Update on the EUV program at ASML

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Acknowledgement

- This work can be (re)presented today, because of the dedication of ….
  - two tool integration teams on site,
  - research, development, and customer support teams in Veldhoven,
  - all development partners (Zeiss SMT AG, Philips Extreme UV, Media Lario, TNO, Philips AppTech, etc.).

- This is their story…

Content

- Introduction
- AD-tools: performance in the field
- EUV roadmap: High Volume Manufacturing tool
- Summary

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Introduction

- ASML has shipped two AD-tools to customers.
- Developing and using the AD-tools enables
  - ASML's learning about system design, system assembly, shipment, and on-site tool setup,
  - customer's EUV mask- and process development for the 32nm node
  - joint learning on vacuum lithography in all its aspects
    - vacuum-specific reticle- and wafer stage technology, incl. chucking,
    - all-reflective optics (illumination system and lens) and optics usage,
    - source operation,
    - tool performance stability, including overlay and CDU.
- The AD-tools are in final phase of on-site qualification
    - we present a subset of the data that has been collected.

Two Alpha Demo Tools are at research centers

IMEC (Leuven, Belgium)

CNSE (Albany, NY, USA)

- λ 13.5 nm
- NA 0.25
- Field 26 x 33 mm^2
- Magnification 4x reduction
- Sigma 0.5
- Chief ray angle at mask is 6 degrees

- Single stage, 300mm wafer, linked to track
- ATHENA alignment sensor
- Single reticle load (no library)
- X REMA only; UNICOM
- Uses TWINSCAN technology (eg focus)
- Reflective optics
- Sn DPP source

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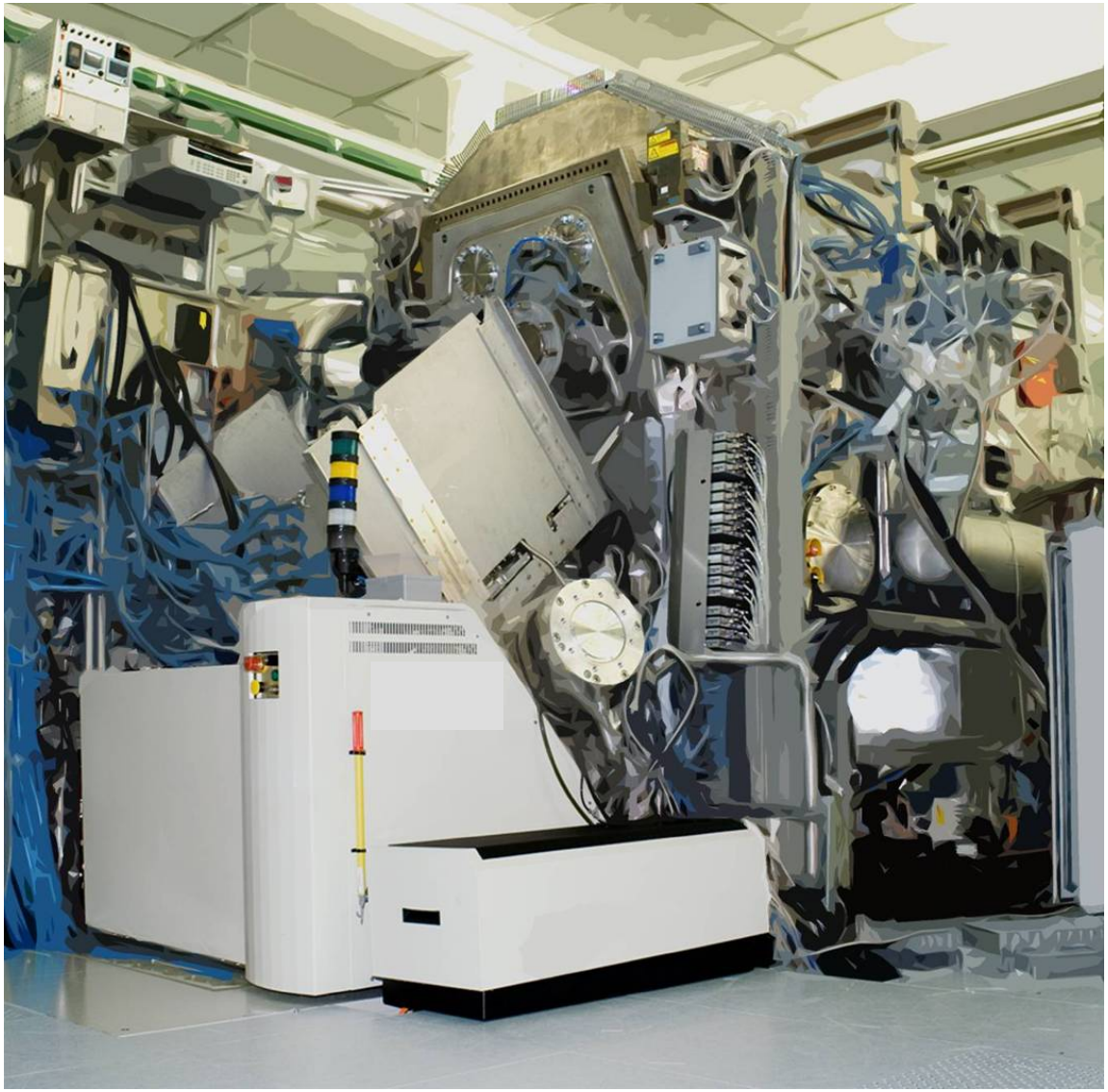
Sn SoCoMo has been installed at customer sites

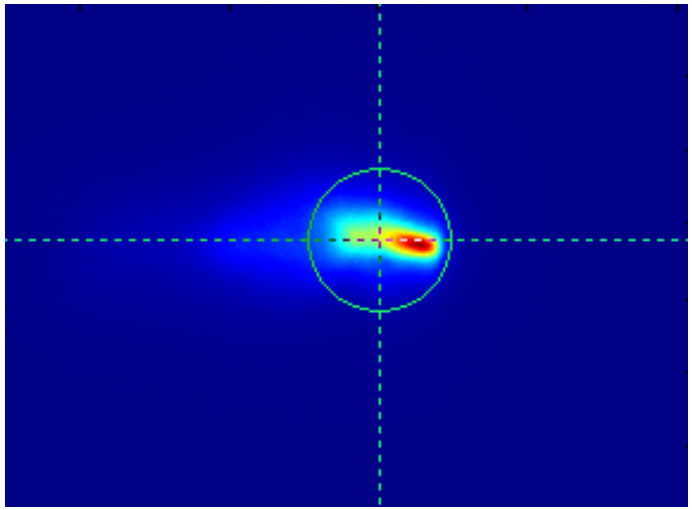


- Sn SoCoMo* module has been qualified at intermediate focus (IF) and has been installed.
- Tool “photon” set up is ongoing, and scanning lithography can be done with this source.
- In parallel, work continues to optimise the debris mitigation system (DMS) and increase source power.

** SoCoMo = source-collector module*

Realisation of 120 W/2π (~7 W at IF*) in progress

- Target: 120 W/2π with 70% collectable through IF
  - effectively 84 W/2π



pinhole image and data courtesy of Philips Extreme UV (this conference)

Collection Efficiency = 70 %

- Status (lab): >190 W/2π with ~70% collectable through IF
  - effectively ~130 W/2π
- Improvements on tin- and laser control ongoing, to further increase collectable power.

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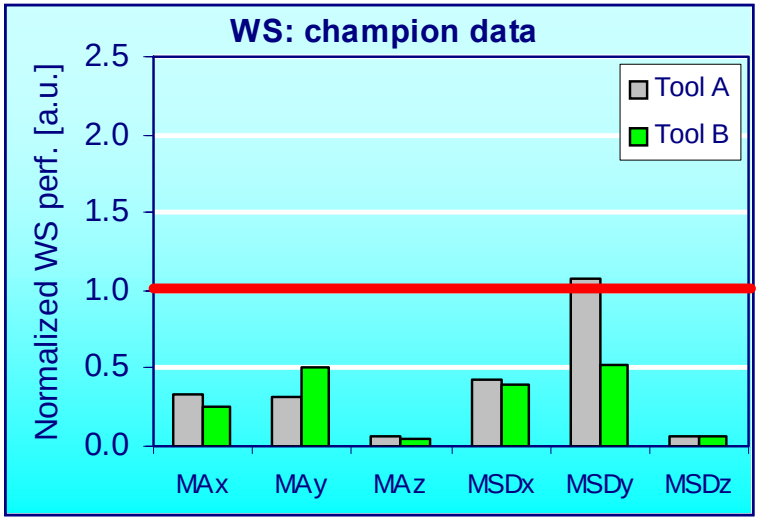
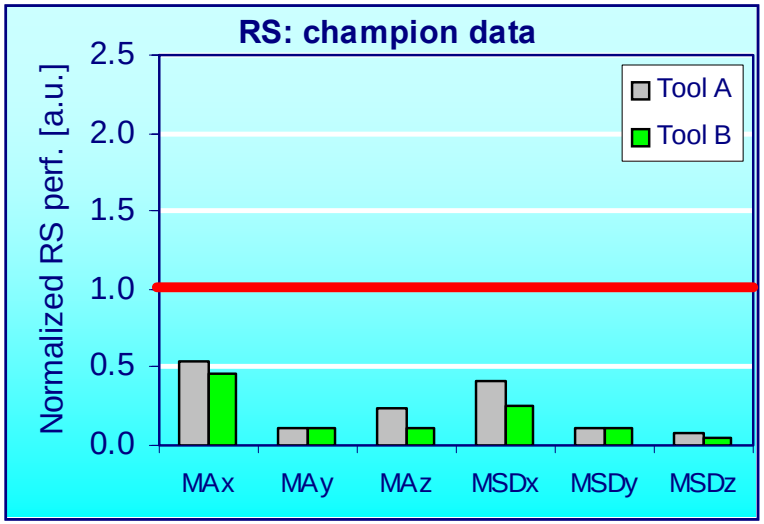
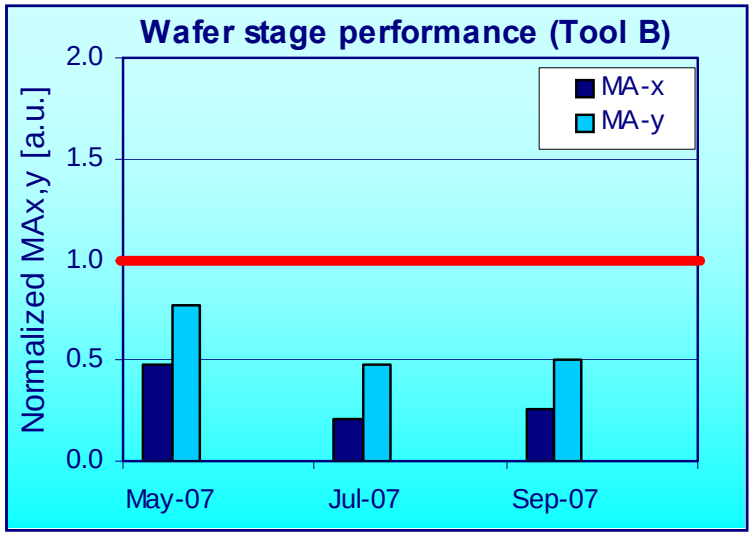
Stage dynamics meet 32nm node requirements





MA = Moving Average (part of Overlay budget)
MSD = Moving Standard Deviation (part of CD budget)

All measured values are normalized to their respective requirements



- Wafer- and reticle stage performance meets requirements, and is stable over time.

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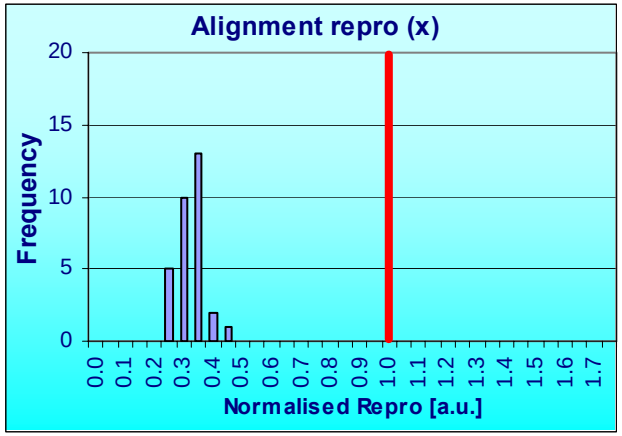
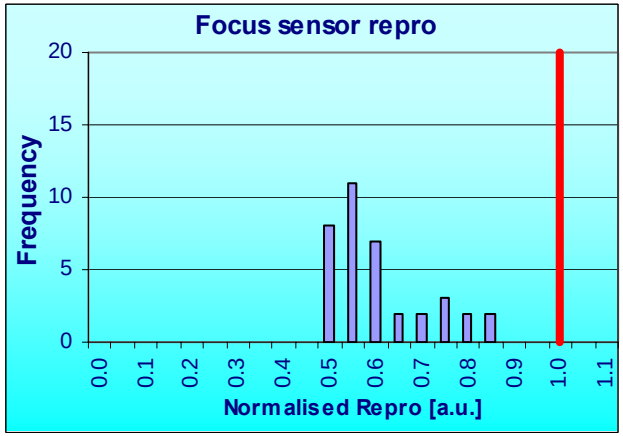
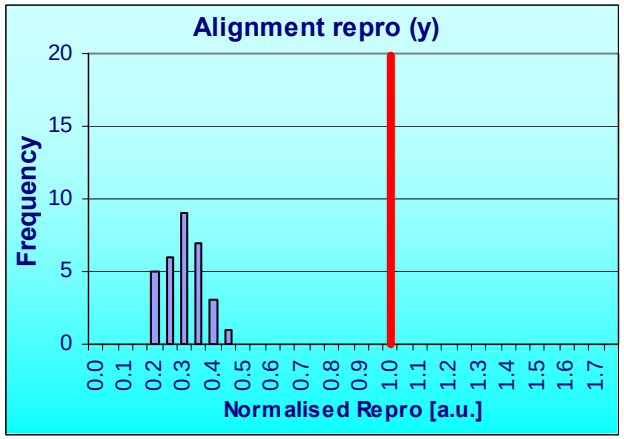
Alignment- and focus sensor performance is stable

Measurement conditions:
- 27 measurements in a >5 weeks timespan (end Aug. – end Sep.'07)
- all results within specification.

Measurement conditions:
- 35 measurements in a >6 weeks timespan
- all measurements within specification.







All measured values are normalized to their respective requirements

Conclusion

- Wafer metrology sensor performance is well within specifications, and stable over time.

frequency = amount of times a bin value was measured

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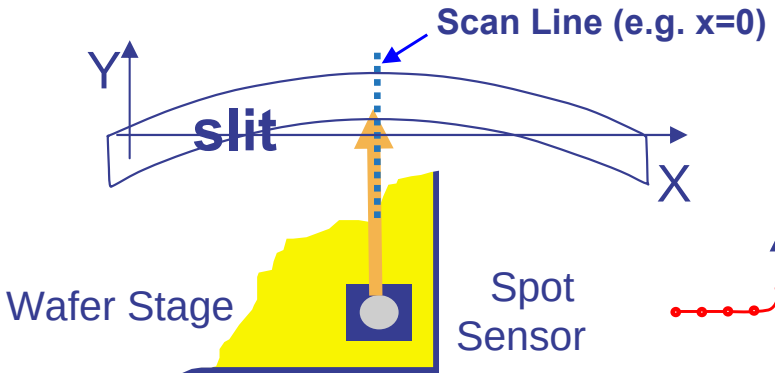
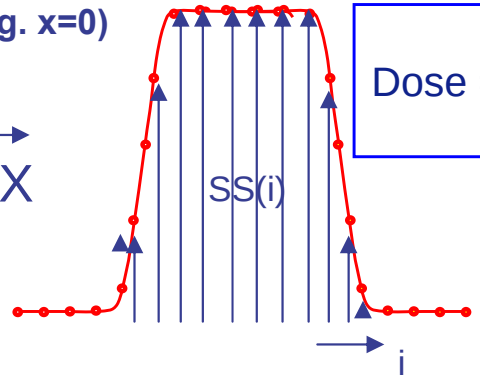
Dose repeatability meets requirements; accuracy needs improvement

- Tests are done by scanning the spot sensor through the slit at different stage speeds (depending on dose).
- Doses: 0.5, 5, and 15 mJ/cm^2 using 100 scans



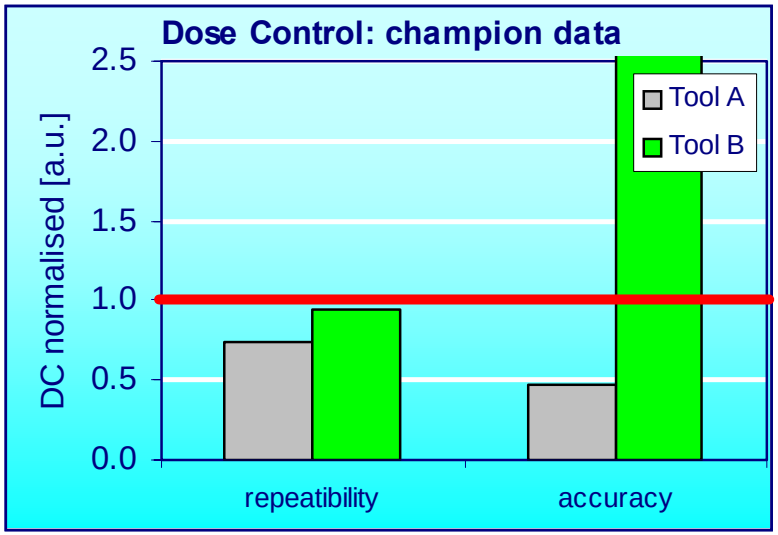


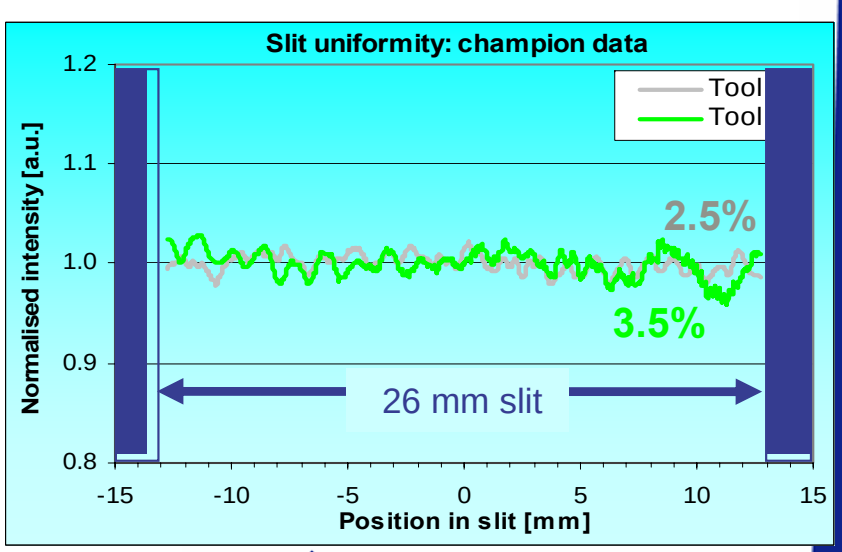
$$\text{Dose} = \sum_{i=1}^{i=n_p} SS(i)$$

$$\text{Dose accuracy} = \frac{|Dose_{set} - Dose_{mean}|}{Dose_{set}} \times 100\%$$

$$\text{Dose Repeatability} = \frac{Dose_{max} - Dose_{min}}{Dose_{max} + Dose_{min}} \times 100\%$$

- **Result**:





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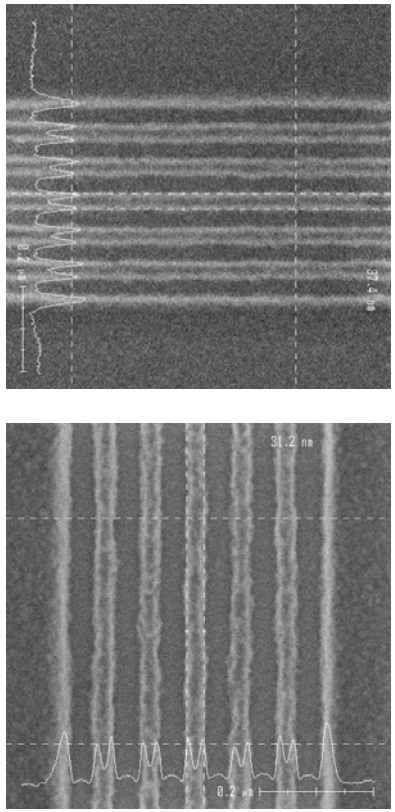
Scanned imaging with Sn source is successful…

Tool A

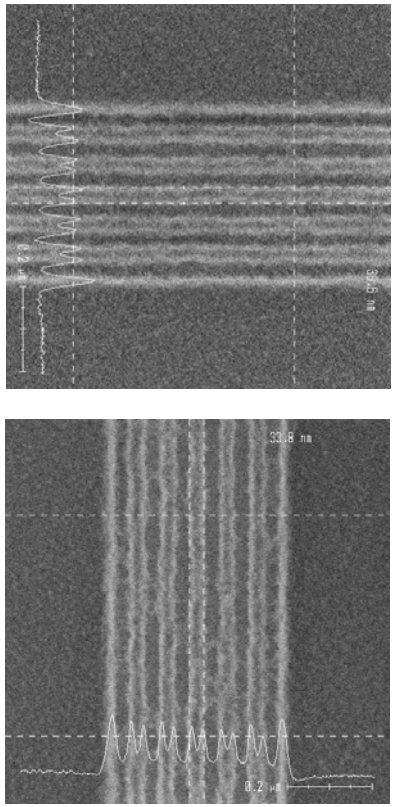
Tool B

H

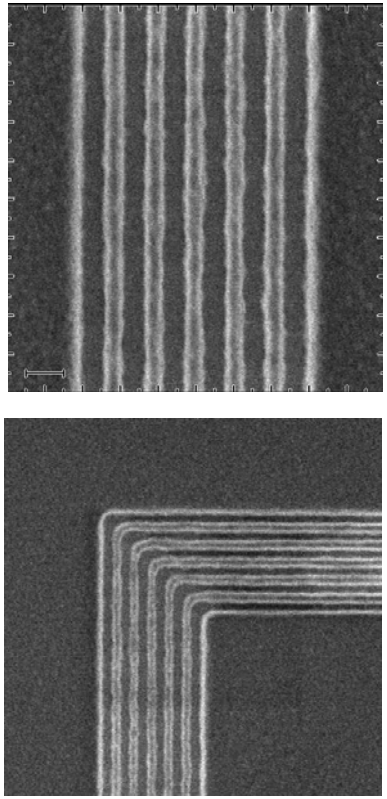
V



40 nm HP



35 nm HP



35 nm HP

Dose-2-clear wafer exposed

Resist: 150 nm thick MET1K (XP-4502-J), 120°C SoftBake; 60s PEB at 110°C. (recipe I-MET1K-150). Reticle: BA-EUV-Setup: 4556444N001 (Bright area).

- Resist: R&H 100, 120 nm MET-2D (~22 mJ/cm^2)
- Reticle: 40 and 35 nm coded
- Conventional illumination, fixed σ = 0.5
- Softbake: 120-130°C, 60 s, PE Bake: 110-120°C, 60-90s

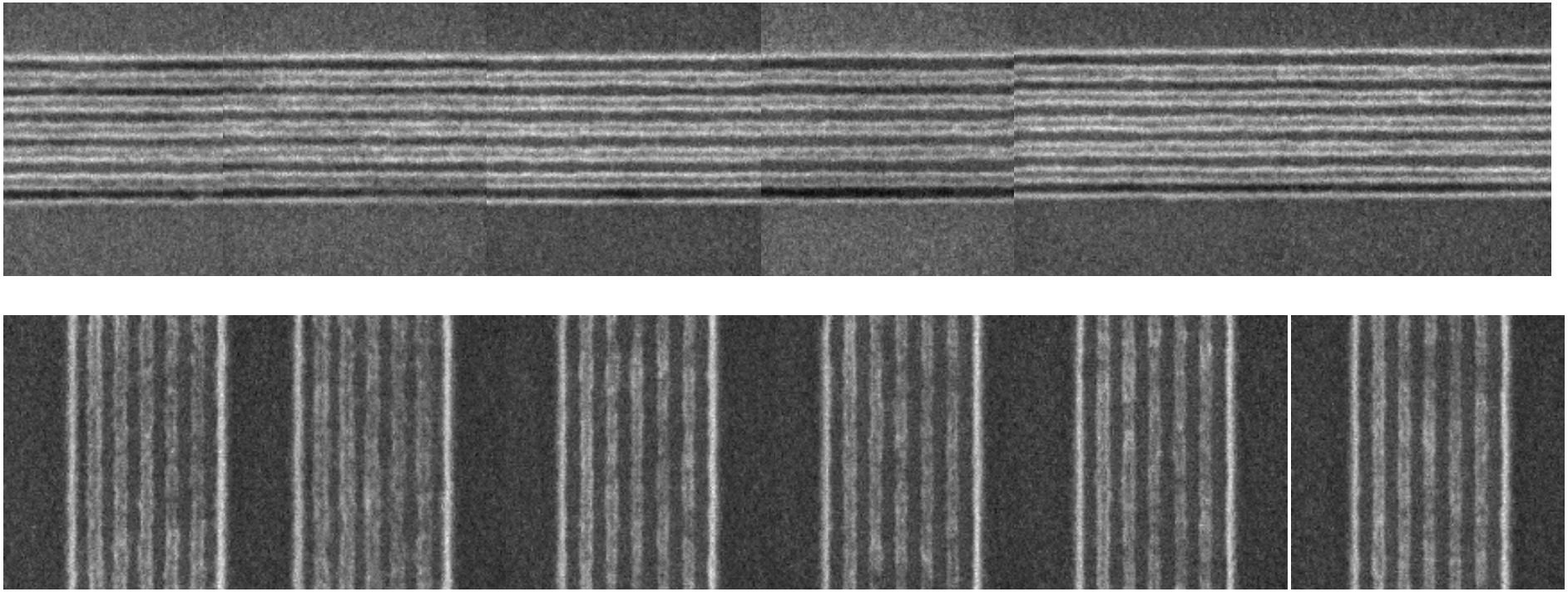
… so are 35 nm HP lines through >200 nm DoF …

FOCUS (nm)

-120 -80 -40 NF +40 +80

H

V



Resist: R&H XP-5721F (MET-2D)

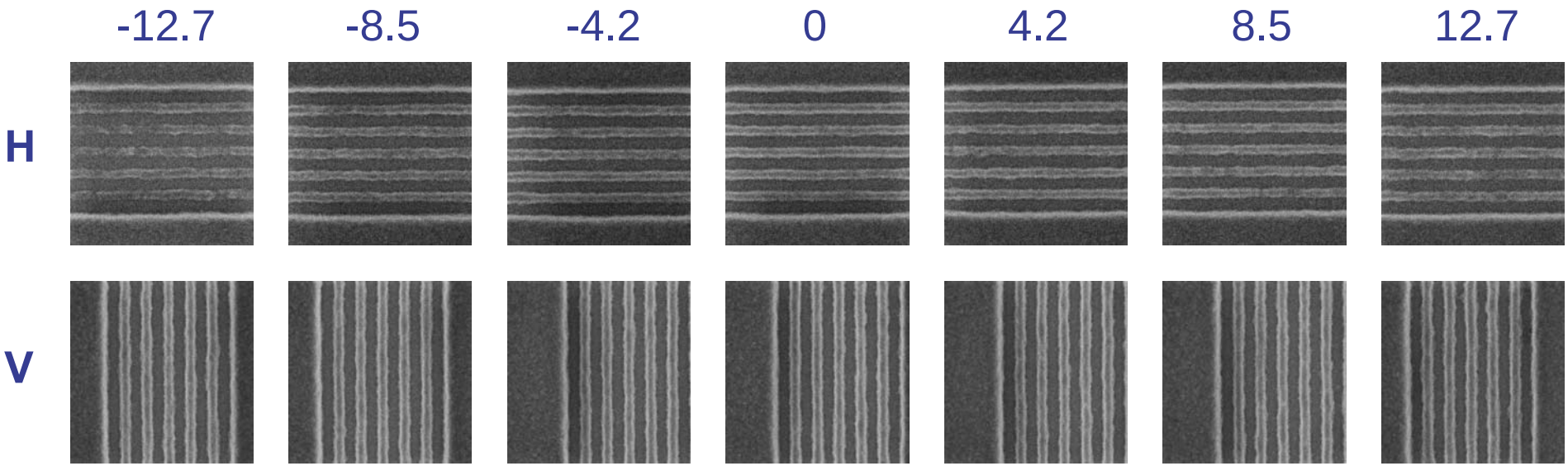
Thickness: 120nm

Dose: ~20 mJ/cm²

NA=0.25 σ= 0.5

… and 40 nm HP lines through slit…

Slit x-position (mm)



Horizontal and vertical lines have a programmed offset of 6 nm, to compensate for mask shadowing

Resist: R&H XP-5721F (MET-2D)

Thickness: 120nm

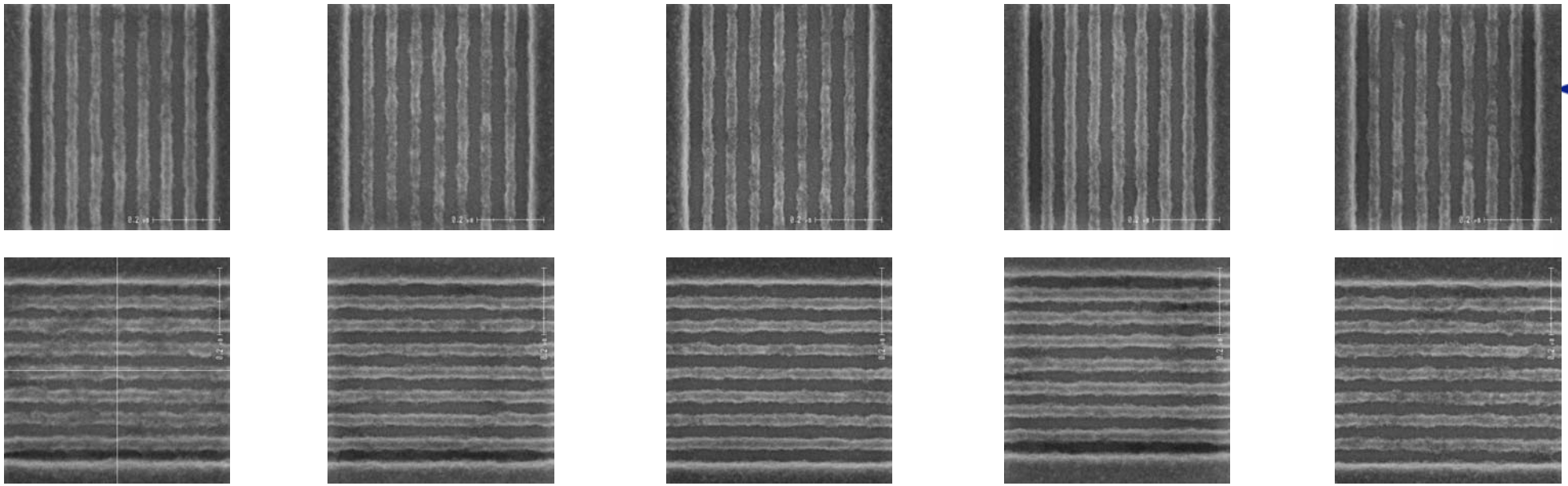
Dose: ~20 mJ/cm^2

NA=0.25 σ= 0.5

… and 35 nm HP lines through slit…

Slit x-position (mm)

-12.72 -6.36 0 6.36 12.72



Horizontal and vertical lines have a programmed offset of 6 nm, to compensate for mask shadowing

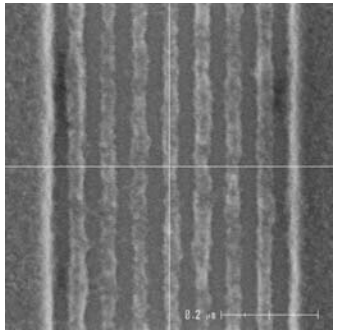
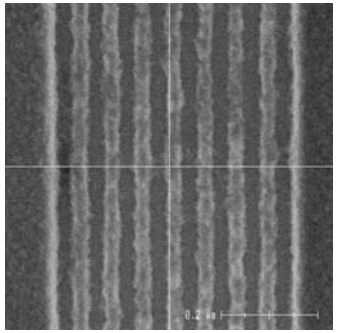
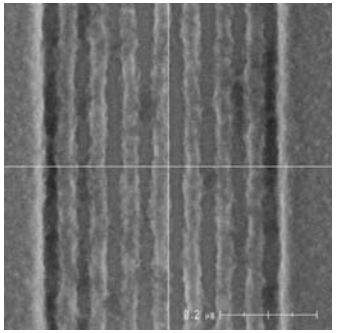
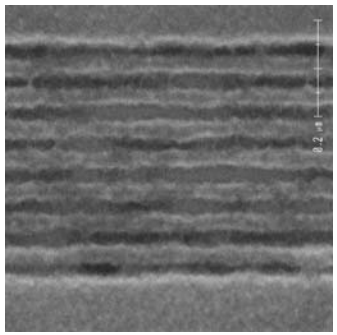
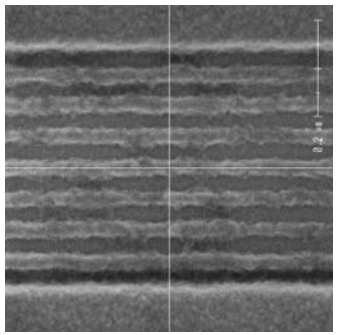
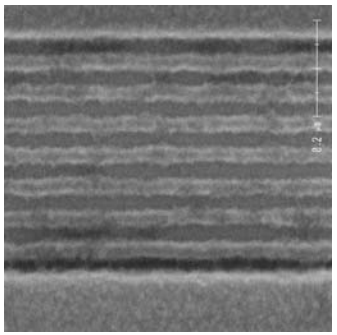
Resist: R&H XP-5721i (MET-2D)

Thickness: 100nm

Dose: ~25 mJ/cm^2

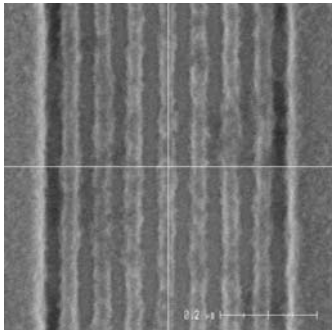
NA=0.25 σ= 0.5

… and 32 nm HP lines through focus …

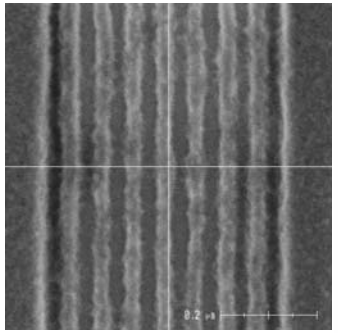
	F - 40nm	Focus = F	F + 40nm
V			
H			

pushing the resist limit:

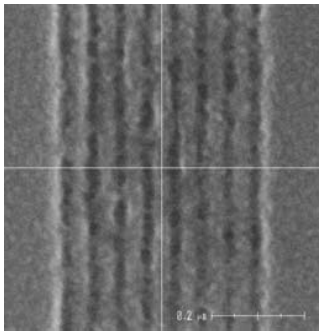
31nm



30nm

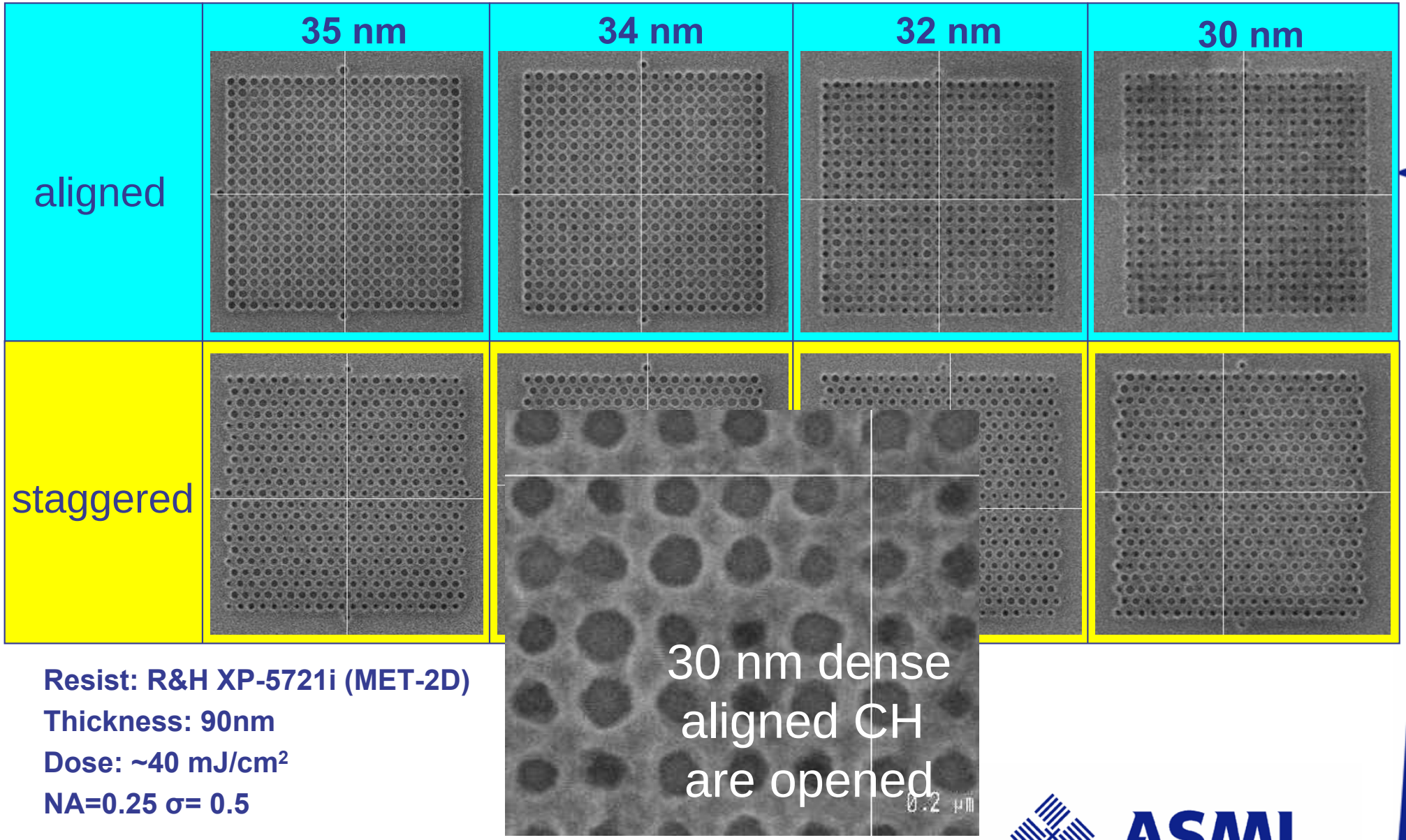


29nm



Resist: Rohm Haas XP-5721i (MET-2D)
Thickness: 90nm
Dose: ~25 mJ/cm²
NA=0.25 σ= 0.5

Excellent Contact Hole printing has been reconfirmed, down to 30 nm

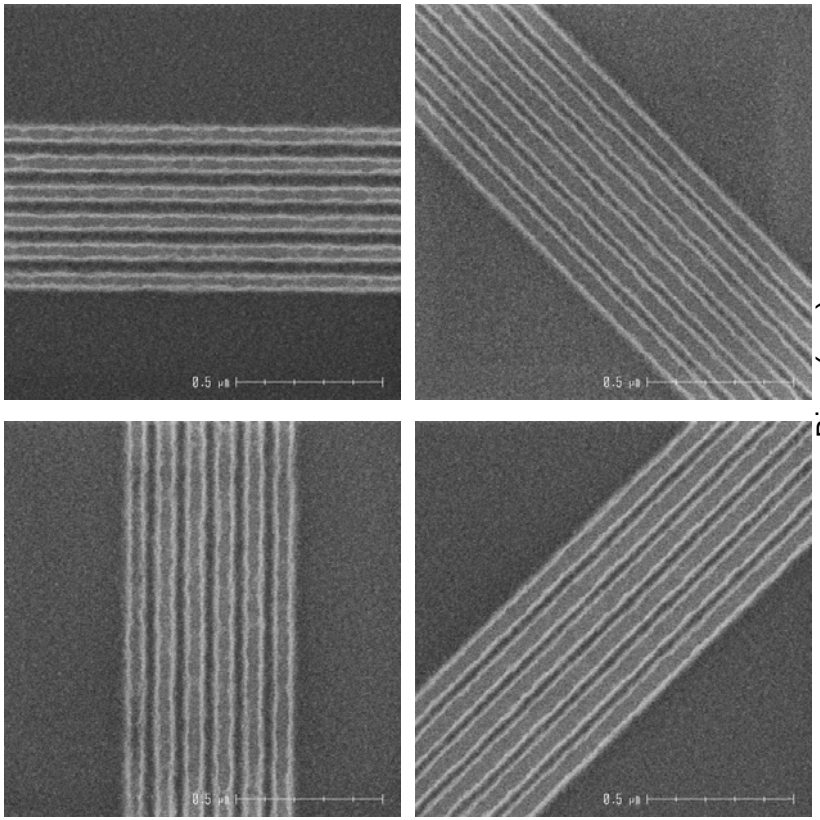


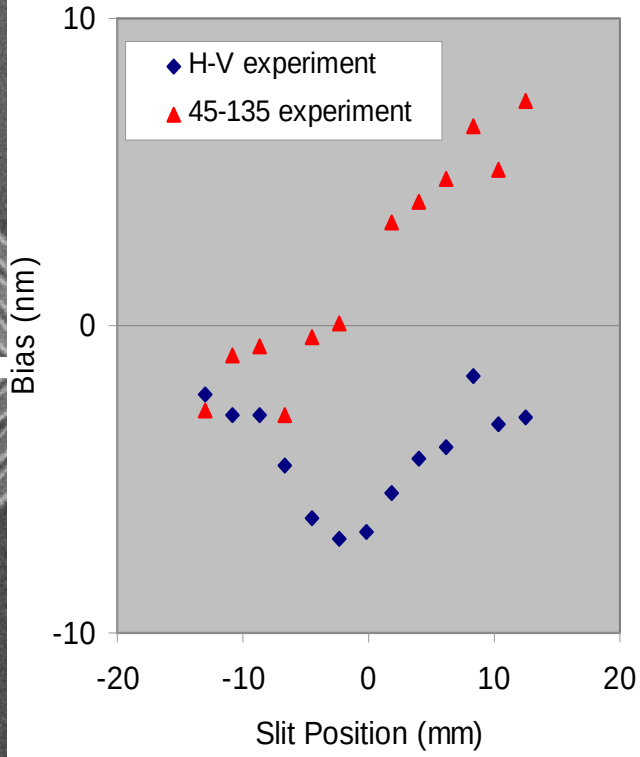
Resist: R&H XP-5721i (MET-2D)
Thickness: 90nm
Dose: ~40 mJ/cm²
NA=0.25 σ= 0.5

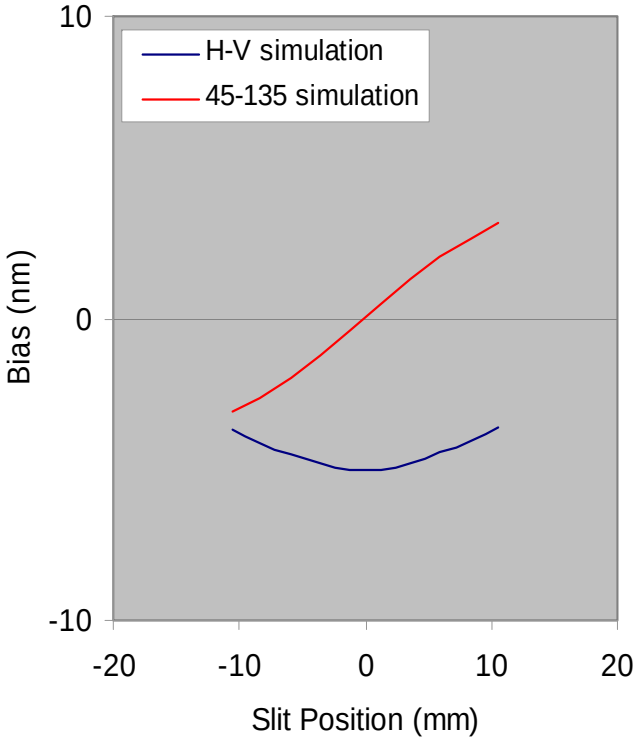
ASML

Shadowing on ASML EUV ADT with Sn Source

Experimental validation







Measurement of 50nm 1:1 L/S at 0^0, 90^0, 45^0, 135^0

Comparison of simulation and experiment for HV bias and 45^0 -135^0 bias through slit

The experimental measurement of shadowing is in agreement with simulation prediction.

Poster MA-P08 "Shadowing effect compensation", G.F. Lorusso et al

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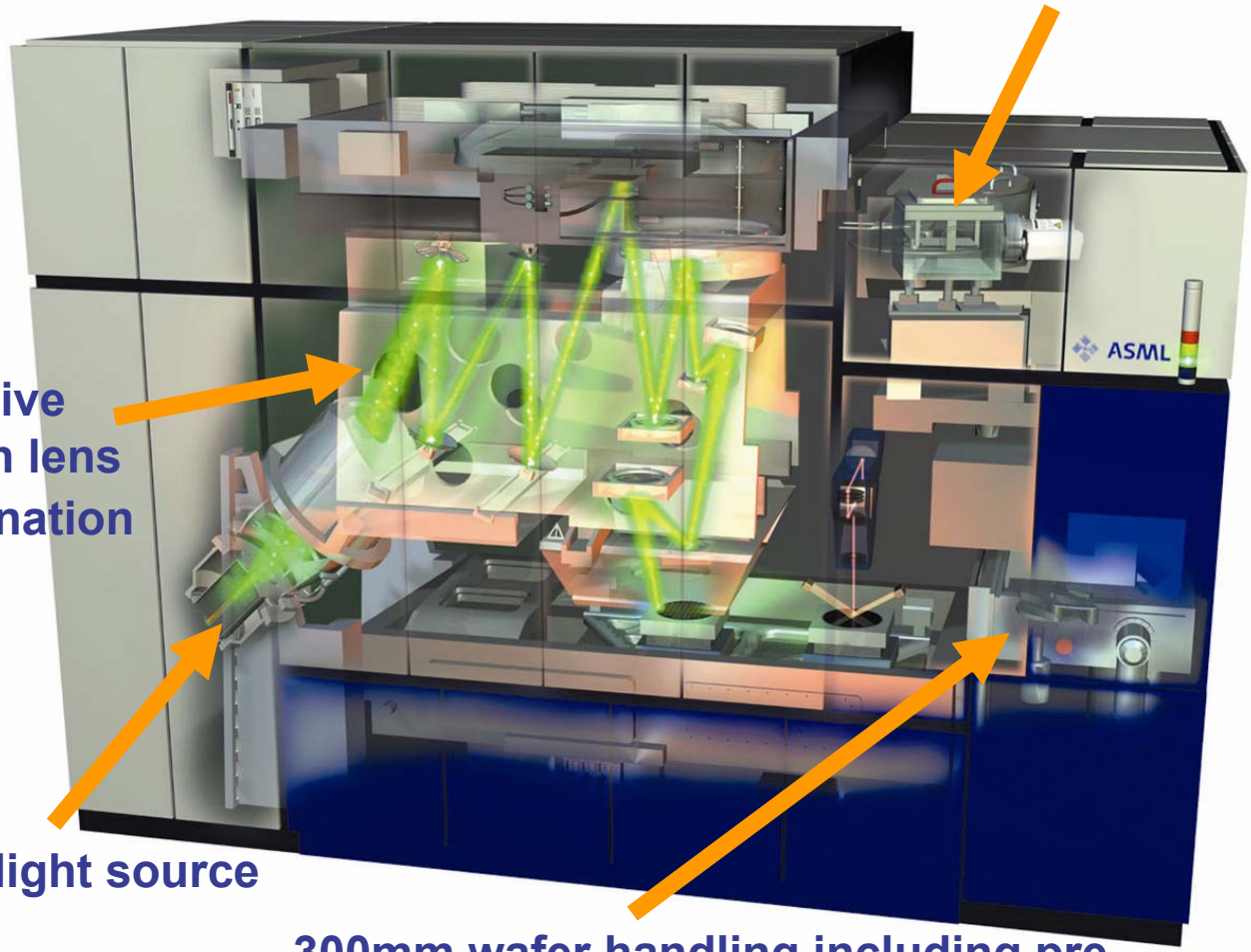
EUV Lithography production system key elements

4x reduction
6” reticle handling and reticle storage



Reflective projection lens and illumination

13.5nm light source

300mm wafer handling including pre-alignment, temp control, FOUP and direct track interface (track to load lock)

Parameter	PreProduction tool specifications
λ	13.5 nm
field size	26 x 33 mm^2
Magnification	4x ($\pm$10 ppm)
Dense lines	32 nm
Isolated lines	32 nm
Contacts	<40 nm
Aperture	0.15 - 0.25 NA
Illumination	σ 0.3 – 0.8
Flare	8%
Overlay (SMO)	4 nm
Throughput	60 wph @10 mJ/cm^2; upgradable to 100 wph

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Pre Production Tool is the path to high volume production (HVM)

- The EUV production system platform
  - supports multiple generations with upgrades,
  - throughput is source limited, but optics and main body are able to support >100 wph at 10 mJ/cm^2.
- System is dual stage, building on all TWINSCAN™ advances for productivity, overlay, and automation.
- Optical configuration builds on Alpha-demo tool type projection optics (NA = 0.25), and supports < 32nm half pitch dense line imaging.

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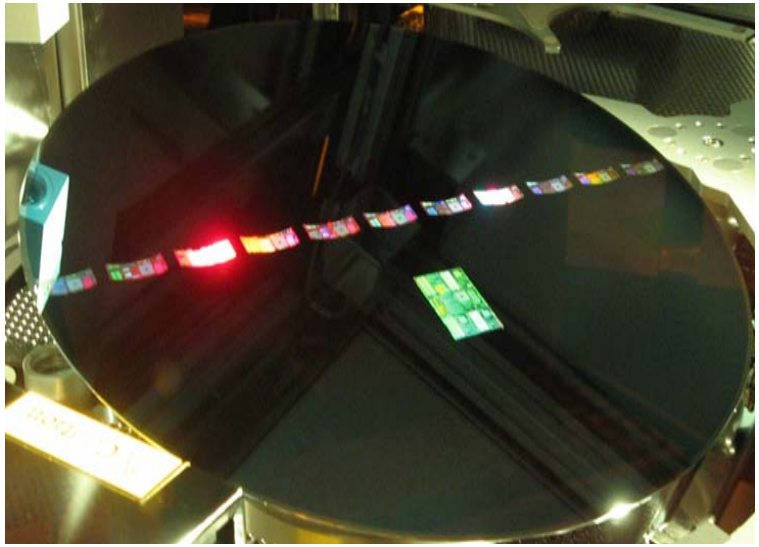
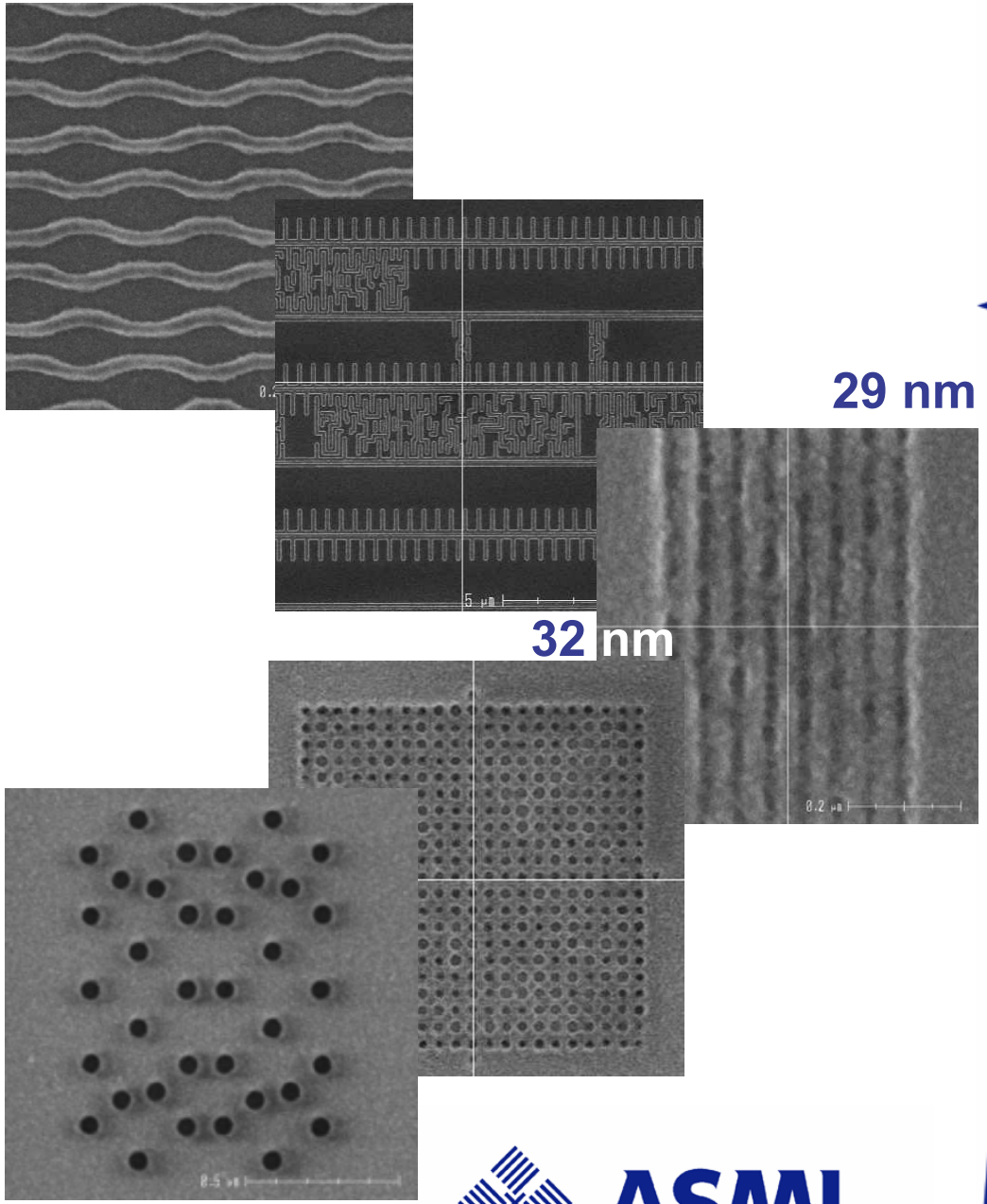
Summary and conclusions

- AD-tools are in final phase of qualification
  - Sn DPP sources are operational
  - Imaging capability exceeds expectations: resolution currently limited by resist performance
- High volume manufacturing tool development is in ramp-up phase
  - multiple purchase orders for PreProduction tool:
    - 3 from IC manufacturers,
    - 1 from R&D center.
- ASML is committed to EUV
  - Two Alpha Demo tools with multi-year plans of use
  - First high volume manufacturing tools are scheduled for 2009

This is EUV lithography !





THANKS !

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