Large area nanopatterning and industrial resist testing with an in-lab EUV Dual Beamline

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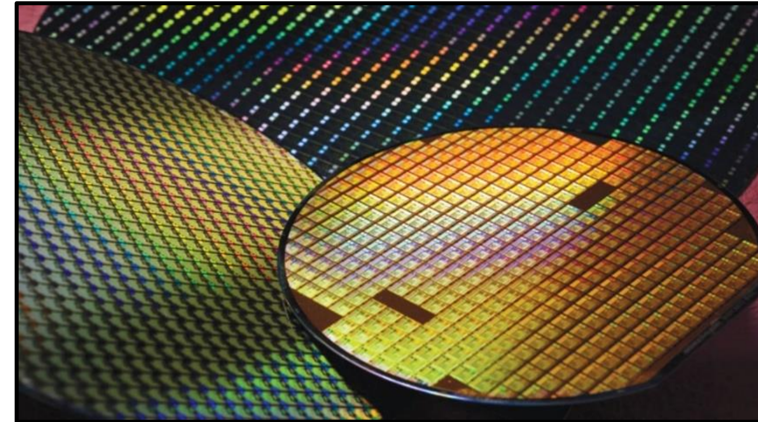
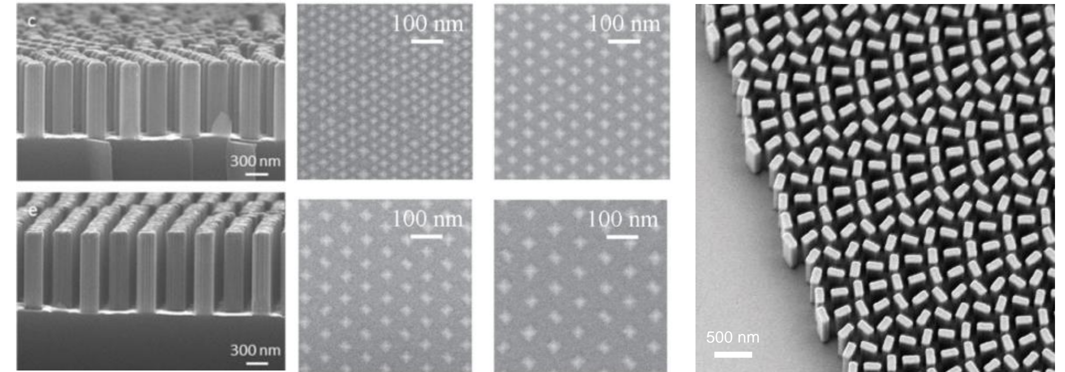
Industrial and scientific need for EUV patterning tools

- In recent years, EUV has entered high-volume manufacturing in the semiconductor industry
- Compact setups offer small to medium enterprises and research institutions access to EUV technology
- Exemplary application fields:

1) Industrial EUV photoresist development and qualification
2) Large area nanopatterning for prototyping or small-batch production

Photograph of processed wafers [1]





Various nanopatterns for scientific applications [2,3,4]

[1] https://photos5.appleinsider.com/gallery/39316-75230-36740-68650-tsmc-wafers-xl-xl.jpg
[2] J. Veerbeeck et al., Chem. Nano. Mat. 4, 874 –881 (2018)
[3] J. Tempeler et al., Nanotechnology 29, 275601 (2018)
[4] B. Chen et al., Nano Lett. 17, 6345-6352 (2017)

EUV Dual Beamline

EUV Dual Beamline in research configuration (footprint: 2.5 x 1.5 m²)

Specifications EUV Dual Beamline	λ = 10.9 nm	λ = 13.5 nm
Intensity @ 2.5 kHz (mW/cm²)	2.0	0.1
Wafer diameter (mm)	up to 100	
Single exposure field (mm²)	2 x 2	5 x 5
Total exposure area (mm²)	up to 64 x 64	
Demonstrated resolution (nm)	28	35

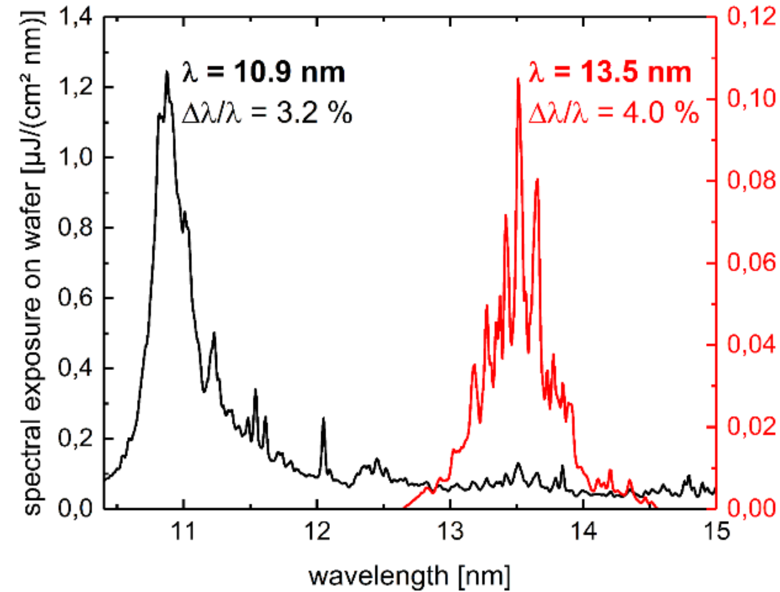
- Compact in-lab setup for high-resolution nanopatterning at two EUV wavelengths:
  1) Industrial photoresist qualification at 13.5 nm
  2) Large area nanopatterning with high throughput at 10.9 nm

- Serves as a basis for industrial prototype development:
  - Optimized source operation
  - Lithographic interference scheme
  - Transmission mask technology

Optimized source operation

Commercial EUV source (FS5440, Fraunhofer ILT)

Spectral exposure for lithographic applications



- Compact discharge-produced plasma EUV source
- Spectral exposure optimized for lithographic applications:

1) Main wavelength
2) Relative spectral bandwidth
3) Sufficient intensity

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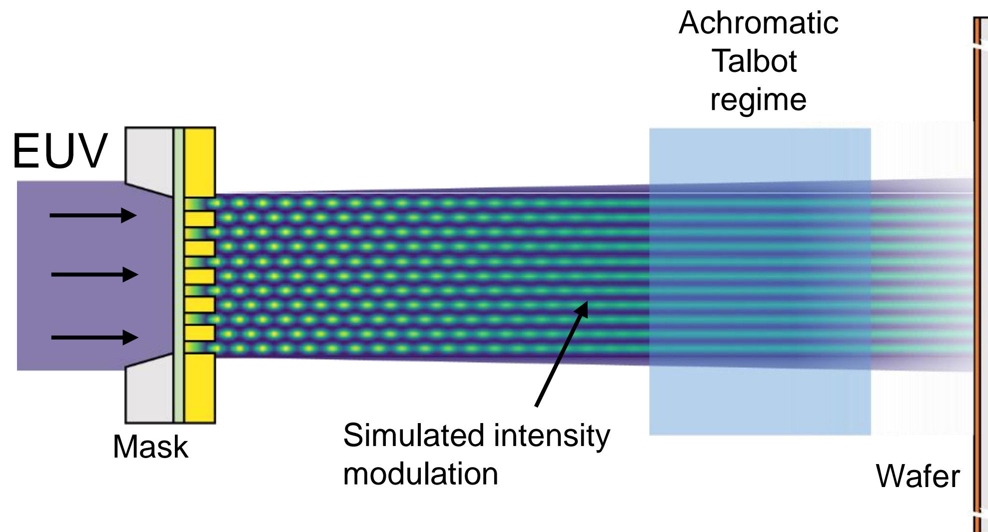
Lithographic interference scheme

Schematic drawing of achromatic Talbot lithography

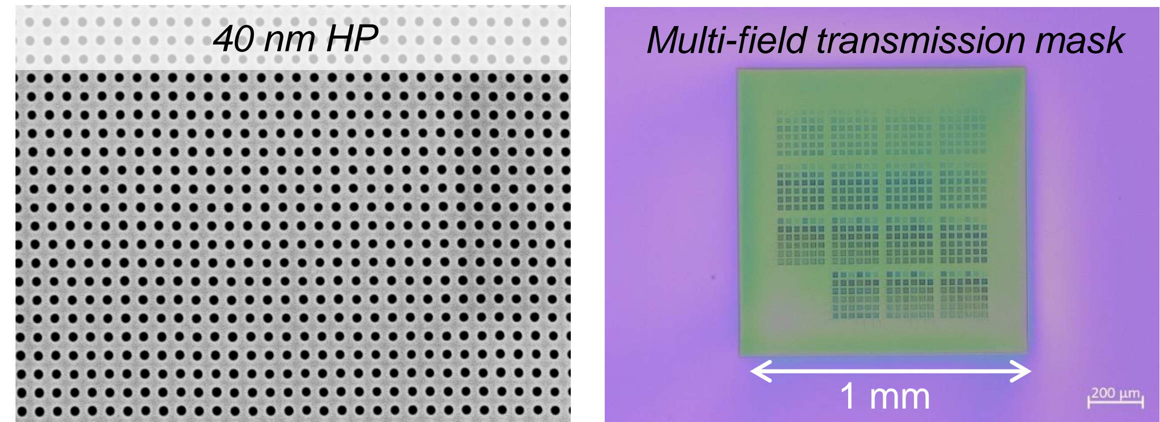


- Achromatic Talbot lithography:
  - High-contrast intensity modulation
  - Up to two times pattern demagnification
  - Efficient use of EUV radiation
- Intensity modulation predictable by rigorous simulation models
- ➢ Enables optimization of transmission mask design

Transmission mask technology

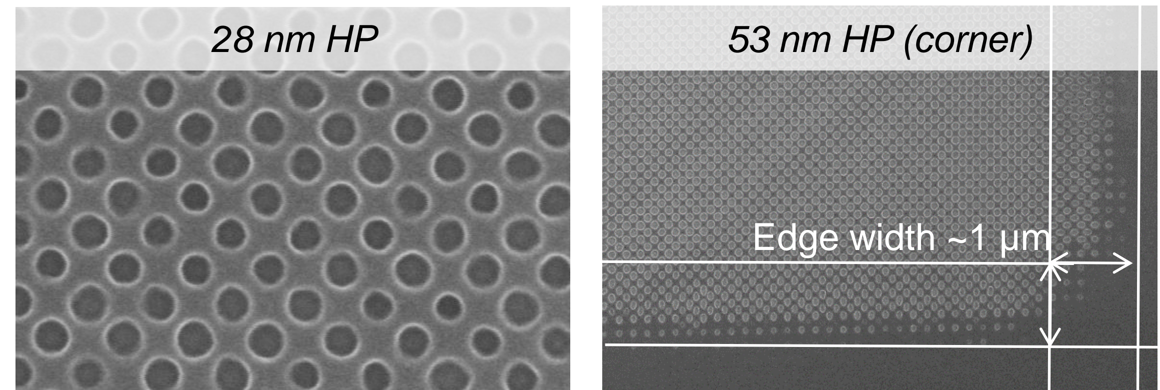
- Established mask fabrication process:
  - Sub-40 nm half-pitch (HP) periodic structures
  - Up to 2 x 2 mm² mask area
  - Single or multi-field transmission masks

Fabricated mask patterns



- High-resolution nanopatterning:
  - Sub-30 nm half-pitch demonstrated (theoretical resolution limit < 10 nm)
  - Single exposure fields are stitched together to cover even larger areas

Exemplary exposure results



→ High-resolution patterning technology for industrial and scientific applications

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Thank you for your attention

Feel free to check out our poster or contact me directly

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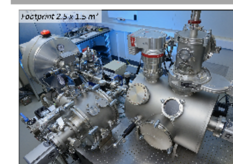
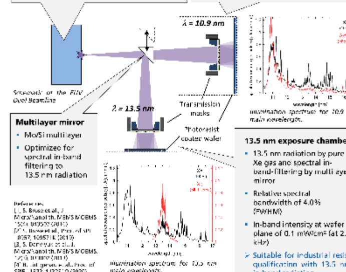
The EUV Dual Beamline is a versatile exposure tool equipped with a compact discharge-produced plasma (DPP) EUV source and can be operated either at an exposure wavelength of 10.9 nm or 13.5 nm, depending on the application. By operating the source with an Ar/Xe gas mixture, a narrow-band spectrum with a main wavelength of 10.9 nm is created without the need of spectral filtering. The resulting intensity of up to 2 mW/cm² in wafer plane allows large area patterning with highest throughput of several mm²/min. Qualification of industrial photoresists regarding sensitivity, contrast and resolution at 13.5 nm is enabled by operating the DPP source with pure Xe. The resulting broadband emission is spectrally filtered to 13.5 nm in-band radiation by a customized multilayer mirror. For partially coherent radiation as provided by the DPP source-based illumination setup, the (achromatic) Talbot lithography has proven to be the most suitable lithographic scheme with a demonstrated resolution in the sub-30 nm regime and theoretical resolution limit below 10 nm. To create high-resolution nanopatterns on the wafer, efficient phase-shifting transmission masks need to be carefully designed and fabricated. Single and multi-field resolution masks can be created to either enable large-area nanopatterning or efficient resolution testing for industrial EUV resists.

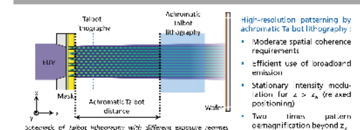
EUV DUAL BEAMLINE



MAIN COMPONENTS

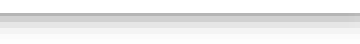


ACHROMATIC TALBOT LITHOGRAPHY



PHASE-SHIFTING TRANSMISSION MASKS

HIGH-RESOLUTION NANOPATTERNING



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