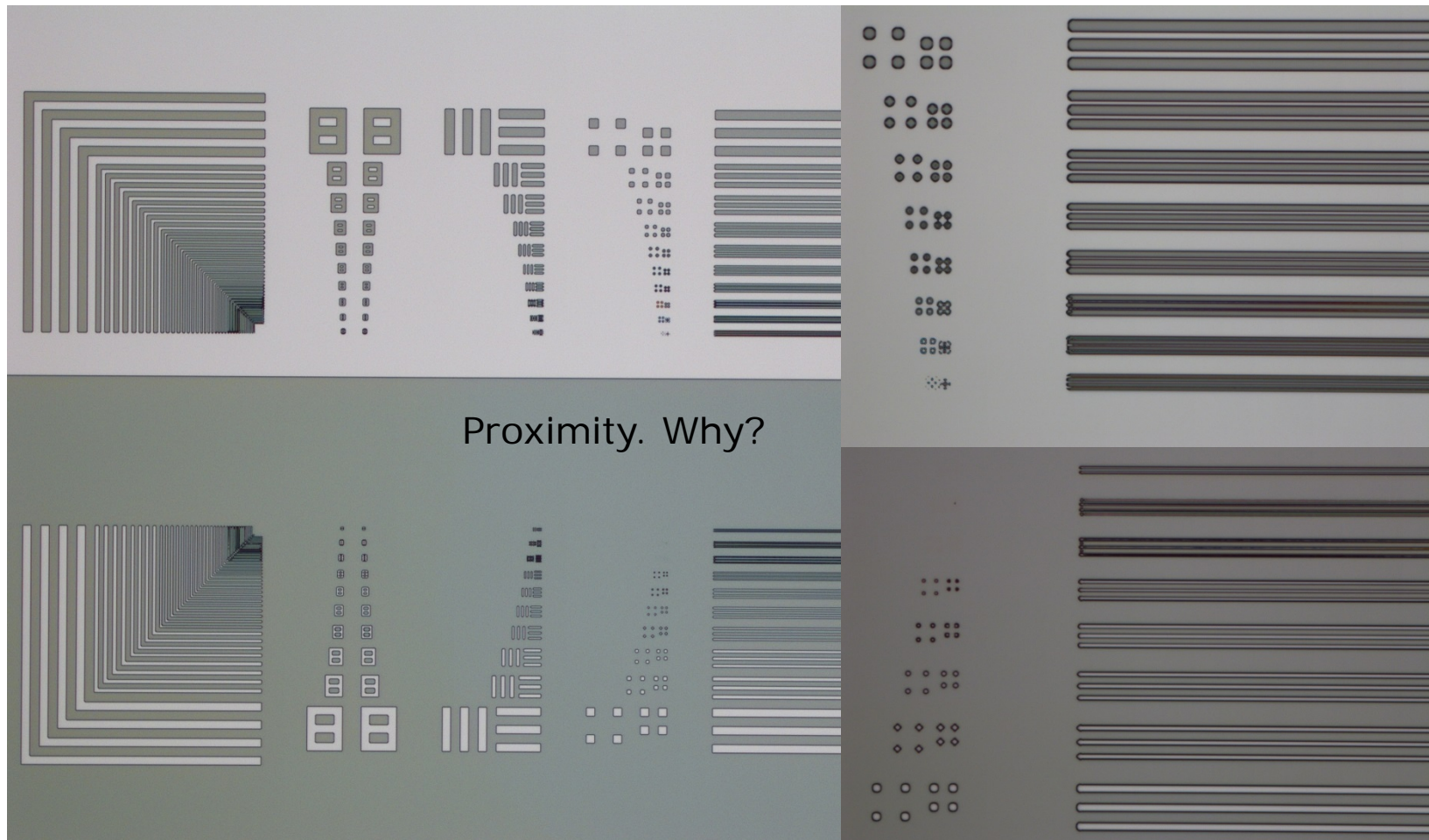
1.5µm 5214E, Hard contact, 72mJ/cm², 60s TMAH puddle

AZ 5214E: process window



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

Exercise: What went wrong?



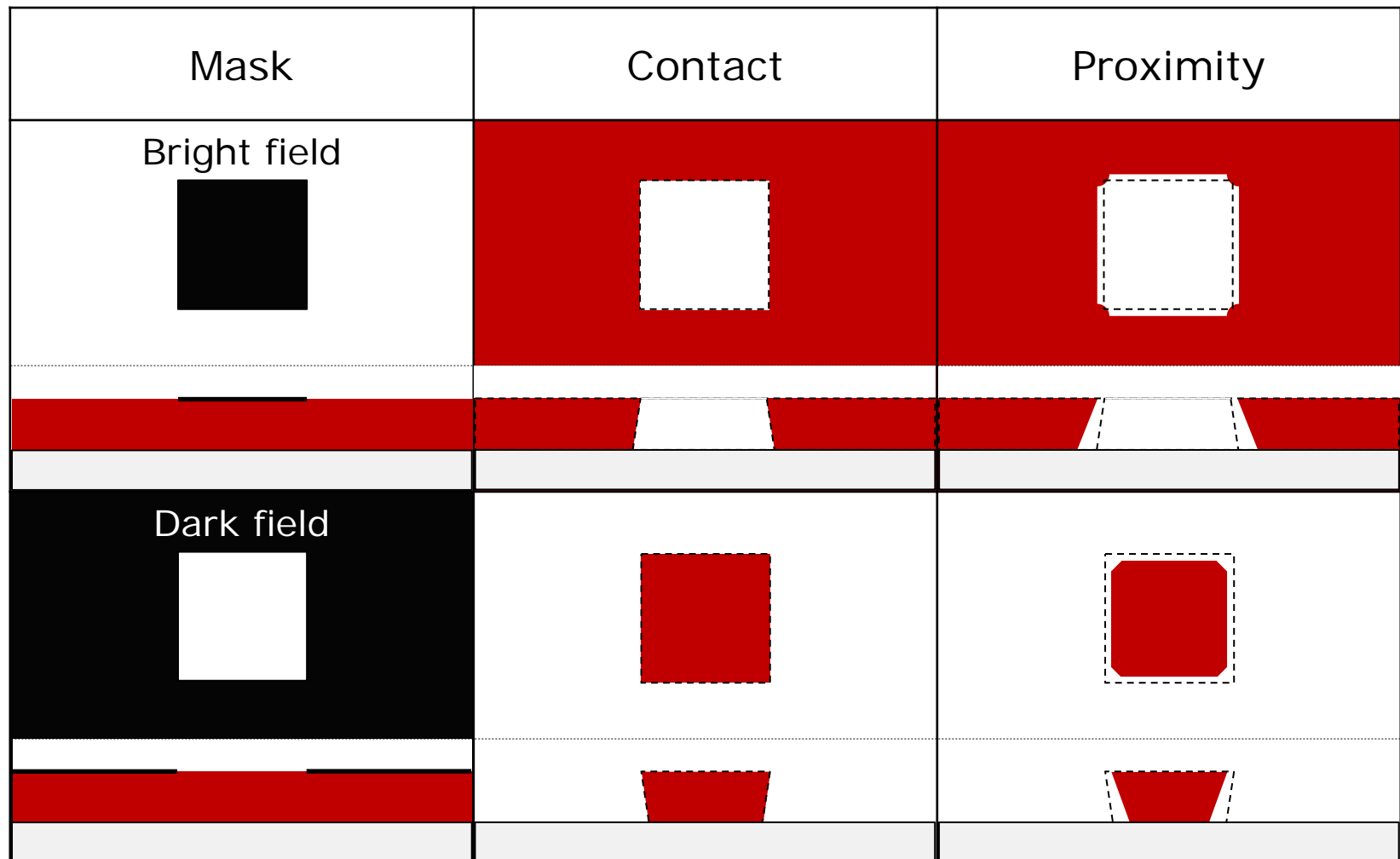
1.5 μm MiR 701, Hard contact, 169mJ/cm², PEB 60s @ 110°C, 60s TMAH puddle

Exercise: a clue...

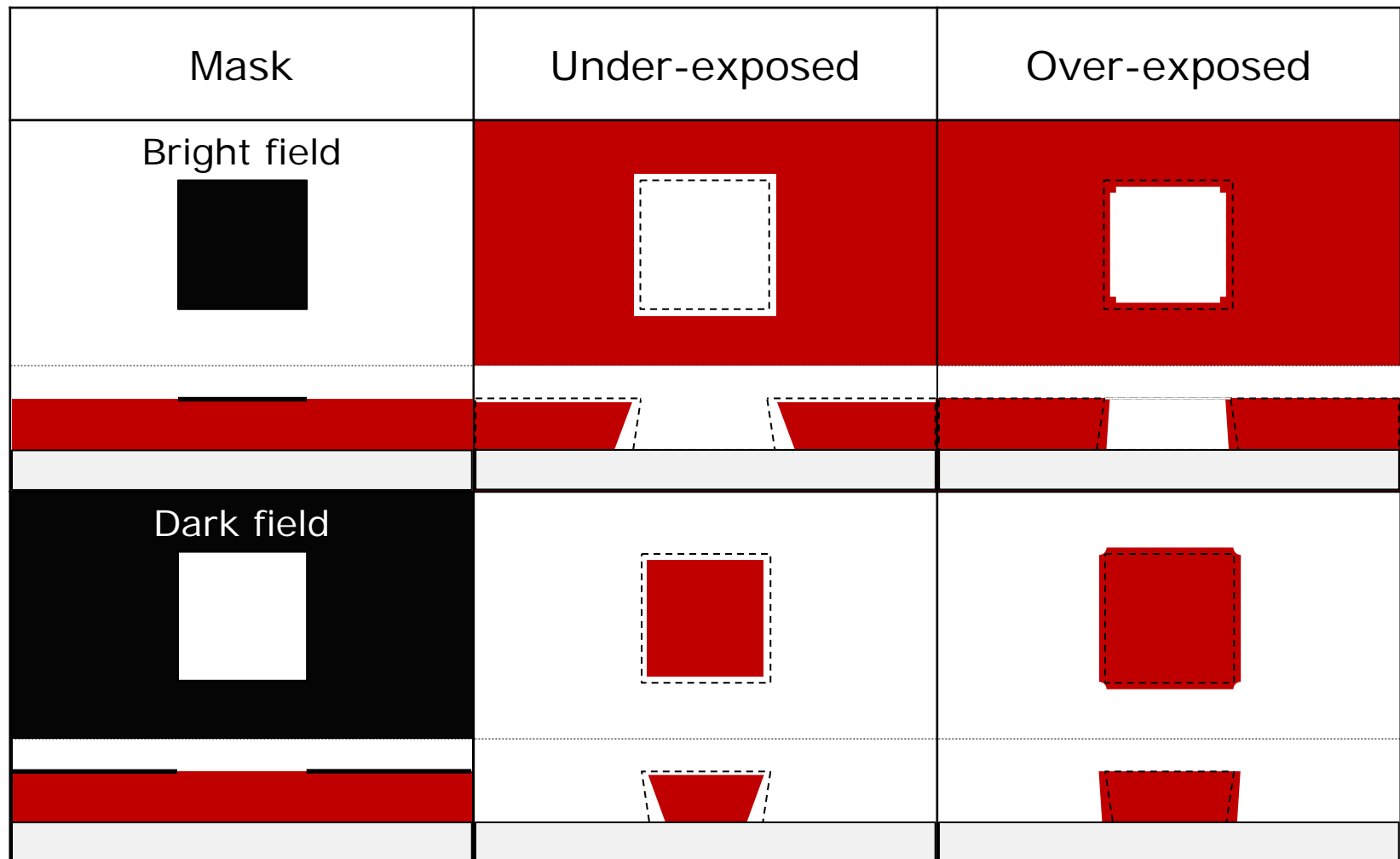


1.5 μ m MiR 701, Vacuum contact, 169mJ/cm², PEB 60s @ 110°C, 60s TMAH puddle

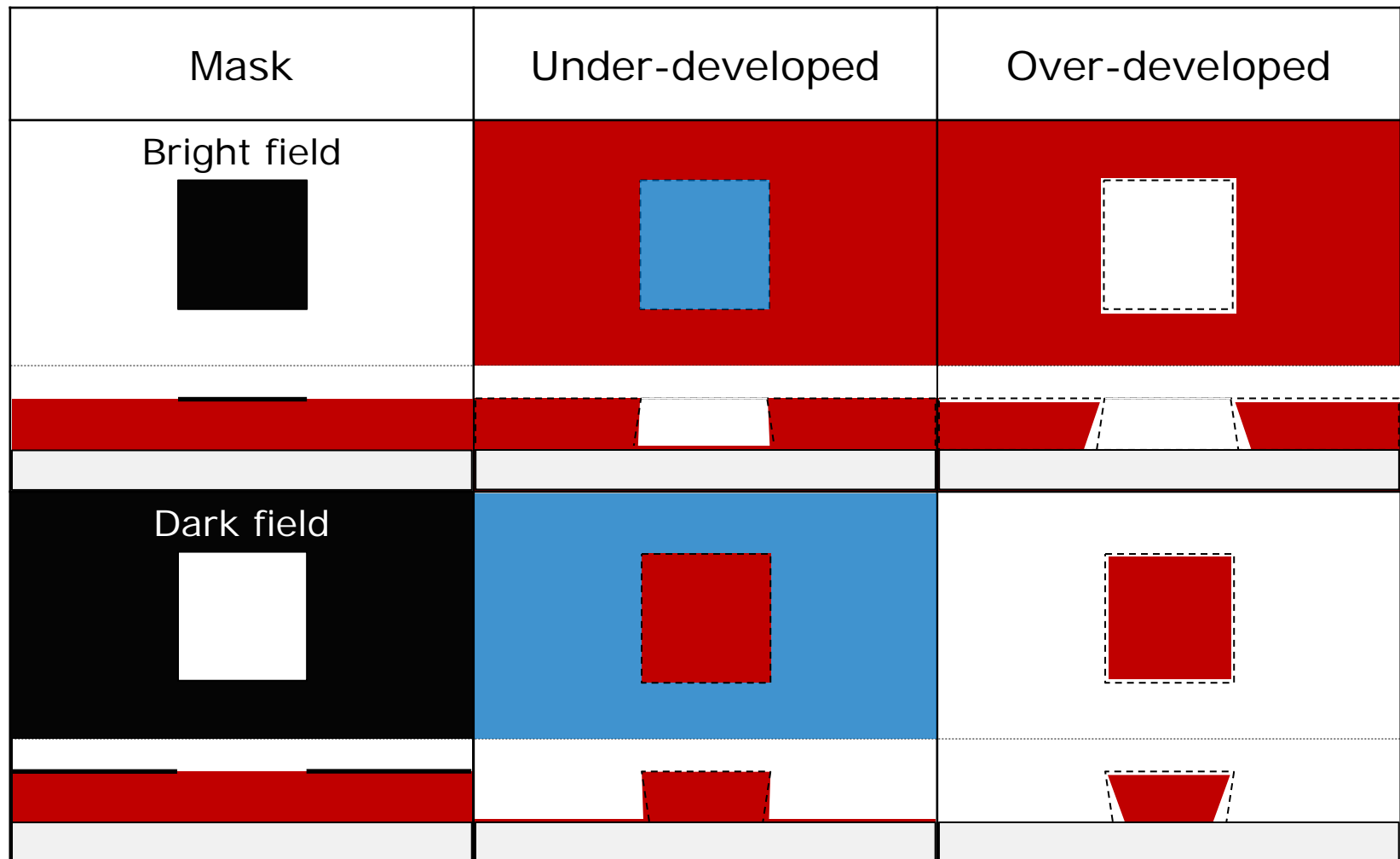
Negative tone resist: exposure mode



Negative tone resist: exposure dose



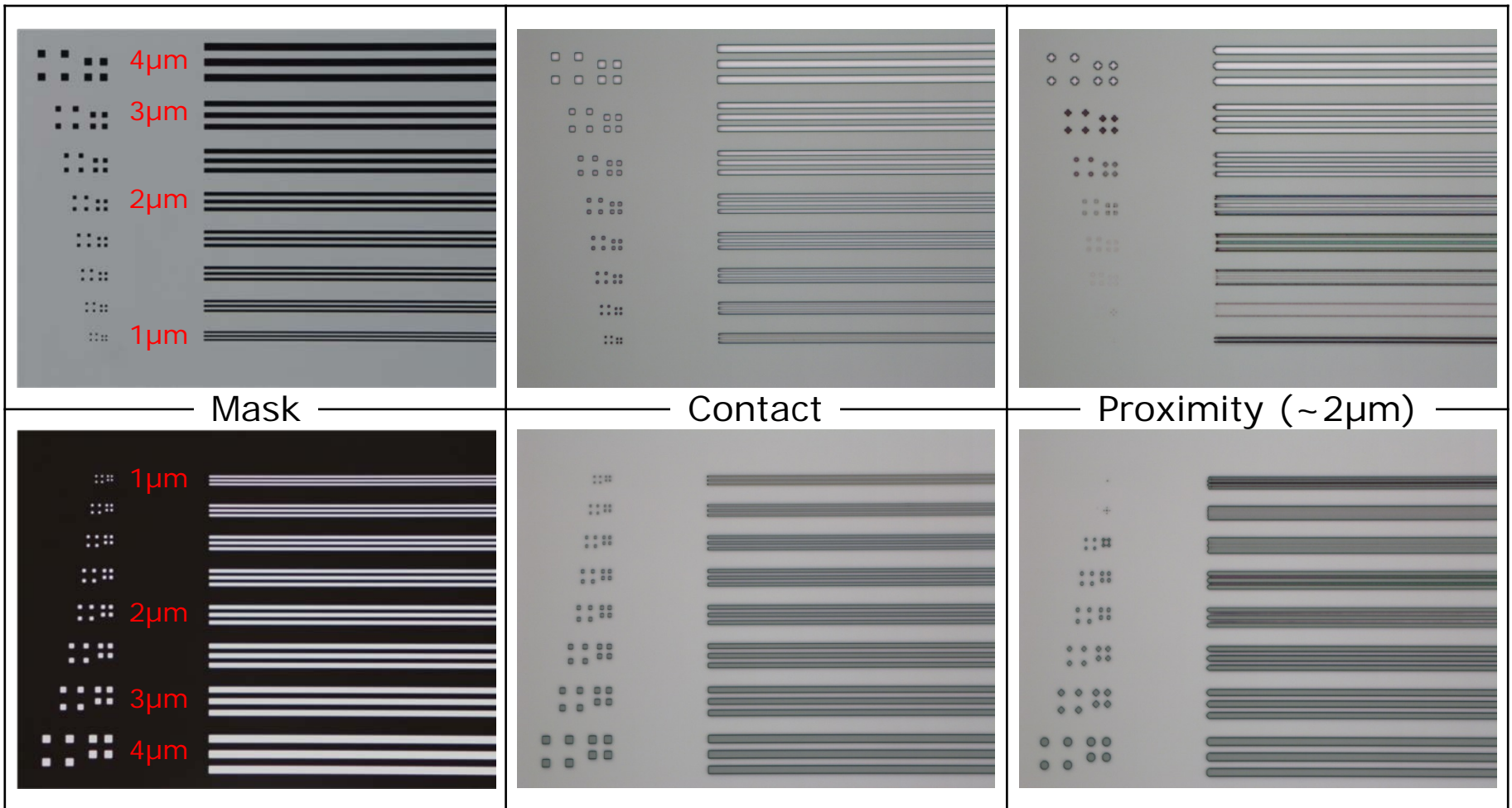
Negative tone resist: development time



AZ nLOF 2020: real life process flow

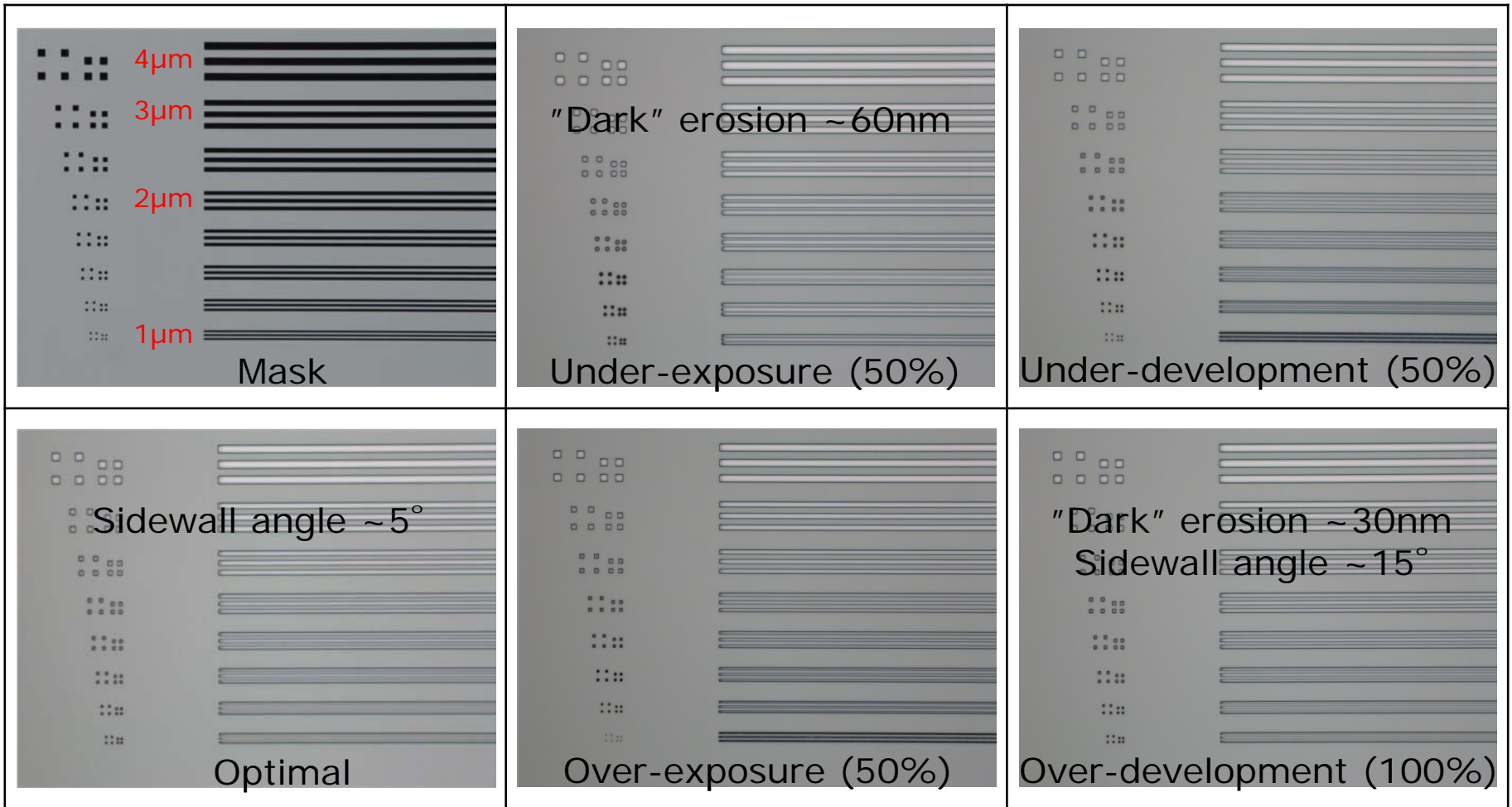
Step Header	Equipment		Comments
1 Spin coat of AZ nLOF 2020 with HMDS priming			
1.1 Coat wafers	Spin Track 1 + 2	Resist: AZ nLOF 2020 (track 2) Spin: 30 s @ 6700 rpm (~1.5 μm) Softbake: 60 s @ 110 °C Flow: T2 nLOF 2020 2um with HMDS	Si substrate HMDS priming: 72 s @ 50°C
2 UV Exposure			
2.1 Exposure	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



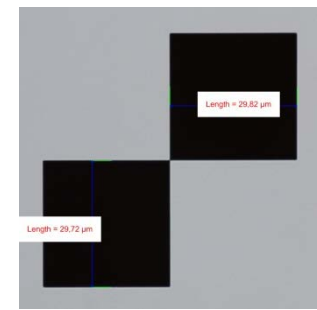
1.5µm nLOF, Hard contact, 104mJ/cm², PEB 60s @ 110°C, 30s TMAH puddle

AZ nLOF 2020: process window



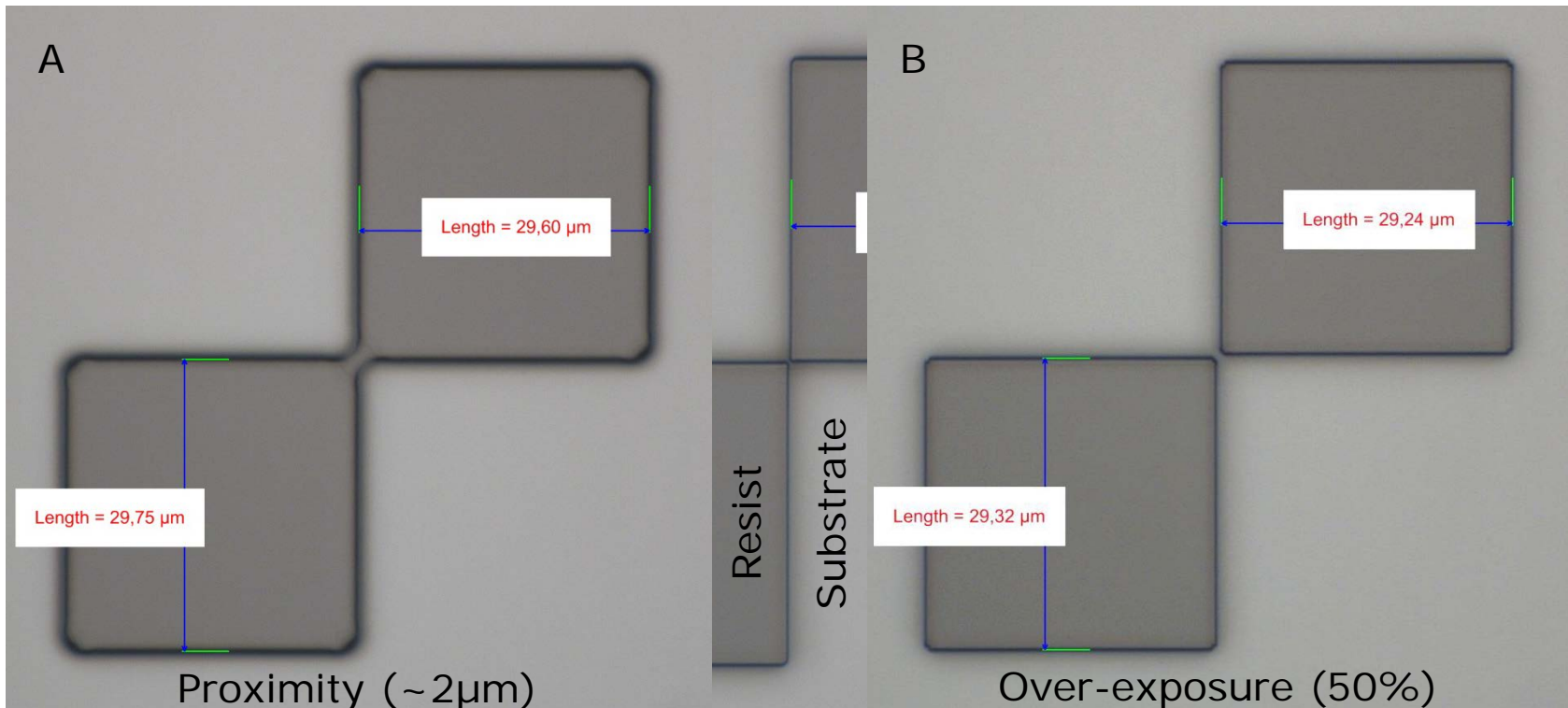
1.5 μ m nLOF, Hard contact, 104mJ/cm², PEB 60s @ 110°C, 30s TMAH puddle

Processing effects: exercise



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

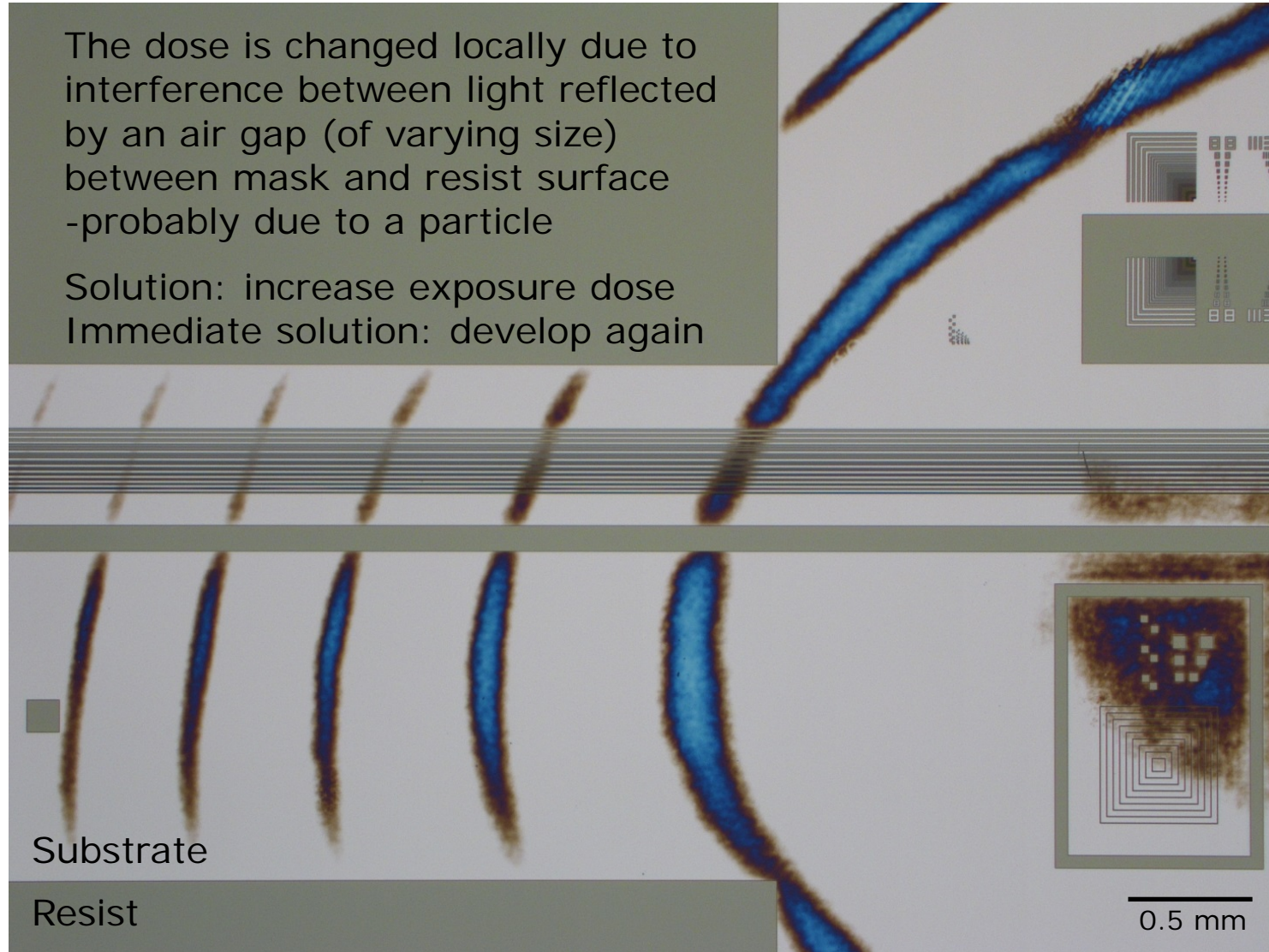
Discuss in teams what process effect may have caused the result in A or B



Processing effects: Newton's rings

The dose is changed locally due to interference between light reflected by an air gap (of varying size) between mask and resist surface -probably due to a particle

Solution: increase exposure dose
 Immediate solution: develop again



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

Substrate

Resist

0.5 mm

Further reading

- MicroChemicals homepage
 - Downloads → Application notes
www.microchemicals.com/downloads/application_notes.html (2017)
 - Notes on composition, processing, and use of photoresists
 - E.g. “Lithography Trouble-Shooter”
www.microchemicals.com/support/troubleshooter.html (2017)
- 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

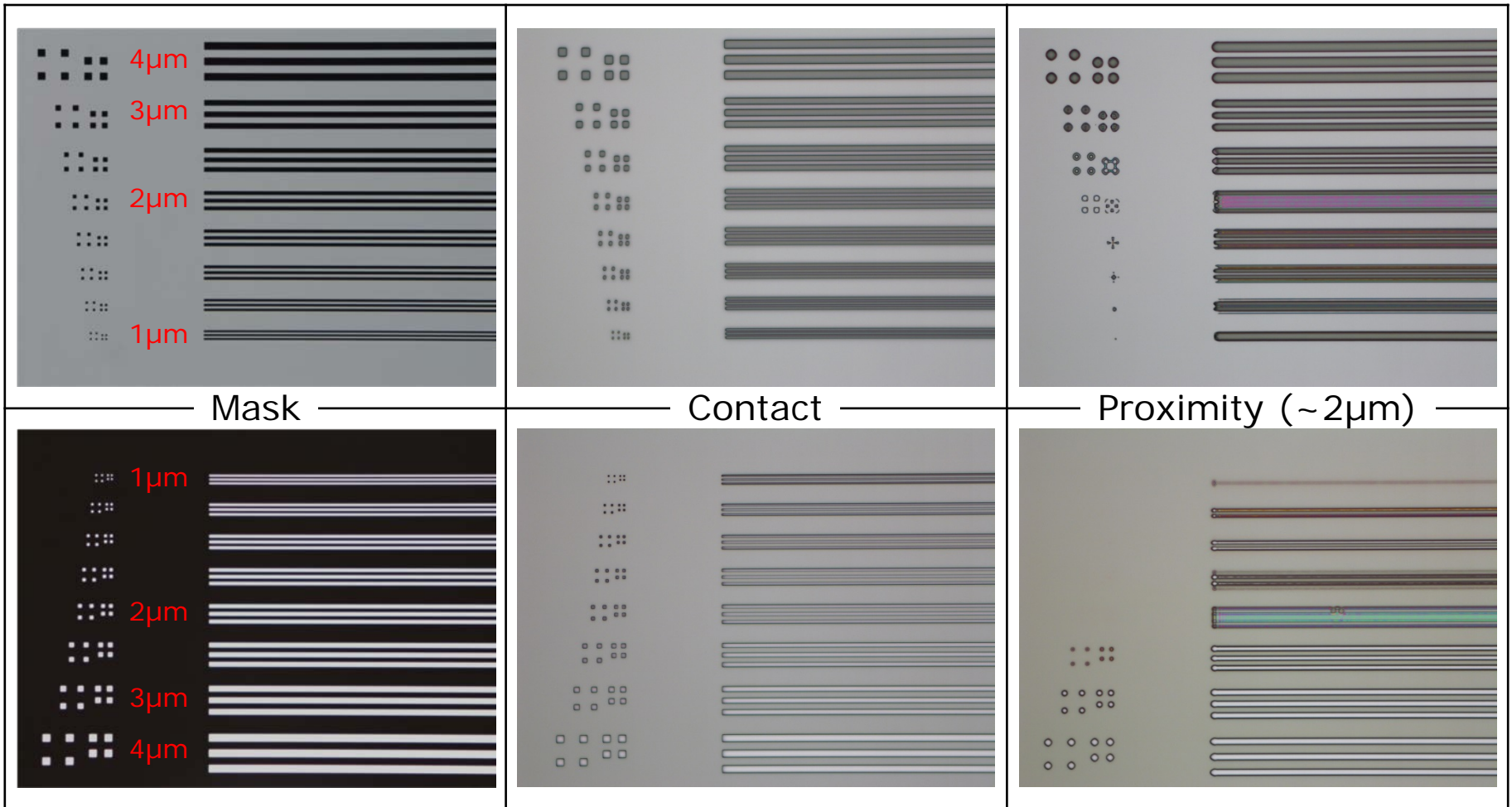
A close-up, low-angle shot of a curved, multi-layered structure, likely a microchip or a component of a lithography machine. The structure is dark with numerous small, colorful square markers (blue, purple, pink, green, yellow) arranged in a grid pattern. The background is blurred, showing more of the same structure with a bokeh effect of colorful lights.

lithography@danchip.dtu.dk

AZ MiR 701: real life process flow

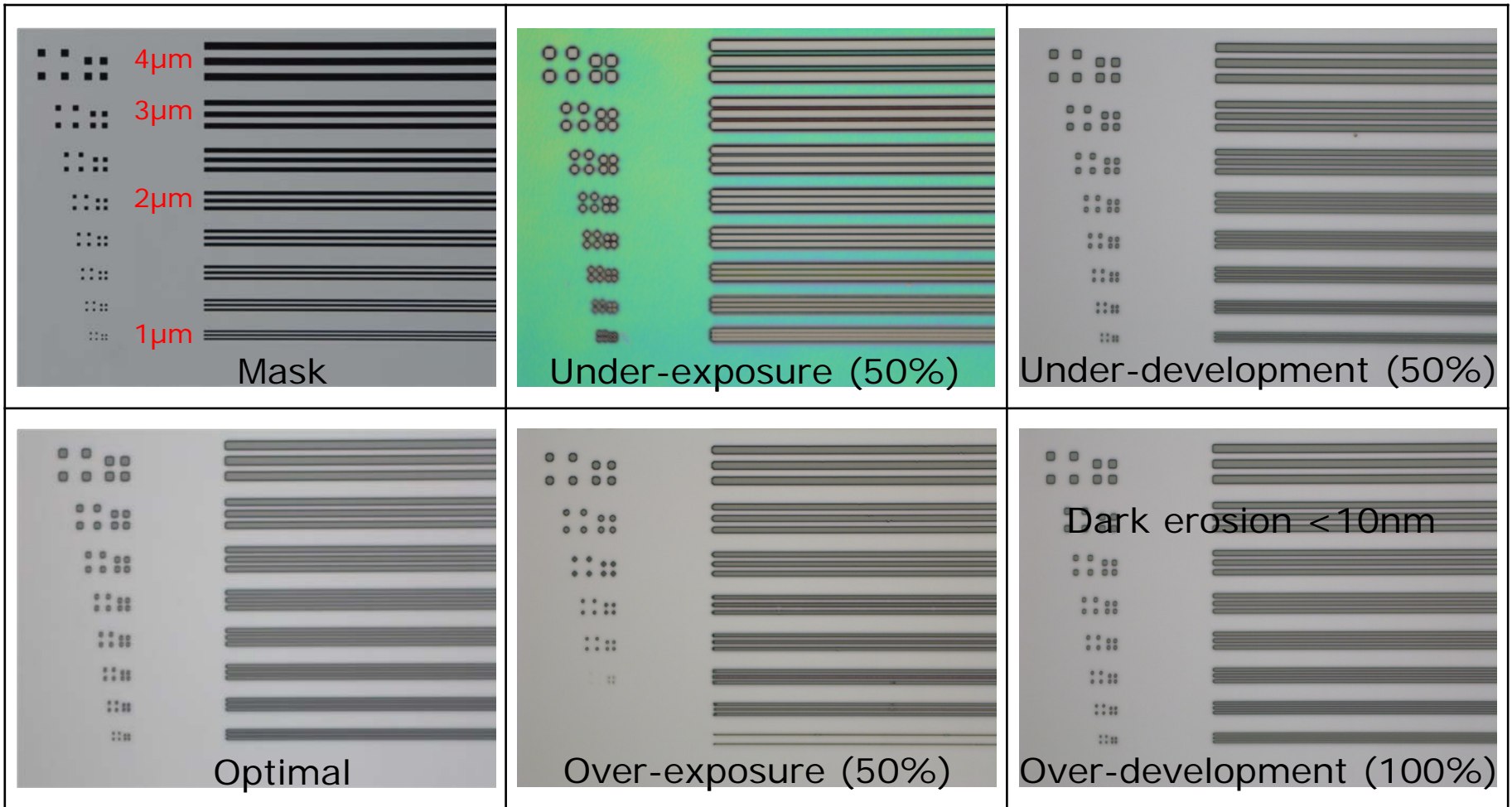
Step Header	Equipment		Comments
1 Spin coat of AZ MiR 701 with HMDS priming			
1.1 Coat wafers	Spin Track 1 + 2	Resist: AZ MiR 701 (track 1) Spin: 30 s @ 5000 rpm (~1.5 μm) Softbake: 60 s @ 90 °C (1 mm proximity) Flow: T1 MiR 701 1,5um with HMDS	Si substrate HMDS priming: 72 s @ 50°C
2 UV Exposure			
2.1 Exposure	Aligner: MA6 – 2	Mask: Litho test Exposure mode: Vacuum contact Exposure dose: 169 mJ/cm ²	Pre vac: 10 s; full vac: 10 s Exposure time: 13 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 Sequences: DCH 100mm PEB60s@110C+SP60s	PEB and development is done simultaneously
4 Development			
4.1 Development	Developer: TMAH UV- lithography	Development in AZ 726 MIF: single puddle, 60s Sequences: DCH 100mm PEB60s@110C+SP60s	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 MiR 701: exposure mode



1.5µm MiR, Vacuum contact, 169mJ/cm², PEB 60s @ 110°C, 60s TMAH puddle

AZ MiR 701: process window



1.5µm MiR, Vacuum contact, 169mJ/cm², PEB 60s @ 110°C, 60s TMAH puddle