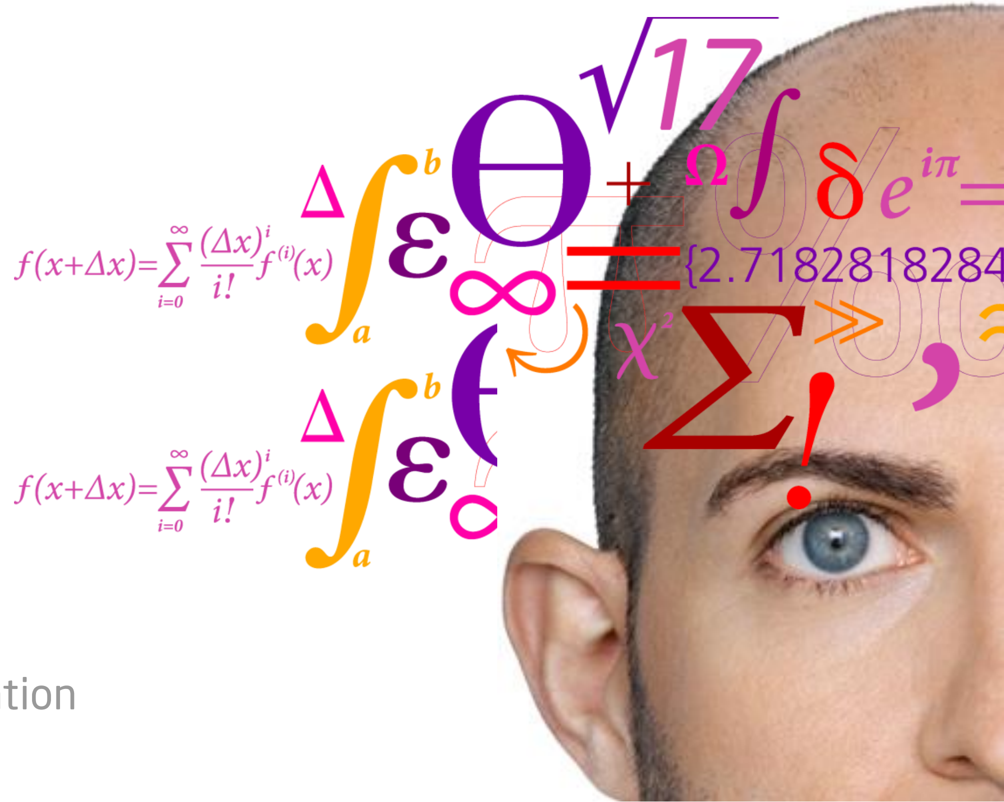
Lithography Tool Package

Introduction to Lithography



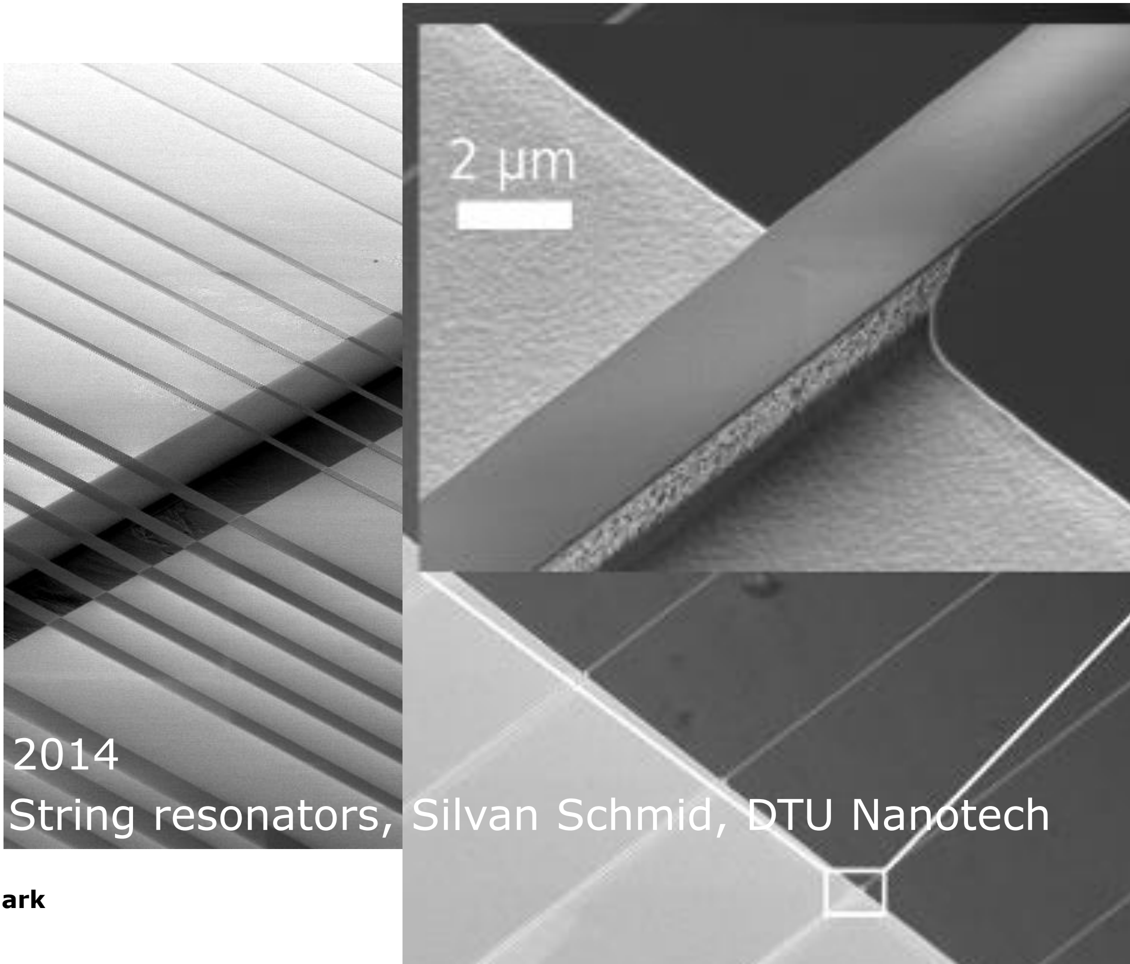
DTU Danchip
National Center for Micro- and Nanofabrication

Lithography

Lithography: from Ancient Greek λὶθος, *lithos*, meaning "stone", and γράφειν, *graphein*, meaning "to write“.

1796

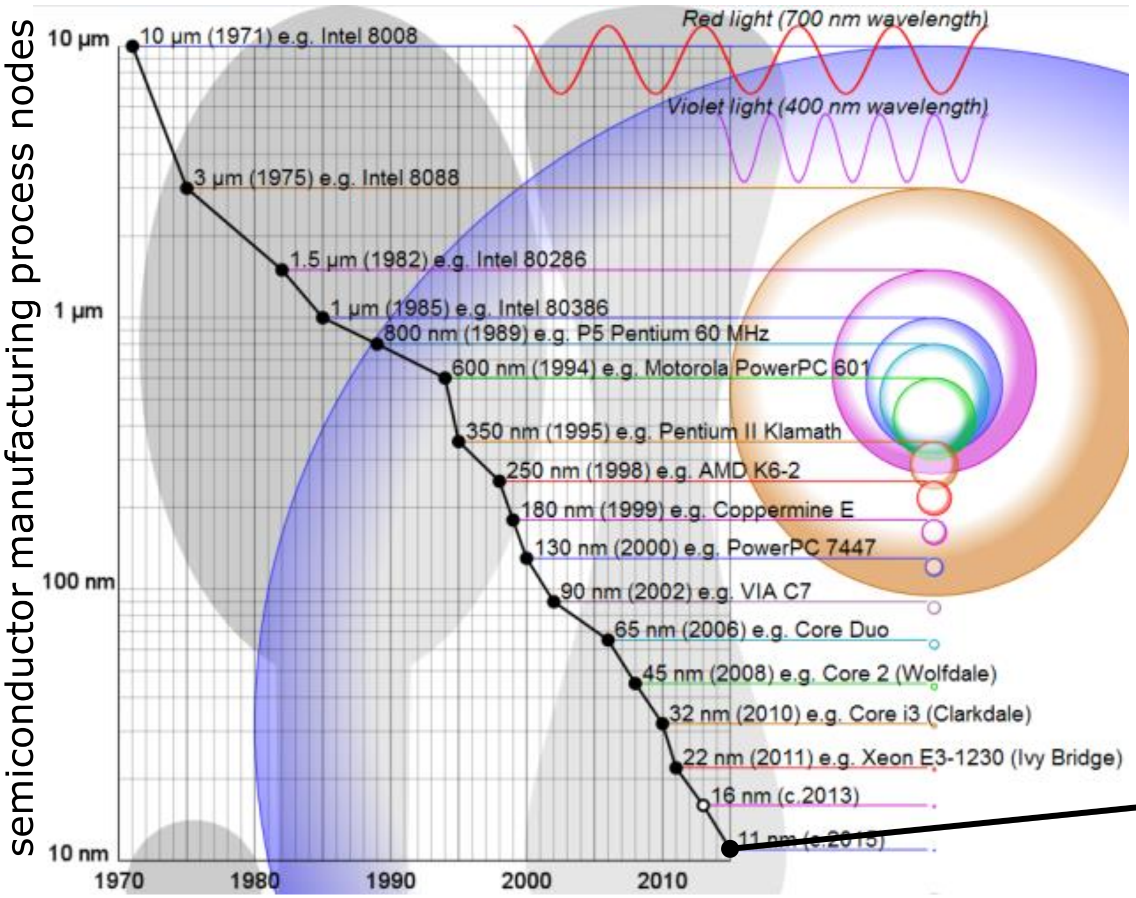
http://www.johnjarroldprintingmuseum.org.uk/lithography.html



2014

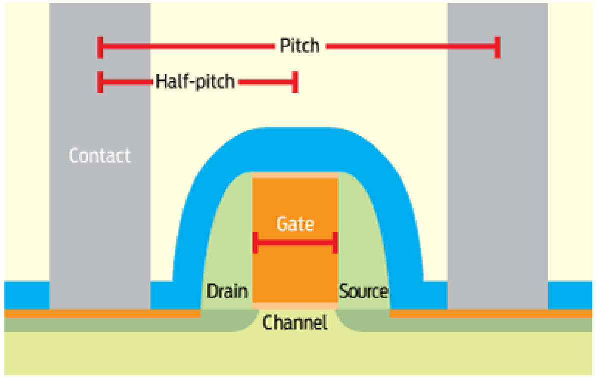
String resonators, Silvan Schmid, DTU Nanotech

Lithography: Why?
→Miniaturization of semiconductor devices



https://en.wikipedia.org/wiki/Semiconductor_device_fabrication

Gate design



1990'ies: node = half pitch

Now: node ≲ gate length

14 nm node

2015
iPhone 6s

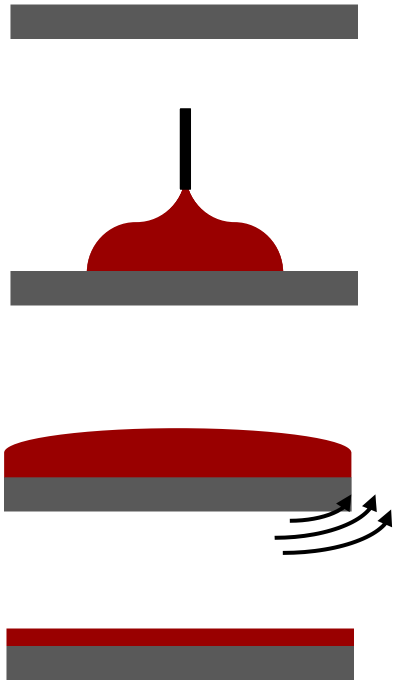
Lithography: methods

Technology	Exposure Source	Wavelength	Minimum Resolution [nm]
UV Contact Lithography	Hg vapor lamp	365 nm	1500
UV Projection Lithography	Hg vapor lamp	365 nm	800 – 350
Deep-UV Projection Lithography	KrF excimer laser	248 nm	250 – 90
Deep-UV Immersion Lithography	ArF excimer laser	193 nm	110 – 38
Extreme-UV Projection Lithography	IR Laser-produced Sn plasma EUV	13.5 nm	< 20
Electron Beam Lithography	Field-emission electron gun (100 keV)	0.39 nm	< 10

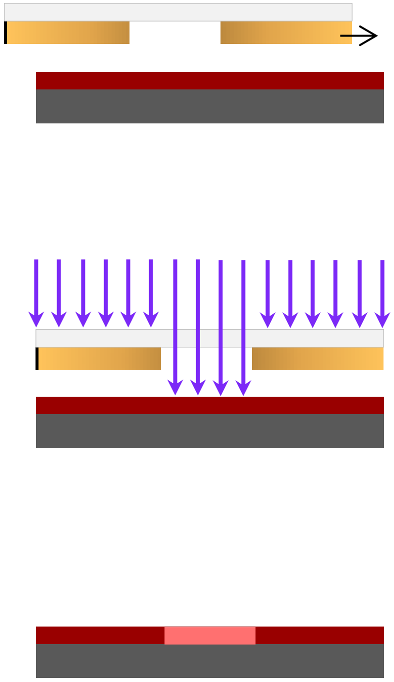
Available at DTU Danchip

UV lithography: process

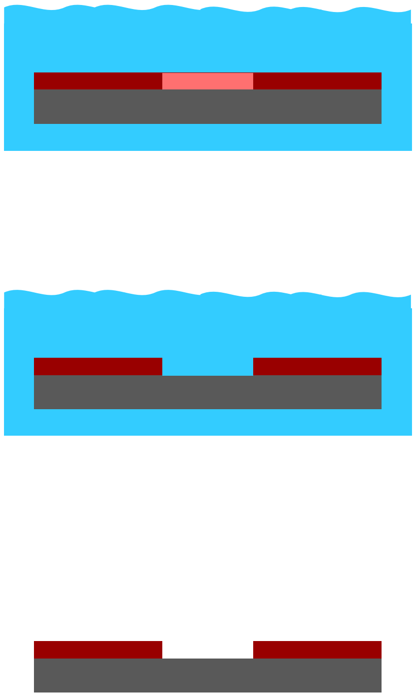
Spin coating of
UV-sensitive resist



Aligning and
exposure

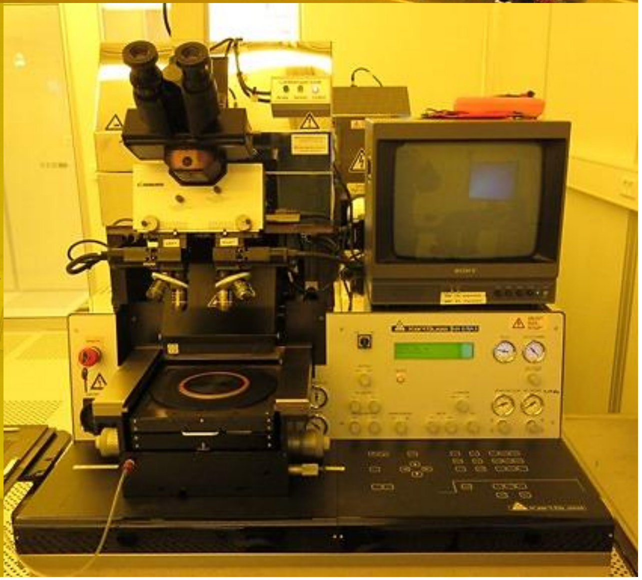


Development

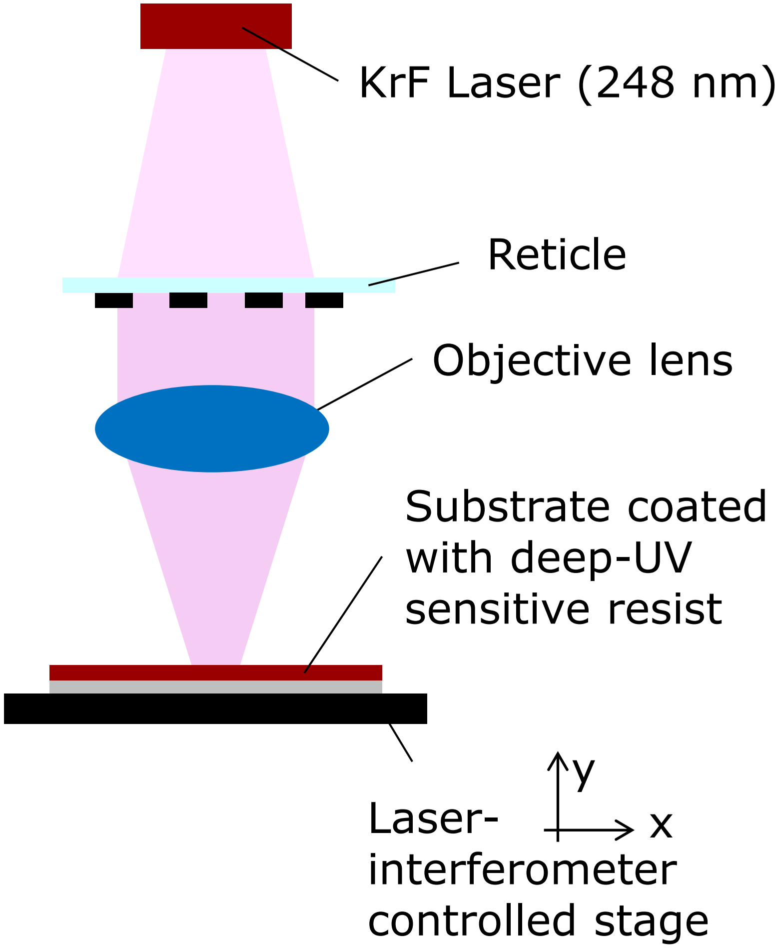


UV lithography: equipment

- Coating:
  - 2 (3) automatic spin coaters
  - 4 manual spin coaters
  - 1 spray coater
- Exposure:
  - 3 mask aligners
  - 1 UV flood exposure source
- Development:
  - 2 submersion developer benches
  - 1 automatic puddle developer
  - 1 manual spray/puddle developer
- Auxiliary:
  - HMDS priming ovens
  - Hotplates
  - Lift-off benches
  - Resist strip bench



DUV Stepper Lithography: principle

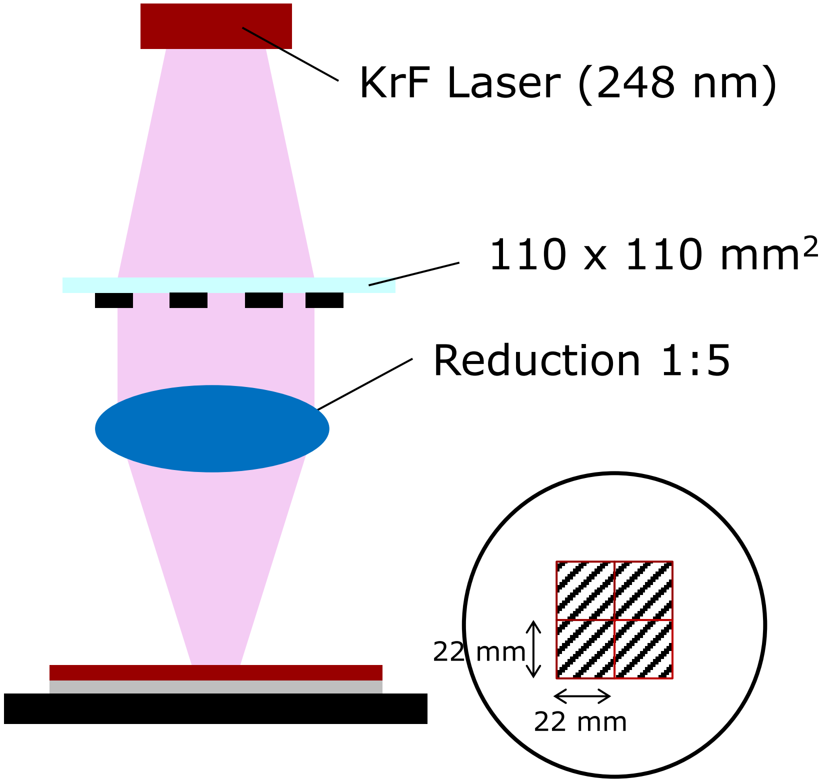


Auxiliary equipment:

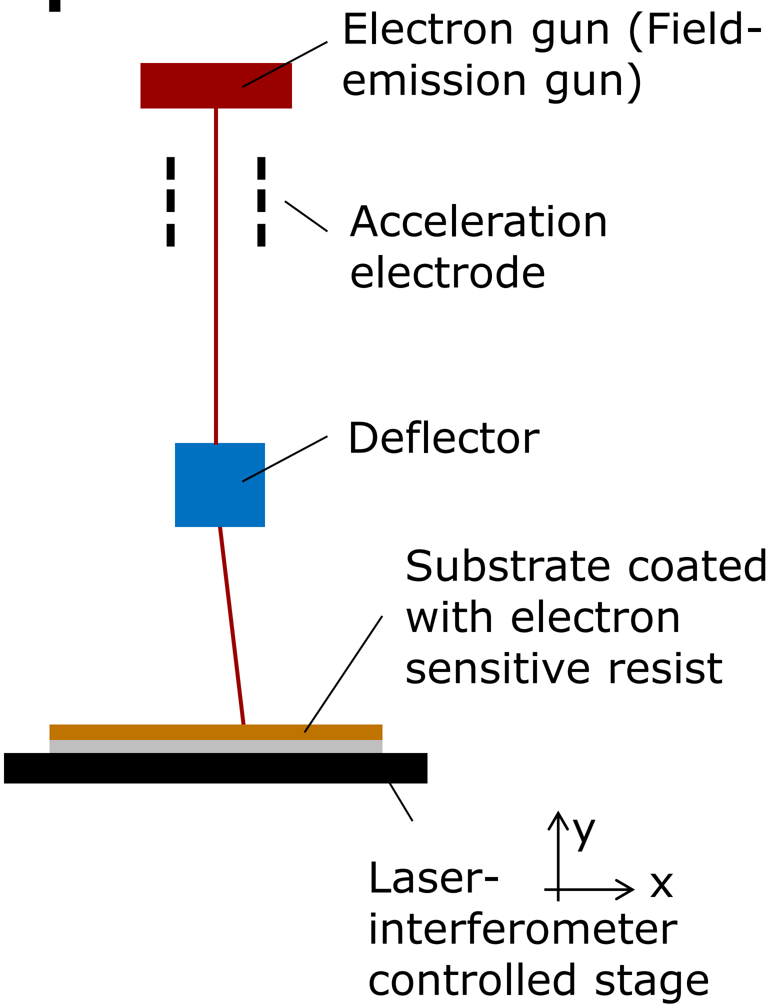
- Automatic spin coater
- Automatic developer

DUV Stepper Lithography: performance

CANON FPA-3000 EX-4	
Light Source	248 nm KrF Laser
Objective Lens	Reduction 1:5
Writing field (Field size on substrate level)	22 mm x 22 mm
Field Stitching accuracy	50 nm
Overlay accuracy	30 nm
Resolution	160-250 nm depending on pitch and pattern



E-beam Lithography: principle

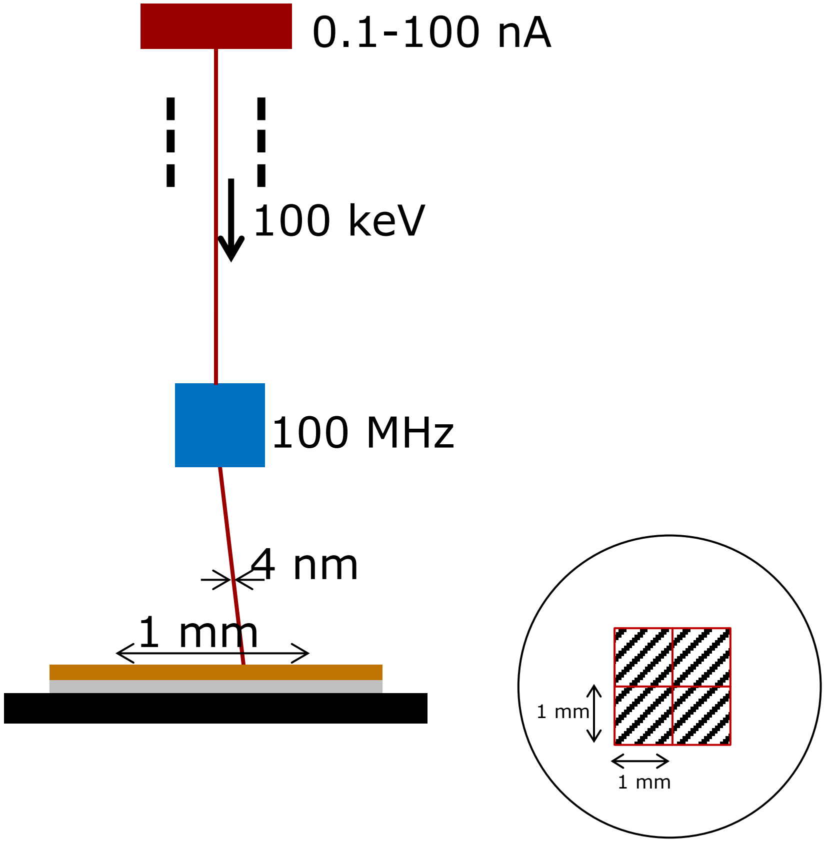


Auxiliary equipment:

- Manual spin coater(s)
- Fume hood for development

E-beam Lithography: performance

JEOL JBX-9500FSZ	
Acceleration voltage	100 keV
Maximum scan frequency	100 MHz
Beam current	0.1-100 nA
Beam Diameter at substrate level	4 nm (@ 0.1 nA)
Writing field (maximum deflection)	1 mm x 1 mm
Field stitching accuracy	< 5 nm
Overlay Accuracy	< 10 nm
Resolution	Down to 10 nm



Lithography: comparison

	UV Lithography	DUV Stepper Lithography	E-beam Lithography
Minimum Resolution	~1.5 µm	~220 nm	~10 nm
Process time (4” wafer)	• ~2 min load and unload • ~10 s per exposure	• ~10 min load and unload • ~1 s per field exposure	• ~1 h of machine calibration + substrate load and unload • A pattern area of 1 cm^2 takes ~8 h to expose with a beam current of 10 nA and a dose of 300 µC/cm2
Throughput (4” wafer)	~25 wafer/hour	≳6 wafer/hour (much higher for 6”)	≲1 wafer/hour
Training	Litho TPT + separte trainings	Processed by DTU Danchip	Only available for Ph.D. and up

Litho Tool Package Training

- First process theory, then equipment training

Today (once a month):

- The hardware, theory, physics, chemistry, steps, and process parameters involved in UV lithography

Later (once a week, max. 6 persons per week):

- A full day of UV lithography process and equipment training, covering
  - Spin coating
  - Exposure and alignment
  - Development
  - Characterization of the results

If you prepare yourself and perform well, there is a chance you will be fully authorized on three pieces of equipment central to UV lithography processing at the end of the Litho TPT

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